Chemical Quality of Surface Waters in Pennsylvania

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1619-W

Prepared in cooperation with the Commonwealth of Pennsylvania Department of Commerce and Department of Forests and Waters

Chemical Quality of Surface Waters in Pennsylvania

By CHARLES N. DURFOR *and* PETER W. ANDERSON

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1619-W

Prepared in cooperation with the Commonwealth of Pennsylvania Department of Commerce and Department of Forests and Waters

---

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1963

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C.

CONTENTS

ILLUSTRATIONS

TABLES

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

CHEMICAL QUALITY OF SURFACE WATERS IN PENNSYLVANIA

By Charles N. Durfor and Peter W. Anderson

ABSTRACT

Pennsylvania has an abundant supply of surface water of good quality. The average rainfall over the 45,300 square miles in the State is about 42 inches per year. Of this amount, about 50 percent appears in the streams as runoff. The combined mean annual runoff of the Delaware, Ohio, and Susquehanna Rivers, at their farthest downstream measuring points in the State, is in excess of 81,000 cubic feet per second.

Variations in the chemical quality of the surface waters in Pennsylvania are caused by areal differences in geology, urban and industrial development, mining, quarrying, land use, and runoff. Waters having the least dissolved solids are found in the glaciated northeastern and northwestern parts of the State; waters having higher values of hardness are found in the limestone terranes in the southeastern and south-central parts. In the anthracite coal fields in the northeast and in the bituminous coal fields in the southwest, many streams receive acid mine drainage, which lowers the alkalinity and increases the sulfate content of the waters.

The chemical quality of surface waters in Pennsylvania is discussed in general terms. Introductory sections of the report cover the main causative factors which influence chemical quality.

INTRODUCTION

Pennsylvania has been abundantly endowed with many flowing streams and glacial lakes. The chemical quality of these waters has been investigated since 1944 by the Geological Survey in cooperation with the Pennsylvania Department of Forests and Waters and the Pennsylvania Department of Commerce. This report summarizes these investigations from 1944 and 1957 and evaluates the chemical character of surface waters in the Commonwealth.

This report is divided into three sections. The first section is a general discussion of the factors influencing the chemical quality of the surface water. The second is a discussion, by areas of similar type, of the chemical quality of the surface waters in the Commonwealth, A third section contains tables of chemical analyses and summaries of chemical analyses at selected locations throughout Pennsylvania.

The location of the sampling sites for the chemical analyses are indicated on figure 1. The number on the map indicates the table in which the chemical analyses are presented.

The discussion of the hydrologic cycle, precipitation, and runoff was prepared by J. J. Molloy. Messrs. J. R. George and D. R. Rima, geologists, U.S. Geological Survey, assisted in the preparation of the geologic maps and discussions of the geology.

METHOD OF INVESTIGATION

The investigation consisted of observation and analyses of information from several sources throughout the Commonwealth to determine variations in quality, both areally and with time. Some observations were made simultaneously; others were made at one locality over a period of time to observe the range of concentration.

Water samples were collected daily from the larger streams near streamflow gaging stations. Temperature and specific conductance were measured on each sample, and pH was determined on samples collected from streams influenced by acid mine drainage. Daily samples collected during the month were composited into three representative samples, and comprehensive chemical analyses were made from these composites. At many locations, streams were not sampled at daily intervals. Some streams were sampled weekly, others monthly, and a few were sampled only at high and at low discharge rates.

Samples were divided into two groups for chemical analysis. One group was given a comprehensive analysis consisting of determination of color, pH, specific conductance, silica, iron, calcium, magnesium, sodium, bicarbonate, sulfate, chloride, fluoride, nitrate, dissolved solids and hardness. The other group was given a partial analysis commonly consisting of the determination of color, pH, specific conductance, bicarbonate, sulfate, chloride, nitrate, and hardness.

PRESENTATION OF DATA

In order to evaluate the chemical data at the daily stations, frequency distributions were determined for the temperature and specific conductance of these streams. Relationships were established between the specific conductance of the water and the concentrations of many dissolved constituents in these streams. On the basis of these empirical relationships and the frequency distribution of specific conductance, the frequency distribution of calcium, magnesium, sodium and potassium, bicarbonate, sulfate, chloride, hardness and dissolved solids were calculated and summarized in the tables of chemical

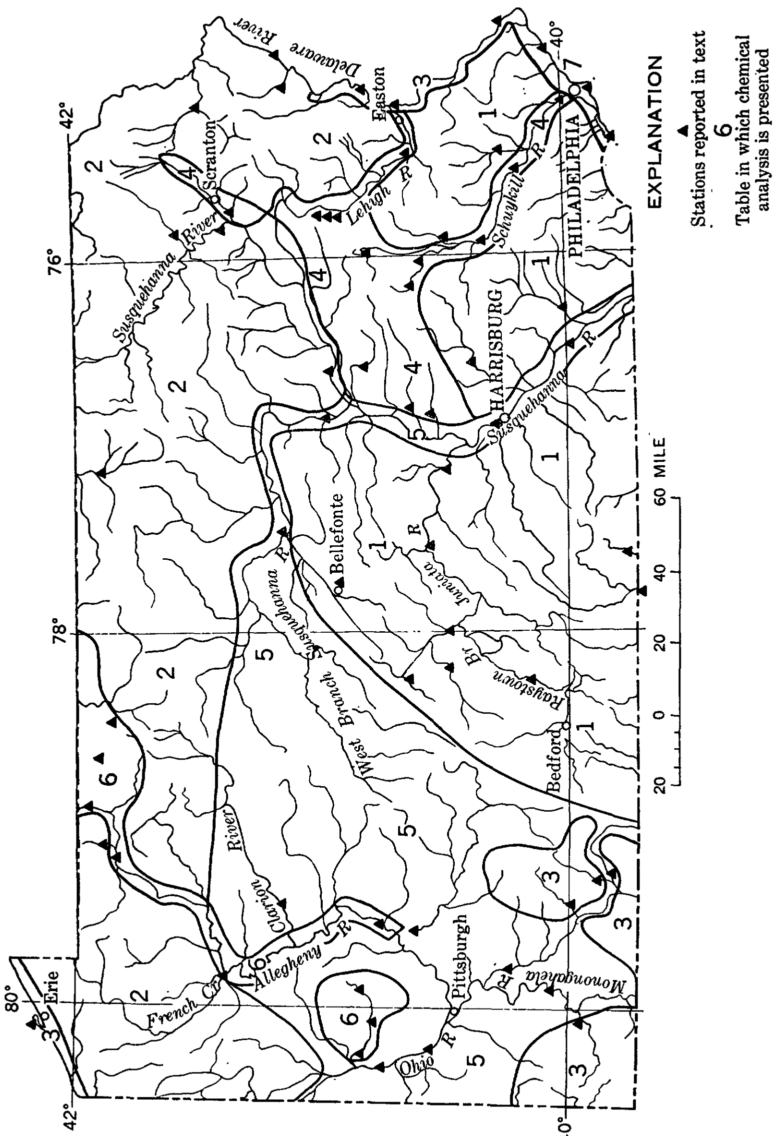


FIGURE 1.—Chemical quality at sampling stations.

analyses. The daily pH of streams influenced by acid mine drainage also was summarized in these tables.

Flow-duration curves were prepared for selected stream locations and the streamflow data were summarized with the chemical quality data.

The concentrations of chemical constituents that equaled or exceeded 1, 10, 50, 90, and 99 percent of the time are summarized in the tables of chemical analyses. The values tabulated as having equaled or exceeded 50 percent of the time are the median values. The values tabulated at 1 and 99 percent represent a range to be expected 98 percent of the time.

Frequency distributions of the concentrations of chemical constituents in the monthly analyses of the Susquehanna River at Harrisburg are summarized in table 5. At some locations where the data were insufficient to prepare frequency tables, the maximum and minimum chemical concentrations of selected constituents are summarized. Representative chemical analyses of streams in each area under discussion are presented in the tables of chemical analyses.

HYDROLOGY

HYDROLOGIC CYCLE

Water, one of our most important natural resources, is a renewable resource. The endless movement of water from the clouds to earth and back again is referred to as the hydrologic cycle or the water cycle. When precipitation occurs, some moisture may evaporate before it reaches the ground. Of the precipitation reaching the ground, part infiltrates the soil mantle, part percolates into the ground water, and part returns to the atmosphere by transpiration. The remaining portion of the original precipitation travels over the ground to rivers and streams. Some of the water that enters the ground comes to the surface again through springs and seeps and joins the surface water flowing in the streams that eventually reach the ocean. Evaporation from the surface of streams, lakes, ponds, and finally from the surface of the ocean completes one hydrologic cycle. Water evaporated and transpired becomes available to be precipitated again. Thus, the hydrologic cycle is endless.

PRECIPITATION

Pennsylvania's average annual precipitation of about 42 inches exceeds the average for the United States by more than 40 percent. Even the lowest annual precipitation of 32 inches seems more than adequate when compared with many arid and semiarid areas of the West.

Although Pennsylvania's annual precipitation is fairly uniformly distributed in time, it must be remembered that variations do occur from year to year and that average values include years of excess precipitation and years during which precipitation was deficient. Also, within any given year, precipitation generally varies from month to month. During a year of average precipitation, periods of both excess and deficient rainfall are to be expected.

RELATION OF PRECIPITATION TO RUNOFF

About 50 percent of the precipitation over Pennsylvania appears in the streams as runoff. The month-to-month variation in streamflow generally is more extreme than the variation in precipitation, because of the larger losses to evaporation and transpiration during the hot summer months and the impenetrability of the soil during the winter months.

Systematic records of streamflow are obtained in Pennsylvania by the operation of about 170 gaging stations shown in figure 2. Comparison of runoff with precipitation, obtained from these stations, indicates that the average annual runoff in Pennsylvania varies from about 35 percent to more than 50 percent of average annual precipitation. Over the United States as a whole, only about 30 percent of the average annual precipitation appears in the stream as runoff (Langbein and others, 1949).

DRAINAGE BASINS

Precipitation falling on Pennsylvania drains into the Atlantic Ocean or the Gulf of Mexico through the five drainage basins shown in figure 2: the Delaware River basin in eastern Pennsylvania drains 6,422 square miles; the Susquehanna River basin in the central region drains 20,965 square miles; the Ohio River basin in the west drains 15,571 square miles; the Potomac River basin in the south-central region drains 1,570 square miles; and the St. Lawrence River basin in the northwest drains 96 square miles in the Genessee River area and 512 square miles in the Lake Erie area.

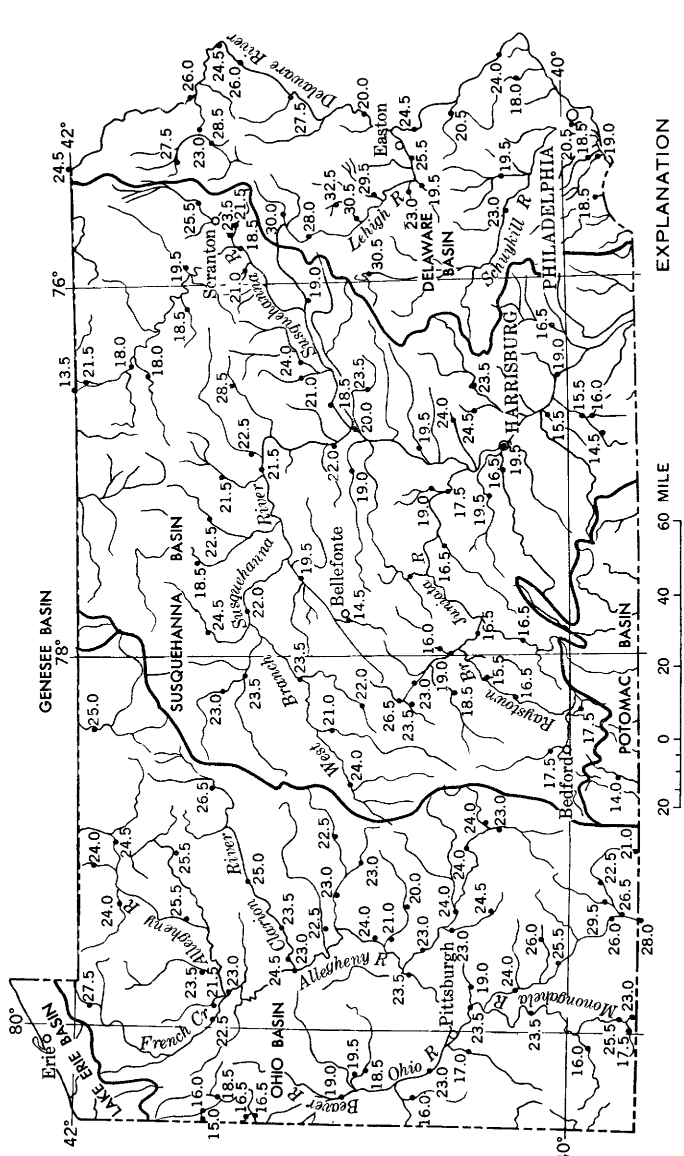
FACTORS AFFECTING CHEMICAL QUALITY

The chemical quality of the surface water in Pennsylvania is primarily influenced by (1) streamflow, (2) geology and ground water, (3) contamination from acid mine drainage and oil-well brines, (4) land use, and (5) tidal saline invasion.

STREAMFLOW

Streamflow is composed of direct or storm runoff and base flow. Following periods of moderate to heavy precipitation, the major

660212—63——2



EXPLANATION

•16.0

Mean annual runoff, to the nearest half inch, at gage for ten or more years of record

FIGURE 2.—Drainage basins and runoff at gaging stations.

portion of the water flowing in streams is the result of direct surface runoff. During periods of fair-weather runoff the dissolved-solids concentration of most streams in Pennsylvania is at a maximum. As the streamflow increases, the dissolved-solids concentration decreases. During periods of low flow, minor increases in discharge have a larger effect upon the dissolved-solids content than similar increases during median or higher stream discharges. Figure 3 shows the relations

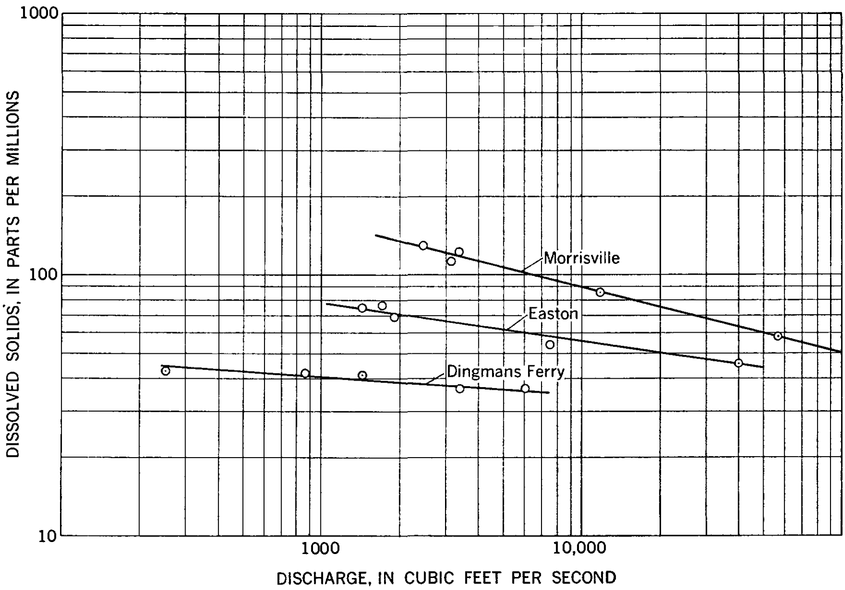


FIGURE 3.—Relation between discharge and dissolved solids.

between discharge and dissolved-solids concentration of the Delaware River at Dingmans Ferry, Easton and Morrisville. Relations between discharge and dissolved-solids concentration differ from stream to stream, and, as indicated in figure 3, the relations may change along the reach of the stream. At Dingmans Ferry, the slope of the discharge-dissolved solids concentration curve is almost negligible which indicates that the concentration of dissolved solids is little influenced by flow rate. At Easton and Morrisville, the slopes of the discharge-dissolved solids curves are greater, and the changes in concentrations of dissolved solids with flow are greater. The concentration of dissolved solids of most surface waters usually increases in a downstream direction.

