DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 24

WATER RESOURCES OF THE STATE OF NEW YORK
PART I.—RAFTER

WASHINGTON
GOVERNMENT PRINTING OFFICE
1899

IRRIGATION REPORTS.

The following list contains the titles and brief descriptions of the principal reports relating to water supply and irrigation, prepared by the United States Geological Survey since 1890:

1890.

First Annual Report of the United States Irrigation Survey, 1890; octavo, 123 pp.

Printed as Part II, Irrigation, of the Tenth Annual Report of the United States Geological Survey, 1888–89. Contains a statement of the origin of the Irrigation Survey, a preliminary report on the organization and prosecution of the survey of the arid lands for purposes of irrigation, and report of work done during 1890.

1891.

Second Annual Report of the United States Irrigation Survey, 1891; octavo, 395 pp.

Published as Part II, Irrigation, of the Eleventh Annual Report of the United States Geological Survey, 1889–90. Contains a description of the hydrography of the arid region and of the engineering operations carried on by the Irrigation Survey during 1890; also the statement of the Director of the Survey to the House Committee on Irrigation, and other papers, including a bibliography of irrigation literature. Illustrated by 29 plates and 4 figures.

Third Annual Report of the United States Irrigation Survey, 1891; octavo, 576 pp.

Printed as Part II of the Twelfth Annual Report of the United States Geological Survey, 1890–91. Contains "Report upon the location and survey of reservoir sites during the fiscal year ended June 30, 1891," by A. H. Thompson; "Hydrography of the arid regions," by F. H. Newell; and "Irrigation in India," by Herbert M. Wilson. Illustrated by 93 plates and 190 figures.

Bulletins of the Eleventh Census of the United States upon irrigation, prepared by F. H. Newell; quarto.

No. 35, Irrigation in Arizona; No. 60, Irrigation in New Mexico; No. 85, Irrigation in Utah; No. 107, Irrigation in Wyoming; No. 153, Irrigation in Montana; No. 157, Irrigation in Idaho; No. 163, Irrigation in Nevada; No. 178, Irrigation in Oregon; No. 193, Artesian wells for irrigation; No. 198, Irrigation in Washington.

1892.

Irrigation of western United States, by F. H. Newell; extra census bulletin No. 23, September 9, 1892; quarto, 22 pp.

Contains tabulations showing the total number, average size, etc., of irrigated holdings, the total area and average size of irrigated farms in the subhumid regions, the percentage of number of farms irrigated, character of crops, value of irrigated lands, the average cost of irrigation, the investment and profits, together with a résumé of the water supply and a description of irrigation by artesian wells. Illustrated by colored maps showing the location and relative extent of the irrigated areas.

1893.

Thirteenth Annual Report of the United States Geological Survey, 1891–92, Part III, Irrigation, 1893; octavo, 486 pp.

Consists of three papers: "Water supply for irrigation," by F. H. Newell; "American irrigation engineering" and "Engineering results of the Irrigation Survey," by Herbert M. Wilson; and "Construction of topographic maps and selection and survey of reservoir sites," by A. H. Thompson. Illustrated by 77 plates and 119 figures.

A geological reconnoissance in central Washington, by Israel Cook Russell, 1893; octavo, 108 pp., 15 plates. Bulletin No. 108 of the United States Geological Survey; price, 15 cents.

Contains a description of the examination of the geologic structure in and adjacent to the drainage basin of Yakima River and the great plains of the Columbia to the east of this area, with special reference to the occurrence of artesian waters.

1894.

Report on agriculture by irrigation in the western part of the United States at the Eleventh Census, 1890, by F. H. Newell, 1894; quarto, 283 pp.

Consists of a general description of the condition of irrigation in the United States, the area irrigated, cost of works, their value and profits; also describes the water supply, the value of water, of artesian wells, reservoirs, and other details; then takes up each State and Territory in order, giving a general description of the condition of agriculture by irrigation, and discusses the physical conditions and local peculiarities in each county.

