Water-Supply and Irrigation Paper No. 108. Series L, Quality of Water, 7

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

QUALITY OF WATER

IN THE

SUSQUEHANNA RIVER DRAINAGE BASIN

BY

MARSHALL ORA LEIGHTON

WITH

AN INTRODUCTORY CHAPTER ON PHYSIOGRAPHIC FEATURES

BY

GEORGE BUELL HOLLISTER

WASHINGTON

GOVERNMENT PRINTING OFFICE

1904

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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
HYDROGRAPHIC BRANCH,
Washington, D. C., March 10, 1904.

SIR: I have the honor to transmit herewith a manuscript entitled "Quality of Water in Susquehanna River Drainage Basin," by Marshall Ora Leighton, and to request that it be published as one of the series of Water-Supply and Irrigation Papers.

In this paper is presented a brief introductory chapter on the physiographic features of the Susquehanna basin, by George B. Hollister, which is followed by a detailed discussion of the population and industries in New York. Numerous analytical reports are presented which show the character of the unpolluted waters in the main stream and its various tributaries, and the effects which have been produced by industrial and domestic pollution. Of special importance are the statements concerning the effect of mine wastes. It is shown that such wastes are not without their beneficial effects, especially in those parts of the river which have been set aside as areas for sewage disposal. The discussion of this matter, together with the consideration of the amount of mine wastes discharged into Susquehanna River, is one of the important features of the paper.

It is intended that this paper shall be followed soon by another (No. 109), entitled "Hydrography of Susquehanna River Drainage Basin," by John C. Hoyt and Robert H. Anderson. The two papers will make available a large amount of valuable information with reference to the resources of the Susquehanna River system.

Very respectfully,

F. H. NEWELL,
Chief Engineer.

Hon. CHARLES D. WALCOTT,
Director U. S. Geological Survey.

QUALITY OF WATER IN THE SUSQUEHANNA RIVER DRAINAGE BASIN.

By M. O. LEIGHTON.

PHYSIOGRAPHIC FEATURES OF SUSQUEHANNA BASIN.

By G. B. HOLLISTER.

The Susquehanna is the largest river of the Atlantic slope, its drainage area covering approximately 27,400 square miles. There are various speculations regarding the origin and development of the present river system, but the evidences on which they are based are too meager to permit the acceptance of the conclusions as final. Disregarding conjectures as to the conditions of drainage existing during Permian time in what is now eastern Pennsylvania, it is safe to assume that during and after the regional depression when the Triassic beds of the eastern portion of the continent were laid down there were a number of streams heading in what is now central Pennsylvania that found their way to the Atlantic coast. It is also probable that this depression gave new vigor to the eastward-flowing streams, which, becoming more active, gradually worked back and succeeded in capturing tributaries of adjacent systems less advantageously situated, so that by the end of this epoch the more important streams became firmly established, and continued in spite of the subsequent uplift. In taking this course, all of these streams were obliged to cross the truncated series of resistant sandstones then practically base-leveled, which have since remained as the Allegheny ridges. So firmly established, however, do the streams appear to have become that these adverse conditions were not sufficient in the main to change their direction and they have persisted in their eastward courses, cutting notches and gaps in the ridges even in spite of the regional uplift which followed the Triassic deposition.

One of these streams corresponded in part to the present Schuylkill and was comparatively large, owing to its capture of parts of a former north-flowing stream.[a] According to Davis another and possi-

[a] Davis, W. M., Rivers and valleys of Pennsylvania: Nat. Geog. Mag., vol. 1, p. 236.

bly a smaller stream was the parent of the Susquehanna. Its headwaters lay in the mountain region of the central portion of the State and it flowed across the Allegheny ridges to the southeast, approxi-

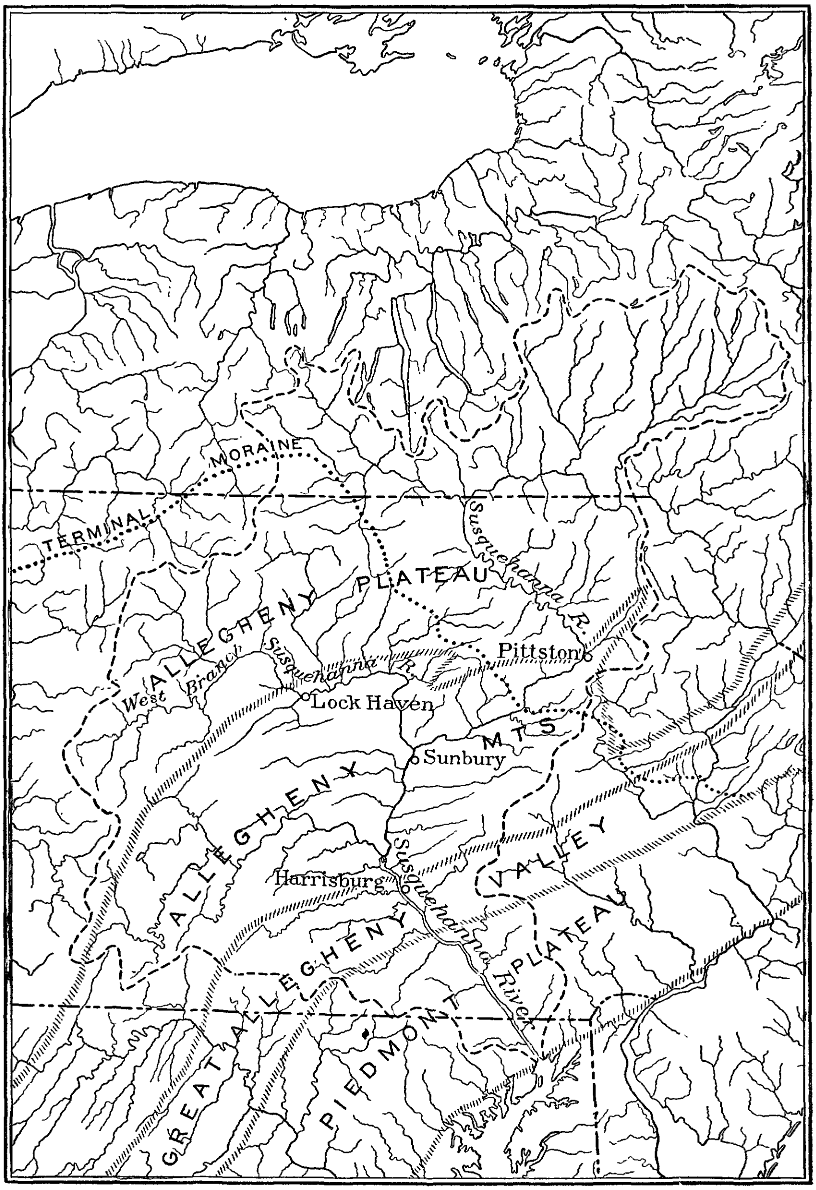


FIG. 1.—Map of drainage area of Susquehanna River.

mately in the position of the lower portion of the present Susquehanna. Various causes combined to render this stream more vigorous in its action than the one previously referred to, and in the course of time it succeeded in capturing many of the branches of the Schuylkill and even in tapping and capturing its entire upper waters. In this manner the Schuylkill was left with a mere remnant of its former volume. The Susquehanna was also strengthened by the capture of the Juniata and other streams on the west, and gradually assumed its prominence as the master stream of the region. This outline of its previous history must be considered merely as a suggestion rather than as demonstrated fact.

The watershed of the Susquehanna embraces portions of four great physiographic regions of the eastern part of the United States—the Allegheny Plateau, the Allegheny Mountains, the great Allegheny Valley, and the Piedmont Plateau. Its distribution among these provinces is approximately as follows:

Physiographic divisions of Susquehanna basin.

	Square miles.	Per cent.
Allegheny Plateau	15,400	56
Allegheny Mountains	8,500	31
Allegheny Valley	1,700	6
Piedmont Plateau	1,800	7

ALLEGHENY PLATEAU.

More than half the Susquehanna drainage area, approximately 56 per per cent, is included in the Allegheny Plateau in New York and Pennsylvania. This region, dissected by the stream and its branches into a succession of high hills and deep valleys, is the remnant of an extended plain. The plain is not confined to the Susquehanna watershed, but may be traced eastward into the Catskill region and southward to Alabama. Its eastward face is usually recognizable in a pronounced escarpment, while westward it merges gradually into the great plain of the Mississippi Valley.

Geologically this plain is composed of Paleozoic sandstones, shales, and limestones, which in New York lie nearly level, with a slight dip toward the south. In Pennsylvania the folds, which are so evident in the Appalachian Mountain region, gradually die out westward in the Allegheny Plateau. The physiographic evidence leads to the belief that the region has been base-leveled and, in common with the Allegheny Mountain region, reduced to a well-defined peneplain. The region was then elevated, and the streams, thus given new energy, have eroded the surface of the plain, which now presents the appearance of a very hilly country. However, from the summits of the hills between the lesser watersheds evidences of the former plain are seen in the remaining hilltops, which stand at approximately even heights as far as the eye can see. The hills, as a rule, rise from 500 to 800 feet above the valleys, with comparatively steep but beautifully symmetrical slopes.

A large proportion of that part of the Susquehanna drainage area within the Allegheny Plateau has been glaciated. The former presence of the ice sheet is recognized by the drift which covers the surface, particularly in the valleys, where immense accumulations are found. Well borings show the thickness of the valley deposits to be from 50 to over 1,000 feet. Owing to the action of ice and the subsequent outflow of water from the ice fields, combined with the distribution of the drift, many changes of drainage seem to have resulted, and not a few streams which previously flowed northward into the Great Lakes have apparently been diverted and now form part of the Susquehanna system.

The effect of the ice on the excavation of the north-south valleys has not yet been fully determined, but from the evidence offered in the Finger Lake region and elsewhere in central New York it may be fairly surmised that many of the valleys were more or less deepened in this manner.

The principal streams in the Susquehanna basin that drain the Allegheny Plateau are the Susquehanna River and the West Branch. Susquehanna River rises in Lake Otsego, Otsego County, N. Y. It flows generally southwestward through the southern tier of counties of New York and enters Pennsylvania in Bradford County near Sayre. Thence its course is generally southeastward to Pittston, where it leaves the plateau region. Its most important tributaries to this point are Chenango and Chemung rivers, both in New York.

West Branch rises in the highlands of Cambria County, Pa., and with its various tributaries drains a number of the central and north-central counties of that State. It leaves the Allegheny Plateau near Lock Haven, about 95 miles from its source. Its chief tributaries on the plateau are Moshannon, Sinnamahoning, Kettle, Pine, Lycoming, and Loyalsock creeks. In the region they traverse the strata are bent in broad, simple folds. The present aspect of the country is extremely rugged, though its plateau character here, as in New York State, is distinctly recognized from the tops of the hills. These rise to an elevation of 1,500 to 2,000 feet and more, and contain a large amount of forest lands.

The general topographic features of this portion of the plateau are distinct from those in the area drained by the Susquehanna in New York. There the slopes are usually gentle and symmetrical, the weathering process having been applied to strata lying approximately horizontal, while here the topography presents more rugged features and more uneven slopes. The rocks are tilted to a greater extent, and the more resistant layers, the sandstones and grits, outlast the more yielding shales and limestones and stand out as ridges. The steeper slope of a hill of this character is usually on the side which exposes the upturned faces of the strata, while the slope parallel to the dip of the strata is gentler and longer.

Lake Otsego, which may be considered the source of the Susquehanna, lies at an elevation of 1,193 feet above sea level. The altitude of the Susquehanna at its junction with the Chenango at Binghamton is 822 feet; at the junction of the Chemung at Athens it is 744 feet; and near Pittston, 232 miles from its source, where the river leaves the Allegheny Plateau and enters the Appalachian belt, it is 536 feet, giving a total fall of 657 feet, or an average fall on the Allegheny Plateau of 2.8 feet per mile.

ALLEGHENY MOUNTAIN REGION.

After leaving the Allegheny Plateau Susquehanna River enters the Alleghany Mountain region. Like the Allegheny Plateau, this physiographic region is not confined to the Susquehanna drainage basin, but extends as a well-defined feature from Alabama to Canada. The ridges generally run northeast and southwest, sweeping off at the north in broad curves to a more easterly direction.

Geologically this is a region of alternating hard and soft sedimentary beds, bent by enormous lateral compression into folds or waves technically known as "anticlines" and "synclines." These folds have a general northeast-southwest trend, and in some limited districts a slight pitch to the southwest. After the rocks had been folded the whole country was base-leveled by erosion; or, in other words, all the layers, hard and soft, were planed down to an approximately uniform surface. Then followed a general uplift of the region, which gave the streams renewed vigor and inaugurated another period of denudation, which has been continued to the present time. As a result of this last cycle of erosion the softer rocks have been gradually worn down and carried away and the more resistant layers stand out as ridges.

The effect of the southward pitch of the folds upon the topography is particularly interesting. Instead of being merely approximately parallel ridges, as would be the case if there were no longitudinal tilting of the layers, the general planation and subsequent denudation have left a peculiar series of canoe-shaped valleys. Where the synclinal folds are eroded the mountains surrounding the valleys gradually converge to form what would represent the prow. Where the anticlinal folds are truncated a series of hemi-cigar-shaped mountains results. This peculiar system of ridges surrounding blind valleys and inclosing narrow valleys within valleys has had a decided influence upon the region in a number of ways. It has greatly increased the difficulty of travel across it, and thus retarded development, and has also increased the expense of railroad construction. Its influence upon the drainage system as a whole has been marked, and the original drainage systems have suffered many very radical changes.

In the Allegheny Mountain region is included the drainage of the lower portion of the Susquehanna, of the Juniata and its tributaries, and of almost the entire West Branch below Lock Haven, with the exception of its northerly and westerly tributaries—in brief, the portion of the Susquehanna system between Pittston and Harrisburg, with the exception of the tributaries of West Branch. The area of this part of the watershed is approximately 8,500 square miles, or about 31 per cent of the entire drainage basin. The slopes of the main stream and its principal branches are as follows: From Pittston to the junction with West Branch, at Sunbury, a distance of 68 miles, the fall is 114 feet—an average of 1.6 feet per mile. From Sunbury to Harrisburg, 53 miles, the fall is 124 feet—an average of 2.3 feet per mile. The portion of West Branch in this region is 65 miles long, and falls 110 feet at an average rate of 1.6 feet per mile from Lock Haven to its mouth. The Juniata has an average fall of 3.1 feet per mile.

The slopes in this region differ greatly from those in the Allegheny Plateau. There the streams have etched the plateau, leaving symmetrical and well-rounded hills. The elevations of the Allegheny Mountain region are long, straight, or slightly curved ridges, with level tops, but comparatively steep sides. Some of them may be traced for long distances as continuous mountains, which are broken only where they have been cut by streams. A notable example of such a range is Kittatinny Mountain, which forms the southeasternmost ridge of the group. This ridge runs out of Pennsylvania through northwestern New Jersey and southern New York to Hudson River, interrupted only by notches and water gaps.

One of the most striking features of the river in this part of its course is its bold persistence across the trend of the Allegheny ridges. Just above Pittston it flows into the fertile Wyoming Valley, which lies parallel to the mountain chain. It follows this valley until it reaches Nanticoke, where it bends gradually southward across the Lee-Penobscot Mountain and again resumes its southwestward course, which it holds until reaching Sunbury. Here it turns southward again, crossing Mahantango, Berry, Peters, Second, and Blue mountains, and emerges into Allegheny Valley near Harrisburg.

ALLEGHENY VALLEY.

After leaving the Allegheny Mountain region the river crosses the greater Allegheny Valley, which forms a striking contrast in topographic feature to the other portions of the region. Instead of being composed of level-crested parallel ridges, as is the region lying immediately west, Allegheny Valley is, as the term indicates, a wide depression having true valley characteristics. It is in reality a strip of low country extending from St. Lawrence Valley southward, embracing a portion of Hudson River Valley and all of Wallkill Valley in New York, the valleys of the Wallkill and Paulins Kill in New Jersey, the Cumberland and Hagerstown in Pennsylvania and Maryland, and the Shenandoah in West Virginia. The Susquehanna enters it near Harrisburg and leaves it where it crosses the western edge of the crystalline and Triassic areas. It is somewhat difficult to define with precision the limits of Allegheny Valley in this section. The river, however, may be said to cross the dividing line between the valley and the Allegheny Mountain region near Rockville, a few miles north of Harrisburg, and to intersect its southern edge near Highspire, where it meets the Piedmont Plateau. The distance between these points is approximately 11 miles, in traversing which the river falls 19 feet, or an average of 1.7 feet per mile. Allegheny Valley is not a large portion of the watershed, containing in all but 1,700 square miles, or approximately 6 per cent of the total drainage area, but its features are distinct and its general characteristics strikingly different from those of the other physiographic divisions under consideration. The valley is characterized geologically by limestones, which are much more easily eroded and have undergone greater denudation than the shales to the west. The tributaries in this portion of the watershed are small, being Conedogwinet and Yellow creeks on the west and Swatara Creek on the east. The fall of the main stream and of its tributaries in the Allegheny Valley system is slight. This is particularly noticeable in the case of Conedogwinet Creek, which flows in wide meanders in the last 15 or 20 miles of its course.

PIEDMONT PLATEAU.

After leaving Allegheny Valley the river flows through the Piedmont Plateau, whose northern limits are not clearly defined in this portion of the State. The Piedmont Plateau extends from New England to Alabama. It receives its name from the fact that it lies at the foot of the Allegheny Mountain ridges and borders them for their entire length on the southeast. It consists mainly of crystalline and metamorphic rocks highly altered and disturbed, and also includes Triassic shales and sandstones with their trap intrusives. Susquehanna River may be said to enter the region 6 to 10 miles below Harrisburg.

The topography is characterized by comparatively low, well-rounded hills on the divides and by rather steep-sided valleys along the streams, especially in their lower portions. South Mountain, the continuation of the Highlands, has a somewhat greater elevation. This division as a whole is a farming country, with a small proportion of forested areas. It has a heavy soil, resulting from the disintegration of the metamorphic series underlying it. The side streams flow with rather steep grades on bed rock, and the Susquehanna passes over a number of reefs and shoals suitable for the development of power. On the eastern edge of the Piedmont Plateau the river finds its mouth at the head of Chesapeake Bay, its lower course in particular being confined in a steep-sided valley.

In crossing the Piedmont Plateau the river flows approximately 59 miles. In this distance it falls 286 feet, or an average of about 4.5 feet per mile.

SUMMARY OF SLOPES.

For the sake of comparison the slopes of the main stream and its principal branch on the different portions of the watershed are here given.

Slopes of Susquehanna River and the West Branch.

ALLEGHENY PLATEAU.

Stream.	Length.	Fall.	Average per mile.
	Miles.	*Feet.*	*Feet.*
Susquehanna	232	657	2.8
West Branch	95	578	5.9

ALLEGHENY MOUNTAIN REGION.