GEOLOGY AND GROUND WATER

During long dry periods, the flow of streams is maintained by ground-water discharge. Consequently, streams generally reflect the chemical character of ground water during dry periods. The quality and movement of ground water is influenced by the character of the water-bearing material.

Few streams in the State originate and run their course in the same geologic setting. Most streams originate in one geologic setting but may be influenced by two or more geologic environments before the stream reaches its mouth. Each geologic environment influences the chemical character of the stream draining the terrain. Streams draining lands underlain by soluble rocks that issue large amounts of ground water have a strong influence on the chemical character of the surface water. The more insoluble the rock and the smaller the yield of ground water, the more the influence of the geology and ground water are subdued.

Pennsylvania is underlain by a wide variety of rocks. The limestone and dolomite terranes (fig. 5) yield large amounts of ground water that is high in pH, hardness, bicarbonate, and dissolved solids. Some of the shales and sandstones adjacent to these terranes yield small amounts of calcium and magnesium bicarbonate water that is not as high in pH or alkalinity. Ground water issuing from the sandstones, shales, and flagstones in southeastern Pennsylvania contains principally calcium and bicarbonate ions when the dissolved solids are less than 300 ppm (parts per million) and predominantly calcium and sulfate ions when the concentration is higher. Acid mine drainage from the coal fields in eastern and western Pennsylvania (fig. 8) causes the streams in these areas to be low in pH and high in sulfate, hardness, and dissolved solids. In south-central and southwestern Pennsylvania, the sandstones and quartzites are hydrologically similar to the pre-Cambrian crystalline rocks in the southeastern part of the State. Water issuing from these rocks is low in dissolved solids and calcium, magnesium hardness. The influence of the sandstones and shales in the central and northern part of the State is mostly subdued by the mantle of glacial drift. Surface waters draining areas of glacial outwash are low in dissolved solids and calcium, magnesium hardness.

CONTAMINATION

ACID MINE DRAINAGE

Water draiming from many coal mine areas contains sulfuric acid. The principal sources of sulfuric acid in water are pyrite and marcasite in coal and associated rock and shale strata, which are oxidized in the presence of air and water to form iron sulfate and sulfuric acid. The resultant acid mine drainage, as it leaves the mine, is low in pH and high in iron, sulfate, and free sulfuric acid content. Waters which drain rock, slate, and culm banks near coal mines are low in pH and high in iron, sulfate, and free sulfuric acid content. High concentrations of aluminum and manganese are commonly found in surface streams in Pennsylvania affected by acid mine drainage.

Although acid mine waters are similar in composition, they vary in concentration depending upon the amount of sulfur-containing materials exposed in the coal strata, the amount of air and water present, and the biological activity. The chemical composition and concentration of the streams receiving acid mine drainage correlate closely with the composition of the mine drainage.

WELL BRINES

In the upper drainage basins of Connoquenessing Creek and Allegheny River, petroleum mixed with brine is pumped from deep wells. The amount of brine pumped with each barrel of oil varies but usually exceeds the volume of oil. Some of this brine, which at some locations is 7½ times as concentrated as ocean water, enters the surface water. Numerous abandoned oil wells also allow the upward migration and spread of the brine into both ground and surface waters. These waters contain high concentrations of sodium chloride.

TIDAL SALINE INVASION

Below Morrisville, the chemical quality of the Delaware River and its tributaries is influenced by the salty water from the Delaware Bay moved upstream by the tide. The portion of the Delaware River and its tributaries nearest to the bay contain the greater concentrations of sodium chloride water. The salinity of the water increases when the stream discharge is reduced, and, when the low discharges persist, the salty water encroaches progressively upstream from Marcus Hook toward Philadelphia and into the tidal tributaries.

LAND USE

The extent of forest cover, the amount of farm cultivation and the degree and type of urbanization and industrialization of the drainage basin influence the chemical quality of surface runoff.

Forest lands usually have high infiltration capacities and yield little surface runoff during most storms. During rainfall of high intensity and long duration, the ground becomes saturated and the surface runoff is appreciable. The amount of surface runoff from cultivated lands depends upon the type of vegetation, stage of growth, and manner of cultivation; but, in general, it exceeds the surface runoff from forest lands. The precipitation falling upon urban and industrial areas and other areas with low infiltration capacities becomes almost

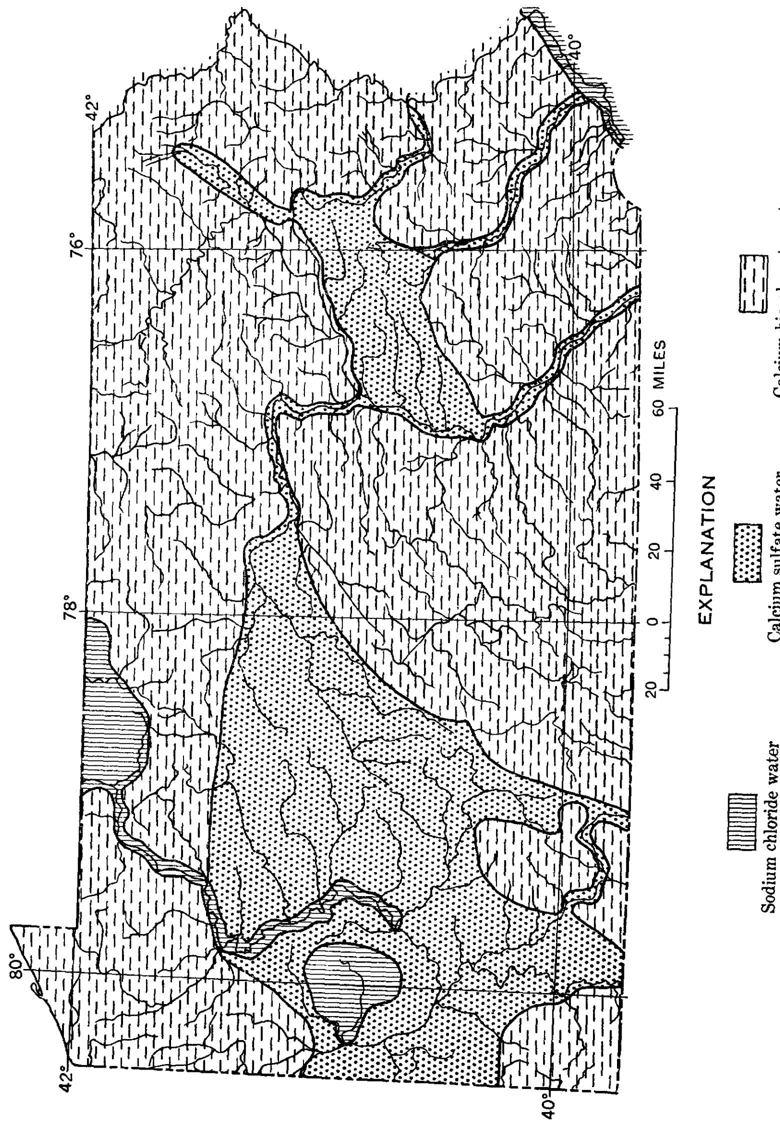


FIGURE 4.—Areas of similar chemical quality of surface water in Pennsylvania.

entirely surface runoff. The relation between dissolved solids and discharge is discussed under "Streamflow."

Fertilizers applied to cultivated farm lands are dissolved by surface runoff and increase the potassium, nitrate, and phosphate content of the receiving streams. As the vegetative litter of swamps and forests decomposes, its color deepens to a dark brown or black. The dark-colored nitrogeneous products of decomposition are carried by surface runoff into receiving streams, increasing the color and nitrate content.

CHEMICAL QUALITY OF SURFACE WATER

The three principal types of surface water in Pennsylvania are calcium bicarbonate, calcium sulfate, and sodium chloride. In order to evaluate and discuss the chemical quality of surface waters, the Commonwealth is divided into areas, each containing mainly one of these types of water. Figure 4 is a map of Pennsylvania showing the boundaries of these areas. Most of the streams in each area are of the same general type and are influenced by the same factors. A discussion of the chemical quality of the water in these areas follows.

CALCIUM BICARBONATE WATER

As indicated in figure 4, a large part of the state has surface water which contains predominantly calcium bicarbonate. A few isolated streams are contaminated by acid mine drainage or by salt.

LIMESTONE AND DOLOMITE AREAS

In southeastern and south-central Pennsylvania, Cambrian and Ordovician limestones and dolomites constitute practically a single lithologic unit. The limestones are very dense, but being hard, brittle and soluble, they are generally fractured. Tublar openings or other solution channels are dissolved out along such fractures by percolating water charged with carbon dioxide. Solution channels range in size from minute openings to large limestone caverns. The limestone terranes in Pennsylvania (fig. 5) have a major effect on the quality of water exposed to them.

The largest known springs in Pennsylvania, Boiling Springs and Big Spring in Cumberland County, issue from solution channels in limestone and dolomite. The waters flowing from these formations are high in calcium, magnesium and bicarbonate. Representative analyses of two springs in these limestone and dolomite regions, Thompson Spring and Rock Spring, are presented in table 1.

The chemical composition of the surface water in these regions is determined by the calcium bicarbonate water from the many springs and seeps in the limestone and dolomite formations. Most of these

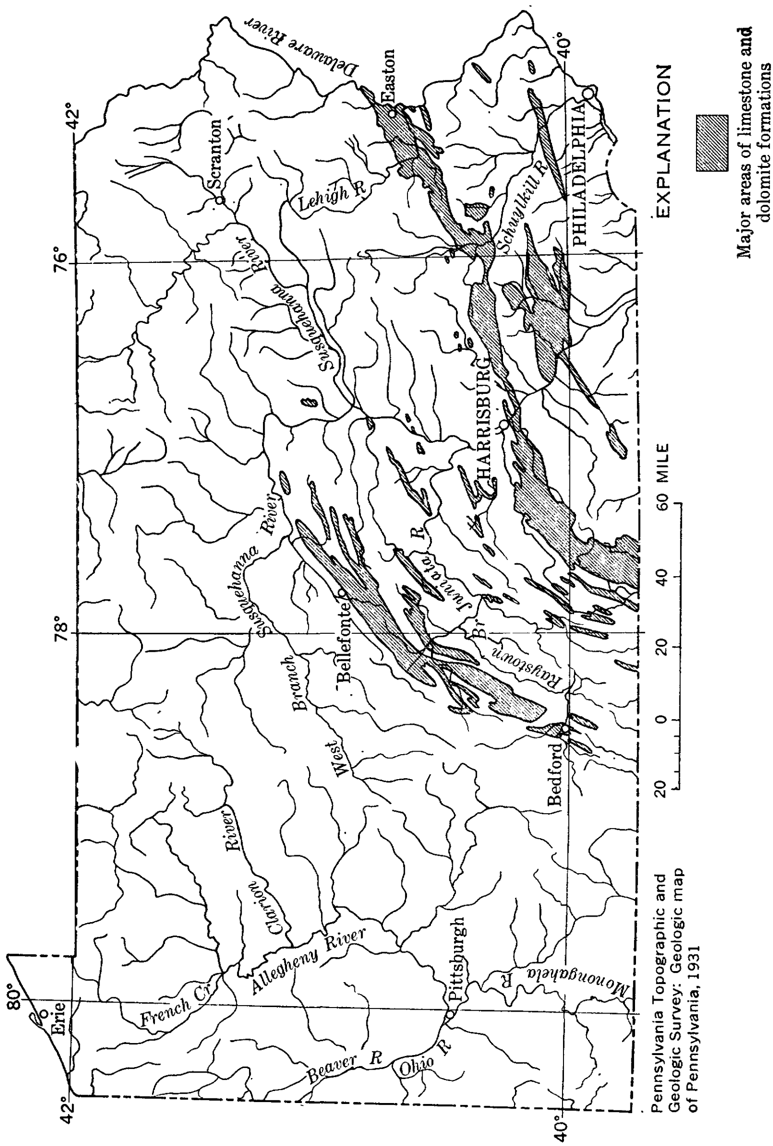


FIGURE 5.—Limestone terranes.

surface waters are alkaline (pH 7.0 to 8.5) and may contain in excess of 25 ppm of calcium and magnesium, and in excess of 100 ppm of bicarbonate (table 1). It is interesting to note that the changes in the concentration of sulfate of the Conestoga Creek at Lancaster were slight during the period of record (Oct. 1947–Sept. 1950) when compared with the twofold or more changes in concentration of calcium, magnesium and bicarbonate. Examples of the chemical quality of water in these areas are found in table 1.

The slightly higher runoff rates and increased shale deposits in the Potomac River basin cause lower bicarbonate and dissolved-solids concentrations in these surface waters than in the adjacent limestone areas. The maximum and minimum analyses of Conococheague Creek at Fairview, Md. and Antietam Creek near Waynesboro, Pa. in table 1 give the range of concentrations of the chemical constituents in surface waters of this area.

JUNIATA RIVER BASIN

The headwaters of the Little Juniata, the Raystown Branch and the Frankstown Branch of the Juniata River originate in areas underlain by coal-bearing rocks. A short distance below the headwaters, these streams flow into areas underlain by limestone and dolomite (fig. 5). The influence of these geologic environments upon the chemical character of the Juniata River was demonstrated in a survey of the basin during a period of low flow. The chemical analyses of this survey of the Juniata River basin are reported under the Susquehanna River basin in table 1.

Small streams draining the isolated coal pockets in the southern part of Huntingdon County (fig. 6) contribute acid-sulfate water to the Raystown Branch near Saxton. These acid-sulfate loads increase the sulfate and lower the bicarbonate of the Raystown Branch. The chemical character of the Raystown Branch as it joins the Juniata River at Huntingdon is summarized in table 1. Downstream from Huntingdon, the Juniata River gradually decreases in dissolved solids, bicarbonate, and hardness. A comparison of the summary tabulation of chemical analyses of the Juniata River at Huntingdon and at Newport (table 1) indicates that the decreases occurred in at least 90 percent of the period of record. As reported in table 1, the concentration of sulfate of the Juniata River at Huntingdon ranged from 27 to 34 ppm for the period October 1947 to September 1951 and at Newport from 20 to 82 ppm for the period October 1944 to September 1952.