Fourteenth Annual Report of the United States Geological Survey, 1892–93, Part II, Accompanying papers, 1894; octavo, 597 pp.

Contains papers on "Potable waters of the eastern United States," by W J McGee; "Natural mineral waters of the United States," by A. C. Peale; and "Results of stream measurements," by F. H. Newell. Illustrated by maps and diagrams.

(Continued on third page of cover.)

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UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

WATER RESOURCES

OF THE

STATE OF NEW YORK

PART I

BY

GEORGE W. RAFTER

WASHINGTON
GOVERNMENT PRINTING OFFICE
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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, November 26, 1898.

SIR: I have the honor to transmit herewith a manuscript entitled Water Resources of the State of New York, prepared by Mr. George W. Rafter, and to recommend that it be published in the series of pamphlets upon Water Supply and Irrigation. The data herewith presented were brought together by Mr. Rafter during 1897 and transmitted early in February, 1898. Publication has been somewhat delayed by various obstacles which could not be readily overcome. The data are, however, of general interest and value, not only to the people of New York State, but also to engineers and persons in all parts of the country interested in the development and utilization of the water resources. Particular attention is given to the discussion of floods and low-water flow, these being to a large extent the determining factors in considerations of the utilization of water power.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

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

WATER RESOURCES OF THE STATE OF NEW YORK, PART I.

By George W. Rafter.

INTRODUCTION.

The preeminent position of the State of New York is due almost entirely to her great natural water resources. Reaching from the ocean on the east to the Great Lakes on the west, she has gathered to herself the treasures of the foreign world as well as those of half the Western Continent. Her inland rivers, with their great water powers, have been in the past and will continue to be in the future a perpetual source of wealth. Taking into account the commercial supremacy guaranteed by the Erie Canal, it may be said that the history of the State's progress during the nineteenth century is largely a history of the development of her water resources. It is the purpose of the author in this report to relate briefly not only in what manner these resources have been employed, but to indicate the recent lines of development and the probable future of the State if her water is utilized to the fullest degree. It is proposed to describe in a general way the river systems, giving brief descriptions of several of the more important utilizations of water in New York, together with a discussion of some of the economic problems confronting the people of the State.

As regards the water power of New York, it may be noted that the Tenth Census of the United States, 1880, Vols. XVI and XVII, gives in great detail the statistics of the main water powers as they existed in 1882. Many of these show considerable increase at the present time, although the new works are for the most part similar to those described in the census report, and hence present few additional features of interest. Several of the recent plants, however, are on quite different lines both as to their scope and as to the method of development adopted. It has therefore seemed more important to describe a few of the new plants and to give the main facts of the great storage projects of the Hudson and Genesee rivers than to spend time on small and relatively unimportant powers.

The peculiar relation of the State to water-power development on the main rivers of New York should be here mentioned. Owing to the circumstances of the early settlements and the development of the canal system, the State has assumed ownership of the inland waters, or, at any rate, of all streams used as feeders of the canals. This assumption has worked injustice to riparian owners, and is at present a bar in the way of the full development of important streams by private enterprise.

The data embodied in this report have been gathered from many sources—the annual reports of the State engineer and surveyor, the superintendent of public works, the forest commission, the State board of health, the State weather service, and other public documents. The data in the reports on the Water Power of the United States, Tenth Census, have been used in many cases where later data are not available. During the years 1896 and 1897 the author, in addition to his regular duties in the State engineer's department, gathered a large amount of information bearing on the water resources of the State and not published in the annual reports of the State engineer's department. Much of this is in the way of piecing out earlier information and bringing the subject up to date. By the courtesy of the State engineer and surveyor these special data have been embodied in the present report.

The figures as to drainage area have been obtained by checking on French's map, published in 1860, those given in the reports on the water power of the United States, Tenth Census, so far as they are available, and by planimeter measurement on the topographic atlas sheets of the State made by the United States Geological Survey. Bien's Atlas of the State of New York has also been used as a check in some cases, and a number of areas have been taken from the report of the Deep Waterways Commission.

