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CHARLES D. WALCOTT, DIRECTOR

SEWAGE POLLUTION

IN THE

METROPOLITAN AREA

NEAR NEW YORK CITY

AND

ITS EFFECT ON INLAND WATER RESOURCES

BY

MARSHALL ORA LEIGHTON

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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., May 24, 1902.

SIR: I have the honor to transmit herewith a manuscript by Mr. Marshall O. Leighton, relating to sewage pollution in the metropolitan area, and to request that it be published in the series of Water-Supply and Irrigation Papers. In an investigation of the water resources of the country it becomes necessary in the thickly settled portions to give consideration not merely to the quantity of water and its fluctuations, but also to the quality, and to the changes that are taking place owing to the presence of various industries.

The best methods of utilizing the water resources of the country are dependent not only upon geologic and topographic features, but also upon what has been termed cultural conditions, the latter embracing all of the changes brought about by man. The accompanying discussion by Mr. Leighton relates to a portion of the most thickly settled part of the United States, and shows that water resources may be so misused that streams which in their natural condition were useful and attractive may be rendered obnoxious and made sources of loss to the community.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

HON. CHARLES D. WALCOTT,
Director United States Geological Survey.

SEWAGE POLLUTION IN THE METROPOLITAN AREA NEAR NEW YORK CITY AND ITS EFFECT ON INLAND WATER RESOURCES.

By Marshall O. Leighton.

NORMAL WATERS.

In a primeval country, undisturbed by the advance of civilization, where there are no houses, barns, or factories, the water that flows from a drainage basin may be said to be normal. This, however, does not mean that the water is chemically pure. The water of precipitation or rainfall, which is the origin of all surface waters, takes three courses, the proportion carried along each depending upon many physical characters and conditions. There is, first, that which is evaporated or absorbed by vegetation; second, that which runs off the ground directly into water courses; and third, that which sinks into the ground and reappears in various well-known ways after having filtered through the earth.

The character of the water is markedly influenced by the ingredients which it takes up along these courses, and therefore chemically pure water is seldom found in nature. Water that runs along the earth's surface directly into natural water courses carries in suspension a large quantity of fine particles which lie in its way—vegetable matter in a state of complete disintegration, organic matter in various stages of oxidation, minute particles of sand and mineral matter from the earth, and large quantities of silt. On the other hand, water that sinks into the ground leaves behind, in the majority of cases, these suspended particles, but when it reappears it carries in solution the soluble mineral constituents of the earth through which it has passed, and, if it then contains any dissolved organic matter it is usually in an advanced state of oxidation. Water thus discharged from drainage areas is by no means uniform in composition, nor is it of the same nature in the same area during a series of examinations. Run-off water varies in character according to the amount of precipitation, the season of the year and consequent state of vegetation, the extremes of temperature, the nature and slope of the surface of the land, and many other physical conditions, varying familiarly from season to season. During the season of copious rains it is observed that water from a drainage area carries along more sediment than during seasons of normal precipitation, and analysis would show that the organic matter contained in the water is in larger proportion. At the close of the warm season, during which vegetation has been flourishing, there is much less decayed and dried vegetable matter to be carried along than during the spring season, after the winter has destroyed the tender growth of the previous summer. Again, during the warm season there is a larger proportion of precipitation absorbed by vegetation and evaporated. The season is also a factor in determining the condition of water in countries in which snow covers the ground for a part of the year. During the time of snow the water which during warm seasons would be immediately diverted to its accustomed channels is retained upon the surface of the earth, to be evaporated by prevailing winds or to be melted quickly upon the approach of spring.

The slope and the nature of the surface of the land are important factors in determining the character of surface waters. Where surfaces are steep and smooth a large proportion of water runs directly into streams, and with it a great amount of sediment, while upon most flat surfaces nearly all the precipitation not directly evaporated sinks into the ground. Between the steep, smooth surfaces and the flat ones there are many gradations, each having its effect upon the final content of run-off water.

Distance from the ocean is another factor influencing the character of water. This has been the subject of an extended series of investigations by the Massachusetts State board of health, and later by other bodies, both corporate and private. It is found that the amount of chlorine is highest at coast points, and as we recede farther and farther inland the proportion in normal waters grows correspondingly smaller, so that it is possible to trace upon the map of a country the lines of uniform normal chlorine in much the same manner that lines of equal altitude are traced upon a topographic map.

The state of preservation of the forests of a country exerts an influence of great importance upon the character of surface waters and upon the flow of streams. In the absence of trees there is less absorption of rain water by the ground and a correspondingly larger proportion is carried directly into the water courses with a greater amount of sediment, so that a drainage area that has been largely denuded of trees is subject to greater variation of stream flow and more frequent freshets than is an area that is in large part covered by forests. On denuded areas there is less evaporation, and ultimately the whole character of the surface may be so changed by loss of vegetation and extensive erosion that the immediate run-off water may comprise almost the entire precipitation.

Having reviewed the more important conditions and influences that affect the character of normal water, let us consider the economic value of water to the community. Intercepted and stored in reservoirs it has become indispensable to large communities for domestic and manufacturing uses; from prehistoric times large rivers have been used as avenues of transportation; as motive power water has been used for ages; vast harvests of ice are gathered from the surface of Northern rivers; in arid countries water finds extensive use in irrigation; it may be the source of food supply through fisheries, and its presence in a country is valuable from a purely æsthetic point of view, lakes and fountains forming a natural nucleus for parks, resorts, and places of rest and recreation.

POLLUTED WATERS.

When, however, man makes his abode in any area and carries on his normal life, the water draining that area soon assumes characters which it had hitherto not possessed. It now contains the products of excretions of man and of the domestic animals that accompany him, and the amount of change in the character of the water depends entirely upon the number of people and their pursuits. In the beginning pollution is indirect, but with social and commercial progress come modern improvements, and eventually the public sewer is laid to the nearest and most convenient body of water. This is the natural course, and in inland municipalities there may be developed in the course of time a system of sewerage conducting such a volume of city waste that the largest river on the globe can not dilute it sufficiently to disguise its presence. Let us consider briefly whether water so polluted can be applied to all of the uses to which normal waters have been found applicable.

Many American cities have been taught by dear experience that it is fatal to provide polluted waters for household purposes. Lowell and Lawrence, Newark and Jersey City, Albany, Pittsburg, Louisville, Cincinnati, and many other cities have profited by that experience. Philadelphia has just shaken off the lethargy of decades and is now preparing to filter the refuse of municipalities on the upper Schuylkill and Delaware. Other cities have their lesson yet to learn, but each will probably learn it only when its group of mourners has become large enough to demand attention. With childlike faith the city of Albany, reassured by the advice of an eminent chemist, established its water intake in the cesspool of the Hudson. Yet after a few years, during which many lives were lost in the ravages of water-borne disease, it constructed one of the most extensive filters in the country, at a cost of half a million dollars. He who says that a polluted river will purify itself in the course of several miles reckons with an unknown force which will probably fail him at the critical time.

The same conditions and statements apply to ice. Although recent work seems to show that the germs of typhoid fever do not remain intact in ice as long as was formerly supposed, there is yet but little evidence obtained concerning the bacteria of other water-borne diseases. Irrespective of disease organisms, the use of ice from polluted waters in our houses and markets is abhorrent and will not be tolerated.

As a rule, the presence of pollution in water used for irrigation is not a detriment. On the contrary, it may be an aid to vegetation, although the manurial value of sewage is not so great as is popularly supposed.

The use of water for power is not usually affected by pollution, although in some cases mill ponds have become grievous nuisances on account of the storage of pollution from a municipality above. In certain kinds of manufacturing, however, pure water must be used, and in such cases the use of polluted water from a neighboring stream is prohibited, so that an added expense is necessitated for another supply and the value of the near-by stream is diminished.

A single stream very seldom—almost never—embraces all of the uses enumerated above. If the waters are navigable to any extent there can be no power sites, nor can the "raw" water be used for public supply, and only seldom is the ice which it bears a wholesome product. If, on the other hand, waters are to be conserved for power or for public supply, it will be impossible to use them for traffic. If a stream which is not navigable is polluted, it may be, if the pollution be extensive, that the water will be rendered unfit for any purpose whatever; for, transportation or ice cutting being precluded by the physical conditions, we have only irrigation, power, and public supply remaining. Of these three the last may be entirely cut off, the second may be modified, and only the first may remain practically intact. As irrigation is important only in the dry areas of the West, this asset does not apply in the remainder of the country, and so we find that in many cases the entire value of a stream may be lost through pollution.

Extensive pollution unfits a river for a nucleus for park areas. Deposits of filth upon the banks of streams make noxious odors and render such places undesirable as dwelling sites. The value of property is impaired, the neighborhood is shorn of desirable population, and places that were once fair to look upon may become, by reason of sewage pollution, famous only for foul odors and unpleasant associations.

The consideration of such matters is very familiar in treatises on questions involving public health. It has been conceded that, from a general hygienic standpoint, no stream should be polluted with sewage. It is, however, the purpose of this paper to consider the matter from a standpoint of diminution of natural resources with special reference to the rivers in "the metropolitan area," comprising northern New Jersey, southern New York, and the western part of Massachusetts. It is proposed to take into account the water resources of this section and to show, as closely as available information will permit, the loss which has come about by reason of river pollution. This part of the United States has become the metropolitan area chiefly because of its natural resources, both maritime and inland. Among these sources of economic supremacy the value of the inland waters stands in the front rank.

The consideration of financial loss due to sewage pollution of streams in this area becomes, therefore, of immediate importance; and as we shall enumerate in the following pages the expenditures made necessary by this discredited practice, it is possible that we shall find sewage pollution not only an agency most destructive to human life, but one of the most far-reaching drains upon human wealth that has yet been considered. In addition to the mere question of existing pollution there is the problem of abatement or prevention, which is receiving consideration in many States under authority granted by legislative enactment. This method of consideration may serve admirably in the several States, but what of interstate pollution? State boundaries in the eastern part of this country are so closely set that instances of interstate grievance are numerous. A municipality made miserable by polluted water from another State is deplorably helpless to obtain remedy. There is no national authority over such matters.

RARITAN RIVER.

The Raritan River is the largest in New Jersey, and the second in economic importance. The drainage area—1,105 square miles in extent—is of a mixed type, having 275 square miles of highland area, 100 square miles of sandy plain, and the remainder of red sandstone. Budd Lake, 1½ miles long and three-quarters of a mile wide, is the only extensive storage reservoir in the basin. Only about 13 per cent of the area is in forest, and the bareness of vegetation, in connection with the limited storage facilities and the extensive steep trap-rock surfaces, causes an excessive flood flow, which at times does a large amount of damage. The river is navigable to New Brunswick, 10 miles from the mouth, and is affected by tides to a point 4 miles higher. Records of gagings have been maintained since the year 1890 at the Delaware and Raritan Canal dam, 15 miles above the mouth of the river. In the report of the Geological Survey of New Jersey (Vol. III, p. 209) there appears a flow table computed from these gagings, covering the years 1890–1893, inclusive, as follows:

TABLE I.—*Flow of the Raritan at Bound Brook, 1890–1893.*

[Drainage area, 879 square miles.]

Month.	Rain.	Flow.	Flow in second-feet.		
			Greatest.	Least.	Average.
1890.	*Inches.*	*Inches.*			
February 17 to 28	1.58	0.98	2,772	1,406	1,938
March	6.26	6.13	17,818	872	4,727
April	2.74	2.26	3,265	874	1,773
May	4.95	1.96	4,060	752	1,489
June	3.97	1.32	2,824	426	1,040
July	5.68	1.18	2,022	498	898
August	5.18	1.58	3,405	498	1,205
September	4.13	1.34	2,823	493	1,064
October	6.74	3.06	7,133	859	2,360
November	.88	1.30	1,779	781	1,016
December	3.55	2.16	7,526	462	1,654
1891.					
January	7.06	4.92	23,746	420	3,738
February	4.21	3.47	6,056	1,295	2,931
March	4.64	4.47	10,142	1,386	3,404
April	1.83	1.62	3,439	512	1,276
May	2.70	.59	735	245	450
June	1.75	.24	509	113	189
July	3.92	.28	326	180	213
August	6.58	.94	5,804	148	716
September	1.72	.86	2,564	253	687
October	2.68	.43	804	208	328
November	2.21	.54	1,174	201	426
December	4.74	2.36	8,215	292	1,798
1892.					
January	5.58	4.57	22,760	990	3,482
February	1.19	1.31	5,182	720	1,066
March	3.98	2.59	7,941	796	1,974
April	2.02	1.25	1,893	677	985
May	4.62	1.47	3,177	513	1,120
June	4.06	1.60	10,927	443	1,261
July	4.11	.57	2,764	180	434
August	3.61	.47	2,201	180	358
September	2.75	.31	711	180	244
October	.32	.24	201	122	183
November	6.99	2.18	20,698	122	1,718
December	1.68	1.29	2,610	609	983
1893.					
January	3.39	2.11	12,514	720	1,608
February	6.23	4.16	15,772	1,228	3,494
March	3.14	5.27	19,125	878	4,016
April	4.65	4.00	10,091	918	3,152
May	4.28	3.30	10,987	387	1,515
June	3.57	.64	2,130	180	504
July	3.14	.43	820	180	328
August	8.27	1.45	5,893	180	1,105
September	3.60	.71	3,284	157	559
October	3.86	.95	4,494	180	724
November	3.59	1.50	7,352	291	1,190
December	3.12	2.63	2,698	180	2,004

As a source of water power the Raritan River is not so important as the size of the drainage area and the fall of the river would indicate. The tributaries are widely divergent, and do not, as in the most valuable power streams, join in a common course at any considerable distance above the mouth of the river. In this case the important branches of the system are not united until they arrive at a point within 7 miles from the head of tide water and even then at an elevation of only 17 feet. The largest developed power is at High Bridge, on the South Branch. The extreme floods above mentioned occur frequently, unfitting the basin for any large development of power.

It would seem, upon first consideration, that the Raritan River is not especially valuable as a source of water supply. In quick-spilling basins large amounts of suspended matter are brought down, and in this river there is nearly always apparent a varying amount of red mud. Upon settlement, however, the water is suitable for public use, and there is no reason why excellent water supplies could not be derived from this stream by proper management; but up to the present time the river has been very little utilized for this purpose.

TRIBUTARIES OF THE RARITAN.

SOUTH RIVER.

This river rises in or near Freehold Township, at a point 20 miles due south from where it empties into the Raritan at Sayreville. The flow is much more steady than that of any other branch of the system, and this has led to an extensive use of the stream as a source of power. No large water supply can well be conserved in this drainage area. At the present time, it is true, the city of Perth Amboy derives its water from Tennent Brook, a tributary of South River, but the daily consumption amounts to practically the normal yield of the watershed. It would be possible, by carefully selecting sites for small reservoirs, to conserve several small supplies which, when combined, would be of considerable value.

NORTH BRANCH OF THE RARITAN.

The drainage area of North Branch occupies 191.6 square miles, in the northernmost portion of the Raritan Basin. It is sharply divided into the highland area and red sandstone plain, the former occupying the greater part of the country tributary to this branch. It lies at an elevation of 800 to 1,100 feet, 30 per cent of which is in forest. The population averages 72 per square mile. The red sandstone plain has an elevation of from 200 to 300 feet.

Mr. C. C. Vermeule, author of the report of the Geological Survey of New Jersey above referred to, estimates that there are 7.8 horsepower per foot of fall at the mouth of North Branch. In the entire tributary there are developed 1,052 horsepower at 46 sites.

There are many possibilities for developing excellent water supplies in the basin of the North Branch. Mr. Vermeule states that on the Lamington River, which is the main affluent of the tributary, there is an area of 31.4 square miles above the 500-foot contour which can be developed to yield 21,000,000 gallons daily. Similarly on the North Branch, above the junction of Peapack Brook, there is a drainage area of 29.1 square miles, from which may be derived 19,000,000 gallons a day. At other points in the basin there may be economically gathered a total of about 20,000,000 gallons daily.

SOUTH BRANCH OF THE RARITAN.

This branch drains 276.5 square miles of territory, which is divided into the highland area and red sandstone plain, like that on the North Branch. In this case, however, the plain occupies the larger part of the basin, with an average elevation of about 400 feet. Budd Lake, already described, lies at the head of the South Branch.

As a source of water power South Branch has been rather extensively developed. At 67 sites there is developed a total net horsepower of 2,681.

As a source of water supply the entire basin has a capacity of nearly 100,000,000 gallons daily, with 7 inches storage. Budd Lake has a watershed of 4.5 square miles, is at an elevation of 933 feet, and affords a pondage which will supply 3,000,000 gallons daily.

POLLUTION IN RARITAN RIVER.

The country included in the drainage basin of the Raritan has not yet been sufficiently developed to be damaged to any great extent by sewage, except possibly in the lower part. On the highland tributaries there are few important towns, and the character of the water is not affected to any great degree by pollution. The first city above the mouth of the Raritan is New Brunswick, which has a population of 20,006. The river at this point is tidal and within the limit of salt-water influence. Damage done by pollution can therefore be only that which arises from the general nuisance accompanying the discharge of sewage.

A few miles above New Brunswick is Bound Brook, a borough of 2,622 inhabitants, while farther on are Somerville and Raritan, towns of 4,843 and 3,244 inhabitants, respectively. These three places contribute a certain amount of pollution, which, while it does not do any appreciable damage to the general resources of the river, certainly unfits it for use as a source of water supply without filtration.

Above Raritan there are numerous small villages of a few hundred inhabitants, but all of these are unimportant as agencies of pollution.

The Raritan River, in spite of its proximity to the metropolis of the United States, strangely enough, presents a fairly clean record as to pollution except in a limited area about the mouth of the stream. It is thus notable, especially when contrasted with other rivers in this part of the country, and the contrast shows in a striking manner the difference between water resources yet unimpaired and those which have been injured or destroyed by careless and inconsiderate municipal management. In this case we find that in the majority of tributaries the water flowing out of the Raritan Basin is fit for immediate use in a public supply. The water powers developed have not been reduced in value by reason of any nuisance arising from the concentration of municipal sewage behind the various milldams. Fisheries have been preserved intact. The ice, as far as it is harvested, is above reproach, and the whole country is available for economic development. Let us see how it appears in the case of a river draining the country immediately adjoining.

PASSAIC RIVER.

By far the most valuable drainage system in New Jersey is that of the Passaic. It comprises a territory of 941.1 square miles, in which are situated the drainage areas of the Passaic proper (including the upper and lower valleys), the Saddle, Ramapo, and Wanaque rivers, which extend into New York State on the north, and the Pequanac, Rockaway, and Whippany on the west. Within this territory there are said to be 8 square miles of lakes and 26 square miles of swamp land.

The Passaic River rises in Morris County, in a region adjacent to that from which the North Branch of the Raritan is derived. Its course is exceedingly irregular, passing in or adjacent to six counties before finally reaching Newark Bay. The distance from source to

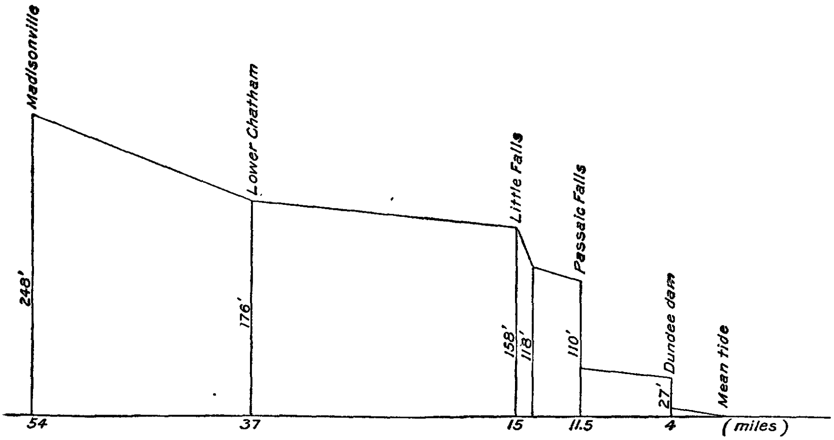

FIG. 1.—Profile of Passaic River.

mouth in a direct line is about 25 miles, while the river measures somewhat over 80 miles in its course.

The profile of the river is interesting and shows clearly the amount of power available in the lower valley. Tide influence extends about 13 miles above the mouth of the river, to a point nearly opposite Passaic. Commerce is developed extensively at Newark, and the river is navigable to the head of tide water. Four miles above this point is Dundee dam (see Pl. III, *A*), the lowest power site in the main river. Above it is a drainage area of 822.4 square miles. The fall is 22 feet, and the net horsepower developed is 1,235. The elevation of the crest of Dundee dam is 27 feet above mean tide. From this point there is a rise of 13 feet in 7.5 miles to the foot of the Great

Falls of the Passaic (see Pl. I, *B*), an imposing cataract, sheer 70 feet in height. In a distance of 4 miles, from the top of Great Falls to the foot of Little Falls, there is a rise of 8 feet. The series of falls and rapids at Little Falls, together with the height of the dam at the crest, make a total rise of 40 feet. This point is the head of power on the main river; it marks the boundary between the middle and lower valleys of the Passaic, uniting the drainage from an area of 772.9 square miles. The elevation is about 158 feet above mean tide, and the distance from tide water is only 15 miles.