Susquehanna (Pittston to Rockville)	116	234	2
West Branch (Lock Haven to Rockville)	113	231	2

ALLEGHENY VALLEY.

Susquehanna (Rockville to Highspire)	11	19	1.7

PIEDMONT PLATEAU.

Susquehanna (Highspire, near Harrisburg, to mouth)	63	286	4.5

The striking feature observable from the above table is the relatively sharp drop of the stream on the Piedmont Plateau, which, it will be remembered, is traversed by the river in the last 63 miles of its course. This condition is unusual, for streams in their erosive cycles normally reach base-level along their lower courses first, their gradients becoming relatively steeper as the headwaters are approached. This does not seem to be the case with the Susquehanna, which shows three distinct conditions of grade:

First, in the Allegheny Plateau the fall appears to be normal. To be sure, the figures show that the main stream drops 2.8 feet per mile while West Branch falls 5.9 feet per mile, but the two streams fall approximately through the same distance and the difference in average gradient seems to be entirely due to the difference in their length, which is marked, the shorter stream having relatively the steeper gradient, as would be expected.

Second, in the Allegheny Mountain region the fall is also normal. The lengths of the main stream and of West Branch are approximately the same, and their average fall is remarkably uniform. The difference in average fall per mile between portions of the stream on the Allegheny Plateau and in the Allegheny Mountain region is also normal, as it is to be expected that the fall on the upper portions of the system will be greater than on any portion lower down.

Third, the stream, which has thus far followed the laws of all well-developed river systems, begins its last stage—namely, that upon the Piedmont Plateau—with an entire reversal of the natural conditions; for here, instead of entering smoothly upon the last part of its slope curve, which with steadily decreasing fall should approach flatness at the river's mouth, it abruptly changes its grade, and the average fall suddenly increases from 2 feet to 4.5 feet per mile. The waters of the stream from this point pass rapidly over a series of shoals and successive drops which reach almost to sea level, the fall in about 60 miles being approximately 300 feet. This is a fall more than twice as great as that of the river in its previous stage across the Allegheny Mountain region and nearly double its fall in crossing the Allegheny Plateau.

This unusual fall in the Susquehanna on the Piedmont Plateau is a matter of considerable interest, and an investigation of the causes producing it is worthy of more attention than can be given in the limits of this chapter. It may be of interest, however, to call attention to a few of the facts which may throw some light upon the problem. First, the narrow, gorge-like valley of the Susquehanna upon the Piedmont Plateau, and also of its tributaries on the same area, indicates a comparatively recent elevation of the entire region. It is an extremely suggestive fact that indications of this uplift appear on the lower Potomac and to a less extent on the lower Delaware during the passage of each of these streams across the Piedmont Plateau, where this same condition of gorge-like valley is also found. On the other hand, the extensive embayment of the mouths of the Delaware, Hudson, Susquehanna, and Potomac rivers gives evidence of a wide regional depression which must have involved the entire portion of the seaboard region in question.

It is also evident that the changes producing the present peculiar conditions on the lower Susquehanna were not confined to the limits of its watershed, as the same sudden increase in fall is found on Delaware and Potomac rivers as they cross the Piedmont Plateau. Hence it seems that the causes for these phenomena must be found in a study of the regional changes that are known to have taken place along the whole portion of the Atlantic seaboard drained by these systems. Studies of the sand and gravel deposits near Washington, D. C., and in Maryland and New Jersey, and recent investigations on Long Island, indicate quite clearly that between the late Tertiary and the present time the Atlantic coast has been subjected to a series of regional uplifts and depressions. It was during these uplifts that the profound degradation of the Coastal Plain was accomplished and its present topographic features produced. The graded streams flowing across the Piedmont Plateau must have been considerably accelerated by these uplifts, and must have begun at once to alter their grades to conform to the new conditions.

According to this idea the sudden drop of the Susquehanna from Harrisburg to its mouth may be considered as a temporary stage in the river's attempt to again reach a normal slope curve. In the accomplishment of this object the slope has been affected only as far back as the limits of the Piedmont Plateau, but given sufficient time the effects may be expected to extend even to the headwaters.

The unusual occurrence of such conditions of grade at the lower end of a large stream like the Susquehanna offers opportunities for the development of water power. At a number of places on the lower course of the river it seems possible to erect power plants of considerable magnitude, and it is understood that capitalists are now studying the conditions at some of these with a view to future developments.

POPULATION AND INDUSTRIAL DEVELOPMENT IN NEW YORK.

Industrial development in the drainage basin of Susquehanna River has been important, especially in Pennsylvania, where the enormous mineral wealth has attracted a large number of settlers and encouraged industries.

In this basin in New York are the important cities of Binghamton, Elmira, and Corning, together with smaller ones like Hornellsville, Bath, Owego, Oneonta, Norwich, and Cortland. In this portion of the basin dairying and agriculture are the principal industries.

The run-off water from the Susquehanna drainage area in New York is of excellent character. There are, as a rule, not sufficient dissolved alkaline earth constituents to render the water very hard, and except at times of extraordinary floods little suspended material is carried in the streams. The water is comparatively free from color, and for all purposes is probably as good as any that can be found in the United States, with the possible exception of New England. Dairying is the principal industry in a large part of the region. The farms are famous for the excellent character of the water, which is available at small cost.

The following table shows the population of the cities and towns in the New York portion of the Susquehanna drainage area:

Population in drainage area of Susquehanna River in New York, by counties and towns.

ALLEGANY COUNTY:	
Alfred (one-half)	808
Almond	1,436
Birdsall (one-third)	211
West Almond	601
BROOME COUNTY:	
Barker	1,072
Binghamton	40,494
Chenango	1,372
Colesville	2,773
Conklin	946
Kirkwood	918
Lisle	1,710
Maine	1,534
Nanticoke	666
Triangle	1,727
Union	5,707
Vestal	1,850
Windsor	2,967
CHEMUNG COUNTY:	
Ashland	954
Baldwin	664
Big Flats	1,705
Catlin	1,109
Chemung	1,500
Elmira	35,672
Erin	996
Horseheads	4,944
Southport	2,201
Van Etten	1,406
Veteran (one-third)	551
CHENANGO COUNTY:	
Afton	1,920
Bainbridge	1,991
Columbus	997
Coventry	987
German	423
Greene	3,152
Guilford	2,208
Lincklaen	646
McDonough	907
New Berlin	2,525
Norwich	7,004
Otselic	1,234
Oxford	3,545
Pharsalia	780
Pitcher	751
CHENANGO COUNTY—Continued.	
Plymouth	1,026
Preston	662
Sherburne	2,614
Smithville	1,105
Smyrna	1,290
CORTLAND COUNTY:	
Cincinnatus	912
Cortland	9,014
Cortlandville	2,907
Cuyler	991
Freetown	610
Harford	753
Homer	3,864
Lapeer	538
Marathon	1,664
Preble	857
Scott	852
Solon	622
Taylor	762
Truxton	1,217
Virgil	1,326
Willett	687
DELAWARE COUNTY:	
Davenport	1,620
Franklin	2,529
Harpersfield (two-thirds)	814
Kortright (one-half)	737
Masonville	1,245
Meredith	1,508
Sidney	4,023
HERKIMER COUNTY:	
Columbia	1,268
Litchfield	931
Warren	1,240
Winfield	1,475
LIVINGSTON COUNTY:	
Springwater (one-third)	672
MADISON COUNTY:	
Brookfield	2,726
De Ruyta	1,410
Georgetown	998
Hamilton	3,744
Lebanon	1,243
ONONDAGA COUNTY:	
Fabius	1,686
Tully (one-half)	733

OTSEGO COUNTY:	
Burlington	1,263
Butternuts	1,698
Cherry Valley	1,802
Decatur	559
Edmeston	1,767
Exeter	1,087
Hartwick	1,800
Laurens	1,483
Maryland	1,998
Middlefield	2,100
Milford	2,007
Morris	1,689
New Lisbon	1,225
Oneonta	8,910
Otego	1,817
Otsego	4,497
Pittsfield	1,101
Plainfield	1,101
Richfield	2,526
Roseboon	1,031
Springfield	1,762
Unadilla	2,601
Westford	910
Worcester	2,409
SCHUYLER COUNTY:	
Catharine (one-half)	693
Cayuta	459
Orange	1,391
Tyrone	1,586
SCHOHARIE COUNTY:	
Jefferson (one-half)	704
Summit (one-half)	608
STEUBEN COUNTY:	
Addison	2,637
Avoca	2,125
Bath	8,437
Bradford	771
Cameron	1,353
STEUBEN COUNTY—Continued.	
Campbell	1,467
Canisteo	3,432
Cohocton	3,197
Erwin	1,851
Fremont	1,033
Greenwood	1,129
Hartsville	787
Hornellsville	1,833
Howard	1,704
Jasper	1,430
Lindley	1,306
Prattsburg	2,197
Rathbone	1,059
Thurston	1,017
Troupsburg	2,015
Tuscarora	1,301
Wayne (one-half)	419
West Union	1,025
Wheeler	1,188
Woodhull	1,787
TIOGA COUNTY:	
Barton	6,381
Berkshire	1,011
Candor	3,330
Newark Valley	2,164
Nichols	1,564
Owego	8,378
Richford	1,142
Spencer	1,868
Tioga	2,113
TOMPKINS COUNTY:	
Caroline	1,938
Danby (one-third)	483
Newfield (one-half)	951
YATES COUNTY:	
Italy Hill	1,094
Total	345,850

Area of Susquehanna basin in New York .... square miles .. 6,267
Population per square mile 55

CHARACTER OF SURFACE WATERS.

SUSQUEHANNA RIVER IN NEW YORK.

The character of run-off water from the drainage area of this river is well shown by the analyses given below, which were made by George C. Whipple, of Mount Prospect Laboratory, Brooklyn.

Analyses of water from Susquehanna River above Binghamton, N. Y.

[Parts per million.]

Date.	Turbidity.	Color.	Odor.	Nitrogen as— Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Chlorine.	Total residue.	Hardness. Alkalinity.	Normal hardness.	Iron.	Gage heights, Binghamton, N. Y.
													Feet.
Jan. 3, 1901	----	10	None.	0.045	0.005	0.004	1.540	3.500	75.0	50	0	-----	------
Mar. 24, 1902	9	12	2V	.066	.004	.000	.400	1.400	74.0	35	9.5	0.60	6.32
June 17, 1902	8	15	3V+1M	.104	.024	.002	.040	1.600	109.0	47	8.0	.15	3.28
Sept. 16, 1902	2	10	3V	.098	.044	.002	.030	2.100	101.0	50	0	.20	2.85
Jan. 7, 1903	31	21	3V	.102	.012	.001	.200	1.000	95.0	33	3.5	.65	3.83
Aug. 18, 1903	2	13	3V	.114	.016	.001	.020	1.500	86.5	54	6.0	.10	2.30

The analyses in the above table are of a water which is typical of a large drainage area which has received a small amount of sewage. The condition of the organic matter as shown by the analyses would not condemn the water for domestic purposes. On the contrary, the report is somewhat reassuring. Only in the high and unsteady chlorine content is there any indication of pollution, although the table gives no information concerning the time at which the polluting ingredients entered the stream. So far as the analysis is concerned the water might be a highly desirable potable beverage. It is known, however, from observation that such is not the case.

Below Binghamton Susquehanna River runs southwesterly, and a short distance below the State line it is joined by the Chemung. This stream drains a basin of practically the same character as that drained by the Susquehanna, and the conditions with respect to settlement are analogous. The following determinations were made by James M. Caird, Troy, N. Y.:

Analyses of water from Chemung River at Elmira, N. Y.

[Parts per million.]

Date.	Turbidity.	Color.	Odor.	Nitrogen as— Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Chlorine.	Total residue.	Hardness.	Iron.	Bacteria per cubic centimeter.	Number of analyses made.
Mar. 26–31, 1900	16	20								65		7,000	6
May 18–24, 1900	18	26								114		1,800	7
Aug. 2–8, 1900	26	32								160		1,300	7
Aug. 29–31, 1900	10	95										600	12
Sept. 1–26, 1900	7	95										525	26
Sept. 27–30, 1900	18	25								68		950	4
Oct. 1–3, 1900	13	23								61		1,250	3
Dec. 18–20, 1900	30	55								39		26,500	3
Apr. 27, 1901	0			0.048	0.024	0	2.55	4.0	75.7		0	500	1
Jan. 6–11, 1902	25	25								52		11,500	6
Mar. 9, 1902	30	35								55		4,200	1
Mar. 10, 1902	98	40								21		26,000	1
Oct. 5, 1902	40	45								68		7,200	1
Oct. 6–10, 1902	25	29								65		11,100	5

The above table contains only four determinations, but they are probably the most valuable of all for practical purposes in this case. The record shows that the water of Chemung River is of good physical quality, but is polluted by wastes. Compared with Susquehanna River at Binghamton the water here shows, on the average, somewhat higher turbidity and color, while it contains considerably more hardening constituents. From a bacteriologic standpoint the record for Chemung River is unsteady, showing that usually the water contains little impurity, and only now and then betrays the excess of organic matter which is poured into the stream from the cities on its banks.

SUSQUEHANNA RIVER JUST ABOVE NORTHERN ANTHRACITE COAL BASIN.

In the table below are given a few results of analysis of samples taken from the river just above the northern anthracite coal basin.

Analyses of water from Susquehanna River just above northern anthracite coal basin.

[Parts per million.]

Date.	Turbidity.	Color.	Odor.	Nitrogen as—				Chlorine.	Hardness.		Normal hardness.	Bacteria per cubic centimeter, 1,980.	Gage height, Wilkesbarre.
				Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.		Total residue.	Alkalinity.			
Feb. 11, 1899	0	10	0	0.072	0.004	0.000	0.250	1.850	127	6.2		------	----
Mar. 16, 1899	Very turbid.	20	Faint.	.156	.038	.000	.200	1.786	168	------	------	------	----
Apr. 7, 1899	Cons.	15	Faint.	.202	.014	.000	.000	1.607	161	------	------	------	7.4
May 13, 1899	0	12	Very faint.	.102	.020	.000	.080	1.965	142.5	------	------	------	5.1
Oct. 27, 1901	Slight.	10	Very faint.	.082	.242	.000	.000	6.000	166	107.5		------	3.4
Dec. —, 1902	0	10	0	.058	.018	.000	.000	4.090	130	81.4		------	----
Feb. 15, 1903	40	17	0	.118	.030	.000	.006	2.000	112.5	3.9	32.5	1,980	10.8
May 22, 1903	5	8	Very faint.	.132	.036	.001	.000	3.200	132.5	20.1	69.9	2,750	3.5
July 20, 1903	10	20	0	.158	.032	.000	.000	3.000	126	12.7	47.3	2,450	4.6
Sept. 15, 1903	8	17	0	.106	.044	.000	.002	2.400	129.5	4.3	67.1	2,000	5.2

The analyses in the above table denote a water which, except for its high chlorine content, appears to be excellent, and if the history of the stream above this point were not known it might be maintained that the water could be used with safety for domestic purposes. In its course from Binghamton and Elmira across the sparsely settled country the water has become somewhat purified and shows a distinct improvement. It is clear, almost colorless, and comparatively soft, but is unfit for domestic uses unless purified.

SUSQUEHANNA RIVER IN NORTHERN ANTHRACITE COAL BASIN.

SEWAGE POLLUTION.

In the northern anthracite coal basin the conditions along the Susquehanna are entirely different from those previously encountered. At Pittston the river is joined by the Lackawanna, which flows near the median line of the coal basin and draws most of its water from it. The Lackawanna is not a large river, and of all streams in the United States it is probably the least attractive in appearance. It contains sewage from Carbondale, Archbald, Jermyn, and Scranton.

Carbondale, situated in Lackawanna County, upon Lackawanna River, has a population, according to the Twelfth Census, of 13,536. The public works consist of a sewerage system and municipal water supply, the latter being under the control of a private corporation. The municipal sewage is poured directly into Lackawanna River, but there are no manufacturing plants which produce any important amount of polluting material. Above the city the river presents a fairly acceptable appearance. It has a sluggish flow at low water, but rises quickly after heavy precipitation. Considerable discomfort is experienced at times by persons living along the river below the city.

Carbondale is supplied with an impounded water conserved in Crystal Lake, a few miles west. An artificial distributing reservoir is situated east of the city on high ground. The daily consumption is 3,500,000 gallons, equivalent to 260 gallons per capita. Crystal Lake is a body of water 195 acres in extent, while the artificial reservoir covers 35 acres. Its surface is about 200 feet above the average distributing reservoir.

Scranton, situated in Lackawanna County, along Lackawanna River, has a population, according to the Twelfth Census, of 102,026. It is provided with a sewerage system, the total cost of which up to August, 1902, was $720,500. The river which flows past the city is usually a black, foul, ropy mass of fluid, due to the enormous amounts of culm and municipal waste turned into it. There are no industrial plants in Scranton from which damaging waste is turned into the sewers.

Scranton is provided with an impounded water supply, the system being owned by the Scranton Gas and Water Company. A description of this system will be found in subsequent pages.

COAL-MINE WASTE.

In addition to the large amounts of sewage there are discharged into Lackawanna River enormous amounts of coal-mine waste. This is a peculiar solution containing a high percentage of calcium sulphate, free sulphuric acid, and iron. Concerning this waste, Dr. Charles B. Dudley, of Altoona, Pa., makes the following statement:

Much trouble is experienced in Pennsylvania, Ohio, Indiana, and Illinois from the corrosive condition of the water that must necessarily be used in steam boilers. The sources of supply, especially the rivers and small streams in those States, receive large amounts of drainage from coal mines, and this drainage is extremely corrosive. To such an extent is this the case that at the Homestead Steel Works, in order to neutralize the corrosive characteristic of Monongahela River water, many barrels of soda ash are used every month.

The corrosive material in water contaminated with mine drainage may be twofold, namely, it may be free sulphuric acid or it may be sulphates of iron and alumina. The origin of the sulphuric acid and sulphates is undoubtedly from the coal. It is believed that coal may contain sulphur in three forms, namely, as sulphate of lime, as sulphide of iron or iron pyrites, and possibly as organic sulphur. Just exactly how this sulphur is converted into either sulphuric acid or sulphates of iron and alumina has possibly not yet been determined, but samples of coal have been obtained from certain mines, which on being coarsely crushed and put in a funnel and washed with distilled water actually yield free sulphuric acid in the filtrate. More commonly, however, the drainage from the mines comes out of the mines in the form of protosulphate of iron, $FeSO_4$. On exposure to the air this salt breaks up, yielding hydrated oxide or free basic sulphate of iron, which precipitates and gives a yellowish color to many of the waters of the small streams into which the mine drainage runs, and sesquisulphate or ferric sulphate, which remains in solution. This ferric sulphate when brought in contact with metallic iron or steel, such as the inside of a boiler, attacks iron freely, the metal being converted thereby into protosalt again. Fresh water containing oxygen being added to the boiler as feed water, apparently the protosalt again breaks up into hydrated oxide or basic sulphate, which is thrown out of solution, and ferric sulphate, the same operation being repeated over and over again, resulting, as is readily seen, in very rapid destruction of boilers. The separated hydrate or basic sulphate of iron is washed out usually as a reddish powder. Waters containing mine drainage do not usually form scale in the boilers and as long as any carbonates of any kind are present, even if the water contains mine drainage, there is no corrosion. Accordingly where mine-drainage waters must be used it is customary to add soda ash in certain amounts sufficient to a little more than react with the ferric salts that may be in the water, and if perchance mixed waters are used, some of which contain mine drainage, and some contain sufficient carbonate of lime in solution as bicarbonate to react with the iron salts, there is no corrosion.