660212—63——3

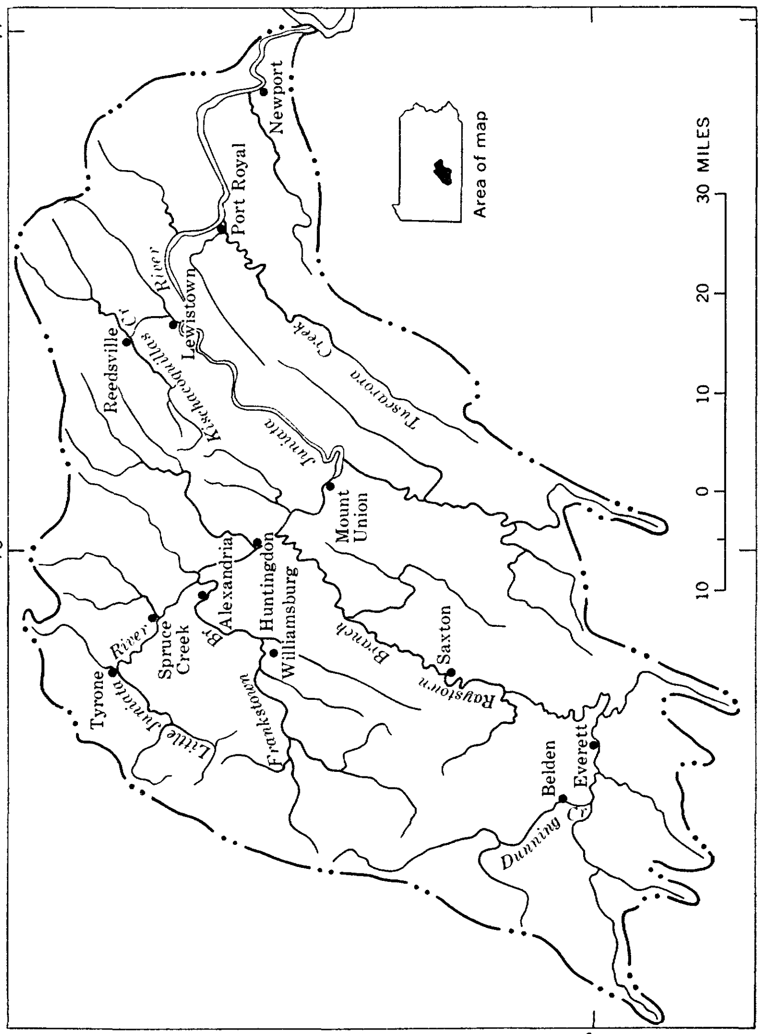


FIGURE 6.—Juniata River basin.

SWATARA CREEK BASIN

The headwaters of Swatara Creek are influenced by acid mine drainage from the Southern Anthracite coal fields (fig. 8) and are low in pH (less than 4.5) and high in sulfate (table 1). As the water of Swatara Creek and its tributaries flows from the coal fields to the Susquehanna River, its chemical character is influenced greatly by the underlying sandstone, shale, limestone, and dolomite. The streams decrease in concentration of sulfate and increase in pH, calcium-magnesium hardness, and concentration of dissolved solids and bicarbonate in a downstream direction from the headwaters. At high flow rates, the concentration of bicarbonate of Swatara Creek near Harper Tavern approximates the concentration of sulfate, and at low flow rates, the concentration of sulfate is two to three times the concentration of the bicarbonate. Near the mouth of Swatara Creek, the underlying limestones increase the pH of the surface water to about 9.0.

GLACIAL DRIFT

During the Pleistocene age, the northern part of Pennsylvania was covered at least three times by successive ice sheets or glaciers. As the ice advanced, the soil and decomposed rock were scraped off and shoved along by the moving ice. During the retreat of the glaciers, rock materials were left scattered over the surface as a veneer of drift or in mounds known as moraines. Streams that had been flowing north were effectively dammed by the advancing ice sheets causing them to break over their headwater divides and flow south. These streams transported large amounts of debris that was later deposited as glacial outwash in pre-existing stream valleys. Many of the present streams draining the glaciated portions of Pennsylvania flow over buried valleys filled with several hundred feet of glacial outwash. These valley-fill deposits constitute the most productive water-bearing material in the Commonwealth. The character and thickness of the valley-fill deposits vary widely from place to place causing variations in the quality of the water.

NORTHEASTERN PENNSYLVANIA

The summary of chemical analyses of the Delaware River at Dingmans Ferry and the chemical analyses of the Lackawaxen River and Bushkill Creek in table 2 are representative of the surface waters in northeastern Pennsylvania. In northeastern Pennsylvania, the ground and surface waters are low in calcium, magnesium, hardness as calcium carbonate (10 to 40 ppm) and low in dissolved solids (16 to 65 ppm). The pH of these waters ranges from 6.0 to 7.5.

NORTH-CENTRAL PENNSYLVANIA

A large portion of north-central Pennsylvania was glaciated and is covered with undisturbed forest land. There are no radical changes in chemical quality within a drainage basin. Thus, the chemical quality samples have been collected near the mouth of the streams and should be representative of the entire drainage basin. Because of the similarity in land use, geology, and runoff throughout north-central Pennsylvania, many streams in this area have similar chemical concentrations and compositions. In north-central Pennsylvania the surface waters have a calcium, magnesium hardness of less than 100 ppm and less than 150 ppm of dissolved solids, and have a pH range of 6.0 to 7.8 (table 2). At Pittston, the mineralized waters of the Lackawanna River increase the dissolved solids of the Susquehanna.

The steams in the northeastern and the north-central parts of the State drain rough, hilly, well-wooded lands in the glaciated areas that are underlain by drift deposits and shale and sandstone formations. Although the land use and geology are similar, the runoff in the Delaware River basin is usually greater per square mile than in the adjacent Susquehanna River basin. Thus, streams in the Delaware River basin are usually lower in dissolved solids than the streams in the adjacent Susquehanna River basin. The chemical analysis of the Lackawaxen River is representative of the water in the Delaware River basin, and the chemical analysis of the Tunkhannock Creek is representative of the water in the glacial drift areas of the Susquehanna River basin (table 2).

The Lackawanna River which receives acid mine drainage from the anthracite coal fields contributes water to the Susquehanna River at Pittston. Catawissa Creek, Nescopeck Creek, and other minor tributaries also receive acid mine drainage and discharge into the south side of the Susquehanna River between Nescopeck and the confluence of the West Branch. These streams have higher hardness, sulfate, and dissolved-solids content. Thus, the hardness, dissolved solids, specific conductance, and sulfate values of the Susquehanna River at Danville (table 2) always exceed the values at Falls for the same frequency intervals.

The streams that drain into the north side of the Susquehanna River between Nescopeck and the confluence of the West Branch are typical of most streams in north-central Pennsylvania and are low in dissolved solids, hardness, and sulfate and have a pH between 6.0 and 7.6.

The Tioga River, in north-central Pennsylvania, is affected by acid mine drainage from the isolated pockets of bituminous coal and contains free sulfuric acid and higher values of sulfate and hardness than most other streams. Chemical analyses of isolated reaches of Sinnemahoning Creek, Young Womans Creek, and adjacent ground water indicates concentration of sodium and chloride indicative of gas and oil-well brine pollution.

NORTHWESTERN PENNSYLVANIA

The ground water from glacial drifts covering the northwestern section of Pennsylvania may be the most dominant geologic factor affecting the chemical quality of surface water. Most streams in northwestern Pennsylvania contain less than 10 ppm of silica, magnesium, potassium, chloride, and nitrate. The pH ranges from 6.3 to 8.3 in these streams, and the dissolved-solids content ranges from 80 to 225 ppm. Streams with the lowest concentrations of dissolved solids are near the Ohio border. The dissolved-solids content of the Conewango Creek at Russell equaled or exceeded 208 ppm only 1 percent of the time; the dissolved-solids content of French Creek at Franklin equaled or exceeded 162 ppm only 1 percent of the time (table 2).

OTHER AREAS

In the extreme southeastern part of Pennsylvania, the bedrock is predominantly crystalline rock of pre-Cambrian age, with some Ordovician limestone, Cambrian quartzite and limestone, and Triassic sandstone, shale, and conglomerate. Pre-Cambrian rocks are dense, massive, and hard with virtually no pore space save for secondary fractures formed by weathering and diastrophism. Recent studies indicate that crystalline-rock terranes are highly absorptive and presumably much water is retained in the weathered zone near the land surface and released to streams at a steady rate. As most of the rock minerals are relatively insoluable, except for local occurrence of marble, the water is generally low in dissolved solids (60 to 150 ppm) and low in calcium, magnesium hardness (34 to 134 ppm), the lower concentrations being in streams of the Susquehanna River basin. The changes of chemical composition of surface waters in southeastern Pennsylvania are caused by the diverse geologic formations underlying the area.

DELAWARE RIVER

Figure 7 is a stream map of the Deleware River basin. The chemical quality of the streams draining into the Deleware River between Dingmans Ferry (fig. 7) and Richmond (a distance of about 25 miles) is similar in chemical quality to the tributaries draining into the Delaware River above Dingmans Ferry (table 2). Thus, concentration of most constituents of the Deleware River at Dingmans Ferry usually compares within 3 ppm with the Delaware at Richmond at all time intervals (table 3). The drainage areas of the streams flowing into the Delaware River between Richmond and Easton are underlain

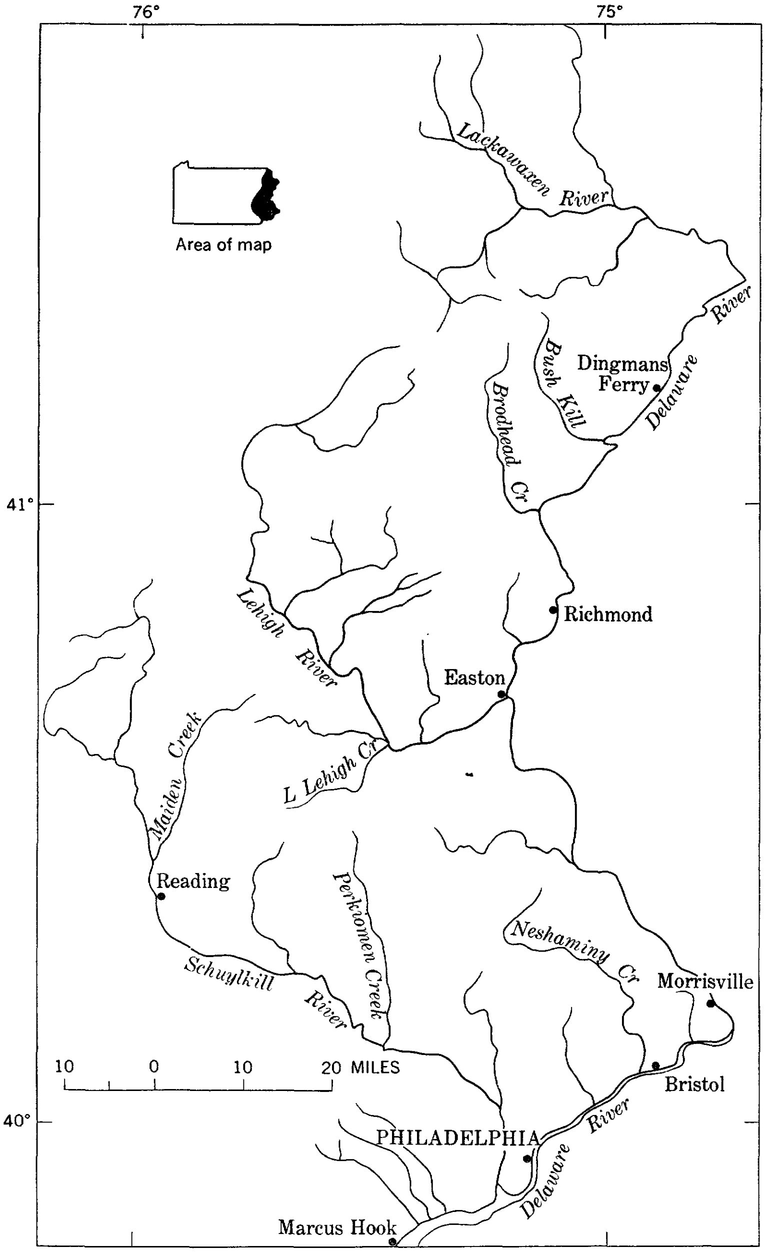


FIGURE 7.—Delaware River basin.

by limestone. Water from these streams increase the calcium and bicarbonate concentrations of the Delaware River water. The chemical quality of the Delaware River at Easton (fig. 7) reflects the influence of these higher bicarbonate tributary streams and of the upper Delaware River (table 3).

At Easton, where it joins the Delaware River, the Lehigh River contains considerably more sulfate and has a lower pH than the Delaware River upstream from the Lehigh River. Although the sulfate content of the Lehigh River decreases after leaving the anthracite coal fields, the sulfate load alters the chemical character of the Delaware River. Below Easton, the chemical character of the streams tributary to the Delaware River are similar to the chemical quality of tributaries above Richmond (table 2). Thus, the chemical quality of the Delaware River at Morrisville is influenced by the chemical character of the Delaware River above Easton, the Lehigh River, and the tributaries of the Delaware River between Easton and Morrisville.

LAKE ERIE

The chemical quality of the water of Lake Erie does not vary greatly throughout the year, the water consistently has a bicarbonate content of about 90 ppm, a calcium-magnesium hardness of about 120 ppm, and chlorides of 15 to 25 ppm. The dissolved-solids content of Lake Erie water between 1934 and 1957 has gradually increased from about 145 to 175 ppm. A chemical analysis of Lake Erie water is reported in table 3.

SOUTHWESTERN PENNSYLVANIA

In the extreme southwestern part of the Commonwealth, the presence of minor limestone formations and the lack of workable bituminous coals separate the chemical character of South Fork Ten Mile Creek, Ten Mile Creek, Dunkard Creek, the headwaters of Loyalhanna Creek, and several tributaries of Youghiogheny and Casselman Rivers from that of adjacent low pH, calcium sulfate waters. The pH of these waters often exceeds 7.5 and is seldom less than 5.5. The calcium-magnesium hardness ranges from 15 to 150 ppm. At low flow the chemical quality of the streams is influenced by acid mine drainage, and thus, the streams contain calcium sulfate type water (table 3). At higher flow rates the acid mine water is diluted and these streams may contain calcium and bicarbonate as the principal ions.

CALCIUM SULFATE WATER

The calcium sulfate waters consist primarily of surface waters whose chemical quality is influenced by pollution from acid mine drainage. Figure 8 is a map of the coal fields in Pennsylvania. In the northeastern part of the Commonwealth, anthracite coal occurs in four irregular shaped fields—the Northern, Western Middle, Eastern Middle, and Southern fields. In figure 8 all anthracite fields have been classified the same. Bituminous coal underlies most of the west-

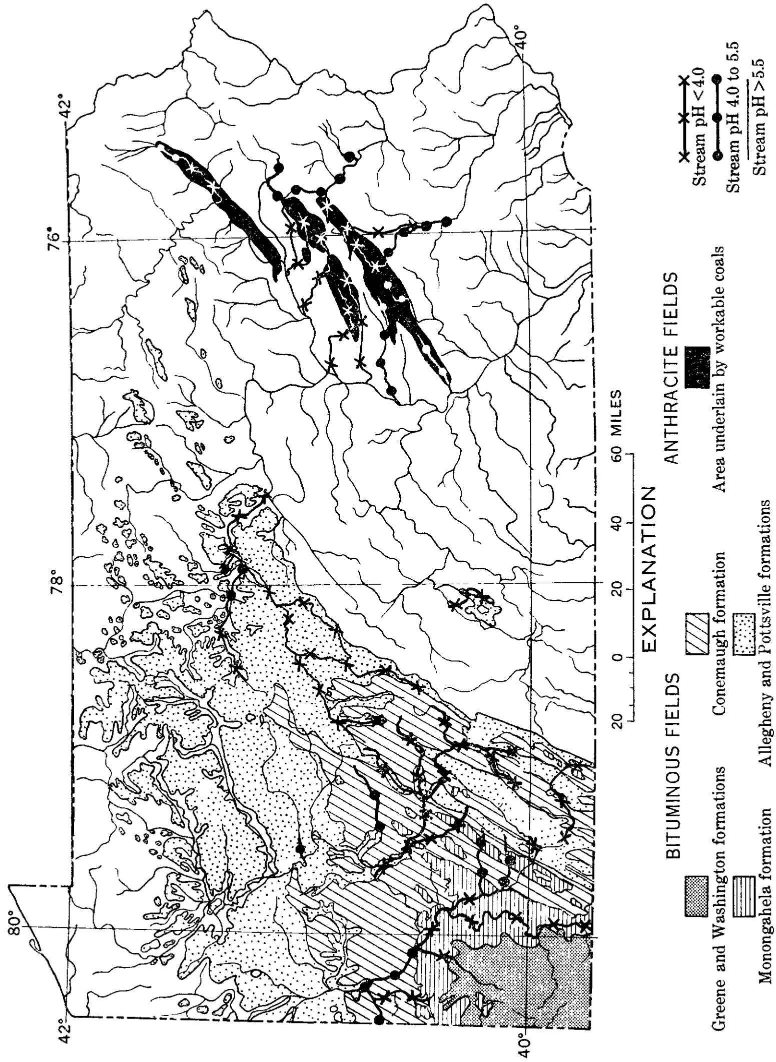


FIGURE 8.—Coal fields and streams affected by acid mine drainage.

ern part of Pennsylvania and occurs in detached hilltop pockets in the northern part. The bituminous coals have been classified into four major fields consisting of (1) the Greene and Washington formations, (2) the Monongahela formation, (3) the Conemaugh formation, and (4) the Allegheny and Pottsville formations.