At Two Bridges, a short distance above Little Falls, Pompton River enters the Passaic. Above Two Bridges the Passaic follows a winding channel 22 miles long, through a large meadow area, until at Chatham, at an altitude 6 feet above Two Bridges, the bed takes a sharper grade. From this point to the source of the stream, a distance of 18 miles, there is a rise of 72 feet.

The resources of the river that are developed most completely in the lower valley of the main stream are considered in detail in Vol. III of the report of the Geological Survey of New Jersey and in the report of the Tenth Census (Vol. XVI, pp. 647–652), so that only a general description will be given here. From mean tide up to the crest of Little Falls, 102 feet is developed and only 25 feet of the remainder is available for development. The Dundee dam is 450 feet long and impounds a lake of 224 acres, diverting the entire flow of the river in dry seasons. There is here a continuous horsepower during nine months of the year of 36.18 per foot fall, which, when used ten hours a day, allows the Dundee Water Power and Land Company to rent 1,764 horsepower. The fall of the stream has been carefully recorded at this point since 1877, and the results of the record are given in Tables II and III. These are compiled from a diagram in the report of the New Jersey geological survey above referred to.

TABLE II.—*Daily flow of Passaic River at Paterson and Dundee.*

[Inches on watershed.]

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly average.
1877	0.029	0.081	0.202	0.107	0.032	0.021	0.015	0.015	0.013	0.096	0.164	0.081	0.071
1878	.084	.138	.126	.046	.055	.054	.027	.053	.018	.019	.058	.237	.076
1879	.027	.071	.182	.143	.055	.034	.035	.051	.031	.010	.012	.075	.061
1880	.115	.092	.080	.030	.036	.012	.013	------	.012	.011	.027	.021	.041
1881	.037	.131	.215	.042	.029	.056	.037	.010	.010	.010	.018	.052	.054
1882	.069	.171	.127	.117	.105	.061	.061	.018	.197	.043	.019	.038	.094
1883	.031	.115	.106	.098	.053	.024	.033	.013	.013	.047	.044	.024	.050
1884	.092	.215	.157	.094	.067	.022	.043	.030	.010	.019	.035	.011	.066
1885	.137	.081	.066	.115	.054	.016	.015	.026	.010	.027	.089	.102	.063
1886	.109	.189	.097	.114	.113	.034	.017	.018	.010	.018	.032	.037	.066
1887	.105	.171	.118	.087	.039	.069	.080	.052	.014	.027	.021	.109	.074
1888	.145	.138	.166	.195	.024	.014	.013	.034	.160	.015	.105	.138	.096
1889	.192	.087	.104	.137	.104	.059	.088	.145	.142	.055	.215	.148	.123
1890	.066	.118	.107	.099	.087	.051	.031	.035	.151	.084	.047	.051	.077
1891	.192	.205	.169	.076	.029	.015	.014	.023	.023	.012	.026	.065	.071
1892	.158	.052	.065	.054	.045	.038	.019	.019	.014	.011	.048	.039	.046
1893	.121	.203	.227	.130	.155	.077	.025	.023	.020	.041	------	.056	.098
Monthly average	.101	.133	.136	.099	.064	.039	.033	.035	.050	.032	.067	.070	-------

A. ALONG THE PASSAIC BELOW PATERSON.

B. GREAT FALLS OF THE PASSAIC AT PATERSON, N. J.

TABLE III.—*Daily flow of Passaic River at Paterson and Dundee.*

[Cubic feet per second.]

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly average.
1877	640	1,190	4,467	2,365	706	464	330	330	286	2,123	3,924	1,790	1,570
1878	1,856	3,049	2,785	1,014	1,215	1,193	596	1,171	396	418	1,281	5,239	1,680
1879	596	1,567	4,022	3,159	1,215	750	772	1,127	684	220	262	1,658	1,347
1880	2,541	2,032	1,768	662	794	264	286	......	264	242	596	464	907
1881	816	2,895	4,753	926	640	1,237	816	220	220	220	396	1,149	1,193
1882	1,523	4,078	2,807	2,585	2,321	1,347	1,347	396	4,357	1,051	418	838	2,079
1883	684	2,541	2,343	2,164	1,171	530	728	286	286	1,039	973	530	1,105
1884	2,032	4,753	3,770	2,076	1,479	486	951	662	220	418	772	242	1,457
1885	3,027	1,790	1,457	2,541	1,193	252	330	574	220	596	1,966	2,255	1,391
1886	2,409	4,176	2,142	2,519	2,497	750	374	396	220	396	706	816	1,457
1887	2,321	4,078	2,607	1,922	860	1,516	1,768	1,149	308	596	464	2,469	1,636
1888	3,203	3,049	3,968	4,308	530	308	286	750	3,836	330	2,321	2,949	2,123
1889	4,242	1,922	2,299	3,027	2,299	1,304	1,944	3,506	3,440	1,215	4,753	3,572	2,719
1890	1,357	2,607	2,365	2,186	1,922	1,127	684	772	3,638	1,856	1,039	1,127	1,702
1891	4,242	4,533	4,034	1,680	640	330	308	508	508	264	574	1,435	1,570
1892	3,792	596	1,435	1,193	995	838	420	420	308	242	1,061	860	1,017
1893	2,673	4,489	5,019	2,873	3,726	1,702	552	508	442	907	......	1,237	2,167
Monthly average	2,233	2,939	3,005	2,186	1,413	860	728	772	1,105	706	1,479	1,548	....

Concerning the methods of observation and accuracy of the determinations set down in Tables II and III, Mr. C. C. Vermeule, author of the report, says:

We have, by the courtesy of several users of water power, been able to obtain measurements of flow covering a period of seventeen years and a very wide range of rainfall conditions, from 70.88 to 37.03 annually. These gagings were at Little Falls and points below, and have been reduced, compared, and adjusted, two series being for several years contemporaneous. The results we have much confidence in. They are consistent, and bear the test of close analysis as well as any series of gagings we have made.

Table II gives the average daily flow in inches upon the watershed for each month of the period 1877–1893, and also the daily flow for each year and the monthly averages for the whole term. Table III gives similar information, except that it is expressed in terms of cubic feet per second actually flowing through the channel.

The power site at Great Falls, Paterson, is one of the oldest large water powers in the United States. Above the head of the falls is a low stone dam, affording, however, sufficient pondage to concentrate the entire dry season flow into working hours. The Society for Establishing Useful Manufactures, which controls this power, receives about $36 per gross horsepower per annum for about 2,300 horsepower, but the dry-weather flow does not supply more than half of this, and the power is not, therefore, guaranteed. The conservance of water from the upper Pequanac area for the city of Newark and the large drafts upon the river at Little Falls for the supply of Paterson, Passaic, and Jersey City have increased the uncertainty of the power at this place. The Rockaway area is now being set apart for the use of Jersey City, and it is expected that the constantly increasing demands of the water-supply interests will soon bring the power values to a very low basis. The power, both at Dundee and Great Falls, has passed into the control of the New Jersey General Security Company, a corporation closely allied to the East Jersey Water Company, and the contest between power and water-supply interests which was at one time probable has been averted.

At Little Falls about 450 horsepower was developed, but it has been greatly reduced by the lowering of the dam for the purpose of draining the Great Piece Meadows, a wide area over which the water stands for days during freshets. The actual power value is therefore not great. Since the assumption of control by the East Jersey Water Company, the necessity for greater pondage has not been evident, sufficient being necessary to properly flood the water intake only. This intake is located on the north side of the river, a little above and at a short distance from the dam. Above the meadows the power sites on the main stream are not of great importance.

This stream forms a nucleus for a water supply which in capacity and quality can not be excelled in the metropolitan district, and from the manner in which it is now being developed it is probable that at no distant date that part of the river between Little Falls and Passaic will lose much of its value as a source of power.

TRIBUTARIES OF THE PASSAIC.

The Pompton River, which joins the Passaic at Two Bridges, above Little Falls, combines the flow of the Ramapo, Wanaque, and Pequanac, representing a combined area of 379.9 square miles. Through the Great Piece Meadows flows Rockaway River, draining 138.4 square miles, and farther up the Whippany, draining 71.1 square miles. Each of these areas forms by itself a gathering ground from all of which, except the latter, can be diverted water supplies equal to almost any emergency which the great cities of northern New Jersey are likely to encounter during the next century. The Rockaway and Pequanac, as stated above, have already been claimed. The Ramapo is now under the control of a New York corporation, which endeavored to secure a metropolitan monopoly. There remain only the Wanaque, a small available area in the Whippany, and the Upper Passaic for future development. These will be considered, each by itself as a separate stream, after we have examined the Passaic proper as a source of supply.

In spite of the largely diverted drainage of its highland tributaries, the Passaic will always be a valuable source of water supply, for it possesses a large drainage area of itself. Above Little Falls, on the main river, there is at the present time a supply that will afford, without storage, nearly 88,000,000 gallons daily. With the highland

A. GREAT FALLS OF THE PASSAIC AT PATERSON, FROM THE CREST.

B. PASSAIC RIVER BELOW GREAT FALLS AT PATERSON.

tributaries diverted, as they are likely to be in the future, there will still be a drainage area of 208 square miles, affording a supply of approximately 25,000,000 gallons daily, without storage. For years the cities of Newark and Jersey City took water from the river at Belleville, below Passaic, amounting to from 30,000,000 to 40,000,000 gallons daily. The intakes are now out of use, Newark having gone up to the Pequanac area for its water supply and Jersey City to Little Falls temporarily, until the supply from the Rockaway shall have been established. Immediately above Little Falls, on the meadows, there is no good point on the Passaic for a reservoir, and the large area of flat land causes generally muddy and unsatisfactory water. Above this, in the upper Highlands, is an excellent basin, called Great Passaic Swamp, which might easily be set apart as a storage reservoir. The drainage area is small and rather thickly populated, yet the situation remains available and can be used in case of need.

SADDLE RIVER.

This is the lowest and least important branch in the Passiac system. It rises in Rockland County, New York State, flows south for 17 miles and empties into the Passaic about 12 miles from the mouth. The drainage area contains 60.7 square miles, underlain by the red sandstone common to the main basin. It has 8 square miles of drainage area in New York State, and the population, according to the report of the Geological Survey of New Jersey in 1894, was about 122 per square mile. As a source of water power the river is not important. Out of a total fall of 90 feet there have been utilized about 60.5 feet, the power from which is divided into 47 sites along the river, representing a gross horsepower of 1,700. It is fairly good gathering ground for a limited water supply, and might be developed as an auxiliary to be used in an emergency. With a storage of 7.5 feet upon the reservoir it would yield 14,000,000 gallons daily.

RAMAPO RIVER.

Although emptying into the Passaic by way of Pompton River, this stream belongs largely to New York State, as about 70 per cent of the 160.7 square miles of drainage area is located beyond the Jersey limits. About 75 per cent of this area is forested, and the population is approximately 60 per square mile. Gagings of the flow of the river, extending through a period of two years, were made at the works of the Pompton Steel and Iron Company, and are compiled in Table IV, which is taken from the report of the Geological Survey of New Jersey (Vol. III, 1894, p. 168).

TABLE IV.—*Flow of Ramapo River at Pompton.*

[Drainage area, 159.5 square miles.]

Month.	Rain.	Flow.	Flow in cubic feet per second.		
			Greatest.	Least.	Average.
1890.	*Inches.*	*Inches.*			
February 7 to 28	4.45	3.29	1,913	277	643
March	6.40	4.85	2,020	277	643
April	2.68	3.05	1,032	231	429
May	4.72	2.75	762	170	377
1890-91.					
June	4.98	1.25	334	55	176
July	6.06	.94	338	40	125
August	4.75	.80	601	41	108
September	4.14	1.51	948	55	209
October	6.95	2.22	839	91	301
November	.77	1.10	320	80	155
December	4.02	1.77	1,583	80	238
January	8.51	6.36	4,552	318	879
February	4.50	5.28	2,130	264	853
March	4.25	5.23	1,686	299	729
April	2.80	2.34	695	143	335
May	2.70	.67	187	41	94
June to May	54.43	29.47			
1891-92.					
June	2.13	.37	79	33	52
July	4.88	.31	70	22	44
August	5.54	.96	536	33	135
September	2.28	.67	318	40	94
October	2.39	.30	53	40	42
November	2.93	1.47	601	33	207
December	4.77	2.78	1,175	104	391
January	5.65	5.65	1,949	267	794
February	1.34	1.19	267	123	167
March	3.65	2.30	662	147	323
April	1.73	1.33	293	117	188
May	4.66	1.83	748	91	258
June to May	41.95	19.16			
1892.					
June	4.07	2.00	1,095	45	281
July	3.37				
August	4.36				
September	1.97				
October	.68	Gagings Oct. 10, 22.5 cubic feet per second.			

At Pompton, 1.5 miles above the confluence of the Ramapo with the Pompton, the Ramapo has a fall of 29 feet. The lake, which is traversed by a 7-foot dam, is about 202 acres in extent. The power developed at this place, as estimated by Mr. Vermeule, is 17.04 horsepower per foot fall. There are many other sites on the watershed which are not yet developed, but none are of great importance. The river has never been a favorite power stream.

In many ways Ramapo River is a favorable gathering ground for a city water supply. The name has, during the past few years, become well known in the metropolitan area by reason of the existence of a water corporation known as the Ramapo Company, which endeavored to acquire, and almost succeeded in obtaining, the most valuable water franchise in America—that of New York City—charging rates which, at the end of the contract period, would involve a loss to the city of New York of about $190,000,000. Although this corporation

A. DUNDEE DAM, WHICH HOLDS BACK AND CONCENTRATES THE SEWAGE FROM PATERSON.

B. DUNDEE CANAL.

controls the water rights on the New York part of the drainage area, this portion was not included as a source of supply in the plan that was presented to the city of New York. The river yields, without storage, at Pompton, 14,500,000 gallons daily. With a storage equal to 7 inches upon the watershed, the available supply would be approximately 120,000,000 gallons daily.

WANAQUE RIVER.

In its general geographic course this stream is not unlike the Ramapo. Greenwood Lake (see Pl. IV, *A*), situated on the line between New York and New Jersey, and extending into New York State about 3 miles, and Sterling Lake, entirely within New York State, afford excellent pondage. Greenwood Lake has an elevation of 621 feet, has 6 square miles of surface, and receives the drainage of 28 square miles. Its storage capacity, according to Croes and Howell, is 134,000,000 gallons, and it will supply 18,000,000 gallons daily throughout the year. Sterling Lake has an area of 321 acres and a watershed of 4.69 square miles. It will supply throughout the year about 3,000,000 gallons daily.

The only series of gagings available for Wanaque River is that made under the direction of the Geological Survey of New Jersey at the dam near Pompton station. These gagings cover a period when the stream is least affected by drafts from Greenwood Lake, and are compiled in Table V.

TABLE V.—*Flow of Wanaque River, 1890–91.*

[Drainage area, 101 square miles.]

Month.	Rain.	Flow.	Flow in cubic feet per second.		
			Greatest.	Least.	Average.
1890.	*Inches.*	*Inches.*			
October	6.95	2.49	594	91	217
November	.77	.93	126	44	84
December	4.02	1.59	799	44	138
1891.					
January	8.51	6.27	4,943	91	549
February	4.50	5.51	1,107	217	548
March	4.25	5.55	914	217	516
April	2.80	1.92	303	92	174
May	2.96	.61	77	45	54
December to May	27.04	21.45	Loss, 5.59 inches.		

On account of the large pondage, the flow of this river could be made comparatively uniform, and the power developed would be of considerable value. At the mouth of the river there are about 10 horsepower per foot fall, a part of which is contributed by Greenwood Lake. Power sites are available in the upper parts of the stream, and the one located in the Ringwood district could be developed to yield a steady horsepower of 2,000 during working hours.

This river forms another excellent source of city supply. It has already been stated that there is a pondage representing the drainage from 33 square miles. For the remaining run-off water there are good sites for conservance, and with a total utilization of 14 inches upon the watershed there would be afforded a supply of 75,000,000 gallons daily. Of the watershed, 28.2 square miles are in New York, and 80 per cent of the entire area is forested.

PEQUANAC RIVER.

Mr. Vermeule, author of the report of the Geological Survey of New Jersey above quoted, describes the Pequanac River as follows (p. 175):

This is another branch of the Passaic, and with the Ramapo and Wanaque forms the Pompton River just below Pompton. Its drainage area lies high on the Archean highlands. For nearly its whole course it flows transversely to the ridge and valley structure of these highlands, thus differing from the Ramapo and Wanaque, which flow through deep valleys. The headwaters of the Pequanac are at an elevation of nearly 1,500 [feet], while the mouth, at Pompton, is only 170, consequently the stream has great fall. From Post's dam at Riverdale, 2 miles above the junction of the Ramapo, to New Foundland, 12.5 miles above, the fall is 45 feet per mile; thence to Wallace's corners it is 9.2 feet per mile for 6.5 miles; for 2 miles above this, to Stockholm, it is 30 feet per mile. The watershed is 6 or 7 miles wide by 16 miles long and the branches are quite uniformly distributed along the course of the main stream, mostly coming in from the northeast. Forests cover 78 per cent of the area.

The flow of the river is compiled in Tables VI and VII, the first of which was made under the direction of the Geological Survey of New Jersey, while the second was made by Mr. Clemens Herschell, chief engineer of the East Jersey Water Company.

TABLE VI.—*Flow of Pequanac River at Riverdale.*

[Drainage area, 84.7 square miles.]

Month.	Rain.	Flow.	Flow in cubic feet per second.		
			Greatest.	Least.	Average.
1890.	*Inches.*	*Inches.*			
February	4.45	3.38	686	125	273
March	6.40	4.02	891	155	296
April	2.68	2.70	382	75	205
May 1 to 5	.31	.20	155	74	91
June					
July					
August					
September 27 to 30	.58	.08	90	25	45
October	6.95	3.61	959	25	264
November	.77	1.42	301	25	100
December	4.02	1.08	437	25	75
1891.					
January	8.51	5.17	2,352	48	387
February	4.50	5.05	1,384	46	276
March	4.25	4.12	683	46	192
April	2.80	1.50	234	46	215
May	2.70	.62	77	45	53
December to May	26.78	17.49			

A. GREENWOOD LAKE, HEAD OF WANAQUE RIVER.

B. DAM AT MACOPIN INTAKE, NEWARK WATER SUPPLY

TABLE VII.—*Flow of Pequanac River at Macopin intake.*

[Drainage area, 63.7 square miles.]

Month.	Rain.	Flow.	Average weekly flow in cubic feet per second.		
			Greatest.	Least.	Average.
1891-92.	*Inches.*	*Inches.*			
June	1.76	0.55	48	16	31
July	5.01	.27	20	20	15
August	5.75	1.39	254	16	80
September	1.93	.90	90	25	51
October	2.11	.34	23	15	19
November	3.19	1.73	172	16	97
December	4.99	3.77	415	105	212
January	5.95	5.96	450	173	335
February	.99	1.63	115	72	92
March	4.30	2.58	183	125	145
April	1.43	1.73	128	44	97
May	5.39	2.17	190	70	122
June to May	42.80	23.02			
1892-93.					
June	4.33	2.37	221	76	133
July	3.83	.53	40	15	30
August	4.63	.53	40	12	30
September	2.06	.47	53	8	26
October	.71	.16	10	8	8.8
November	6.80	1.53	224	24	86
December	1.55	1.62	140	53	92
January	4.07	1.86	212	50	104
February	6.72	3.73	293	124	212
March	3.55	6.82	614	331	383
April	4.83	4.26	277	196	240
May	5.66	4.98	606	104	280
June to May	48.74	28.86			

In past years this river has been important as a power stream, about 18 sites, with a total of 1,034 horsepower, having been developed. They have nearly all been acquired by the East Jersey Water Company and the city of Newark, and the whole drainage area will eventually be reserved for water supply. There remain notable power sites, such as those at Butler and Bloomingdale, and other points along the river, where the value of the manufacturing is still large. Such sites, however, will be preserved only so long as they do not interfere with water conservation, and therefore the future of the river as a power stream is uncertain.