Results of analysis of three representative samples of this mine waste are given below. The analyses were made for the Geological Survey by Mr. George C. Whipple, of Mount Prospect Laboratory, Brooklyn, N. Y.

Analyses of three samples of mine waste from northern anthracite coal basin, Pennsylvania.

[Parts per million.]

	1.	2.	3.
Turbidity	130	210	190
Color	26	23	6
Odor	0	0	0
Albuminoid ammonia in solution	.082	.094	.034
Albuminoid ammonia in suspension	.094	.070	.022
Albuminoid ammonia total	.176	.164	.056
Free ammonia	.840	2.400	.282
Nitrites	.004	.007	.000
Nitrates	.000	.000	.000
Total residue on evaporation	1,977	3,003	792
Loss on ignition	279	280	64
Fixed solids	1,698	2,723	728
Calcium and magnesium sulphates	1,036	1,424	477
Sulphuric acid	164	150	39
Oxide of iron	143	393	78.6
Sodium chloride	3.3	6	.7
Ammonium sulphate	4	11.3	1.3
Silica and alumina	347.7	738.7	131.4

1. From Mineral Railroad and Mining Company, collected from pump No. 1, sump, Cameron colliery, Shamokin, Pa.

2. From slope No. 4, Susquehanna Coal Company, Nanticoke, Pa.

3. From pump delivery at Short Mountain colliery, Lykens Valley Coal Company, Lykens, Pa.

The three samples above described are representative types in the anthracite region.

The above analyses do not show the most important facts desirable in this discussion. The determinations of turbidity, color, odor, and the four nitrogens are without special consequence, although they retain a measure of interest because the amounts of albuminoid and free ammonia are very large in comparison with the nitrites and nitrates. This would seem to indicate that the organic matter in the mine water is the result of recent pollution. This, however, is probably incorrect. The organic matter has a remote source and has remained available in the first stages of oxidation because of the lack of oxygen.

The most important part of the analytical statement is that which begins with the results of the determination of total residue on evaporation. The residue is extremely large, especially in Nos. 1 and 2. The loss on ignition is extensive in all three samples, and without doubt there was driven off a large proportion of matter, the nature and amount of which should have appeared in the list of inorganic ingredients. For example, the amounts of sulphuric acid which appear are entirely insufficient to combine with all the iron and alumina, and it is probable that a large part of the matter lost on ignition was sulphuric acid. These wastes are known to be highly acid, and there is probably an excess of sulphuric acid over that required to combine with the iron and alumina in the solution, although it is apparent that the evidences of free acid which appear by reason of the corrosive properties of the water may be due to the ferric sulphate.

It is unfortunate, too, that a separate determination was not made of the amount of alumina, for, as will be shown in the following pages, this mine waste has remarkable coagulating and precipitating properties, which are believed to be due to aluminum sulphate.

The analyses show unmistakably that the water is highly corrosive and probably scale-forming, although in the presence of acid the calcium sulphate, of which the water contains so high a proportion, would not be precipitated as a scale, but in the form of a powder.

CULM WASTE.

The third waste which is turned into Lackawanna River is very fine coal, or culm. This material is discharged into the streams of this region in enormous quantities from the coal washeries. A washery is a plant erected for the purpose of working over the old waste piles (see Pl. I, *A*) to secure coal which in the earlier times and cruder methods of handling passed out as waste. The fine material is separated from the coarse by a sort of decantation process, the supernatant water loaded with coal dust being turned into the streams. Wherever it is turned into a small brook, where the amount of water is not suf-

A. RECOVERY OF COAL FROM CULM PILE.

B. SUSQUEHANNA RIVER IN WYOMING VALLEY.

ficient to transport the culm, the stream bed soon becomes filled, and in some cases no channel is left, the water running at will over the lands adjoining.

This black combination of sewage, acid mine waste, and culm slowly makes its way down the valley. Here the sediment has filled a depression and there it has been piled high on one side of the stream. Along the Lackawanna near its confluence with the Susquehanna the level of the bottom land has been raised and the stream winds through a broad tract, changing its course through the loose, shifting piles at every influx of storm water.

The Susquehanna at its confluence with the Lackawanna undergoes a complete change. It enters the coal basin a bright, clear stream. Below the mouth of the Lackawanna the inky black trail extends downstream along the eastern shore and may be seen for a long distance, while on the opposite side the water remains clear. As progress is made downstream the black swath becomes wider and wider until finally it covers the entire breadth of the channel.

From the mouth of Lackawanna River southward the Susquehanna traverses the heart of the northern anthracite coal basin through what is known as Wyoming Valley. (See Pl. I, *B*.) In this beautiful basin are situated the cities of Pittston, West Pittston, Wilkesbarre, Kingston, Plymouth, and Nanticoke, which combined have a population of 99,734.

EFFECT OF MINE WASTES.

The sewage from these towns and enormous amounts of culm and mine waste are poured into the Susquehanna. The river along this portion has, however, only a slight grade, and at the lower end of the valley there is a dam. This structure, about 7 feet in height, backs up the water to Wilkesbarre and forms a slack-water basin which serves as an excellent sedimentation reservoir in all except high stages of the river.

Before discussing in detail the effect of mine waste a brief description of the northern anthracite basin will be given.

This basin is divided into four districts: Carbondale, Scranton, Pittston, and Wilkesbarre. In that part of the coal basin above Nanticoke dam there were at the time of the report of the Pennsylvania geological survey, in 1883, about 160 shafts or slopes. Without doubt some of the collieries reported at that time have been "worked out," but it is equally probable that as many more have been opened. Therefore the total number is at least as great as in 1883, although precise information upon this subject has not been obtained.

It is of course impossible to determine with any degree of accuracy the amount of mine waste that is pumped from shafts or allowed to run out from slopes into Susquehanna River and its tributaries. At only a few mines are continuous records kept. At some others the results of a few days' run are noted, while at others records are made occasionally. As the amount of water which it is necessary to pump varies widely, it would be imperative to have a continuous record at each shaft for a term of years to secure data of any value. Even then there would be no record of the water which runs out of the slopes requiring no pumping. Below are given some data which show the amount pumped at the shafts represented. These figures are only approximately accurate, but are in nearly all cases less than the actual amount pumped.

Mine waste pumped from collieries in northern anthracite coal basin, Pennsylvania.

Company.	Colliery.	Cubic feet per second.	Total.
Scranton Coal Co.	Johnson No. 1	7.04	
	Johnson No. 2	.90	
	Richmond No. 3	1.29	
	West Ridge	.26	
	Richmond No. 4	.89	
	Raymond	3.56	
	Ontario openings	3.10	
	Capouse	4.08	
	Pine Brook	3.05	
	Mount Pleasant	1.39	
	Pancoast	.26	
			25.82
Hillside Coal Co.	Forest City	2.74	
	Clifford	2.83	
	Erie	6.01	
	Glenwood	6.35	
	Consolidated	2.01	
	Elmwood	4.01	
			23.95
Pennsylvania Coal Co.	Gypsy Grove	.79	
	No. 1	.81	
	No. 5	.49	
	Old Forge	2.59	
	Central	6.51	
	Barnum	.28	
			11.47
Lehigh and Wilkesbarre Coal Co.	Hollenbach	1.22	
	Empire	1.10	
	Stanton	1.30	
	South Wilkesbarre	.18	
	Sugar Notch	.41	
	Lance	.41	
	Nottingham	2.25	

Mine waste pumped from collieries in northern anthracite coal basin, Pennsylvania—Continued.

Company.	Colliery.	Cubic feet per second.	Total.
Lehigh and Wilkesbarre Coal Co.	Reynolds	.04	
	Wanamie	.93	
	Maxwell	1.07	
			8.91
Parish Coal Co	Plymouth	1.32	
	Buttonwood	.59	
			1.91
Delaware and Hudson Co	Conyngham (in April, 1902)	[a] 11.8	
	Conyngham (in May 1902)	[a] 10.2	[b] 11.00
	Plymouth No. 1 (in April, 1902)	[a] 31.22	
			31.22
Plymouth Coal Co	Dodson	....	1.44
	Gaylord [c]		
Delaware, Lackawanna and Western R. R.	Archbald	1.34	
	Avondale	13.25	
	Bellevue	6.14	
	Bliss	2.76	
	Brisbin	2.73	
	Cayuga	2.91	
	Continental	1.58	
	Diamond	4.64	
	Dodge	5.44	
	Halstead	17.82	
	Hampton	1.67	
	Holden	.49	
	Hyde Park	1.78	
	Manville	.54	
	Pettebone	1.57	
	Pyne	2.24	
	Sloan	.75	
	Storrs	2.64	
	Taylor	4.53	
	Woodward	2.24	
	Central	4.64	
	Central Air Shaft	1.00	
			82.75
Temple Coal and Iron Co	Lackawanna	6.68	
	Edgerton	1.11	
	Mount Lookout	3.12	

[a] Accurate records.
[b] Average for Conyngham.
[c] Gaylord belongs to another company. Shut down at time of measurement, and water was pumped through Dodson colliery.

Mine waste pumped from collieries in northern anthracite coal basin, Pennsylvania—Continued.

Company.	Colliery.	Cubic feet per second.	Total.
Temple Coal and Iron Co	Sterrick Creek	4.46	
	Babylon	2.67	
	Forty Fort	1.78	
	Harry E	1.34	
			21.16
Susquehanna Coal Co., Nanticoke district.	No. 1 [a]	2.47	
	No. 2 [a]	2.09	
	No. 2 Slope [a]	.61	
	No. 4 [a]	1.30	
	Stearns [a]	.80	
	Glen Lyon [a]	2.03	
			9.30
Total			227.49

[a] Actual pumpage, one day of twenty-four hours, June, 1902.

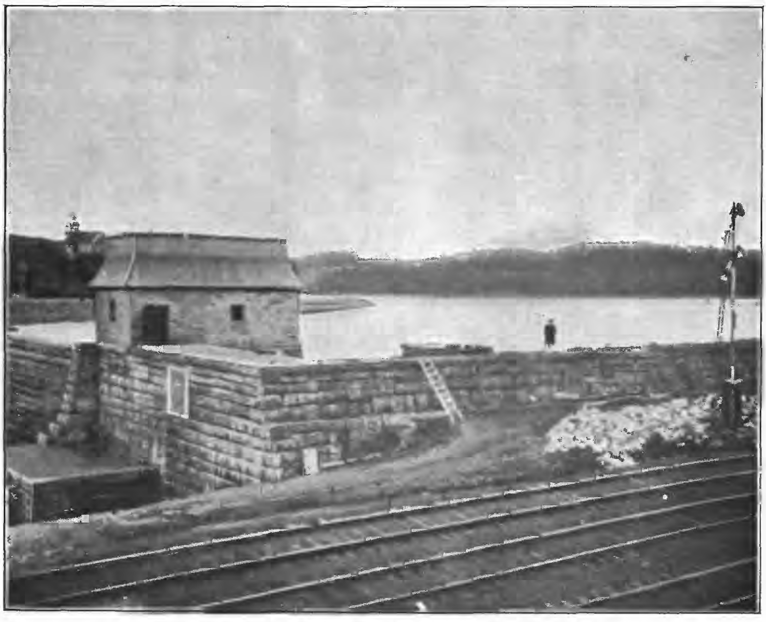
The daily records of pumping at the Luke Fiddler colliery by the Susquehanna Coal Company, contributed to this report by R. V. Norris, chief engineer, show that the average daily pumpage was 1.27 cubic feet per second in 1899; 1.33 cubic feet per second in 1900, and 1.29 cubic feet per second in 1901. These records are from a mine outside of the immediate area under discussion, but are added for the purpose of showing the average yearly pumpage and its general uniformity over long periods.

There are enumerated in the above table 74 collieries, from which are pumped 227.49 cubic feet of acid mine water per second. If from the remainder of the collieries in the Susquehanna basin above Nanticoke dam there is pumped a proportionately equivalent amount—and this assumption is believed to be fairly safe—there is an average of 491.9 cubic feet of waste per second turned into the river.

The flow of Susquehanna River at Wilkesbarre on September, 1902, was 2,100 second-feet. At Nanticoke dam (see Pl. II, *A*), 7 miles below Wilkesbarre, the flow at that time was somewhat more, probably 2,500 second-feet. Assuming that the pumpage of 491.9 second-feet of mine water is sufficiently close for practical purposes, about one-fifth of the water flowing in Susquehanna River through Wyoming Valley was acid mine waste artificially turned into the stream. Under such conditions any effects which this mine water might have would be most pronounced.

The appearance of a small stream into which coal-mine waters are

A. SUSQUEHANNA RIVER AT NANTICOKE DAM.



B. ELMHURST RESERVOIR, SCRANTON, PA.

discharged is peculiar. The bottom of the channel is colored a light yellow, and there appear no signs of vegetation of any kind. All fish life in a stream is immediately destroyed at the first appearance of coal-mine waste. Where culm as well as acid mine waste is dumped into the channel the appearance is well-nigh beyond description. Many of the small brooks emptying into Susquehanna River in Wyoming Valley have no permanent channel; the old channel has been filled by deposits of culm, and the stream takes a new course whenever freshets arise, often covering fertile fields with culm and doing great damage.

The important question to be considered in this connection is the effect of the acid mine waste upon the water of Susquehanna River. It has been shown that the run-off from the Lackawanna basin is befouled with sewage, impregnated with acid, and blackened by culm. Susquehanna River below this point is generally of the same character, as it receives the pumpage waters from all the mines and the sewage from the cities in Wyoming Valley. Below this great influx of putrescible matter one would confidently expect to find a water of high organic content, supporting enormous numbers of bacteria. The remarkable fact is that a series of chemical analyses shows that the water is actually more free from organic matter at the lower end of Wyoming Valley than at the upper. This effect is traceable to nothing else than the large amounts of mine waste which are turned into the stream. The analyses in the table below show results which are altogether unique. The fact that the enormous quantity of fine culm turned into Susquehanna River a short distance above Nanticoke is not apparent is due to the coagulating property of the combination which causes the large quantities of fine coal and the organic matter from city sewers to precipitate on the bottom of the stream. It is really a somewhat crude application of the coagulating process used in connection with mechanical filtration. The bottom of the channel of Susquehanna River shows that precipitation occurs rapidly, for there are places at which the bottom has been raised from 8 to 12 feet, and, in fact, this has been a contributory cause of recent damaging floods in the city of Wilkesbarre.

Analyses of water from Susquehanna River at Nanticoke dam.

[Parts per million.]

Date.	Turbidity.	Color.	Odor.	Nitrogen as—				Chlorine.	Total residue.	Hardness.		Gage height, Wilkesbarre, Pa.	Bacteria per cubic centimeter.
				Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.			Alkalinity.	Normal hardness.		
1902.												Feet.	
Nov. 22	12	2.00	0	0.078	0.070	0.000	0.0000	3.8	134.5	0.0	80.0	4.2	1,278
Dec. 20	60	.22	1E	.110	.046	.000	.0000	2.4	109.5	.0	32.5	11.3	2,816
1903.													
Jan. 10	25	10.00	0	.090	.050	.000	.0000	2.8	116.0	2.9	47.1	6.8	524
Feb. 14	40	17.00	0	.088	.030	.000	.0060	2.4	119.5	1.3	40.3	11.0	1,520
Mar. 7	50	18.00	1E	.104	.032	.000	.0010	1.8	122.0	5.2	27.3	12.1	......
Apr. 11	35	18.00	0	.080	.030	.000	.0000	1.8	93.0	4.3	51.4	9.8	980
May 8	10	15.00	0	.104	.068	.000	.0004	3.0	134.5	5.7	82.9	4.0	840
July 14	20	2.00	0	.114	.102	.000	.0000	3.2	139.5	15.7	70.0	3.8	7,000
Aug. 15	15	.20	......	.110	.086	.000	.0030	2.4	121.5	5.7	74.3	4.9	1,110
Sept. 14	7	17.00	0	.098	.062	.000	.0020	2.8	115.5	10.0	70.0	5.6	1,270
Oct. 28	15	26.00	......	.070	.072	.000	.0050	2.8	122.0	5.7	84.3	6.5	490
Nov. 28	15	.23	0	.062	.042	.000	.0000	2.0	90.0	2.8	68.6	5.8	542
Dec. 21	25	.21	......	.082	.028	.000	.0000	2.2	94.5	4.2	52.9	8.9	1,320

IMPORTANT INGREDIENTS AND THEIR VARIATION.

The monthly analyses of the water in Susquehanna River at the head and foot of Wyoming Valley afford an opportunity to show the variation in character of water according to the stage of the river. The United States Geological Survey gage at Wilkesbarre, which is read twice daily, is situated about midway between the sampling points, and therefore the readings express accurately the relative conditions with regard to the river stage at those points. Sufficient determinations are not at hand to enable one to make a positive statement regarding the relation of the character of water to the amount flowing in the channel. However, the material available shows the relative changes and the general variation in the ingredients according as the river rises or falls. Figs. 2 and 3 show the relation of turbidity, chlorine, normal hardness, and alkalinity to quantity of water in Susquehanna River water at opposite ends of Wyoming Valley. In these figures the character of the water has been used as ordinates and the gage heights as abscissæ. In fig. 2, which represents the determinations made at the upper end of the valley, the curve does not vary widely from a straight line drawn between the determinations representing the highest and lowest gage heights. The curves show that with an increased flow in the stream the turbidity increases, while the chlorine, alkalinity, and normal hardness decrease. This is a very natural variation often exemplified in rivers, and it would indicate that the ground waters contribute the carbonates, sulphates, and chlorides, while the waters that run off directly after a storm carry large amounts of suspended matter, with an extremely small proportion of carbonates, sulphates, and chlorides, and serve to dilute the inorganic constituents generally.

