Chemical Quality of Surface Water in the Allegheny River Basin Pennsylvania and New York

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GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1835

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

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By E. F. McCARREN

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By E. F. McCarren

ABSTRACT

The Allegheny River is the principal source of water to many industries and to communities in the upper Ohio River Valley. The river and its many tributaries pass through 19 counties in northwestern and western Pennsylvania. The population in these counties exceeds 3 million. A major user of the Allegheny River is the city of Pittsburgh, which has a population greater than 600,000.

The Allegheny River is as basic to the economy of the upper Ohio River Valley in western Pennsylvania as are the rich deposits of bituminous coal, gas, and oil that underlie the drainage basin. During the past 5 years many streams that flow into the Allegheny have been low flowing because of droughts affecting much of the eastern United States. Consequently, the concentration of solutes in some streams has been unusually high because of wastes from coal mines and oil wells. These and other water-quality problems in the Allegheny River drainage basin are affecting the economic future of some areas in western Pennsylvania.

Because of environmental factors such as climate, geology, and land and water uses, surface-water quality varies considerably throughout the river basin. The natural quality of headwater streams, for example, is affected by salt-water wastes from petroleum production. One of the streams most affected is Kinzua Creek, which had 2,900 parts per million chloride in a sample taken at Westline on September 2, 1959. However, after such streams as the Conewango, Brokenstraw, Tionesta, Oil, and French Creeks merge with the Allegheny River, the dissolved-solids and chloride concentrations are reduced by dilution. Central segments of the main river receive water from the Clarion River, Redbank, Mahoning, and Crooked Creeks after they have crossed the coal fields of west-central Pennsylvania. At times, therefore, these streams carry coal-mine wastes that are acidic. The Kiskiminetas River, which crosses these coal fields, discharged sulfuric acid into the Allegheny at a rate of 299 tons a day during the 1962 water year (October 1, 1961, to September 30, 1962).

Mine water affects the quality of the Allegheny River most noticeably in its lower part where large withdrawals are made by the Pittsburgh Water Company at Aspinwall and the Wilkinsburg-Penn Joint Water Authority at Nadine. At these places raw river water is chemically treated in modern treatment plants to control such objectionable characteristics as acidity and excessive concentrations of iron and manganese.

Dissolved-solids content in the river varies along its entire length. In its upper reaches the water of the Allegheny River is a sodium chloride type, and at low flow, the sodium chloride is more than half the dissolved solids. In its lower reaches the water is a calcium sulfate type, and at low flow the calcium sulfate is more than half the dissolved solids. In middle segments of the river from Franklin to Kittanning, water is more dilute and of a mixed type.

Many small and several larger streams in the upper basin—such as the Conewango, Brokenstraw, Kinzua, Tionesta, and French Creeks—support large populations of game fish. Even in segments of the Clarion River, Mahoning, and Redbank Creeks, which are at times affected by coal-mine wastes, fish are present. Although different species withstand varying amounts of contaminants in water, the continued presence of the fish indicates that the water is relatively pure and suitable for recreation and many other uses.

INTRODUCTION

This report describes the chemical quality of streams in the Allegheny River drainage system from which more than 1,100 samples of water taken from 109 selected locations were chemically analyzed in laboratories of the U.S. Geological Survey. Examination of these basic data may be made on request to the District Chief, U.S. Geological Survey, Water Resources Division, U.S. Custom House, Second and Chestnut Streets, Philadelphia, Pa. 19106.

The main river and its branching tributaries drain 11,705 square miles of Pennsylvania and New York, of which 9,771 square miles is in western Pennsylvania. The area drained in Pennsylvania is 52 percent greater than that drained by the Delaware River in Pennsylvania.

Several communities in the drainage area have undergone a rapid growth in population during the past decade. Urbanized areas in Allegheny County, for example, have increased 17.7 percent since 1950 (1960 census).

From the selected locations most samples of water were systematically taken during varying conditions of flow, and quantitative determinations made for silica, aluminum, iron, manganese, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, chloride, fluoride, nitrate, hardness as calcium carbonate, and dissolved solids as residue on evaporation at 180°C. Other analytical determinations were made for acidity, pH, color, and specific conductance.

Specific conductance (electrical conductivity of water), a useful characteristic of water, is frequently used in this report because it serves as a water-quality criterion. Dependence on specific conductance for quality evaluations, however, is limited because conductance indicates only the sum of ions in water and not their chemical identities. When ionized materials become more concentrated, water will conduct electricity more readily; so as specific-conductance values increase, they indicate the concentration of dissolved materials has also increased.

PURPOSE AND SCOPE

The purpose of this investigation is to summarize the chemical-quality data of streams in the Allegheny River basin to identify wherever possible by association the environmental factors that cause water composition to vary from place to place.

Much of the basic information used to interpret the quality of water at various locations throughout the drainage system was obtained by analyzing samples taken on consecutive days. Water from these stations was analyzed and its quality described in greater detail than from places where samples were taken irregularly, monthly, or when streamflow was high or low.

This description of water quality at selected places is for general use, and will be especially helpful to those engaged in managing the water resources of western Pennsylvania. It is intended also that the delineation of stream quality at the various locations throughout the drainage area will be useful to engineers locating new reservoirs and dams, treatment plants and water distribution facilities.

ACKNOWLEDGMENTS

This report was written under the general supervision of Norman H. Beamer, District Chief, U.S. Geological Survey. Hereby acknowledged with sincere appreciation is the invaluable aid and cooperation of the Wilkensburg–Penn Joint Water Authority, the Pittsburgh Water Company, the Pennsylvania Electric Company, the Pennsylvania Department of Health, the U.S. Weather Bureau, and the U.S. Army Corps of Engineers for providing supplemental basic data to the Geological Survey.

ALLEGHENY RIVER BASIN

LOCATION

The Allegheny River originates in Sweden Township in Potter County of north-central Pennsylvania at an elevation of 307 feet (pl. 1). The Allegheny flows northwestward through McKean County, thence into New York for approximately 50 river miles. It reenters Pennsylvania at Corydon in Warren County flowing in a southwesterly direction. The distance from its source in the western slope of the Allegheny Mountains to its confluence with the Monongahela River at Pittsburgh, where the two rivers meet to form the Ohio, is 322 miles. The Allegheny and its tributaries drain all or parts of Erie, Crawford, Warren, McKean, Potter, Venango, Forest, Elk, Clarion, Jefferson,

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Clearfield, Butler, Armstrong, Indiana, Allegheny, Westmoreland, Cambria, Mercer, and Somerset Counties.

HISTORICAL BACKGROUND

The Allegheny, which means "fair water," was named by the Seneca Indians. The river was a lifeline for the early settlers of western Pennsylvania. In the scenic upper valley of the river basin there still are dense forests and sparkling, clear streams from which fish were speared by the Indians. Fish are still plentiful in the river and many of its tributaries. Wildlife drink from them and roam along their shores and on nearby mountainsides.

The first white man to explore the Allegheny River Valley was René Robert Cavelier de La Salle, 1669–70. The French called the river "La Belle Rivière." In 1749 the French laid claim to all the area drained by the Allegheny and its tributaries. Although an English mapmaker named Lewis Evans described the area as infested with "vermon, venomous reptiles, and stinging muskeetoes," the English, who had already established trading posts in the valley, refuted the French claim of possession because the Allegheny connected trading posts that extended from Canada to Louisiana.

The same Lewis Evans who described the area as an undesirable place to settle, reported in his "Analyses of Travels and Explorations in the Middle British Colonies," published in 1755, that there were beds of salt and coal along the Kiskiminetas River. The first record of coal in the area, however, is credited to John Pattin, an Indian trader whose map of travels dated 1750 shows "sea coal" along the Kiskiminetas. Coal mines were opened in the area by 1760 (Billinger, 1954).

About 1850 part of the population along the eastern seaboard shifted to the promising frontier in northwestern Pennsylvania where oil was discovered. Oil City, in Venango County where Oil Creek flows into the Allegheny River, became a boom town that grew from one or two houses into a city in a matter of weeks as the world's petroleum industry began. No doubt it was about this time that the natural quality of the Allegheny and its tributaries first became affected by man's use of land and his often misuse of water.

More than half a century ago (1915) the first quality-of-water survey of the Allegheny River basin was made by the Pennsylvania Department of Health. After this early investigation they reported the following on the river: "dangerously polluted with sewage and impregnated with mine drainage and manufactural wastes"; "Lumber camps started typhoid fever epidemics by polluting small mountain streams that were used as water supplies to towns further downstream"; and "Tanneries discharged offensive dark-brown wastes into streams.

Horses and cows contracted anthrax after drinking from some of these streams."

Most of these diseases were traced to sewage-bearing water and although typhoid fever is not an extinct disease, it is controlled today by treating water in modern purification plants. In 1937 a comprehensive pollution-control act was passed which gave the Pennsylvania Sanitary Water Board power to impose severe penalties for infractions that result in stream damage by sewage and industrial wastes. This act has helped to discourage the misuse of streams in Pennsylvania.

TOPOGRAPHY

The Allegheny River drains the Allegheny Plateau, Allegheny Mountains, Pittsburgh Plateaus, and glaciated sections of the Appalachian Plateaus province. The eastern part of the basin is characterized by steep-sided narrow valleys. The terrain west of the river valley is less rough and is extensively farmed.

In the northwest approximately 25 percent of the basin is glaciated, containing swamps and lakes. Conneaut Lake, in Crawford County, is the largest of these lakes in Pennsylvania. It is more than 2.5 miles long, at an elevation of 1,082 feet. In the glaciated region large boulders weighing 70 tons and more mark the countryside. The valleys are broad, resulting from flood waters from the receding Wisconsin glaciers.

The Allegheny National Forest, most of which lies east of the river, encompasses 740,000 acres of the upper basin. Approximately 85 percent of the area of Warren, McKean, Potter, Forest, and Elk Counties is forested, and this, in combination with permeable soil, protects against rapid runoff, soil erosion and sudden high-rising streams.

CLIMATE

There is considerable variation in temperature among the physiographic regions of the Allegheny River basin where westerly winds prevail. In the Allegheny Plateau and Allegheny Mountain sections (Fenneman, 1938), the winters are cold; and from November to March much of the countryside is blanketed with snow. Because of the cold weather and the snow, Denton Hill State Park in Potter County, the first State-owned winter resort, is being developed. To the west of Potter County at Kane, in McKean County, some of the lowest temperatures in Pennsylvania (−30° to −40°F) have been recorded.

Usually the summers are cool in this part of the basin. Although the summers are also cool in areas west of the Allegheny River, the winters are normally milder there than in the northeast parts of the basin because of the moderating influence of Lake Erie.

The mean monthly temperature in the northern part of the basin at Warren for 37 years of record ranged from 24.5°F in February to 69.5°F in July; the mean annual temperature was 47.2°F. Mean annual precipitation at Warren for 58 years of record was 43 inches.

To the northwest at Meadville in Crawford County the mean monthly temperature for 21 years of record ranged between 26°F in February and 70.9°F in July; the mean annual temperature was 48.5°F. The mean precipitation for 22 years of record was 39.5 inches.

At Vandergrift, in the lower basin, the mean monthly temperature for 17 years of record ranged from 30.2°F in January to 73°F in July; mean annual temperature was 51.9°F. The mean precipitation for the period of record was 39 inches (U.S. Weather Bureau, 1964).

GEOLOGY

The bedrock surface underlying the Allegheny River basin in Pennsylvania consists of sedimentary rocks of Carboniferous and Devonian age (pl. 1). Most of the upper half of the drainage basin, north of the Clarion River, is underlain by Upper Devonian shale, siltstone, and sandstone strata of the Conneaut Group of Chadwick (1935), the Conewango Formation and by Mississippian sandstone of the Pocono Formation. The Devonian formations consist of variegated shale, sandtsone, and conglomerate, which contain deposits of petroleum, salt (NaCl), water, natural gas, some lignite, and various grades of clays, some of which are economically useful. The Chemung Formation is the chief source of ground water within the Devonian rocks of northwestern Pennsylvania.

The Pocono Formation consists predominantly of sandstone strata, and is the principal source of ground water in the bedrock formations of the Allegheny basin. Pocono sandstones from the bedrock surface in the northwestern part of the basin, in the valley of the Clarion River, and underlie younger rocks throughout most of the Pennsylvania section of the basin.

Except for the northern tier of counties, most of the Pennsylvania section of the Allegheny basin is underlain by rock strata of Pennsylvanian age. The principal rock units are the Pottsville and Conemaugh Formations and the Allegheny Group, which consists chiefly of sandstone, but include members of variegated shale, limestone, and bituminous coal. The coal has been mined extensively by deep- and strip mine methods.

The bedrock formations in parts of Erie, Crawford, Venango, and Warren Counties, and adjoining areas in New York, are covered by glacial drift. The drift contains many deposits of sand and gravel interbedded with silt and clay. The valleys of tributaries to the Allegheny River in the glaciated area are filled with glacial deposits including permeable sand and gravel outwash. The valleys of the Tionesta, Tunungwant, and Potato Creeks in the unglaciated area also contain glacial outwash carried by melt waters that drained away from the glaciers. The Allegheny River Valley along its entire reach from its source to its confluence with the Monongahela River at Pittsburgh is also partly filled with glacial and alluvial sediments. The glacial and alluvial sediments in the river valleys are the greatest poential source of ground water in the Allegheny River basin.

ECONOMIC SIGNIFICANCE OF THE ALLEGHENY RIVER DRAINAGE BASIN AND ADJACENT AREAS

Within the political boundaries of the 19 counties drained or partly drained by the Allegheny River and its vast network of tributaries there are 300 public water supplies. Population of the area during the decade 1955–64 has increased 5.6 percent, while the increase for the Commonwealth has been 7.1 percent. The national average population increase from 1950 to 1964 was 18.6 percent.

Most of the counties in the Allegheny River basin produce either crude petroleum, natural gas, bituminous coal, or lignite. Significant quantities of building brick, lime, fire clay, and miscellaneous stones are produced in Armstrong County.

In the basin area are blast furnaces and large steel mills. Pittsburgh, the largest steel-making center in the United States, produced an estimated 32 million tons in 1962—more than one-fifth of the Nation's total.

Important manufactured products are machinery, fabricated metal products, stone, clay, and glass products, chemicals, food products, lumber and wood products, paper products, and apparel and other fabric products. In 1963, manufacturing and mining establishments in these counties produced goods valued at $7,899,454 (Pennsylvania Department of Internal Affairs, 1965). In 1954 on 3.5 million acres, about 39 thousand farms produced agricultural, livestock, and livestock products valued at 316.7 million dollars (Pennsylvania Department of Internal Affairs, 1956).

Since 1879, when the Federal government began channel improvements, the construction of locks and dams in the Allegheny and Monongahela Rivers have helped to make Pittsburgh the most important river port in the United States, on the basis of waterborne tonnage. For a 5-year period ending in 1963, the average annual traffic on the Allegheny River was 4,395,000 tons. The reported traffic for 1963 was 4,850,000 tons. On the Monongahela, which joins the Allegheny at Pittsburgh, the reported traffic for 1963 was 31,378,000 tons. Waterborne traffic on both rivers consisted mostly of coal, coke, sand and gravel, iron and steel, and petroleum products.

Because the Allegheny River basin has plenty of surface and ground water (pl. 1, and Schneider and others, 1965, sheet 10), new industries, as well as those established and expanding, will have a supply adequate for their varied needs. For example, in the headwaters the average discharge of the Allegheny River at Kinzua, Pa., for 28 years was 3,756 cfs (cubic feet per second). The mean discharge of the Allegheny River at its mouth at Pittsburgh is approximately 19,800 cfs, or 12,797 mgd (million gallons per day). This is about 7,000 cfs more water than the average discharge of the Monongahela River at Braddock; about 8,000 cfs more than the average discharge of the Delaware River at Trenton, N.J., and about half the average discharge of the Susquehanna River at Harrisburg.

The economy of several areas in the Allegheny River drainage basin is endangered because their surface-water supplies are threatened by pollution with acid mine drainage. Most of these areas are in the Pennsylvania parts of Appalachia, and therefore part of the financial aid to be provided by the Federal Appalachia Program for revitalizing the economy of coal-producing regions will likely be directed toward a solution of Pennsylvania's mine-drainage problems.

Growing populations and increased demands by industry, old and new, in parts of the Allegheny River drainage basin, indicate that more water will be needed by some communities and their industries in the future. For example, by the year 2000 it is expected that the water needs of the chemical industries will multiply 10 times, those of the pulp and paper industries 8 times, and those of the steel industry 3.5 times over what was used in 1959 (U.S. Congress, 1960).

ACID-MINE-DRAINAGE PROBLEMS

East of the Allegheny River in west-central Pennsylvania, the Clarion River, Redbank, Mahoning, and Crooked Creeks, and the Kiskiminetas River system drain one of the most productive bituminous coal-mining regions in the United States (fig. 1). In 1963 coal production in Clarion, Jefferson, Armstrong, Indiana, and Westmoreland Counties increased between 16 and 30 percent. Although increased production in Clarion and Westmoreland Counties was accomplished by fewer operating mines than in the preceding year, Jefferson and Indiana Counties had 16 additional mines operating (Kerr, 1963).

The effluents from active and idle mines contain sulfuric acid, and the materials leached from spoil banks in the area help to increase the dissolved-solids content of nearby streams. More than 1,000 miles of streams in the Allegheny River drainage system are affected to some degree by coal mining. The discharge of these tributaries into

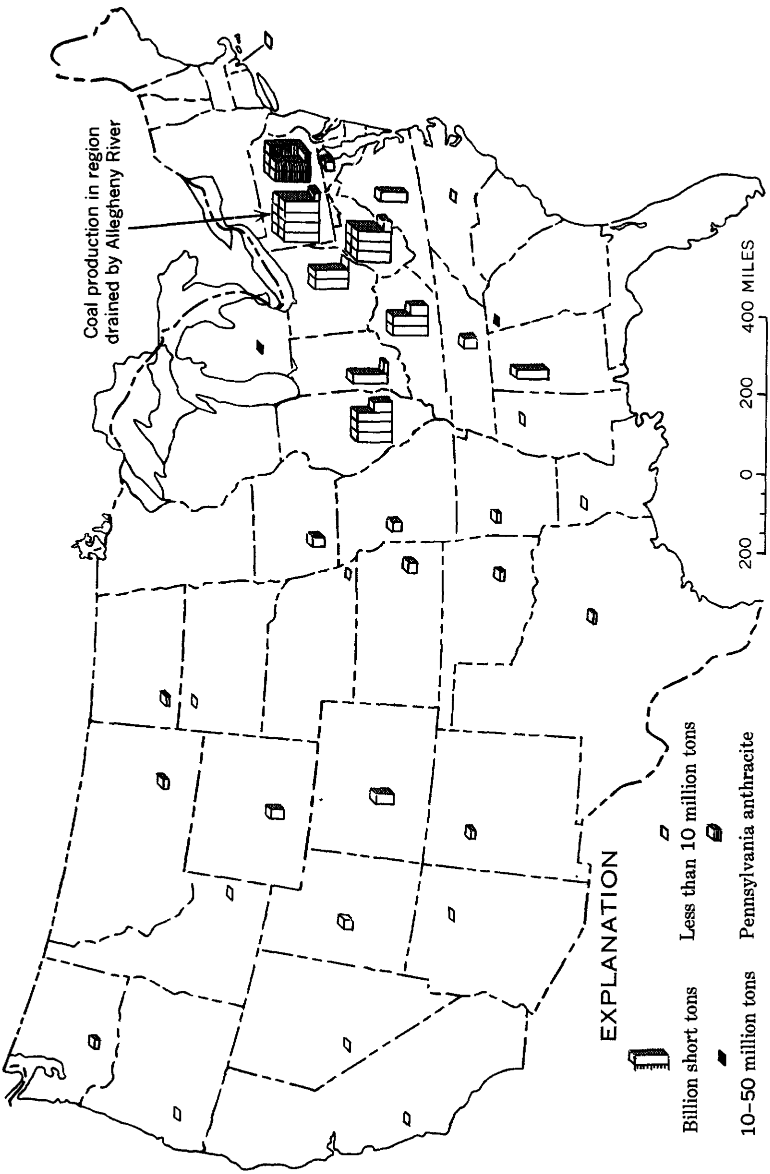

FIGURE 1.—Cumulative coal production in the conterminous United States to January 1, 1959 (U.S. Bur. Mines).

the Allegheny affects its quality downstream as far as Pittsburgh and beyond.

From Freeport to Pittsburgh, a distance of approximately 28 river miles, the Allegheny River is affected most by the Kiskiminetas River (fig. 2). The effects of mine water on the river become more pronounced when it is at low flow.

Sulfuric acid and the acid salts of iron, manganese, and other metals are formed when water is saturated with atmospheric oxygen, which oxidizes sulfuritic materials such as iron pyrite (FeS_2) in mines and spoil banks. However, the high dissolved-solids content of mine water, including iron and sulfate, may also be caused by reactions on rock by water in the mine which do not necessarily involve circulating air or measurable amounts of dissolved oxygen in water (Barnes and Clarke, 1964).

Acid water, once formed, is a stronger weathering agent. For example, the following reaction of sulfuric acid in water on soils consisting of shales and clays shows how aluminum is brought into solution:

$$H_4Al_2Si_2O_9 + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 2H_2SiO_3 + 3H_2O$$

Similar reactions involving acid-bearing water and the soils of the Allegheny River basin will bring into solution increased amounts of dissolved solids, including iron and manganese, more readily than will the weathering processes of natural water.

Iron and manganese impart objectionable taste and staining to water and commonly adds to the cost of its treatment. The imprudent discharge of acidic mine water into streams may destroy fish and many of the aquatic organisms on which fish feed (California State Water Pollution Control Board, 1963).

Because of the rich reserves of coal still unmined in west-central Pennsylvania, mining will probably continue for many generations and some streams will flow acidic unless practical methods are developed to prevent them from being affected.

Several methods for controlling acid mine drainage have been tried. Sealing abandoned mines from circulating air to prevent further oxidation of sulfur-bearing minerals was reported to have partially succeeded in West Virginia. During an experiment in 1936 more than 500 abandoned mines with 3,644 openings were sealed at a cost of about $1,000 per mine (West Virginia State Water Commission, 1936). A recent evaluation of the streams originally benefited showed, however, that the benefits were temporary.