As a gathering ground for water supply the value of this area has been demonstrated to the satisfaction of all concerned. The water now supplied to the city of Newark has proved excellent, and has been the means of improving the general health of the city to a remarkable extent. On account of various laxities in preparing the reservoirs and because of other circumstances the water has not been as free from sediment as is considered desirable, but sources of contamination have been largely removed, and analyses show that the character of the water is uniformly satisfactory. At the present time only the upper part of the area is reserved for a gathering ground, the water being stored in three reservoirs. That at Oak Ridge has a capacity of 2,555,000,000 gallons and is 383 acres in extent. Clinton reservoir has an area of 423 acres, a drainage area of 9.5 square miles, and a capacity of 3,518,000,000 gallons. Canistear reservoir has a capacity of 2,500,000,000 gallons and is 350 acres in extent.

With 7 inches storage upon the entire drainage area, 14 inches may be collected annually, equal to a total daily supply of 56,000,000 gallons. In the report of the Geological Survey of the State (Vol. III, 1894, p. 179) a list of possible reservoir sites in this drainage area includes 10 locations, with a combined capacity of 23,920,000,000 gallons.

ROCKAWAY RIVER.

This stream is 40 miles long from source to mouth and has a drainage area of about 140 square miles, more than 80 per cent of which is in forest. It bears a strong resemblance to the Pequanac, although it is much less uniform in character. Within this area are numerous ponds and lakes, which afford a large proportion of storage. Splitrock Pond is 315 acres in extent, with a watershed of about 5 square miles. With the present 12-foot dam raised 3½ feet it would, according to the measurements of Mr. Vermeule, have a capacity of over 700,000,000 gallons and would, if drawn off 7 inches on the watershed, supply continuously 3,500,000 gallons daily. Green Pond, at an elevation of 1,048 feet and with an area of 460 acres, could be made to supply 1,200,000 gallons daily.

The flow of the river at Dover, as determined by the Geological Survey of New Jersey (Vol. III, 1894, p. 182), is given in Table VIII, the readings for which were made on Sundays, when the mills were shut down.

TABLE VIII.—*Flow of Rockaway River at Dover, 1890.*

[Drainage area, 52.2 square miles.]

Date.	Cubic feet per second.	Inches on watershed in 24 hours.	Date.	Cubic feet per second.	Inches on watershed in 24 hours.
March 30	253	0.180	August 24	78	0.056
April 6	182	.129	August 31	78	.056
April 13	182	.129	September 7	50	.036
April 20	115	.082	September 14	165	.117
April 27	115	.082	September 21	129	.092
May 4	175	.125	September 28	89	.063
May 11	103	.071	September 30	39	.028
May 18	182	.129	October 5	136	.097
May 25	121	.086	October 12	104	.074
June 1	128	.091	October 19	159	.113
June 8	110	.078	October 26	208	.148
June 15	115	.082	November 2	116	.083
June 22	115	.082	November 9	88	.063
June 29	41	.029	November 16	88	.063
July 6	80	.057	November 23	61	.043
July 20	39	.028	December 7	88	.063
July 27	272	.194	December 14	43	.031
August 3	318	.226	December 21	88	.063
August 17	39	.028			

As a source of power the Rockaway has in the past been one of the most valuable rivers in the State, furnishing in the year 1890, at 29 sites, 1,398 horsepower, with many available sites unimproved. The water rights upon the area have now come into the possession of Jersey City, and the river will be used as a source of water supply, and in the future will not figure largely as a power stream.

Above Old Boonton, on the Rockaway shed, there are 122.5 square miles of highland-drainage area which have been included in the tract set apart for the water supply of Jersey City. The plan proposed by Patrick H. Flynn, contractor, and which was accepted by the city, provides that a main intake and reservoir shall be located at Old Boonton, which shall leave an area, as improved, for 50,000,000 gallons daily delivery, of 949 acres and a capacity above the effluent pipes of 1,362,000,000 gallons. Tributary to this reservoir will be the whole flow of Rockaway River, including the waters of Longwood Valley, Green Pond, Denmark Lake, Beach Glen, Splitrock Pond, Dixon Pond, Showgum Lake, and tributary streams.

Provision will be made for increasing the supply by raising the height of the dam so that the area of the reservoir will be 1,177 acres, with a capacity of 12,683,000,000 gallons, and a supply of 70,000,000 gallons daily.

WHIPPANY RIVER.

This stream is comparatively unimportant as a source of power, and the area is not well developed to become a source of water supply. The population on the watershed is large and furnishes a large measure of pollution, to which reference will be made below.

POLLUTION OF PASSAIC RIVER SYSTEM.

It needs only a superficial inspection of the Passaic River at any point below the city of Paterson to discover the bad state of affairs there existing. Commencing in a small way, the sewerage systems emptying into this part of the stream have increased with the growth of the municipalities, until the conditions all along the lower reaches of the river have become insufferable. The clutch of pollution seems to have fastened itself there, and in spite of the best efforts of intelligent men no satisfactory legislation has yet been enacted to alleviate the conditions. In considering the Lower Passaic—i. e., that part lying between Little Falls and Newark Bay—the Passaic Valley sewerage commission, created by an act of the legislature of New Jersey in February, 1896, described the conditions in its report dated February, 1897, as follows:

> The great extent of the pollution of the Lower Passaic may be illustrated in several ways. It is apparent to the eye in the conditions of the river during the summer, in the foulness of the shores where sewage-laden mud, when exposed to the sun, gives out foul odors; and it is demonstrated by every practical test. The cities of Newark and Jersey City have been compelled to seek water supplies elsewhere at great expense, and the immediate decrease in zymotic diseases in those places which followed the change has shown how necessary it was.

Fish life, excepting a few hardy kinds, has disappeared from the river, and fifteen years ago shad, which formerly frequented the stream, abandoned it. The manufacturers have reported that the acid in the sewage-laden water has affected the boilers so as to make its use inadvisable. The use of the river for pleasure purposes, which at one time made it a delight to thousands, has become comparatively infrequent, and the attractiveness of the river [see Pl. I, *A*] may be said to have disappeared.

The commissioners in their meetings at the various towns on the river found all citizens deeply concerned and anxious for action to remove pollution. Their testimony was substantially identical, and while there was a natural desire to avoid doing injury to the fair name of their towns, it was their unanimous sentiment that the pollution of the river had caused great depreciation in property values along the stream. During the hot months residences within a short distance of the river were reported to be almost uninhabitable on account of the stench, and the necessity of keeping windows closed on hot nights to bar out the evil odors was frequently mentioned as showing the extent of the actual nuisance. The injury to property at all points below Paterson was testified to be large and increasing, despite the many natural advantages of the valley and its neighboring heights for suburban residences. The actual direct effect of the stench upon the public health was discussed with caution by physicians and health authorities, but that its influences were gravely injurious admitted of no doubt.

Finally, the quantity of sewage discharged, compared with the low-water flow of the river, was shown to be beyond the power of the river to assimilate, and exceeded the limits which have been regarded as permissible for an open stream by sanitary authorities of other countries and States.

The ratio of increase in population for the Lower Passaic district from 1880 to 1890 is placed by the engineers at 43.2 per cent, and from 1890 to 1895 at 22.6, the ratio for the five years thus exceeding that of the decade previous. The river now receives the sewage of the cities of Paterson, Passaic, Orange, Newark, and the towns of East Orange, Bloomfield, Montclair, Harrison, Kearney, East Newark, and part of Rutherford. Sewerage facilities for other places are an admitted necessity of the early future. It therefore appears beyond question that the river pollution is sure to increase enormously unless remedial measures be taken.

This part of the investigation by the commissioners therefore demonstrated:

That the daily discharge of 70,000,000 gallons of sewage into the Passaic River below the Great Falls of Paterson is beyond its power to assimilate.

That the pollution has become a nuisance to residents along the banks by the stench and had caused depreciation of property and injury to health.

That the fisheries had been destroyed.

That the river had ceased to be desirable for pleasure purposes, boating, bathing, etc., no longer possessing the park values which so generous a stream should afford the large population on its banks.

That the use of the river for manufacturing purposes is suffering on account of the pollution.

In short, the pollution of the Lower Passaic River appeared to the commissioners to be completely established as a public nuisance, an injury to health, and an increasing menace to property interests from the beginning at the Great Falls to below Newark.

The report of the commission, quoted above, in dealing with conditions of the Upper Passaic portion, states that the pollution upon that part of the drainage area was inconsiderable, yet the rapid growth of the municipalities thereon warranted the belief that in a short space of time the pollution entering the river above Little Falls would be as unfavorable in its effect upon the river as that of the Lower Passaic, and recommended that there be absolute prohibition of the use of the main stream or tributaries of the Upper Passaic watershed for any crude sewage, and that the extent to which filtered effluent may be permitted to enter this stream should be subject to regulation by a commission in charge of the purification of the river, with power to prevent nuisance. The increase in population since that time has been beyond the expectations of the commission, and the laws that have since been enacted for the protection of rivers are provided with unsatisfactory means of enforcement. There is no doubt whatever that the pollution within this area is far more extensive than at the date of the above-quoted report. It is also true that the commission recognized the enormous burden imposed by the pollution in the Lower Passaic and gave more careful attention to that part of the river than they did to the highland area. Let us therefore examine the conditions as they now exist in the river system above Great Falls, Paterson.

Four miles up the river is Little Falls, a town of 2,908 inhabitants, without any public system of sewerage, but nevertheless producing considerable pollution from private drains and factories. Analyses that have been made of the water at Little Falls dam and at Great Falls dam show an appreciable increase in organic matter at the lower station, and bacteriological examinations indicate at times even more strongly the presence of sewage below Little Falls. The cities of Paterson and Passaic, which have in the past taken their water supply from the head of Great Falls, have not during that time been free from epidemics of typhoid, which, in the opinion of the sanitary officials, have been traceable to the water supply.

Farther up the river, beyond the Great Meadows, are the towns of Madison and Chatham, containing, respectively, 3,754 and 1,361 inhabitants. Neither of these has a sewerage system, although one is projected in Madison. The pollution of the river at these towns is more than would be expected from places of their size and condition. Still farther up is Summit, a city of 5,302 inhabitants, having a sewerage system that has been extended through the more thickly settled parts of the city. A sand-filtration area has been provided on the banks of the Passaic, which has been unsuccessful from the standpoint of purification, the effluent being not at all satisfactory, putrifying in a short time and causing a serious nuisance at the Chatham dam, a few miles below. Indeed, so unsatisfactory has been the work of this filter that its abandonment has been practically decided upon. A plan has received legislative authority whereby Summit may join with Milburn, Vailsburg, West Orange, South Orange, and a part of Newark in the construction of a tide-water trunk sewer which shall discharge into Arthur Kill.

Upon the Whippany are Morristown and Morris Plains, the former with a population of 11,267, both without sewerage systems, and the former especially contributing a large amount of sewage by means of private drains from houses and factories, so that the river and its branches ramifying through the city often present a most disgusting sight. It is not apparent to the observer that the municipal authorities there have taken any effectual steps to prevent pollution of these streams, and in certain parts of the town sewage may be seen running into the brooks via the street gutters.

Boonton, Rockaway, and Dover, with a combined population of 11,322, are situated upon Rockaway River. All three are in the drainage area embraced in the reservoir now under construction, the waters of which will reach up well into the town of Boonton. In the contract entered into between the city of Jersey City and Patrick H. Flynn, the contractor, there is a provision that all sewage shall be diverted from the catchment area, and a plan has been provided whereby the contractor shall build an intercepting sewer which shall collect all the sewage from these three municipalities and empty it into the Rockaway below Old Boonton. The present plan, therefore, will not relieve the river of its pollution, except upon that part of the Rockaway above the proposed dam.

Upon the streams converging into the Pompton are Bloomingdale and Butler, with upward of 800 people, and Pompton Village, at the mouth of the Wanaque, and upon the Ramapo in New York State are Suffern, Hillburn, and Tuxedo, the former of which has a small sewerage system emptying into the river. Here is an instance of interstate pollution. Although at present not of great importance, there is every reason to believe that as the town increases in size the pollution may become sufficiently extensive to affect the value of the Ramapo watershed in New Jersey. The laws that may be enacted and the surveillance which it is hoped to establish in New Jersey over watersheds can have little effect in New York, be they enforced ever so efficiently. The same is true of the upper part of the Wanaque watershed, and also of Saddle River. Greenwood Lake, situated in both States, is a favorite summer resort, within easy distance of New York. There is likely to develop a community of no mean importance at the New York head in years to come, the pollution from which would injure not only the water-supply value of the lake, but also the ice industry, which amounts annually to about 60,000 tons.

In the year 1899 the East Jersey Water Company, being compelled to give up the water from the Pequanac, which would in September, 1900, pass into the hands of the city of Newark, offered to another municipality with which the company was under contract, and to which it was then furnishing Pequanac water, a supply from the new intake at Little Falls. The town officials not being satisfied with the proposed change, and believing the water to be inferior to that of the highland stream, employed Mr. George W. Fuller, of New York, to examine into and report upon the subject. After a period lasting six months, during which the whole matter was explored in minute detail, Mr. Fuller submitted his report, from which the following extract is made:

While admitting that Passaic River water from Little Falls might be used * * * without any serious detriment to the public health, it is my judgment that this water can not, from a strictly sanitary standpoint, be rated as a pure and wholesome water. This judgment is based on the fact that there are no thoroughly efficient means of eliminating the germs of water-borne diseases before they shall reach the consumers at * * * in the event that such disease should become prevalent at one of nearly a dozen centers of population.

The Passaic Valley sewerage commission was succeded in 1889 by the State sewerage commission. The report of this body to the legislative session of 1900 reads concerning the Passaic River as follows:

The purification of the Passaic River has been and is the greatest problem which has demanded the attention of the commission. The magnitude of the undertaking can hardly be exaggerated. The report of the Passaic Valley sewerage commission of 1897 set forth the then existing conditions. The commissioners appointed under the act of 1898 to "consider the pollution of rivers and streams in this State" said, referring to the Passaic River: "The condition of the Passaic River has been getting worse, and during the last summer the conditions were even more intolerable than during the drought of 1895." Bad as was the condition then, that during the summer of 1899 has been far worse than ever before known. As early as June serious complaints were made of its condition, which have continued during the whole summer and into the autumn.

It is a common error to suppose that the condition is solely the result of pollution of Paterson and Passaic and the municipalities at or above the head of tide water. While these communities are large polluters of the river, others are equally guilty. During much of the time the Passaic River is little more than a tidal estuary, in which the outward flow of the tide is not of sufficient duration to empty the river of the polluted water. The incoming tide meets the sewage of Newark, Orange, Bloomfield, Montclair, Harrison, and neighboring towns, driving it up the river to meet that coming from above, so that to a great extent the same water, with constantly increasing quantities of sewage being added, is driven up and drawn down by the tide until large rainfalls occur, when there may be a flow of water from above sufficient to force the sewage out and fill the river with clean water. This temporary relief continues as long as there is water coming down sufficient to force back the tide and allow the sewage to find its way into the bay.

The commission received numerous complaints from residents along the river, it having been necessary for people a half a mile from the river to close their windows during the hottest weather to keep out the stench. The constantly increasing quantity of sewage being poured into the river, together with the decreasing amount of water coming down for the dilution of the sewage, have hastened the time when some remedial action has become imperative. It is recommended that legislative action be promptly taken to abate the foul condition of the Passaic River. To this end a bill has been drafted empowering the State sewerage commission to require such other disposition of the sewage and other polluting substance as shall meet its approval, believing that when it becomes obligatory for those fouling the river to do something else with their sewage they will join with your commission in seeking the best way. The commission has sought to unite the different municipalities in some voluntary action, and with that end in view invited the several municipalities now discharging sewage into the river to appoint committees to meet with the State commission for the purpose of considering the subject.

In a further report to the legislature of 1901, the same commission speaks concerning the Passaic as follows:

The sewage pollution of the Passaic has, during the last year, increased in its evil effects. Heretofore the objectionable odors have been limited to the summer months; but during the last autumn the stench continued until the freezing weather locked the foulness into ice. The rainfall was below the average during the autumn, and wide spaces of sewage-befouled mud were exposed to the air, giving forth nauseating odors. The effects were felt with severity all the way from Paterson to Newark Bay, and factory hands in Paterson and in Newark, near the river, were compelled to stop work a number of times on account of nausea from the river stench. * * *

The flow of fresh water from above Great Falls is showing a steady diminution, principally owing to the diversion of the river water above for city supplies, and the amount of the discharge will unquestionably increase constantly. The effect upon the river above the tidal flow, between Paterson and Dundee dam, is disastrous, leaving insufficient water to carry down ordinary sewage discharge, much of which lodged during the summer and autumn in the bare river bed, giving forth stench and threatening disease in the heart of Paterson. The scouring by floods, which served for a periodical cleansing, is now rarely effective, and the conditions seem to grow worse. The evil condition of the whole river can scarcely be exaggerated, and what was apparent to the instructed four years ago is now evident to any person who may casually observe the river.

VALUE OF PASSAIC RIVER SYSTEM AND ITS MODIFICATION BY POLLUTION.

WATER POWER AND WATER SUPPLY.

As a source of power the Passaic system is worth about $1,500,000. According to the report of Mr. Vermeule the total available gross horsepower of the stream is 8,924. Assuming the usual efficiency of 70 per cent upon the wheel, there may be developed a net horsepower of 6,246.8, which, at the average New Jersey rental of $22.50 per horsepower, would yield an annual rental of $140,553. With a capitalization of 10 per cent we find a total valuation of $1,405,530.

The value of the river as a source of water supply is a more difficult problem to estimate and varies according to the means used to collect the water. It has already been stated that at the head of Little Falls the river will supply without storage about 85,000,000 gallons daily. The only important addition to the flow below this point is Saddle River, which furnishes daily a minimum of about 2,600,000 more throughout all seasons. This total of about 87,600,000 gallons is undoubtedly a conservative estimate of the supply available at the Belleville pumping station, and the total flow of the river past that point would, except in extraordinary cases, be far greater. If, then, pollution were excluded from the Passaic and the minimum flow were pumped from the river at Belleville, there would be no disturbance of the power value of the river, so that, in addition to the power valuation, there would be the value of the water. Pumped from the river at Belleville and raised to a height sufficient to serve the metropolitan areas of Essex and Hudson counties, this water, at a fair valuation, would bring $25 per million gallons, assuming, of course, that the present pollution had never existed.

If, however, storage is provided in the highland areas and the water is allowed to flow into the cities by gravity we shall have a measure of resource far greater than that above estimated. Mr. Vermeule states that 666,094 gallons per square mile are daily collectible with storage upon the Passaic system. Considering only the 773 square miles above Little Falls, and the 60.7 square miles of Saddle River there can be developed through storage a resource equal to 555,000,000 gallons daily. This amount of water, utilized at the extremely low rate of $15 per million gallons and on the basis of only 60 per cent conservance, would yield an annual income of $1,823,175, which capitalized at 10 per cent equals $18,231,750. Under such a system the water power would be largely if not completely destroyed, so that this value would necessarily be deducted from the above figures.

It has already been shown that the water pumped from the river below Belleville is polluted beyond all possibility of use in its crude state, and indeed the city of Newark had this fact brought to its attention during the winter of 1899, when, during a continued cold season, the consumption of water reached the limit prescribed in the contract and the water was again pumped into the mains at Belleville. The typhoid epidemic resulting therefrom was a severe lesson.

Expert examination has shown that it is unsafe to use the water from Little Falls in its crude state. If we examine the history of the water supply upon the Passaic we shall find the following facts: Previous to the year 1888 the municipalities of Newark, Harrison, Arlington, Belleville, Nutley, Kearney, Passaic, and Paterson, situated upon the Lower Passaic, and Jersey City, situated upon the Hudson, all derived their water supply from the Passaic. On the one side of the river Jersey City, Harrison, and Kearney received their supply from the intake owned by the first-mentioned city, while across the river, at Belleville, was situated the Newark pumping station. From the latter intake there were pumped 16 to 20 million gallons daily, at a cost of $15 to $17 per million gallons, while at the former intake about the same amount was taken, at approximately the same cost. Passaic and Paterson were supplied from an intake situated at the head of Great Falls and owned by the Passaic Water Company. All of these municipalities, especially those supplied from the Newark and Jersey City intakes, suffered excessively from typhoid fever, due to sewage pollution in the river.

In 1889 the source of supply of the Newark system was transferred to the Pequanac area under a contract with the East Jersey Water Company, and in September, 1900, the ownership passed to the city at the cost of $6,000,000. Although the change from Belleville to Pequanac involved a change from a pumping to a gravity system, which in years to come will be more economical, during a long term of years the fixed charges upon the plant will make the water cost Newark $30 per million gallons, an amount equal to twice the cost of the Belleville water.