In Pennsylvania, most of the acid mine drainage comes from coal fields in the Allegheny and Pottsville, Conemaugh and Monongahela formations. In eastern Pennsylvania, the coal beds of the Allegheny formation are the principal sources of acid mine drainage. Owing to its topographic position, the Pottsville formation has little or no effect on the quality of the surface water in the eastern part of the Commonwealth.

In western Pennsylvania, many of the Pottsville formation coal beds have been exposed by strip mines and contribute acid mine drainage to surface waters. The Allegheny formation overlies the Pottsville and contains a number of coal beds that are extensively mined and contribute acid mine drainage. The overlying Conemaugh formation contains less workable coal and more limestone than the Allegheny formation and, thus, produces less acid mine drainage. The Monongahela formation, which overlies the Conemaugh, is exposed in western and southwestern Pennsylvania and is mined for bituminous coal.

In November 1949, the pH of many streams influenced by acid mine drainage was determined. The streams were classified according to pH into the following three categories: (1) greater than 5.5, (2) from 4.00 to 5.5, and (3) less than 4.00. The results of this study, carried out by the Sanitary Water Board, Pennsylvania Department of Health, are presented on figure 8. This stream survey was made during a period of low streamflow, and some of the streams have a higher pH at higher flow rates.

ANTHRACITE COAL FIELDS

The anthracite coal fields in eastern Pennsylvania yield acid mine drainage which lowers the pH and bicarbonate and increases the hardness, the sulfate, and dissolved solids, of the water. Acid mine drainage is received into the headwaters of the Schuylkill River, the Lehigh River, and several streams flowing to the Susquehanna River. The lower reaches of the Lackawanna River receive acid mine drainage from the Northern Anthracite coal fields. Representative analyses of streams draining the anthracite coal fields are presented in table 4.

SCHUYLKILL RIVER

The Schuylkill River above Port Clinton is underlain principally by conglomerate, sandstone, shale, and coal of Pennsylvanian age.

The coals are the heavily mined anthracites of the Southern Anthracite coal fields which extend from the Lehigh River on the east to the Susquehanna River on the west. The Schuylkill River (fig. 9) above

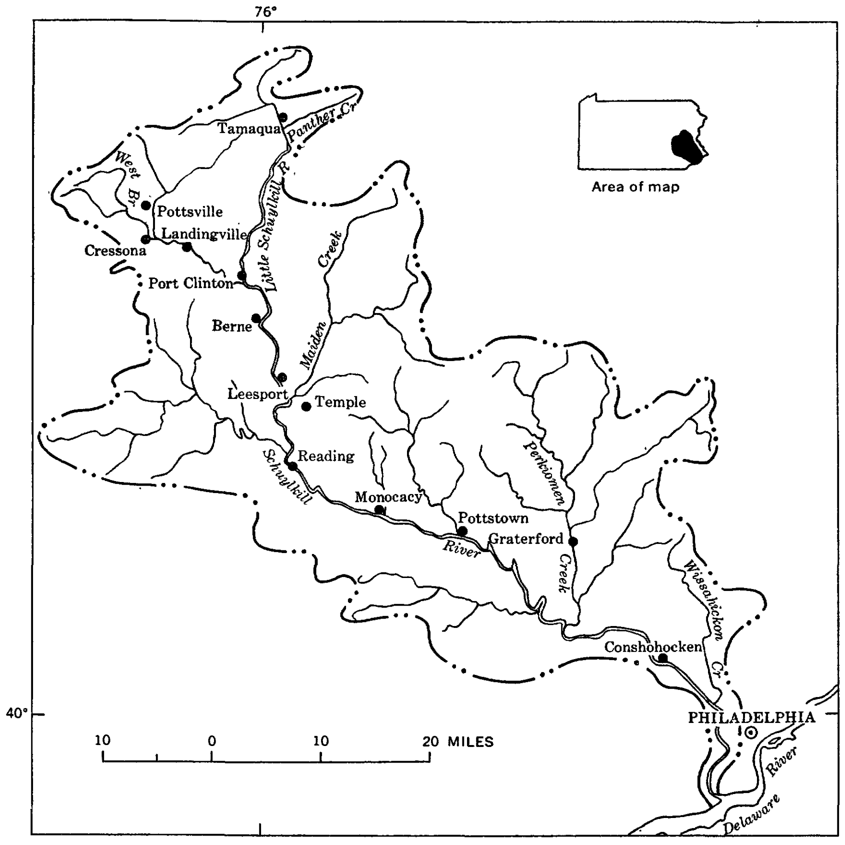


FIGURE 9.—Schuylkill River basin.

Port Clinton and its main tributaries, the West Branch Schuylkill River and the Little Schuylkill River, carry the major portion of the acid mine drainage from the Southern Anthracite coal fields. Chemical analyses of the Schuylkill River from its headwaters to the Delaware River are presented in table 4.

Acid mine drainage from coal fields affects the chemical quality of the Schuylkill River drainage basin above Port Clinton and of the main stem south to its confluence with the Delaware River. Most of the streams in the Schuylkill River basin, above Port Clinton, have a pH less than 4.5, contain free sulfuric acid, and have a predominantly sulfate anion content. These low pH waters also have high concentrations of iron, aluminum, and manganese. The higher concentrations of dissolved constituents, mainly sulfates and free sulfuric acid, are found near the source of introduction of acid mine drainage. The Little Schuylkill River above Tamaqua, which frequently has a pH less than 4.5, usually has a dissolved-solids content of less than 200 ppm. At Tamaqua, Panther Creek contains acid mine drainage and may contribute sulfate in excess of 1,000 ppm, aluminum in excess of 50 ppm, iron in excess of 5 ppm, manganese in excess of 15 ppm, and free sulfuric acid to the Little Schuylkill River. Below Tamaqua, the waters of the Little Schuylkill River are low in pH and high in sulfate, calcium-magnesium hardness, and total acidity.

The Little Schuylkill River and Schuylkill River receive acid-sulfate drainage downstream to Port Clinton. At Port Clinton (fig. 9), the Little Schuylkill River usually contains higher concentrations of dissolved solids than the Schuylkill River. From the confluence of Little Schuylkill River with Schuylkill River at Berne, where the pH equaled or exceeded 4.5 during only 10 percent of the period of record, down to Leesport, which is just above the mouth of Maiden Creek, the pH of the water of the Schuylkill River usually is less than 4.5. Below Leesport, the alkaline calcium bicarbonate water of Maiden Creek increases the pH of the Schuylkill River to more than 4.5. From the mouth of the Maiden Creek to Pottstown, calcium bicarbonate waters of the tributaries tend to increase the pH and bicarbonate and lower the sulfate concentration of the Schuylkill River. Thus, although the bicarbonate content of the Schuylkill River is negligible at Berne, it is usually 25 ppm or more at Pottstown. The hardness and sulfate content of the Schuylkill River at Pottstown is generally lower than at Berne. The decrease in hardness, sulfate, and dissolved-solids content of the Schuylkill River between Pottstown and Philadelphia is caused by the more dilute waters of the Perkiomen Creek and Wissahickon Creek.

LEHIGH RIVER BASIN

Above Stoddartsville, the headwaters of the Lehigh River are not influenced by acid mine drainage. Below Stoddartsville (fig. 10), the Lehigh River receives acid mine drainage from the Middle Anthracite coal fields. Several streams (table 4) containing acid mine drainage, which include Hunter Run, Black Creek and Nesquehoning Creek, empty into the Lehigh River between Lehigh Tannery and Jim Thorpe (Mauch Chunk). The acid-sulfate water from these tributaries lowers the pH and increases the sulfate content of the Lehigh River. Downstream from Jim Thorpe, the Lehigh River does not receive acid mine drainage. The tributaries of the Lehigh River between Jim Thorpe and the Delaware River contain con-

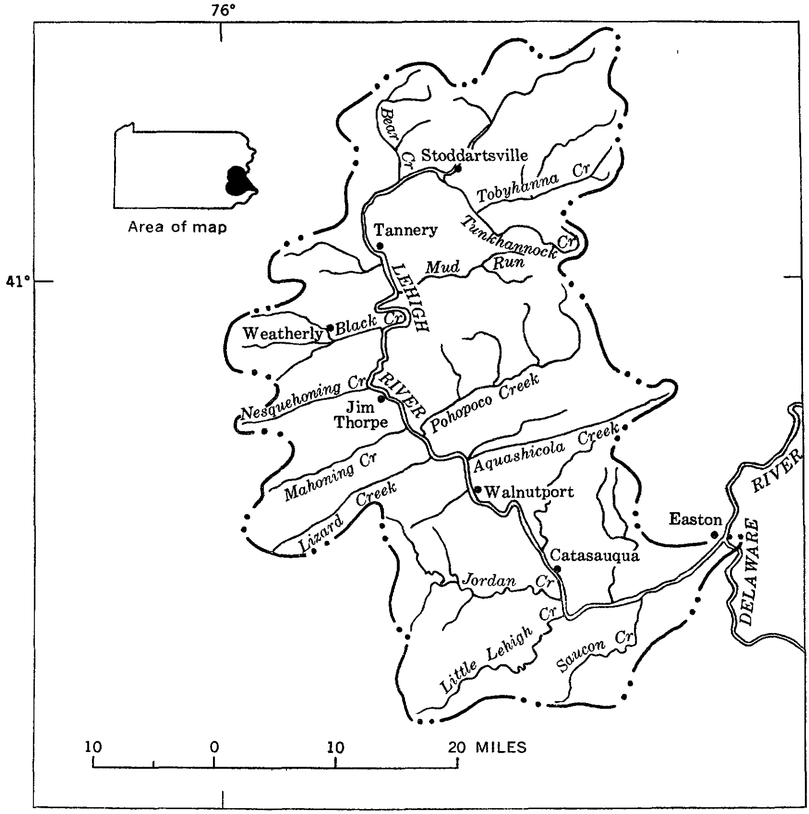


FIGURE 10.—Lehigh River basin.

centrations of bicarbonate in excess of those of the Lehigh River. Frequent analyses of the Lehigh River at Walnutport indicate that the pH of the river at this location is usually between 4.5 and 5.5. At Catasauqua, during 90 percent of the time, the dissolved solids of the Lehigh River exceed 165 ppm, the pH exceeds 6.0, the sulfate seldom exceeds 81 ppm, and the calcium-magnesium hardness seldom exceeds 100 ppm (table 4).

OTHER BASINS

Between Pittston and Millersburg (fig. 12), some tributaries to the east side of the Susquehanna River originate in the anthracite coal fields.

The streams draining the coal fields and surrounding areas vary in chemical composition and pH along the length of the individual streams and from stream to stream. The dissolved-solids content of Mahantango Creek ranges from 72 to 144 ppm and of Shamokin Creek from 1,160 to 1,510 ppm. The greatest concentrations of dissolved solids are usually found near the coal fields. A few streams in this area do not have their headwaters in the anthracite coal fields but contain high percentages of calcium, magnesium, and sulfate (table 4). These streams are usually low in dissolved solids and have a pH greater than 4.5. Wiconisco Creek is an example of a nonacid (pH greater than 4.5) stream. The nonacid streams neutralize and dilute the streams with a pH less than 4.5. Some streams that originate in the anthracite coal fields have a pH less than 4.5 throughout their entire course; others have a pH in excess of 4.5 before they drain into the Susquehanna.

The Lackawanna River drainage basin below Forest City and that of several small streams that pass through or near Wilkes-Barre and drain directly into the Susquehanna River are underlain by the canoe-shaped Northern Anthracite coal fields. Although the Lackawanna River above Forest City usually has a pH ranging from 6.5 to 7.0, the pH of the river at Old Forge equaled or exceeded 4.4 only 10 percent of the period of record (table 4).

Almost all the rainfall in the Lackawanna basin that reaches the Lackawanna River as runoff flows over mine workings. All surface waters draining the coal fields have a pH less than 4.5, free sulfuric acid, and dissolved solids composed almost entirely of calcium and sulfate. These low pH waters contain relatively high concentrations of iron (6.0 ppm), aluminum (14 ppm), and manganese (8.8 ppm).

As the tributaries to the Lackawanna River flow through the Northern Anthracite coal fields, their pH decreases to less than 4.5. Ninety-eight percent of the time, the dissolved-solids content of the Lackawanna River and its tributaries range from about 121 to 1,330 ppm, the hardness of water from 58 to 775 ppm, and the sulfate concentration from 66 to 853 ppm. The highest concentrations of dissolved solids discharged by the Lackawanna River into the Susquehanna River near Pittston occur at low flow during the summer.

BITUMINOUS COAL FIELDS

The bituminous coal fields of western Pennsylvania (fig. 8) are almost completely underlain by sandstone, shale, coal, limestone, and conglomerate of Pennsylvanian age and contain exposures of Mississippian sandstone and conglomerate. To facilitate location of some of the streams draining the bituminous coal areas, a separate illustration (fig. 11) of the lower Allegheny River and Monongahela River basins is included.