The elevations of points above tide water have been compiled from all available sources of information, such as Dictionary of Altitudes in the United States, Bulletin No. 76 of the United States Geological Survey; the reports of the New York State survey and railway canal profiles; the topographic atlas sheets of the United States Geological Survey, and the reports on the water power of the United States, Tenth Census, 1880.

GENERAL STATEMENT.

A report of this character is prepared for the benefit of two classes: First, professional or business men who read during leisure hours in order to add to their stock of general information; second, engineering specialists, physicists, and men of expert scientific attainments generally who desire full details as part of their stock of professional knowledge. The latter class will naturally study the details, while for the former a succinct statement of the results of the study is generally sufficient. It is from this point of view that a statement of the general results of the study of the water resources of New York is here introduced at the beginning of the report.

FAVORABLE NATURAL CONDITIONS.

New York State is great in water resources, not only by virtue of her position between the Atlantic Ocean and the Great Lakes, but because topographic, geologic, and climatic conditions have combined to make her the highway of commerce as well as the manufacturing center of the United States. Some of the contributing causes to this preeminent position may be found in her mountain systems, affording three great water centers, from which large streams descend to the neighboring lowlands, affording large opportunities for the economic development of water power. As regards water power, the other chief contributing causes are the possession, as part of her domain, of Niagara and St. Lawrence rivers, with their extensive possibilities for future water-power development.

A study of the climatology of New York shows that in nearly every portion of the State the amount and distribution of the rainfall are such as to insure a large enough run-off of streams to furnish, even under natural conditions, considerable water power.

ARTIFICIAL MODIFICATIONS.

Natural conditions have been largely interfered with by the cutting off of forests and the consequent extensive development of the agricultural interests of the State. As a tentative proposition, it is assumed that the general cutting off of the forests of New York State has decreased the annual run-off of streams issuing from the deforested areas to a depth of from 4 to 6 inches per annum.

The run-off of Niagara River has been commonly assumed, on the authority of the Lake Survey, at about 265,000 cubic feet per second. The recent studies indicate that the extreme low flow of a cycle of minimum years may be not more than 60 per cent of this figure. From this point of view the people of the State of New York have the greatest possible interest in any project which would tend to decrease the low-water run-off of that stream. Such interest is equally pronounced in the case of St. Lawrence River.

Measurements of discharge of a number of the inland streams of New York indicate considerable variations in water yield in different parts of the State. For instance, Genesee River, in the western part, in 1895 gave, with a rainfall of 31 inches, a minimum flow for the year of 6.67 inches. The drainage area of this stream is mostly deforested, whence it results that serious floods are frequent. For example, from May 19 to 24, 1894, the total discharge was nearly 6,900,000,000 cubic feet, the maximum, which occurred at 3.30 a. m., May 21, being 42,000 cubic feet per second. The drainage area above the point where this flood occurred is 1,070 square miles.

The lowest annual run-off thus far measured in the State of New York is that of the Hemlock Lake drainage area, where, in 1880, the total run-off from an area of 43 square miles was only about 3.35 inches.

Oswego, Mohawk, and Hudson rivers and their tributaries in this State all have large pondage on natural lakes, which, with other conditions, tend to maintain the low-water flow. Croton River presents surface geological conditions which tend to increase its low-water flow. Without going into detail, we may say that these streams will yield a minimum flow of about 0.3 of a cubic foot per square mile per second. Variations from this limit are given in the chapters specially discussing minimum flow.

As a typical flood stream of the State, Chemung River may be mentioned, where serious floods, due to deforestation of a mountainous drainage area, have become so common as to necessitate the carrying out of extensive protection works at the large towns on that stream.

WATER STORAGE.

Large development of water power on Genesee River has led to a demand for extensive storage reservoirs on that stream. The surveys made by the State indicate that a storage reservoir of 15,000,000,000 cubic feet capacity can be constructed at a cost of $2,600,000, or at the rate of about $173 per million cubic feet stored. It is considered that the construction of such a reservoir is commercially feasible, and, provided the State legislature will grant the necessary permission, the project will probably be carried out by a private company. The developed water power of Genesee River has increased from about 6,000 horsepower in 1882 to about 18,000 horsepower in 1898.