The source of supply for Jersey City was, in the year 1898, transferred to the new intake of the East Jersey Water Company at Little Falls, a temporary arrangement which will continue during the completion of the dam at Old Boonton, on the Rockaway, which, when developed to a capacity of 70,000,000 gallons daily, will cost the city about $9,000,000. Here, again, the transference from pumping to gravity will, in the end, be the means of securing the water at a cheaper rate, but the fixed charges in the meantime will operate similarly to those in Newark.

In 1899 the source of supply of Paterson, Passaic, and Nutley, which had for years been taken at the head of Great Falls, was transferred to the new intake at Little Falls. The reasons for this change are not entirely confined to those of pollution, although there is no doubt, and indeed it is admitted by the officials of that company, that pollution from the town of Little Falls had rendered the water unsafe for domestic use. The cost of this change is, of course, not made public, yet it can be easily understood that so radical a move must have been attended by a considerable outlay, as well as the surrendering of large values by the disuse of the Great Falls pumping plant.

The opinion of Mr. Fuller, already stated, having been unfavorable to the Little Falls water in its raw state, and pressure having been brought to bear upon the company by the municipalities using it, it became necessary to construct a filter, which is nearing completion and which will cost about $400,000. Subsequent additional charges for maintenance will amount to about $6 per million gallons.

ICE INDUSTRY.

Up to the present time the value of the Passaic system as a source of ice supply has not been greatly injured by pollution. Greenwood Lake, which is by far the most valuable of the Passaic ice fields, affords an annual average supply of about 60,000 tons. On the river below Paterson there was in former times a fairly large ice industry, amounting in favorable seasons to 10,000 tons. It has, however, been completely destroyed by the pollution of the river, and the first of a proposed series of suits against the city of Paterson has been won in the lower court by an injured ice dealer.

FISH.

There was a time when Passaic shad were as highly valued in the eastern markets as are those in the North River to-day. The industry flourished and was a source of no inconsiderable income to the dwellers along the river. Under the present conditions only one hardy, inedible fish will live in these waters.

REALTY VALUES.

Pollution of the Passaic has caused its greatest damage in the reduction of realty values. We can not estimate with any degree of correctness the amount of this damage, but we know that it is enormous. The banks of the Passaic from Paterson to Newark are naturally attractive, and there is, in the northern portion of New Jersey, no more suitable nucleus for a public park. Especially along the shores of Dundee Lake are there situations which are ideal for suburban homes, and their accessibility to the large cities of the metropolitan area would naturally make them desirable in the eyes of that constantly increasing number of city business men who are making for themselves homes outside of Greater New York. Yet the area is practically uninhabitable—the residents along the shores are principally those who have lived there from birth and inherited the property upon which they dwell, or who moved there before the present conditions existed, and are encumbered with property which they can neither abandon nor sell. Only a few years ago the value of this land for farming purposes was from $500 to $800 per acre, and building sites were held at a much higher value. For one piece of property of 14 acres, in a particularly favored situation, $40,000 was refused less than twenty years ago. To-day, however, this plot can not be sold at any price, nor is there any market for the property along the entire shore of the lake.

SUMMARY.

We have seen that the natural resources of the Passaic system are very extensive, embracing water power, water supply, ice fields, fisheries, transportation, and natural scenic advantages, but that all but one of these have been so damaged by pollution as to produce the following results:

1. Abandonment of three water-supply intakes and the establishment of three others, at a total expense of not less than $20,000,000.
2. Extensive decline of power values because of inadaptability of water for use in boilers and in manufacturing processes.
3. Loss of annual harvest of ice weighing 10,000 tons.
4. Absolute destruction of fisheries in lower valley.
5. Impairment of realty values, the extent of which can not be too highly estimated in view of the fact that similar properties in clean localities have been made of immense value.

HUDSON RIVER.

Perhaps the most resourceful and certainly the most famous river on the Atlantic coastal plain is the Hudson. The history of its discovery and development has been many times retold; its physical characteristics are subjects of study in common schools, and its resources, especially from the standpoint of water power, have been repeatedly described, notably by Prof. Dwight Porter, in Volume XVI of the Tenth Census report, and later by Mr. George W. Rafter, C. E., in Nos. 24 and 25 of the series to which this paper belongs. It therefore seems unnecessary to consider this branch of the subject in the following pages, and as, up to the present time, very little, if any, detriment has arisen to water-power values through sewage pollution anywhere in the basin, the subject of power is not pertinent.

The extreme flatness of the bed of the Hudson throughout the first 150 miles from its mouth, and the depth of water maintained thereon, give to it the character of an elongated bay, or arm of the ocean, rather than that of a river. At Troy, the head of natural navigation and also of tide water, the level of the river at mean low tide is only 2.07 feet above mean sea level in New York harbor. Under these conditions, the influence of salt water extends a great distance inland, the brackish taste being appreciable at times at Poughkeepsie, 80 miles above Sandy Hook (see Pl. V, *A*). The influx of sea water by the flood tide was studied by Mr. H. L. Mandarin, under the authority of the United States Coast and Geodetic Survey, in 1871, the results of which may be seen in Table IX.

TABLE IX.—*Specific gravities of water in the Hudson River at and below the surface, reduced to a temperature of 60° F., September, 1871.*

Distance from Sandy Hook.	Station.	End of flow current.			End of ebb current.		
		Surface, specific gravity.	Below.		Surface, specific gravity.	Below.	
			Depth.	Specific gravity.		Depth.	Specific gravity.
Nautical miles.			*Feet.*			*Feet.*	
17⅛	Twentieth street	1.0198	57	1.0206	*a* 1.0141	53	1.0181
34¼	Dobbs Ferry	1.0024	30	1.0114	1.0013	30	1.0022
38¼	Tarrytown	1.0021	30	1.0089	1.0016	30	1.0076
42½	Tellers Point	1.0011	30	1.0087	1.0013	30	1.0087
49½	Verplanks Point	1.0012	30	1.0034	1.0014	30	1.0014
53¼	Iona Island	1.0017	30	1.0037	1.0012	30	1.0012
56¾	Dermings Landing	1.0016	--------	1.0028	1.0012	--------	1.0021
61	Cold Spring	1.0015	30	1.0026	1.0010	--------	--------
65	New Windsor	--------	--------	--------	1.0006	--------	--------
70¼	Carthage	1.0003	48	1.0016	1.0006	48	1.0012
75	Barnegat	1.0006	60	1.0006	1.0006	60	1.0006
79¼	Poughkeepsie	1.0007	48	1.0007	1.0006	48	1.0007

a 1872.

The drainage area of the Hudson is estimated by Professor Porter as 13,366 square miles, 8,034 of this being above Troy. Its tributaries extend into New Jersey, Massachusetts, and Vermont, and the minimum flow past Poughkeepsie is said to be about 1,500,000,000 gallons daily. In his report to the Merchants' Association of New York upon

A. POUGHKEEPSIE, N. Y., THE HEAD OF SALT-WATER INFLUENCE ON THE HUDSON.

From photograph in possession of American Museum of Natural History, New York City.

B. DELAWARE AND HUDSON CANAL TERMINUS, RONDOUT, N. Y.

From photograph in possession of American Museum of Natural History, New York City.

available sources of water supply for that city Mr. James H. Fuertes computed a probable flow of 2,900,000,000 gallons daily at the time of the measurements in the table above.

Before considering the subject of pollution in the Hudson it will be advisable to examine briefly into the character of the river and to contrast the conditions which prevail with those dealt with in connection with the Passaic. We have seen that the Passaic River is a comparatively small stream, and that it has upon its banks numerous large cities and towns which pour into it a volume of sewage at times greater than the flow of the river. In the Hudson Basin we have an area more than thirteen times the size of the Passaic, contributing to a flow which exceeds the latter in like proportion. Consequently the amount of sewage poured into the river must be as great in proportion to the flow as that in the Passaic and of similar character and distribution in order to accomplish the serious results that we have noted in the latter. From the cities in the basin of the Hudson River and its tributaries there comes a pollution far greater in amount than from those in the Passaic Basin, yet the proportion of contaminating matter to the total flow is so much less in the Hudson than in the Passaic that they bear no significant relation to one another. Few if any points in the Hudson watershed have been damaged to a degree which at all compares with the distress that has arisen along the Passaic Valley, because of the fact that the natural flow of the Hudson so largely dilutes the sewage poured into it that not infrequently the effects thereof are not traceable by sanitary analysis. In the year 1893 Dr. Thomas M. Drown, now president of Lehigh University, found that the water from the river above Poughkeepsie, which is below practically all of the polluting points in the basin, did not reveal upon analysis any serious traces of sewage matter; indeed, the water appeared altogether better than that of the Schuylkill River, from which the city of Philadelphia has for years been drawing the greater part of its supply.

TABLE X.—*Average analyses of Hudson River water at Poughkeepsie, June, 1893.*[a]

[Parts per 100,000.]

	Albumenoid ammonia.	Free ammonia.	Nitrogen as nitrates.	Nitrogen as nitrites.	Oxygen consumed.	Chlorine.
At intake of Poughkeepsie waterworks, average of 9 samples taken, 5-8 feet below surface	0.0144	0.0031	0.0007	0.0108	0.5197	0.110
At one-third distance from east shore, average of 19 samples taken at surface, 30 feet and 50 feet below surface	.0137	.0034	.0006	.0106	.5159	.107
At two-thirds distance from the east shore, average of 19 samples taken at surface, 30 feet and 50 feet below surface	.0149	.0034	.0006	.0110	.5389	.109
7 miles above Poughkeepsie, average of 6 samples across river, 30 feet below surface	.0143	.0034	.0006	.0095	.4606	.113

[a] From report of James H. Fuertes to Merchants' Association of New York.

In considering pollution upon the Hudson it will be necessary to take into account only that part lying above Poughkeepsie, for salt-water influence extends up to this point, and this of itself destroys many resources which have been noted in the preceding pages as subject to damage by pollution. All succeeding calculations will be based upon the watershed above this point unless otherwise noted. Above Poughkeepsie the river still maintains the character of an inland-traffic course, plied by steamers and canal boats. Pollution is therefore unavoidable, for if all city sewage were excluded from the river the ejecta from passenger steamers passing up and down would make the raw water unsafe as a domestic supply, especially when such matter was discharged near a supply intake. It appears, then, from what has gone before, that from the standpoint of pollution the Hudson divides into three sections: First, that within the salt-water influence, i. e., from New York to Poughkeepsie; second, that between Poughkeepsie and Troy, which by reason of its commercial value must be polluted; third, the upper or highland section, along which power sites are available and which partakes of the character of an ordinary power stream. In order to show the extent and population of the country drained by the Hudson the following table has been prepared, in which the populations have been calculated according to the Twelfth Census Reports:

TABLE XI.—*Drainage areas and population in the Hudson River Basin.*

State.	County.	Number of municipalities.	Combined area in square miles.	Population.	Population per square mile.	Sewered population.
New York	Essex	7	649	11,382	17.5	
	Warren	11	940	29,943	31.8	12,613
	Washington	11	557	31,110	55.9	3,521
	Saratoga	20	800	61,089	76.4	24,173
	Hamilton	8	1,767	4,947	2.8	
	Herkimer	21	1,459	51,049	35	21,074
	Oneida	21	[a] 896.7	117,518	131	71,726
	Lewis	1	[a] 72	917	12.7	
	Madison	1	[a] 39.3	2,024	51.5	
	Otsego	1	[a] 40	1,802	45	
	Fulton	12	567	42,842	75.4	28,479
	Montgomery	11	396	47,488	119.9	20,929
	Schoharie	16	647	26,854	41.5	2,327
	Schenectady	6	200	46,852	234.3	31,682
	Albany	13	499	165,571	331.9	132,382
	Rensselaer	17	643	121,697	189.3	86,383
	Columbia	19	691	43,211	62.5	9,528
	Dutchess	19	772	77,337	100.2	24,029
	Greene	14	660	31,478	47.7	8,219
	Ulster	21	1,157	88,422	76.4	24,535
	Orange	19	683	59,410	86.9	19,495
	Sullivan	3	[a] 60.7	8,121	13.4	
	Delaware	1	[a] 45	2,134	47.4	
Massachusetts	Berkshire	8	[a] 239	43,191	180.7	
Vermont	Bennington	13	[a] 520	19,407	37.3	
New Jersey	Sussex	10	[a] 292	13,031	44.6	

[a] These areas are estimated and are only approximately correct.

North of Poughkeepsie, on the east side, there flow into the Hudson, in the order mentioned, Crum Elbow Creek, Fallsburg and Landsman kills, Stony Creek, Roeliff Jansen Kill, Claverack and Kinderhook creeks, Moordener, Wynant and Poeston kills, Hoosic River, Batten Kill, Moses Kill, and Schroon River. Of these, Crum Elbow Creek, Fallsburg Kill, Stony and Claverack creeks, Roeliff Jansen and Moses kills, and Schroon River are not important from the standpoint of pollution, as they flow into the Hudson in a comparatively pure state. Landsman and Wynant kills and Kinderhook Creek receive a certain amount of pollution indirectly at the centers of population in the courses of the three streams. Hoosic River is badly polluted, and Batten Kill to a less extent.

On the west side of the Hudson the river branches enter in the following order: Rondout Creek, Esopus, Catskill, Hannacrois, and Coeyman creeks, Norman Kill, Mohawk River, Anthony Kill, Fish Creek, Snook Kill, and Sacandaga, Indian, Cedar, and Rock rivers. Of these, Hannacrois and Coeyman creeks, Norman and Snook kills, and Sacandaga, Indian, Cedar, and Rock rivers need no discussion because of their comparative freedom from pollution. Rondout, Kaaterskill, and Catskill creeks receive considerable indirect and private drain pollution, while Wallkill and Mohawk rivers and Esopus and Fish creeks are directly polluted by sewage systems.

It has already been stated that pollution along the middle or navigable section of the Hudson above salt-water influence is unavoidable, even if city sewage were entirely excluded from the river. In order to make the whole pure it would be necessary to close the river to commerce, and as its value as a means of transportation far overtops all other values which it may have, such a suggestion is manifestly absurd. We are forced, then, to conclude that, for the present at least, while pollution may unfit the Hudson up to Troy for use as a domestic water supply without filtration, the damage to the resources is insignifiant compared to the damage which would occur by excluding sewage from the river. While the water remains fit for filtration, then, the Middle Hudson is of more value as a polluted stream than it would be if preserved unpolluted. But if the time should ever come when the condition of the Hudson should approach that of the Lower Passaic, then it would be highly necessary to enforce sewage purification upon the towns and cities along the banks. Such a contingency is, however, very remote.

The reports of the Tenth, Eleventh, and Twelfth Census bureaus show that the growth in population along the Hudson below the mouth of the Mohawk has not been marked. During the last decade the cities of Albany, Troy, and Hudson have actually decreased in population, while the gain in others has been subnormal. Any alarming increase in the amount of sewage poured into the Hudson can not, therefore, be expected, and it will not probably be in danger of becoming the consummate pest that the Passaic has become should there be no regulation of sewage disposal for generations.

It will be necessary to consider the sources of pollution along the middle section of the Hudson in order that the conditions there existing may be clearly shown. Catskill, Hudson, Albany, Rensselaer, Watervliet, and Troy (including Lansingburg) are sewered cities along the middle section of the river, containing a combined population of 204,196. The amount of sewage discharged from these places is unknown; no gagings have been made, and any estimate which might be given would not be even approximately correct. Judging from the population involved it might be expressed as about one-half that discharged into the lower section of the Passaic.

Catskill is a village of 5,484 inhabitants, having shown a growth of 11.5 per cent during the last decade. The manufacture of bricks forms a large industry, and the textile mills are important. Its source of water supply is the Hudson, the water from which is filtered previous to distribution. A system of sewerage has been extended throughout the corporate limits, and the sewage is discharged, unpurified, into the mouth of Catskill Creek.

Hudson is a city in Columbia County, which is largely devoted to manufactures of iron and lumber. It is also the seat of several State homes and schools. During the past decade the population has dropped from 9,970 to 9,528. It is supplied with filtered water from the Hudson, and discharges about 1,200,000 gallons of unpurified sewage daily through a combined system of sewerage.

Albany, the capital of the State of New York, has also decreased in population. During the decade 1890–1900 the loss amounted to .81 per cent. Although in the past the city has suffered severely from polluted water supply, the filters recently installed under the direction of Mr. Allen Hazen, M. Am. Soc. C. E., have made Hudson River water acceptable. The sewers discharge raw wastes into the Hudson, but there appear to be no available records of gagings of the amount. The average daily consumption of water at the present time is, however, about 18,000,000 gallons.

Rensselaer, situated opposite Albany, in Rensselaer County, is a municipality in which there has been a slight growth, the population, according to the Twelfth Census, being 7,466. It is supplied with water from the Hudson, filtered by a Jewell mechanical filter. A separate system of sewerage discharges raw wastes into the river, the amount of which is said to average about 1,500,000 gallons daily. The accuracy of this statement is uncertain, however, and it is probable that the actual discharge is considerably more than the above.

Watervliet, formerly known as West Troy, and Troy, which now includes the former city of Lansingburg, have a combined population of 87,567. The increase in population at Watervliet and Lansingburg has been normal, but at Troy the Twelfth Census returns show a decrease in the last decade of 300. Troy water is largely taken from the Hudson and has caused a great amount of disease. Plans are now being executed which will relieve this condition by the conservance of a highland supply a short distance away from the city.

At Lansingburg the drainage into the Hudson has been defective, and plans for making more perfect, more direct pollution have been approved by the State board of health.

Besides the above-mentioned municipalities there are located upon the banks of this section of the Hudson the following small places included in Table XII, some of which have no public sewerage systems, yet which furnish considerable pollution.

TABLE XII.—*Population, water supply, and sewerage of certain towns on Hudson River.*

Place.	Population.			Water supply.	Sewerage.
	1890.	1900.	Change.		
Saugerties	4,237	3,679	− 540	Yes	No.
Athens	2,024	2,171	+ 147	No	Do.
New Baltimore	2,455	2,283	− 172	Yes	Do.
Coeyman	3,669	3,925	+ 283	do	Do.
Hyde Park	2,821	2,806	− 15	No	Do.
Bath	3,261	4,994	+1,733	Yes	Do.
Rhinebeck	1,649	1,494	− 155	do	Do.
Tivoli	1,350	1,153	− 197		
Castleton	1,127	1,214	+ 87		
Coxsackie	1,611	2,735	+1,124	Yes	Yes.

Above Troy navigation on the Hudson is confined to the transfer of canal boats through the pool of the State dam at Troy up the river to Waterford, where they enter the Champlain Canal. According to recent reports there has been a reduction in canal traffic in New York State, so that the value of the river above Troy for heavy traffic can be regarded as somewhat transitory. Above this point, then, the river is valuable principally for power, water supply, and ice.

Civic pollution becomes more important above the confluence of the Mohawk, where the flow is considerably less, and the danger is that, as the cities increase in population, there will arise conditions similar to those on the Passaic. The cities and villages above Troy have all shown a healthy growth during the past decade, and, strangely enough, have collectively increased at a rate far higher than places nearer the metropolis.

TABLE XIII.—*Centers of pollution on Upper Hudson.*

City.	Population.		Sewerage.	Place of disposal.	Water supply.
	1890.	1900.			
Cohoes	22,519	23,910	Yes	Hudson and Mohawk.	Yes.
Waterford	(*a*)	3,146		Mohawk and Hudson.	Hudson River.
Mechanicville	2,679	4,695	Combined	Hudson	Plum Brook.
Schuylerville	1,387	1,601	No		No.
Fort Edward	(*a*)	3,251	Yes	Hudson	Yes.
Sandy Hill	2,895	4,473	No		Do.
Glens Falls	9,509	12,613	Yes	Hudson	Do.

a Incorporated since 1890.

The above-named cities and villages represent a sewered population of 47,615. Mechanicville is a village devoted to manufacturing, the thread industry being the most important. It shows a growth of about 74 per cent during the past decade. Schuylerville has considerable private drain pollution, yet it is without marked effect upon the river. At Fort Edward there is a satisfactory water supply, and a sewerage system has been recently constructed which extends nearly throughout the corporate limits.

Sandy Hill is another thriving village, showing a growth of 55 per cent during the last decade. Although no sewerage system has yet been constructed, the river pollution is comparatively serious. In 1896 plans for a system of sewerage and disposal works were submitted to the State board of health and accepted, so that even though nothing further has been accomplished the establishment of another source of pollution can not be far removed. Glens Falls, a short distance above Fort Edward, is supplied with water and sewerage systems, which are well extended through the village. The place of the final disposal of the sewage is described by the village engineer, George P. Slack, as a "sink hole in ledge," which probably means that it takes the most obvious course, i. e., the Hudson River, accompanied, very likely, by a slight purification. This village has a population of 12,613, having increased from 9,509 during the last decade.