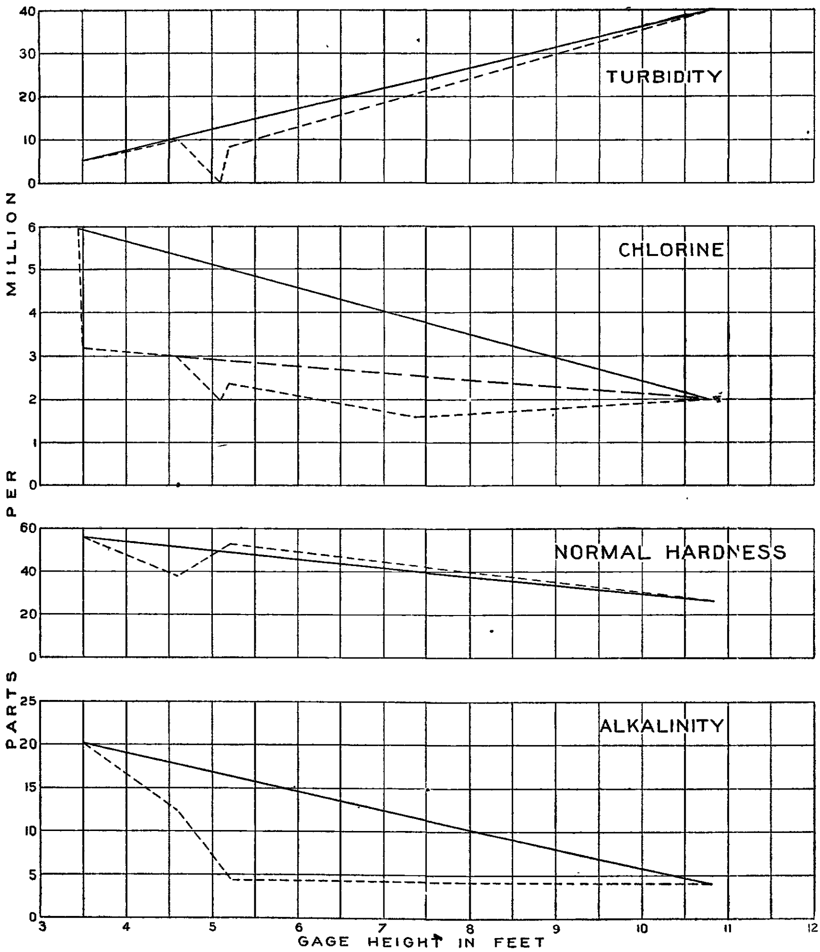


FIG. 2.—Diagram showing relation of character and quantity of water in Susquehanna River at upper end of Wyoming Valley.

Turning to the curves in fig. 3, which show the relations at the lower end of Wyoming Valley, there is a somewhat wider variation in the amounts as the water in the river increases, this being especially true in the case of turbidity and alkalinity. This is readily accounted for by the fact that at the head of Wyoming Valley the water in the stream is the result of natural drainage and has not been polluted to any degree since passing Binghamton, a long distance above, while at Nanticoke dam the water has been highly charged with sewage and

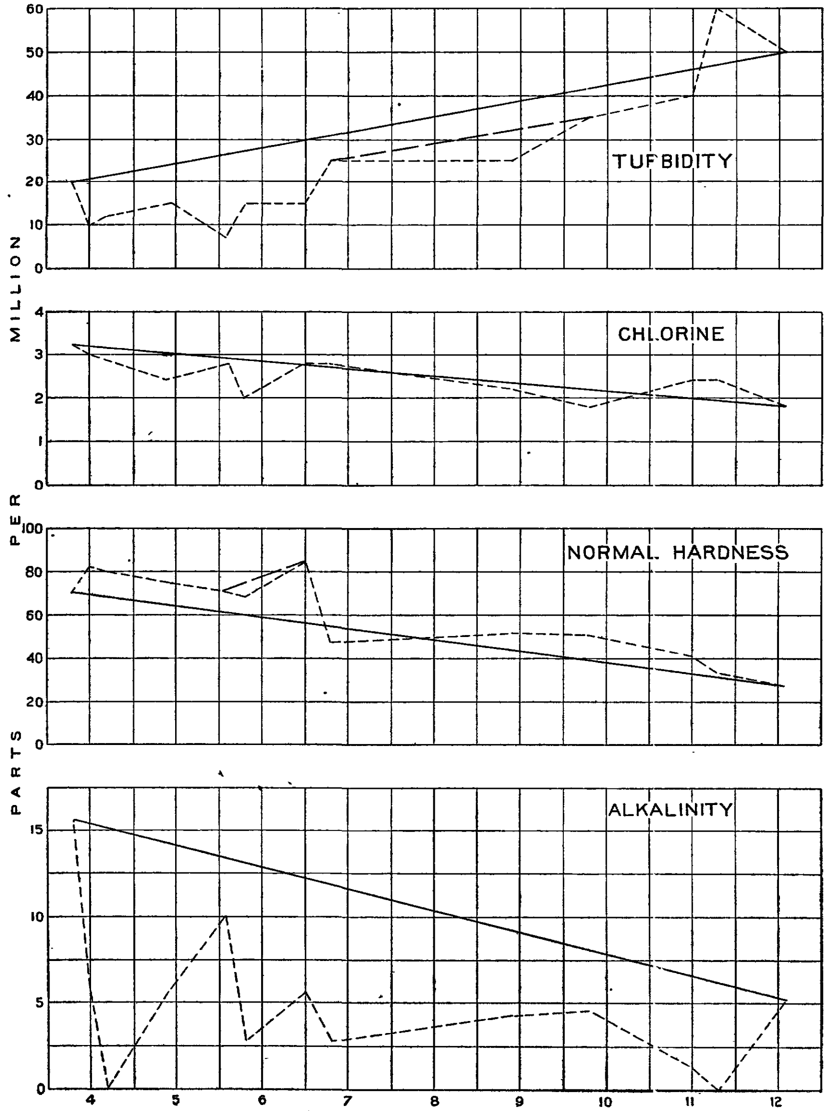


FIG. 3.—Diagram showing relation of character and quantity of water in Susquehanna River at lower end of Wyoming Valley.

acid coal-mine waste. The amounts of sewage and mine waste, and consequently the character of the water, vary from day to day. It may be expected, then, that the artificial conditions which exist to a large extent just above the sampling point will cause the relations between characteristics and gage height to be less uniform than above the entrance of this unusual pollution. However, in fig. 3 the general trend of the curves is the same as in fig. 2, and even the pronounced effect of the acid mine waste and sewage in Wyoming Valley does not make an exception to the general statement that there is increase in turbidity and decrease in chlorine, normal hardness, and alkalinity with the rise of water in Susquehanna River.

PUBLIC WATER SUPPLIES.

Before leaving the consideration of that part of the Susquehanna drainage area included in the northern anthracite coal basin it will be of interest to discuss the domestic water supply in that region.

Along the heights bordering the valley of Lackawanna River and in the mountains forming the perimeter of Wyoming Valley (Pl. I, *B*) are exceptional sites for storage systems. The water-supply systems of Scranton and Wilkesbarre and of neighboring towns have been developed in the highland regions in a manner worthy of note. Naturally these highlands are ideal for water-supply purposes. They are excellent examples of that class of lands which in the opinion of hydrographic experts should be forever set aside for the raising of timber and the conservation of water. Indeed, they are good for nothing else. Agriculture is practically an impossibility, for the soil is both poor and shallow. A plowed field in this highland region after a rain has washed the loose earth from the small stones appears like a waste heap of some quarry. Only along the bottoms of the Susquehanna is there any good, arable land.

The entire region has been deforested. Save for scrub thicket and immature trees, which may at some distant date produce timber, the hills are bare. There are few places in the east where the natural beauties of mountain scenery and the natural resources of timber lands have been destroyed to the extent that has taken place in northern Pennsylvania. One may journey for miles without encountering a mature tree. The situation is an excellent one in which to consider the value and possibilities of intelligent forestation. The water resources of the country are great, but this very greatness only serves to indicate what might have been if the timber had not been destroyed. Judicious cutting would have been beneficial; in any event, it would not have been practical devastation.

UNPOLLUTED SOURCES.

Although the locality here dealt with is generally populous, settlement along the ridges is sparse. Water of great purity is available almost anywhere. In the following table are recorded analyses of waters from various small tributaries of the Susquehanna. Some of these waters are normal, and the whole table indicates extremely well the general character of the run-off in this region. The records were contributed by the Spring Brook Water Supply Company, of Wilkesbarre, through its chemist, W. H. Dean.

Analyses of waters from unpolluted tributaries of Susquehanna River in northern anthracite coal basin.

[Parts per million.]

Date.	Turbidity.	Color.	Odor.	Nitrogen as— Albuminoid ammonia.	Nitrogen as— Free ammonia.	Nitrogen as— Nitrites.	Nitrogen as— Nitrates.	Chlorine.	Total residue.	Total hardness.	Location.
HUNTSVILLE RESERVOIR.											
1899.											
May 3	Slight.	1.5	Strong.	0.290	0.040	0.000	0.000	1.072	65.0	------	
June 9	Cons.	2.2	Strong.	.236	.224	.000	.000	1.070	105.5	------	
July 12	Slight.	3.5	Strong.	.378	.272	.000	.000	1.432	70.0	------	
Oct. 21	Cons.	2.3	Strong.	.910	.390	.000	.000	1.260	98.5	------	
1900.											
June 16	Cons.	-----	Strong.	.320	.020	.000	.000	-------	92.5	------	
Sept. 17	Slight.	3.5	Strong.	.254	.238	.000	.000	1.600	70.0	------	
Oct. 19	Slight.	2.0	Faint.	.296	.026	.000	.000	1.600	68.5	------	
1901.											
Aug. 16	Cons.	5.0	Rank.	.252	.288	.000	.000	2.000	101.0	------	
1902.											
Mar. 29	Cons.	2.0	Faint.	.136	.084	.000	.000	2.400	117.5	------	
GARDNERS CREEK.											
1899.											
Aug. 10	0	1.8	0	0.110	0.056	0.000	0.000	-------	39.5	30.0	
Dec. 27	0	1.8	0	.028	.010	.000	.000	1.200	74.0	18.2	
1900.											
Feb. 22	Cons.	2.5	Faint.	.116	.032	.000	.000	1.000	166.0	------	
June 15	0	0	Very faint.	.0054	.012	.000	.000	.800	68.5	------	
MILL CREEK.											
1899.											
Mar. 4	Slight.	1.0	0	0.046	0.020	0.000	0.000	1.428	72.5	------	Intake waterworks.
Apr. 22	0	.5	0	.038	.012	.000	.000	1.072	70.0	------	Do.
Apr. 26	0	.8	0	.044	.020	.000	.000	.714	76.5	------	Storage reservoir.
July 19	Cons.	3.0	Strong.	.088	.186	.000	.000	.714	75.0	12.7	Bottom reservoir.
July 19	Cons.	2.0	Moldy.	.254	.096	.000	.000	.714	86.5	11.1	Top reservoir.
July 19	Slight.	2.0	Foul.	.080	.022	.000	.040	.714	75.0	12.7	Intake waterworks.
July 20	Cons.	1.5	Moldy.	.330	.246	.000	.000	-------	------	------	Top reservoir.
July 28	Slight.	2.0	Sw'mpy.	.140	.270	.000	.000	-------	------	------	Bottom reservoir.
Aug. 10	0	1.2	Foul.	.064	.042	.000	.200	.750	65.0	26.0	Intake waterworks.
Dec. 27	0	2.0	0	.076	.002	.000	.000	1.200	60.5	11.1	Reservoir.
1900.											
Feb. 22	Cons.	2.0	Foul.	.062	.028	.000	.000	1.200	62.0	------	Intake waterworks.
June 15	0	1.5	Very foul.	.056	.010	.000	.000	.800	64.5	------	Do.

Analyses of waters from unpolluted tributaries of Susquehanna River in northern anthracite coal basin—Continued.

MILL CREEK—Continued.

Date.	Turbidity.	Color.	Odor.	Nitrogen as— Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Chlorine.	Total residue.	Total hardness.	Location.
1900.											
June 15	0	1.5	Very foul.	.046	.030	.000	.000	1.200	65.0	......	Bottom reservoir.
June 30	0	2.0	Faint.	.070	.054	.000	.000	.714	59.0	11.1	Storage reservoir.
Sept. 14	Slight.	2.1	Moldy.	.114	.164	.000	.000	1.200	73.5	......	Bottom reservoir.
1901.											
Feb. 8	Slight.	1.2	0	.028	.008	.000	.000	1.200	52.5	......	Stream opposite dam.
May 15	0	1.2	0	.028	.020	.000	.000	1.200	35.0	......	Bottom reservoir.
July 30	0	2.0	0	.050	.026	.000	.000	1.600	81.5	9.5	Intake waterworks.
July 30	0	2.5	W.	.042	.064	.000	.000	1.200	66.5	15.6	Bottom reservoir.
Sept. 9	0	.8	0	.026	.008	.000	.000	1.400	78.0	......	Intake waterworks.

LAUREL RUN.

Date.	Turbidity.	Color.	Odor.	Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Chlorine.	Total residue.	Total hardness.	Location.
1899.											
Mar. 4	0	0	0	0.032	0.008	0.000	0.000	0.357	84.0	......	Laurel Run.
Apr. 19	0	0	0	.026	.008	.000	.000	.893	93.5	......	No. 1 reservoir.
Apr. 22	0	.5	0	.038	.010	.000	.000	1.250	64.0	......	Kelleys Run.
Apr. 22	Slight.	0	0	.048	.012	.000	.350	.536	74.0	......	Gin Creek.
Apr. 22	0	.5	0	.060	.022	.000	.000	1.070	65.0	......	Above Gin Creek.
1900.											
Mar. 29	0	.5	0	.006	.006	.000	.000	1.000	118.5	......	Kelleys Run.
Mar. 29	Slight.	.5	0	.020	.008	.000	.300	1.400	39.0	......	Laurel Run.
Apr. 20	0	.5	0	.022	.002	.000	.400	1.600	57.5	......	Do.
May 4	0	.5	0	.022	.006	.000	.350	.800	68.5	......	Do.
May 12	0	.3	0	.008	.012	.000	.000	.800	......	......	Below Gin Creek.
May 30	0	0	0	.012	.034	.000	.350	.800	57.5	......	Dynamite works.
May 30	0	0	0	.008	......	.000	.060	1.200	41.5	......	Above dynamite works.
July 7	0	.5	0	.032	.006	.000	......	3.200	60.0	......	Below dynamite works.
Oct. 29	0	.5	0	.024	.016	.000	......	1.600	79.0	......	
Nov. 29	Cons.	1.0	0	.012	.028	.000	.800	2.200	......	......	Gin Creek.
1901.											
July 1	0	.5	0	.016	.002	.000	.200	1.000	95.0	......	
Sept. 20	0	.7	0	.014	.008	.000	.500	1.400	103.0	......	
Oct. 31	0	0	0	.034	.006	.000	.500	1.200	69.5	......	No. 2 dam.
1902.											
Feb. 6	0	.5	0	.020	.020	.000	.500	2.000	55.5	......	Do.
Mar. 28	0	.2	0	.028	.016	......	......	....	53.0	......	Do.

SCRANTON SYSTEM.

The water supply of the city of Scranton is owned by the Scranton Gas and Water Supply Company, of which W. M. Marple is chief engineer. The water is obtained from upland brooks from which all apparent dangerous contamination has been eliminated. The following facts with reference to the system were contributed by Mr. Marple. The principal impounding reservoirs are known as Scranton Lake and Elmhurst reservoir. (Pl. II, *B*, and Pl. III, *B*.)

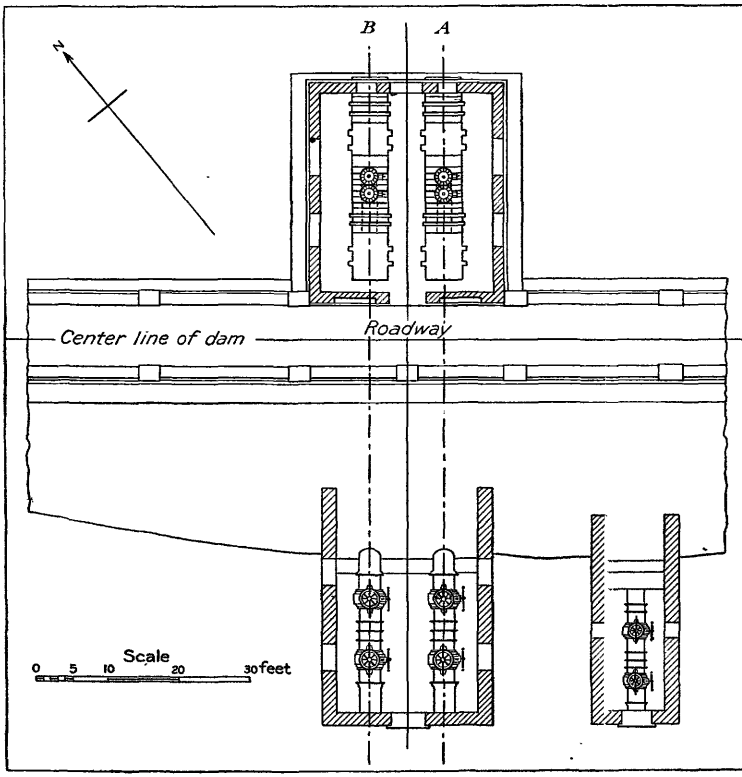


FIG. 4.—Plan of valve houses at Scranton Lake dam.

Scranton Lake has an area of about 225 acres, a capacity of 2,513,972,000 gallons, and a spillway elevation of 1,282.28 feet. It is situated in the basin of Stafford Meadow Brook and has a direct contributing area of 8 square miles. In addition to this, however, 37 square miles are indirectly contributory through a 36 by 30 inch cast-iron pipe, which conducts water from Elmhurst reservoir. The latter is situated in Roaring Brook basin and has an area of 195 acres and a capacity of 1,393,459,000 gallons. The spillway is at an elevation of 1,425.5 feet, while the business portion of the city of Scranton is but 743 feet above sea level.

Reservoirs in Scranton water-supply system.

Reservoir.	Drainage area.	Area of water surface.	Capacity.	Extent of contributing drainage area.	Elevation of spillway above tide.
		Acres.	*Million gallons.*	*Square miles.*	*Feet.*
Scranton Lake [a]	Stafford Meadow Brook.	225	2,514	45	1,282.8
Williams Bridge	do	42.6	343	5½	1,360.6
No. 5 distributing [b]	do	10	32	11½	922.2
Elmhurst	Roaring Brook	195	1,393	34¾	1,425.5
Oak Run [c]	do	75	418	2¼	1,467.8
Lake Henry [d]	do	69	205		1,905.8
No. 7 distributing [e]	do	19	100	13	1,058.5
Dunmore system	Little Roaring Brook.	22.5	78	5¼	1,212.62
Providence system: [f]					
Griffin	Leggitts Creek	105	579	2 to 3	1,354.4
Summit Lake	do	54	212	½	1,378.4
3 small distributing reservoirs (combined area).	do	4	9		

[a] Immediate drainage, 8 square miles. Supplementary by 36 by 30 inch pipe from Elmhurst reservoir, 37 square miles.