UPPER OHIO RIVER BASIN

The drainage area of the Allegheny River above the Kiskiminetas River is forested in the northern part and farmed in the southern part. The area has no large mining operations but has many small coal

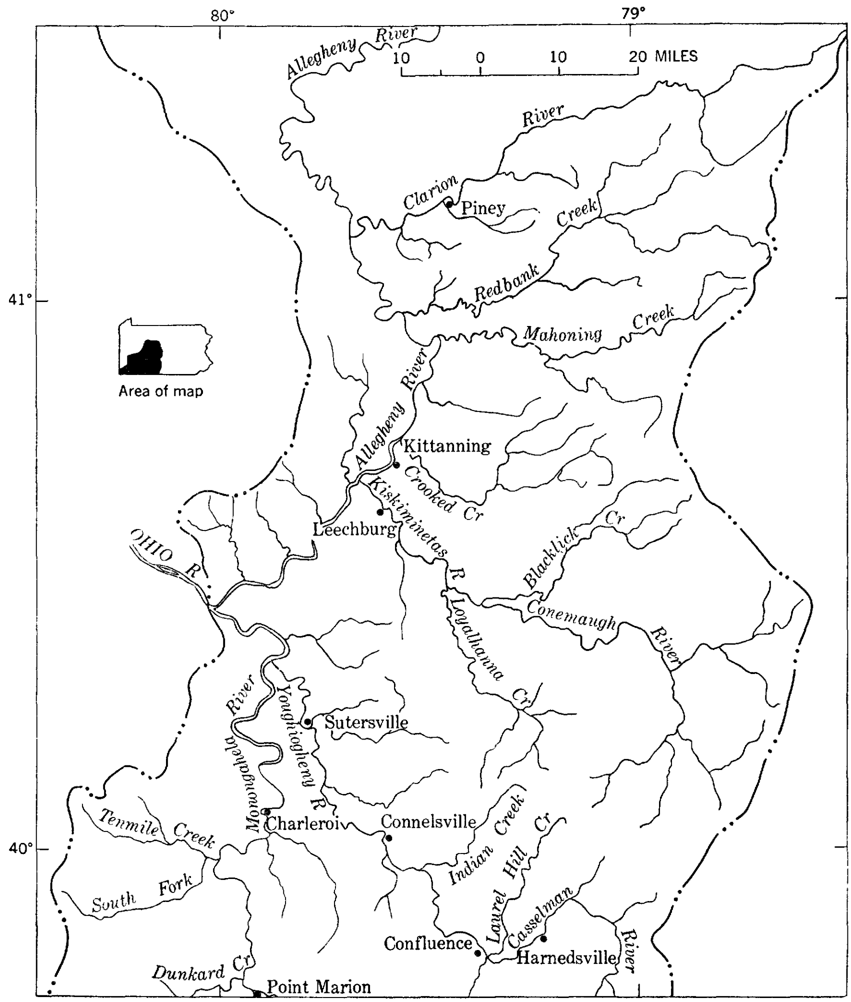


FIGURE 11.—Lower Allegheny River basin.

mines, some active and some inactive. The acid mine water from the coal fields finds its way into streams at many places along their courses. The apparent variability in the quality of water in this area seems to be due to variations in the quantity and the type of coal that has been or is being mined and to the effectiveness with which inactive coal mines have been sealed.

In this area, calcium and sulfate are the principal constituents of most of the streams. The pH is usually above 5.5, although during periods of low flow the pH decreases to less than 4.5 in some of the small streams (fig. 8). Also during periods of low flow, many of these streams have bicarbonate concentrations in excess of 100 ppm;

at higher flow rates, the bicarbonate concentration decreases. The sulfate concentration commonly exceeds the bicarbonate. The sulfate concentration is usually maximum at low flow rates and decreases with increasing flow rates. In the northern part of the Allegheny basin, some streams contain appreciable amounts of chloride. For example, the Clarion River at Piney (table 5) contains 69 ppm of chloride at least 10 percent of the time.

Representative chemical analyses and summaries of chemical analyses of surface waters in this area are presented in table 5. The dissolved solids and hardness of surface water in this area have had a wide range of values. Ninety-eight percent of the time the dissolved solids of the Beaver River at New Brighton ranged from 131 to 422 ppm; dissolved solids of the Clarion River at Piney ranged from 65 to 423 ppm. The hardness of the surface water ranged from soft to hard; most of the hardness was noncarbonate.

The area below the Kiskiminetas River includes portions of the Kiskiminetas, Conemaugh, Youghiogheny, Monongahela, Allegheny, and Ohio Rivers. Many steel plants and other industrial plants of the greater Pittsburgh area are located along the banks of the Allegheny, Monongahela, and Ohio Rivers. This area is underlain by sandstone, shale, conglomerate, limestone, and coal of the Pennsylvanian age. Acid mine drainage from the extensively developed bituminous coal fields lowers the pH of most streams in this area and causes high concentrations of free sulfuric acid, sulfate, and trace metals including iron, aluminum, and manganese. Chemical analyses of the Casselman, Youghiogheny, Monongahela, and Kiskiminetas Rivers and representative analyses of their tributaries for many years are summarized in table 5.

As indicated in figure 8, the majority of the streams draining into the Kiskiminetas River have high concentrations of calcium and sulfate and have a pH less than 4.00. The pH of the Kiskiminetas River at Leechburg (fig. 11) exceeded 4.5 less than 10 percent of the period of record. The free sulfuric acid of the Kiskiminetas River lowers the pH and the concentration of bicarbonate and increases the sulfate of the Allegheny River below Freeport. However, between the Kiskiminetas and Monongahela Rivers, the pH of the Allegheny River does not become less than 4.5 because many of the smaller tributaries to the river have a pH greater than 5.5. The further addition of free sulfuric acid by the Monongahela River lowers the pH of the Ohio River.

As indicated on figure 11, the water of the Casselman River, upstream from Confluence, commonly has a pH less than 4.5. At Harnedsville (fig. 11), the river usually contains sulfate in excess of 100 ppm and has a pH less than 5.0. Below Harnedsville, many of the tributaries to the Casselman River contain concentrations of bicarbonate in excess of 25 ppm and tend to increase the pH and lower the sulfate content of the Casselman River. The Casselman River contributes acid-sulfate waters to the Youghiogheny River at Confluence.

The pH of the Youghiogheny River upstream from Confluence (fig. 11) exceeds 5.5, and calcium sulfate ions are the principal constituents. Although the free acidity of the Casselman River lowers the pH of the Youghiogheny River, the tributaries to the Youghiogheny River downstream from the confluence of the Youghiogheny and the Casselman Rivers contain appreciable amounts of calcium and bicarbonate ions and raise the pH of the Youghiogheny River above 5.5. Downstream from Connellsville, acid mine drainage from tributaries of the Youghiogheny River lowers the pH and increases the sulfate content in the main stem. The pH of the Youghiogheny River at Sutersville exceeded 5.7 less than 10 percent of the time of record. The Youghiogheny River joins the Monongahela River just north of Sutersville at McKeesport.

During the greater part of the year, the pH of the Monongahela River, as it enters from West Virginia, at Point Marion (fig. 11) is less than 4.5 (table 5). Most of the tributaries draining into the west side of the Monongahela River have a pH greater than 5.5. Two exceptions are Peters Creek and the downstream portion of Ten Mile Creek. Several of the tributaries on the east side of the river have a pH less than 4.5 and contain free sulfuric acid and sulfate concentrations in excess of 70 ppm. The pH of the Monongahela River at Charleroi equaled or exceeded 4.9 only 10 percent of the period of record (table 5). At McKeesport, the acidity and sulfate content of the Monongahela River are increased by the inflow of the Youghiogheny River.

The Ohio River is formed by the addition of the Allegheny River and the Monongahela River. The free sulfuric acid content of the Monongahela River lowers the pH of the Ohio River. At Ambridge, the pH of the Ohio River exceeded 5.5 about half the period of record and equaled or exceeded 4.40 about 90 percent of the time. The hardness and dissolved solids of these waters increase with decreases in pH.

SUSQUEHANNA RIVER BASIN

The chemical quality of the Susquehanna River is influenced by many conflicting factors as it flows through Pennsylvania. The southern tributaries of the West Branch Susquehanna River upstream from Lock Haven are influenced by acid mine drainage from bituminous coal fields. The quantity and quality of the acid mine waste vary seasonally; and, the dissolved solids of most streams in this area vary with the amount and concentration of waste water introduced, and with the streamflow. Figure 12 is a stream map of the upper Susquehanna River basin. Although the area influenced by acid mine waste water is large, the dissolved-solids concentration of most streams in this area seldom exceeds 800 ppm. Most of the southern tributaries of the West Branch Susquehanna River have a pH of 4.00 or less, and most of the remaining streams have a pH between 4.00 and 5.5. The pH of the West Branch Susquehanna River at Lock Haven exceeded 4.5 less than 10 percent of the time (table 5).

Downstream from Lock Haven, the tributaries to the West Branch Susquehanna River drain farm land underlain by the limestone terranes. The resulting calcium bicarbonate water decreases the sulfate concentration and increases the pH and bicarbonate concentration of the West Branch Susquehanna River. A comparison of the frequency tables of the West Branch at Lock Haven with the river downstream at Lewisburg (table 5) indicates that the specific conductance, hardness, and concentration of sulfate and dissolved solids at Lock Haven exceed the concentration at Lewisburg.

Downstream from its confluence with the West Branch, the Susquehanna River contains the calcium and sulfate ions from the acid mine drainage in the headwaters of the West Branch. The tributaries draining into the west side of the Susquehanna River are principally calcium bicarbonate waters, and most of the tributaries draining into the east side of the Susquehanna River contain acid mine drainage from the anthracite coal fields. These opposing influences produce an interesting variation in the chemical quality across the river at Harrisburg. (See the cross-sectional analyses of October 18, 1956, presented in table 5). Note that in the east to west direction (1) the pH rose from 7.3 to 8.2, (2) the sulfate decreased from 142 to 36 ppm, (3) the bicarbonate increased from 20 to 106 ppm, and (4) the hardness of water had a low value near the center of the stream and increased towards the banks. Near the east bank, the hardness was mostly noncarbonate (sulfate), but on the west bank, it was mostly carbonate. These observations are confirmed by the monthly frequency data of the three-point cross section of the Susquehanna River at Harrisburg (table 5).

Below Harrisburg the Susquehanna River receives drainage from calcium bicarbonate tributaries from both sides of the river. A cross-sectional sampling of the river at Columbia, 25 miles downstream from Harrisburg (table 5), indicates that the river still contains cross-sectional differences in chemical characteristics similar to those at Harrisburg.

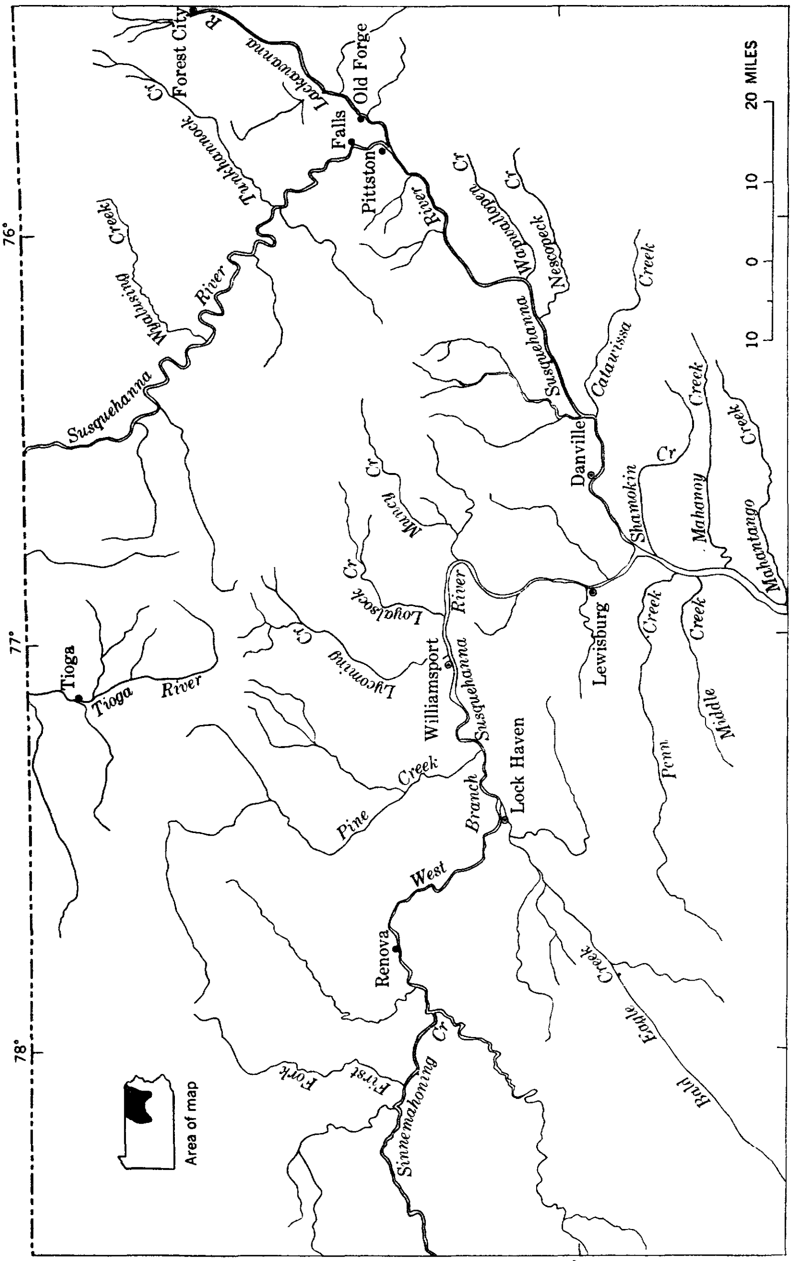


FIGURE 12.—Upper Susquehanna River basin.

SODIUM CHLORIDE WATER

WELL BRINES

The main influence upon the chemical quality of surface water in the upper Allegheny River basin is contamination by sodium chloride brine from oil wells. Examination of oil-well records indicates that considerable amounts of brine are pumped to the surface with the oil. Brine also escapes to the surface because of faulty plugging of abandoned oil wells. A plug that is not set deeply enough in the well permits seepage of the brine into shallow aquifers, thereby increasing the sodium chloride content of the ground water. If the ground water reaches the surface, the surface water also becomes contaminated. These surface and ground waters contain high concentrations of sodium chloride. The highest concentrations of dissolved solids are found near the source of the brine.

The Allegheny River, as it reenters Pennsylvania, contains remnants of the brine load picked up in its headwaters. The sodium chloride concentrations in the Allegheny River are diluted in a downstream direction, first by calcium bicarbonate streams flowing into the Allegheny River between Warren and Franklin, and then by calcium sulfate streams draining into the river below Franklin. At Kittanning, the chloride concentration exceeded 70 ppm less than 1 percent of the period of record, but at Warren it exceeded 70 ppm 99 percent of the period of record (table 6). The sodium and chloride concentrations and, thus, the dissolved solids of the Allegheny River decrease in a downstream direction.

The chemical quality of ground and surface waters in the Conoquenessing Creek basin is also affected by sodium chloride brines from oil and gas wells. The higher concentrations of sodium and chloride and, thus the dissolved solids, occur in the headwaters of the stream and decrease in a downstream direction to the confluence with the Beaver River. Little or no brine is added to the surface waters below the headwaters. Representative chemical analyses of the surface waters at selected locations are presented in table 6.

ESTUARINE BRINES

The Delaware River becomes tidal near Morrisville at Trenton Falls (fig. 7). Between Morrisville and Philadelphia, the river drains the fertile farmlands. The Philadelphia area is one of the greatest industrial regions of the United States.

The water flowing into the tidal portion of the Delaware River at Morrisville has a pH of about 7.0 and the following maximum concentrations: chloride, 11 ppm; hardness, 104 ppm; and dissolved solids, 152 ppm. At average and above-average flow rates, the chemical quality of the Delaware River between Morrisville and Marcus

Hook is similar to that at Morrisville. The dissolved solids of the river water increase slightly from Morrisville to Philadelphia during average and above-average flow.

During periods of low flow, the Delaware River below Philadelphia is invaded by salt water from the Delaware Bay and the ocean. The salt water is carried upstream on the floodtide and downstream on the ebb tide. The amount of salt water in the river at any location is dependent on (1) the distance from the ocean, (2) the fresh-water inflow, (3) the quantity of salt water moving upstream from the ocean, (4) the stage of tide, and (5) the range of tide. During the summer and early fall, fresh-water inflow is at a minimum, and the mean sea level, which controls the movement of salt water into the estuary, is at a maximum; these are favorable conditions for movement of salt water upstream. During late October or early November, the fresh-water flow increases and the sea level decreases concurrently, causing the salt water to recede downstream.