This part of the river, comprising in its drainage area about 5,000 square miles, is said to have an average flow of about 174,528,000 cubic feet daily, which is probably approximately correct. It partakes of the nature of a highland river, having a fall from Glens Falls to Troy, a distance of 46.5 miles, of 282 feet, and is largely given up to lumber business and lime manufacture.

Waterford and Cohoes are at the mouth of the Mohawk. At both places mill manufacturing is the largest industry, Cohoes possessing one of the largest cotton mills in the world. Pollution from these two cities, added to that already imparted to the Mohawk from cities above, is responsible for the high morbidity rate from waterborne diseases in the cities of Troy and Albany.

EASTERN TRIBUTARIES OF THE HUDSON.

The tributaries of the Hudson that receive only pollution incident to the drainage of unoccupied land require only slight consideration in these pages, while those that are comparatively normal as to condition of water do not come within the scope of this discussion. The tributaries entering the Hudson from the east belonging to the first class above noted are Landsman and Wynant kills and Kinderhook Creek.

Landsman Kill, a small stream entering the Hudson at Vanderburg Cove, carries considerable pollution from the village of Rhinebeck, which contains 1,484 inhabitants. A report from the secretary of the local board of health stated that a water supply has been provided and that the village has no system of sewerage. It is further stated that at least 75,000 gallons of sewage a day enters the stream. The method of estimating this amount is not shown, however, and it is more than probable that the result is a wide approximation made with questionable data. However this may be, it is certain that the amount ejected has no appreciable effect upon the lower reaches of the river, and its presence is apparent locally only in the area immediately around the various points of discharge. The village of Rhinebeck has decreased considerably in population during the past decade, and the question of future pollution at this point can not be regarded as serious.

Wynant Kill empties into the Hudson a short distance below Troy, having flowed northwest through an agricultural region. Its ultimate source of supply is a chain of lakes in and around the town of Sandlake, in Rensselaer County. At Averill Park and other small settlements there is unimportant pollution. The drainage area seems to be slowly losing its population and the future is therefore not regarded with apprehension.

Kinderhook Creek passes through country similar to that drained by Wynant Kill. Upon its banks are the comparatively important settlements of Nassau, Valatie, and Stockport. The latter is upon Claverack Creek near its confluence with Kinderhook. The observations above made may well apply to the conditions upon this creek.

Hoosic River and Batten Kill are polluted to a greater extent than the rivers considered immediately above. Both of these streams, and especially the former, are damaged considerably by contaminating waters.

Upon Hoosic River are the centers of population shown in Table XIV.

TABLE XIV.—*Centers of population on Hoosic River.*

Name.	Population.		Water.	Sewerage.
	1890.	1900.		
Schaghticoke	1,258	1,061	No	No; many private drains in Hoosic.
Johnsonville[a]			do	No.
Valley Falls[a]			do	Do.
Hoosic Falls	7,014	5,671	Yes	Yes; separate system.
Cambridge	1,598	1,578	do	No; many private drains in Owl Kill.
Bennington	3,971	5,656	do	Yes.
North Adams	16,047	24,200	do	Yes; partly emptying into Hoosic.

[a] Part of Pittston town; no separate returns.

The Hoosic drainage basin extends through Rensselaer and parts of Washington and Columbia counties into the States of Vermont and Massachusetts, comprising an area of 730 square miles. The average flow of the river is stated to be about 450 cubic feet per second, with a minimum of 180. It is a most important power system, and for that reason there is a fairly large population within the basin.

At Schaghticoke, a village of 1,061 inhabitants, there is no public water supply and no sewerage system, but there is nevertheless a large amount of pollution from drains and factories, which undoubtedly has an appreciable effect upon the water of the river.

At Hoosic Falls there are 5,671 inhabitants supplied with water from wells dug along the banks of the river. Filtration is such that the pollution above this point does not affect the water drawn from the wells. There is also a separate sewerage system, emptying raw sewage into the Hoosic.

On a branch of the Hoosic called Owl Kill is the village of Cambridge, with 1,578 inhabitants. It has a water supply and no sewers, so that the pollution, although considerable in amount, is somewhat indirect.

Bennington, in Vermont, with a population of 5,656, has a sewerage system emptying into the Wallomsic, a branch of the Hoosic.

At North Adams, Mass., a city of 24,200 inhabitants, lying near the head of Hoosic River, there arises the most serious contamination along the whole length of the stream. The condition is at times exceedingly offensive, and the local board of health has found it advisable to prohibit the sale of ice from the river and from polluted ponds emptying into it. The condition is well set forth in the reports of the Massachusetts State board of health. The following table of average analyses is taken from the report issued for the year 1900 (p. 330), the water having been taken from the river at Williamstown, a short distance below North Adams.

TABLE XV.—*Chemical examination of water from the Hoosic River at Williamstown, Mass.*

[Averages by years, in parts per million.]

Date of collection.	Turbidity.[a]	Color.[b]	Nitrogen as—				Chlorine.	Total residue.	Hardness.
			Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.			
1888	D.	1.0	0.187	0.040	0.010	0.306	2.4	102.1	....
1894	D.	2.3	.265	.111	.009	.157	3.5	107.7	73
1895	D.	2.8	.334	.146	.013	.162	3.9	124.1	81
1896	D.	2.1	.326	.261	.015	.323	4.4	118.3	81
1897	D.	2.3	.273	.125	.008	.252	2.7	99.2	64
1898	D.	2.4	.286	.152	.005	.187	2.6	91.3	58
1899	D.	2.8	.505	.223	.018	.141	5.0	123.7	69
1900	D.	2.4	.436	.328	.026	.146	4.7	118.5	65

[a] "D." is a term used to indicate the general appearance of the water, and means "decided."
[b] Determined according to Nessler standards.

In the above table it is of interest to note the increase from year to year in the ammonias, nitrites, and chlorine, indicating unmistakably the increase in pollution from North Adams, along with municipal growth.

The Hoosic River is therefore a stream which becomes a troublesome nuisance almost at its starting point, and passes through Vermont into New York State in a badly damaged condition. During the long stretches through New York it improves in quality through oxidation of its organic contents and sedimentation of its suspended matter, and, in spite of the contamination it receives at various points, enters the Hudson probably in better condition than when it crosses the New York-Vermont State line. It is the clearest case of interstate pollution which we have yet considered.

Next above the Hoosic is Batten Kill, which is one of the most valuable power streams tributary to the Hudson. It has a drainage area of about 450 square miles, and the average flow has been roughly determined at about 280 cubic feet per second.

The important centers of population along the river are Greenwich and Salem, which have 1,869 and 3,191 inhabitants, respectively. Neither of these places has a public sewerage system, yet pollution of the river from these points is well marked.

It is a surprising fact that nearly all of the towns and villages lying east of the Hudson in New York seem to be unprogressive, many of them having decreased in population during the last decade. Pollution is therefore not a growing danger in the eastern tributaries, and the water which flows from them into the Hudson is pure as compared with that of the main river.

WESTERN TRIBUTARIES OF THE HUDSON.

Pollution upon the western basin of the Hudson is far more serious than that on the east. The facts concerning the important rivers joining the main river from the west are given in Table XVI

TABLE XVI.—*Western tributaries of Hudson River.*

Stream or branch.	Number of pollution points.	Number of sewerage systems.
Rondout Creek	3	None.
Wallkill	16	3; two doing considerable damage.
Esopus Creek	8	1; part of Kingston system.
Catskill Creek	4	None.
Kaaterskill	6	Do.
Hannacrois Creek	None.	Do.
Norman Kill	2	Do.
Mohawk River. (*See* special discussion below.)		
Anthony Kill	1	1
Fish Creek	2	2
Sacandaga River	3	None.
Indian River	None.	Do.
Cedar River	None.	Do.
Rock River	None.	Do.

Catskill and Esopus creeks, Wallkill River, and Rondout Creek have during the last few months received the attention of the engineering corps of the water department of New York City in cooperation with the Division of Hydrography of the United States Geological Survey. The various drainage areas have been examined, and gaging stations have been established in the streams at convenient and important points.

RONDOUT CREEK AND WALLKILL RIVER.

Entering the Hudson at Kingston is Rondout Creek, which drains an important area in New York and a few square miles in New Jersey. Its principal tributary is the Wallkill, whose drainage area is described in Water-Supply and Irrigation Paper No. 65, pages 71 and 72. At New Paltz, N. Y., a gaging station has been established, and the current-meter measurements that have been made at that place since July, 1901, are reproduced upon pages 72 and 73 of the above-mentioned report.

The principal branch of the Wallkill is Shawangunk Creek. A large amount of sewage enters the main river, and of late it has increased markedly. The principal foci of pollution are at New Paltz, Modena, Gardiner, Wallkill, Walden, Montgomery, Goshen, Middletown, Warwick, New Millford, Hamburg, Deckertown, and Florida. At Middletown (a manufacturing and dairy center) there has been established a sewerage system which discharges into a small tributary of the Wallkill a total of about 865,000 cubit feet of sewage per day. The damage arising from this practice has been so great that it was made the subject of a special investigation by the State board of health of New York. In the twelfth annual report of that body is an account of the investigation, written by Mr. Charles C. Brown, formerly a professor at Union College, Schenectady. A part of Professor Brown's report reads as follows:

The condition of the stream in the future, if left unattended to, will become rapidly worse, for the amount of pollution entering the stream is rapidly increasing. The sewerage system of the city of Middletown is practically but two years old [1891] and the proportion of houses connected with the system is still quite small. * * * Additional sewers are put in at frequent intervals and the city is steadily increasing in population. * * *

This makes early attention to the improvement of the stream absolutely necessary. As far as Mohegan Brook is concerned, the trouble could be remedied by constructing an outlet sewer to Wallkill River. I believe the river is not large enough to take care of the amount of sewage discharged from the main sewer without the production of nuisance. Villages along the course of the Wallkill below Middletown are discussing the propriety of using the water for domestic purpose.

Since the date of this report, Middletown has increased to a city of 14,552 inhabitants, a gain of 21 per cent over the returns for 1890. The average daily water consumption is 2,000,000 gallons, and Mohegan Brook has been condemned by the courts as a sewage course, making it necessary for the city to provide a sewage-purification plant.

At Goshen the pollution of the small creeks which run through the village is remarkable. In a report made to the State board of health in 1890 Professor Brown stated:

This brook at present receives much drainage from houses and business blocks in the village and nearly all the street drainage. But the headwaters of one branch of the stream furnish the water supply for the village, and what is left forms only a small brook, which must become very foul during ordinary seasons when there are no frequent heavy showers to flush it out. On my last visit I found the brook in this foul condition, throughout both its main branches in the village. * * *

I have no doubt that the condition of this brook is responsible to a large extent for the epidemics of zymotic diseases to which the village seems to be subject.

A water and sewerage system has been installed at Walden, a thriving dairying center of 3,147 inhabitants. The total daily water consumption is 80,000 gallons, but as the "combined" system of sewerage has been installed the discharge into the Ten Broeck and Wallkill is considerably more than the water consumption in stormy seasons.

Deckertown, N. J., having a population of 1,306, has installed an excellent water-supply system, and although no sewers have yet been laid a large amount of pollution enters the Wallkill. This forms another opportunity for future trouble arising from interstate pollution. The difficulties of regulating the New Jersey end of the watershed were recognized in the report of the engineering committee of the Merchants' Association of New York upon the Water Supply of the City of New York (p. 78). It was regarded as a "serious complication" in the way of adopting the Wallkill water for the city of New York, although these complications were recognized as due as much to other features of interstate regulation as to pollution.

Chester and Montgomery, villages of 1,250 and 973 inhabitants, respectively, are supplied with water systems, and the pollution of the river is by private drains and contaminated run-off water only.

New Paltz, a village of 1,022 inhabitants, furnishes a surprising amount of contamination, even though it possesses no system of sewerage. Plans were approved by the State authorities for such a system October 27, 1892, which provided for the ultimate disposal of the sewage in Wallkill River, with three main points of discharge. Although almost a decade has passed the system has not been laid, and in the interim extensive private sewers have been laid into the Wallkill in defiance of the State authorities.

ESOPUS CREEK.

A description of the drainage area of Esopus Creek appears upon page 63 of Water-Supply and Irrigation Paper No. 65, and current-meter discharge measurements which have been made at Kingston since July, 1901, are reported upon pages 64 and 65 of the same paper.

On Esopus Creek above the city of Kingston there is only incidental pollution from a few small hamlets, the effects of which upon the river are not important. At Kingston there is a system of sewerage, a part of which discharges directly into the stream. Previous to the installation of this system the State board of health sent its consulting expert, Professor Brown, to examine into the question of probable results of such installation, with especial reference to its effect at Saugerties, where at that time the water was used for drinking purposes by about 900 mill hands. A consideration of the ice industry and the damage that it would probably suffer by the installation of the sewers was included. After determining the physical characteristics of the river with reference to its natural advantages for assisting the process of sedimentation, and taking into consideration the distance of the proposed outlet above Saugerties, Professor Brown made no very direct statement of the probable effect of Kingston's sewage, but finally recommended that all the sewage from the west end of the city be dumped into Rondout Creek, where it would be conducted more directly to the Hudson. This suggestion was not followed when the sewerage system was laid, and the results have been marked in Esopus Creek, so that it became necessary for the city of Kingston to construct a sewage purification plant. When that part of the system now under construction has been completed it will properly dispose of the sewage from two of the nine wards now discharging into Esopus Creek.

CATSKILL CREEK.

A description of the drainage basin of Catskill Creek appears upon page 61 of Water-Supply and Irrigation Paper No. 65. The records of current-meter measurements of the stream at South Cairo, N. Y., are set forth upon page 62 of said paper. The Catskill, with its principal branch, the Kaaterskill, is another of the western tributaries of the Hudson that is damaged only slightly by pollution. Here and there are small villages along the banks, none of which have sewerage systems, but which contribute manufacturing wastes and private-drain sewage in appreciable amounts, yet which as a whole have no marked effect upon the character of the water. Catskill, a city at the mouth of the river, is the only large place on it, and the pollution from there is carried quickly into the Hudson.

Hannacrois and Coeyman creeks and Norman Kill are not important from the standpoint of pollution.

MOHAWK RIVER.

This great western arm of the Hudson is nearly as widely known as the main river itself. The valley of the Mohawk was made famous in colonial times by Indian wars, and its beauty and the fertility of its land made it a favored line of western travel along which New England emigrants passed or within which they settled according to their tastes and resources. Cities along the banks of this river have grown into prominence, especially since the opening of the Erie Canal, and it is a favored section of the country, which is generally regarded as continuously prosperous.

Under the authority of the United States Geological Survey and the New York State engineer and surveyor, the Mohawk has been studied as has no other tributary of the Hudson. The results of this work are recorded in the Twentieth Annual Report of the Survey and in the State Report by Edward A. Bond, State engineer, made December 1, 1901, entitled Report on the measurement of the volume of streams and the flow of water in the State of New York.

According to the latter report the drainage area of the Mohawk is 3,400 square miles. Results of measurements of flow at a station

A. A LAKE IN THE CATSKILL MOUNTAINS AT THE HEAD OF THE CATSKILL RIVER, NEW YORK.

From photograph in possession of American Museum of Natural History, New York City.

B. WINNISOOK LAKE, NEW YORK.

From photograph in possession of American Museum of Natural History, New York City.

located at the New York State feeder dam, 4 miles below Schenectady, are expressed in the following diagram:

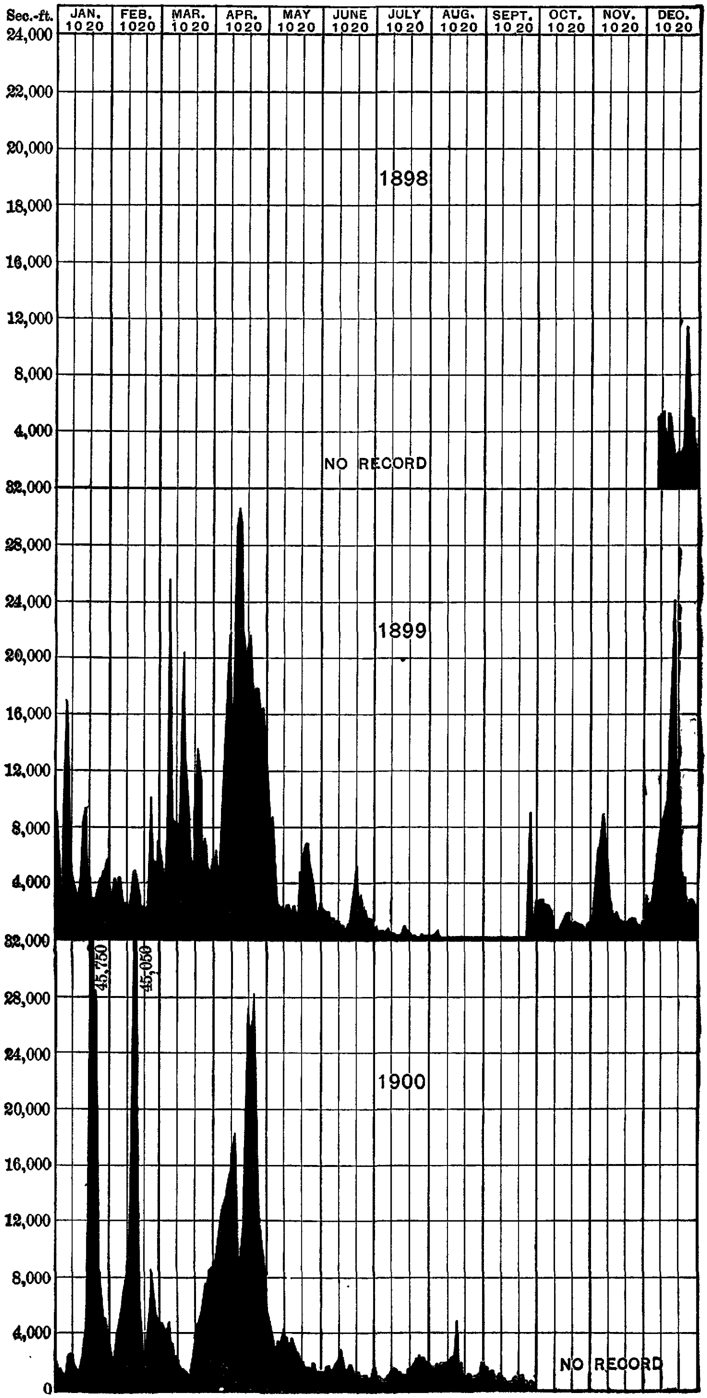

FIG. 2.—Discharge of Mohawk River at Rexford Flats, N. Y., 1898–1900.

Similar measurements were made at Little Falls, Herkimer County with results expressed as follows:

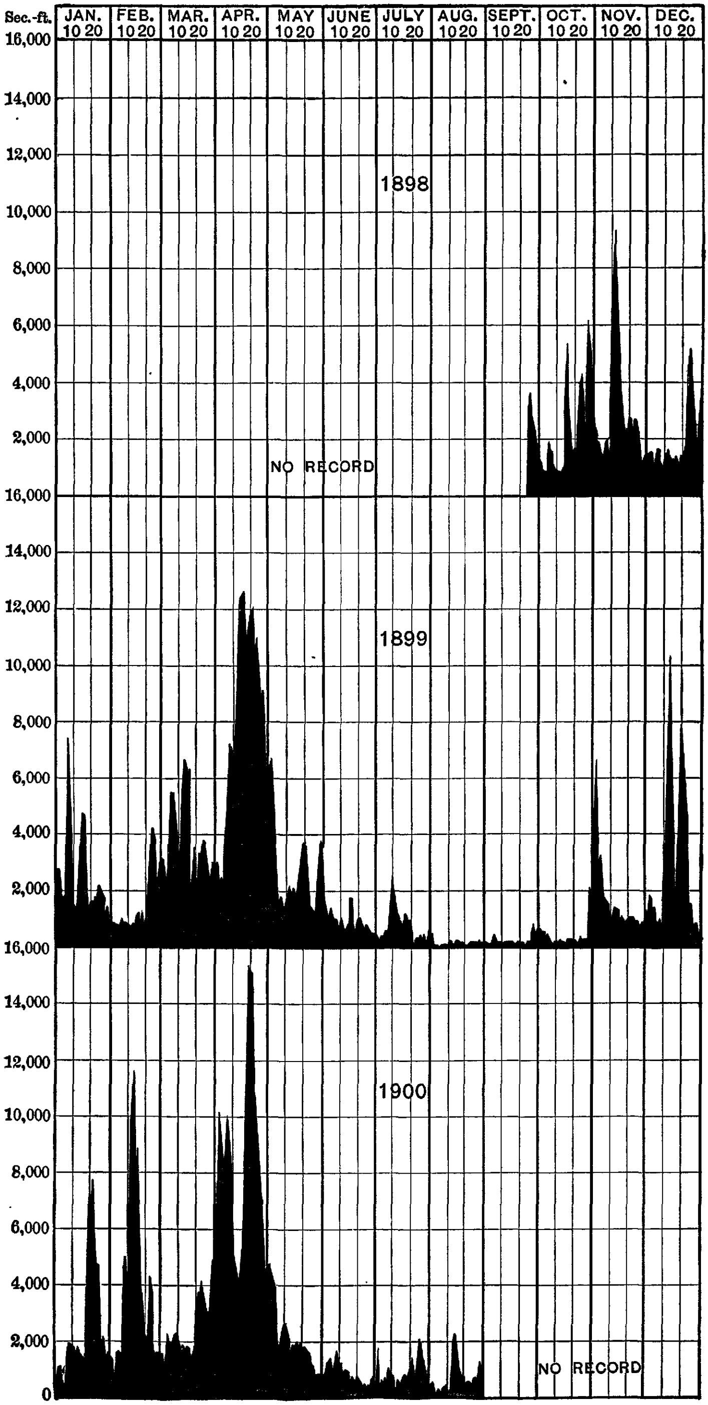

FIG. 3 —Discharge of Mohawk River at Little Falls, N. Y., 1898-1900.