Treatment plants for neutralizing acid mine water with limestone at the mine have been suggested. As early as 1914 a coal company near Mount Pleasant, Pa., set up a treatment plant for this purpose

(Tracy, 1920). In 1951 a pilot-plant study was made of methods of neutralizing the acid mine drainage at the mine site. Mostly for economic reasons the operations were declared not feasible (Pennsylvania Sanitary Water Board, 1951).

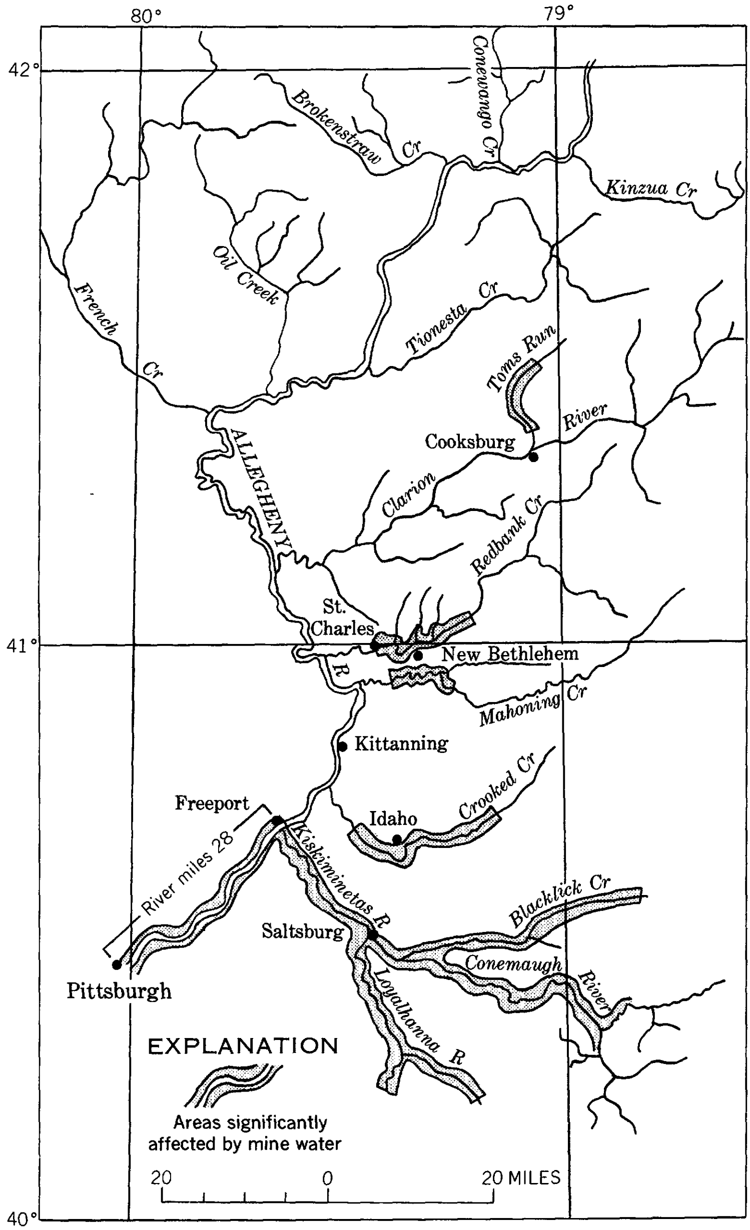

FIGURE 2.—Tributaries to the Allegheny River affected by coal-mine wastes.

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Various limestone products have been used to neutralize acid water; these include quicklime, agricultural lime, granular limestone, and hydrated lime. Recently, cement-mill stack dust was proposed and is in use experimentally by the Interstate Commission on the Delaware River Basin (absorbed by the Delaware River Basin Commission) in stream areas of the Pocono Mountains. Costs of these alkaline materials vary, and quantities required depend on the amount of acid in the water, the degree of deacidification desired, and the quantity of acidic water to be treated.

Efforts to lessen the damage done by acid mine drainage by diverting water away from unworked mines or by diluting acid-bearing streams with nonacidic water (McCarren and others, 1961) may be practical remedies under some circumstances. In Pennsylvania, joint Federal-State mine-drainage programs were authorized by the 84th Congress, and concrete channels and conduits are under construction for diversion of surface water from mine entrances. Mixing suitable nonacidic streams with acidic streams by engineering methods to neutralize or dilute the acid water has not been tried on a large scale.

A review of the literature shows that more than 200 articles have been written about coal-mine wastes and their effects on water quality in the United States (Lorenz, 1962). Many aspects of acid mine drainage have been investigated, and a number of recommendations made on how to prevent, control, or minimize the effects of these wastes on water quality. Presently (1964) the U.S. Bureau of Mines and the Ohio River Valley Sanitation Commission (Orsanco), are jointly seeking practical solutions to the problems of acid mine drainage in the Allegheny River basin. Fieldwork has begun at Kittanning, and a proposal has been approved for building a portable pilot plant for treating mine drainage before discharge to streams.

RESERVOIRS

Acid mine drainage, brines, and industrial wastes are most damaging to receiving streams in the Allegheny River basin when they are at low flow. The impact of such wastes on water quality, therefore, can be significantly minimized if waste discharges are not made to streams during low flow. An alternate means of stream quality-protection lies in the potential of some reservoirs to provide water of suitable quality which could be released as a diluent to augment flow in receiving streams and thereby help offset the effects of dissolved solids and wastes. Regulation of streamflow by releasing water from impoundments became lawful by enactment on July 20, 1961, of Public Law 660 by the U.S. 87th Congress.

Conserving water in reservoirs for times of drought was practiced by prehistoric cultures of Jordan, Iraq, and Israel. In modern times there are other reasons for impounding water. For example, the uncontrolled forces of floodwaters may devastate entire regions, and engineers therefore design and construct dams to prevent recurring destruction. Other very important reasons are to generate electric power and to stabilize riverflow and (or) improve water quality for downstream users by dilution. Also, impounded waters are made available for recreation.

The value of stored water in open reservoirs is subject to the law of diminishing returns (Langbein, 1959). Large areas of water in open reservoirs are normally exposed to wind and the sun's rays, and unless evaporation is suppressed by covering the surface, for example, with a monomolecular film, losses may offset the benefits derived from the multiple-purpose operation of open reservoirs. Also, water stored in open reservoirs for controlled release during drought may not always be suited for improving downstream quality (McCarren, 1962). There remains, therefore, a need for environmental research to help determine when and how much impounded water of given quality should be released to alleviate downstream conditions caused by low flow and (or) pollutants.

Turbidity, silica, and color are generally reduced when water is impounded, but the quality of impounded water may also be affected in other ways. Sunlight and photosynthesis may cause increased biological activity; water temperatures and carbon dioxide content may be increased and dissolved oxygen depleted (Love, 1961). Water weathering of some minerals from exposed soils in dirt reservoirs may increase the dissolved-solids content of reservoir water. Water in reservoirs may not be homogeneous in quality because of variations in temperature and density at different depths. Therefore, when impounded water is stratified, some parts of it can at times be more suited for release to improve stream quality than other parts (Mendieta and Blakey, 1963). Large parts of reservoir water can be made useless by radioactive contamination and other incoming wastes unless the water is safeguarded against such hazards.

During the past 25 years, six major flood-control reservoirs have been built by the U.S. Army Corps of Engineers in the Allegheny River basin. These reservoirs store some of the runoff from six tributary drainage basins in northwestern and western Pennsylvania. Reservoirs are on the Conemaugh and East Branch Clarion Rivers and on Tionesta, Mahoning, Crooked, and Loyalhanna Creeks.

The efficiency of existing reservoirs and dams is being improved by modernization and repair. Surveys of the Clarion, Conemaugh, and

Kiskiminetas Rivers and of Blacklick, French, Loyalhanna, Mahoning, Pine, and Redbank Creeks are being made in order to select locations for economically justifiable multipurpose reservoirs (U.S. Army Corps of Engineers, 1965; U.S. Geological Survey, 1963).

The increasing number of users requiring water of good quality in western Pennsylvania justifies the conservation of suitable water in reservoirs. Parts of the water can be released when needed to improve the quality of some streams by dilution. The continued development of water-storage facilities in the Allegheny River basin will aid industrial expansion and the increased urbanization in the lower Allegheny River valley. Flood-control features of existing reservoirs are presented in table 1.

TABLE 1.—*Existing reservoirs and flood-control features on Allegheny River above Pittsburgh*

[Courtesy of the U.S. Army Corps of Engineers. Asterisk (*) indicates minimum]

Reservoir	Drainage area sq mi	Percentage of controlled area			Flood control	Flood control storage		Bankfull capacity	
		Tributary	Main river	Above Pittsburgh		Acre-feet	Inches of runoff	Cfs	Cfs per sq mi
Allegheny [1]	2,180	18.6	18.6	11.4	Winter*	940,000	8.09	25,000	11.5
					Summer*	607,000	5.22	--------	
Tionesta	478	99.6	4.1	2.5	All year	125,600	4.87	10,000	21.0
East Branch [1]	72.4	5.9	.6	.4	Winter*	38,700	10.02	1,600	22.2
					Summer*	19,000	4.92	--------	
Mahoning [1]	340	80.2	2.9	1.8	All year	69,700	3.84	9,000	26.5
Crooked Creek	277	95.5	2.4	1.4	do	89,400	6.06	7,500	27.1
Conemaugh [2]	1,351	[2] 71.8	11.5	7.1	do	270,000	3.75	28,000	20.7
Loyalhanna [2]	290	[2] 15.4	2.5	1.5	do	93,300	6.03	7,000	24.2

[1] Multipurpose reservoir.
[2] Kiskiminetas River basin.

The capacity of the Allegheny Reservoir at Kinzua is 1,180,000 acre-feet of gross storage which includes water for flood control, conservation, and power generation. The Allegheny Reservoir is the largest in the basin. About 10 miles upstream from Warren, at Devils Elbow, Pa., the dam connects two river valley hills. Several villages such as Corydon and Kinzua have been covered by a vast lake formed by the dam. Extending 28 miles to Salamanca, N.Y., the lake has a 91-mile shoreline. This reservoir and the East Branch Clarion River reservoir are designed for storage and controlled release of water for augmentation of low streamflow during dry periods. Maintaining adequate flow in streams in the Allegheny River basin by releases of water of suitable quality from these and other reservoirs will increase the supply of available water to downstream users and help to maintain stream quality by dilution.

An estimate of the effects of released water from the Allegheny Reservoir at Kinzua on water hardness at Aspinwall during the 1930 drought was determined by the U.S. Army Corps of Engineers and is shown in figure 3.

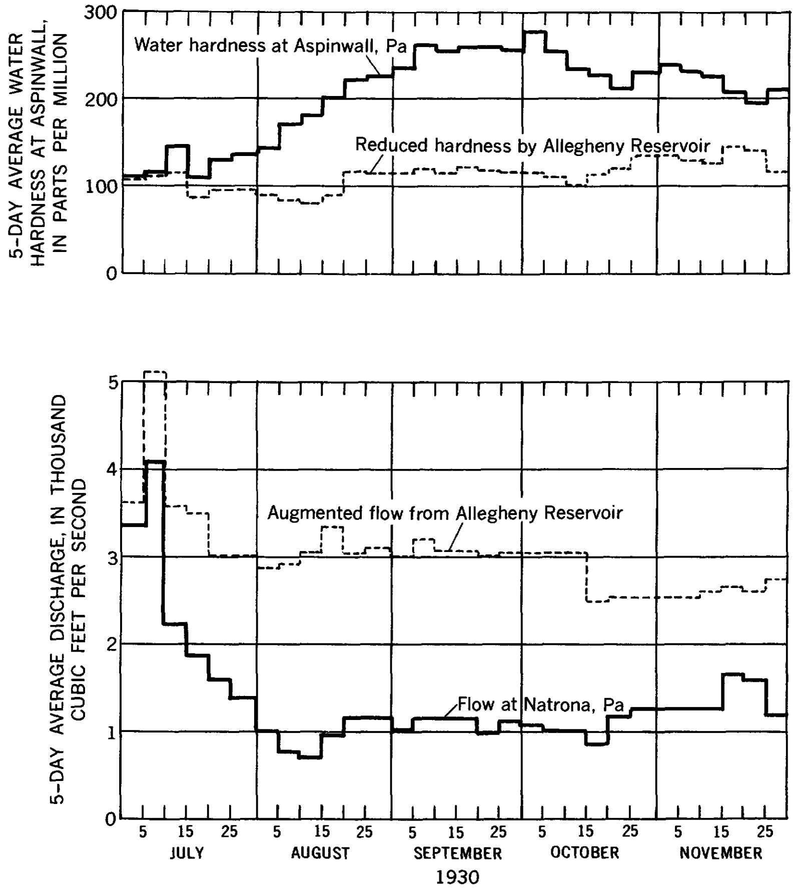

FIGURE 3.—Probable effects on water quality by releases of water from the Allegheny Reservoir (U.S. Army Corps of Engineers).

CHEMICAL QUALITY OF STREAMS

Climate determinates the amount of precipitation that falls on the earth to form its rivers and lakes and replenish underground water. Precipitation begins to change in quality while it falls through the atmosphere, where it absorbs gases and washes solids from the air. However, the total atmospheric material in water is small compared with the amounts of soluble materials removed from rock after precipitation reaches the earth. Part of the precipitation flows over and erodes the earth's surface, a process wearing stream paths, transporting sediment, and dissolving some of the earth's materials. Another part of the precipitation seeps through permeable surfaces of the earth where it is stored underground.

The solution of material by water is generally greater underground because water and rock are in contact with each other for longer periods. Because of this longer contact, ground water is normally more concentrated with solutes than is surface water, and therefore ground water can introduce additional minerals to surface streams by seepage. The composition of rock determines to what extent the rock materials will dissolve and thus influence water quality.

The effects of ground water on stream quality are more noticeable during low streamflow when ground water normally becomes the dominating influence on stream quality. During the fall of 1963 water discharge of some streams in the Allegheny River basin was the lowest of record. The specific conductance and calcium and magnesium hardness of these streams is shown by figure 4. In figure 4 a

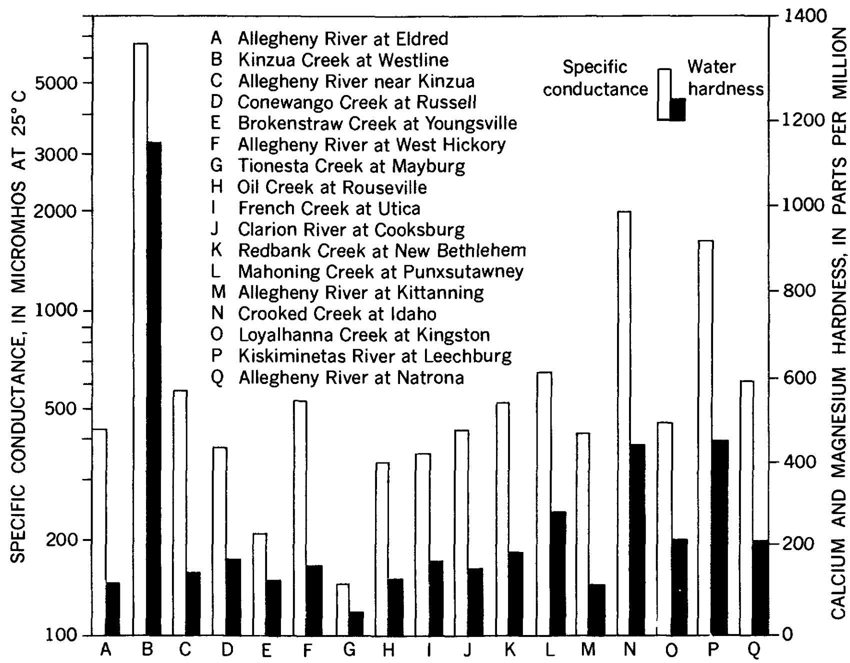

FIGURE 4.—Specific conductance and water hardness of the Allegheny River and tributaries during the drought of 1963.

logarithmic scale on the left side shows specific conductance, in micromhos, and a linear scale on the right side shows hardness, in parts per million.

The quality of the Allegheny changes from a sodium chloride water at Kinzua to a calcium sulfate water at Natrona. During a low flow at these locations in November 1960, these constituents were in concentrations greater than 50 percent of the sum of constituents determined. In middle segments of the river water was of a mixed type, more dilute in dissolved solids and not noticeably dominated by any of its components (fig. 5).

Streams in the Allegheny River basin transport wastes from cities and their suburbs, from farm and mining areas, and often from industrial processes.

Petroleum production in the Allegheny River valley affects stream quality. In the headwater region there are large underground deposits of salt, crude oil, and natural gas. Oil pumped to the surface is accompanied by heavily concentrated brines which flow into nearby streams. These brines cause the main river and several of its tributaries in the upper basin to have high concentrations of sodium chloride. The lower part of the river at times is acidic from sulfuric acid and contains other products of coal-mine wastes such as aluminum, iron, and manganese. The effluents from mines and other industries have caused water-quality changes of unpredictable frequency and duration through the Allegheny River basin. Significant changes in dissolved-solids content and chemical character of the river occur beyond the confluence of tributaries (fig. 6).

The broken lines that separate constituents in figure 6 indicate that the concentration of constituents between selected locations is assumed to change gradually. However, the changes that occur between locations may not be gradual, nor can all changes be attributed solely to the influence of the nearest upstream tributary. A more comprehensive study of the chemical reactions in water, ground-water seepage, and other hydrologic factors observed between the confluence of major tributaries would be needed to explain the presence and changes in concentration of some ions in the river water.

ALLEGHENY RIVER AT RED HOUSE, N.Y.

From its source in Potter County, the Allegheny flows westward into McKean County before turning northwestward into New York. At Red House, approximately 13 miles north of the point where the river

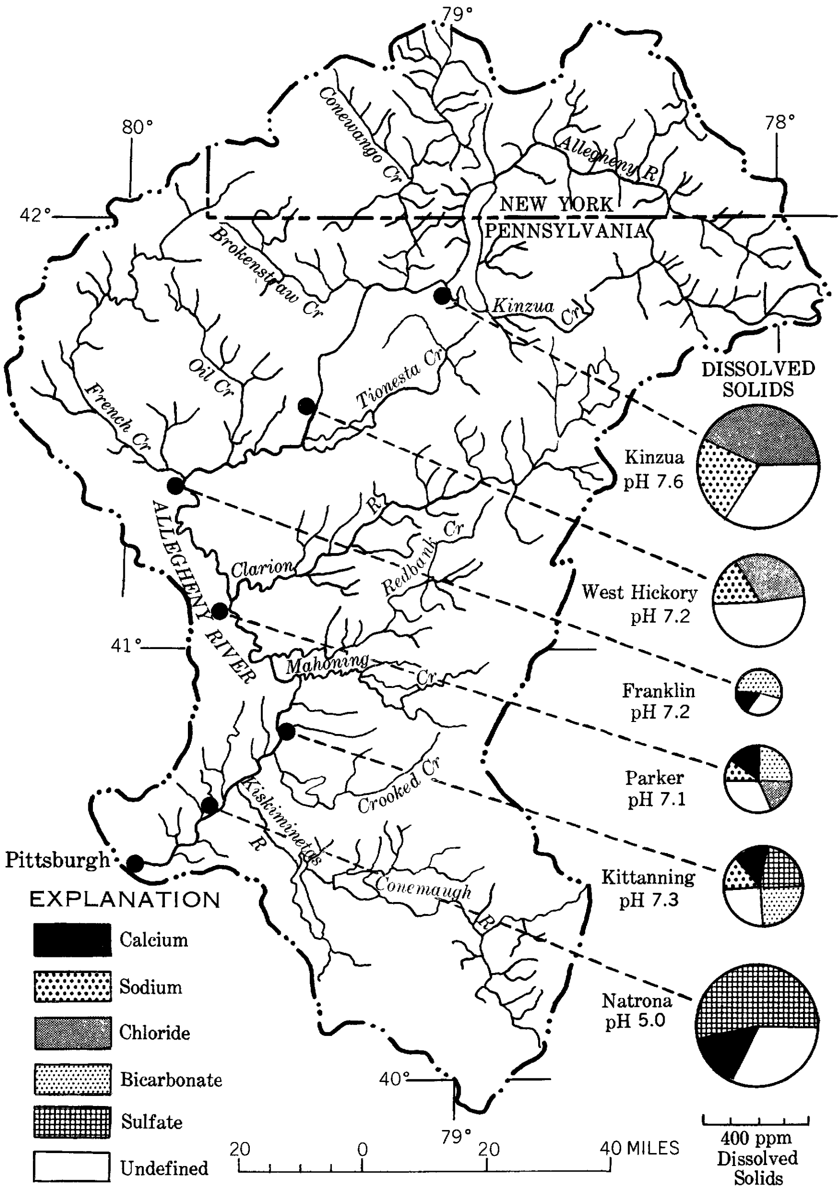

FIGURE 5.—Predominant water constituents at selected locations during low flow. Allegheny River, November 1960.

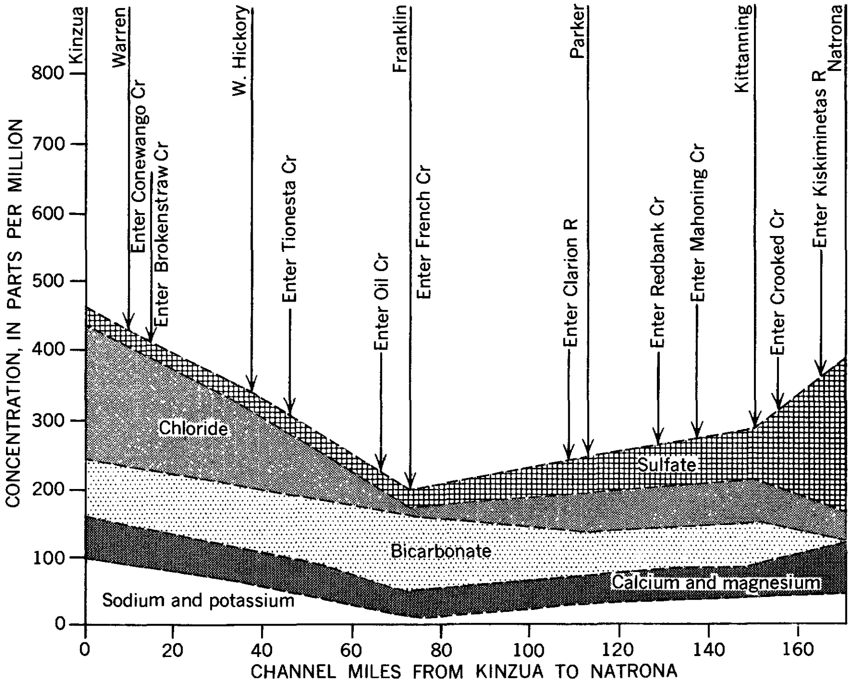

FIGURE 6.—Composition of the Allegheny River at low flow, early November 1960.

returns to Pennsylvania, the river drains an area of 1,690 square miles of north-central Pennsylvania and southwestern New York.