Extended studies have also been made of the possibilities of water storage on Hudson River, where the water power has increased from less than 13,000 horsepower in 1882 to something like 55,000 horsepower at the beginning of 1898. The studies, so far as carried, show that it is possible to create on that stream a continuous, permanent power of about 175,000 horsepower. Probably when the studies are complete it will appear that considerably more than this can be developed at a cost which will be commercially feasible.

The great power developments on Niagara River at Niagara Falls, and on St. Lawrence River at Massena, are the most significant industrial movements now taking place in the United States. The future power of these two streams may easily be placed at several hundred thousand horsepower.

ERIE CANAL AT THE CITY OF BUFFALO.

ERIE CANAL.

Erie Canal, a view of which is given on Pl. I, was the first great development of the internal water resources of New York, and grew out of the demand for transportation facilities between the Atlantic seaboard and the Great Lakes. The impulse which it gave to the development of New York State, and of the entire territory tributary to the Great Lakes, can hardly be estimated. Taking into account its far-reaching consequences, it may be considered the greatest public work thus far carried out in the United States. Nevertheless, Erie Canal has not only passed its day of usefulness, but, to some extent, stands in the way of future development, the chief cause for this being a too pronounced regard for the canal's former greatness. The historical matter cited in the body of the report may serve to indicate how strongly the feeling that Erie Canal should be maintained in perpetuity has been impressed upon the people of the State of New York.

By way of illustrating the rise and decline of Erie Canal, it may be cited that in 1837 the total freight carried was 1,171,296 tons, valued at $55,809,288; in 1880 the total freight carried was 6,457,656 tons, valued at $247,844,790; in 1895 the total freight carried was 3,500,314 tons, valued at $97,453,021. Statistics show that the great bulk of all the freight now carried on Erie Canal is through freight carried for Western producers, local business being only a small per cent of the whole. Statistics show that freights are now carried by railways as cheaply as they can be carried by the canal, and this, too, at a profit, while the canal, in order to obtain any freight at all, has been obliged to do away with all tolls, thus making the cost of shipment by canal the bare cost of transportation proper.

In 1895 an improvement of Erie Canal was authorized at a cost of $9,000,000. The work of this improvement is now in progress. Recently it has been found that the cost will be $16,000,000, instead of $9,000,000, as originally expected. On this basis, and throwing out of the account former expenditures, we may say that Erie Canal will cost the people of the State of New York annually at least $1,230,000. Assuming a traffic for the enlargement of the canal of 5,000,000 tons per annum, carried 200 miles, we have a total of 1,000,000,000 ton-miles per annum on which the people of the State of New York must pay in the way of interest and cost of maintenance and operation about 1.25 mills per ton-mile, while canal freights now average about 1.2 mills per ton-mile; hence the people of the State of New York will be obliged to pay under the new conditions over 50 per cent of the total cost of the transportation. At present the local canal freights are only 15 per cent of the total.

Owing to her extensive inland-navigation system the experience of New York as to loss of water from artificial channels has been very extensive. Measurements made at different times show that in a canal of the dimensions of the original Erie Canal, which had a section of 40 feet water surface, 28 feet bottom, and 4 feet depth, there should be provided, in order to cover the evaporation and percolation losses, a water supply of about 100 cubic feet per mile per minute. Details relating to this special subject may be found further on.

The State early adopted the policy of leasing surplus waters of Erie Canal for power purposes. The most extensive development growing out of such leases is that at Lockport, where several thousand horsepower are in use supplying establishments valued at about $2,500,000 a year, and employing nearly 1,900 operatives, with an annual product of about $3,000,000.

VALUE OF WATER TO INDUSTRIES.

Water power is extensively sold at Oswego, Cohoes, and Niagara Falls, and to some extent at Rochester. It will also be extensively sold at Massena when the development there is completed.