[b] No. 5 distributing reservoir is 3 miles below Scranton Lake. It is kept full by water of Scranton Lake.

[c] Oak Run reservoir is on a small creek of same name and is included in drainage area of Elmhurst reservoir.

[d] Lake Henry is principally fed by springs.

[e] No. 7 distributing reservoir is on Roaring Brook, nearly 7 miles below Elmhurst (in borough of Dunmore). There is 13 square miles of drainage area between it and Elmhurst.

[f] Undetermined.

Scranton Lake dam is about 325 feet long (Pl. III, *A*). At the south end is a core wall of hydraulic masonry 265 feet long, with earth embankments, which slope 3½ to 1 on the inside and 3 to 1 on the outside. The spillway is situated about one-fourth mile from the dam in a natural depression 100 feet wide. Details of the dam construction are shown in figs. 4, 5, and 6. There are two gate houses, one at the dam and the other at the opposite end of the reservoir. The former has sluice gates at different levels and there are four 36-inch

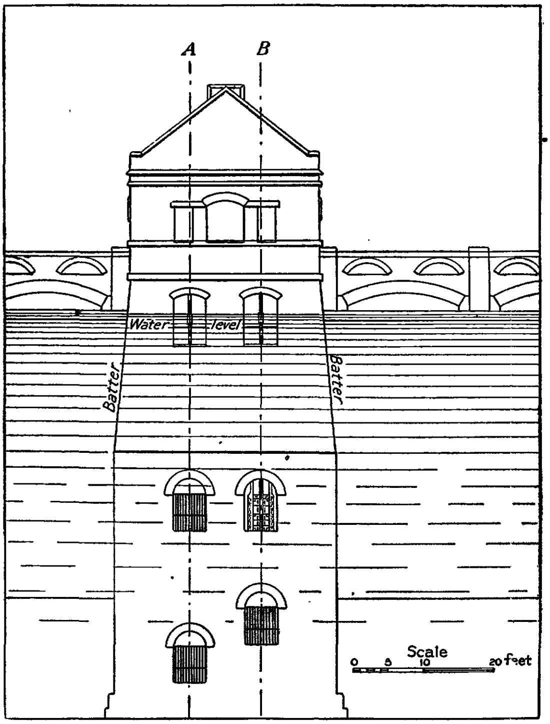


FIG. 5.—Rear elevation of valve house at Scranton Lake dam.

valves. The masonry structure, which is surmounted by an arch-bridge driveway, is very substantial and represents an excellent type of the municipal water-supply dam common in the northeastern part of the United States.

WYOMING VALLEY SYSTEM.

The water-supply system of Wyoming Valley, which includes the municipalities of Pittston, West Pittston, Wilkesbarre, Kingston, Plymouth, Nanticoke, and smaller places, is owned by the Spring

A. SCRANTON LAKE DAM, SCRANTON, PA.

B. ELMHURST RESERVOIR DAM, SCRANTON, PA.

Brook Water Supply Company. The system is an extensive one. A portion was constructed for the various municipalities by separate companies which were afterwards consolidated, and other parts have been constructed since. Some of the original plant has been abandoned, notably those systems which involved the pumping of water from Susquehanna River.

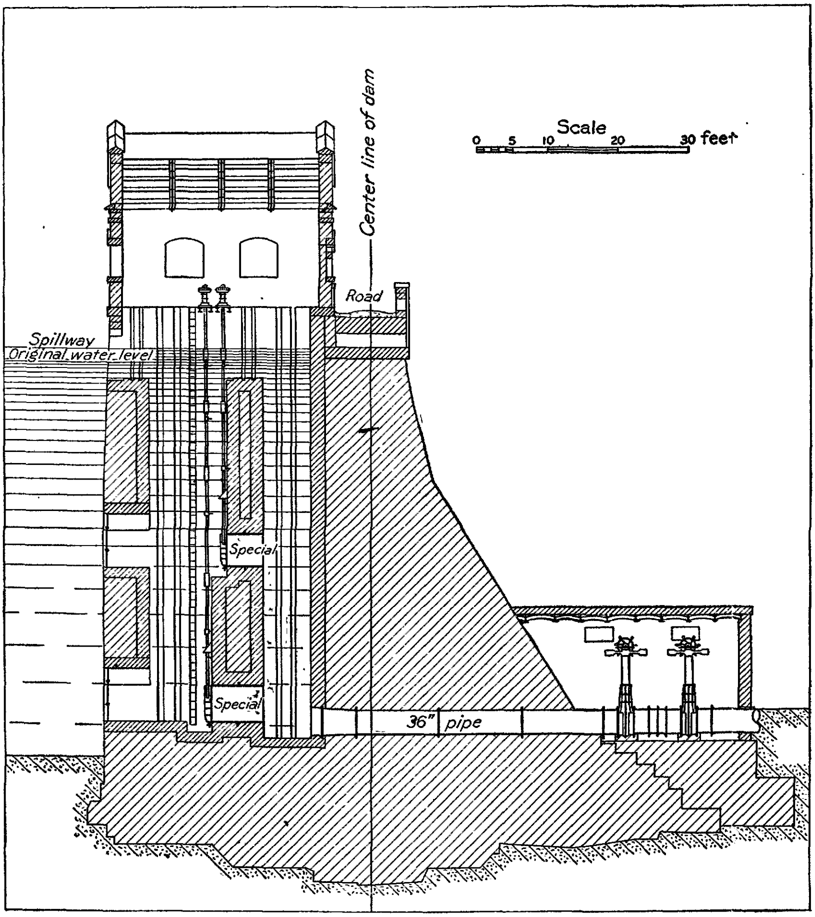


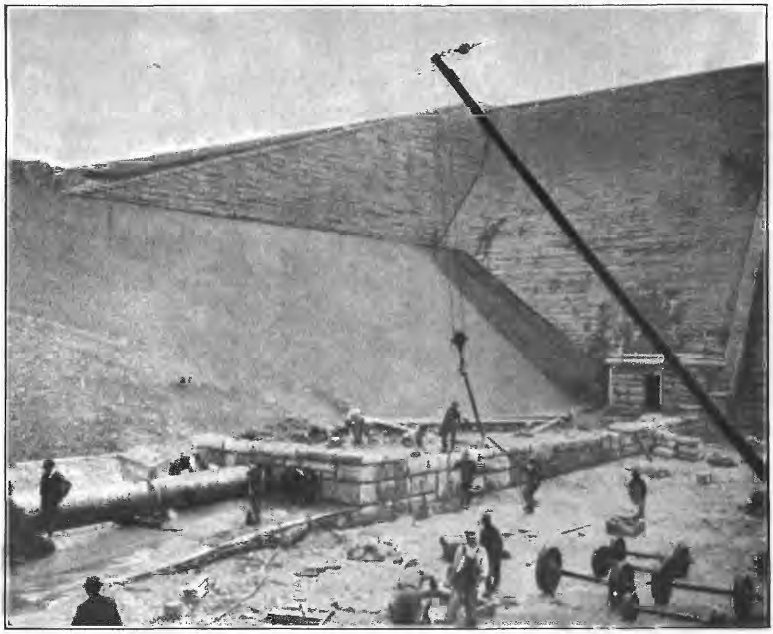
FIG. 6.—Cross section of valve house and dam at Scranton Lake.

Thirty-three reservoirs and intakes are scattered over the region. As many of these basins are connected by an intricate system of pipes and gate valves, the water from almost any of them can be delivered to any part of the valley, according to the temporary conditions in the various drainage areas.

The following list of reservoirs comprising the Wyoming Valley system is published by courtesy of O. M. Lance, general manager for Spring Brook Water Supply Company.

Reservoirs of water supply system controlled by Spring Brook Water Supply Company, of Wilkesbarre, Pa.

	Reservoir.	Stream.	Drainage area.	Capacity.	
			Sq. miles.	*Gallons.*	*Cubic feet.*
1	Maple Lake	Spring Brook	1.07	300,000,000	40,000,000
2	Nesbitt	do	15.74	75,000,000	1,000,000
3	Round Hole	do	36.00	1,322,300,000	173,306,000
4	Intake	do	53.00	50,000,000	6,666,600
5	Covey	Covey	.47	10,000,000	1,333,300
6	Trout and Monument.	Reservoir	7.52	10,000	1,330
7	Intake	Gardners Creek	2.13	70,400,000	9,386,600
8	Laflin	do	2.88	10,000	1,330
9	No. 1	Mill Creek	5.07	616,700,000	82,226,600
10	Intake	do	10.00	4,000,000	533,300
11	do	Deep Hollow	.87	1,000	130
12	No. 2	Laurel Run	8.35	10,000,000	1,333,300
13	No. 1	do	8.95	6,000,000	800,000
14	Crystal Lake		2.95	1,310,000,000	174,666,600
15	Intake	Statlers Creek	.17	10,000	1,330
16	No. 4	Crystal Spring	2.96	10,000	1,330
17	No. 1	do	4.00	1,000,000	133,300
18	No. 6	do	.44	10,000	1,330
19	No. 5	do	2.18	10,000	1,330
20	Red Mill	do	7.38	20,000	2,660
21	Intake	Sugar Notch	1.35	20,000	2,660
22	Storage	do	.04	5,000,000	666,600
23	do	Hanover	.46	4,000,000	533,300
24	Intake	do	.54	50,000	6,600
25	Storage	Wanamie	.77	10,000,000	1,333,300
26	Intake	do	.91	50,000	6,600
27	do	Coal Creek	4.07	1,000,000	133,300
28	No. 2	do	3.47	2,500,000	333,300
29	No. 3	do	2.50	2,500,000	333,300
30	No. 4	do	1.45	6,000,000	800,000
31	Storage	Huntsville	8.44	1,750,000,000	233,333,300
32	Intake 2	do	14.84	2,000,000	266,600
33	Intake 1		14.84	3,000,000	400,000
	Total		115.91	5,541,600,000	



A.

B.

ROUND HOLE DAM, MOOSIC, PA.

A. Buttress walls and sluice openings.
B. Dam and spillway.

The largest reservoir noted in the above table is that at Round Hole on Spring Brook. As this reservoir is of recent construction it is of considerable interest in that locality and of general interest to the engineering profession. The construction did not involve any unusual engineering difficulties, although it presented some peculiar features. The work was done by the Water Supply Company with its own laborers working by the day. The project was planned and executed by Mr. John Lance, engineer of the company. The stone was quarried upon the drainage area and brought to the site by a specially constructed switch-back road, which was also built by the company. The whole plant was completed at exceedingly small cost.

Round Hole reservoir is situated 6 miles from Moosic station on the Delaware and Hudson Railroad. It has a length of 1.5 miles, an area of 118.7 acres, and a capacity of 1,322,000,000 gallons. The drainage area above the dam is 36 square miles. At the dam the water is 87 feet deep and at the spillway is at an elevation of 1,155.13 feet above sea level. The dam, of which two views are shown on Pl. IV, is 500 feet long; 280 feet of this is masonry. The remainder is an earthen embankment with masonry core wall. Two-foot wing walls (Pl. IV, *A*) retain the embankment at its junction with the masonry. On the west end of the masonry the structure joins the natural rock, which rises in a precipitous bluff to a height of about 20 feet above the dam crest. The dam foots in the bed rock, which was excavated to a depth of 15 feet. The height from foundation to capstones is 104 feet.

The cross section of the dam (see fig. 7) is based upon a right triangle having its base three-fourths of its altitude. The crest is 9 feet thick and the lower edge along the spillway is appropriately curved. Below this, on the lower face of the dam, is a batter of 9 inches per foot. The determination of stress showed the necessity of a batter of one-half inch per foot on the back face of the dam, commencing 30 feet below the overflow. On the foot of the spillway a curve of 20 feet radius was introduced for horizontal deflection of falling water. The spillway channel below the dam is heavily paved with large cut blocks for about 100 yards.

There are 37,710 cubic yards of masonry in the dam; 25,085 barrels of cement were used, which is equivalent to about 1 barrel to 1.26 cubic yards of masonry. The mortar used in construction was made of Portland cement and sand in proportions, by volume, of 1 cement to 3 sand; that used for pointing and filling exposed joints was mixed in proportions of 1 cement to 1 sand. The cements used were Lehigh, Saylor's, and Atlas. The stone used in building the dam was Pottsville conglomerate, a tough, gray, heavy stone, which dresses roughly and gives an admirable adhering surface for the cement. This conglomerate has a specific gravity of 2.742 and weighs 165 pounds per cubic foot. The average size of the stones was 0.54 cubic yards and the largest laid contained 3 cubic yards.

The embankment at the end of the masonry section of the dam rises to a height equal to that of the masonry. Its front and back slope is 2½ to 1, and it is paved on the back face to a depth of 18 feet below the spillway elevation. The core wall supporting this embank-

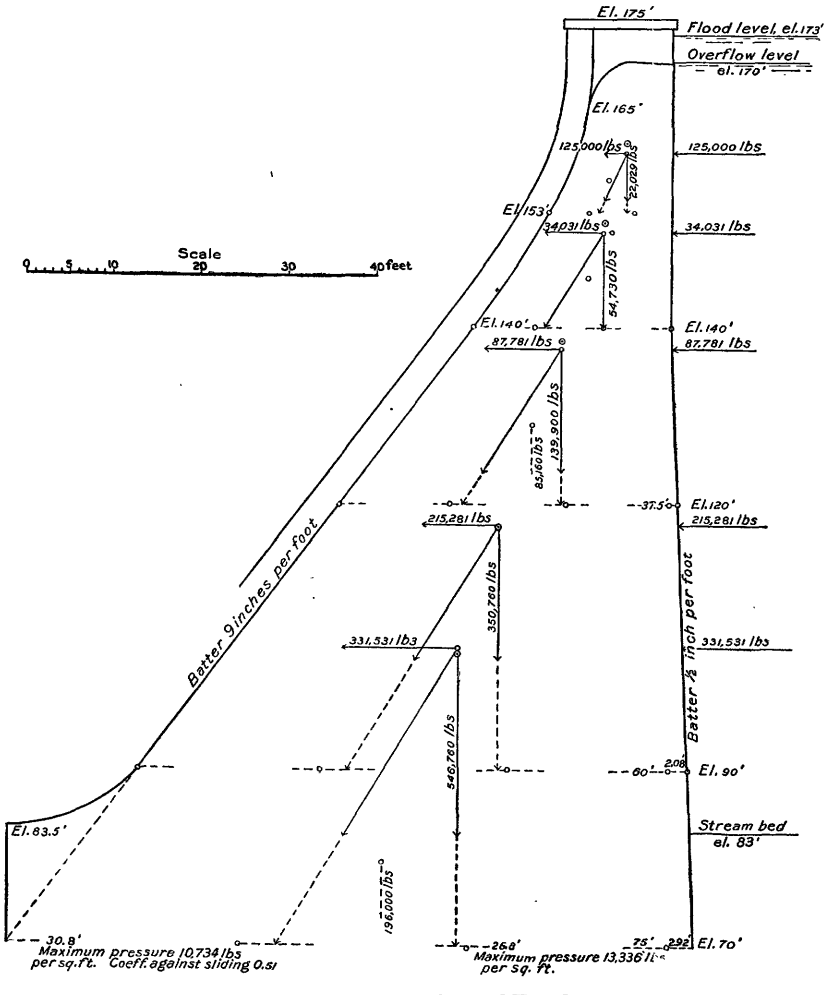


FIG. 7.—Cross section of Round Hole dam.

ment is 3 feet wide at the top, extending to a height of 3 feet above the spillway. The core is also reenforced by buttresses on front and back faces sloping 1 in 6.

The discharge pipes are 2 in number, 30 inches in diameter and 36 inches apart. They were carefully laid on wedges to a true line and a grade of 1 per cent, and then mortar was worked under and around them. When this had set sufficiently the wedges were removed and large blocks of stone, of such a height as to reach about 3 inches above the pipes, were set on either side between them, the space between these blocks and the pipes being carefully filled with mortar. Other large blocks, having a thickness of at least 15 inches and a length at least 5½ feet, were laid on full beds of mortar across the tops of pipes, but not resting upon them. Although it was impossible to break joints the mortar was so worked in about the pipe that no moisture was noticeable at the downstream face of the dam. Two gates were set on each line below the dam, separated by a piece of pipe 30 inches long, and the lower gate on each line was anchored back to the masonry to a distance of 15 feet by iron bars, which were bent over a length of 12 inches at the ends. The capacity of these pipes is about 350,000,000 gallons per day.

In the construction of this work it was necessary to lay 2.3 miles of railroad on a graded roadbed of an old lumber road, at a cost of $7,235. A branch from the construction road to the quarry, 2 miles long, erected on a steep side hill with about 1,500 feet of rock work, cost $4,600, exclusive of rails. Workable stone was obtained with the first shot at the quarry, and thereafter cost of quarrying was about $1.59 per cubic yard.

The average number of men employed on the construction was 220, and the time occupied was from August 16, 1899, to December 14, 1901, leaving out about 100 days each winter.

The total cost of the dam, including everything but the railroad, was $240,547.93. The masonry alone cost $5.98 per cubic yard.

SUSQUEHANNA RIVER BELOW NORTHERN ANTHRACITE COAL BASIN.

After passing Nanticoke dam the Susquehanna emerges from the northern anthracite coal basin through a deep gorge, and for some distance flows in a southwesterly direction along the edge of the coal field. It makes an abrupt turn at Shickshinny and flows south for some distance, and then takes a southwesterly direction to its junction with West Branch at Sunbury.

The country tributary to Susquehanna River between the northern anthracite coal basin and Sunbury is sparsely settled, and save for a comparatively small amount of contamination from a few towns along its banks and considerable mine-water drainage from Nescopeck Creek, Catawissa Creek, and Roaring Creek, which enter from the south, draining the middle coal basin, the stream is not damaged to any extent. The municipalities of Nescopeck, Berwick, Mifflinville, Bloomsburg, Catawissa, and Danville, containing a total population of 22,204, contribute a small amount of pollution to the stream; but from the physical appearance of the water and the general survey of the entire region it is apparent that the stream at Sunbury is in a better condition than at Nanticoke.

WEST BRANCH OF SUSQUEHANNA RIVER.

West Branch of Susquehanna River, which joins the main stream at Sunbury, drains a country in northern Pennsylvania which has not been so thickly settled and upon which there are fewer municipalities than along the main stream. The principal towns located along this branch are Milton, Lewisburg, Muncy, Lock Haven, Renovo, Driftwood, and Jersey Shore. The population in the drainage area, by counties, is as follows:

Population in drainage area of West Branch of Susquehanna River.