The principal tributaries of the Mohawk are Schoharie Creek, with a drainage area of 974 square miles, East Canada Creek, draining 285.7, and West Canada Creek, the basin of which covers 584 square miles. This leaves to the main river and minor tributaries a drainage area of about 1,557 square miles. The centers of population on the Mohawk proper, from the point of view of pollution, are set forth in Table XVII:

TABLE XVII.—*Centers of population on Mohawk River.*

Name of municipality.	Population.		Water supply.	Sewerage system.	Sewered population.
	1890.	1900.			
Schenectady	19,902	31,682	Yes	Yes	31,682
Amsterdam	17,336	20,929	do	do	20,929
Fonda	1,190	1,145	do	do	1,145
Canajoharie	2,089	2,101	(a)	(a)	
Fort Plain	2,864	2,444	Yes	Yes	2,444
Nelliston	721	634	(a)	(a)	
St. Johnsville	1,263	1,873	Yes	No	
Little Falls	8,783	10,381	do	Yes	10,381
Herkimer		5,555	do	do	5,555
Mohawk	1,806	2,028	(a)	(a)	
Ilion	4,057	5,138	Yes	Yes	5,138
Frankfort	2,291	2,664	No	Partial	
Utica	44,007	56,383	Yes	Yes	56,383
Rome	14,991	18,343	do	do	18,343
Fultonville	1,122	977	No	No	
	120,422	162,277			152,000

[a] No returns.

The city of Schenectady, the first above Cohoes, is an important manufacturing center. It is provided with water from wells outside the city limits, a new supply which was installed when the city was

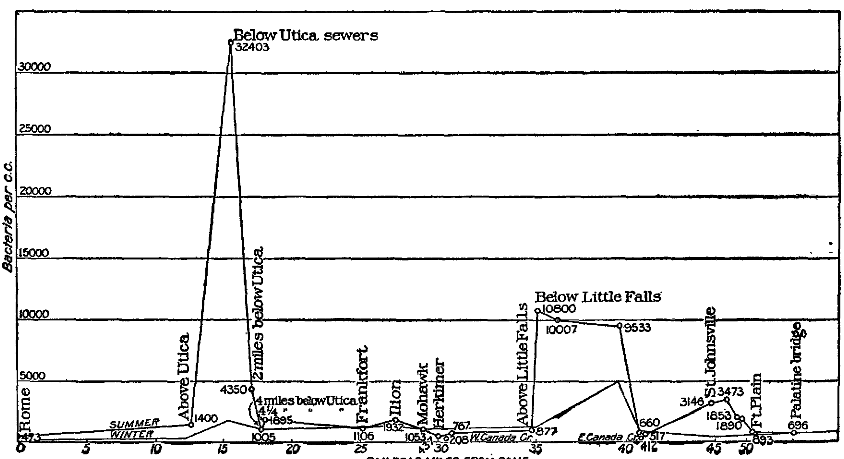

FIG. 4.—Diagram showing extent of pollution at various places along Mohawk River.

obliged to give up the use of the raw water from the Mohawk because of pollution from the cities above. There is also established a separate system of sewerage, from which, according to rough measurements, there are poured into the river 6,000,000 gallons of raw sewage daily.

Amsterdam, a short distance above Schenectady, is also provided with a separate system of sewerage. The small villages of Fort Hunter, Fultonville, Fonda, Canajoharie, Fort Plain, and Nelliston follow in the order stated, each adding its increment to befoul the water of the Mohawk. At Fonda and Fort Plain the sanitary and storm sewers pour considerable sewage into the river, while at the other places there is only the incidental pollution common to unsewered towns.

At St. Johnsville there is provided a double system of water supply, one part of which is for domestic purposes and the other, drawn from a local creek, for fire and domestic purposes. The filthy impregnation of the soil is immense, and the report of the secretary of the local board of health states that, while the amount of sewage flowing into the river has not been determined, there is "plenty of it."

Little Falls has established a combined system of sewerage, which has been extended throughout the corporate limits. Herkimer has a separate system, which discharges about 200,000 gallons of raw sewage daily. At Ilion sewers have been extended practically throughout the corporate limits, and from them about 300,000 gallons are poured into the Mohawk. Farther up on the river is the large city of Utica, grossly polluting the river, and finally Rome, the sewerage system of which constitutes the head of pollution.

TRIBUTARIES OF MOHAWK RIVER.

Cobleskill is the only important point of pollution upon Schoharie Creek, while West and East Canada creeks have not at the present time sufficient pollution to warrant attention here.

The foulest branch of the Mohawk is Cayadutta Creek, a small stream entering the Mohawk from the north at Fonda. The nuisance occasioned by sewage from Gloversville and Johnstown has been of sufficient importance to demand a special investigation by order of the governor of the State of New York.

The following extracts are taken from the Eighteenth Annual Report of the State Board of Health of New York (pp. 85–100):

The undersigned residents of the city of Johnstown, N. Y., respectfully beg to present to your attention the unwholesome condition of a certain portion of this city, situated along East Main street and near the foot of Chase street, consisting of low, marshy land, having communication by a small stream crossing Chase and East Main streets, known as Prindle Creek, with Hale Creek, a large stream flowing for some distance parallel to East Main street, and about 350 feet distant therefrom, and emptying into Schiver's Pond, the waters of which flow into Cayadutta Creek and thence into the Mohawk River, at Fonda, N. Y., 4 miles to the south. Into this locality and into the said Prindle Creek—the waters of which are very low during the summer season at the point where said creek crosses East Main street—empties a sewer about 12 inches in diameter, running

A. AUSABLE RIVER, NEW YORK.

From photograph in possession of American Museum of Natural History, New York City.

B. DEVASEGO FALLS, SCHOHARIE RIVER, NEW YORK.

From photograph in possession of American Museum of Natural History, New York City.

through a portion of East Main street west of said Prindle Creek, which conveys sewage from the houses along that portion of East Main street and from the houses along that portion of Fon Clair street, which intersects East Main street, being about 35 in number. Into Hale Creek, a short distance to the northwest, and at a point within 250 feet of the residences along said East Main street, empties another sewer of the same size, which conveys sewage from the houses and business places along the remaining portion of East Main street west of Prindle Creek, and from the houses on Glebe and a portion of East State street, which intersect said East Main street, in all being about 150 in number. These sewers have been laid a number of years, and their outflow has been recognized and pronounced by the local board of health to be a public nuisance, and orders have been issued by said board for the abatement of the nuisance. Into said Prindle Creek and the territory aforesaid at or near Chase street also empties a sewer pipe about 14 inches in diameter, running through Chase street and other streets to the south thereof, and which conveys the sewage from the houses on Prospect street, Whitmore avenue, East Clinton, Cady, and East Montgomery streets, a part of East State street, and a part of Fon Clair street. The three sewers mentioned convey all the sewage from the houses and business places in the southeastern portion of the city, comprising in all about 500 in number. The outlet of the said Chase street sewer is within 400 feet of the public school on East State street, at which there is a daily attendance of about 300 pupils.

The condition of affairs in this portion of the city has been frequently, during the past two years, called to the attention of the local board of health and the common council of the city, as the extracts from their minutes of proceedings hereto annexed and made a part of this petition will show, and although they have frequently taken the matter into consideration, no steps have been taken to correct or abate the nuisance and relieve the residents of that portion of the city.

The territory in the neighborhood where these sewer deposits are made is surrounded by residences of the better class, most of them recently built, and those along East Main street, east of the Prindle Creek, which number thirty-five, have thus far been unable to get any sewerage, because it is alleged that the bed of the Prindle Creek is not low enough to permit of sewering into that stream, and the local authorities have thus far refused to provide any other method.

In this connection it may be well to state that all the sewage of the city of Gloversville, and most of that of the city of Johnstown, is discharged, directly or indirectly, into the Cayadutta Creek, and thence into the Mohawk River at Fonda, without being treated, and it has been suggested that the territory referred to in this petition can be properly sewered by a pipe running through the bed of Schrivers Pond into Cayadutta Creek, and it is apparent that no special harm will come from this additional quantity of sewage thus disposed of. The undersigned, who live within the pernicious influence of this nuisance, which is admitted to be a nuisance by the local authorities, respectfully represent that the situation demands immediate action, that a loathsome stench pervades the locality under certain conditions of temperature, and that already, during the hot weather of this summer, this stench has been prevalent. Sickness has occurred which has been attributed by physicians to this cause. The nuisance increases in gravity every year, while the sewage more deeply impregnates and pollutes the soil.

The undersigned beg your excellency to lay the matter before the State board of health with instructions to investigate it and adopt such measures as shall without delay put an end to this nuisance. Efforts have been made for two years past without avail to accomplish this object, and we appeal to your authority to set in motion the measures which shall promptly relieve us of a distressing and dangerous pest.

[Signed by thirty-eight residents of Johnstown, N. Y.]

The report of Dr. F. C. Curtis, consulting expert, who went to investigate the conditions alleged in the above petition, is as follows:

Johnstown is supplied with sewers which provide for the house waste of a considerable portion of the city, all emptying into Cayadutta Creek. East Main street, referred to in the petition, is a continuation of Main street into a more recently built part of the city. The topography is such that it is impossible for a sewer from this section to connect with already existing sewers, as it lies at a considerably lower level. East Main street, which is built up with detached residences of a good class for some distance, has no sewerage outlet, the residences depending upon cesspools for their waste. To the southeast of this street the ground rises rather abruptly, and several streets, more or less built up, are laid out upon it. Coming down from this territory is a small stream, Prindle Creek, which traverses East Main street obliquely and flows across low meadows to Cayadutta Creek, or, rather, in its course, through Schrivers Pond. This is the natural drainage medium for the southeastern area of the city. The stream as I saw it, after prolonged rain, was a considerable one, but it soon dwindles to a very moderate flow of perhaps 10 gallons per second. Just before it reaches East Main street it crosses Chase street, which extends up the abrupt hillside for a few blocks and terminates at the bottom, as do all its parallel streets, in East Main street. In this Chase street is a recently laid 12-inch tile sewer which collects and carries off the sewage not only of Chase street, but of a number of lateral streets which branch into it. This sewer, with no provision for flushing it, terminates beneath a small bridge in the little stream, and as the volume of this stream is inadequate to carry away the sewage thus turned into it, this deposits directly at the sewer outlet and along its course, especially in the low meadow land on the other side of East Main street. It becomes a tortuous, uneven, open sewer, and by means of its improper use a serious nuisance, inevitably filling the surrounding atmosphere with offensive and unwholesome odors. There is no question of this, from my own observation, nor on the part of the health officer and citizens with whom I conferred.

In the Nineteenth Annual Report of the State Board of Health (pp. 74–76) Prof. Olin H. Landreth, who was engaged by the city of Johnstown to investigate the matter, reports in part as follows:

The only manufacturing waste of sufficient amount to warrant consideration in conjunction with the matter of sewage is the tannery and leather-dressing waste and refuse. There are at least 18 establishments in the city engaged in this business, employing in the aggregate about 750 men when in ordinary operation.

Returns were duly received from the majority of the concerns, representing over two-thirds of the total number of men employed and three-fourths of the total output, and means were taken to secure the best estimates possible for the remainder of the plants. The aggregate exhibit for all the plants representing those covered by both returns and estimates is as follows:

Number of men employed		746
Weight of hides per annum	pounds	5,600,000
Gallons of water per diem		150,000
Weight of lime per annum	pounds	725,000
Weight of alum per annum	do	230,000
Weight of salt per annum	do	1,500,000
Weight of oil vitriol	do	45,000
Weight of copperas per annum	do	6,000
Weight of bluestone per annum	do	600

Weight of muriatic acid	pounds	4,000
Weight of soda ash	do	50,000
Weight of hyposulphate soda	do	18,000
Weight of bichromate potash	do	12,000
Weight of fish oils	do	500,000
Weight of flour	do	100,000
Weight of logwood	do	1,500,000
Weight of Brazil wood	do	21,000
Weight of fustic	do	320,000
Weight of hypernic	do	110,000
Weight of quercitron	do	28,000
Weight of gambier	do	500,000
Weight of anilines	do	1,000
Weight of lactic acid	do	1,100
Weight of sal soda	do	15,000
Weight of alder wood	do	7,000
Weight of egg yolk	do	105,000

Accurate statistics of the amount of leather produced from the hides could not be obtained, but from estimates made by several individuals conversant with the business it is safe to conclude that the weight of leather, independent of the materials which it finally contains as filling and coloring matter, is less than one-half the weight of the hides used, indicating about 3,000,000 pounds per annum of refuse animal matter, chemical preservatives, and filth. Certain portions of this refuse material are preserved for utilization as by-products, but there is good ground for the estimate that not less than one-third of the above amount, or 1,000,000 pounds, and quite possibly 2,000,000 pounds, of the most offensive parts of this refuse from the hides is discharged into the creek. The returns show that of the water used by the tanneries less than 1 per cent is taken from the city supply, the remainder being about equally divided between creek water and deep-well water.

Of the chemicals tabulated, it is not to be inferred that all pass into the creek, nor that all that does pass enters the creek in the chemical form in which they are tabulated. A considerable portion of the chemical and coloring matter used is carried away in the leather, and much of what remains undergoes neutralization and other chemical changes before entering the creek, and also to some extent after entering the creek, as not all the establishments employ the same methods and chemicals nor discharge their refuse at the same time. The coloring and filling materials are largely retained in the leather, while smaller proportions of the active chemicals in the aggregate are so retained, and this latter class of materials forms the larger portion of the whole. Of the 5,800,000 pounds of chemicals and other materials used, not including the hides, my inquiries and study of the question lead to the conclusion that not less than 3,000,000 pounds are discharged after use into the stream either in solution or suspension (except as to the spent time), widely changed or neutralized, highly polluted and diluted. If to this we added 1,500,000 pounds per annum refuse from hides, estimated above, the aggregate of animal refuse, chemical, coloring matter, etc., discharges into the creek, independently of the water with which it is diluted, will be 4,500,000 pounds per annum, or 15,000 pounds per working day.

The general effect of pollution in the Mohawk and Hudson, from Rome to Albany, has been carefully studied by Prof. C. C. Brown and Dr. Theobald Smith, under the authority of the State board of health, and a statement of the results is made in the reports for 1892 and 1893, pages 531–547 and 680–736, respectively. Chemical examinations of water from Hudson and Mohawk rivers through Schenectady to Cohoes were made by Prof. William P. Mason and Willis G. Tucker, while the biological and engineering work was under the charge of Messrs. Smith and Brown, respectively.

The investigation shows in a striking manner the effect of pollution upon the waters of the Mohawk. Starting above Rome, where the water is practically normal both from a chemical and bacteriological standpoint, the samples taken at different points along the river to the mouth show greater or less pollution according as the points from which they were taken were near to or some distance below the outlets of sewers of the different cities. By way of illustration, the series of chemical analyses made by Prof. William P. Mason is reproduced in Table XVIII, taken from the Twelfth Annual Report of the State Board of Health of New York, pages 544–545.

TABLE XVIII.—*Pollution at different points on Mohawk and Hudson rivers.*

[The analyses are in parts per 100,000.]

	Chlorine.	Nitrogen as nitrites.	Nitrogen as nitrates.	Free ammonia.	Albuminoid ammonia.	Required oxygen.
At Rome	0.25	0.0000	0.0206	0.0045	0.0090	0.440
1. Just above Schenectady	.40	.0004	.0202	.0040	.0200	.485
2. Just below Mill Creek	.50	.0004	.0202	.0065	.0200	.440
3. Schenectady intake	.45	.0004	.0289	.0050	.0170	.425
4. Below New York Central bridge	.45	.0004	.0289	.0045	.0175	.430
5. Just below main Schenectady sewer	.45	.0005	.0288	.0040	.0195	(a)
6. Between Delaware and Hudson and highway bridges	.40	(a)	.0288	.0075	.0155	(a)
7. Opposite lower ice houses	.40	.0004	.0244	.0060	.0180	.395
8. One mile above aqueduct dam	.40	.0002	.0246	.0050	.0140	.365
9. Crest of aqueduct dam	.40	.0002	.0246	.0030	.0140	.355
Dunsbeck's ferry	.40	.0005	.0288	.0030	.0160	.330
10. Crest of Cohoes dam	.40	.0002	.0246	.0060	.0210	.355
11. Below Cohoes Falls	.40	.0003	.0290	.0130	.0255	.375
12. Waterford intake (Hudson River)	.25	.0000	.0123	.0045	.0170	.830
13. Troy intake	.25	.0000	.0041	.0040	.0150	.840
14. Below State dam (ebb)	.25	.0000	.0123	.0035	.0185	.610
15. A (ebb)	.25	(b)	.0123	.0040	.0140	.660
16. B (ebb)	.25	(b)	.0164	.0060	.0155	.620
17. C (ebb)	.25	(b)	.0164	.0030	.0180	.640
18. D (ebb)	.25	(b)	.0123	.0060	.0165	.670
19. E (ebb)	.25	(b)	.0123	.0060	.0160	.680
20. F (ebb)	.25	(b)	.0123	.0050	.0175	.685
21. G (east shore), ebb	.25	.0000	.0041	.0060	.0240	.900
22. G (middle), ebb	.25	.0000	.0041	.0050	.0215	.670
23. G, Albany intake (ebb)	.25	(c)	.0082	.0070	.0200	.570
24. H (ebb)	.30	.0000	.0000	.0115	.0140	.685
25. I (ebb)	.20	(b)	.0041	.0135	.0150	.695
26. J (ebb)	.25	(b)	.0041	.0125	.0160	.765
27. K (ebb)	.25	(b)	.0041	.0130	.0165	.620
28. L, Van Wies Point (ebb)	.25	(b)	.0041	.0115	.0170	.585
29. Below State dam (flood)	.25	.0010	.0000	.0030	.0185	.590
30. A (flood)	.25	.0000	.0041	.0055	.0160	.655
31. B (flood)	.25	(b)	.0000	.0050	.0165	.650
32. C (flood)	.25	(b)	.0000	.0055	.0170	.630
33. D (flood)	.25	.0000	.0000	.0060	.0150	.630
34. E (flood)	.25	.0000	.0041	.0045	.0175	.630
35. F (flood)	.25	(b)	.0000	.0055	.0215	.660
35½. Greenbush intake (flood)	.25	.0000	.0000	.0085	.0195	.675
36. G (east shore) (flood)	.25	.0000	.0041	.0070	.0215	.610
37. Albany intake (flood)	.25	.0000	.0041	.0075	.0185	.600
38. H (flood)	.30	.0001	.0041	.0120	.0205	.605
39. I (flood)	.25	(b)	.0041	.0110	.0185	.605
40. J (flood)	.30	.0002	.0082	.0120	.0170	.610
41. K (flood)	.30	(b)	.0082	.0125	.0170	.665
42. L, Van Wies Point (flood)	.30	(b)	.0082	.0090	.0165	.645

[a] Lost. [b] Trace. [c] Large trace.

With even more striking clearness does the record of numerical determinations of bacteria along the river show the compromising effect of pollution, and the positive tests for fecal bacteria to which the water was submitted by Dr. Theobald Smith make it unquestionably certain that waters polluted by domestic sewage retain the effects of fecal pollution, even beyond the point at which sanitary analysis would show an unpolluted stream.

Table XIX, which gives the results of numerical determinations on the Mohawk River, is taken from the same report as Table XVIII.