The value of the internal waters of the State to some of the leading industries, such as the lumber industry and the wood-pulp and paper industry, may be noted. On Hudson River from 1851 to 1897, inclusive, the total number of logs taken to market by water transportation was 23,313,585, these market logs furnishing 4,662,717,000 feet B. M. of lumber. The cost of driving logs from the head waters of the Hudson to the Big Boom above Glens Falls is said to be from 50 to 75 cents per thousand feet B. M.

The wood-pulp and paper industry is developed in New York State to a point beyond that reached in any other State of the Union. On January 1, 1898, there were at least 125,000 net water horsepower in use in the State in the production of mechanical wood pulp, while probably from 30,000 to 35,000 more are consumed in operating paper mills.

One obstacle to the easy operation of water power in this State is the formation on many streams of frazil or anchor ice. A study of the formation of frazil and anchor ice, as made by the Montreal harbor commissioners, indicates that it may be possible to learn in the future how to remedy this difficulty.

OWNERSHIP OF WATER.

The sand areas of Long Island present conditions of water yield different from those of the other drainage areas of the State. We have here an extended region of coarse, deep sand, into which the rainfall sinks easily, there being almost no surface run-off. These sand areas form subterranean reservoirs, from which from 0.7 to 0.8 cubic foot per square mile per second may be drawn, the same as from artificial reservoirs on the earth's surface, these natural underground reservoirs possessing the advantage of furnishing a filtered water of a high degree of purity.

The taking of the water supply of Brooklyn from the sand areas of Long Island has led to the development of legal principles relating to rights in underground water somewhat different from those derived from the common law of England. The decision in a test case now before the courts is, in effect, that when subterranean water is taken in large quantity for the supply of cities or for manufacturing purposes the party taking it is liable to the adjacent landowners the same as in the case of diverting surface water.

Owing to the development of the internal navigation system, and the consequent assumption on the part of the courts and State officials that the State's rights to the inland waters were, in effect, paramount to all other rights, no general mill act has ever been enacted in the State. Nevertheless, the demand for water storage on the streams of the northern part of the State and on St. Lawrence River, which are not in any way tributary to Erie Canal, has led to the enactment of a number of special laws which have the force of mill acts in that they grant the right of eminent domain for the purpose of improving the hydraulic power of streams. This phase of development of the laws of this State relating to riparian rights is an exceedingly interesting one.

Titles to lands under water and water rights have been considerably complicated in New York because of the peculiar circumstances of the early settlement. It is well-established law that Hudson and Mohawk rivers belong to the State, while the Genesee and the other large rivers belong to the riparian owners. A confusion of ideas arising out of such contradictory facts as these has undoubtedly assisted in obscuring the real relations of the State to riparian owners in New York.

In the case of Black River large quantities of water have been diverted for the supply of Black River and Erie Canal, which has been compensated for in kind by the construction of a system of State reservoirs on the head waters of that stream capable of storing nearly 3,800,000,000 cubic feet. The State has further recognized the rights of riparian owners in the Black River reservoirs by creating a commission of owners and users of water power on Black River to manage the discharge from the reservoirs.

Skaneateles Lake presents a case where the State, having originally appropriated water for the supply of Erie Canal, has later, by act of legislature, allowed the taking of the said water for a municipal supply.

With restrictive legislation repealed and a proper mill act enacted, we may hope ultimately to develop in New York approximately 1,518,000 gross horsepower, worth to the people of the State anywhere from $150,000,000 to $200,000,000 a year, or as much as the present entire agricultural product of the State.

PHYSICAL CONDITIONS.