Cambria County	17,516
Cameron County	7,048
Clearfield County	74,754
Center County	19,498
Columbia County	512
Elk County	5,416
Lycoming County	52,658
Montour County	2,574
Northumberland County	6,959
Potter County	10,642
Sullivan County	12,134
Tioga County	16,897
Union County	15,492

The character of the water in West Branch with respect to pollution is not different from that of the main stream above Binghamton, shown in the analyses on page 21. Along its lower reaches the water is certainly not fit for domestic supply in its raw state, yet it is probably as good or better than that in any large stream in Pennsylvania. The following analyses of water from the drainage area of West Branch are here reproduced by courtesy of Dr. Charles B. Dudley, of the Pennsylvania Railroad:

Analyses of waters from various sources in drainage area of West Branch of Susquehanna River.

[Parts per million.]

Location and source.	Date.	Turbidity.	Color	Odor.	Nitrogen as—				Chlorine.	Total residue.	Iron.	Bacteria.	
					Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.				Total bacteria per c. c.	B. Coli. Com.
West Branch at Williamsport, Pa	May 25, 1897	Trace.			0.028	0.022	Trace.	0.860	21.00	207.9			
Water supply, Williamsport, Pa	Apr. 11, 1901	0		0	.047	.020	.000	1.600	3.00	25.7			
West Branch at railway bridge 156, Watsontown, Pa.	Feb. 21, 1898				.018	.022	Trace.	2.460	7.00	153.8			
West Branch at bridge, Northumberland, Pa	Nov. 28, 1902	0			.084	.032	Small amount	.350	4.40	79.0	0	340	0
West Branch, 2,500 feet west of bridge, Northumberland, Pa.	do	0			.104	.040	Small amount	.400	4.40	79.1	0	420	Few.
Paddy Run above dam, Renovo, Pa	July 6, 1893	Slight.			.020	.000	.000	.200	Trace.	20.0			
Reservoir, Renovo, Pa	Nov. 29, 1893	Slight.			.600	Trace.	.000	.200	3.50	24.5	Very little.		
Drury Run, Renovo, Pa	Jan. 31, 1903	0			.049	.026	.000	.240	2.20	24.0	0	3,800	Some.
Do	do	0			.049	.023	.000	.240	2.20	24.0	0	3,350	0
Do	Apr. 7, 1903	Trace.			.088	.028	.000	.200	2.20	22.9		1,070	Some.
Do	do	Slight.			.091	.020	.000	.200	2.20	31.0		2,600	Some.
Stream, Ralston, Pa	Jan. 9, 1896				.164	.008	.000	.860	5.90	186.5			
City supply sample No. 1, Osceola, Pa	July 29, 1899				.016	Trace.	.000	.300	13.80	44.0	0		
Delaware Run, Dewart, Pa	Feb. 21, 1898				.078	.034	.000	1.700	7.00	116.7			
Stream, Benezett, Pa	Jan. 25, 1901	0			.016	.008	.000	.110	4.50	29.6	0	29,000	0
Stream, Trout Run, Pa	Apr. 25, 1901	0			.022	Trace.	.000	.375	2.90	19.8	Trace.	463	0
Pond, Penhryn, Pa	Apr. 27, 1901	0			.154	.088	.000	2.300	5.60	59.9	Trace.		
Water station, Bellefonte, Pa	May 25, 1901	0			.026	.038	.000	.830	11.00	145.4	Trace.	64,000	0
Water station, Lewisburg, Pa	do	0			.142	.072	.000	.390	3.90	47.9	Trace.	7,900	Some.
Stream, Caledonia, Pa	Jan. 22, 1902	0			.038	.016	.000	.100	5.00	24.9	0	1,624	0
Stream, Tyler, Pa	Jan. 23, 1902	Slight.			.090	.040	.000	.220	5.00	66.5	0	3,600	0
Stream, Driftwood, Pa	Jan. 27, 1902	0			.016	.041	.000	.250	5.00	39.2	0	620	0
Stream, Spangler, Pa	May 8, 1902	Marked.			.070	.022	.000	.400	1.60	84.0	0	10,600	0
Water supply, Spangler, Pa	May 29, 1902	Slight.			.102	.020	.000	.190	2.60	67.9	0	168	0
Castanea reservoir, Lock Haven, Pa	Mar. 18, 1903	0			.043	.030	.000	.120	2.50	22.8	0	24,400	0

SUSQUEHANNA RIVER BELOW WEST BRANCH.

The city of Sunbury is located immediately below the confluence of Susquehanna River and West Branch. At this point the slack water caused by the Shamokin dam affords a basin which is quite effectual in disposing of such sewage as is discharged from Sunbury, and from all evidences at hand it is practically certain that the city sewage has little effect upon the chemical characteristics of the river water below.

The country traversed by the Susquehanna immediately below West Branch is sparsely settled and receives little or no sewage contamination. The tributaries entering from the east, however, carry large quantities of coal-mine waste of the character described in the preceding pages, while those entering from the west are in many cases highly alkaline.

In the table below are given results of analyses of water from Susquehanna River at Clarks Ferry, made by Prof. W. B. Lindsay, of Dickinson College, Carlisle, Pa.

Analyses of water from Susquehanna River at Clarks Ferry, Pa.

[Parts per million.]

Date.	Turbidity.	Color.	Odor.	Nitrogen as—				Chlorine.	Total residue.	Hardness.		Bacteria per cubic centimeter.	Gage heights at Harrisburg, Pa.	Character of sample.
				Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.			Alkalinity.	Normal hardness.			
1902.													Feet.	
Nov. 4	60	2	None	0.101	0.132	0.0	0.15	5.35	170	42.99	87.84	375	4.00	Composite.
Nov. 25	5	10	None	.235	.078	.0	.25	4.37	252.5	15.89	154.19	475	1.66	Do.
Dec. 16	5	5	None	.1071	.017	.0	1.25	2.3	155	1.87	75.69	850	4.00	Do.
1903.														
Jan. 27	10	2.5	None	.112	.104	.0	1.2	1.68	155	.0	88.88	12,000	3.50	Do.
Feb. 24	10	5	None	.066	.073	.0	1.2	.43	115	2.63	90.05	2,400	4.33	Do.
Mar. 17	55	5	None	.149	.069	.0	1	1.38	163	.0	78.67	850	7.83	Do.
Apr. 14	35	3	None	.128	.063	.001	.6	.46	190	.0	76.85	300	6.50	Do.
May 12	— 7	3	None	.032	.125	.0	.4	1.38	185	.0	149.51	200	2.16	Do.
June 1	5	3	1 M	.237	.209	.0	.2	2.16	413	.0	165.65	600	1.00	Do.

Below Harrisburg the character of the water in Susquehanna River is well shown by the following results of analyses made by Prof. W. B. Lindsay, of Dickinson College, Carlisle, Pa.

Analyses of water from Susquehanna River at Steelton and New Cumberland, Pa.

[Parts per million.]

Date.	Turbidity.	Color.	Odor.	Nitrogen as— Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Chlorine.	Total residue.	Hardness. Alkalinity.	Normal hardness.	Bacteria per cubic centimeter.	Gage heights at Harrisburg, Pa.	Character of sample.
1902.													Feet.	
Nov. 4	55	1	1 M	0.110	0.157	0.004	1.5	6.34	148.3	41.12	74.46	6,600	4.00	Composite.
Nov. 25	10	7	1 M	.101	.185	.007	.55	4.27	147.5	58.88	71.96	3,500	1.66	Do.
Dec. 16	20	15	2 M	.198	.181	.002	2.55	3.68	179	12.47	75.49	31,000	4.00	Do.
1903.														
Jan. 27	15	15	2 M	.136	.115	.012	2.80	2.53	200	53.04	80.28	2,500	3.50	Do.
Feb. 24	15	10	2 M	.166	.155	.005	4.80	1.72	160	66.54	53.03	186,000	4.33	Do.
Mar. 17	20	17	2 M	.176	.114	.0003	1.40	1.96	110	6.67	53.34	2,700	7.83	Do.
Apr. 14	110	30	1 M	.268	.247	.005	1.20	3.22	200	26.29	44.58	1,500	6.50	Do.
May 12	10	20	1 M	.155	.207	.008	1.96	3.90	161	44.45	81.83	Enormous.	2.16	Do.
June 1	10	25	1 M	.207	.190	.008	1.30	3.20	170	21.83	90.13	21,000	1.50	Do.

JUNIATA RIVER.

Juniata River enters the Susquehanna from the west a few miles above Harrisburg. In the entire basin drained by this tributary there are no important cities except Altoona, near the extreme western divide. Below Altoona there is without doubt a considerable amount of organic pollution discharging into the headwaters of the river, but long before it reaches the Susquehanna all chemical evidence at least is destroyed.

Population in drainage area of Juniata River.

Bedford County	39,468
Blair County	85,099
Cumberland County	21,645
Franklin County	25,213
Fulton County	1,894
Huntingdon County	34,650
Juniata County	12,181
Mifflin County	23,160
Perry County	9,119

In the table below are set forth results of analyses of waters taken from several points in the Juniata basin. The analyses were made in the laboratory of the Pennsylvania Railroad at Altoona under the direction of Dr. Charles B. Dudley, chief chemist.

Analyses of waters from various points in Juniata River basin.

[Parts per million.]

Source.	Date.	Turbidity.	Color.	Odor.	Nitrogen as— Albuminoid ammonia.	Nitrogen as— Free ammonia.	Nitrogen as— Nitrites.	Nitrogen as— Nitrates.	Chlorine.	Total residue.	Iron.	Bacteria per cubic centimeter.
City supply, Altoona, Pa	July 21, 1897	0			0.026	0.034	0.00	0.200	7.00			
Pottsgrove Reservoir No. 1, Altoona, Pa	Aug. 10, 1897				.152	.160	Slight trace.	.360				
Pottsgrove Reservoir No. 2, Altoona, Pa	do				.128	.056	Slight trace.	Trace.				
Pottsgrove Reservoir No. 3, Altoona, Pa	do				.246	.022	Slight trace.	Small amt.				
Well at car shops, Altoona, Pa	Oct. 3, 1901				.072	.030	.000	.790	5.00			22,800
Mountain Reservoir, near Altoona, Pa	Apr. 1, 1903	Trace.	0	0	.052	.024	.000	.170	2.50	21.8		71
Do	do	Trace.	0	0	.080	.016	.000	.120	2.10	28.5		1,780
City supply, Altoona, Pa	do	Trace.	0	0	.029	.016	.000	.140	5.00	76.5		60
Stream above Fountain Inn, near Altoona, Pa	July 20, 1903	0			.051	.014	.000	.280	3.00	42.5		1,260
The same, below Fountain Inn	do	0			.076	.026	.000	.330	3.00	41.0		1,360
Bell Mill dam, Altoona, Pa	Oct. 14, 1901	0			.156	.454	Some.	.560	9.10			15,600
Water station, Blair Furnace, Pa	July 29, 1897	Cons.		Slight.	.170	.040	.000	Trace.	Trace.			
Stream at Barre, Pa	Mar. 23, 1903	0			.040	.012	.000	.140	2.80	21.4		180
City supply, Kittanning Point, Pa	Aug. 11, 1893				.066	.014	Trace.	Trace.	Trace.			
Do	Nov. 8, 1895				.018	.022	.000	.400	6.50			
Do	do				.006	.048	.000	.440	6.50	77.4	Some.	
Dam at Elizabeth Furnace, Pa	Oct. 3, 1900				.104	.032	.000	1.040	5.00			15,000
Reservoir, Martinsburg, Pa	July 24, 1895				.012	Trace.	.000	.000	Trace.	26.1	Little.	
Water supply, Tyrone, Pa	Jan. 20, 1897				Trace.	Trace.	.000	.000	3.50	38.4		
Reservoir, Lewistown, Pa	do				.010	Trace.	.000	.900	7.00	211.9		
Kishacoquillas Creek, Lewistown, Pa	do	Marked.			.256	.080	.000	1.300	3.50	581.90	Trace.	

In the table immediately below are results of analyses of waters from Juniata River near its confluence with the Susquehanna, made by Prof. W. B. Lindsay, of Dickinson College, Carlisle, Pa. The results show that there is little or no chemical evidence of the sewage pollution which is turned into the river at Altoona.

Analyses of water from Juniata River above its confluence with the Susquehanna.

[Parts per million.]

Date.	Turbidity.	Color.	Odor.	Nitrogen as— Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Chlorine.	Total residue.	Hardness Alkalinity.	Normal hardness.	Bacteria per cubic centimeter.
1903.												
Jan. 27	10	17.5	0	0.1155	0.008	0.0	1.10	2.133	125	35.84	64.51	4,200
Feb. 24	12	17.5	0	.057	.005	.0005	1.80	1.075	125	31.98	49.34	6,100
Mar. —	15	15	0	.084	.010	Trace.	1.40	1.840	123	40	--------	900
Apr. 14	15	23	0	.111	.014	.004	1.00	1.840	190	43.43	36.58	1,700
May 12	— 7	.15	0	.105	.012	.001	1.00	2.070	117	75.77	44.45	300
June 1	— 7	.15	0	.093	.017	.005	1.30	1.470	160	46.85	61.70	700

INORGANIC INGREDIENTS OF UNDERGROUND AND SURFACE WATERS.

From the analytical records of the Pennsylvania and the New York Central and Hudson River railroads there has been collected a large amount of data with reference to the inorganic ingredients of the waters of the Susquehanna River basin. These analyses are supplied through the courtesy of Dr. Charles B. Dudley and Mr. R. H. Mahon, chemists of the respective roads. The analyses give in definite terms the determinations of total solids, total chlorines, and incrusting and nonincrusting matter; the other constituents are stated qualitatively. The four determinations above mentioned will therefore be dealt with in this discussion.

CHEMUNG BASIN.

UNDERGROUND WATERS.

The table on page 52 shows that the ground waters in various parts of the Chemung basin contain only a fairly large amount of incrusting constituents. In fact, none of the analyses indicate that the water would be especially objectionable for use in boilers, and it is clearly a water that is treatable if it should be necessary to reduce the small amount of incrusting constituents contained.

It will be noted that the sources from which the samples were taken are all shallow wells and that there is no evidence with reference to the character of the water from greater depths. It is apparent, however, that the supply from shallow wells is sufficient for all needs that have so far been apparent in this region, and therefore the supply, so far as its incrusting constituents are concerned, may be considered unobjectionable.

Inorganic ingredients of ground waters in Chemung drainage basin.

[Parts per million.]

Source	Depth.	Location.	Total solids.	Incrusting solids.	Nonincrusting solids.	Total chlorine.
	Feet.					
Driven well	15	Snediker, Pa	123.462	101.061	22.401	77.866
Well	64	do	205.200	184.680	20.520	14.022
Do	64	do	225.720	145.350	80.370	6.498
Do		do	297.198	173.394	123.804	30.438
Driven well	15	Beaver Dams, N. Y.	205.200	129.447	75.753	5.472
Well	12	do	183.483	155.61	27.873	5.985
Do	45	Horseheads, N. Y.	226.233	176.814	49.419	7.011
Do		Southport, N. Y.	209.988	142.956	67.032	13.680
Do	22	Elmira, N. Y.	193.401	122.949	70.452	8.892

SURFACE WATERS.

From the boiler standpoint the river water is even better than the water from shallow wells. The analytical statements in the table below include waters from widely distributed points in the Chemung basin, as well as from the main river itself. It is apparent upon examination of this table that the water from any of the streams may be accepted for use in boilers without prejudice.

Inorganic ingredients of surface waters in Chemung drainage area.

[Parts per million.]

Stream.	Location.	Mineral solids.	Incrusting solids.	Nonincrusting solids.	Total chlorine.
Crooked River	Hammond, Pa	102.70	75.75	27.873	9.92
Tioga River	C. V. Junction, Pa	125.57	87.723	39.843	9.92
Do	Lawrence, Pa	102.70	69.768	33.858	4.959
Cowanesque River.	Academy Corners, Pa.	83.79	61.902	21.888	3.933
Tioga River	Presho, N. Y.	119.7	101.75	35.06	3.933
Poster Creek	Beaver Dams, N. Y.	114.57	78.66	35.91	3.591
Do	Townleys, N. Y.	143.64	119.70	23.94	2.907
Chemung River	Corning, N. Y.	253.08	199.386	53.694	16.929
Do	Elmira, N. Y.	75.411	48.051	27.360	3.933

SUSQUEHANNA BASIN NORTH OF SUNBURY, CHEMUNG BASIN EXCLUDED.

There are available only a few boiler analyses of the waters of that part of the Susquehanna drainage area outside of the Chemung basin and most of the waters analyzed are from the main stream. The table below gives the results of determinations of minerals and incrusting solids in waters taken from this basin. It will be readily noted that none of these samples contain an amount of dissolved solids of incrusting constituents sufficient to be objectionable for boiler use. In fact, the surface waters and most of the ground waters in the basin of Susquehanna River are generally unobjectionable from this standpoint.

Inorganic ingredients of surface waters of Susquehanna basin, exclusive of Chemung basin.

[Parts per million.]

Source.	Location.	Mineral solids.	Incrusting solids.	Nonincrusting solids.	Total chlorine.
Susquehanna River	Susquehanna, Pa	63.954	44.118	19.836	2.548
Chenango River	Binghamton, N. Y	99.522	63.099	36.423	15.048
Brook	Canton, Pa	59.850	36.765	23.085	3.933
City water	Wilkesbarre, Pa	20.007	15.732	4.275	3.420
Do	do	91.827	63.783	28.044	10.260
Do	Nanticoke, Pa	39.843	29.925	9.918	3.420
Harvey Creek	do	67.887	23.940	43.947	6.840
Boyds Run	Pond Hill, Pa	48.906	36.936	11.970	3.420
Susquehanna River	Nescopeck	29.925	23.940	5.985	Trace.
Do	Danville	92.511	69.255	23.256	8.550
Do	do	134.577	77.976	56.601	12.483

WEST BRANCH OF SUSQUEHANNA RIVER BASIN.

UNDERGROUND WATERS.

At Barnesboro there are three wells, 18, 55, and 230 feet deep, respectively, which are characterized by water containing traces of iron and much calcium carbonate and magnesium sulphate. Boiler water high in solids and incrustants, but containing moderate amounts of chlorine is obtained from the 55-foot well, while the two deeper wells supply drinking water. The chlorine in the 55-foot well is low and that in the 230-foot well is moderate in quantity. One of the samples from the 230-foot well was very turbid and carried a large amount of undissolved limestone, clay, and some oxide of iron in suspension.

At Gallitzin there is a flowing well with water that contains moderate amounts of chlorine and much magnesium carbonate, and is used for boilers. Water secured from a test hole at the same place contains very little chlorine. The city water is neutral in reaction, low in solids, contains moderate amounts of chlorine, and but little magnesium and calcium sulphate, the former predominating.

A 300-foot well at Osceola supplies boiler water carrying moderate amounts of solids, incrustants, and chlorine, and much calcium carbonate and magnesium sulphate.