At Red House, the average discharge of the Allegheny for 60 years (1903–63) was 2,769 cfs, or 1,790 mgd. The maximum discharge of 49,100 cfs occurred on March 8, 1956, and the minimum of 80 cfs on December 15–17, 1908 (U.S. Geological Survey, 1963). Ordinarily, streamflow is greater during the winter and early spring, and the concentration (but not the total load) of dissolved minerals in the river during these periods is generally less than during the summer.

Before the Allegheny reenters Pennsylvania from New York its quality is influenced by surface runoff and ground-water seepage, the geology, and most directly by salt water from oil fields. Chemical analyses of samples taken daily from October 1954 to September 1955 (Pauszek, 1959), showed that the river was brackish most of the time.

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The sum of the average concentration of sodium and chloride for this period of study represented 56 percent of the total dissolved solids by weight. On the basis of equivalents per million (epm), the ratio of sodium to chloride was 1 to 1.3. Calcium and magnesium, the principal ions that cause water hardness, constituted 13.4 percent of the total dissolved solids. The ratio of calcium to magnesium was 3 to 1. Bicarbonate and sulfate constituted 27 percent of the total dissolved solids, and the ratio of bicarbonate to sulfate was 2 to 1.

The average concentration of mineral constituents analyzed during the 1955 water year and the extremes of concentration of several constituents for the period of recorded sampling are given in U.S. Geological Survey (1959, p. 306–309) Water-Supply Paper 1400. Specific conductance, pH, temperature, and chloride concentrations are reported for samples taken daily during the 1956 water year in U.S. Geological Survey (1960, p. 338–340) Water-Supply Paper 1450. During 1955 and 1956 the discharge of chloride ranged from an average of 176 tons per day in January to 399 tons per day in March. For the period 1953–56 the maximum concentrations were: dissolved solids, 669 ppm; hardness, 277 ppm; and chloride, 376 ppm. The maximum specific conductance was 1,510 micromhos, and the maximum temperature, 83°F. Recent chemical analyses of the river at Red House can be obtained from the District Chief, Water Resources Division, P.O. Box 948, Albany, N.Y. 12201.

CONEWANGO CREEK

Conewango Creek originates in Chautauqua County in southwestern New York. Of the total area drained by the Conewango (898 sq mi), 137 square miles is in northern Warren County, Pa.

During the 1952 water year, samples of Conewango Creek taken daily at Russell, Pa., were composited at 10-day intervals and chemically analyzed. Specific conductance, pH, and temperature of the stream were also recorded daily. During this period of study, Conewango Creek water was of a calcium bicarbonate type. The maximum concentrations of calcium and magnesium were 42 and 9.4 ppm, respectively, and the bicarbonate ion concentration was equal to or less than 120 ppm in 92 percent of the samples taken. The pH ranged from 6.4 to 8.3. Specific conductance was equal to or exceeded 210 micromhos 40 percent of the time (fig. 7). Other chemical and physical characteristics of the New York parts of Conewango Creek and its principal tributaries are given by Beetem (1954).

The water in the 13.5 miles of the Conewango in Pennsylvania is good for recreation and is usable after moderate treatment for domestic or industrial supply. The species of fish in the Pennsylvania parts of the stream are largemouth and smallmouth bass, walleye, muskellunge, bullhead, carp, sucker, and northern pike. The muskellunge is native to the Conewango (Pennsylvania Fish Commission, 1965).

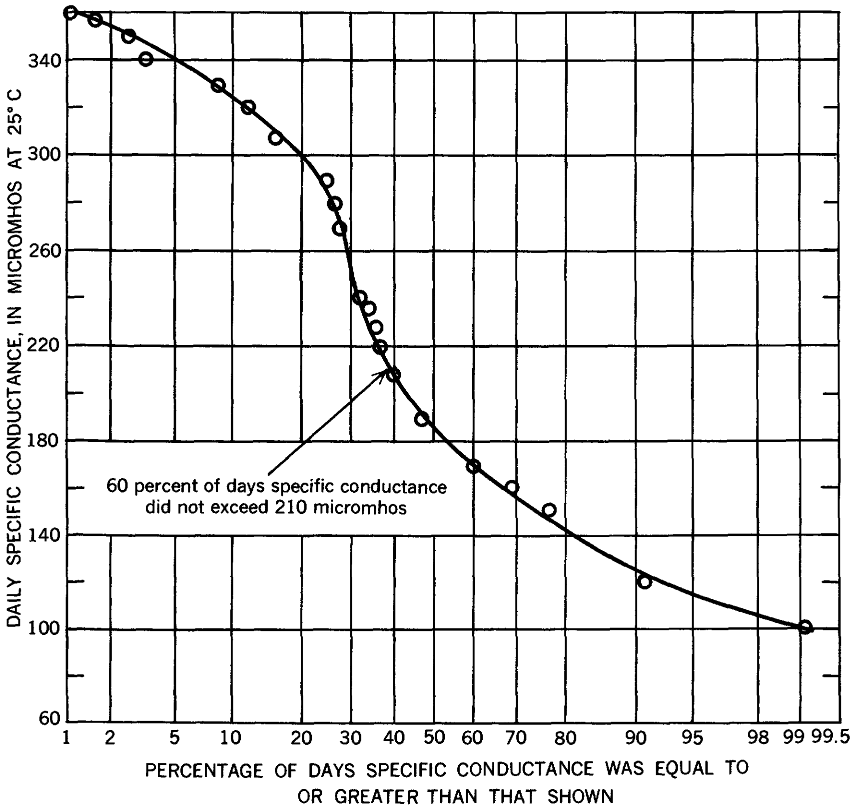

FIGURE 7.—Cumulative frequency curve of specific conductance, Conewango Creek at Russell, Pa., October 1951 to September 1952.

ALLEGHENY RIVER NEAR KINZUA

The discovery of oil in northwestern Pennsylvania stimulated prospecting by many landowners who began drilling thousands of wells. Brine, from oil-well operations, was often allowed to flow into nearby streams after the oil had been separated from it. The brine may originate in the brine-bearing aquifers of northwestern Pennsylvania in which salt of ancient oceans has become more concentrated because of evaporation loss of water due to heat. Brine may also be of sedimentary origin—that is, the salt may go into solution when water is forced through and around deposits during an oil-recovery process known as "five spotting" (Miller, 1954).

One of the streams in northwestern Pennsylvania affected by brines is Kinzua Creek, which originates in Keating Township in central McKean County and enters the Allegheny River from the east. It is 34 miles long, draining 182 square miles of a sparsely settled area whose terrain is underlain by shale and sandstone. Because of the brines, dissolved solids in Kinzua Creek near Westline have exceeded 5,000 ppm, more than four-fifths of which was sodium chloride.

The gage at the Kinzua site on the Allegheny River is about 2.3 miles downstream from the mouth of Kinzua Creek. The area drained by the main river near Kinzua is 2,333 square miles. The average discharge of the Allegheny River near Kinzua for 28 years (1935–63) was 3,756 cfs. This is equivalent to 2,430 mgd. The maximum discharge was 60,500 cfs on March 8, 1956; the minimum of 149 cfs occurred on September 15, 1936 (U.S. Geological Survey, 1963).

During low flow the Allegheny River near Kinzua has a sodium chloride water and contains higher than average concentrations of dissolved solids which are greater on the east and left side of the river because Kinzua Creek is at confluence with the river upstream on the east bank and the waters from two streams have not completely mixed. An analytical comparison of the left side of the river near Kinzua with the part of the river at right center was made on September 26, 1962. The specific conductance of the left side was 1.8 times greater than the right-center sample (1,430 and 793 micromhos), and the chloride content of the left-side sample was 2.2 times greater (362 and 165 ppm).

At average flow and higher, the river is frequently a mixture of sodium chloride and calcium bicarbonate water. At high flow, when dissolved solids are less concentrated, calcium usually predominates. Although less concentrated at high flow, bicarbonate, sulfate, and chloride maintain approximately the same concentration ratio to dissolved solids and to each other as during low flow. The specific conductance of samples taken monthly since 1956 ranged from 94 to 1,430 micromhos; the hardness, from 22 to 252 ppm; and pH, from 6.1 to 8.1.

ALLEGHENY RIVER AT WARREN AND A PROGNOSIS OF RESERVOIR INFLUENCE

At Warren, approximately 12 river miles downstream from Kinzua, the river is predominantly a sodium chloride water. At both Warren and Kinzua the chemical constituents of the river are virtually the same, except that dissolved solids are less concentrated at Warren. The highest concentration of dissolved solids recorded at Warren for the period of record ending September 10, 1962, was 573 ppm (table 3), whereas the Allegheny near Kinzua, below the mouth of Kinzua Creek, had a concentration of 793 ppm dissolved solids on November 3, 1960, of which 55 percent was sodium chloride. The ions of this salt do not always dominate, however, because at times river water at Warren is a mixed type, containing increased concentrations of calcium and bicarbonate.

Chlorides at Warren have exceeded 200 ppm (White, 1951). Nevertheless, at Warren the river contains lower concentrations of dissolved solids and normally contains less chlorides than it does at Red House, N. Y. because of dilution (fig. 8). Between Red House and Warren the river drains approximately 490 square miles, which increases the average discharge of the river at Warren by approximately 1,000 cfs. Much of the increased flow is suited for diluting dissolved solids in the river.

Discharge by Conewango Creek to the river at Warren is normally heaviest during April when the river is also high because much of the runoff is snowmelt. Consequently, dissolved solids in the river are less concentrated during early spring (fig. 9). The effects of dilution on the quality of the Allegheny River at Warren are also indicated by the relation between mean daily specific conductance and discharge (fig. 10). The percentage of days on which tabulated values of determined constituents was equaled or exceeded (1948–51) is shown in table 2. About 25 percent of the days (1948–51) the specific conductance equaled or exceeded 600 micromhos. However, half of the days it did not exceed 350 micromhos (fig. 11).

TABLE 2.—*Frequency of concentration levels for dissolved chemical constituents, Allegheny River at Warren, Pa., for the period October 1948 to September 1951*

[Results in parts per million, except as indicated]

	Concentration (ppm) and specific conductance equaled or exceeded for indicated percent of days				
	1	10	50	90	99
Calcium (Ca)	59	52	23	16	12
Magnesium (Mg)	17	11	5.5	4.2	2.7
Sodium (Na) and potassium (K)	117	92	31	18	8.2
Bicarbonate (HCO_3)	91	77	37	27	22
Sulfate (SO_4)	30	27	18	16	14
Chloride (Cl)	225	186	59	32	14
Dissolved solids (residue on evaporation at 180°C)	441	374	146	105	72
Hardness as $CaCO_4$:					
Calcium, magnesium	190	161	65	45	32
Noncarbonate	------	104	45	35	------
Specific conductance, in micromhos at 25°C	975	815	350	190	118

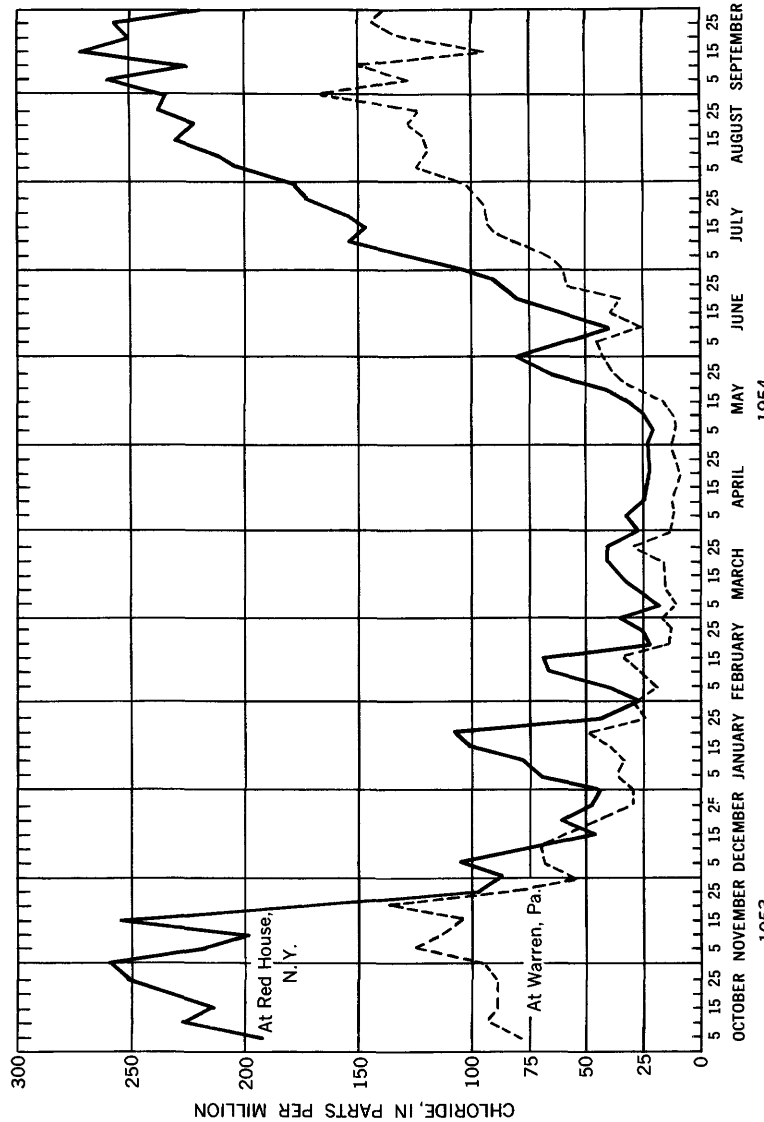

FIGURE 8.—Daily chloride concentration of the Allegheny River at Red House, N.Y., and Warren, Pa., October 1953 to September 1954.

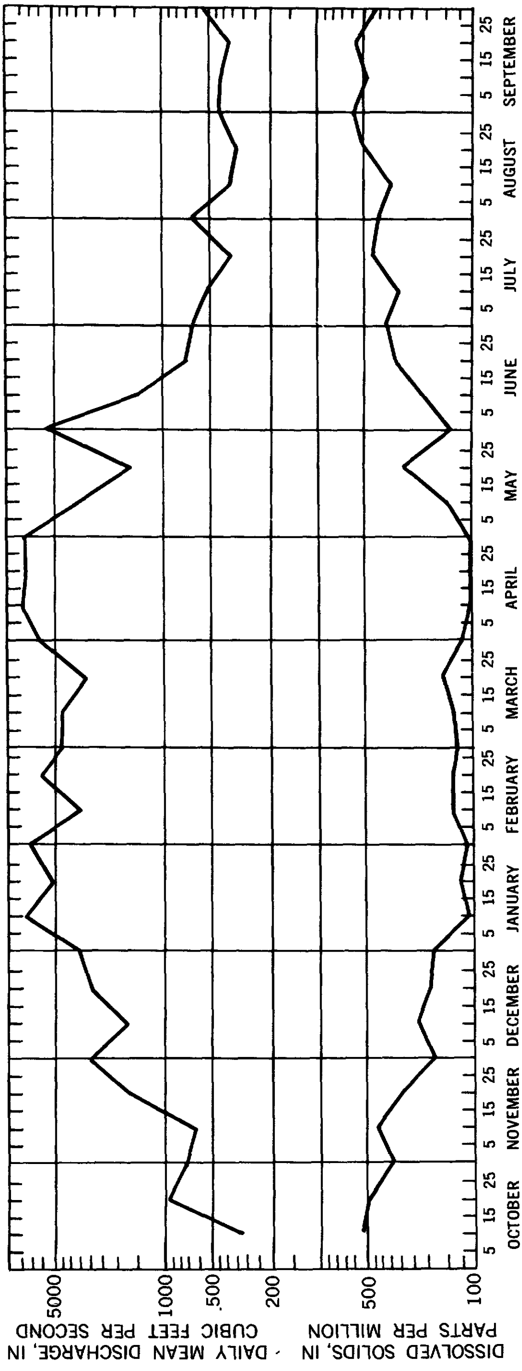

FIGURE 9.—Hydrograph of discharge and dissolved solids, Allegheny River at Warren, Pa., October 1948 to September 1949.

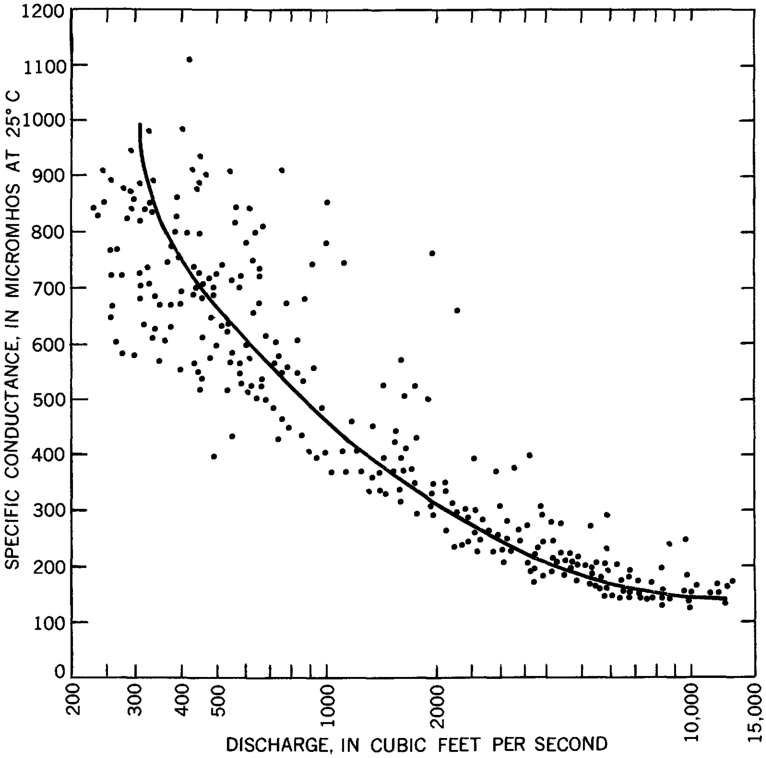

FIGURE 10.—Daily mean discharge versus daily specific conductance, Allegheny River at Warren, Pa., October 1948 to September 1949.

Chemical-quality variations of the river at Warren during the 1962 water year are presented in table 3. Analyses of composited samples taken daily from 1962 to 1965 are given in table 4. Water-temperature variations are shown in table 5. During the 1962 water year the highest water temperature of the Allegheny river recorded at Warren was 76°F on July 8, 9 and on August 7. The average water temperature for the month of July was 71°F. This was 5°F cooler than the average July temperature of the river at Kittanning (76°F).

Since 1944 the U.S. Geological Survey has systematically analyzed water of the Allegheny River near Kinzua and Warren, Pa. On the basis of these analyses, a prognosis can be made of the effects that water released from the Allegheny Reservior will have on the quality of the river.

A purpose of good reservoir management will be to store the best possible water in the conservation pool of the Allegheny Reservoir. Minimum levels of the pool will be reached and held after periods of excessive runoff—times when dissolved solids in Pennsylvania streams

TABLE 3.—*Chemical analyses and recorded extremes, Allegheny River at Warren, Pa., water year October 1961 to September 1962*

[Results in parts per million, except as indicated]

Location.—At bridge on U.S. Highway 6, Warren County, approximately 9.5 miles downstream from gaging station near Kinzua.
Drainage area.—2,233 sq mi.
Records Available.—Chemical analyses: Oct. 1948 to Sept. 1951, Oct. 1961 to Sept. 1962. Water temperatures: Oct. 1948 to Sept. 1951, Oct. 1961 to Sept. 1962.
Extremes, 1961–62.—Specific conductance: Max daily, 896 micromhos, Sept. 13; min daily, 43 micromhos, Jan. 22. Water temperatures: Max, 76°F, July 8, 9, Aug. 7; min, freezing point on many days during winter months.
Extremes, 1948–51, 1961–62.—Dissolved solids (1948–49): Max, 573 ppm, Sept. 11–20, 1949; min, 70 ppm, Apr. 1–10, 1962. Hardness (1948–51): Max, 180 ppm, Oct. 1–10, 1948; min, 27 ppm, Mar. 1–10, 1951. Specific conductance: Max daily, 1,110, micromhos, Oct. 13, 1948; min daily, 43 micromhos, Jan. 22, 1962. Water temperatures: Max, 84°F, July 13, 14, 1949; min, freezing point on many days during winter months.
Remarks.—Records of specific conductance of daily samples available in district office, Philadelphia, Pa.

Date of collection	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO)	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
1961																		
Oct. 4 [1]	0.8	0.00	0.01	37	6.0	54	2.6	68	16	115	0.2	0.4	322	117	62	530	6.9	3
Oct. 5–10	3.9	.00	.00	31	10	60	2.5	74	18	113	.1	.0	286	119	58	534	7.8	3
Nov. 1–10	3.0	.00	.00	29	8.5	50	2.0	68	18	98	.0	.0	247	108	52	471	7.6	5
Dec. 1–10	6.0	.02	.00	16	3.8	20	1.5	36	16	37	.1	.6	113	56	26	218	7.5	5
1962																		
Jan. 1–10	6.7	.00	.00	19	3.6	22	1.5	40	16	42	.1	1.3	142	63	30	243	7.2	2
Feb. 1–10	6.5	.03	.00	14	3.0	16	1.5	28	14	31	.1	1.6	106	48	25	188	7.1	5
Mar. 1–10	5.3	.03	.00	15	2.8	17	1.5	29	13	33	.1	2.5	129	49	25	199	7.1	2
Apr. 1–10	5.1	.03	.00	7.8	2.1	6.2	1.2	15	12	12	.0	1.3	70	28	16	98	7.1	5
May 1–10	4.6	.03	.00	11	2.6	8.8	1.0	28	13	17	.1	1.1	85	38	15	132	7.0	4
June 1–10	3.4	.02	.00	25	3.6	32	1.8	61	16	61	.1	.4	198	78	28	332	7.3	4
July 1–10	4.1	.04	.01	32	5.8	41	1.8	79	17	74	.0	1.3	249	104	40	429	7.0	3
Aug. 1–10	4.1	.02	.02	38	8.3	66	2.1	82	18	128	.2	.9	330	129	62	565	7.4	5
Sept. 1–10	2.8	.01	.03	41	12	80	2.2	96	20	158	.0	.2	404	152	74	730	7.7	2

[1] Mean discharge, 620 cfs; temperature, 54°F.