Considering only the broader topographic features, the streams of the State may be pictured as coming from three main water centers. The first of these in importance is the Adirondack area, the peaks of which are over 5,000 feet in height. Next to this are the Catskill Mountains, in the southeastern part of the State, the greatest heights of which are about 4,000 feet; and third are the highlands of the southwestern portion of the State, portions of the Allegheny Plateau. In extent the Adirondack Region is much the largest, and owing to this fact and its higher elevation it is the most important water center of the State. The Catskill Region, from its lower altitude and from changes introduced by cutting off the forests, is much less valuable in yield of water. The issuing streams are flashy and uncertain, pouring down destructive floods in spring and running nearly dry during the summer and fall. It is, without doubt, largely owing to this fact that water-power development has made less progress in this part of the State than in the other power-producing sections. The Allegheny Plateau has also greatly deteriorated in water-yielding capacity on account of deforestation. The serious effect of such decrease is discussed later in connection with the Genesee River storage project.

MOUNTAINS AND FORESTS.

The mountain belt included in the Adirondacks proper—the Bouquet, Schroon, Kayaderosseras, and Luzerne ranges, with the Highlands immediately to the west—has come to be commonly known as the Adirondack Plateau. Describing this broadly, it may be considered as bounded on the east by Lake Champlain, on the west by the valley of Black River, on the north by the farming regions of the St. Lawrence, and on the south by those of the Mohawk Valley. The mountain belt proper, however, occupies only the eastern and southern part of the Adirondack Plateau. Its greatest width is about 40 miles. The mountain ranges, however, are not always distinct; sometimes these are lateral spurs interlocked and sometimes single mountains occupy the space between the ranges, filling the valleys.

From the Adirondack Plateau streams flow to the north, southeast, and west. The principal streams flowing north, east, and west to the St. Lawrence system are Moose, Beaver, Oswegatchie, Grass, Raquette, St. Regis, Salmon, Saranac, Ausable, and Bouquet rivers. The southern streams, which all belong to the Hudson system, are Sacundaga, Indian, Cedar, Opalescent, Boreas, and Schroon rivers, and East Canada and West Canada creeks. All these streams head in lakes, of which the most important, tributary to the St. Lawrence, are Placid, Saranac, St. Regis, Loon, Rainbow, Osgood, Meacham, Massawepie, Cranberry, Tupper, Smiths, Albany, Red Horse Chain, Beaver, Brandeth, Bog

A. BEAVER MEADOW, NEAR INDIAN LAKE, A TYPICAL RESERVOIR SITE IN THE ADIRONDACKS.

B. BOG RIVER IN THE ADIRONDACKS.

River Chain, Big Moose, Fulton Chain, Woodhull, Bisby, Raquette, and Blue Mountain. Typical views are given on Pl. II.

Following are the principal lakes of the Adirondack Plateau tributary to the Hudson system: Pleasant, Piseco, Oxbow, Sacundaga, Elm, Morehouse, Honnedaga, West Canada, Wilmurt, Salmon, Spruce, Cedar, Lewey, Indian, Rock, Chain, Catlin, Rich, Harris, Newcomb, Thirteenth, Henderson, Sanford, Colden, Boreas, Elk, Paradox, Brant, Schroon, and Luzerne.

The great forest of northern New York occupies the central part of the Adirondack Plateau, and deserves notice from its importance as a conservator of the streams issuing from that region. According to a map accompanying the report of the forest commissioners of New York for 1891, the outlines of the great forest are substantially as follows: Its eastern boundary coincides quite closely with a line drawn through Keene Valley and thence along the valleys of Schroon River and the upper Hudson; its southern boundary is for the main part identical with that of Hamilton County and the town of Wilmurt, in Herkimer County, although in some places the forest extends a short distance into Fulton County; its western boundary is the county line between Lewis and Herkimer counties; its northern boundary runs in an irregular line from a point near Harrisville, on the Lewis and St. Lawrence County line, to the Upper Chateaugay Lake, which is situated near the line between Franklin and Clinton counties. This territory contains about 3,590,000 acres, of which 3,280,000 acres are considered to be covered with dense forests. Within this region there are from 1,300 to 1,400 lakes and ponds, while from it the eighteen important streams just enumerated diverge in every direction. The general elevation of the Adirondack Plateau is about 2,000 feet above the level of the sea. Little discussion is needed, therefore, to show the great value of this elevated forest-covered plateau as a conservator of the natural waters of the State.