In the period from 1950 to 1955, the chloride content of the Delaware River at Philadelphia exceeded 50 ppm about 6 percent of the time, and at Marcus Hook, near Delaware, it exceeded 50 ppm about 34 percent of the time. Maximum and minimum values of analyses at Morrisville (fig. 7), Bristol, Philadelphia, and Marcus Hook are presented in table 7.

REPRESENTATIVE CHEMICAL ANALYSES OF SURFACE WATER

CALCIUM BICARBONATE WATER

TABLE 1.—*Chemical analyses of water in limestone areas*

[Chemical analyses in parts per million]

Location	Date	Percent of time	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Non-carbonate	Specific conductance (micromhos at 25°C)	pH	Color
Representative analyses of streams and springs																			
Delaware River basin:																			
Maiden Creek near Temple, Pa.	Apr. 13, 1946	------	[1]675	6.0	------	------	------	------	[2]78	31	------	------	------	------	40	------	212	9.0	1
	Sept. 10, 1947	------	[1]47	6.7	0.01	28	8.2	1.3	103	14	3.1	0.1	3.6	121	104	19	208	7.7	4
	Apr. 20, 1948	------	------	7.4	.10	19	5.9	3.8	60	19	3.5	.0	7.5	108	72	22	166	7.3	12
	Oct. 25, 1948	------	------	6.9	------	------	------	------	143	15	3.0	.0	4.8	------	125	8	267	7.7	5
	Oct. 15, 1957	------	[1]60	------	------	------	------	9.2	116	23	5.2	------	4.2	------	110	15	253	7.1	6
Susquehanna River basin:																			
Thompson Spring at University Park, Pa.	Aug. 12, 1944	------	[1]8	5.3	.02	47	21	3.2	227	10	3.2	.0	12	221	204	18	386	7.6	5
Rock (Benner) Spring near Bellefonte, Pa.	Aug. 12, 1944	------	[1]16	5.4	.02	37	14	2.9	171	5.8	1.9	.0	9.2	162	150	10	287	7.8	4
Little Juniata River above Tyrone, Pa.	Aug. 17, 1948	------	[1]13	5.6	.12	40	9.1	23	100	67	18	.0	13	278	137	55	375	7.0	10
Frankstown Br. Juniata R. near Williamsburg, Pa.	Aug. 17, 1948	------	[1]91	2.8	.05	49	15	18	162	57	18	.0	5.7	263	184	51	406	7.9	10
Raystown Br. Juniata R. at Saxton, Pa.	Aug. 16, 1948	------	[1]188	2.4	.05	35	11	------	168	38	3.0	.0	2.7	168	134	44	268	8.0	8
Juniata River at Lewiston, Pa.	Aug. 18, 1948	------	[1]617	1.2	.04	35	11	8.4	114	40	10	.0	1.4	186	132	39	298	7.8	10
Juniata River at Newport, Pa.	Aug. 18, 1948	------	[1]762	2.0	.06	35	11	18	108	65	11	.0	.9	208	133	44	345	7.8	5
Swatara Creek at Harper Tavern, Pa.	Feb. 24, 1949	------	1,530	2.0	.08	9.5	2.8	3.5	[3]16	19	5.0	.0	3.6	51	35	------	87	9.4	5
	Aug. 26, 1949	------	45	5.2	.19	27	10	5.2	38	75	5.0	.2	3.5	154	108	77	241	7.2	5
	Oct. 12, 1957	------	[1]47	------	------	------	------	13	44	85	3.0	------	3.0	------	104	68	266	6.5	6

See *footnotes at end of table.*

TABLE 1.—*Chemical analyses of water in limestone areas*—Continued

[Chemical analyses in parts per million]

Location	Date	Percent of time	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Non-carbonate	Specific conductance (micromhos at 25°C)	pH	Color
Maximum and minimum observed values for specific conductance and chemical analyses [Based on once-a-week sampling]																			
Delaware River basin:																			
Neshaminy Creek near Langhorne, Pa.—Max	November 1946 to August 1949.	------	2,110	15	0.31	18	9.6	14	79	44	14	0.1	9.9	139	93	53	241	8.0	------
Min		------	28	2.2	.01	9.6	4.6	2.8	16	21	4.0	.0	1.2	111	43	18	107	6.1	------
Perkiomen Creek at Graterford, Pa.—Max	September 1947 to September 1950.	------	7,020	16	.88	26	11	12	122	44	10	.2	8.8	155	108	44	251	8.2	------
Min		------	27	4.8	.01	10	4.5	4.2	18	5.6	2.0	.0	.4	94	43	0	108	6.5	------
Brandywine Creek at Chadds Ford, Pa.—Max	January 1947 to September 1950.	------	1,440	18	.37	26	9.0	10	83	27	8.5	.2	17	168	102	28	242	8.0	------
Min		------	108	5.1	.02	8.0	3.3	2.9	22	15	3.1	.0	4.0	61	34	7	96	6.2	------
Potomac River basin:																			
Conococheague Creek at Fairview, Md.—Max	April 1948 to September 1949.	------	------	9.0	.31	51	12	9.7	198	31	9.0	.2	14	206	257	------	343	8.5	35
Min		------	------	.4	.03	29	5.6	.3	77	12	2.5	.0	1.2	118	82	------	180	7.0	1
Antietam Creek near Waynesboro, Pa.—Max	April 1948 to September 1949.	------	------	7.6	.22	53	17	8.9	208	20	8.0	.1	12	212	257	------	391	8.2	35
Min		------	------	1.4	.04	24	7.1	1.3	56	8.4	3.0	.0	3.5	125	51	------	130	7.1	1

Percent of days in which value tabulated was equaled or exceeded

Susquehanna River basin:																			
Juniata River at Huntingdon, Pa.	October 1947 to September 1951.	1	------	------	------	51	14	18	168	34	32	------	------	252	180	42	433	------	------
		10	------	------	------	47	13	15	155	34	29	------	------	235	169	39	405	------	------
		50	------	------	------	34	10	9.6	104	30	17	------	------	167	121	31	284	------	------
		90	------	------	------	26	7.9	5.2	70	28	8.1	------	------	126	87	25	202	------	------
		99	------	------	------	23	7.1	3.8	58	27	5.4	------	------	112	75	21	174	------	------
Raystown Br. Juniata R. near Huntingdon, Pa.	October 1946 to September 1950.	1	------	------	------	37	14	2.4	105	59	4.1	------	------	183	146	67	305	------	------
		10	------	------	------	33	13	2.4	92	53	3.8	------	------	165	130	59	273	------	------
		50	------	------	------	20	7.0	2.3	52	32	2.5	------	------	104	75	34	169	------	------
		90	------	------	------	13	4.2	2.3	31	22	2.0	------	------	72	47	21	116	------	------
		99	------	------	------	11	3.3	2.2	22	18	1.5	------	------	60	36	12	94	------	------
Juniata River at Newport, Pa.	October 1944 to September 1952.	1	------	------	------	43	12	25	141	82	15	------	------	265	170	65	440	------	------
		10	------	------	------	38	11	20	119	70	13	------	------	230	148	51	375	------	------
		50	------	------	------	26	6.7	11	72	41	7.1	------	------	148	96	32	238	------	------
		90	------	------	------	19	4.3	5.2	47	26	3.8	------	------	99	65	22	156	------	------
		99	------	------	------	16	3.1	3.7	37	20	2.0	------	------	91	54	20	125	------	------
Conestoga Creek at Lancaster, Pa.	October 1947 to September 1950.	1	------	------	------	53	16	9.3	193	27	8.3	------	------	262	191	------	400	------	------
		10	------	------	------	52	16	8.1	189	26	8.3	------	------	234	189	44	393	------	------
		50	------	------	------	45	14	6.0	158	24	7.0	------	------	206	163	33	342	------	------
		90	------	------	------	34	10	4.3	112	23	5.3	------	------	164	123	25	265	------	------
		99	------	------	------	23	6.8	2.8	65	23	3.3	------	------	120	82	24	185	------	------

[1] Discharge at time of sampling.
[2] Includes equivalent of 9 ppm of carbonate (CO_3).
[3] Includes equivalent of 6 ppm of carbonate (CO_3).

TABLE 2.—*Chemical analyses of water in glacial-drift areas*

[Chemical analyses in parts per million]

Location	Date	Percent of time	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Non-carbonate	Specific conductance (micromhos at 25°C)	pH	Color
Representative analyses of streams																			
Delaware River basin:																			
Lackawaxen River at Hawley, Pa.	July 28, 1949	------	[1] 66	1.6	0.04	11	3.2	2.8	32	17	2.5	0.0	0.6	54	41	14	89	7.2	15
	Feb. 14, 1956	------	675	------	------	------	------	3.9	15	11	3.0	------	3.0	------	22	10	70	6.8	8
	Apr. 4, 1956	------	2,220	------	------	------	------	------	12	11	------	------	2.5	------	24	14	60	6.3	4
	Aug. 7, 1956	------	62	------	------	------	------	4.6	31	11	2.5	------	1.9	------	32	7	91	7.2	5
	Oct. 9, 1957	------	89	------	------	------	------	3.0	27	14	3.6	------	1.3	------	36	14	98	5.8	4
Bush Kill at Shoemakers, Pa.	July 28, 1949	------	[1] 28	3.6	.02	4.4	1.0	1.9	13	5.7	1.0	.1	.7	34	15	4	37	6.9	25
	Feb. 14, 1956	------	150	------	------	------	------	3.9	8	8.5	2.0	------	.3	------	10	3	41	6.2	8
	Oct. 9, 1957	------	[1] 28	------	------	------	------	2.1	12	7.5	1.2	------	.2	------	15	5	43	5.9	2
Susquehanna River basin:																			
Tioga River at Tioga, Pa.	Oct. 9, 1956	------	------	------	------	------	------	10	3	73	4.6	------	6.4	------	68	66	194	5.6	5
	Oct. 10, 1957	------	------	------	------	------	------	------	0	136	3.5	------	.7	------	96	96	307	4.20	3
Tunkhannock Creek at Dixon, Pa.	Oct. 11, 1957	------	58	------	------	------	------	6.9	46	18	4.5	------	.4	------	48	11	134	7.1	5

Percent of days in which value tabulated was equaled or exceeded

Delaware River basin:																			
Delaware River at Dingmans Ferry, Pa.	October 1950 to September 1952.	1	------	------	------	10	2.0	4.5	30	10	4.7	------	------	56	33	------	85	------	------
		10	------	------	------	7.8	1.8	3.2	20	9.8	3.3	------	------	46	26	------	68	------	------
		50	------	------	------	6.4	1.4	2.2	14	9.3	2.2	------	------	39	21	------	57	------	------
		90	------	------	------	5.0	1.3	1.4	8	9.2	1.5	------	------	33	16	------	47	------	------
		99	------	------	------	4.6	1.2	1.0	6	8.8	1.1	------	------	31	15	------	42	------	------
Susquehanna River basin:																			
Susquehanna River at Falls, Pa.	October 1944 to September 1952.	1	------	------	------	40	6.8	10	123	23	12	------	------	165	126	24	292	------	------
		10	------	------	------	32	5.7	8.0	101	21	9.8	------	------	140	104	22	243	------	------
		50	------	------	------	23	4.2	6.0	70	18	6.5	------	------	104	76	18	177	------	------
		90	------	------	------	16	3.0	3.8	44	16	3.2	------	------	77	52	15	123	------	------
		99	------	------	------	14	2.6	3.1	34	15	2.2	------	------	65	42	14	101	------	------
Susquehanna River at Danville, Pa.	October 1945 to September 1952	1	------	------	------	58	24	14	------	259	11	------	------	373	238	191	555	------	------
		10	------	------	------	45	18	11	------	164	8.5	------	------	288	186	142	432	------	------
		50	------	------	------	26	9.6	6.2	------	70	4.5	------	------	158	101	70	245	------	------
		90	------	------	------	17	5.0	3.9	------	34	2.9	------	------	96	60	31	150	------	------
		99	------	------	------	13	3.2	3.0	------	26	2.4	------	------	75	46	20	117	------	------
Ohio River Basin:																			
Conewango Creek at Russell, Pa.	October 1951 to September 1952	1	------	------	------	47	9.5	16	140	27	13	------	------	208	157	34	360	------	------
		10	------	------	------	42	8.7	14	125	24	11	------	------	197	142	34	324	------	------
		50	------	------	------	24	5.0	6.5	63	20	4.5	------	------	106	80	32	180	------	------
		90	------	------	------	16	3.5	3.5	38	17	2.0	------	------	74	56	31	123	------	------
		99	------	------	------	12	1.0	1.0	23	15	.5	------	------	54	40	------	96	------	------
French Creek at Franklin, Pa.	October 1946 to September 1947	1	------	------	------	38	7.6	12	119	30	9.2	------	------	162	127	------	285	------	------
		10	------	------	------	37	7.3	11	116	29	9.0	------	------	159	123	------	264	------	------
		50	------	------	------	24	5.0	7.0	69	23	5.0	------	------	108	80	------	182	------	------
		90	------	------	------	15	3.0	4.3	37	20	2.0	------	------	73	50	------	114	------	------
		99	------	------	------	12	2.5	3.2	27	18	1.0	------	------	62	41	------	93	------	------

[1] Discharge at time of sampling.

TABLE 3.—*Chemical analyses of other calcium bicarbonate waters*

[Chemical analyses in parts per million]

Location	Date	Percent of time	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Color
Representative analyses of streams and Lake Erie																			
Ohio River basin:																			
Laurel Hill Creek at Ursina, Pa.	Feb. 9, 1956	----	[1] 838	----	----	----	----	0.1	4	12	1.0	----	3.7	----	20	17	68	6.1	2
	June 30, 1956	----	89	----	----	----	----	2.0	10	9.0	2.5	----	1.2	----	18	10	50	6.9	5
Indian Creek near Champion, Pa.	June 27, 1956	----	----	----	----	----	----	2.3	20	13	2.5	----	2.0	----	30	14	80	6.7	3
Ten Mile Creek near Millsboro, Pa.	Mar. 27, 1956	----	----	8.2	0.03	37	6.0	13	88	60	6.0	0.1	3.3	200	117	45	300	7.9	1
	June 28, 1956	----	[1] 133	----	----	----	----	27	96	72	16	----	1.6	----	118	39	365	8.2	5
St. Lawerence River basin:																			
Lake Erie at Erie, Pa.	June 11, 1957	----	----	.6	.02	35	8.5	11	111	20	20	.2	1.1	171	122	32	294	7.2	7
Percent of days in which value tabulated was equaled or exceeded																			
Delaware River basin:																			
Delaware River at Richmond, Pa.	October 1944 to September 1947.	1	----	----	----	10	3.0	4.8	32	13	3.0	----	----	53	37	7	90	----	----
		10	----	----	----	9.1	2.5	3.9	27	12	2.4	----	----	48	32	7	80	----	----
		50	----	----	----	7.4	2.1	3.1	22	11	1.8	----	----	44	28	7	70	----	----
		90	----	----	----	6.1	1.5	2.4	13	10	.9	----	----	38	23	7	58	----	----
		99	----	----	----	4.8	.9	2.1	12	9.8	.5	----	----	35	18	7	49	----	----
Delaware River at Easton, Pa.	October 1947 to September 1951.	1	----	----	----	16	5.0	6.0	55	18	4.1	----	----	85	59	15	141	----	----
		10	----	----	----	14	4.0	5.0	45	16	3.0	----	----	75	50	14	121	----	----
		50	----	----	----	11	3.0	4.0	32	14	2.6	----	----	62	39	14	96	----	----
		90	----	----	----	8.0	2.0	2.7	21	13	2.0	----	----	51	28	13	74	----	----
		99	----	----	----	6.5	1.5	2.4	15	12	1.7	----	----	44	21	13	61	----	----
Delaware River at Morrisville, Pa.	October 1944 to September 1954.	1	[2] 62,000	----	----	27	10	8.0	78	38	11	----	----	152	104	45	260	----	----
		10	[2] 27,000	----	----	21	7.0	6.0	60	31	8.0	----	----	124	82	36	206	----	----
		50	[2] 9,200	----	----	15	5.0	4.0	38	23	5.0	----	----	86	55	25	140	----	----
		90	[2] 3,090	----	----	10	3.0	3.0	25	18	3.0	----	----	63	38	18	100	----	----
		99	[2] 1,980	----	----	8.0	2.0	2.0	18	15	2.0	----	----	51	29	14	78	----	----

[1] Discharge at time of sampling.
[2] Period of record; 1942–45.