TABLE 4.—*Chemical analyses, Allegheny River at Warren, Pa., for the period October 1962 to March 1965*

[Results in parts per million, except as indicated]

Date of collection	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (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
1962																		
Oct. 1–10	4.8	0.01	0.03	25	6.1	38	1.8	48	21	74	0.0	--	235	88	48	391	7.5	2
Nov. 1–10	2.8	.03	.01	18	3.4	22	1.1	39	16	42	.0	--	156	59	27	263	7.0	7
Dec. 1–2, 4–5, 7, 9–10	6.4	.01	.01	20	3.4	24	1.8	44	16	44	.1	0.1	156	64	28	279	7.4	5
1963																		
Jan. 1–10 [1]	6.0	.02	.02	28	5.6	34	2.1	57	24	64	.2	.6	215	93	47	386	7.4	5
Feb. 1–10 [1]	6.5	.00	.00	23	5.4	27	3.0	48	17	58	.2	1.7	182	80	40	346	7.2	5
Mar. 1–5	11	.02	.02	28	8.3	35	.5	68	19	72	.1	2.0	231	104	49	389	6.9	5
Mar. 6 [2]	--	--	--	--	--	--	--	--	7.6	22	--	--	--	8	8	93	4.7	10
Mar. 7	--	--	--	--	--	--	--	--	4.8	1.0	--	--	--	4	1	29	5.4	5
Apr. 8–10	--	--	--	--	--	--	--	29	14	16	--	1.5	--	41	17	138	6.7	3
May 1–10	3.8	.00	.00	14	3.9	15	.5	40	13	28	.1	.8	107	51	18	184	7.3	3
June 1–10	2.9	.00	.00	18	3.9	19	1.2	46	13	37	.1	1.3	119	61	24	231	7.0	3
July 1–10	5.4	.02	.02	30	6.3	41	1.0	68	14	82	.1	1.0	246	101	46	417	7.2	5
Aug. 1–10	2.8	.00	.00	32	5.8	46	2.0	75	16	87	.2	.5	247	104	43	454	7.3	3
Sept. 1–10	4.4	.00	.00	39	7.2	59	2.8	84	18	120	.1	.1	342	127	58	582	7.3	7
Oct. 1–10	3.5	.00	.00	47	7.3	60	1.0	110	20	125	.0	.2	333	148	58	579	7.5	5
Oct. 22 [1]	--	--	--	--	--	68		95	20	141	--	.2	374	150	72	663	7.5	3
Nov. 1–10	6.2	.00	.00	40	7.8	68	3.7	78	19	134	.0	.2	360	132	68	620	7.1	4
Dec. 3, 4–7, 9	4.9	.06	.00	14	2.7	13	2.2	28	15	30	.0	1.5	109	46	23	183	7.2	7
1964																		
Jan. 1–10	4.6	.02	.00	20	3.6	25	1.9	41	16	52	.0	1.8	158	65	32	279	6.7	6
Feb. 1–10	--	--	--	--	--	17		33	15	31	--	2.1	--	50	23	143	7.1	7
Mar. 1–10	--	--	--	--	--	18		29	13	34	--	2.4	194	48	24	194	7.1	3
Apr. 1–10	--	--	--	--	--	7.8		22	12	14	--	1.5	--	34	16	116	6.0	4
May 1–10	--	--	--	--	--	14		35	13	14	--	.7	--	46	18	169	7.0	3
June 1–10	--	--	--	--	--	27		56	15	54	--	.1	--	78	32	305	7.0	3
July 1–10	--	--	--	--	--	40		72	17	79	--	.1	--	102	43	413	7.5	3

Aug. 1–10	5.2	.00	.00	33	7.5	46	1.4	74	16	97	.1	.6	272	114	53	475	7.5	15
Sept. 1–10	-	-	-	-	-	49		74	17	94	-	7.4	263	110	50	470	7.6	5
Oct. 1–10	-	-	-	-	-	78		90	20	155	-	1.8	383	146	72	690	7.7	7
Nov. 1–10	-	-	-	-	-	77		95	20	160	-	.6	400	158	80	721	7.4	3
Dec. 1–10	-	-	-	-	-	41		54	20	84	-	1.6	234	96	52	411	7.2	8
1965																		
Jan. 1–10	-	-	-	-	-	14		26	16	26	-	1.3	100	46	2.5	170	6.4	3
Feb. 1–10	-	-	-	-	-	17		32	15	31	-	2.2	112	51	25	196	7.1	5
Mar. 1–10	-	-	-	-	-	12		25	13	20	-	1.9	86	38	18	146	7.1	7

1 Temperatures (°F): Jan. 1–10, 1963, 34°F; Feb. 1–10, 1963, 33°F; Oct. 22, 1963, 58°F.

2 Total acidity as H_2SO_4; Mar. 6, 1963, 1.4 ppm.

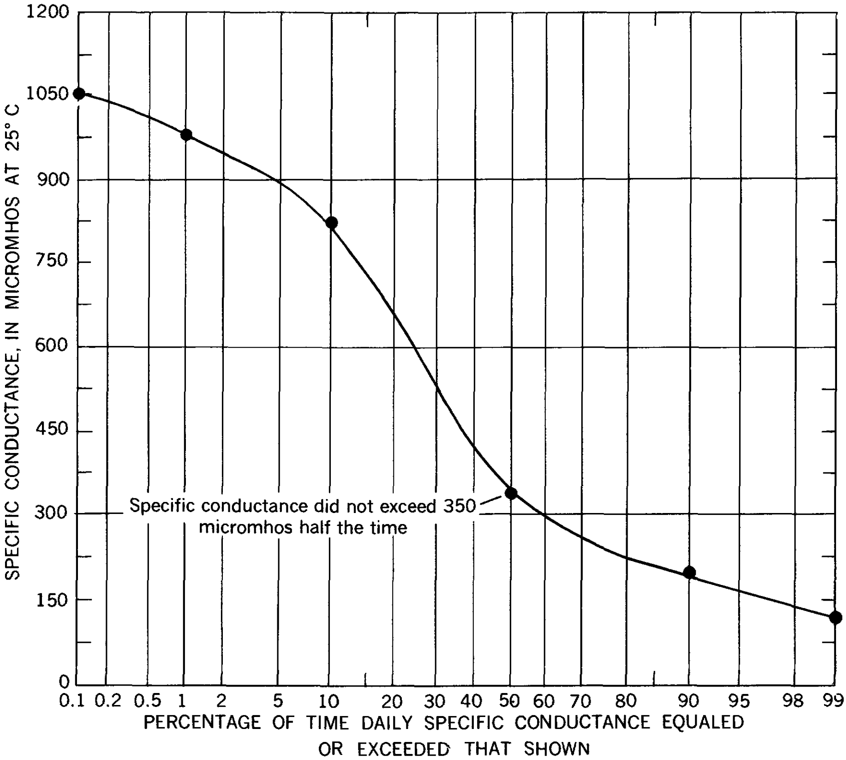

FIGURE 11.—Cumulative frequency curve of specific conductance, Allegheny River at Warren, Pa., 1948–51.

are normally at a minimum. The storage of floodflows in the conservation pool therefore should provide water of good quality relatively low in dissolved solids that can be released when needed to help stabilize flow in the river or dilute water of its dissolved solids content in downstream areas.

The initial chemical quality of water in the Allegheny Reservoir will be determined largely by the quality of water coming in from the drainage area above the dam. Although several streams above Warren in Pennsylvania and some streams in New York contain sodium chloride in preponderance over other constituents, the chemical-quality history of the Allegheny River at Kinzua and Warren indicates that during an average or greater flow the chloride content in the Allegheny was less than 100 ppm. Normally, therefore, this value should not be exceeded in the impounded areas of the river because runoff will be stored during high flow.

TABLE 5.—*Temperature of water, in degrees Fahrenheit, Allegheny River at Warren, Pa., water year October 1961 to September 1962*

Day	1961			1962								
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	------	53	36	33	33	33	38	62	69	74	68	74
2	------	54	37	33	33	33	36	62	68	73	70	73
3	------	52	39	34	33	33	36	58	65	73	68	69
4	54	53	39	34	33	33	36	52	67	73	72	70
5	52	53	44	33	34	33	36	53	67	74	72	63
6	54	53	44	32	34	33	40	58	66	72	75	60
7	54	50	38	33	33	33	43	56	66	74	76	58
8	55	46	34	34	34	33	43	54	67	76	69	58
9	56	42	36	32	33	33	43	52	68	76	75	62
10	58	39	36	33	33	33	42	53	70	70	70	64
11	62	37	37	33	33	34	43	55	70	70	67	64
12	63	38	38	33	33	34	43	55	68	73	62	62
13	62	42	38	33	33	34	42	56	66	74	71	62
14	62	44	34	32	33	34	40	58	60	72	68	67
15	------	43	35	34	34	34	40	59	------	70	65	62
16	51	45	32	32	34	34	40	62	62	71	66	61
17	50	43	32	32	34	34	40	65	62	73	68	60
18	52	44	32	32	34	34	40	65	68	72	67	60
19	52	44	33	32	34	33	42	70	72	72	66	60
20	54	42	32	32	33	34	43	70	70	72	68	56
21	54	40	32	32	33	34	43	70	------	74	72	53
22	54	34	35	33	35	33	47	66	62	74	69	53
23	49	34	33	32	33	35	53	65	70	74	66	54
24	50	36	33	33	34	34	47	66	71	68	67	54
25	52	36	33	33	33	35	50	65	70	69	68	54
26	52	40	33	33	34	35	52	66	72	69	70	57
27	52	39	34	33	34	40	57	65	71	64	72	57
28	46	36	33	33	34	40	60	62	72	62	70	56
29	50	36	33	34	------	41	62	61	72	66	70	55
30	52	36	33	34	------	43	62	66	72	67	70	51
31	53	------	33	32	------	42	------	72	------	74	70	------
Average	54	43	35	33	34	35	45	61	68	71	69	60

The following concentrations of chloride are considered normally nondeleterious for the uses stated (California State Water Pollution Control Board, 1963).

Supply	*Parts per million*
Domestic	250
Industrial	50
Irrigation	100
Stock and wildlife	1,500

In impoundments, stratification occurs because of thermal and density differences. The upper and relatively light surface stratum of impoundments (epilimnion) is normally separated from the colder more dense bottom stratum (hypolimnion), by the (thermocline) a stratum in which temperature and density abruptly change. This difference by stratification suggests that water in some parts of impoundments is more suited than water in other parts for release to improve quality in downstream areas.

Under some circumstances it may seem desirable and economical to have in impoundments water of homogeneous quality that could be made available for release when needed to improve the quality of streams by dilution or lowered temperatures. Nevertheless, the beneficial results expected from mixing water in some reservoirs in order to achieve uniform quality should be thoroughly investigated because the practicality of mixing water in large impoundments has yet to be demonstrated. Most successful results have been reported on pilot studies where small bodies of water were utilized (13 billion gal max).

Much of the water stored in the Allegheny Reservoir will consist of winter and early spring runoff. Temperatures of runoff will be relatively low during this time because of low air temperatures and snowmelt. After storage, however, the temperature of reservoir water, will vary with the seasons, with time in storage, and with depth; at depth, the water will be cooler and remain cool for longer periods.

Most of the water to be impounded in the Allegheny Reservoir is trout bearing because of its relative purity and coolness. Cool water is important to some species of fresh-water game fish because they cannot complete their life cycles in water that exceeds 58°F (California State Water Pollution Control Board, 1963). Headwater streams of the Allegheny River basin have relatively pure cool water, and consequently trout are plentiful. Should releases be made to the Allegheny River from bottom stratas of the reservoir, the probable temperatures of this water would range from 39°F in March and April to 55°F and 60°F in October. Water temperatures would probably be affected as far as 25 miles downstream (U.S. Army Corps of Engineers, 1958).

Exercise of some controls over the temperature of the river by releasing cool water from the reservoir may add to the costs of treating the river water in some areas for domestic use because more coagulants are required to treat cool water. Nevertheless, the advantages of cool water for industrial use seem to outweigh the additional cost of its treatment. For example, steel mills normally require that water temperatures be less than 76°F. Much lower temperatures are required by the paper and pulp industry. Water for barley malting should be about 55°F (California State Water Pollution Control Board, 1963).

A reserve supply of cool water suited for release to the Allegheny River from impoundments can also buffer river temperatures that have been elevated by industrial discharges. Where industrial discharges raise stream temperatures, oxygen in water is depleted, and this often results in the destruction of aquatic life (Moore, 1958). Further, the recreational potential of a river system is endangered where industrial discharges elevate stream temperature because warm water promotes the growth of algae and often intensifies the toxicity of many foreign substances in water. Cool water of suitable quality fed to the Allegheny River can therefore help significantly to lessen these dangers.

BROKENSTRAW CREEK

The source of Brokenstraw Creek, like that of Conewango Creek, is in Chautauqua County in southwestern New York. Thirty miles of this stream is in Pennsylvania, where the stream drains 254 square miles of eastern Erie and northwestern Warren Counties before it flows into the Allegheny River at Irvine, about 6 miles below Warren. Shale and sandstone formations underlie the drainage basin.

The average discharge of Brokenstraw Creek at Youngsville for 54 years (1909–63) was 568 cfs (368 mgd). The maximum discharge for the period of record was about 18,000 cfs on March 25, 1963. The minimum flow was 19 cfs on October 14, 1934 (U.S. Geological Survey, 1963).

Brokenstraw Creek water is a calcium bicarbonate type of good quality. Where this water enters the river it helps to improve the chemical quality of the river. The creek contains trout, largemouth and smallmouth bass, northern pike, carp, sucker, and walleye.

ALLEGHENY RIVER AT WEST HICKORY

At West Hickory, approximately 28 river miles downstream from Warren, the Allegheny River drains 3,660 square miles. The average discharge for 22 years (1941–63) was 6,431 cfs, or 4,213 mgd. The maximum discharge of 101,000 cfs occurred on March 8, 1956; the minimum was not determined.

During low flow at West Hickory the river is sodium chloride water that is often high in dissolved-solids content. When the flow increases, the river becomes a mixed sodium chloride-calcium bicarbonate type water. At average and greater flows, the water is suited for both domestic and industrial uses after only moderate treatment. The good quality of Brokenstraw and Conewango Creeks, with their low dissolved-solids content, normally should help dilute the concentration of dissolved solids in this area of the river. Although the changes in the chemical composition of the Allegheny between Warren and West Hickory are not sharply defined, at times the ratio of bicarbonate to dissolved solids increases in bicarbonate by as much as 15 percent.

TIONESTA CREEK

Originating in Warren County, Tionesta Creek enters the Allegheny River at Tionesta about 6 river miles downstream from West Hickory. Its 58-mile length drains an area of 485 square miles including parts of Warren, McKean, Elk, Forest, and Clarion Counties. The stream flows through a picturesque and densely wooded area of some virgin timber that is underlain by shale and sandstone formations containing oil and gas.

The Tionesta Creek flood-control reservoir was completed in 1941. The earth-fill dam forming the reservoir is approximately 1.8 miles from the creek's mouth (U.S. Geological Survey, 1963). The average discharge of the creek at Tionesta Creek Dam, Pa., for 23 years (1940–63) was 861 cfs, or 556 mgd; maximum discharge of 10,300 cfs was on June 6, 1946, and the minimum discharge of 1.5 cfs was on October 16, 17, 1960 (U.S. Geological Survey, 1963). Tionesta Creek Dam, Pa., is 0.9 miles from the creek's mouth.

Tionesta Creek commonly discharges a mixed bicarbonate-type water, with sodium bicarbonate and calcium bicarbonate predominating alternately. The good quality of the creek is mostly unaffected by man. Samples of the stream that were taken intermittently under different flow conditions in the headwaters and downstream halfway to the mouth and near the mouth did not exceed 86 ppm dissolved solids. Analyses of samples taken twice a month at Tionesta Creek Dam, Pa., by the Corps of Engineers from 1953 to 1958 showed the following ranges: pH, 5.7–7.2; bicarbonate, 10–40 ppm; and hardness, 17–68 ppm.

OIL CREEK

Oil Creek, 35 miles long, has its source in Lake Canadotha in Bloomfield Township, Crawford County. The creek drains 335 square miles including parts of Erie, Crawford, Warren, and Venango Counties before it enters the Allegheny River at Oil City. The stream basin lies in a glaciated area. Underlying shales and sandstones contain oil, gas, and some coal deposits.

At Rouseville the average discharge of Oil Creek for 31 years (1932–63) was 512 cfs, which is equivalent to 331 mgd. Maximum discharge of 21,000 cfs occurred on January 22, 1959, and the minimum of 22 cfs was observed on July 29 and September 5 and 7, 1934.

After the first recovery of oil in 1859 from a well drilled by Edward L. Drake at Titusville in the Oil Creek drainage basin, small refineries were built. A simple process of refining the crude oil was its distillation in an iron still, usually heated by coal. The oil vapor was condensed first as naphtha, then as lamp oil, and finally as heavy oil containing paraffin. At least 40 percent of the crude oil refined was waste, much of which was dumped into Oil Creek. But long before the first well at Titusville gave forth a thick crude oil to start the world's petroleum industry, the Indian soaked his blanket on the surface of Oil Creek to recover oil to make liniment and war paint.

Early settlers of northwestern Pennsylvania, in about 1848, were attracted by unusual mounds of dirt in the region of Oil Creek. Investigation showed that the mounds of dirt had come from dug pits about 8 feet long, 6 feet wide, and 6 to 10 feet deep. In the center of some pits, trees two to three hundred years old were growing, an indication that the pits dated to about 1548. Whoever dug them probably did so to confine some of the crude petroleum that was coming to the land surface with water. Flooding the pits with water obtained from springs and nearby Oil Creek floated the oil to the top of the pits where the oil could be skimmed off the water surface (Miller, 1954).

Seepage of oil with spring water and the oil from pits in the flood plains of Oil Creek probably accounted for the streams' pollution during high runoff. However, today oil is less abundant near the land surface. Also, because of modern coal and oil-production methods and Pennsylvania laws limiting stream pollution, Oil Creek no longer has an oily surface as Pennsylvania historians reported it had hundreds of years ago.

Oil Creek water is of a calcium bicarbonate type. When flow is near average, calcium and bicarbonate ions make up about 53 percent of the dissolved solids, whereas at low flow they total 62 percent. Sodium, potassium, and chloride accounted for about one-third the dissolved solids at average and low flow.

Analyses of samples taken at Titusville, below Titusville, and at Oil City showed a pH range from 6.4 to 8.1. Specific conductance of samples ranged from 154 to 342 micromhos, varying inversely with discharge.

The Pennsylvania Fish Commission reports that sportsmen catch trout, carp, sunfish, and muskellunge in Oil Creek at Rouseville.

FRENCH CREEK

French Creek, originating in Chautauqua County in southwestern New York, flows 78 miles through Pennsylvania before entering the Allegheny River at Franklin. In the French Creek drainage area of 1,246 square miles—which includes a part of southwestern New York, and parts of Erie, Crawford, Mercer, and Venango Counties in Pennsylvania—there are many lakes and swamps of glacial origin. There are also numerous mineral springs in Crawford County near Cambridge Springs.

Bedrock is mostly shale and sandstone. In the lower basin these rocks contain oil.

At Utica, about 9 miles upstream from the mouth of the creek, the average discharge for 31 years (1932–63) was 1,699 cfs, or 1,098 mgd. The maximum discharge of 22,100 cfs occurred on April 1, 1960, and the minimum of 43 cfs occurred on July 30, 1934.

For its entire length French Creek is a calcium bicarbonate water. At Utica and other locations, samples representing stream quality seasonally have been analyzed since 1944. Samples collected intermittently for the period of record at Utica (1944–63) showed dissolved-solids content did not exceed 226 ppm, nor did specific conductance exceed 383 micromhos. The pH ranged from 6.4 to 8.0.

During low flow at Utica, calcium and bicarbonate commonly make up more than 60 percent of the sum of the constituents analyzed. During the 1962 water year when samples were taken monthly, the concentration of calcium and bicarbonate, in equivalents per million, was 63 percent of the total constituents analyzed at low flow (101 cfs Sept. 11, 1962). Earlier in the water year, on October 26, 1961, (138 cfs), these constituents were 65 percent of the total constituents analyzed; under similar flow conditions 18 years earlier on August 9, 1944 (148 cfs), they made up 68 percent of the determined constituents.

When flow at Utica was above average (3,520 cfs, Apr. 6, 1961) and high (5,650 cfs, May 13, 1962), calcium and bicarbonate made up 58 and 57 percent, respectively, of the total constituents analyzed.

During the 1947 water year, samples taken daily from French Creek at Franklin were composited for chemical analysis in groups of 10 samples taken on consecutive days (table 6). During this water year, 97 percent of the composited samples ranged from 59 to 156 ppm in dissolved-solids content. The lowest daily specific conductance of 70.6 micromhos occurred on April 7 (table 7), when flow was about seven times greater than the average for the period of record. The maximum specific conductance of 277 micromhos occurred on November 8 when the discharge was about one-seventh of average flow.

The quality of French Creek is such that it improves the quality of the Allegheny River by dilution where the river and creek mix. French Creek contains game fish, and drains an area having high potential for recreational development. Water withdrawn from the creek needs only moderate treatment for use as a domestic supply and for most industrial purposes.

TABLE 6.—*Chemical analyses and recorded extremes, French Creek at Franklin, Pa., water year October 1946 to September 1947*

[Results in parts per million, except as indicated]

Location.—At raw-water intake of Franklin filter plant, 1½ miles upstream from Franklin, Venango County, Pa.
Drainage area.—1,200 sq. mi.
Records available.—Chemical analyses: Oct. 1946 to Sept. 1947.
Extremes, 1946–1947.—Dissolved solids: Max, 156 ppm, Nov. 1–10; min, 59 ppm, Apr. 1–10. Total hardness: Max, 117 ppm, Nov. 1–10; min, 37 ppm, Apr. 1–10.
Remarks.—Records of water discharge based on records for French Creek at Utica and for Sugar Creek at Sugar Creek. Records of specific conductance and pH of daily samples available in district office, Washington, D.C.