TABLE XIX.—*Pollution of the Mohawk River by bacteria, 1891.*

Date.	Number.	Time.	Number of bacteria per c. c.	Average of— Samples.	Average of— Plates.	Remarks.
July 29	1	7.00 p.m.	765	1	2	Rome waterworks dam, above city.
Do	2	8.00 p.m.	473	1	2	Below feeder dam at Rome.
July 30	3	8.45 a.m.	1,400	1	2	Above Utica; below bone works
Do	4	10.15 a.m.	32,403	1	2	Below Utica sewers.
Do	5	11.00 a.m.	4,350	1	2	Opposite Masonic Home, 2 miles below Utica.
Do	6	11.25 a.m.	1,005	1	2	About 4 miles below Utica.
Do	7	11.30 a.m.	1,895	1	2	About 4½ miles below Utica.
Do	8	3.00 p.m.	1,106	1	2	Frankfort, above New York Central station.
Do	9	4.55 p.m.	1,932	1	2	Ilion, below New York Central station.
July 31	10, 11, 13, 14	9 a.m. to 1 p.m.		(*a*)		Water roily from rain.
August 6	17	2.37 p.m.	1,503	1	2	Opposite canal lock at Mohawk.
Do	18	2.55 p.m.	437	1	2	Opposite Herkimer at lower bridge.
Do	20	3.50 p.m.	298	1	2	West Canada Creek.
Do	19	3.30 p.m.	767	1	2	One-half mile below mouth of West Canada Creek.
July 31	15	2.35 p.m.	877	2	4	State dam above Little Falls.
August 6	21	5.40 p.m.				
July 31	16	4.30 p.m.	10,800	2	4	Just below foot of falls, Little Falls.
August 6	22	6.15 p.m.				
August 7	23	10.00 a.m.	10,007	1	1	About 1½ miles below Little Falls.*b*
Do	24	12.10 p.m.	9,533	1	2	State dam, 5 miles below Little Falls.
Do	25	2.55 p.m.	660	1	2	Above mouth of East Canada Creek.
Do	26	3.05 p.m.	412	1	2	East Canada Creek.
Do	27	3.15 p.m.	517	1	2	Twenty rods below mouth of East Canada Creek.
August 8	28	10.15 a.m.	3,146	1	2	St. Johnsville, below creek draining village.
Do	29	10.55 a.m.	3,473	1	1	One-half mile below St. Johnsville, below rapids.
Do	30	11.30 a.m.	1,953	1	2	Three miles below St. Johnsville.
Do	31	1.15 p.m.	1,890	1	2	About 2 miles above Fort Plain.
Do	32	2.35 p.m.	833	2	3	Fort Plain, above New York Central station.
August 11	33	11.35 a.m.				
Do	34	12.50 p.m.	696	1	1	One mile above Palatine bridge.
Do	35	2.15 p.m.	304	1	1	Just above Palatine bridge.
Do	36	3.00 p.m.	273	1	1	Three-fourths of a mile below Palatine bridge.
Do	37	4.50 p.m.	560	1	1	At Sprakers, above rapids.
Do	38	5.20 p.m.	672	2	2	Three-fifths of a mile below Sprakers, below rapids.
August 12	40	9.20 a.m.				
Do	41	2.25 p.m.	164	1	1	Above Cayadutta Creek.
Do	42	2.30 p.m.	2,288	1	1	Cayadutta Creek.
Do	43	2.35 p.m.	306	1	2	One-half mile below Cayadutta Creek.

TABLE XIX.—*Pollution of the Mohawk River by bacteria, 1891*—Continued.

Date.	Number.	Time.	Number of bacteria per c. c.	Average of— Samples.	Average of— Plates.	Remarks.
August 12	44	2.40 p. m.	416	1	2	Three-fourths of a mile below Cayadutta Creek, below rapids, Fonda, and Fultonville.
Do.	45	5.20 p. m.	283	2	4	Above Schoharie Creek.
August 14	47	12.40 p. m.				
August 12	46	5.45 p. m.	51	2	4	Schoharie Creek.
August 14	48	12.55 p. m.				
Do.	49	3.15 p. m.	331	1	2	Opposite Akin station.
Do.	50	3.30 p. m.	276	1	2	One-half mile below Akin.
Do.	51	4.25 p. m.	231	1	2	Just above Amsterdam.
Do.	52	4.50 p. m.	12,080	1	2	Chuctanunda Creek.
Do.	53	4.53 p. m.	11,765	1	2	Opposite Wendell's drug warehouse, Amsterdam.
Do.	54	5.03 p. m.	5,403	1	2	Opposite Armour's beef house, Amsterdam.
Do.	55	5.13 p. m.	6,562	1	2	Just below Amsterdam.
Do.	56	6.20 p. m.	2,904	1	1	One-half mile below last mill in Amsterdam.
Do.	57	6.30 p. m.	9,812	1	1	One mile below last mill, Amsterdam, near garbage dump.
Do.	58	7.00 p. m.	6,060	2	2	Opposite Cranes village, floating sewage.
August 15	59	9.00 a. m.				
Do.	60	9.20 a. m.	1,104	1	2	One mile below Cranes village.
Do.	61	11.20 a. m.	1,084	1	2	One-fourth of a mile below Hoffman's ferry.
Do.	62	11.45 a. m.	710	1	2	One and one-fourth of a mile below Hoffman's ferry.
Do.	63	1.50 p. m.	448	1	1	Above Fitchburg Railroad bridge.
Do.	64	2.35 p. m.	656	1	2	Three and one-half miles above Schenectady.
Do.	65	4.00 p. m.	1,634	1	2	One-fourth of a mile above Van Slykes Island, above Schenectady.
Do.	66	4.45 p. m.	791	2	4	Above Glenville bridge, Schenectady.
August 17	68	10.45 a. m.				
Do.	69	11.00 a. m.	444	1	2	Binnekill Branch above Edison sewer.
Do.	70	11.05 a. m.	7,276	1	2	Mill Creek.
Do.	71	11.10 a. m.	3,836	1	2	Binnekill Branch below Edison sewer and Mill Creek.
August 15	67	4.55 p. m.	1,145	2	4	Opposite waterworks, at intake.
August 17	72	11.20 a. m.				
Do.	73	11.21 a. m.	440	1	2	Opposite waterworks, north side of channel.
Do.	74	11.22 a. m.	432	1	2	Above New York Central bridge, opposite ice house
Do.	75	11.25 a. m.	312	1	2	Below New York Central bridge, opposite ice house.
Do.	76	1.30 p. m.	196	1	2	Two hundred feet below sewer outlet; pond, sluggish current.
Do.	77	1.50 p. m.	294	1	2	Above Delaware and Hudson Railroad bridge.
Do.	78	2.00 p. m.	424	1	2	Below Delaware and Hudson Railroad bridge, opposite ice house.
Do.	79	3.30 p. m.	296	1	2	One mile above aqueduct.
Do.	80	4.10 p. m.	216	1	2	Aqueduct dam.

a Rejected. *b* Garbage dump, three-fourths mile above the locality of this sample.

NOTE.—Accidents happened to samples below the aqueduct, and reliable results were not obtained.

Table XX gives the results of tests made to determine the presence of fecal bacteria at the Albany water intake, together with the total number of bacteria in the samples.

TABLE XX.—*Pollution by bacteria of water at Albany water intake.*

Date.	Stage of tide.	Number of fecal bacteria.	Number of bacteria.					
			West side.		Middle channel.		East side.	
			Surface.	Bottom.	Surface.	Bottom.	Surface.	Bottom.
October 29, 5 p. m.	1.10 before low water.	54	2,050	4,020	4,530	4,950	4,430	....
October 22, 2 p. m.	0.19 before low water.	26	1,180	1,850	2,600	2,430	2,770	....
October 15, 9 a. m.	0.21 after low water...	22	3,290	3,590	5,170	4,390	8,200	....
October 1, 9 a. m.	1.03 after low water...	92	3,620	3,620	7,150	6,450	5,400	6,120
October 22, 5 p. m.	1.08 before high water.	82	2,030	3,020	2,260	2,030	1,870	....
October 15, 1 p. m.	0.53 before high water.	32	2,840	2,730	3,220	3,960	4,170	....
October 29, 1 p. m.	2.26 after high water...	41	4,250	3,900	4,610	4,700	9,320	....
October 1, 1 p. m.	0.18 after high water..	26	1,980	2,090	2,950	5,280	4,090	....

A further investigation of the water supply of Schenectady includes the determination of fecal bacteria, with special reference to *Bacillus coli communi*, the organism which is closely identified with intestinal contents. The localities from which the samples were taken are different, convenient, and favorable points along the Mohawk between Amsterdam and Schenectady. Table XXI gives the results of these investigations, taken from the Thirteenth Annual Report of the State Board of Health of New York, pages 731–732.

TABLE XXI.—*Determination of fecal bacteria in Mohawk water between Amsterdam and Schenectady.*

[The column "Number bacteria" gives the number of bacteria obtained by the gelatin-plate method. The column "Number coli" gives the number of *Bacillus coli communi*, and the column "Number fecal bacteria" gives the total number of the three kinds of fecal bacteria determined.]

DECEMBER 16.—FIRST SET.

Locality.	Number bacteria.	Number coli.	Number fecal bacteria.
Second lock	18,000	16	25
Below first rapids	20,000	....	....
Head Van Slykes Island	9,100	....	....
Below Sanders's house	6,800	....	....
Above Glenville bridge	22,000	13	19
Intake	13,000	45	49

DECEMBER 24.—SECOND SET.

Second lock	8,200	8	15
Below first rapids	....	....	....
Head Van Slykes Island	....	....	....
Below Sanders's house	6,100	....	....
Above Glenville bridge	5,700	12	12
Intake	5,900	12	12

JANUARY 14.—THIRD SET.

Opposite Akin, south side of river	16,000	7	7
Just below last Amsterdam sewer	27,000	....	7
One mile below last Amsterdam mill	25,000	15	22

JANUARY 21.—THIRD SET.

Locality.	Number bacteria.	Nhmber coli.	Number fecal bacteria.
At Cranes village	12,000	3	3
One and one-half miles below Cranes village	16,000	13	13
At Hoffmans ferry	9,000	13	13
One and one-half miles below Hoffmans ferry	15,000	13	17

JANUARY 26.—THIRD SET.

Locality.	Number bacteria.	Nhmber coli.	Number fecal bacteria.
At Fitchburg railroad bridge	18,000	25	29
At second lock	17,000	13	13
Half way from Sanders's house to Glenville bridge	20,000		
Eight hundred feet above Glenville bridge	14,000	16	19
Intake of waterworks	18,000	13	13

SCHENECTADY INTAKE.—DECEMBER 24.

Time	Number bacteria.	Nhmber coli.	Number fecal bacteria.
7.15 a. m	3,700	23	31
11.30 a. m	5,900	12	12
4.00 p. m	4,900	31	37

The work outlined above was done in the early years of the last decade, when the science of bacteriology was still in its infancy. Since that time improved methods have shown that the bacteria isolated by Dr. Smith's famous process are not necessarily all fecal bacteria, but that there are other forms which respond to the same test. This does not reduce the weight of Dr. Smith's conclusions in the above case, however; for, taking into consideration the circumstances and conditions attending, there is good reason to believe that the greater part, if not all, of the organisms isolated by Dr. Smith were true fecal bacteria.

ANTHONY KILL.

Running in a general westerly direction from Ballston Lake, through Round Lake, Anthony Kill enters the Hudson at Mechanicville. Aside from the pollution that it receives from this village above the confluence with the Hudson, the only polluting area of importance is the camp-meeting settlement on the western border of Round Lake, and this has been rendered innocuous by the establishment of very satisfactory sewage precipitation works, described on page 371 of Sewage Disposal in the United States, by Messrs. Rafter and Baker. The permanent population of Round Lake is stated as about 400, and in summer, during some days, there are 7,000 people on the grounds. The source of water supply is Round Lake, and into this pond the purified sewage is discharged, but apparently without appreciable effect upon the water.

FISH CREEK.

Entering the Hudson at Schuylerville is Fish Creek, which takes a very irregular northwesterly trend from Saratoga Lake. The country about the lake is of wide repute, having been at one time probably the most famous resort in the East, and is still holding its own with most of the watering places in the United States.

Saratoga Springs, with a permanent population of 12,409, and Ballston Spa, a village of 3,923 inhabitants, are situated within the drainage area of Saratoga Lake. Both municipalities are supplied with sewerage systems, and the extensive pollution of the lake is accurately described in a petition to the governor of the State of New York, signed by various residents of Saratoga County, from which the following extracts are taken:

> The petition of the undersigned residents of the county of Saratoga respectfully shows as follows: That Saratoga Lake in said county is about 5 miles long and about 2 miles wide, and is about 4 miles from the village of Ballston Spa and Saratoga Springs, and that Saratoga Springs is a summer resort, visited by thousands of tourists every summer, and to Saratoga Lake is the chief drive and resort; that said lake has been for a great many years a prominent and attractive resort for fishing, hunting, and boating, and for the past few years offensive odors have arisen from the waters in the said lake near the shores, causing annoyance and breeding disease; that large numbers of fish have been picked up dead along the shores of the lake, and the shores thereof in certain portions are covered with filthy and noxious material, offensive to the eye and giving out offensive odors; that in the opinion of your petitioners, unless measures are taken to prevent the defilement of said lake, and its condition continues to grow worse, all the fish in the lake will be killed, and people will cease to occupy cottages on the shores, and it will cease to be attractive as a summer resort.
>
> That the causes of defilement of the waters of the lake are various; that they proceed from the discharge of the sewage of the villages of Saratoga Springs and Ballston Spa into said lake, and from the discharge into said lake of chemicals and refuse from certain manufacturing establishments located in or near the village of Ballston Spa.
>
> [Signed by 31 residents of the county of Saratoga.] [a]

The extent to which Fish Creek is affected by pollution is so far undetermined. It is probable that the actual damage in the stream is far less than in the lake, due, of course, to sedimentation. The report of Professor Landreth, made in response to the above petition, recognizes the importance of the offense and recommends that judicial proceedings be prosecuted to ascertain the exact amount of nuisance, and the responsibility therefor.

As a result of the action above outlined, the sewage-disposal systems of Saratoga Springs and Ballston Spa have been condemned and sewage purification must be established by both municipalities.

Victory Mills, a village of 795 inhabitants, is situated upon the creek a short distance above Schuylerville. It has no water nor sewerage system, and contributes an inappreciable amount of pollution to the river.

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[a] Nineteenth Annual Report of State Board of Health of New York, p. 107.

DAMAGE TO WATER RESOURCES OF HUDSON RIVER SYSTEM BY POLLUTION.

It is not possible to estimate, with any considerable degree of accuracy, the amount of damage that has been done to the Hudson River system by sewage pollution. This is true, not because such damage is of incalculable extent nor because there is a lack of data, but by reason of the fact that there are so many features to be considered in this large area, and so many modifying conditions, that deductions must be drawn simultaneously from many different points of view and the resulting composite conclusions must ever be to a large degree modified by personal opinion. If we survey the different tributaries and note the points of contamination and the extent thereof we shall very soon realize that in nearly every stream there is such enormous dilution and so many opportunities for sedimentation that, taken individually, there is hardly any reason to believe that any material damage has been done. Going further, we look for the results of the concentration of all this sewage into a main water course, and find that that course is the middle section of the Hudson, which, as has already been stated, is of more value to the State of New York in its present contaminated condition than if regulations were enforced which would maintain its purity.

Summing up the total amount of raw sewage emptying into the river system, and taking into account the vast number of people living in cities along its banks, it would appear that the pollution is sufficient to entirely destroy the value of the water course and make the surrounding country an undesirable locality for many purposes; yet when consideration is taken of the fact that the amount of run-off water in this basin is sufficiently large to dilute this sewage so that in places it almost escapes detection, the actual damage done appears to be greatly modified, or, in the opinion of many, it becomes almost nil. This very question opens all the contested points concerning the amount or percentage of pollution within the safety limit; the idea of self-purification of rivers is brought to the front and with it questions as to the effect of the contour of river beds and the existence of artificial works, such as dams and mill ponds. In the discussion of different points of pollution in the preceding pages instances were cited of local nuisances due to contamination at near-by points, which contrast in a very confusing manner with the statement that off Poughkeepsie, where we might expect all this filth to give evidence of itself, Dr. Drown found what was, from a chemical standpoint, a very fair potable water.

In the results of bacteriological examination of the Mohawk by Dr. Theobald Smith we have seen that the high percentage of bacteria that appeared in samples of the water taken below cities gradually fell off as the points of pollution were left farther and farther behind.

When these results were plotted geometrically there appeared a series of crests and troughs in the curve, the distance between the crests corresponding exactly to the distance between points of pollution, measured at the same scale.

All these apparent paradoxes have their logical explanation, the disputed points being confined largely to minor details. It would, indeed, be an endless and unprofitable task to attempt to reconcile the different features which modify conclusions, and it will not be attempted here.

It is proposed to point out the losses and damages for which pollution is responsible, confining qualifications thereof to a few well-attested instances in which it is apparent that river pollution is less expensive than the avoidance of it. There are many cases in which the cost of purifying sewage before turning it into a river, or the expenses entailed in securing some other place of final disposal, far exceed the cost of providing a pure-water supply from highland or other sources, and in such cases it is manifestly better, if there are no other rights to be considered, to use a stream as a sewage course rather than a source of water supply. Such instances should be treated from the standpoint of general public economy, every apparent consideration being taken into account.

WATER POWER.

It has already been stated that damages to water-power interests in the Hudson drainage area are not, comparatively speaking, large. There are, indeed, a few mills that have been obliged to give over the use of river water in various manufacturing processes because of impurities it contains, but the loss entailed does not appear to be serious. Neither does the future promise any remarkable change in this respect. Without doubt, new sewerage systems that are approved from time to time by the State commissioner of health will be provided with means of purification if the installation of such systems promises any great increase of river pollution.

There are few cases in which mill ponds have become public nuisances by reason of deposits of sewage upon the banks, but such will be taken up under the consideration of damages to realty values.

ICE.

The Hudson River ice crop has a national reputation, yet few people realize its extent, and fewer can locate the points at which storage houses are gathered. In the April number of the Ice Trade Journal for 1901 nearly four pages are occupied by a list of ice houses along this river and a statement of the amount stored in each. The crop depends entirely upon the winter's temperature, and the amount of ice that is available for harvest varies accordingly. During the winter of 1900–1901 there were cut and stored 4,606,800 tons, this being the largest crop ever gathered. During the preceding year there were stored only 1,430,670 tons, which, although large in itself, seems small when compared with the enormous amount harvested in the succeeding winter.

There seems to be no special center for the industry, the field extending all along from Schuylerville, past Cohoes, Waterford, and Troy, nearly down to the limit of salt water influence. On Rondout, Esopus, Catskill and other creeks there are large ice houses, and from certain lakes, such as Rockland, Croton, and Mahopac, there is gathered a considerable harvest, 230,000 tons being cut from these three lakes during the past winter. By far the greater amount, however, comes from the main river.

Sufficient data have been presented to show how great, even in the most unfavorable years, is the value of the Hudson River as a source of ice supply. It has been stated in preceding pages that pollution in a river is a damage to the ice industry, and that, even though recent research indicates that the typhoid bacillus does not survive during long periods when locked in ice, public use of this commodity when polluted with sewage will not be tolerated. A little reflection will show how worthless is a polluted stream or lake as a source of ice supply. Modern biology has found means effective for the purification of contaminated water. Such means are not applicable to ice, and thus polluted ice is, or should be, a total loss; it can not be sterilized nor in any way relieved of its dangerous qualities. With the ever-increasing use of this article in and upon our food there is a necessity that greater care be taken as to its source. The absence of typhoid fever bacilli in polluted ice is by no means a guarantee of its safety for domestic use. The dangers are well expressed in the following paragraph, taken from an article by James M. Anders, M. D., LL. D., of Philadelphia:

> While I shall endeavor later to emphasize the potency of impure water, especially when bacterially contaminated, in causing certain diseases, I desire at the outset to insist that the deleterious and devitalizing effect of imbibing such water, upon the general health of the community, is practically inconceivable. By lowering the resistance to that large class of infectious diseases, its indirect influence as a causative factor must be considerable, not to speak of the suffering occasioned by the habitually depressed and weakened systemic condition thus engendered. Much inconvenience and ill health caused by impurities in the drinking water originates primarily from the alimentary tract, and is due to gastric and intestinal disturbances. The ingestion of contaminating materials may be a cause of dyspepsia or diarrhea, and most probably also renders the system receptive to the invasion of the bacillus coli, the bacillus of Shiga, and other pathogenic organisms, and this *quite independently of any pollution of the drinking water by the disease-producing germs themselves* [italics by M. O. L.].—American Medicine, March 29, 1902, p. 503.