CALCIUM SULFATE WATER

TABLE 4.—*Chemical analyses of water draining anthracite-coal areas*

[Chemical analyses in parts per million]

Location	Date	Percent of time	Mean discharge (cfs)	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180° C)	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Noncarbonate	Total acidity as ($H+^1$)	Specific conductance (micromhos at 25° C)	pH	Color
Representative analyses of streams																						
Delaware River basin:																						
Hunter Run near Rockport, Pa.	Nov. 1, 1945	----	[1] 10	10	16	0.70	0.82	8.4	8.0	----	0	175	2.8	0.1	1.0	223	192	192	3.1	599	3.10	6
Black Creek near Weatherly, Pa.	Oct. 31, 1945	----	[1] 50	12	12	.13	2.2	17	14	4.1	0	172	6.2	.0	.6	255	181	181	1.8	416	3.70	8
Nesquehoning Creek near Jim Thorpe, Pa.	Nov. 1, 1945	----	[1] 17	11	12	.02	2.8	55	16	3.7	0	270	4.2	.1	.2	392	285	285	1.8	582	3.70	3
Schuylkill River at Pottsville, Pa.	Apr. 12, 1948	----	[1] 570	----	----	----	----	----	----	----	0	256	----	----	----	----	210	210	1.4	564	3.85	1
	Oct. 4, 1949	----	[1] 27	14	7.3	.17	7.9	92	52	26	2	533	6.0	.0	.8	871	491	489	2.0	1,020	4.6	10
W. Br. Schuylkill River at Cressona, Pa.	Apr. 12, 1948	----	----	7.0	----	----	----	----	----	----	1	233	----	----	----	----	207	----	.2	523	5.0	---
	Oct. 4, 1949	----	[1] 24	9.5	3.3	.14	5.2	115	59	63	5	665	4.0	.0	.7	1,020	558	554	.5	1,210	5.0	5
Schuylkill River at Port Clinton, Pa.	Apr. 12, 1948	----	[1] 914	----	----	----	----	----	----	----	0	139	----	----	----	----	123	123	.4	345	4.7	1
	Oct. 4, 1949	----	[1] 65	11	2.8	.11	4.6	68	34	19	4	347	6.0	.0	.8	514	334	330	.9	683	4.8	5
Little Schuylkill River at Tamaqua, Pa.	Apr. 13, 1948	----	[1] 235	5.0	----	----	----	----	----	----	1	25	----	----	----	----	26	----	.2	90	4.9	1
	Oct. 4, 1949	----	[1] 16	7.0	5.7	.16	.90	14	5.6	4.3	0	91	2.0	.0	1.2	142	93	93	1.1	218	4.20	6
Panther Creek at Tamaqua, Pa.	Apr. 13, 1948	----	[1] 73	----	----	----	----	----	----	----	0	798	----	----	----	----	660	660	6.6	1,430	3.60	1
	Oct. 4, 1949	----	[1] 21	26	50	6.0	17	156	103	30	0	1,170	6.0	.0	1.8	1,870	1,140	1,140	10	2,090	3.05	5
Little Schuylkill River at Port Clinton, Pa.	Apr. 12, 1948	----	[1] 725	----	----	----	----	----	----	----	0	110	----	----	----	----	76	76	.8	289	4.25	1
	Oct. 4, 1949	----	[1] 83	14	25	.84	6.0	64	32	12	0	443	6.0	.0	4.0	676	445	445	3.4	893	4.65	6
Schuylkill River at Reading, Pa.	Apr. 13, 1948	----	[1] 2,410	7.0	----	----	----	----	----	----	12	87	----	----	----	----	80	----	----	234	6.9	1
	Oct. 4, 1949	----	[1] 238	13	----	.02	----	44	19	9.5	21	192	4.0	.0	1.3	311	188	171	----	464	6.8	5
Schuylkill River at Monocacy, Pa.	Apr. 14, 1948	----	[1] 4,020	8.0	----	----	----	----	----	----	34	64	----	----	----	----	81	----	----	234	7.4	1
	Oct. 5, 1949	----	[1] 402	7.0	----	.03	----	42	18	15	56	138	14	.0	6.0	275	179	133	----	429	6.8	5
Schyulkill River at Conshohocken, Pa.	Apr. 15, 1948	----	[1] 15,100	7.0	----	----	----	----	----	----	49	43	----	----	----	----	68	----	----	205	6.8	1
	Oct. 5, 1949	----	[1] 585	4.0	----	.14	----	50	21	15	77	158	16	.1	8.1	321	211	148	----	506	7.1	20

See footnotes at end of table.

TABLE 4.—*Chemical analyses of water draining anthracite-coal areas*—Continued

[Chemical analyses in parts per million]

Location	Date	Percent of time	Mean discharge (cfs)	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Noncarbonate	Total acidity as (H^{+1})	Specific conductance (micromhos at 25°C)	pH	Color
Representative analyses of streams—Continued																						
Susquehanna River basin:																						
Shamokin Creek at Weigh Scale, Pa.	Apr. 21, 1950	----	[1] 147	20	20	3.8	9.6	114	55	78	0	785	7.5	0.0	0.8	1,200	511	511	8.0	1,680	3.70	4
	Sept. 21, 1950	----	[1] 50	20	15	53	8.7	126	70	106	8	802	165	.0	1.4	1,510	602	596	6.1	1,860	4.9	140
Wiconisco Creek at Elizabethville, Pa.	Apr. 21, 1950	----	[1] 120	4.9	------	.05	------	20	12	8.9	28	87	2.5	.0	2.0	155	99	76	-----	228	7.1	4
	Sept. 21, 1950	----	[1] 29	6.5	------	.08	------	28	15	12	37	114	4.5	.0	2.6	207	132	101	-----	319	7.4	3
Percent of days in which value tabulated was equaled or exceeded																						
Delaware River Basin:																						
Lehigh River at Catasauqua, Pa.	October 1944–	1	[2] 9,750	------	------	------	------	24	9.1	11	30	81	5.5	-----	-----	165	100	82	-----	262	[3] 7.5	---
	September 1952	10	[2] 4,100	------	------	------	------	18	6.8	8.0	22	60	4.3	-----	-----	124	75	64	-----	198	[3] 7.1	---
		50	[2] 1,550	------	------	------	------	12	4.4	5.2	14	39	3.0	-----	-----	82	48	41	-----	130	[3] 6.6	---
		90	[2] 590	------	------	------	------	8.9	3.0	3.2	9	26	2.3	-----	-----	59	33	28	-----	92	[3] 6.0	---
		99	[2] 410	------	------	------	------	7.1	2.5	2.6	7	22	1.8	-----	-----	50	28	22	-----	77	[3] 5.5	---

Schuylkill River at Berne, Pa.	October 1948 to September 1952	1	--------	------	------	------	------	81	48	24	----	522	10	-----	-----	784	424	------	-----	1,010	5.0	---
		10	--------	------	------	------	------	69	43	20	----	443	6.9	-----	-----	690	368	------	-----	888	4.6	---
		50	--------	------	------	------	------	42	26	12	0	260	4.2	-----	-----	404	220	------	-----	552	4.25	---
		90	--------	------	------	------	------	25	16	7.5	0	150	3.2	-----	-----	234	131	------	-----	352	3.85	---
		99	--------	------	------	------	------	16	11	4.5	0	92	2.1	-----	-----	145	83	------	-----	245	3.50	---
Schuylkill River at Pottsville, Pa.	October 1944 to September 1951.	1	[4] 9,900	------	------	------	------	58	26	19	55	202	14	-----	-----	396	251	------	-----	576	------	---
		10	[4] 4,200	------	------	------	------	51	23	16	50	178	12	-----	-----	348	221	190	-----	510	------	---
		50	[4] 1,450	------	------	------	------	35	15	11	38	119	7.9	-----	-----	239	151	100	-----	355	------	---
		90	[4] 525	------	------	------	------	25	10	7.0	29	78	5.1	-----	-----	164	102	------	-----	245	------	---
		99	[4] 330	------	------	------	------	20	8.0	5.0	25	58	3.4	-----	-----	126	78	------	-----	193	------	---
Schuylkill River at Philadelphia, Pa.	October 1945 to September 1954.	1	[5] 17,000	------	------	------	------	52	24	21	85	154	20	-----	-----	360	228	------	-----	550	------	---
		10	[5] 6,300	------	------	------	------	45	21	17	75	132	17	-----	-----	312	198	140	-----	480	------	---
		50	[5] 1,800	------	------	------	------	32	14	11	52	89	11	-----	-----	214	135	84	-----	330	------	---
		90	[5] 395	------	------	------	------	23	9.3	5.4	36	58	6.5	-----	-----	146	92	58	-----	228	------	---
		99	[5] 205	------	------	------	------	18	7.3	3.0	29	44	4.6	-----	-----	115	72	47	-----	180	------	---
Susquehanna River basin:																						
Lackawanna River Old Forge, Pa.	October 1947 to September 1951.	1	--------	------	------	------	------	130	90	42	----	853	5.0	-----	-----	1,330	775	------	-----	1,580	6.0	---
		10	--------	------	------	------	------	116	80	37	0	752	5.0	-----	-----	1,130	695	------	-----	1,420	4.40	---
		50	--------	------	------	------	------	71	47	23	0	427	5.0	-----	-----	623	402	------	-----	935	3.60	---
		90	--------	------	------	------	------	37	21	10	0	207	4.5	-----	-----	323	195	------	-----	495	3.30	---
		99	--------	------	------	------	------	12	6.5	3.9	0	66	4.0	-----	-----	121	58	------	-----	190	3.00	---

[1] Discharge at time of sampling.
[2] Based on discharge of Lehigh River at Bethlehem, Pa., adjusted by a factor of 0.80 (drainage area ratio); period of record, 1944–56.
[3] Period of record, 1945–47.
[4] Period of record, 1944–46.
[5] Based on discharge over Fairmount Dam and not including water diverted for Municipal Supply of Philadelphia; period of record, 1944–56.

TABLE 5.—*Chemical analyses of water draining bituminous-coal areas*

[Chemical analyses in parts per million]

Location	Date	Percent of time	Mean discharge (cfs)	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$: Total	Hardness as $CaCO_3$: Noncarbonate	Total acidity as (H^{+1})	Specific conductance (micromhos at 25°C)	pH	Color
Representative analyses of streams																						
Susquehanna River basin:																						
Susquehanna River at Harrisburg, Pa.																						
East channel 120	Oct. 16, 1956	----	--------	-----	-----	-----	-----	------	------	7.8	20	142	7.5	----	2.7	------	160	144	-----	371	7.3	4
1120		----	--------	-----	-----	-----	-----	------	------	4.4	26	66	6.0	----	1.0	------	90	68	-----	211	7.3	4
West channel 600		----	--------	-----	-----	-----	-----	------	------	9.9	26	64	4.5	----	1.5	------	74	52	-----	204	7.1	4
1100		----	--------	-----	-----	-----	-----	------	------	17	90	45	9.5	----	1.6	------	100	26	-----	272	8.0	4
1320		----	--------	-----	-----	-----	-----	------	------	17	106	36	13	----	1.5	------	108	21	-----	283	8.2	4
Susquehanna River at Columbia, Pa.																						
East side	Oct. 16, 1956	----	50,100	-----	-----	-----	-----	------	------	3.1	20	57	5.0	----	6.2	------	81	65	-----	220	6.5	4
East center		----	50,100	-----	-----	-----	-----	------	------	4.0	16	59	4.5	----	4.9	------	76	63	-----	217	6.4	2
Center		----	50,100	-----	-----	-----	-----	------	------	6.5	20	49	4.5	----	6.7	------	65	49	-----	193	6.7	2
West center		----	50,100	-----	-----	-----	-----	------	------	2.6	28	26	3.0	----	6.6	------	54	31	-----	153	6.8	8
West side		----	50,100	-----	-----	-----	-----	------	------	1.6	40	19	2.5	----	6.6	------	58	25	-----	153	7.0	10
Ohio River basin:																						
Crooked Creek at Idaho, Pa.	Aug. 3, 1944	----	[1] 15	10	4.6	0.11	-----	60	23	90	0	399	38	0.2	0.6	652	275	275	0.8	949	3.90	2
	Apr. 5, 1945	----	[1] 2,080	7.0	.4	.47	.00	9.0	3.3	4.4	4	37	2.2	.1	1.8	72	39	36	.2	106	5.8	4
Monongahela River at Point Marion, Pa.	Mar. 27, 1956	----	--------	6.6	-----	.06	-----	24	7.2	12	0	131	2.5	.1	.1	191	90	90	-----	379	3.70	1
	June 28, 1956	----	--------	10	-----	.03	-----	22	9.4	9.4	0	97	2.0	.1	1.7	167	74	74	-----	261	4.30	3
Percent of days in which value tabulated was equaled or exceeded																						
Susquehanna River basin:																						
W. Br. Susquehanna River at Lock Haven, Pa.	October 1945 to September 1951	1	[2] 39,000	-----	-----	-----	-----	45	------	9.8	-----	247	8.3	----	-----	------	222	-----	-----	685	4.8	---
		10	[2] 14,500	-----	-----	-----	-----	36	14	7.8	-----	191	6.4	----	-----	288	172	-----	-----	530	4.5	---
		50	[2] 3,400	-----	-----	-----	-----	15	5.9	3.4	0	80	2.7	----	-----	123	74	-----	-----	225	4.05	---
		90	[2] 465	-----	-----	-----	-----	9.8	3.5	2.1	0	46	1.7	----	-----	74	45	-----	-----	135	3.60	---
		99	[2] 250	-----	-----	-----	-----	7.7	2.7	1.6	0	35	1.3	----	-----	58	36	-----	-----	105	3.30	---
W. Br. Susquehanna River at Lewisburg, Pa.	October 1944 to September 1952	1	--------	-----	-----	-----	-----	38	12	14	-----	127	11	----	-----	232	144	-----	-----	371	------	---
		10	--------	-----	-----	-----	-----	27	8.4	9.4	-----	91	7.8	----	-----	166	102	94	-----	267	------	---
		50	--------	-----	-----	-----	-----	15	4.9	5.0	-----	50	3.9	----	-----	94	57	50	-----	151	------	---
		90	--------	-----	-----	-----	-----	10	3.2	3.0	-----	33	2.2	----	-----	63	37	31	-----	101	------	---
		99	--------	-----	-----	-----	-----	7.6	2.5	2.5	-----	25	1.4	----	-----	48	28	21	-----	78	------	---
Susquehanna River at Harrisburg, Pa. Station E1180	October 1944 to September 1946	1	[3] 202,000	-----	-----	-----	-----	40	14	15	48	126	9.0	----	-----	244	156	-----	-----	369	7.5	---
		10	[3] 82,000	-----	-----	-----	-----	30	10	10	40	90	6.5	----	-----	170	114	86	-----	278	7.2	---
		50	[3] 22,000	-----	-----	-----	-----	20	5.9	6.1	26	54	4.2	----	-----	110	73	47	-----	180	6.9	---