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (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
1946																		
Oct. 1–10	115	0.4	0.01	34	6.9	8.4	2.9	112	23	12.0	0.1	0.6	145	113	21	252	7.7	8
Oct. 11–20	369	2.0	.01	32	6.5	6.9	3.1	105	24	7.4	.1	1.2	139	107	21	245	7.5	6
Oct. 21–31	386	1.4	.01	32	6.1	5.8	2.8	88	34	5.9	.1	.7	138	105	33	235	7.5	8
Nov. 1–10	233	1.2	.01	35	7.2	6.9	5.3	105	37	7.5	.1	.8	156	117	31	266	7.6	11
Nov. 11–20	636	5.2	.01	31	6.1	4.6	6.1	88	36	5.8	.1	1.4	141	102	30	232	7.6	16
Nov. 21–30	1,200	4.2	.02	27	5.3	5.5	2.9	67	37	5.2	.1	1.6	123	89	34	203	7.9	14
Dec. 1–10	676	5.6	.03	27	5.1	5.4	2.4	64	35	5.2	.1	1.4	122	88	36	201	7.1	22
Dec. 11–20	2,224	7.1	.02	20	4.0	3.3	1.6	44	30	3.9	.1	1.8	98	66	30	156	7.0	30
Dec. 21–31	2,775	5.8	.03	21	4.0	3.6	1.4	50	28	4.1	.1	2.0	97	69	28	160	7.0	30
1947																		
Jan. 1–10	3,188	5.4	.01	17	3.4	3.0	1.5	36	26	3.5	.1	2.0	82	56	27	133	7.0	32
Jan. 11–20	3,588	5.1	.02	18	3.6	3.1	1.2	42	25	3.2	.0	2.0	83	60	25	128	6.9	13
Jan. 21–31	5,893	4.5	.02	15	3.1	2.4	1.0	32	23	2.8	.0	2.3	71	50	30	115	6.8	15
Feb. 1–10	3,589	5.3	.04	17	4.1	3.0	1.3	39	24	3.2	.1	2.6	85	59	27	136	6.3	15
Feb. 11–20	1,399	6.5	.03	22	4.3	3.6	1.4	55	24	4.0	.1	3.0	100	73	28	164	6.4	8
Feb. 21–28	940	6.3	.03	24	4.6	4.2	1.2	63	25	4.5	.1	2.6	107	79	27	176	6.6	11
Mar. 1–10	828	6.5	.03	24	4.8	4.5	1.3	67	24	4.2	.1	2.9	109	80	25	183	6.6	10
Mar. 11–20	4,316	5.1	.04	16	3.4	3.0	1.3	41	21	3.1	.1	3.2	80	54	20	130	7.0	10
Mar. 21–31	5,638	5.1	.06	14	2.9	2.6	1.1	34	19	2.9	.0	3.2	70	47	19	111	6.9	12
Apr. 1–10	12,420	4.9	.20	11	2.3	2.0	1.2	25	16	2.1	.0	2.3	59	37	16	90	6.8	25
Apr. 11–20	4,703	4.7	.05	16	3.1	2.6	1.3	40	20	2.9	.1	2.2	76	53	20	122	7.0	25

TABLE 6.—*Chemical analyses and recorded extremes, French Creek at Franklin, Pa., water year October 1946 to September 1947*—Continued

[Results in parts per million, except as indicated]

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (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
Apr. 21-30	5,524	3.7	0.02	15	3.1	2.2	0.9	37	19	2.1	0.1	1.4	72	50	20	116	7.4	8
May 1-10	3,950	3.7	.02	17	3.5	2.3	.9	47	19	2.4	.1	1.2	78	57	18	129	7.7	9
May 11-20	2,870	2.9	.02	18	3.8	3.0	.8	52	19	2.8	.1	1.1	83	60	18	139	7.8	9
May 21-31	6,218	3.8	.04	16	3.0	1.9	1.5	46	16	2.0	.1	1.0	74	52	15	117	6.9	20
June 1-10	8,080	3.9	.13	15	2.8	1.7	1.5	45	14	1.5	.1	1.2	72	49	12	110	7.0	30
June 11-20	3,423	4.0	.16	19	3.5	2.3	1.6	59	15	2.2	.1	1.1	87	62	13	137	7.1	32
June 21-30	853	3.3	.04	27	6.0	4.0	1.5	85	19	3.9	.1	.8	113	88	18	191	7.7	14
July 1-10	436	1.6	.02	31	5.7	6.4	1.3	104	23	5.8	.1	.6	130	101	16	229	7.8	8
July 11-20	896	3.5	.03	28	5.1	5.0	1.3	87	20	6.5	.1	1.0	118	91	20	204	7.5	10
July 21-31	1,290	4.2	.03	23	4.0	3.2	1.1	73	18	2.0	.1	1.0	100	74	14	164	7.5	22
Aug. 1-10	339	2.1	.02	30	5.5	5.7	1.6	99	22	5.8	.2	.5	125	97	16	218	7.6	10
Aug. 11-20	318	2.1	.01	32	5.7	6.4	1.7	104	22	6.5	.1	.8	131	103	18	231	7.5	9
Aug. 21-31	270	3.1	.02	31	5.7	7.6	1.7	102	26	7.1		.8	135	101	17	235	7.8	8
Sept. 1-10	490	3.3	.02	30	5.7	5.6	1.8	98	24	5.9	.1	.8	128	98	18	220	7.9	10
Sept. 11-20	523	2.1	.02	32	5.8	7.3	1.5	101	27	7.0	.1	.2	137	104	21	237	8.1	13
Sept. 21-30	282	3.3	.02	33	6.5	8.1	1.8	109	25	7.5	.1	.4	143	109	20	250	7.6	5
Average	2,537	4.0	.04	24	4.6	4.4	1.8	68	24	4.6	.1	1.5	106	79	23	177	------	15

TABLE 7.—*Specific conductance (micromhos at 25° C), French Creek at Franklin, Pa., water year October 1946 to September 1947*

Day	1946			1947								
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	254	265	172	132	91.7	184	122	135	130	214	196	235
2	251	261	183	136	98.5	184	104	138	136	219	202	237
3	256	265	191	117	117	182	89.4	132	89.7	220	210	235
4	265	269	201	108	128	184	84.2	123	84.5	225	217	243
5	254	271	203	114	139	187	79.9	121	95.2	228	218	230
6	256	267	208	124	152	186	75.1	123	117	228	221	221
7	256	271	210	133	154	188	70.6	125	121	233	226	185
8	256	277	214	146	156	185	73.3	128	106	236	230	192
9	267	273	215	155	162	179	90.1	131	101	240	226	206
10	259	271	211	165	165	173	106	131	108	236	233	213
11	270	273	204	164	163	173	119	136	125	233	239	218
12	255	271	168	159	164	172	123	142	140	228	242	227
13	243	265	136	164	168	163	127	145	150	223	240	229
14	255	231	125	168	169	132	131	146	156	231	237	232
15	262	225	134	139	168	106	139	146	136	216	251	235
16	234	214	145	108	166	98.2	115	141	122	183	257	242
17	245	210	154	107	161	103	117	139	119	193	194	249
18	237	216	158	114	162	107	109	136	127	182	217	251
19	228	219	165	124	160	114	117	137	142	169	213	243
20	213	225	163	121	168	123	121	120	155	181	205	243
21	216	223	168	117	169	126	106	119	161	181	207	244
22	218	227	172	109	184	129	95.3	105	171	182	209	246
23	226	228	176	121	175	133	102	110	176	187	215	256
24	231	231	176	127	177	119	115	115	184	195	229	266
25	241	237	176	120	177	90.3	124	125	193	109	235	254
26	226	230	174	106	180	82.4	120	112	187	124	246	246
27	236	214	178	100	181	86.9	119	113	204	138	251	244
28	244	154	155	104	181	103	120	115	204	152	253	241
29	239	151	136	114	------	109	120	125	207	165	251	242
30	239	162	108	122	------	116	127	118	208	177	240	851
31	252	------	120	113	------	121	--------	120	--------	187	223	------

ALLEGHENY RIVER AT FRANKLIN

The Allegheny River at Franklin in Venango County drains 5,982 square miles. The average discharge here for 49 years (1914–63) was 10,200 cfs, or 6,592 mgd. The maximum discharge of 138,000 cfs occurred on March 13, 1920; the minimum of 334 cfs occurred on July 30, 1964.

At Franklin, the Allegheny River below confluence with French Creek is a calcium bicarbonate water of good quality. On November 2, 1960, when the discharge was about one-eleventh of the average flow for the period of record (925 cfs) and the specific conductance was 266 micromhos, analyses of the river at other locations showed that dissolved solids in segments near Franklin were relatively lower than in either the upper or lower parts of the river (fig. 5). By weight, calcium and bicarbonate ions at Franklin were 74 percent of the total-dissolved solids; magnesium was 3.5 percent; sulfate, 12 percent; sodium and potassium, 5 percent; chloride, 5 percent; and fluoride and nitrate, less than 1 percent.

For about 35 river miles downstream from Franklin, river water is moderately diluted by several small streams, the largest of which are Sandy Creek and East Sandy Creek. In this part of the Allegheny River, water quality does not change significantly until the Clarion and Allegheny merge near Parker.

CLARION RIVER

The main stream of the Clarion River, 95 miles in length, is formed by the junction of the East and West Branches at Johnsonburg in Elk County. Its mouth is near Parker on the Allegheny River. The Clarion drains 1,232 square miles of parts of McKean, Elk, Jefferson, Forest, and Clarion Counties, and the upper part of the basin is densely wooded with virgin timber. Most of the bedrock in the basin is shale and sandstone containing deposits of coal, oil, and gas.

The East Branch Clarion River Reservoir, in Elk County about 8 miles upstream from where the East and West Branches meet, was completed in 1952. It was designed for flood control and water conservation through storage during periods of excess runoff. The impounded water is used for recreation and to augment flow in the river when it is at low levels.

In the headwaters of the East Branch, above and below the reservoir, several small streams have a low dissolved-solids content and are excellent in quality. But other streams such as Swamp Creek are sometimes acidic because of strip mines and spoil banks. Such acidic streams affect the river and the quality of water in the reservoir. For example, the pH of reservoir water most of the time is less than 7.0, but on March 25, 1957, the Corps of Engineers reported an unusually low pH of 4.10. Obviously, releases of water to augment river flow when the reservoir water pH is 4.10 would not normally help to improve water quality downstream.

The average discharge of the river near Piney, Pa., for 19 years (1944–63) was 1,702 cfs, or 1,100 mgd. The maximum discharge of 50,000 cfs was reported by the Pennsylvania Electric Co. on March 18, 1963; the minimum flow was not determined. Nevertheless, low flow usually occurs between June and October.

During the 1947 water year, samples taken daily during average or high flow showed the river water was a calcium sulfate type (table 8). During low flow when the dissolved solids were more concentrated, the river became a mixed calcium sulfate–sodium chloride type water. Usually, the quality of water was improved by direct runoff because dissolved-solids concentration was reduced by dilution. Yet, the concentration of the constituents of water was not reduced proportionately by runoff (fig. 12). During low flow, sodium, potassium, iron, man-

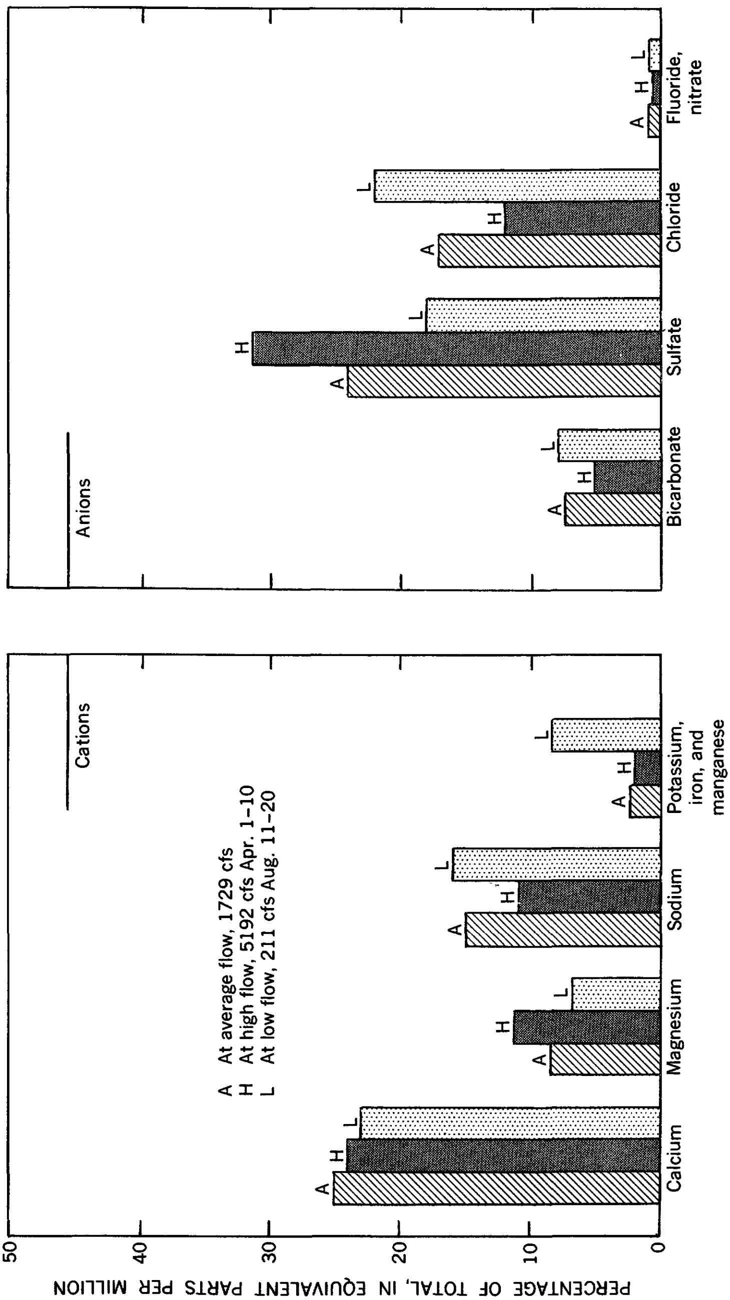

FIGURE 12.—Percentage composition of dissolved solids at average, high, and low flows, Clarion River near Piney, Pa., October 1946 to September 1947.

TABLE 8.—*Chemical analyses, Clarion River near Piney, Pa., water year October 1946 to September 1947*

[Results in parts per million, except as indicated]

Date of collection	Mean discharge (second-feet)	Color	pH	Specific conductance ($K \times 10^6$ at 25°C)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$ Total	Hardness as $CaCO_3$ Noncarbonate
1946																			
Oct. 1–10	276	65	6.9	409	2.8	0.14	0.00	39	6.8	29	2.9	40	79	50	0.1	1.3	257	125	92
Oct. 11–20	1,027	70	6.7	401	2.6	.13	.00	38	6.4	27	3.4	41	77	49	.1	1.6	251	121	88
Oct. 21–31	1,183	35	7.0	308	5.0	.02	.00	30	4.9	18	6.9	33	61	35	.1	.3	191	95	68
Nov. 1–10	594	30	6.7	236	4.4	.04	.00	22	4.3	10	7.9	22	52	24	.1	.3	150	73	55
Nov. 11–20	627	31	6.5	225	4.4	.05	.00	21	4.3	14	2.7	20	52	23	.1	.3	142	70	54
Nov. 21–30	857	32	6.6	267	5.4	.19	.03	26	4.7	18	1.5	28	58	30	.2	.2	170	84	61
Dec. 1–10	636	50	6.8	242	5.4	.15	.06	24	4.3	15	1.9	24	51	27	.2	.4	157	78	58
Dec. 11–20	1,475	45	6.5	226	5.2	.04	.03	23	3.8	13	2.0	22	48	25	.2	.4	142	73	55
Dec. 21–31	1,623	42	6.4	168	5.3	.12	.03	16	3.1	9.5	1.4	17	39	14	.2	.4	105	53	39
1947																			
Jan. 1–10	3,857	10	6.0	111	4.6	.09	.03	11	2.5	4.7	1.3	11	27	8.6	.1	.6	67	38	29
Jan. 11–20	2,906	10	6.0	115	4.8	.07	.05	11	2.7	5.1	1.2	11	29	8.6	.1	.6	70	39	30
Jan. 21–31	4,183	9	5.9	101	4.6	.02	.07	9.0	2.8	4.3	1.0	5	27	7.0	.1	.6	62	34	30
Feb. 1–10	2,348	10	5.8	100	4.7	.07	.11	9.0	2.6	4.1	1.0	6	26	7.2	.1	.4	62	33	28
Feb. 11–20	962	10	5.2	130	5.0	.06	.15	11	3.3	5.9	1.4	6	34	10	.1	.4	81	41	36
Feb. 21–28	608	25	5.5	173	5.6	.22	.06	16	3.9	8.4	1.4	10	44	15	.1	.5	113	56	48
Mar. 1–10	505	28	5.5	201	5.4	.26	.00	18	4.2	11	1.5	13	49	18	.1	.4	130	62	52
Mar. 11–20	2,177	27	6.2	214	4.4	.04	--------	20	4.2	12	2.4	16	49	21	.2	.4	141	67	54
Mar. 21–31	3,355	9	6.1	110	4.2	.02	--------	9.8	2.4	5.0	1.5	9.0	26	9.0	.1	.5	71	34	27
Apr. 1–10	5,192	10	6.1	91	4.5	.10	.09	7.8	2.2	4.0	1.3	5	24	6.6	.0	.6	59	28	24
Apr. 11–20	2,033	15	6.1	108	4.8	.16	.07	9.4	2.6	4.8	1.2	7	28	8.1	.1	.4	74	34	28
Apr. 21–30	3,745	12	6.2	116	4.7	.23	.08	10	2.7	5.5	1.3	7	29	9.6	.1	.4	76	36	30
May 1–10	4,286	8	6.8	95	4.0	.12	.22	8.3	2.8	3.8	1.0	5	26	6.8	.1	.4	62	32	28
May 11–20	2,945	7	6.7	112	3.9	.22	.23	10	3.1	4.9	1.0	6	30	9.2	.1	.4	77	38	33
May 21–31	3,724	9	6.4	106	3.8	.15	.08	9.2	2.6	4.7	1.0	5	27	8.6	.1	.2	71	34	30

June 1-10	3,721	20	6.1	122	4.6	.24	.12	10	2.7	6.4	1.5	6	29	11	.1	.2	79	36	31
June 11-20	2,264	20	6.1	115	4.6	.18	.00	10	2.6	5.7	1.5	7	28	9.6	.1	.2	75	36	30
June 21-30	703	22	6.3	141	5.5	.26	.00	12	3.1	8.1	1.5	11	32	13	.1	.1	90	43	34
July 1-10	443	30	6.4	177	5.3	.30	.08	16	3.6	7.8	1.3	13	39	18	.1	.1	113	55	44
July 11-20	493	54	6.5	263	5.6	.83	.60	22	5.3	16	1.8	20	56	31	.1	.2	172	77	60
July 21-30	425	65	6.6	343	4.4	.99	.12	30	6.0	23	1.7	26	68	45	.2	.4	223	100	78
Aug. 1-10	237	60	6.3	348	4.6	.70	.20	30	6.2	25	2.3	25	65	46	.2	.5	225	100	80
Aug. 11-20	211	60	6.3	356	4.6	.54	.00	31	6.1	26	2.3	27	65	49	.2	.5	230	102	80
Aug. 21-31	523	65	6.4	392	4.8	.61	.55	34	6.8	29	3.0	32	71	55	.1	.5	254	113	87
Sept. 1-10	459	70	6.6	465	4.6	.67	.60	42	7.6	35	2.7	40	84	66	.1	.8	310	136	103
Sept. 11-20	604	80	6.7	477	4.2	.82	.80	44	7.8	35	3.2	45	83	69	.2	.8	317	142	105
Sept. 21-30	335	50	6.4	402	4.6	.52	.00	37	5.9	30	2.3	39	63	59	.2	1.1	247	117	85
Time weighted average	1,729	33	------	221	4.6	.26	.13	20	4.2	14	2.1	18	47	25	.1	.5	142	67	52

ganese, and chloride became a larger part of the total dissolved solids. During high flow, when the river was normally more dilute, the concentrations of magnesium and sulfate increased.

From October 1946 to September 1952 dissolved solids in the river near Piney equaled or exceeded 320 ppm for 10 percent of the days and 78 ppm for 90 percent of the days (table 9). Other chemical characteristics of the river near Piney for the 1947 water year and for October 1952 through June 1953 are given in tables 8 and 10. Samples of the river at Piney are taken monthly for chemical analysis.

TABLE 9.—*Frequency of concentration levels for dissolved chemical constituents, Clarion River at Piney, Pa., for the period October 1946 to September 1952*

[Results in parts per million, except as indicated]

	Concentration (ppm) and specific conductance equaled or exceeded for indicated percent of days				
	1	10	50	90	99
Calcium (Ca)	60	45	17	12	10
Magnesium (Mg)	12	9.8	4.4	3.6	3.0
Sodium (Na) and potassium (K)	49	36	12	7.0	5.0
Bicarbonate (HCO_3)	60	43	12	6	3
Sulfate (SO_4)	117	92	44	34	31
Chloride (Cl)	96	69	20	9.0	6.0
Dissolved solids (residue on evaporation at 180°C)	423	320	120	78	65
Hardness as $CaCO^3$:					
Calcium, magnesium	197	151	59	40	34
Noncarbonate	170	120	45	30	25
Specific conductance, in micromhos at 25°C	660	495	190	125	105

TABLE 10.—*Chemical analyses and recorded extremes, Clarion River near Piney, Pa., for the period October 1952 to June 1953*

[Results in parts per million, except as indicated]

Location.—At hydroelectric plant of Pennsylvanin Electric Co., 2.5 miles from Piney, Clarion County, and a quarter of a mile upstream from gaging station.

Drainage area.—951 sq mi (above gaging station).

Records available.—Chemical analyses: Oct. 1946 to June 1953.
Water temperatures: Oct. 1949 to June 1953.