At Viaduct eight samples were collected from two wells, one known as the 240-foot and the other as the drilled well. The 240-foot well supplies a natural water that is almost colorless, but carries some sediment containing oxides, moderate amounts of solids and incrustants, and low chlorine contents. The analyses indicate the presence of small amounts of calcium carbonate and sulphate, magnesium sulphate, and sodium chloride. The water in the drilled well is slightly alkaline, is colored because of suspended sediment, and contains moderate amounts of chlorine, solids, and incrustants. Of five analyses each shows traces of oxides, calcium carbonates, calcium sulphate, magnesium carbonate, magnesium sulphate, magnesium chloride, alkali carbonates, alkali sulphates, and alkali chlorides.

The 900-foot well at Sizerville, in Cameron County, supplies a slightly alkaline and turbid boiler water containing very considerable amounts of chlorine, solids, and nonincrustants, and only a small quantity of incrustants. The nonincrustants are composed of sodium chloride chiefly, with a small amount of magnesium chloride and some calcium chloride, while the incrustants include some calcium carbonate, calcium sulphate, and a small amount of clay. Drinking water taken from a spring at Shippen was found to be low in solids, incrustants, nonincrustants, and chlorine. The water from two springs at Rock Run is similar in composition.

The analysis of boiler water taken from an 18-foot well at Rock Run shows very large amounts of solids, incrustants, nonincrustants, and chlorine. In its normal condition the water is slightly alkaline and clear, and contains a large quantity of calcium carbonate and magnesium chloride, with traces of oxides, magnesium carbonate, and alkali carbonates and chlorides.

A spring at Hecklin, near Gillintown, furnishes a neutral and clear water, very low in both solids and chlorine.

At Lock Haven the water drawn from the Castenea reservoir is neutral and low in solids and chlorine. It contains a little clay sediment and some calcium and magnesium sulphate.

The 24-foot McKinney well at Oakgrove supplies water with a moderate quantity of solids, incrustants, and chlorine. This is also true of a well at Stokesdale Junction which furnishes a slightly alkaline water containing some calcium carbonate and traces of alkali carbonate and magnesium chloride.

Springs at Leaches and Jersey Shore contain clear and neutral water, low in solids and chlorine, and suitable for domestic purposes.

Two wells at Ralston, 19 feet and 234 feet deep, furnish a boiler water showing moderately low amounts of solids and incrustants and moderately high amounts of chlorine.

There were a number of wells at Williamsport whose waters were analyzed. Boiler and drinking water from one of the wells contains so large a quantity of chlorine and total solids, chiefly calcium carbonate, that it is worthy of further investigation. Waters from a well 140 feet deep and from an artesian well sunk to the depth of 166 feet show moderately large amounts of solids and incrustants, and small quantities of chlorine. The above artesian well furnishes a supply of both drinking and boiler water carrying much calcium carbonate and magnesium sulphate in solution. The Williamsport city water is very low in total solids, moderately low in chlorine, and contains but little calcium and magnesium carbonate.

Analyses of underground waters obtained in the drainage basin of West Branch of Susquehanna River.

[Parts per million.]

Location.	Sources of supply.	Total residue.	Incrustants.	Nonincrustants.	Chlorine.
Barnesboro	230-foot well	446.139	400.311	45.828	6.327
Do	18-foot well	397.746	289.161	108.585	6.840
Do	55-foot well	169.461	119.700	49.761	1.026
Do	230-foot well	151.506	119.529	31.977	3.420
Gallitzin	Test hole	174.078	113.373	60.705	1.026
Do	Flowing well	162.450	109.440	53.010	8.550
Do	City water	59.850	43.947	15.903	3.420
Do	Water supply	43.605	29.925	13.680	6.840
Osceola	300-foot well	125.514	84.645	40.869	6.840
Munson		30.007	25.992	4.015	1.881
Viaduct	240-foot well	176.301	125.001	51.300	2.907
Do	do	170.316	120.555	49.761	2.907
Do	do	165.870	127.908	37.962	2.907
Do	Drilled well	170.487	114.912	55.575	6.498
Do	do	118.845	88.920	29.925	6.498
Do	do	107.901	71.991	35.910	6.498
Do	do	92.169	56.601	35.568	6.498
Do	do	78.489	22.572	55.917	6.498
Sizerville	900-foot well	1,246.077	137.313	1,108.764	616.284
Shippen	Spring	35.568	30.267	5.301	3.078
Rock Run	do	32.832	23.940	8.892	2.052
Do	18-foot well	497.097	324.216	172.881	53.523
Gillintown	Spring at Hecklin	31.977	5.903	16.074	2.052

Analyses of underground waters obtained in the drainage basin of West Branch of Susquehanna River—Continued.

Location.	Sources of supply.	Total residue.	Incrustants.	Nonincrustants.	Chlorine.
Forks	Spring	61.902	47.880	14.022	2.907
Do	Big spring	21.888	16.416	5.472	1.881
Do	do	20.007	14.022	5.985	2.907
Lock Haven	Castanea reservoir	30.780	20.178	10.602	2.394
Do	do	22.743	17.271	5.472	2.394
Oakgrove	24-foot McKinney well.	226.746	148.428	78.318	5.643
Stokesdale Junction	do	199.386	167.580	31.806	7.011
Leaches	Spring	39.843	34.884	4.959	2.052
Jersey Shore	do	33.858	21.888	11.970	3.933
Ralston	234-foot well	175.104	121.410	53.694	13.509
Do	Well	160.911	106.704	54.207	7.524
Do	19-foot well	91.143	57.114	34.029	8.892
Williamsport	Well	521.379	287.280	234.099	97.812
Do	300-foot well	218.880	140.220	78.660	
Do	140-foot well	217.854	143.469	74.385	2.907
Do		207.423	173.394	34.029	20.862
Do	Artesian well 166 feet.	201.096	126.198	74.898	3.591
Do	City water	25.650	19.665	5.985	2.993
Lewisburg	Tank	99.693	79.857	19.836	Little.

SURFACE WATERS.

Near the headwaters of West Branch of Susquehanna River, at Spangler, Barnesboro, and Cush Creek Junction, the waters analyzed are rather low in solids, incrustants, and chlorine. This holds true especially of the water used for drinking and boiler purposes at Spangler, which is neutral in reaction and contains a small amount of calcium carbonate and magnesium sulphate, besides a little clay sediment.

At Mahaffey West Branch is joined by Chest Creek, at the head of small branches of which are the towns of Carroltown and Hastings. Near the former place is located Peter Campbell's pond, containing turbid water with rather large amounts of oxides and a medium quantity of chlorine. At Hastings a tributary of Chest Creek evidently receives a large amount of material that considerably raises its contents in solids and incrustants (chiefly calcium sulphate), while the chlorine remains nearly stationary. As a result West Branch at Mahaffey is moderately high in solids and incrustants. The sample tested was found to be high in chlorine, this being possibly due to pollution by sewage from the town, as the water in the neighboring run was found to be very low in chlorine.

At Bower the water of West Branch is evidently of good quality, neutral in reaction, and low in solids and chlorine. Curwensville receives from Anderson Creek a water supply that is free from carbonates, but contains some little calcium and magnesium sulphates.

Clearfield Creek empties into West Branch of Susquehanna River below Clearfield. The water of Clearfield Creek near Smoke Run is low in solids and incrustants and shows only a trace of chlorine. It is used for both drinking and boiler purposes, and is of excellent quality. At the creek dam, on the other hand, the water used for steam-generating purposes was found to be high in solids and incrustants, and showed a moderate amount of chlorine, together with much carbonate and sulphate of lime, magnesia, and iron. At Belsena the water of Clearfield Creek varies within rather large limits, and contains from a very low to a moderately large quantity of solids (sulphates of lime, magnesia, and iron), incrustants, and chlorine. Pine Run at Belsena is very low in all of these constituents.

At Clearfield Bridge Clearfield Creek is joined by Little Clearfield Creek, on which are located the towns of Kerrmoor and Porters. At these towns the water is neutral in reaction. It contains very moderate amounts of chlorine, solids, and incrustants at Kerrmoor, and small amounts at Porters, the difference being probably largely due to suspended sediment.

At and near Clearfield a large number of water samples were collected from various places on West Branch, and from Clearfield, Moose, and Montgomery creeks. The town supply of Clearfield and the water from Moose and Montgomery creeks are very low in solids, incrustants, and chlorine, thus indicating a very good quality of potable water. There were found present in the water, which has a neutral reaction, only traces of the following constituents: Iron and aluminum oxides, calcium and magnesium sulphates, magnesium carbonate, and the chlorides and sulphates of the alkalies. Directly at the inlet on West Branch of Susquehanna River the solids and incrustants were found to be large in quantity and the chlorine content extremely high, indicating a condition worthy of serious investigation. The river at the time of sampling was very low, however, and the water was turbid in appearance. It is significant that the analyses show a considerable quantity of magnesium chloride and sulphate besides a large amount of the alkaline chlorides.

Nearly all the numerous other samples of waters from Clearfield Creek and West Branch of Susquehanna River, especially at the first and second dams near Clearfield, show moderate amounts of solids, such as lime and alkali sulphates, and a little calcium and magnesium carbonate, a neutral reaction, and moderately large amounts of chlorine.

Moshannon Creek rises above Osceola, flows past Philipsburg, Munson, and Viaduct, and empties into West Branch of Susquehanna River above the town of Karthaus.

At Osceola the water of Moshannon Creek used in boilers is very high in chlorine and solids, the sulphates of lime, iron, and magnesia constituting the incrustants. The drinking water of Osceola is obtained from Mountain Branch, is low in solids, and contains only moderate amounts of chlorine. At Philipsburg the city water and the water of Cold Stream are low in solids, incrustants, and chlorine, and are evidently neutral waters of good quality, while the water obtained from Moshannon Creek was found to be moderately high in solids and chlorine and to contain large amounts of sulphates, probably due to the inflow of acid mine waters. At Viaduct the water of Moshannon Creek has an acid reaction, is high in solids, and contains a large amount of calcium and iron sulphates.

The water of Upper Three Run below Karthaus is low in solids, incrustants, and chlorine.

Bennett Branch and Driftwood Branch flow into Sinnamahoning Creek, which, in turn, empties into West Branch of Susquehanna River at Keating. The towns of Tyler, Caledonia, and Benezett, located on Bennett Branch, all secure good potable water from this stream. The samples tested gave a neutral reaction, were low in solids and incrustants, and moderately low in chlorine. This is also true of the water supply of Emporium, on Driftwood Branch, and Driftwood, on Sinnamahoning Creek.

At Keating the water of Jewels Run is clear, neutral in reaction, free from carbonates, and contains only traces of oxides and sulphates of the alkalies, calcium and magnesium. It is very low in solids and moderately low in chlorine.

Near Renovo, Drury Run and Paddy Run empty into West Branch. Every sample of the waters of the streams analyzed shows very low contents in solids, incrustants, and chlorine, has a neutral reaction, and contains but a small quantity of sulphates and sediment. The water of these streams is excellent for drinking and steam-generating purposes.

Beech Creek passes the towns of Forks and Beech Creek, and near the latter place empties in Bald Eagle Creek, which in turn empties into West Branch of Susquehanna River below Lock Haven.

The waters of Beech, Bald Eagle, and Canoe creeks at or near Beech Creek show moderate to rather large quantities of solids and incrustants and moderate contents in chlorine. At Beech Creek, when the stream was low, it was found to be strongly acid, possibly due to acid waters from the wood-alcohol works in this neighborhood, and to contain calcium and magnesium sulphate, but no carbonates. Bald

Eagle Creek, on the other hand, was alkaline in reaction and contained calcium and magnesium carbonates, while Canoe Creek carried a neutral water, even at a low stage. At Lock Haven, Bald Eagle Creek, while not much higher in solids (principally calcium carbonates) than at Beech Creek, showed a considerable increase in chlorine.

At Oak Hall station, near the head of one of the smaller branches of Bald Eagle Creek, the water is rather high in solids and moderately low in chlorine. At Bellefonte the city and station water supply is moderately high in chlorine and solids, principally carbonate of lime, carbonate of iron, and sulphate of magnesium.

Pine Creek rises in Potter County and flows east and south past Cedar Run, Cammal, and Ramsey station into West Branch of Susquehanna River near Jersey Shore Junction. Near Ansonia it is joined by Marsh Creek, which rises near Wellsboro. Marsh Creek at Wellsboro is moderately low in solids, incrustants, and chlorine, and is generally characterized by a neutral reaction and clear appearance. The water of the run at Stokesdale Junction and of Marsh Creek at Marshcreek has a slightly alkaline reaction, is dark, owing to coloration by organic matter, and contains also a moderately high quantity of chlorine and carbonate of lime. Darling Run, near Ansonia, is clear in appearance, neutral in reaction, and low in chlorine and solids. The stream at Antrim is neutral and low in solids and chlorine, while the water taken from the pond at the same place, which receives drainage from a charcoal iron furnance and wood-alcohol distillery, is naturally considerably higher in all of these constituents, excepting chlorine. The latter constituent is only increased by a moderate amount. The water in the pond carries much calcium carbonate and magnesium sulphate in solution. The water of Jacob Run at the town of Cedar Run and the water of Ramsey Run at the station of the same name are clear, neutral in reaction, and low in solids and chlorine, while samples of water taken from the stream at Cammal are similar in composition, except higher contents in chlorine. Both West Branch and Pine Creek near Jersey Shore Junction are clear, neutral in reaction, moderately low in solids, and contain moderate amounts of chlorine.

Lycoming Creek starts at Penhryn and flows in a generally southerly direction by Ralston and Trout Run into West Branch of Susquehanna River above Williamsport. Red Run at Ralston contains moderate amounts of solids and chlorine, while Rock Run at the same place is somewhat lower in these constituents. The water of Red Run is peculiar in that it carries a considerable quantity of a red sediment in suspension, is acid in reaction, and contains hydrogen sulphide besides considerable sulphate of lime and magnesia. Lycoming Creek at Trout Run furnishes an excellent potable water, which is neutral in reaction, free from all turbidity and sediment, and low in dissolved solids and chlorine.

Below Lock Haven are the towns and cities of Youngdale, Oakgrove, Jersey Shore, Newberry Junction, Williamsport, Dewart, Watsontown, Lewisburg, and Northumberland, the surface waters of which will be discussed in the order given.

The water of McElhattan Creek at Youngdale is neutral, low in solids, and moderately low in chlorine. At Oakgrove the waters of West Branch of Susquehanna River and Pine Creek contain moderate amounts of solids, but rather high chlorine contents, and the city supply is low in solids and chlorine and possesses a slightly alkaline reaction.

At Newberry Junction the water supplied to the city, while neutral in reaction and not carrying more than moderate quantities of solids, is high in chlorine. This water posssibly needs further investigation to ascertain if it is not contaminated by sewage.

At Dewart the waters of Delaware Run and of the stream 2 miles west of the town are very much like those of West Branch of Susquehanna River at Watsontown, and contain exactly the same quantity of chlorine, which is present in moderately large amounts. The solids and incrustants are not very large in quantity. While some of the samples are free from carbonates and contain only sulphates, they usually carry but small amounts of the latter and much combined carbonic acid.

At Northumberland, finally, the water of West Branch of Susquehanna River, used for municipal purposes by the city and as a source of boiler water, is neutral in reaction, carries a little sediment, and contains some calcium carbonate and magnesium sulphate, besides a moderate amount of chlorine.

Analyses of surface waters obtained in the drainage basin of West Branch of Susquehanna River.

[Parts per million.]

Location.	Source of supply.	Total residue.	Incrustants.	Nonincrustants.	Chlorine.
Spangler	Tank	116.622	85.500	31.122	6.840
Do	Water supply	67.716	53.865	13.851	2.565
Do	Stream	83.790	68.724	15.066	1.539
Cherry Tree	Killen Run	76.095	55.746	20.349	2.565
Carroltown	Peter Campbell's pond	161.595	139.536	22.059	8.037
Cush Creek Junction.		65.151	52.497	12.654	3.078
Hastings		537.966	343.539	194.427	3.591
Mahaffey	West Branch Susquehanna River.	159.543	99.693	59.850	20.862
Do	Run	33.858	25.992	7.866	2.907
Do	do	23.940	14.022	9.918	1.881

Analyses of surface waters obtained in the drainage basin of West Branch of Susquehanna River—Continued.

Location.	Source of supply.	Total residue.	Incrustants.	Nonincrustants.	Chlorine.
Bower	West Branch Susquehanna River.	74.727	55.917	18.810	3.933
Do		55.917	45.828	10.089	3.933
Do	Hazletts Run	35.055	23.940	11.115	2.052
Kerrmoor	Little Clearfield Creek	155.610	105.678	49.932	7.011
Porters		33.858	23.940	9.918	2.907
Curwensville	Anderson Creek	39.672	29.070	10.602	6.840
Clearfield	West Branch, directly at inlet.	481.707	116.793	364.914	196.137
Do	Clearfield Creek	187.416	111.663	75.753	5.985
Do	do	186.903	137.826	49.077	10.944
Do	River at dam	107.730	69.768	37.962	11.970
Do	Tank	119.700	79.857	39.843	11.970
Do	West Branch Susquehanna River.	112.689	77.805	34.884	14.022
Do	Second dam breast	103.626	67.203	36.423	15.903
Do	River	95.760	61.902	33.858	11.970
Do	Moose Creek, 2,000 feet from mouth.	41.382	21.888	19.494	4.617
Do	City supply	17.100	11.970	5.130	2.907
Do	Moose and Montgomery creeks.	16.416	13.851	2.565	2.394
Do	Town supply	15.732	13.509	2.223	2.052
Clearfield Junction.	Creek	167.580	108.756	58.824	7.011
Woodland		61.902	47.880	14.022	4.959
Summit	Little Spring Branch	79.857	23.940	55.917	34.884
Belsena	Clearfield Creek	169.461	112.518	56.943	13.680
Do	Pine Run	29.925	20.007	9.918	Trace.
Do	Clearfield Creek	49.932	39.843	10.089	Trace.
Smoke Run	Creek dam	771.723	612.693	159.030	6.840
Do	Stream	67.716	59.850	7.866	Trace.
Osceola	Moshannon Creek	364.059	234.954	129.105	29.070
Do	Small Creek	60.192	43.947	16.245	6.840
Do	Mountain Branch Creek	43.947	24.795	19.152	6.840
Philipsburg	Moshannon Creek	279.243	233.415	45.828	13.680
Do	do	187.759	110.808	76.951	4.788
Do	City water (Water Co)	37.962	26.505	11.457	3.933
Do	Reservoir of Citizens' Water Co.	29.925	19.494	10.431	3.933
Do	Cold Stream	33.858	27.873	5.985	2.052
Viaduct	Moshannon Creek	339.093	193.401	145.692	9.918
Do	Run	29.925	23.940	5.985	2.052

Analyses of surface waters obtained in the drainage basin of West Branch of Susquehanna River—Continued.