		90	[3] 5,300					12	2.8	3.0	18	28	2.4			65	42	30		105	6.6	
		99	[3] 3,200					10	2.2	2.4	16	21	2.0			54	34	27		88	6.2	
Station E. 120 (monthly samples)	October 1946 to September 1952	1									31	270	17				268			665	7.1	
		10									24	218	8.8				225			497	6.6	
		50									9	115	5.2				116			290	6.0	
		90									4	63	2.4				70			175	4.7	
		99									2	48	1.4				48			132	4.5	
Station E. 1180 (monthly samples)	October 1946 to September 1952	1									70	114	11				148			358	7.6	
		10									45	82	7.8				114			260	7.0	
		50									23	45	4.0				62			152	6.6	
		90									11	30	2.3				40			100	6.2	
		99									6	25	1.5				34			90	5.8	
Station W. 1320 (monthly samples)	October 1946 to September 1952	1									183	55	12				171			392	8.1	
		10									163	31	9.6				157			326	7.6	
		50									114	24	4.8				115			245	7.2	
		90									66	20	2.8				75			165	6.9	
		99									40	18	1.9				48			122	6.5	
Ohio River basin:																						
Clarion River at Piney, Pa.	October 1946 to September 1952	1						60	12	49	60	117	96			423	197	170		660		
		10						45	9.8	36	43	92	69			320	151	120		495		
		50						17	4.4	12	12	44	20			120	59	45		190		
		90						12	3.6	7.0	6	34	9.0			78	40	30		125		
		99						10	3.0	5.0	3	31	6.0			65	34	25		105		
Kiskiminetas River at Leechburg, Pa.	October 1946 to September 1951	1						140	46	91	0	811	24			1,230	666			2,280	4.35	
		10						103	36	70	0	607	16			910	493			1,710	3.75	
		50						54	21	32	0	298	8.8			460	241			870	3.25	
		90						24	11	11	0	129	5.2			207	106			410	2.80	
		99						17	10	6.8	0	87	3.6			139	70			290	2.50	
Monongahela River at Charleroi, Pa.	October 1944 to September 1952.	1	[4] 52,000					68	24	70		475	16			682	327	327		1,160	6.0	
		10	[4] 22,500					50	18	50		312	11			470	232	232		800	4.9	
		50	[4] 5,600					28	9.3	19	0	142	6.2			231	119	119		392	4.10	
		90	[4] 1,000					20	6.6	11	0	93	4.6			153	81	78		250	3.55	
		99	[4] 430					17	5.6	6.7	0	76	4.0			120	66	60		200	3.30	
Casselman River at Harnedsville, Pa.	October 1949 to September 1950.	1																		440	5.9	
		10						29	9.5	5.0		129	3.0			202	108	108		338	5.1	
		50						17	6.0	3.5	0	72	2.0			118	65	65		207	4.20	
		90						10	4.5	2.0	0	38	1.5			68	38	34		126	3.70	
		99						8.0	3.5	2.0	0	27	1.5			50	29	20		100	3.50	
Youghiogheny River at Sutersville, Pa.	October 1947 to September 1950.	1																		1,150	6.3	
		10						25	8.9	21		129				198	98	97		345	5.7	
		50						20	7.0	14		91				146	75	67		245	4.6	
		90						16	6.0	9.0	0	64				109	58	47		180	4.05	
		99						12	5.0	7.0	0	53				94	51	40		150	3.35	
Ohio River at Ambridge, Pa.	October 1945 to September 1952.	1						79	22	66		362	43				298	298		942	6.6	
		10						58	17	46		257	32			441	220	220		690	6.3	
		50						30	9.0	21		118	18			212	110	95		340	5.6	
		90						20	6.0	12	0	67	12			132	71	52		212	4.40	
		99						16	5.1	7.7	0	47	10			101	56	40		168	3.85	
Beaver River at New Brighton, Pa.	October 1945 to September 1952.	1						72	16	32	64	196	41			422	239	183		657		
		10						59	13	25	54	157	32			343	195	148		535		
		50						43	10	17	43	111	18			251	132	109		395		
		90						28	6.8	8.3	32	68	12			163	99	70		258		
		99						23	5.6	5.5	29	52	8.7			131	82	56		208		

[1] Discharge at time of sampling.
[2] Based on discharge at Renovo, Pa., adjusted by a factor of 1.125 (drainage-area ratio); period of record, 1944–56.
[3] Period of record, 1944–56.
[4] Period of record, 1944–56.

SODIUM CHLORIDE WATER

TABLE 6.—*Chemical analyses of water draining well-brine areas*

[Chemical analyses in parts per million]

Location	Date	Percent of time	Mean discharge (cfs)	Silica (SiO$_2$)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO$_3$)	Sulfate (SO$_4$)	Chloride (Cl)	Fluoride (F)	Nitrate (NO$_3$)	Dissolved solids (residue on evaporation at 180°C)	Hardness as CaCO$_3$: Calcium, magnesium	Hardness as CaCO$_3$: Non-carbonate	Specific conductance (micromhos at 25°C)	pH	Color
Representative analyses of streams																			
Ohio River basin:																			
S. Br. Cole Creek near Farmers Valley, Pa.	Aug. 24, 1954			38	0.25	257	69	694	131	32	1,620	0.0	12	3,020	924	817	5,120	8.0	8
	Aug. 9, 1955								120	23	1,200				720	622	4,100	7.9	2
E. Br. Tunungwant Creek near Lewis Run, Pa.	Aug. 24, 1954								53	26	652				392	348	2,170	6.8	3
	Aug. 9, 1955								100	59	1,840				1,090	1,010	6,000	7.7	
W. Br. Tunungwant Creek near S. Bradford, Pa.	Aug. 25, 1954								30	30	340				208	184	1,200	6.7	5
	Aug. 10, 1955								70	44	587				370	312	2,100	7.5	3
	Sept. 25, 1958							8.4	36	29	175		.2		124	95	689	6.6	3
Tunungwant Creek at Tuna, Pa.	Sept. 25, 1958			5.0	.02	50	8.5	111	49	39	220	.0	3.8		160	120	859	6.5	5
Allegheny River at Corydon, Pa.	Aug. 25, 1954								88	27	181				180	108	787	7.2	5
	Aug. 10, 1955								85	23	128				144	78	621	7.7	7
Connoquenessing Creek at Butler, Pa.	Sept. 25, 1946		[1]2	5.2	.04	281	54	877	36	115	1,900	.0	2.3	3,410	923	894	5,990	7.6	3
	Sept. 23, 1958			6.9	.04	20	5.6	28	29	45	29	.0	1.9	160	73	49	261	6.9	5
Little Connoquenessing Creek at Eidenau, Pa.	Sept. 25, 1946		[1]2	1.8	.02	42	13	106	48	71	194	.1	.9	458	158	119	871	7.2	7
Connoquenessing Creek at Hazen, Pa.	Sept. 26, 1946		[1]29	2.2	.03	143	29	171	84	357	280	1.6	10	1,070	476	407	1,690	7.3	8
Connoquenessing Creek at Ellwood City, Pa.	Sept. 26, 1946		[1]84	1.8	.02	80	16	61	64	207	90	.2	2.6	546	265	213	807	6.7	8
	Oct. 9, 1957		[1]28					60	77	180	49		4.7		192	129	594	6.4	6
Connoquenessing Creek near Sewickley, Pa.	Sept. 23, 1958			8.2	.07	24	7.3	12	36	59	16	.1	6.1	161	90	61	251	6.6	3

Percent of days in which value tabulated was equaled or exceeded

Ohio River basin:																			
Allegheny River at Warren, Pa.	October 1948 to September 1951.	1	------	------	------	59	17	117	91	30	225	------	------	441	190	------	975	----	----
		10	------	------	------	52	11	92	77	27	186	------	------	374	161	104	815	----	----
		50	------	------	------	23	5.5	31	37	18	59	------	------	146	65	45	345	----	----
		90	------	------	------	16	4.2	18	27	16	32	------	------	105	45	35	190	----	----
		99	------	------	------	12	2.7	8.2	22	14	14	------	------	72	32	------	118	----	----
Allegheny River at Kittanning, Pa.	October 1944 to September 1952.	1	------	------	------	40	9.0	42	75	72	70	------	------	290	139	82	500	----	----
		10	------	------	------	34	7.8	34	62	61	57	------	------	242	118	69	415	----	----
		50	------	------	------	20	4.8	15	33	38	27	------	------	133	70	38	226	----	----
		90	------	------	------	14	3.8	7.2	20	28	13	------	------	83	49	25	140	----	----
		99	------	------	------	12	3.2	4.1	17	25	9.1	------	------	70	42	19	108	----	----

[1] Discharge at time of sampling.

TABLE 7.—*Chemical analyses of water from estuarine-brine areas*

[Chemical analyses in parts per million]

Location	Date	Percent of time	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180° C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25° C)	pH	Color
Maximum and minimum observed values for specific conductance and chemical analyses																			
[Based on once-a-month sampling]																			
Delaware River basin:																			
Delaware River at Morrisville, Pa. max..	August 1949 to	----	----	28	0.29	25	9.8	4.2	76	38	35	0.2	5.8	156	103	----	266	----	----
min..	December 1957.	----	----	1.9	.00	7.9	1.3	.1	15	12	1.0	.0	1.0	53	25	----	68	----	----
Delaware River at Bristol, Pa. max..	August 1949 to	----	----	7.3	.31	23	9.8	20	63	47	17	.3	11	209	93	----	281	----	----
min..	December 1957.	----	----	.8	.00	7.1	1.7	.6	11	12	1.0	.0	.7	50	23	----	58	----	----
Delaware River at Philadelphia, Pa. max..	August 1949 to	----	----	12	.34	27	14	127	64	100	190	.5	18	380	140	----	934	----	----
min..	December 1957.	----	----	.8	.00	8.0	2.6	.3	10	13	1.2	.0	.1	59	22	----	58	----	----
Delaware River at Marcus Hook, Pa. max..	August 1949 to	----	----	16	.74	75	147	1,240	71	409	2,240	2.0	19	4,500	792	----	7,270	----	----
min..	December 1957	----	----	1.2	.00	9.9	3.3	2.4	0	18	3.0	.0	.8	73	18	----	82	----	----

SELECTED BIBLIOGRAPHY

Ash, S. H., Felegy, E. W., Kennedy, D. O., and Miller, P. S., 1951, Acid mine drainage problems, anthracite region of Pennsylvania: U.S. Bur. of Mines Bull. 508.

Ash, S. H., Link, H. B., and Romischer, W. M., 1954, Surface-water seepage into anthracite mines in the southern field: U.S. Bur. Mines Bull. 539.

Beamer, N. H., 1953, Chemical character of surface water in Pennsylvania, 1949–51: Pennsylvania Dept. Commerce State Plan. Board Pub. 26.

Bennett, H. H., 1939, Soil conservation: New York, McGraw-Hill Book Co.

California State Water Pollution Control Board, 1952, Water-quality criteria: [California] State Water Pollution Control Board Pub. 3.

Cohen, Bernard, and McCarthy, L. T., Jr., Salinity of the Delaware River estuary: U.S. Geol. Survey Water-Supply Paper 1586–B.

Colman, E. A., 1953, Vegetation and watershed management: New York, Ronald Press Co.

Durfor, C. N., and Keighton, W. B., 1954, Chemical characteristics of Delaware River water: U.S. Geol. Survey Water-Supply Paper 1262.

Fenneman, N. M., 1946, Physical divisions of the United States: U.S. Geol. Survey, Special Maps, set of 100 topographic maps, assembled 1955, pl. 1.

Greenmen, D. W., 1955, Ground water resources of Bucks County, Pa.: Pennsylvania Geol. Survey Bull. W 11, 4th ser.

Hall, G. M., 1934, Ground water in southeastern Pennsylvania: Pennsylvania Geol. Survey Bull. W 2, 4th ser.

Kittredge, J., 1948, Forest influence: New York, McGraw-Hill Book Co.

Langbein, W. B., and others, 1949, Annual runoff in the United States: U.S. Geol. Survey Circ. 52.

Leggette, R. M., 1936, Ground water in northwestern Pennsylvania: Pennsylvania Geol. Survey Bull. W 3, 4th ser.

Leighton, M. O., 1904, Quality of water in the Susquehanna River drainage basin: U.S. Geol. Survey Water-Supply Paper 108.

Lohman, S. W., 1937, Ground water in northeastern Pennsylvania: Pennsylvania Geol. Survey Bull. W 4, 4th ser.

———1938, Ground water in south-central Pennsylvania: Pennsylvania Geol. Survey Bull. W 5, 4th ser.

———1939, Ground water in north-central Pennsylvania: Pennsylvania Geol. Survey Bull. W 6, 4th ser.

———1941, Ground water resources of Pennsylvania: Pennsylvania Geol. Survey Bull. W 7, 4th ser.

Miller, B. L., 1934, Limestones in Pennsylvania: Pennsylvania Geol. Survey Bull. M 20, 4th ser.

Moulton, E. Q., 1957, The acid mine drainage problem in Ohio: Eng. Expt. Sta., Ohio State Univ. Bull. 166., v. 26, no. 5.

Noecker, M., Greenman, D. W., and Beamer, N. H., 1954, Water resources of the Pittsburgh area, Pa.: U.S. Geol. Survey Circ. 315.

Pennsylvania Department of Commerce, 1947, Industrial utility of water in Pennsylvania, chemical character of surface water, 1944–1946: Pennsylvania State Plan. Board Pub. 17.

———1937, Drainage basin study of Pennsylvania, pt. 1, Delaware, Lehigh, and Schuylkill Rivers: Pennsylvania State Plan. Board Pub. 10.

———1937, Drainage basin study of Pennsylvania, pt. 2, Susquehanna, Potomac, Genesee Rivers, and Chesapeake Bay: Pennsylvania State Plan. Board Pub. 10.

Pennsylvania Department of Commerce, 1937, Drainage basin study of Pennsylvania, pt. 3, Upper Ohio and Beaver Rivers and Lake Erie: Pennsylvania State Plan. Board Pub. 10.

Pennsylvania Geological Survey, 1956, The ground-water program for Pennsylvania: Pennsylvania Geol. Survey Circ. 7, 4th ser.

Pennsylvania Topographic and Geologic Survey, 1931, Geologic map of Pennsylvania.

Pennsylvania Water Supply Commission, 1917, Gazetteer of streams: Water resources inventory report, pt. 3.

Piper, A. M., 1933, Ground water in southwestern Pennsylvania: Pennsylvania Geol. Survey Bull. W 1, 4th ser.

Tyron, C. A., and others, 1956, Man and the waters of the upper Ohio basin: Pymatuning Lab. Field Biol., Univ. Pittsburgh, pub. 1.

U.S. Geological Survey, 1956, Surface-water supply of the United States, 1953, pt. 1B: U.S. Geol. Survey Water-Supply Paper 1272.

——— 1957, Surface-water supply of the United States, 1955, pt. 3A: U.S. Geol. Survey Water-Supply Paper 1385.

U.S. Public Health Service, 1943, Ohio River pollution control: Supp. to pt. 2.

White, W. F., 1951, Chemical character of surface water in Pennsylvania 1946–1949: Pennsylvania Dept. Commerce, State Plan. Board Pub. 23.

White, W. F., and Lindholm, C. F., 1950, Water resources investigations relating to the Schuylkill River restoration project: Pennsylvania Dept. Forests and Waters.

Willard, Bradford, 1935, Pennsylvania geology summarized: Pennsylvania Geol. Survey Bull. 113.

INDEX