Above Albany were cut, last season, 502,700 tons of ice. By far the greater part of this was taken below the mouth of the Mohawk and in that river itself. At Crescent, a bend in the Mohawk, a few miles below the outlet sewers of Schenectady, the reports show a total crop of 163,000 tons. From the mouth of the river, where the pollution from Cohoes, Waterford, and Lansingburg is most dangerous, were taken 200,000 tons more, and below Troy and Watervliet the harvest amounted to about 75,000 tons. The water taken from practically these same points was found by Dr. Theobald Smith to contain fecal bacteria.

South of Albany, within 4 miles from the outlets of the sewers of that city, and at Rensselaer there were harvested during the season of 1901 over 300,000 tons of ice. The water in the Hudson above Albany is now being purified for potable use in that city, because the citizens found by costly experience that it could not be used in its raw state. What, then, must be the condition of that water shortly after the sewage of 101,617 more persons has been added to it?

In spite of the conditions outlined above, this river is the principal source of ice supply for the great metropolitan area, and although the value of the artificial-ice business is growing at a rapid rate, due in part to distrust of ice from the Hudson and other polluted sources, such has been the growth in the demand for ice that the market for this contaminated product remains undisturbed. It can not, however, remain indefinitely firm, and when the facts have been placed before the public with sufficient intensity the value of the Hudson as a source of ice will be materially damaged. Reference to the report of Prof. William P. Mason made to the Manufacturers' Association of Brooklyn will show very clearly the character of Hudson ice. He substantiates the belief that the formation of ice eliminates impurities to a certain extent, but found upon testing samples of ice taken from germ-polluted fields in the Hudson River, just below the junction of the Mohawk River, that certain disease germs were still alive, and condemned this ice as wholly unfit for use in cooling beverages. Typhoid germs were not killed, as was proved scientifically. He cited the case of a typhoid epidemic which spread from Schenectady to Albany, the Mohawk River carrying the typhoid germs down to its mouth, polluting the ice formed in the Mohawk, whence the ice supply of both cities was obtained. In this manner both cities suffered with a typhoid epidemic.

The association is to present petitions to both the State and city health boards, asking that some steps be taken to prevent the polluted ice being sold in this market.[a]

The above declaration from so distinguished an authority can not be barren of results, and the consequent action taken by the Manufacturers' Association can not fail to be adverse to the use of ice cut on the Hudson. It will produce no widespread revulsion, nor will the ice industry of the river be destroyed in a season, but there can not fail to be a gradual concurrence in the idea that Hudson River ice

[a] Abstract in Municipal Journal and Engineer.

is an inferior article, the price of which will be forced lower and lower by the active commercial spirit of this country. It will not be necessary even to advance hygienic considerations beyond the point at which they are able to beget distrust in the market of New York.

According to prevailing prices, the last Hudson ice crop is worth at least $8,000,000. In unfavorable seasons the pure article from that source could not fall below an annual value of $3,000,000. For what fraction of this sum annually could all the Hudson Basin sewage be purified?

WATER SUPPLY.

The estimation of loss of capital in a river which is polluted to the degree apparent in the Hudson can not be brought to a very fine point of accuracy. If we were to consider the effect of sedimentation, and figure out all the other factors that are effectual in the so-called self-purification of rivers; if we were to consider the amount and character of the sewage and the dilution thereof, we might be able to reach an approximate figure of damage, and even then it would be of little more value than the rough résumé that can easily be made. If the science of water purification were in the same state in which it was a quarter century ago the problem would be more simple, for at that time there were no well-established, reliable means of purification in common use in this country. To-day, however, the purification of polluted water for domestic use has reached that state of perfection at which it has become the practice of reputable engineers to take polluted water from a stream at the very doors of the city and purify it, rather than to expend large sums of money in conserving an unpolluted supply miles away in a sparsely settled district. The case of Philadelphia at the present time is pertinent: On January 4, 1901, the United States Senate Committee on the District of Columbia convened at New York to discuss with the engineering profession the question of filtration of water supply at Washington, D. C. Mr. Rudolph Hering, M. Am. Soc. C. E., stated in his testimony with reference to the experience of Philadelphia that, in 1883, he was engaged by that city to make studies for the new city water supply. As the subject of water filtration was not fully developed at that time he recommended an unfiltered water, taken from the Blue Ridge. More recently, during his connection with the Philadelphia waterworks, he recommended the Schuylkill River and the Delaware, because of the fact that this water could now be made sufficiently pure for use, and under the circumstances it presented a more feasible plan from every standpoint, for both present and future generations.

It becomes necessary then, in considering pollution in a river from the standpoint of water supply, to make allowance for the fact that the water can be purified and that its precedent pollution does not constitute a complete loss of resource. Under such circumstances the actual amount of damage done consists of the difference between the cost of pumping raw water for direct use and the cost and maintenance of a filtration system.

There remain certain rivers, the pollution of which seems altogether unnecessary, which could be preserved in approximately their normal state, yet which receive sewage enough to damage their water supply values. Such streams are the Wallkill and Batten Kill. In such instances, where the cost of sewage disposal would be comparatively small, there seem to be no compensating factors to offset the damage done to the river as a source of water supply, and pollution becomes needless and unwarranted.

The cities on Hudson River proper that now derive all or a part of their water supply from the river by pumping are Poughkeepsie, Catskill, Hudson, Albany, Rensselaer, and Troy, including the recently annexed Lansingburg. In all of these places except the latter the water is filtered, and in the latter case only a part of the supply is derived from the Hudson.

The filtration systems at Poughkeepsie, Catskill, and Hudson were established before the present knowledge concerning the action of filters was very clearly defined, and there was no idea of purification of the water in the sense that that term is now understood by the profession. The main object of these filters was that of clarification, i. e., an elimination of the sediment which is carried down the Hudson in large quantities, and if there had been clear water in the river the chances are that neither of these filters would have been installed at that time. The cost of construction in these three cases can not, therefore, be charged against the debt of sewage pollution. Whatever may have been the initial cause of installing the Poughkeepsie, Hudson, and Catskill filters, it is apparent that they are at present maintained for the added purpose of biological purification as well as that of clarification. It would be quite unlikely that, should the waters of the Hudson become free from sediment, the filtration system would be abandoned in the face of all the sewage coming past their respective intakes, so that it is a fair position to assume that pollution is partially responsible for the expense of maintenance of these filters. While this section of the Hudson is under consideration it may be of value to pursue this subject with the help of a projected enterprise that emphasizes in a forcible manner the damage that must be faced in such rivers.

One of the most thoroughly discussed water-supply problems that has been before the public for many years is that of the present and future supply of the city of New York. In August, 1899, Mr. William Dalton, commissioner of water supply for the city of New York, startled the city and convulsed the engineering profession by recommending that the board of public improvements approve a forty-year contract with the Ramapo Water Company, under which the city was bound to buy at least 200,000,000 gallons of water daily at a cost of $70 per million gallons. The excessive cost of the water was only one item of disadvantage to which the city was to be subjected by the execution of the contract. The immediate opposition which was developed, headed by Comptroller Bird S. Coler, caused a stay in the proceedings, during which time the matter was investigated by the comptroller and independently by the Merchants' Association of New York, a body whose power in city affairs and in the establishment of sound corporate policy has ever been notable. An organized staff was made up from the association and, aided by the comptroller and Governor Roosevelt, every phase of the proposed swindle was laid bare. In addition to this, investigations were made into every branch of the water-supply question, and the report that was issued is one of the most valuable of the recent publications on this subject. The engineering committee, under the leadership of Mr. Rudolph Hering, instituted among other things an investigation into the available sources of supply for the city and, with their consulting engineer, Mr. James H. Fuertes, carefully considered every adequate source of supply in the State, finally deciding that the most feasible plan was the pumping of the water from the Hudson River itself, at a point just above the city of Poughkeepsie, where a supply of 1,500,000,000 gallons daily was easily available if proper compensating reservoirs were constructed in the Adirondacks for replenishing the river during dry seasons.

It is the consideration of this extensive project and the analysis of the estimates of cost and maintenance thereof that give the inquirer his first adequate idea of the loss which may arise and the damage which may accrue to the resources of the Hudson River through pollution. These estimates were based upon a proposed supply of 500,000,000 gallons daily, which is probably the maximum additional supply that will be required by the city during a long term of years. The minimum cost for such a system would be $72,374,000, of which $32,557,000 is for filters and pumping plant, largely made necessary by sewage pollution. The minimum cost for the water at this rate would be $30.39 per million gallons, of which $4, or about 13 per cent, is the amount expended for filtration. In the estimated annual cost of operation and maintenance is included $730,000 for cost of filtration. If in the course of years it should become neeessary to develop such a system to its full capacity the cost of overcoming the effects of sewage pollution would increase accordingly. Thus it may be seen that if at any time in the future the city of New York should adopt the Hudson supply and use the maximum amount, the polluted condition of the river would necessitate an annual expenditure of at least $2,000,000 in addition to the initial cost of establishing so gigantic a filtration system.

The history of the Albany water supply is closely linked with the history of pollution in the Hudson at that point, and the recent establishment there of what was, at the time of construction, the largest filter in the country is a direct consequence of the sewage in the river from the Albany sewers as well as from the numerous places within a short distance above. In the year 1873 it became necessary to augment the gravity system of water supply then in use at Albany, and an intake was placed in the Hudson and water was pumped therefrom into the reservoirs, to be mixed with the upland water. With the growth of the city more and more was pumped from the Hudson, until at the present time the pumped water exceeds in amount that taken from the old gravity system. Throughout the history of its water system Albany has employed eminent authorities to guide her steps, and the establishment of this Hudson intake appears to have been undertaken advisedly. When, after the lapse of some years, there arose a feeling that all was not well with the water, fears were again quieted by the reassurances of a distinguished gentleman. Whatever deleterious material might be poured in the river at Troy, 4 miles above the intake, would be, said the expert, rendered entirely harmless through various influences, among which were sedimentation, dilution, and oxidation. The fact that the death rate and morbidity from typhoid fever was high seemed to have no bearing upon the case, nor was there, in the opinion of the city's advisers, any significance in the fact that epidemics at Albany followed those at Troy, Schenectady, and other places. The eminent authority maintained his position and, we believe, sticks to his conclusions to-day.

In 1885 Prof. William P. Mason, in a report to the water board, showed very clearly the deplorable condition of the water and condemned it in unmistakable terms. From that time until 1896 there was a series of efforts to provide a new supply, all of which failed, until in July, 1897, it was finally decided to filter the water from the Hudson. Under the direction of Mr. Allen Hazen, M. Am. Soc. C. E., a covered filter was constructed at a cost of about $500,000, and the expense of operation is about $4.19 per million gallons, or about $20,000 annually. The results have already been more than sufficient to pay for the cost of the construction. The death rate from typhoid fever has been very materially decreased, and the good effects of the filtration system remain undisputed.

Troy up to the present day is drawing a part of its water from the Hudson and delivering it to its citizens in the raw state, and for years efforts have been made to obtain a new supply, until there seems now to be an assurance of better water. This city has been even slower than Albany to realize the damaging effects of Hudson water, and the indifference of the citizens there has called from Prof. William P. Mason the statement, made during his testimony before the Senate Committee on the District of Columbia, that "up in Troy anything short of soup would be satisfactory." The new water supply, which the better element in Troy has at last succeeded in pushing to a successful issue, is to be conserved in sparsely settled districts east of the city. It will furnish, when fully developed, about 40,000,000 gallons daily, and the present plans contemplate an expenditure of $1,250,000.

These are the actual water-supply expenditures which have been made necessary by sewage pollution in the main river and also the costs which would be incurred should the plan recommended by the Merchants' Association for the future supply of the city of New York be adopted. It is clear that the Hudson River along this section must necessarily be polluted, and the expense of water filtration must always be regarded as one of the running expenses to be perpetually maintained in the Hudson Valley. There is no possible way of overcoming it, and it must be considered in a summary of this character. It may be contended that the free drainage of cities into the Hudson is a privilege which compensates for the disadvantages that arise from the damage to the natural water resources. A little reflection will show that such a contention is idle, and that, after allowing for all the items which constitute the credit side of the present account, we shall find that the pollution of the Hudson River is very costly.

The eastern tributaries of the Hudson are not damaged to any great extent by pollution, except the Hoosic and Batten Kill. At the present time the water from the former river is badly contaminated, yet not sufficiently to damage any of the resources which it has, up to this time, been called upon to yield. The ice industry upon the river is not worth considering, and the only resource which is damaged is the water supply. If there should ever be a demand for the water in the basin of the Hoosic it would be necessary to resort to filtration under the present conditions. Pollution in the Hoosic is positively needless, and its existence there is damaging to a resource which, properly cared for, would be one of the fairest in the Hudson River basin. The same statements are true with reference to Batten Kill. Although the contamination of this stream is less than that of the Hoosic, there is sufficient to cripple its usefulness as far as the use of its raw water is concerned.

Similar statements may be made concerning the western tributaries. The Wallkill is a river which seems excellently adapted for water supply, and if proper care were exercised it might be possible for each municipality along its banks to establish its water intake at almost any convenient point along the river and use the water with safety.

There is little to add concerning the Mohawk. We have seen that it is the river which contains the greatest relative amount of pollution of all those tributary to the Hudson, and that the sewered population along its banks numbers 152,000. The only cities which have of late attempted to draw their supplies from the Mohawk are Rome, Schenectady, and Cohoes. Above the first mentioned city the water is fairly satisfactory from a sanitary standpoint, but at Schenectady

LOG JAM IN ADIRONDACK BROOK, NEW YORK.

From photograph in possession of American Museum of Natural History, New York City.

the work of Dr. Theobald Smith was too conclusive to admit of any doubt concerning the dangerous quality of the water. Consequently that city has been obliged to abandon its intakes in the river and is now supplied by driven wells. Cohoes is still contented to drink from the cesspool of its neighbors.

It would, no doubt, be impossible to make the Mohawk pure. If all sewage pollution were eliminated, it is probable that the surface drainage of so populous a country would unfit the water for use in its raw state as a domestic supply. Certainly, if such is not the case at present it will be true within a few years. The present danger is that the conditions along the Mohawk may approach those of the Passaic; it will be remembered that the increase of population here is greater than at any point that we have considered in the Hudson drainage area.

The water-supply damages cited on the Mohawk, then, are total unfitness of the stream as a source of raw supply and necessary abandonment of an intake by the city of Schenectady.

The character of Saratoga Lake, and the use to which it has been put, makes its use as a water supply undesirable. It might, of course, have been used for this purpose before it became so polluted, but, as it is a part of the great summer resort, it is natural, and almost imperative, that it should be given up to recreative purposes and as such it becomes unimportant from the standpoint of water supply.

REALTY VALUES.

There are many places in the Hudson drainage area that have been made undesirable by sewage pollution, but in the majority of cases they are so very close to sewer outlets that nothing else could be expected, and the surrounding neighborhoods have been adapted to meet such conditions. Such places must ever exist—it is necessary for every city to have its garbage area and dust bin, and it has become the custom to develop these surroundings in such a way that the interests involved do not suffer materially by the existence of that which, in residential districts, would seriously impair established values. There is no place on the Hudson where the condition approaches that upon certain parts of the Passaic, where land has been reduced to no value and localities have been brought to a standstill. The region about Johnstown on Cayudutta Creek and the shores of Saratoga Lake have been fast approaching that condition, but up to the present time there has been only a relatively small amount of realty damage.

The law reports of New York State contain, here and there, cases arising out of polluted conditions in this area, the most important of which are the following:

Supreme court, May term, 1891 (67 Hun, p. 294); Joshua Demby *v.* City of Kingston, N. Y.:

The plaintiff and wife were tenants by entirety upon two lots, through which ran a stream that was polluted by city sewers. Plaintiff was obliged to cover stream and to incur considerable expense to get rid of nuisance, and finally sued the city for damages and prayed for an injunction against further pollution.

The city held that it was not responsible, as the nuisance was caused by private connections in a sewer built for storm water, and the city could not go upon private property and remove them. The award of the jury in the lower court was affirmed, the amount being $524, and a permanent injunction was issued.

Supreme court, September term, 1893 (71 Hun, p. 232); Simon Schriver *v.* Village of Johnstown:

The case was presented on appeal from the lower court, in which the jury awarded $2,000 damages, and the court issued a permanent injunction. A part of the opinion of the supreme court is as follows:

> The maintenance by a municipality of a permanent system of sewers, through which sewage passed into a natural stream and pond of private ownership, causing pollution and sediment, presents a case for perpetual injunction and normal damages. The measure of damages in such a case is the depreciation of rental value.

The estimated rental value of the pond was $600 per annum. Of this $400 was still available under the polluted conditions, leaving a balance of $200 for which the city was responsible. Damage for ten years, amounting to $2,000, was affirmed, and the permanent injunction was continued.

Supreme court, appellate division, May term, 1897 (17 New York, p. 207); Moody *v.* Saratoga Springs:

An appeal by defendant from verdict in lower court in favor of plaintiff. Damages were awarded and an injunction was issued.

The principal contention before the court of appeals was that the village was not responsible by reason of the act of the legislature which authorized the construction.

A part of the opinion rendered by the higher court reads:

> The purpose of chapter 149 of Laws of 1885, providing for the extension of the main sewers of Saratoga Springs, was to promote the interests of the village, and the village is liable to the owner of premises near a creek into which said extension is discharged from the injuries resulting from the pollution of air and water caused by such discharge.
>
> An act which authorizes the extension of a sewer authorizes its use, but such use must not result in a nuisance or occasion injury to the legal rights of others.

In conclusion, having considered as minutely as seems advisable the different sources of pollution in the Hudson River basin, and having indicated in a brief, summary manner its effect upon the natural water resources, it now remains to determine what may be the future of these resources and whether pollution will continue to grow or be checked by popular disapproval and consequent legislative enactment.

The whole question has been modified by the successful introduction of filtration for water supplies. It is manifest that the most potent damage that is ordinarily done to the resources of a stream is its destruction for use as a source of water supply, but, having overcome this difficulty by the introduction of filters, it is more than likely that the tendency will be toward toleration of a certain amount of pollution, and the expense of filtration will be regarded as a fixed charge upon the community at large.

The growing use of sewage purification processes has also a bearing upon the pollution question. The effluent from sewage purification works, while properly and theoretically harmless, can not at all times be depended upon to thoroughly eliminate all the pathogenic bacteria that are found in it. There must be laxities, arising in even the most carefully conducted sewage purification plants, that are entirely unavoidable. Sewage will pass through the purification process and will not be treated so efficiently as the process of purification will permit nor so carefully as the diligence of those in charge would seem to warrant. Under such circumstances it is clear that we can not place sufficient dependence upon sewage purification to warrant us in using for potable purposes the raw water from a river into which such effluent is emptied.

Natural surface drainage, too, is to be considered. Upon rivers having large cities along their shores a certain amount of pollution must arise from the natural drainage of occupied land, and this may be a detriment to the river. Such contamination is unavoidable, and is certainly not so important as that from city sewers, yet it is true that the uncertainties that arise make it necessary to avoid the use of water so contaminated for domestic purposes without filtration. So it appears, as already observed, that the tendency will be to assume that the contamination incident to the surface drainage of occupied land and the effluent from sewage purification works is a necessary and unavoidable evil, and to consider that the diminution of natural water resources by this means is one of the prices which society must pay for its social and economic development.

The above applies to rivers with considerable population in their immediate drainage areas. The pollution of upland streams in sparsely settled districts must, however, be regarded as needless, and as a crime against the community. The greater part of these areas possesses little value from an agricultural standpoint. Under the present conditions they are principally useful in raising forests. The highest development of their natural values would arise by setting them aside as regions for the conservance of water. In this way the forestry and water problems could be dealt with coincidently, and the adoption of such as a public policy would be wise.

The damage to ice interests by sewage pollution will, in the course of years, settle itself. The manufacture of ice is a growing industry, and when the time shall come that polluted ice is no longer tolerated, the use of artificial ice will become universal. The rivers that are now used as ice fields are, in the majority of cases, those that are polluted to a greater or less extent, so that the damage to that part of the water resources must also be assumed in the same spirit as that just described with reference to water supplies. It will, in this case, be a surrendering of certain natural sources of wealth for an equal value in a new industry.

Within the area covered by this brief analysis there are a few interstate features, although the questions involved are not now of local interest. We have seen that a part of the drainage area of the Passaic extends over into the State of New York and that the Hudson River Basin comprises small parts of Vermont, Massachusetts, and New Jersey. What the future may bring forth in these places with regard to interstate pollution is a matter of conjecture, yet if the cities of North Adams, Mass., and Bennington, Vt., should grow sufficiently to pollute the Hoosic River to the same extent that the Passaic or Cayadutta Creek is now polluted, there would arise damages to different interests in the State of New York which the courts of that State could not correct. What the result would be is uncertain, for there is not yet any well-defined process nor any established practice by which such matters could be easily adjusted. There is a national authority over common interstate matters, and there should be an equal control over the interstate features of rivers whose courses lie within two or more States.

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