Location.	Source of supply.	Total residue.	Incrust-ants.	Nonin-crustants.	Chlorine.
Tyler, Clearfield County.		66.177	57.627	8.550	4.959
Caledonia		24.795	15.732	9.063	4.959
Benezett		29.583	20.007	9.576	4.446
Emporium		45.144	34.713	10.431	4.959
Driftwood		38.988	27.531	11.457	4.959
Keating	Jewels Run	17.955	11.970	5.985	5.130
Renovo	Drury Run	30.609	25.479	5.130	2.052
Do	do	23.940	16.074	7.866	2.052
Do	do	23.940	15.903	8.037	2.052
Do	do	22.743	18.810	3.933	2.052
Do	Paddy Run	39.843	31.977	7.866	6.840
Do	do	23.940	17.955	5.985	Trace.
Do	do	20.007	14.022	5.985	Slight.
Do	Reservoir	24.282	17.955	6.327	3.420
Do	Pennsylvania R. R. reservoir.	23.940	15.903	8.037	Trace.
Rock Run		17.955	13.851	4.104	3.933
Karthaus	Upper Three Run	34.029	24.111	9.918	3.984
Saltlick, near Karthaus.	Run	29.925	25.992	3.933	2.052
Beech Creek	Beech Creek	237.348	129.618	107.730	3.933
Do	Bald Eagle Creek	144.495	119.700	24.795	3.933
Do	Canoe Creek	55.917	43.947	11.970	3.933
Oak Hall	Water station	254.106	218.880	35.226	4.446
Do	Stream	199.386	171.855	27.531	Very little.
Bellefonte	Water station	145.179	115.083	30.096	0.944
Do	City water	131.499	108.243	23.256	11.457
Howards	West Creek	82.935	55.062	27.873	4.959
Lock Haven	Bald Eagle Creek	186.903	147.060	39.843	17.100
Youngdale	McElhattan Creek	29.925	20.007	9.918	3.933
Oakgrove	West Branch Susquehanna River.	89.262	62.928	26.334	6.840
Do	Pine Creek	73.872	42.921	30.951	10.944
Do	City supply	39.843	26.163	13.680	1.026
Wellsboro	Stream	79.857	65.835	14.022	2.907
Do	do	67.887	47.880	20.007	4.959
Stokesdale Junction.	Run	121.581	79.857	41.724	9.918
Do	Marsh Creek	101.574	81.738	19.836	6.327
Ansonia	Darling Run	71.820	55.917	15.903	2.907

Analyses of surface waters obtained in the drainage basin of West Branch of Susquehanna River—Continued.

Location.	Source of supply.	Total residue.	Incrustants.	Nonincrustants.	Chlorine.
Blackwell	Run	37.962	31.977	5.985	2.907
Antrim	Pond receiving drainage from charcoal iron furnace and wood-alcohol distillery.	205.371	155.610	49.761	3.420
Do	Stream	39.843	23.940	15.903	2.907
Cedar Run	Jacob Run	31.977	23.940	8.037	2.052
Cammal	Stream	79.857	69.768	10.089	7.011
Ramsey	Ramsey Run	22.914	17.955	4.959	2.052
Jersey Shore Junction.	Pine Creek	61.902	35.910	25.992	11.970
Do	West Branch Susquehanna River.	58.824	41.895	16.929	7.011
Newberry Junction.	City	73.872	53.865	20.007	14.364
Penhryn	Pond	59.679	44.631	15.048	Not given.
Ralston	Red Run	116.622	62.244	54.378	5.130
Do	do	83.790	34.200	49.590	4.446
Do	Rock Run	30.780	18.126	12.654	4.446
Trout Run		19.665	13.338	6.327	2.907
Dewart	Delaware Run	116.109	87.552	28.557	7.011
Do	Stream 2 miles west	48.393	29.925	18.468	7.011
Watsontown	Stream at Ridge	153.387	123.291	30.096	7.011
Do	Reservoir	128.763	101.403	27.360	7.011
Do	West Branch Susquehanna River.	80.028	52.668	27.360	7.011
Northumberland	do	78.831	54.720	24.111	4.446
Do	do	76.950	53.523	23.427	4.446

JUNIATA BASIN.

UNDERGROUND WATERS.

At Martinsburg, located near the headwaters of the Piney and Clover Creek branches of Juniata River, is a 12-foot well from which boiler water is obtained showing rather large amounts of dissolved solids, incrustants, and chlorine. The water, which is not acid in reaction, contains considerable calcium and magnesium sulphate and some little iron.

At Altoona water for both drinking and boiler purposes is obtained from a large number of wells sunk to various depths up to 2,000 feet. The best water, to judge from the analytical data submitted, is obtained from a 2,000-foot artesian well, which contains but a trace of chlorine and some calcium carbonate in solution, with a little magnesium carbonate and sulphate, and from the well of the American Brewing Company, which contains in solution but a small amount of salt and total solids, of which the greater part is magnesium sulphate.

There is a well 187 feet deep at the Altamont Hotel, Altoona, from which two samples of boiler and drinking water were collected, the first of which shows a slightly acid water, comparatively low total solids, incrustants, and chlorine, while a second sample, obtained but a week later, is very high in all of these constituents and might be considered dangerous for drinking purposes and to warrant investigation of the condition of this well. The second sample of water showed a slightly alkaline reaction, was slightly turbid, and contained magnesium chloride and calcium carbonate.

The analyses of the waters of other wells at Altoona, ranging in depth from 24 to 85 feet, show from moderate to rather high contents in solids, incrustants, and chlorine, the salts found being chiefly calcium carbonate and to a lesser extent magnesium sulphate. Some of these wells furnish drinking as well as boiler water, while the rest are used as a source of water supply for locomotives.

An 8-foot well at Tyrone shows water containing rather large amounts of solids and chlorine in solution, with much calcium and magnesium sulphates and a little free carbonic acid. It is used for both drinking and boiler purposes.

At Lewistown Junction there is a well from which both drinking and boiler water is obtained. The water is low in chlorine, alkaline in reaction, and moderately high in solids—chiefly magnesium sulphate and calcium carbonate.

A consideration of the analyses of samples of water from various sources of supply that can not be classified accurately or separately under the above heads of streams, wells, and springs leads to the following conclusions:

The city water of Altoona is slightly acid in reaction, contains a small amount of total solids and chlorine, with some iron, calcium, and magnesium sulphate. A like quality is shown by the water at Kittanning Point, which is drawn from the Altoona water supply.

The city water of Tyrone and boiler water at the Pennsylvania Railroad station at that place is of good quality and contains but a small amount of calcium and less of magnesium sulphate and no carbonates.

The boiler water obtained in East Tyrone is higher in solids than the former and contains some calcium carbonate and a small amount of sediment.

The city water supply of Martinsburg, Pa., is apparently excellent in quality. The water does not carry more than a trace of chlorine, is very low in solids, slightly acid (probably due to a trace of sulphates), and shows a little iron in solution. The boiler water secured at the Martinsburg railroad station is higher in all of the above constituents except the iron.

Analyses of water of the Lewistown reservoir and of the railroad water stations at Henrietta and Roaring Spring show the samples to be of the average composition of Pennsylvania waters, sulphates and carbonates of the alkaline earths constituting the principal incrustants.

SURFACE WATERS.

The spring furnishing water used in boilers by the Pennsylvania Railroad at Kittanning Point does not contain more than a very small quantity of salts in solution, the latter being calcium and magnesium sulphate and sodium chloride. This water is evidently of very good quality for the purpose for which it is employed and is also adapted for municipal use generally.

The analysis of spring water obtained at Altoona shows small amounts of total solids and probable incrustants with a medium amount of chlorine. Both calcium sulphate and magnesium chloride are found in this water, which is used in boilers by the Pennsylvania Railroad.

Winnemier's spring, at Sprucecreek, furnishes boiler water showing rather small amounts of solids and incrustants in solution and a medium quantity of saline matter. Calcium sulphate is the chief incrustant present.

At Huntingdon, on Juniata River, several springs, large and small, are found near the reformatory. Upon analysis they average from a small to a moderately large quantity of residue and incrustants, and, with one exception, show only traces of chlorine. Small quantities of calcium and iron carbonates and sulphates are present, but not in sufficent amount to prevent the use of the above water for drinking as well as for generating steam.

At Hollidaysburg, on the headwaters of Little Juniata River, one of the branches of Juniata River, the water from the Little Juniata shows medium amounts of residue after evaporation and of incrustants and chlorine, and in general composition would be classified with the average stream water found in Pennsylvania. Although somewhat high in calcium sulphate, apparently, and also slightly acid, it is regularly used in boilers by the Pennsylvania Railroad.

At Altoona, judging by samples taken both above and below Fountain Inn, the river water is soft, leaves little residue upon evaporation, and is low in incrusting compounds and chlorine. It is neutral in reaction, only slightly turbid, and is advantageously used for both drinking and steam-generating purposes.

Analyses of water from Little Juniata River at Tyrone, Pa., show medium to rather large amounts of total residue and incrustants and somewhat high average contents in chlorine. In most of the samples tested the water is neutral in reaction, although occasionally alkaline, in which case it is also found to be high in calcium carbonate. Frequently calcium and magnesium sulphates are present in large amounts. This water is evidently not considered potable and is only used in boilers.

Farther down Little Juniata River, at Barree, on the Pennsylvania Railroad, very good soft water is again found, the analysis of the stream at this town showing very small amounts of total solids, probable incrustants, and chlorine. This water is employed for both drinking and steam-generating purposes, for which it is certainly well adapted.

At Lewistown, on Juniata River, the water of Kishacoquillas Creek was found to be hard and to contain large amounts of residue upon evaporation, together with large quantities of probable incrustants, but only small amounts of chlorine. The incrustants comprise chiefly clayey matter and calcium carbonate, while the principal nonincrustant appears to be magnesium sulphate. The above water is used for drinking purposes as well as in boilers.

Analyses of water from the drainage basin of Juniata River.

[Parts per million.]

Source of supply.	Total residue.	Incrustants.	Nonincrustants.	Chlorine.
STREAMS.				
Lewistown (Kishacoquillas Creek)	580.374	536.427	43.947	3.420
Barree	21.204	14.706	6.498	2.907
Tyrone (Little Juniata River)	127.566	76.779	50.787	Considerable.
Tyrone (Juniata River)	379.962	285.912	94.050	31.635
Tyrone (stream at water station)	143.127	111.321	31.806	5.985
Tyrone (river at water station)	146.547	114.228	32.319	11.970
Altoona (stream above Fountain Inn)	42.237	34.371	7.866	2.907
Altoona (stream below Fountain Inn)	40.869	31.464	9.405	2.907
Hollidaysburg (Little Juniata River)	129.618	93.708	35.910	6.840
SPRINGS.				
Huntingdon (springs at reformatory)	29.925	27.189	2.736	Trace.
Huntingdon (spring at reformatory)	169.461	159.543	9.918	3.420
Huntingdon (large springs at reformatory)	29.925	27.873	2.052	Trace.
Huntingdon (small springs at reformatory)	41.895	33.858	8.037	Trace.
Altoona	49.932	30.267	9.665	7.011
Sprucecreek (Winnemier's spring)	63.954	30.951	33.003	6.840
Kittanning Point	24.966	11.970	12.996	3.420

Analyses of water from the drainage basin of Juniata River—Continued.

Source of supply.	Total residue.	Incrustants.	Nonincrustants.	Chlorine.
WELLS.				
Altoona (American Brewing Co.)	42.408	28.899	13.509	3.420
Altoona (Mackey House)	503.424	250.344	253.080	71.820
Altoona (well at Eighteenth street)	227.772	162.621	65.151	20.520
Altoona (well at Nineteenth street)	325.071	239.400	85.671	27.873
Altoona (well at car shop, 24 feet)	276.938	237.177	39.761	17.442
Altoona (well, 84 feet)	236.322	178.524	57.798	11.970
Altoona (artesian well, 85 feet, Ninth avenue)	207.423	174.420	33.003	13.680
Altoona (well, 187 feet, Altoona Hotel)	692.892	406.638	286.254	112.689
Do	75.411	45.144	30.267	5.472
Altoona (artesian well, 2,000 feet)	179.550	119.700	59.850	Trace.
Lewistown Junction	389.880	241.110	148.770	3.078
Tyrone (well, 8 feet)	346.617	220.932	125.685	42.750
Martinsburg (12-foot well)	414.504	161.424	253.080	46.512
NOT CLASSIFIED.				
Altoona (city water)	76.266	43.263	33.003	4.959
Kittanning Point (Altoona water supply)	84.987	49.077	35.910	6.840
Tyrone (city water)	38.133	27.873	10.260	3.420
Tyrone (water station)	42.408	31.635	10.773	5.985
East Tyrone (water station)	114.570	82.080	32.490	29.925
Martinsburg (city supply, mountain reservoir)	25.821	15.903	9.918	Trace.
Martinsburg (water station)	249.318	198.360	50.958	2.394
Lewistown (reservoir)	211.356	179.550	31.806	7.011
Henrietta (water station)	56.772	40.869	15.903	6.840
Roaring Spring (water station)	109.611	103.113	6.496	2.394

SUSQUEHANNA RIVER BELOW SUNBURY.

At Sunbury, Pa., located near the junction of West Branch and Susquehanna River, a soft water is used for drinking and other purposes. It contains but a trace of sediment, chiefly clay and iron, and a little calcium sulphate and sodium chloride.

Below Sunbury the first town is Millersburg, the water of which is about the same in quality as that of Sunbury. This is also true of some samples of water at Clarks Ferry, although others taken at the same place are moderately high in total solids and in chlorines, with a neutral or slightly acid reaction.

Rockville water is soft in character and low in solids, incrustants, and chlorine. At West Fairview, both on Susquehanna River and at Conedogwinet Creek, the drinking and boiler water used is appreciably higher in solids, incrustants, and chlorine, and contains a small amount of sediment.

The water of Susquehanna River at Enola is low in total solids, incrustants, and chlorine, is neutral in reaction, with a trace of sediment, and contains some carbonates and sulphates of lime and magnesia. In general it is of fairly good quality.

At Harrisburg the city water shows but very little chlorine upon careful analysis, slight turbidity, little magnesium sulphate, more calcium carbonate, and a little calcium sulphate and iron. At the roundhouse tap the water is moderately high in chlorine and in dissolved carbonates and sulphates of lime, magnesia, and iron. It reacts slightly alkaline after being boiled.

At New Cumberland the water is moderately high in dissolved solids and chlorines and contains but a very small amount of nonincrustants. Similar conditions hold true with the waters of Shenks Ferry, which are neutral in reaction.

The water in the canal at Harrisburg is decidedly acid in reaction, due to the presence of considerable sulphuric acid or sulphates, probably combined with some lime and a little magnesia and iron. The total solids are moderate in quantity and the chlorine contents moderately high.

At Lucknow, near Harrisburg, are some swamp springs which furnish neutral water for boiler and drinking purposes and are of average composition, excepting the moderately high contents in chlorine. Some magnesium sulphate and calcium carbonate with traces of organic matter were detected in this water.

Analyses of water from the drainage basin of Susquehanna River below Sunbury.

[Parts per million.]

Source of supply.	Total residue.	Incrustants.	Nonincrustants.	Chlorine.
STREAMS.				
Sunbury (city water)	55.404	45.315	10.089	3.933
Millersburg	62.415	47.709	14.706	3.933
Clarks Ferry	42.066	32.490	9.576	4.959
Do	251.712	150.309	101.403	5.985
Do	213.066	170.316	42.750	12.825
Rockville	53.010	44.460	8.550	3.420
West Fairview	101.916	73.359	28.557	7.011
West Fairview (Conedogwinet)	188.100	148.428	39.672	4.446
Enola	82.935	63.441	19.494	3.933
Harrisburg (city water)	115.767	89.775	25.992	(a)
Harrisburg (roundhouse tap)	174.762	139.878	34.884	5.985
Harrisburg	207.423	162.108	45.315	8.379
New Cumberland (city water)	131.670	127.737	3.933	7.011
New Cumberland (Kauffman's store)	135.774	126.711	9.063	4.446
Columbia (Pennsylvania R. R. reservoir)	123.633	94.221	29.412	6.840
Shenks Ferry	98.667	90.288	8.379	3.933
CANAL.				
Harrisburg	159.543	117.990	41.553	6.840
SWAMP SPRINGS.				
Lucknow (near Harrisburg)	135.090	108.585	26.505	8.208

a Very little.

SUMMARY.

The value of Susquehanna River as a resource to the inhabitants of the important area which it drains is without question. It has been noted in previous pages that the character of the water in the main stream is markedly variable, while as a whole that of the tributaries is quite satisfactory. The part of the stream which flows through New York is extensively used as a source of water supply, but as it leaves the northern anthracite coal basin in Pennsylvania its usefulness in this line of development is somewhat limited. It has been demonstrated by the water department of the city of Harrisburg that by reason of its peculiar character the water is exceedingly difficult of satisfactory purification.

It has been noted that the pollution of rivers by acid mine refuse is not without certain advantages. This does not mean, however, that such pollution is in the end beneficial, yet from the standpoint of public-water supply it is not as dangerous as the pollution which is freely poured into the stream from city sewers. Acid mine waste is certainly harmful to the resources of any stream, and it is doubtful if a stream so polluted could be used as a domestic water supply with satisfaction. Susquehanna River water could not, however, be used in its raw state for household purposes if no mine drainage was turned into it. This being the case the bad effects of mine drainage which are readily apparent in the small tributaries running from the coal regions, are not important in the main stream, for as shown on previous pages there the effects are altogether beneficial. Stated in another way, it may be said that acid mine drainage does great damage to a water-supply stream, but is of undoubted benefit in a stream which has been converted into a depository for sewage. These benefits are, however, somewhat limited. The precipitation of immense quantities of sewage matter and coal dust will eventually fill up the bed of the river along certain reaches and in the end be troublesome. In fact, the effects are already apparent in some sections.

It is probable that Susquehanna River, especially that portion below West Branch, is of more value as an agent of sewage disposal than it would be if attempts were made to purify it. It would be impossible, with the present large population upon the drainage area, to render the great stream pure; this being the case, it might as well receive city sewage up to a certain limit. The size of the stream and the purifying effect of acid mine waste make it extremely unlikely that the population along the river will increase enough to render the river a nuisance and a damage to realty values. Almost the only serious problem, with reference to the main stream, which presents itself at the present time is that of the disposal of culm from the coal washeries. Although this material has been turned into the stream during a comparatively short period only, its damaging effects are already apparent; therefore it is not difficult to foresee what will transpire in the future if steps are not taken to dispose of it in some other manner. Not the least important feature in this consideration is the enormous waste of material which may at some time in the future be a marketable product.

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