Extremes, 1952–53.—Hardness: Max, 194 ppm, Nov. 11–20; min, 36 ppm, Mar. 21–31.
Specific conductance: Max daily, 613 micromhos, Nov. 20; min daily, 84.6 micromhos, May 27.
Water temperatures: Min, freezing point on several days during winter months.

Extremes, 1946–53.—Dissolved solids (1946–47, 1952–53): Max, 348 ppm Oct. 21–31, 1952; min, 59 ppm Apr. 1–10, 1947.
Hardness (1946–47, 1949–53): Max, 220 ppm, Nov. 21–30, 1949; min, 28 ppm, Apr. 1–10, 1947.
Specific conductance: Max daily, 674 micromhos, Nov. 26, 1949; min daily, 80.0 micromhos, Mar. 7, 1951.
Water temperatures: Max, 77°F Aug. 8, 1952; min, freezing point reached Feb. 7, 1953.

Remarks.—Samples collected by Pennsylvania Electric Co. Records of specific conductance of daily samples available in district office at Philadelphia, Pa. Records of discharge for water year Oct. 1952 to Sept. 1953 given in Water Supply Paper 1275 (U.S. Geological Survey, 1955, p. 47).

Date of collection	Mean [1] discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C)	pH
														Calcium, magnesium	Non-carbonate		
1952																	
Oct. 1-10	123	--------	--------	--------	--------	28		41	93	62	--------	5.5	--------	162	128	482	7.3
Oct. 11-20	109	--------	--------	--------	--------	23		24	78	43	--------	5.8	--------	116	96	372	6.8
Oct. 21-31	91	3.8	0.21	50	7.3	40		46	104	67	0.2	1.6	348	155	117	504	7.5
Nov. 1-10	91	--------	--------	--------	--------	37		40	113	76	--------	2.5	--------	180	147	563	7.3
Nov. 11-20	116	--------	--------	--------	--------	32		47	111	76	--------	3.1	--------	194	156	576	7.2
Nov. 21-30	171	--------	--------	--------	--------	33		46	111	76	--------	2.4	--------	190	152	574	7.2
Dec. 1-10	465	--------	--------	--------	--------	31		36	108	68	--------	3.2	--------	172	142	522	7.1
Dec. 11-13	3,147	--------	--------	--------	--------	20		18	87	46	--------	2.3	--------	128	113	387	6.9
Dec. 14-20	928	--------	--------	--------	--------	11		8	57	20	--------	1.7	--------	72	65	216	6.4
Dec. 21-31	568	--------	--------	--------	--------	5.1		6	48	12	--------	1.8	--------	62	57	176	6.1

TABLE 10.—*Chemical analyses and recorded extremes, Clarion River near Piney, Pa., for the period October 1952 to June 1953*—Con.

[Results in parts per million, except as indicated]

Date of collection	Mean [1] discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (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
1953																	
Jan. 1–10	488					10		8	57	20		2.8		74	67	221	6.5
Jan. 11–20	1,566					8.9		26	56	24		1.0		95	74	248	6.5
Jan. 21–31	2,061					7.5		6	44	14		1.1		55	50	165	6.3
Feb. 1–10	2,205					4.4		4	41	9.0		1.0		50	47	152	6.3
Feb. 11–20	1,484					7.2		5	39	11		1.8		46	42	136	5.6
Feb. 21–28	1,861					6.8		4	45	14		1.2		56	53	161	6.4
Mar. 1–10	1,715					3.2		4	44	8.0		.8		54	51	163	6.5
Mar. 11–20	2,225					4.9		5	37	11		.8		48	44	148	6.0
Mar. 21–31	4,031	4.4	0.15	11	2.2	9.6		3	40	9.0	0.0	.8	87	36	34	129	5.0
Apr. 1–10	2,654					4.7		2	39	8.0		.8		44	42	130	6.1
Apr. 11–20	2,175					4.5		3	43	12		.8		55	53	156	5.8
Apr. 21–30	3,142					9.2		4	46	10		.9		46	43	138	5.8
May 1–10	1,858					8.5		6	39	10		1.0		42	37	132	6.0
May 11–20	2,217					4.3		4	46	8.0		.9		54	51	158	6.4
May 21	2,600					8.6		10	41	16		.9		66	58	183	6.3
May 22–31	8,283					6.5		3	34	9.0		.7		37	35	112	6.0
June 1–10	4,414					5.6		2	37	6.0		3.1		39	37	113	5.6
June 11–20	1,176					8.8		3	50	10		.6		50	48	146	5.6
June 21–30	459					9.1		5	53	15		.5		61	47	184	6.6
Average	[1] 2,943					14		14	60	27		1.8		84	72	253	

[1] For period of record only; mean discharge for water year was 1,564 cfs.

REDBANK CREEK

Redbank Creek, tributary to the Allegheny River at Redbank, is about 48 miles long and drains 585 square miles, including parts of Elk, Clearfield, Jefferson, Clarion, and Armstrong Counties. Underlying the drainage basin are shale, sandstone, and limestone formations containing deposits of coal. The average discharge of Redbank Creek at St. Charles for 45 years (1918–63) was 841 cfs, or 544 mgd.

Redbank Creek is predominantly a calcium sulfate type stream regardless of flow conditions. Samples have been taken at flows ranging from about 0.1 to 2.5 times the average flow; yet the ratio, by weight, of calcium plus magnesium plus sulfate to total dissolved solids only ranged from 0.66 to 0.75.

The ratio of calcium to magnesium in Redbank Creek is about 3 to 1. Calcium and magnesium commonly occur in rocks and soils of the area and are dissolved in surface and ground water by weathering processes.

Sulfate wastes from coal mines and tanneries dominate the chemical composition of the creek. Its acidic properties and the presence of iron and manganese give further evidence of coal-mine waste which makes the stream corrosive to most ordinary metals. Additionally, the concentration of sulfate increases the stream's corrosiveness to ordinary concrete (California State Water Pollution Control Board, 1963). Because of the corrosiveness of the water in Redbank Creek, it is advisable not to use ordinary concrete or metal in the structural parts of flood-control reservoirs, dams, and bridges.

The water of Redbank Creek requires treatment for domestic and most industrial uses. The quality is poorest during low flow. Although the industrial wastes that reach Redbank Creek can destroy acquatic life and limit the stream's recreational potential, there are segments in Clarion and Jefferson Counties above New Bethlehem where the Pennsylvania Fish Commission reports fishermen can find trout, largemouth and smallmouth bass, yellow perch, bullhead, carp, and sucker.

MAHONING CREEK

Mahoning Creek, tributary to the Allegheny River at Mahoning, is 74 miles long and drains 424 square miles including parts of Armstrong, Clearfield, Indiana, and Jefferson Counties. The drainage basin is underlain by shale, sandstone, and limestone formations that contain rich coal deposits, oil, and gas. At Mahoning Creek Dam the average discharge for 25 years (1938–63) was 575 cfs, or 372 mgd. The maximum discharge of 10,400 cfs occurred on March 4, 1962; the minimum of 2.5 cfs occurred on October 13, 1947.

The Mahoning Creek Reservoir, completed in 1941, is about 2 miles upstream from the junction of Pine Run at Eddyville, in Armstrong County. The reservoir controls a drainage area of 339 square miles and provides storage of 69,700 acre-feet for flood control.

Mahoning Creek has a calcium sulfate type water. Approximately 20 stream miles above the reservoir at Punxsutawney, in Jefferson County, the stream often transports coal-mine wastes. On August 8, 1944, during low flow (25 cfs), dissolved-solids content was 734 ppm and the specific conductance, 997 micromhos. When the stream was discharging about five times more water (138 cfs, May 4, 1960), the dissolved-solids content was less (239 ppm) and the specific conductance was lower (336 micromhos). Sulfate decreased from 60 percent by weight of total dissolved solids in 1944 to 50 percent in 1960. This may be because of the differences in discharge (25 cfs and 138 cfs) or because coal-mine operators in the area now exercise more care in preventing waste materials from entering this stream.

ALLEGHENY RIVER AT KITTANNING

At Kittanning the Allegheny River drains 8,973 square miles. The average discharge for 53 years (1904–28, 1934–63) was 15,490 cfs, or 10,010 mgd (adjusted for storage since 1941, Mahoning Creek Reservoir). The maximum discharge of 269,000 cfs was recorded on March 26, 1913, and the minimum of 570 cfs on September 15–17, 1913.

The Allegheny River at Kittanning is commonly a mixed type of water that is generally of good quality and suitable for recreation, domestic use, and most industrial purposes after moderate treatment. (See table 11.) Much of the time the river at Kittanning has a neutral pH. During the 1962 water year the percentage concentration of calcium sulfate ranged from 39 to 57 percent of the dissolved solids, indicating that the river here is influenced by the chemical character of the Clarion River and Redbank and Mahoning Creeks. The principal positive ions in the river water are calcium and sodium, while the negative ions present in preponderance most of the time are sulfate and chloride. When the discharge is low, the chloride concentration may exceed that of sulfate. When discharge is average or high, the bicarbonate may exceed the chloride.

Dissolved-solids content is higher at times of low water discharge. Normally, river water is more concentrated during the summer and early autumn. The maximum dissolved-solids concentration observed for the period of record was 304 ppm on October 11–20, 1946, and the minimum of 63 ppm was found in the composite sample of March 1–10, 1945 (table 11). The concentration of dissolved solids in the river at Kittanning can be estimated by its specific conductance. The relation between dissolved solids and specific conductance is illustrated in figure 13 which shows dissolved solids (*d.s.*), in parts per million,

TABLE 11.—*Chemical analyses and recorded extremes, Allegheny River at Kittanning, Pa., water year October 1961 to September 1962*

Location.—At center of bridge on U.S. Highway 422 at Kittanning, Armstrong County, 2,500 ft downstream from gaging station.
Drainage area.—8,973 sq. mi.
Records available.—Chemical analyses: Oct. 1944 to June 1953, Oct. 1956 to Sept. 1962.
Water temperatures: Oct. 1944 to June 1953, Oct. 1956 to Sept. 1962.
Extremes, 1961–62.—Specific conductance: Max daily, 438 micromhos, Sept. 30; min daily, 118 micromhos, Mar. 26, Apr. 3, 4.
Water temperatures: Max, 78°F, July 7, Aug. 6; min, freezing point Nov. 20.
Extremes, 1944–53, 1956–62.—Dissolved solids (1944–47, 1958–59): Max, 304 ppm, Oct. 11–20, 1946; min, 63 ppm, Mar. 1–10, 1945.
Hardness (1944–47, 1949–53, 1956–59): Max, 148 ppm, Sept. 11–20, 1952; min, 34 ppm, Feb. 21–28.
Specific conductance: Max daily, 580 micromhos, Oct. 18, 1946; min daily, 76 micromhos, Apr. 8, 9, 1947.
Water temperatures: Max, 86°F, July 31, Aug. 4, 1957; min, freezing point on many days during winter months.
Remarks.—Records of specific conductance of daily samples available in district office at Philadelphia, Pa.

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (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
1961																			
Oct. 1-10	1,880	14	0.00	0.00	33	7.9	28	1.8	56	59	46	0.1	0.4	222	115	69	367	7.7	4
Nov. 1-6, 8-10	2,650	14	.03	.00	36	8.4	28	2.0	62	58	49	.1	.2	234	125	74	398	7.7	5
Dec. 1-10	9,680	5.7	.01	.00	16	5.7	9.2	1.8	28	39	15	.2	1.4	113	64	41	186	7.2	3
1962																			
Jan. 2-10	15,860	3.9	.02	.00	20	6.1	12	1.8	32	46	18	.2	1.5	130	75	49	217	7.3	3
Feb. 1-8, 10	13,440	5.3	.01	.09	16	4.3	7.2	1.8	19	39	12	.3	1.4	105	58	42	167	7.1	2
Mar. 2-10	18,480	6.9	.01	.19	16	4.3	7.4	1.6	19	40	12	.3	1.4	105	58	42	167	7.1	2
Apr. 1-10	43,560	5.7	.05	.02	12	3.8	4.5	1.2	13	32	7.8	.1	.0	94	46	35	128	6.6	3
May 1-10	17,790	5.0	.06	.02	15	4.5	6.9	1.2	25	34	11	.1	.9	94	56	36	157	7.0	2
June 1-10	4,070	3.0	.08	.00	23	6.1	15	1.6	42	46	22	.3	.5	146	83	48	246	7.1	3
July 1-10	1,670	5.1	.02	.01	25	5.6	14	1.7	46	52	22	.0	1.1	176	86	48	264	7.0	5
Aug. 1-10	1,500	5.3	.03	.01	32	8.5	27	2.2	58	65	41	.2	.8	223	115	68	369	7.1	3
Sept. 1-10	1,140	4.1	.01	.03	30	10	30	2.2	58	67	48	.2	.3	240	116	69	413	6.9	2

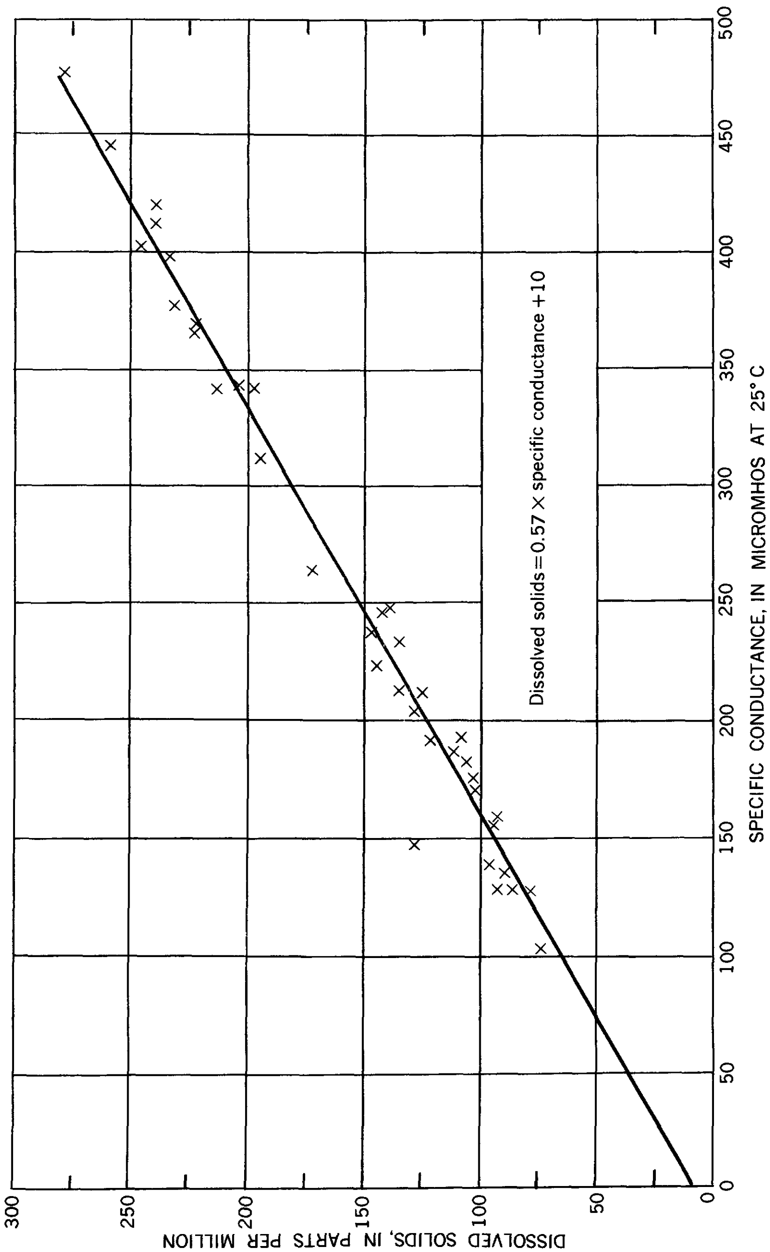

FIGURE 13.—Relationship between dissolved solids and specific conductance, Allegheny River at Kittanning, Pa., 1960–62.

plotted against specific conductance (K) in micromhos at 25°C. The relation of these variables at Kittanning is as follows:

$$d.s. = 0.57K + 10$$

The maximum daily specific conductance of the Allegheny River at Kittanning was recorded as 580 micromhos on October 18, 1946. Other extremes such as those for water hardness and water temperature for the period of record are shown in table 11.

At no time during the 1960 and 1961 water years did water temperature exceed 79°F (tables 12 and 13). The median temperature was 52°F, and 75 percent of the time the water temperature was less than 70°F (fig. 14).

TABLE 12.—*Temperature of water, in degrees Fahrenheit, Allegheny River at Kittanning, Pa., water year October 1959 to September 1960*

[Once-daily measurement between 6 a.m. and 10 a.m.]

Day	1959			1960								
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	70	51	37	36	34	33	38	65	62	72	78	77
2	70	------	37	36	35	33	39	60	62	72	77	78
3	70	------	37	37	34	34	39	61	65	74	78	73
4	70	------	------	36	34	34	40	60	65	73	77	76
5	68	------	39	35	34	34	39	61	65	73	77	76
6	71	------	39	35	36	34	------	60	65	72	78	------
7	74	------	37	36	35	------	49	65	66	71	77	77
8	72	------	36	35	34	33	39	62	69	70	77	77
9	72	------	36	36	34	33	42	58	69	71	77	77
10	48	------	37	36	34	33	42	52	67	71	78	75
11	70	45	36	35	35	33	40	49	68	73	78	75
12	42	44	39	35	35	34	40	48	69	73	73	75
13	69	45	38	35	35	34	41	49	69	73	78	74
14	46	45	37	36	35	34	42	49	71	72	77	73
15	65	45	37	36	34	34	42	50	69	70	78	72
16	63	44	37	37	34	34	48	53	68	72	78	71
17	60	44	37	36	34	------	50	52	67	73	77	71
18	61	43	37	35	35	34	49	55	67	72	76	71
19	60	43	38	35	34	34	50	57	67	73	78	70
20	61	43	40	35	34	35	50	60	66	74	77	70
21	56	43	40	35	34	35	52	62	65	74	77	71
22	55	41	37	34	35	35	53	62	66	74	75	70
23	54	40	35	36	34	34	58	63	67	75	76	70
24	65	40	35	34	34	34	55	63	68	76	75	70
25	63	40	35	33	34	34	56	63	69	------	75	70
26	56	39	35	33	33	34	59	62	69	76	76	69
27	52	39	37	34	35	35	59	63	70	79	------	69
28	50	40	34	35	35	35	59	63	71	76	78	69
29	47	37	35	35	34	36	58	63	71	76	77	69
30	47	38	36	36	------	37	64	63	------	79	78	69
31	51	------	37	35	------	38	------	------	------	78	78	------
Average	61	------	37	35	34	34	48	58	67	74	77	73

TABLE 13.—*Temperature of water, in degrees Fahrenheit, Allegheny River at Kittanning, Pa., water year October 1960 to September 1961*

[Once-daily measurement between 6 a.m. and 10 a.m.]

Day	1960			1961								
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	65	54	45	35	34	39	45	51	58	70	77	62
2	65	54	44	35	33	38	35	52	60	71	77	77
3	65	53	43	36	33	39	42	50	60	64	76	76
4	65	52	41	35	33	40	43	50	62	72	76	79
5	64	55	43	35	33	40	43	49	------	72	76	77
6	65	52	43	36	35	39	42	50	65	71	75	77
7	65	49	43	36	34	40	42	51	67	72	58	78
8	61	48	43	37	35	41	42	52	67	74	73	79
9	64	48	42	36	35	43	42	52	68	74	73	78
10	53	48	40	36	35	42	42	53	68	73	74	77
11	63	47	41	36	36	42	42	54	70	72	75	58
12	63	48	38	36	36	41	42	55	70	72	75	77
13	63	48	37	35	36	41	41	56	71	73	77	------
14	63	47	36	36	36	42	41	60	70	73	75	77
15	64	48	36	37	------	42	42	62	70	74	75	76
16	64	48	36	35	37	32	42	63	69	75	76	74
17	63	48	36	35	37	42	44	63	70	74	76	73
18	63	48	36	36	37	42	43	63	65	74	75	72
19	62	50	35	36	39	41	44	63	67	75	78	72
20	61	49	36	35	37	39	44	62	66	75	78	73
21	59	48	35	36	37	40	44	60	67	75	76	72
22	58	47	35	36	36	41	45	56	67	75	75	72
23	57	47	35	------	37	41	46	55	60	78	75	74
24	57	46	34	34	37	40	48	54	67	77	76	74
25	54	43	34	34	38	42	50	55	67	77	76	73
26	53	44	35	33	38	45	51	58	66	76	77	73
27	53	46	35	33	38	42	52	55	67	77	------	70
28	53	48	35	35	39	45	51	55	66	64	76	70
29	53	47	35	34	------	44	51	57	68	76	76	69
30	54	45	38	33	------	44	50	56	68	76	76	69
31	54	------	36	34	------	44	------	57	------	77	77	------
Average	60	48	38	35	35	41	44	56	66	73	75	73

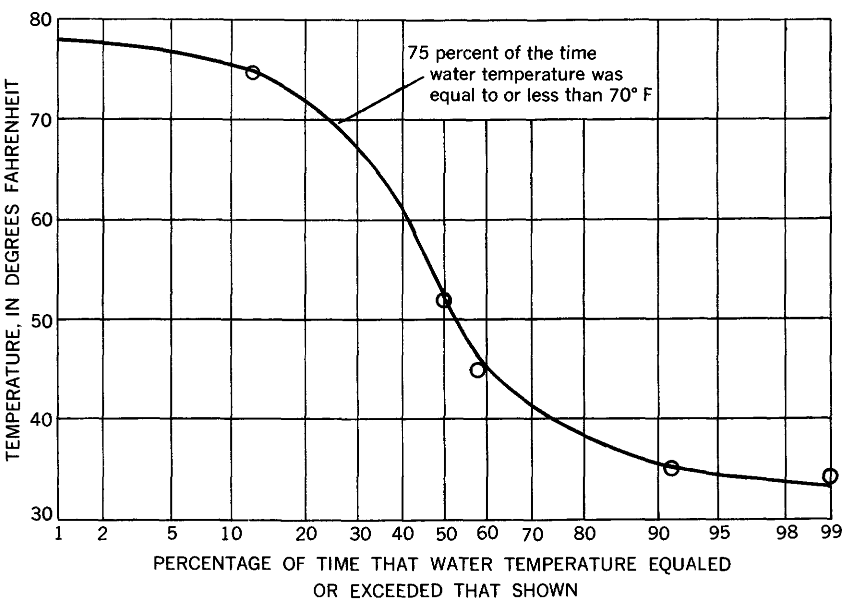

FIGURE 14.—Cumulative frequency curve of water temperature, Allegheny River at Kittanning, Pa., 1961–62.

CROOKED CREEK

Crooked Creek, a tributary to the Allegheny River at Rosston, is 58 miles long and drains 290 square miles of parts of Indiana and Armstrong Counties. Underlying the drainage basin are shale, sandstone, and limestone formations that contain deposits of bituminous coal and gas. At Crooked Creek Dam, Pa., the average discharge of the creek for 54 years (1909–63) was 424 cfs, or 275 mgd (adjusted for storage since May 1940).

Crooked Creek Reservoir, completed in 1940, is 7 miles upsteam from the creek's mouth in Armstrong County. It is operated and maintained by the Corps of Engineers as a unit in the coordinated reservoir network for controlling floods in the Allegheny River basin. The reservoir controls a drainage area of 277 square miles in which bituminous coal mines operate. Strip mining in the creek's headwaters has created spoil banks from which acidic wastes are leached and transported by runoff into Crooked Creek. For the period 1953–59, the pH of reservoir water ranged from 3.50 to 6.5; the median of semimonthly samples analyzed by the Corps of Engineers was 4.9.

Despite acidic properties of the water, the Pennsylvania Fish Commission reports that smallmouth bass, sunfish, bullhead and sucker can be taken from the reservoir.

Upstream from the reservoir at Idaho, Pa., Crooked Creek is acidic. At this location the water is a mixed type with calcium, sodium, and sulfate ions predominating. The water also contains high concentrations of aluminum, iron, and manganese.

During low flow, sulfate concentration is more than 60 percent of the total weight of dissolved solids. During a high flow (2,080 cfs, Apr. 5, 1945), the concentration of sulfate was 37 ppm (parts per million), or 51.5 percent by weight of the dissolved solids. Specific conductance at this time was 106 micromhos and the pH, 5.8.

A sample from Crooked Creek below the dam taken when flow was about half the average for the period of record (241 cfs, May 3, 1960), showed sulfate concentration to be about 59 percent by weight of the dissolved solids. The concentration of aluminum (1.0 ppm) and manganese (0.94 ppm) exceeded the concentration of these ions normally present in natural water.

KISKIMINETAS RIVER

The Kiskiminetas River, the largest tributary to the Allegheny River, has its mouth in Armstrong County near Freeport. In the headwaters above Saltsburg, where Loyalhanna Creek merges with the river, the main stem is known as the Conemaugh River. The two parts of the main river total 78 miles in length, and they drain an area of 1,892 square miles, including parts of Cambria, Somerset, Indiana, Westmoreland, and Armstrong Counties. The Kiskiminetas drainage basin is underlain by shale and sandstone formations containing some limestone and rich deposits of bituminous coal and gas.

About 7.5 miles above Saltsburg the Conemaugh River Reservoir, completed in 1953, controls a drainage area of 1,351 square miles and provides 270,000 acre-feet of usable storage for flood control (U.S. Army Corps of Engineers, 1965). One of the streams feeding into the reservoir is Blacklick Creek, a strongly acidic stream carrying coal-mine waste. The U.S. Army Corps of Engineers reported that during the period 1953–59 the pH of reservoir water ranged from 2.70 to 5.9, while that of Blacklick Creek ranged from 2.2 to 5.9.

At Vandergrift, about 12 river miles from the mouth of the Kiskiminetas, the drainage area is 1,825 square miles. The average discharge for 26 years (1936–63) was 3,020 cfs, or 1,952 mgd (adjusted for storage and diversion). From 1938 to 1960, mean daily discharge equaled or exceeded 3,000 cfs about 32 percent of the time (fig. 15).

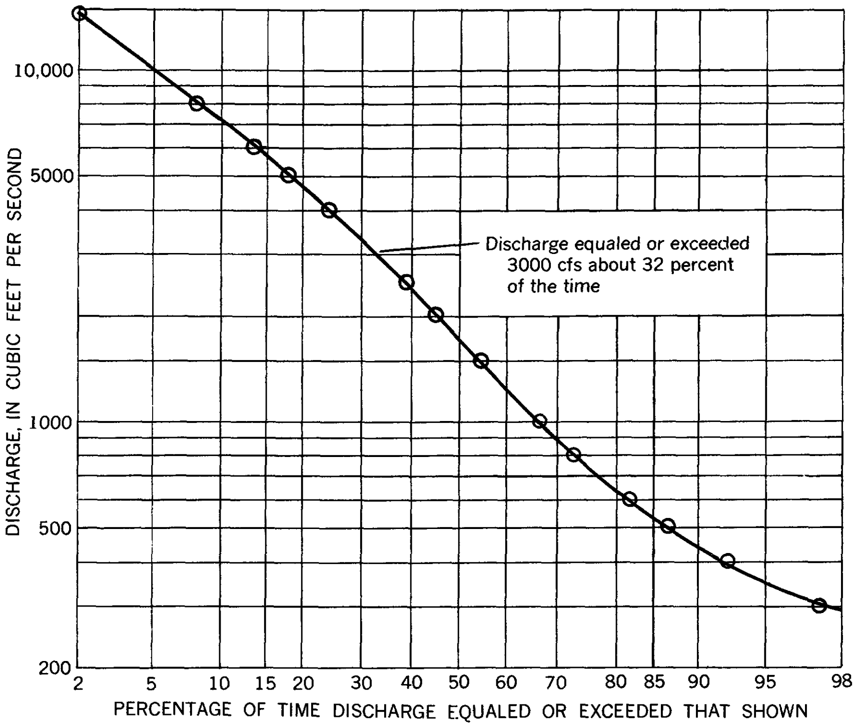

FIGURE 15.—Cumulative frequency curve of discharge, Kiskiminetas River at Vandergrift, Pa., 1938–60.

The maximum discharge of 71,900 cfs occurred on March 31, 1940; the minimum of 56 cfs occurred on October 15, 16, 1952 (U.S. Geological Survey, 1963).

The Kiskiminetas River increases flow in the Allegheny by about one-sixth during average flow conditions in both rivers.

At Leechburg, approximately 6.7 miles downstream from Vandergrift, the Kiskiminetas River is a calcium sulfate type water that is transporting the wastes from widely spread coal-mine operations. Consequently, the river is acidic all the time and is heavily concentrated with dissolved solids. The concentration of dissolved solids is always greatest during low flow. During the 1962 water year, dissolved-solids concentration of composited samples ranged from 198 to 970 ppm. These extremes occurred during periods of high and low flow, respectively. During high flow the sulfate content was 68 percent of the dissolved solids, and during low flow it was 63.5 percent by weight.

Chemical analyses and extremes of dissolved-solids concentration, hardness, specific conductance, and temperature for the period of record are presented in table 14. Daily water-temperature records for 1961–62 are shown in table 15. Daily specific conductance ranged from 220 to 1,840 micromhos, equaling or exceeding 770 micromhos for 50 percent of the time (fig. 16).

During the 1961 water year, the Kiskiminetas River discharged an average of 299 tons of sulfuric acid daily for 239 days into the Allegheny River (table 16). Like other Pennsylvania streams that drain coal-mine regions, the Kiskiminetas also transports high concentrations of aluminum, iron, and manganese.

In Pennsylvania, radioactive wastes have been classified as industrial wastes. At Apollo, near Vandergrift, the Pennsylvania Department of Health analyzed the Kiskiminetas River for radioactivity. The gross counts of alpha and beta-gamma activity present are shown in table 17. Counts from several other streams in Pennsylvania are also given.

Some streams may have a natural background of radioactivity, but in very low levels of concentration (0.1 to 10 micromicrocuries per liter). For example, radioactivity in streams may stem from ground water which enters the stream through the streambed after the water has been exposed for long periods to rock containing radioactive carbon, potassium, plutonium, radium, thorium, or uranium. Nevertheless, the principal source of radioactivity in the Kiskiminetas River was probably fallout. Usually, increases in stream radioactivity has corresponded to periods of testing atomic weapons. Radioactivity from this source varies considerably with stream location and time.

TABLE 14.—*Chemical analyses and recorded extremes, Kiskiminetas River at Leechburg (Vandergrift), Pa., water year October 1961 to September 1962*

[Results in parts per million, except as indicated]

Location.—At raw water intake at west Leechburg plant of Allegheny-Ludlum Steel Corp., 0.2 mile below Brady Run, Armstrong County, and 6.7 miles downstream from gaging station at Vandergrift.

Drainage area.—1,860 sq. mi.

Records available.—Chemical analyses: Oct. 1946 to Sept. 1951, Oct. 1958 to July 1959, Oct. 1959 to Sept. 1962. Water temperatures: Oct. 1946 to Sept. 1951, Oct. 1958 to July 1959, Nov. 1959 to Sept. 1962.

Extremes, 1961–62.—Specific conductance: Max daily, 1,840 micromhos, Sept. 3; min daily, 222 micromhos, Mar. 26. Water temperatures: Max, 81° F, June 30 to July 2, Aug. 5, 6; min, freezing point Jan. 11, 12.

Extremes, 1946–51, 1958–62.—Dissolved solids (1946–47, 1959–62): Max, 970 ppm, Nov. 1–6, 9–10, 1961; min, 141 ppm, Mar. 30 to Apr. 8, 1960. Hardness (1946–47, 1949–51, 1959–62): Max, 514 ppm, Oct. 1–10, 1946; min, 74 ppm, Mar. 30 to Apr. 8, 1960. Specific conductance: Max daily, 5,420 micromhos, Aug. 12, 1951; min daily, 175 micromhos, July 22, 1950. Water temperatures: Max, 90° F, July 25, 1950; min, freezing point on many days during winter months.

Remarks.—Records of specific conductance and pH of daily samples available in district office at Philadelphia, Pa. Records of discharge based on records for Kiskiminetas River at Vandergrift.

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (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	Total acidity as H_2SO_4	Specific conductance (micromhos at 25° C)	pH	Color
1961																					
Oct. 1–2, 4, 6–10	429	19	7.9	0.48	16	98	48	44	15	0	651	19	0.5	1.0	914	442	442	132	1,430	3.05	2
Nov. 1–6, 9–10	407	18	8.8	1.3	12	114	48	51	14	0	659	24	.5	1.3	970	482	482	113	1,490	3.15	3
Dec. 1–6, 8–10	946	14	3.2	.14	6.4	51	20	21	7.5	0	281	12	.3	1.4	425	209	209	49	710	3.50	4
1962																					
Jan. 1–9	2,350	13	3.7	.12	2.7	42	14	15	4.0	0	220	11	.1	1.1	335	163	163	44	572	3.65	1
Feb. 1–4, 6–10 [1]	3,000	11	4.0	.07	2.3	17	......	11	3.0	0	170	7.7	.2	3.5	264	129	129	49	466	3.60	3
Mar. 1–10	9,510	9.2	2.8	.06	1.7	27	8.8	7.2	2.2	0	132	6.7	.2	3.5	208	104	104	39	380	3.65	3
Apr. 4–10	8,280	11	1.8	.02	1.3	25	10	7.5	2.2	0	126	2.0	.3	1.1	198	104	104	15	326	3.90	3
May 1–2, 5–10	2,350	14	2.0	.17	3.2	43	22	14	3.8	0	256	8.5	.4	.2	390	198	198	59	628	3.45	3
June 1–7, 9–10	891	18	7.3	.27	6.9	73	22	27	7.5	0	399	14	.3	.4	602	273	273	78	935	3.40	3
July 1–9	623	19	7.4	1.1	11	84	32	31	11	0	483	15	.3	.4	714	341	341	88	1,100	3.35	3
Aug. 1–10	395	16	8.6	.75	13	92	42	42	18	0	567	20	.3	.6	807	402	402	108	1,320	3.50	3
Sept. 1–10	1,100	15	8.3	1.6	9.4	64	35	34	13	0	454	18	.3	2.1	658	304	304	103	1,180	3.35	3

[1] Approximate average discharge for the period of record.

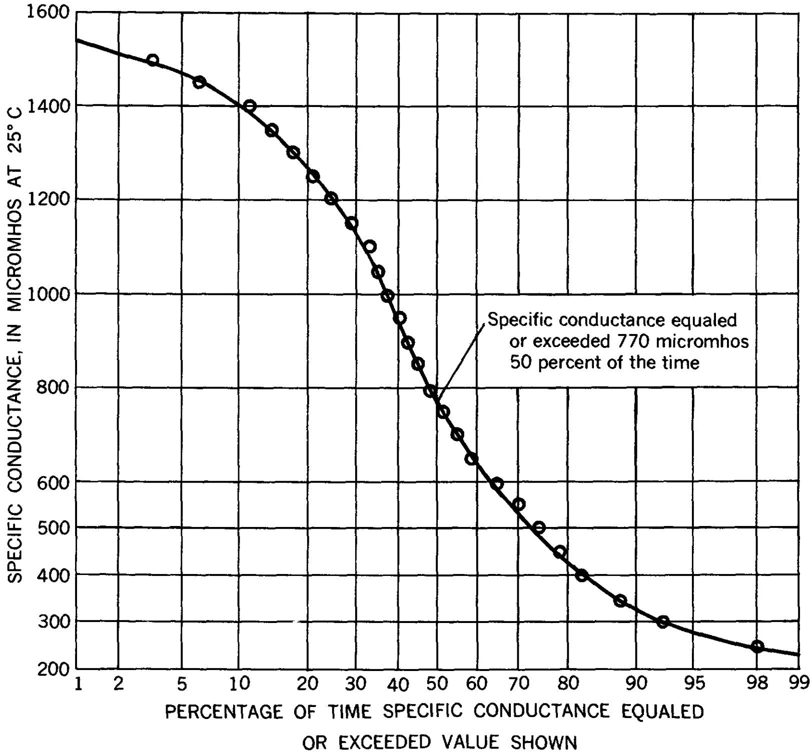

FIGURE 16.—Cumulative frequency curve of specific conductance, Kiskiminetas River at Leechburg, Pa., October 1961 to September 1962.

Some professional health workers suggest a maximum permissible concentration for different types of radioactivity in drinking water (Tsivoglou and Burke, 1962), but concentrations of 10^{-7} microcuries of fission products per milliliter of public water supplies is currently accepted as being medically significant. Radioactive materials in public water supplies, however, can be reduced as much as 75 percent by water treatment.

TABLE 15.—*Temperature of water, in degrees Fahrenheit, Kiskiminetas River at Leechburg, Pa., water year October 1961 to September 1962*

Day	1961			1962								
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	68	57	40	34	34	38	41	70	74	81	76	78
2	60	56	41	34	34	39	48	70	75	81	77	75
3	------	62	41	35	37	37	46	------	72	79	78	73
4	57	58	41	36	40	42	43	------	73	75	79	71
5	------	58	45	38	------	39	47	65	72	76	81	72
6	60	57	41	41	37	36	49	67	73	76	81	68
7	61	------	------	44	34	39	52	64	73	78	79	68
8	63	------	40	40	34	37	49	64	------	79	78	69
9	64	48	37	37	35	38	51	61	75	79	75	68
10	63	47	38	35	33	37	49	62	76	------	72	69
11	64	46	40	32	33	41	49	64	79	79	71	69
12	65	48	40	32	34	42	48	66	76	79	74	70
13	63	50	38	33	34	44	46	67	72	79	75	70
14	------	50	36	35	37	44	46	70	72	78	75	70
15	57	50	38	36	37	42	45	70	71	75	71	70
16	------	49	39	34	35	42	45	71	72	77	75	70
17	52	49	------	34	39	41	45	75	76	79	75	65
18	55	48	39	33	37	43	45	76	77	80	72	67
19	60	45	41	34	42	44	------	77	------	78	73	64
20	60	44	42	34	38	42	48	78	76	79	78	------
21	59	46	41	35	38	42	51	77	------	79	75	60
22	56	------	42	37	39	43	54	74	76	79	74	61
23	55	46	39	------	39	45	55	75	78	77	75	61
24	55	48	38	35	40	46	59	74	78	76	76	62
25	------	46	33	------	40	45	59	75	75	74	77	------
26	54	49	------	37	40	45	62	73	77	75	78	63
27	------	46	36	36	43	47	68	71	78	70	78	62
28	54	42	34	36	42	48	69	70	79	72	76	58
29	53	40	33	35	------	51	70	69	80	75	72	57
30	57	39	33	37	------	54	72	72	81	76	74	57
31	58	------	33	33	------	52	------	71	------	79	78	------
Average	59	49	39	36	37	43	52	70	75	77	76	67

TABLE 16.—*Sulfuric-acid discharge, Kiskiminetas River at Vandergrift, Pa., water year October 1960 to September 1961*

Collection period	Number of days	Mean discharge (cfs)	Sulfuric-acid discharge		
			ppm	Tons per day	Tons per period
1960					
Oct. 1-13	13	516.5	118	164	2,138
Oct. 15 to Nov. 6	23	585	113	178	4,103
Nov. 7-13, 15, 16	9	984.7	69	183	1,650
Nov. 18-20	3	705	49	93	280
Nov. 22, 23, 25-27, 29	6	597.1	78	126	754
Dec. 1-4, 7, 13, 16, 29	8	598.1	78	126	1,007
1961					
Jan. 10	1	2,100	15	85	85
Jan. 15-26, 28, 29, 31	15	1,580	39	166	2,494
Feb. 1, 3, 4, 7, 9, 11, 12, 14, 16	10	1,261	49	167	1,668
Feb. 17	1	3,200	29	250	250
Feb. 18, 19, 21-23, 25, 26, 28	8	12,748	20	688	5,506
Mar. 1-9, 11-13	12	19,130	20	1,033	12,396
Mar. 15-23, 25, 26, 28, 31 and Apr. 1, 2, 4-6, 8, 9, 11, 12	21	5,839	34	536	1,125
Apr. 13-20	8	9,358	20	5,053	4,042
Apr. 22, 23, 25, 26, 28, 30 and May 1, 2	8	10,801	24	700	5,599
May 3, 4, 6, 7, 9, 11-18, 20-24	18	4,077	44	484	8,717
July 6-22	17	9,629	108	2,808	4,774
July 23 to Aug. 1	10	1,541	78	324	3,240
Aug. 2-7	6	4,547	34	417	2,504
Aug. 9-14, 16-18	9	1,617	74	334	3,006
Aug. 19-23	5	661	98	219	1,094
Aug. 24-31, Sept. 1-4, 6-18	25	576.2	118	184	4,587
Sept. 27, 29, 30	3	422.3	142	162	485
Total	239				71,504

TABLE 17.—*Analyses of radioactivity in Pennsylvania streams, 1958–59*

[Measurements in micromicrocuries per liter. All samples collected by Division of Sanitary Engineering, and analyzed by Radiation Laboratory, Division of Occupational Health, Pennsylvania Department of Health]

Stream	Location	Date sampled	Gross alpha activity	Gross beta-gamma activity
Sewickley Creek	Waltz station (near Yukon)	4-30-59	0	160
		5-12-59	14	380
Kiskiminetas River	Apollo	7- 3-58	1.5	0.82
		8-29-58	0.008	0.095
		10-15-58	19	0
		2-13-59	7	132
		3-30-59	0	166
		5-11-59	0	0
Conemaugh River	Blairsville	9-22-59	9.1	11.3
		10- 9-59	8.35	0
		11-24-59	37.8	16.4
		12-30-59	24.6	69.6
		1-13-59	0.205	0
		2-13-59	12.3	0
		3- 6-59	8.46	0
		4- 7-59	12.8	75
Black Lick Creek	Bridge on Pennsylvania Route 680	12-30-58	0	93.3
		2-13-59	4.55	98
		3- 6-59	16.2	0
		4- 7-59	0	134

ALLEGHENY RIVER AT NATRONA

Natrona is about 25 river miles upstream from the mouth of the Allegheny River at Pittsburgh and 6 miles downstream from the mouth of the Kiskiminetas River. At Natrona the Allegheny drains approximately 11,410 square miles. The average discharge for 25 years (1938–63) was 18,980 cfs or 12,267 mgd (adjusted for storage since 1940). The maximum discharge of 365,000 cfs was measured on March 18 by the Corps of Engineers during the 1936 flood. The minimum of 922 cfs occurred on September 3, 1957.

For the period 1928–55, about 30 percent of the time the discharge of the river at Natrona was less than 5,000 cfs, which is equal to about one-fourth of the average flow. About 7 percent of the time discharge was less than 2,000 cfs. When the Allegheny Reservoir is in operation, many of the quality conditions that are characteristic of the river during low flow can be altered by dilution when releases are made from the reservoir (fig. 17).

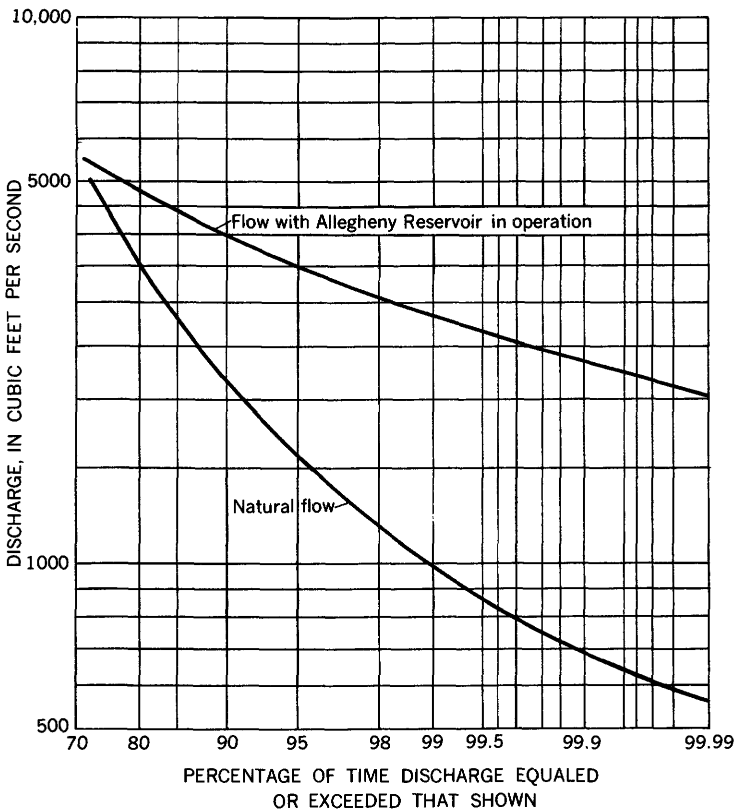

FIGURE 17.—Flow duration curves, Allegheny River at Natrona, Pa., 1928–55, with natural flow and with Allegheny Reservoir in operation (Courtesy of U.S. Army Corps of Engineers).

At Natrona the Allegheny is predominantly a calcium sulfate-bearing river that reflects the influence of the Kiskiminetas River. During World War II, when coal production in the Kiskiminetas drainage area was at its peak, calcium and sulfate concentration in the Allegheny River at Natrona during a low flow (1,890 cfs, Sept. 8, 1944), was 71.8 percent of the total dissolved solids by weight. During a high flow (37,000 cfs, Mar. 31, 1945), their concentration was 69 percent of the dissolved solids. More recently during a low flow at Natrona (2,420 cfs, Nov. 2, 1960), calcium and sulfate represented 69 percent of the dissolved solids by weight, and during a relatively high flow (32,300 cfs, May 14, 1958) they represented 62 percent of the dissolved solids. Nearly two decades separate the time these sample were analyzed, and the percent concentration of calcium and sulfate in the more recent samples suggests that this part of the river is still significantly influenced by the Kiskiminetas River.

This segment of the Allegheny also shows, at times, a significant penetration of chlorides from the river's headwaters. The range of chloride concentration on the samples taken intermittently since 1944 was 5.8 to 47 ppm or from 4 to 10 percent of the dissolved solids, the proportion increasing with decreasing flow.

Although the Allegheny River at Natrona may be acidic (pH 4.20) and contain as much as 430 ppm dissolved solids during low flow, the Pennsylvania Fish Commission reports that the more hardy species of fish survive in the river from Pittsburgh to Freeport—trout and pike excepted.

ALLEGHENY RIVER AT SHARPSBURG AND NADINE

The greatest growth of population and expansion of industry in the Allegheny River basin has been in and around Pittsburgh. Consequently, water from the lower Allegheny has been in greater demand with each successive year.

The Pittsburgh Water Company in the borough of Aspinwall, uses raw water from the Allegheny River. After automatic filtration and treatment the water is distributed from this plant, one of the most modern water-treatment plants in the United States. At Nadine, across from Aspinwall, the privately owned Wilkinsburg-Penn Joint Water Authority also maintains intakes for raw water withdrawals from the Allegheny.

At Sharpsburg, a neighboring community of Aspinwall and Nadine, the U.S. Geological Survey in cooperation with the Pennsylvania Department of Forests and Waters began a systematic water quality study in October 1947. A program for collecting monthly samples from five points across the river continued through 1952. At Sharpsburg the discharge is practically the same as that reported at Pittsburgh, where the average flow is 19,800 cfs, or 12,897 mgd.

The lower part of the Allegheny River (Freeport to Pittsburgh) contains a calcium sulfate water. At Sharpsburg during the 1952 water year the pH ranged from 3.70 to 5.9 (table 18). During low flow in October and November 1951, the river was acidic and the dissolved-solids content was at its highest level; at all times sulfate was the predominant ion. Generally, the river was slightly more acidic and the sulfate content greater on the side left of center. This condition was probably caused by the acidic and high sulfate-bearing Kiskiminetas River which enters the Allegheny upstream from the southeast, or left, bank.

TABLE 18.—*Chemical analyses and descriptive information, Allegheny River at Sharpsburg, Pa., water year October 1951 to September 1952*

[Results in parts per million, except as indicated]

Location.—At Sharpsburg bridge, Allegheny County, 18.8 miles below gaging station at Natrona.
Records available.—Chemical analyses: Monthly cross-section samples Oct. 1947 to Sept. 1952.
Remarks.—Station 100 is approximately 100 ft from north (right) bank and station 800 is approximately 90 ft from south (left) bank.

Date	Station	Time	Temperature (°F)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Hardness as $CaCO_3$	Specific conductance (micromhos at 25°C)	pH	Color
1951		*p.m.*									
Oct. 12	800	12:50	65	--------	246	53	2.3	222	728	3.70	4
	600	12:45	65	--------	217	54	5.1	226	736	3.90	4
	410	12:40	65	--------	244	54	2.5	218	732	3.95	4
	250	12:35	65	--------	243	54	3.1	224	735	4.00	4
	100	12:30	65	--------	243	54	2.5	222	733	4.10	4
Nov. 13	800	4:25	50	4	232	60	2.5	222	708	4.6	4
	600	4:30	50	4	229	60	2.9	220	705	4.8	5
	410	4:35	50	6	228	60	2.9	218	702	5.4	4
	250	4:40	50	6	231	60	2.8	220	705	4.9	4
	100	4:40	50	6	230	60	2.8	216	699	4.9	5
		a.m.									
Dec. 6	800	8:30	38	12	60	17	2.1	72	230	5.4	6
	600	8:35	37	12	58	17	1.8	70	221	5.3	4
	410	8:40	37	14	57	16	1.6	70	217	5.6	5
	250	8:45	38	10	55	16	1.8	70	217	5.4	4
	100	8:50	38	12	57	16	1.7	72	218	5.0	6
1952											
Jan. 18	800	11:05	38	14	46	13	2.0	60	182	5.8	5
	600	11:00	38	14	44	12	1.5	56	175	5.8	5
	410	10:55	38	14	40	11	1.7	52	165	5.6	4
	250	10:50	38	14	37	11	1.5	54	163	5.6	5
	100	10:45	38	18	37	12	1.6	56	171	5.9	6
Feb. 14	800	11:35	35	4	65	11	2.0	66	196	4.5	6
	600	11:40	35	6	62	11	1.9	66	196	4.7	5
	410	11:45	35	6	59	10	1.6	64	186	4.9	5
	250	11:50	36	6	56	10	1.3	64	183	5.3	5
	100	11:55	36	8	52	10	1.5	62	177	6.4	6

TABLE 18.—*Chemical analyses and descriptive information, Allegheny River at Sharpsburg, Pa., water year October 1951 to September 1952*—Continued

[Results in parts per million, except as indicated]

Date	Station	Time	Temperature (°F)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Hardness as $CaCO_3$	Specific conductance (micromhos at 25°C)	pH	Color
1951		*p.m.*									
Mar. 18	800	10:25	41	4	45	8	2.8	50	154	4.8	4
	600	10:30	40	4	46	7	2.0	50	149	5.2	3
	410	10:35	40	6	41	8	2.0	48	143	5.2	2
	250	10:40	39	8	35	8	1.8	46	137	5.3	4
	100	10:45	40	8	35	8	1.3	44	135	5.2	5
Apr. 10	800	9:10	45	6	50	10	1.3	62	184	5.1	4
	600	9:00	45	6	60	10	.9	62	181	5.1	4
	410	8:55	45	8	49	12	.9	60	174	5.7	3
	250	8:50	45	16	40	11	.8	58	177	5.6	3
	100	8:45	46	14	41	12	.6	56	173	5.5	5
		p.m.									
May 12	800	4:15	57	4	86	16	1.2	94	274	5.0	5
	600	4:20	56	4	94	14	.9	94	277	4.8	5
	410	4:30	58	4	94	14	.2	94	274	4.9	4
	250	4:35	50	6	93	14	.4	92	274	5.1	6
	100	4:40	58	6	89	14	1.4	92	277	5.1	6
June 9	800	2:00	74	4	79	13	1.8	84	258	4.0	6
	600	2:05	73	6	84	14	1.7	84	260	5.5	3
	410	2:10	73	6	80	13	.6	82	252	5.1	5
	250	2:15	73	6	81	13	.6	82	250	5.0	5
	100	2:20	74	6	80	13	.6	82	256	5.1	5
		a.m.									
July 11	800	8:05	78	4	163	25	.4	148	468	4.7	4
	600	8:10	79	4	159	26	.4	148	468	5.0	5
	410	8:10	79	4	157	26	.6	148	466	4.8	5
	250	8:15	79	4	100	25	.5	144	464	4.8	4
	100	8:15	79	4	161	26	.5	150	465	5.1	3
Aug. 11	800	6:45	68	-----	-----	-----	-----	-----	645	-----	-----
	600	6:40	68	-----	-----	-----	-----	-----	658	-----	-----
	410	6:35	67	-----	-----	-----	-----	-----	640	-----	-----
	250	6:30	68	-----	-----	-----	-----	-----	633	-----	-----
	100	6:25	68	-----	-----	-----	-----	-----	641	-----	-----
		p.m.									
Sept. 17	800	12:25	77	-----	-----	-----	-----	-----	726	-----	-----
	600	12:30	77	-----	-----	-----	-----	-----	698	-----	-----
	410	12:35	76	-----	-----	-----	-----	-----	716	-----	-----
	250	12:40	76	-----	-----	-----	-----	-----	695	-----	-----
	100	12:45	76	-----	-----	-----	-----	-----	706	-----	-----

The range of dissolved-solids concentration in the river at Nadine for 10 years (1951–61) was 96 to 384 ppm (Wilkinsburg-Penn Joint Water Authority). Ten percent of the time it equaled or exceeded 310 ppm (fig. 18). The higher concentration occurred when discharge was below average. From October through December 1960, when the mean discharge was about 2,260 cfs (one-eighth of the average discharge, determined from Natrona measurements), the calcium and sulfate concentrations represented more than 72 percent of the dissolved solids. During October, November, and December the chlorides were 10.1, 14.4, and 15.2 percent of the total-dissolved solids, respectively. During March 1961 at Natrona when the mean discharge was

49,640 cfs (2.5 times greater than the average), calcium and sulfate at Nadine composed 74 percent of dissolved solids, and chlorides represented 10.6 percent.

Organic pollution from upstream communities has gradually abated in this part of the river through action taken under the Pennsylvania Pure Stream Act. Nitrates, the final oxidation product of organic nitrogen found in water polluted by sewage and nitrogen-bearing fertilizers washed from soil, infrequently exceeded 0.5 ppm during the period 1951–61. Also, during this time, the river contained adequate dissolved oxygen to provide aerobic treatment of the water (table 19).

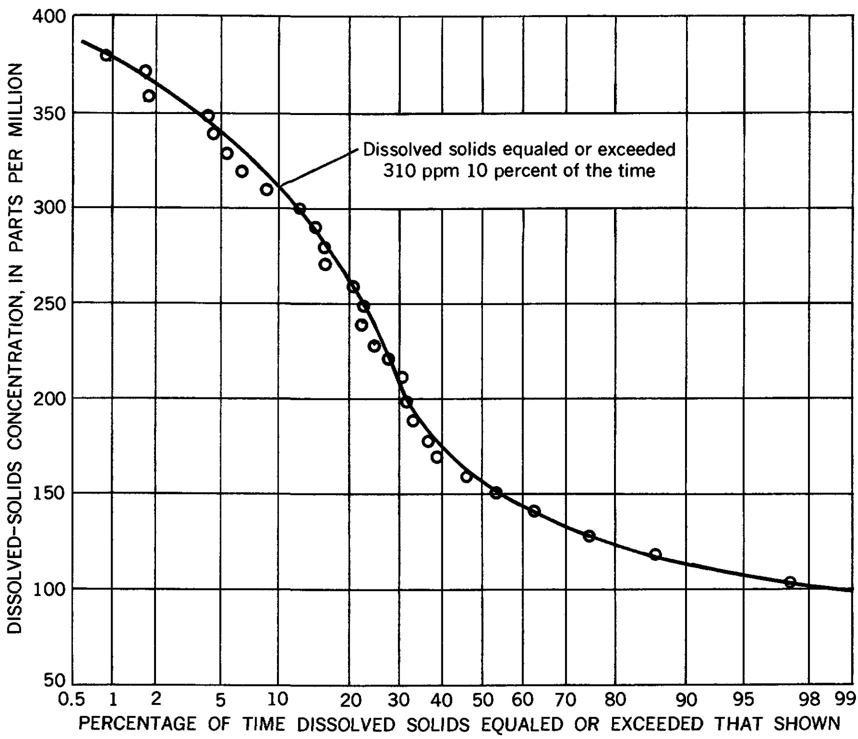

FIGURE 18.—Cumulative frequency curve of dissolved solids, Allegheny River at Nadine, Pa., 1951–61.

TABLE 19.—*Monthly average concentration of nitrate (NO_3) and dissolved oxygen (DO), Allegheny River at Nadine, Pa., water years 1952–61*

[Results in parts per million. Data furnished by the Wilkinsburg-Penn Joint Water Authority]

Month	1952		1953		1954		1955		1956		1957		1958		1959		1960		1961	
	NO_3	*DO*	NO_3	*DO*	NO_3	*DO*	NO_3	*DO*	NO_3	*DO*	NO_3	*DO*	NO_3	*DO*	NO_3	*DO*	NO_3	*DO*	NO_3	*DO*
Oct	0.15	8.8	0.25	7.4	0.30	7.1	0.25	7.4	0.15	5.6	0.15	4.5	0.35	7.9	------	6.7	0.08	7.0	0.15	5.8
Nov	.30	12.4	.30	9.0	.10	8.7	.15	6.9	.20	5.2	.22	8.2	.35	7.8	0.15	5.4	.15	8.4	.20	7.2
Dec	.38	13.2	.20	11.5	.35	12.2	.15	7.0	.22	8.1	.20	8.3	.30	8.5	.30	5.1	.15	9.4	.18	8.8
Jan	.25	10.2	.30	13.3	.70	12.0	.25	13.1	.30	8.7	.25	8.3	.80	5.4	.15	8.0	.30	7.6	.25	8.3
Feb	.25	12.8	1.10	12.6	.40	8.8	.35	12.4	.28	7.7	.15	7.9	.06	8.1	.18	4.0	.50	8.5	.30	7.4
Mar	.18	10.2	.40	10.4	.45	8.8	.30	11.9	.50	7.7	.18	7.1	.30	6.8	.15	7.3	.35	6.9	.25	7.8
Apr	.20	8.0	.18	7.9	.30	7.0	.30	10.8	.15	9.6	.15	5.7	.15	6.4	.12	6.2	.15	6.2	.20	7.3
May	.10	7.1	.30	7.2	.25	6.4	.20	7.6	.20	5.5	.15	5.0	.15	5.3	.12	5.2	.30	5.3	.20	6.2
June	.09	6.6	.17	6.7	.18	6.2	.25	7.5	.20	4.5	.18	4.9	.12	5.1	.15	4.8	.13	4.3	.15	6.6
July	.07	7.4	.30	6.2	.20	5.1	.30	4.1	.25	4.8	.14	4.2	.20	5.2	.15	4.4	.15	5.0	.13	6.5
Aug	.18	6.3	.30	6.9	.18	5.4	.30	6.2	------	------	.35	4.2	.15	4.8	.15	4.7	.25	4.0	.16	6.6
Sept	.15	7.1	.30	7.1	.50	5.8	.25	6.6	.15	5.8	.18	5.0	.12	5.8	.15	5.6	.25	5.7	.30	7.4

Concentration of dissolved solids in the lower Allegheny is relatively higher than in most of the river above Freeport to Kinzua. Iron and manganese, common products of coal mine waste, are noticeable in the lower part of the river, especially during low flow, and are reported by most water treatment engineers to be the chemical impurities with which they are principally concerned.

The severity of damage done to the quality of the Allegheny River by drought and industrial discharges can be lessened at times by water released from reservoirs. For example, the Allegheny Reservoir now provides storage water from which at least 2,320 cfs, or 1,500 mgd, will be released during periods of low flow, a time when the quality of the river can be improved by dilution. Also, should such releases be made to the river from the cool hypolimnium region of stored water, the U.S. Corps of Engineers anticipates that river-water temperatures would be modified for about 25 miles downstream.

SUMMARY

Geology, precipitation and runoff, land and water uses are the foremost factors that cause water quality in the Allegheny River to vary significantly from place to place. Because of the magnitude of the area drained by the river in Pennsylvania and because of local storms, many of its branching tributaries contribute water disproportionately at times. Streams swollen by local storms may strongly dominate the quality of the river for greater than normal distances. Tributaries identified with different environments influence river quality by contributing additional solutes, cause changes by chemical reaction, or dilute the concentration of solutes in the river.

The main river in Potter, McKean, and Warren Counties, upstream from Warren, Pa., contains high concentrations of chloride, as does the water in Potato, Cole, South Branch Cole, Honeoye, Oswayo, East and West Branches Tunungwant, Kendall, Foster, and Kinzua Creeks. Chlorides in Kinzua Creek have exceeded 2,900 ppm, and in Tunungwant Creek they have exceeded 1,200 ppm. Concentrations of a magnitude of 1,000 to 1,500 ppm generally render water unpalatable and objectionable for many industrial uses and irrigation.

Tributaries that most strongly modify the quality of the Allegheny River immediately below Warren are Conewango and Brokenstraw Creeks. These streams discharge water to the river at a combined average rate of about 2,000 cfs. The average discharge of the river near Warren is 3,750 cfs. Conewango and Brokenstraw Creeks are of good quality for most uses after moderate treatment, and are unaffected by oil-well operations that so often are responsible for the high dissolved solids and chlorides in many of the streams that enter the river above Warren.

The beneficial influence of Conewango and Brokenstraw Creeks on the quality of the Allegheny River is noticeable at West Hickory, about 28 river miles below Warren where the river is more dilute. However, the ratio of bicarbonate to dissolved solids in the Allegheny has been increased because of these streams. The average discharge of the Allegheny at West Hickory is 6,430 cfs.

Between West Hickory and Franklin, about 24 river miles, the Allegheny receives the flow of three important tributaries: (1) the Tionesta, with an average discharge at Tionesta Creek Dam, Pa., of 885 cfs, (2) Oil Creek, with an average discharge at Rouseville of 524 cfs, and (3) French Creek with an average flow at Utica of 1,733 cfs. In these streams the calcium and bicarbonate ions dominate other ions in solution, but dissolved solids are relatively low. These tributaries improve the quality of the Allegheny River by dilution where tributary and river waters mix.

Downstream from Franklin for approximately 40 river miles, there is no significant change in the chemical character of the Allegheny River until it receives the waters of the Clarion River (average discharge near Piney, 1,756 cfs), Redbank Creek (851 cfs at St. Charles), and Mahoning Creek (588 cfs at Mahoning Creek Dam). Below the confluence of Mahoning Creek, the average discharge of the Allegheny River is about 15,000 cfs. These tributaries have calcium sulfate type waters that enter the Allegheny from the east after draining an area rich with deposits of coal, oil, and gas. Occasionally, when flow in these streams is low, the inadequate supply of water does not neutralize or dilute the acidic discharges of coal-mine wastes, and therefore sulfuric acid, iron, and manganese are introduced into the river. Normally, the acidic pollution carried by these streams does not greatly affect the quality of the Allegheny River because the processes of neutralization and dilution that starts in the receiving stream is completed in the river at the entry point of the tributary. Also, from June through October, when flow in streams is normally low and solutes in water more concentrated, releases of water are made from the East Branch Clarion River reservoir. Part of the time therefore when water is released from the reservoir, it may act as a diluent to both the Clarion and Allegheny Rivers. Construction of the multiple-purpose reservoir was completed in 1952.

The influence of the Clarion River and Redbank and Mahoning Creeks on the Allegheny River is noticeable downstream as far as Kittanning where the river is commonly a calcium sulfate type. At Kittanning, where the average flow of the river is 10,011 mgd, the quality of water is good for domestic and most industrial uses following moderate treatment, and it will support aquatic life. This part of the river is also suitable for swimming and boating. At Kittanning when river flow is low, chloride is the principal ion; at average or high flow, sulfate and bicarbonate predominate. Dissolved solids are normally more concentrated during the summer and early autumn. The maximum dissolved-solids content for the period of record at Kittanning was 304 ppm; the minimum was 63 ppm.

About 5 miles downstream from Kittanning the river is at confluence with Crooked Creek (average discharge at Crooked Creek Dam, Pa., 428 cfs), and approximately 10 miles further downstream it is at confluence with the Kiskiminetas River (average discharge at Vandergrift, 3,020 cfs). At Natrona, 6 miles downstream from the mouth of the Kiskiminetas, the average discharge of the Allegheny is 18,980 cfs.

Both Crooked Creek and the Kiskiminetas also transport acidic wastes from coal-mining regions, but of the two streams the effects of the Kiskiminetas on the quality of the Allegheny is usually greater because it drains wastes from a larger coal-mining area. Dissolved-solids concentration in the Kiskiminetas River at Leechburg during the 1962 water year ranged from 198 to 970 ppm. Most of the time the Kiskiminetas discharges sulfuric acid into the Allegheny River along with other coal-mine wastes such as aluminum, iron, and manganese. The acid causes water to be corrosive, and the metals contribute to water hardness. The hardness of raw water taken from the Allegheny and the Monongahela Rivers for treatment before distribution as a public supply to Pittsburgh ranged from 121 to 180 ppm (Durfor, 1964).

Water withdrawn from the lower Allegheny below Freeport for domestic and industrial purposes requires more treatment before distribution than would be required to treat the more suitable river water available above the mouth of the Kiskiminetas. Iron and manganese, and the acid salts of other metals in lower reaches of the river impart characteristics to water that most treatment-plant engineers find objectionable.

At Aspinwall the Pittsburgh Water Company has been treating raw river water with potassium permanganate to remove iron and manganese. In addition, the raw water receives prechlorination and postchlorination treatments. Lime is used to adjust pH, alum is used for coagulation, bentonite clay and polyelectrolytes are used as coagulant aids, and soda ash for alkalinity. Activated carbon is used for taste and odor control, sulfuric acid to adjust pH downward when required, chlorine dioxide to correct medicinal taste, and hydrofluosilicic acid for fluoridation.

Nevertheless, throughout a large part of the Allegheny River drainage system there are many sources of good water available to western

Pennsylvanians for distribution to urbanized areas and their industries with only a moderate amount of treatment required. But effective policies of conservation such as can be accomplished by impounding runoff into additional reservoirs and protecting watercourses against preventable pollution would provide more useable water for additional needs and help to preserve present sources for use by future generations.

Because of their water resources, large areas in western Pennsylvania have a great potential for recreational development. Several streams that drain more than 400 square miles flow through many wildly natural and picturesque settings, where there is excellent fishing and hunting for sportsmen and vacationing tourists to enjoy.

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