One important utilization of the waters of this State formerly was the carrying of logs to market through the various streams. By reason of the clearing off of the forests, that business has gradually declined, until, except in the Adirondack Plateau, it is now of little importance. It has been the policy of the State for a number of years to acquire, as far as possible, by tax title and purchase, bodies of land in the Adirondack forest for the purpose not only of conserving the forests in order to increase the yield of streams, but for the further purpose of creating a forest park worthy of the great Commonwealth of New York. In order to carry out this project the forest-preserve board has been empowered to purchase lands within the forest, or, failing to agree on terms with the landowners, to take lands under condemnation proceeding.[1]

[1] The State holdings in the Adirondack Region up to the year 1895 may be determined by reference to a map of the Adirondack forest and adjoining territory as issued by the fisheries, game, and forest commission in 1895.

The Adirondack Plateau is a rugged, rocky region, sparsely populated, and worthless for agriculture. Its chief value lies in a complete utilization of such natural resources as attach to its unparalleled water-yielding capacity. From this point of view it may easily become an important factor in the future development of New York. To insure this result the water yield of every stream of the region needs to be conserved by reservoir systems.

TEMPERATURE AND PRECIPITATION.

In 1826 an elaborate system of meteorological observations at the State academies was inaugurated by the board of regents of the University of New York and was continued until 1863. During a portion of this period, and later, a large amount of data was obtained by volunteer observers of the Smithsonian Institution and at military posts. In 1871 the United States Signal Service took charge of work of this character, and in 1889 the State meteorological bureau was organized. There is, therefore, a large accumulation of material regarding the local climate, such that an account of it would extend beyond the limits of this paper. For details reference should be made to the volumes on meteorology published by the board of regents of the State University; also to the bulletins and annual reports of the State meteorological bureau and of the United States Weather Bureau.

To facilitate the study of meteorological data the individual stations have been grouped in accordance with topographic features and geographic position, the subdivisions being as shown in the accompanying table. The names indicate in a general way the relative position, the Western Plateau including the portion of the Appalachian Highlands west of Seneca Lake, and the Eastern Plateau the remainder of the Appalachian Highlands from Seneca Lake eastward to the Hudson Valley.

The average annual temperature is generally taken as decreasing with altitude at the ratio of 1° F. to every 300 feet of elevation, the rate being somewhat below this average in winter and above it in summer. An approximate determination for the State indicates that the rates of decrease are .3° F. per hundred feet elevation for the winter, and .4° F. per hundred feet for the summer. For the mountains of northern New York a much smaller variation than .3° F. appears to hold for the winter months.

Average monthly and annual temperatures for the 22-year period, 1871–1892. (a)

	Western Plateau.	Eastern Plateau.	Northern Plateau.	Atlantic coast.	Hudson Valley.	Champlain Valley.	St. Lawrence Valley.	Great Lakes.	Central lakes.	Mohawk Valley.	Average of the ten regions.
Altitude (feet)	1,287	1,070	1,578	82	221	186	431	484	645	639	662
January	22.0	21.3	16.0	30.5	21.5	16.3	15.9	23.4	24.2	21.0	21.6
February	23.6	22.5	16.8	31.6	26.9	17.5	17.3	24.3	25.8	22.8	22.9
March	28.5	28.6	24.0	35.9	38.2	25.9	26.5	29.9	30.6	28.8	29.2
April	41.7	42.0	36.8	46.7	46.2	40.8	40.4	42.0	44.2	42.8	42.3
May	54.8	55.0	57.8	57.6	58.8	55.2	55.5	54.8	57.3	55.8	55.7
June	64.3	64.8	60.3	67.0	68.1	64.7	64.2	64.9	66.0	65.0	65.0
July	68.6	68.6	63.8	72.3	72.0	69.9	68.2	69.8	70.8	69.2	69.3
August	66.6	66.3	62.5	71.1	69.6	67.5	65.9	68.1	68.7	67.3	67.4
September	59.3	61.5	55.0	65.3	62.8	58.6	58.4	61.1	61.6	60.0	60.4
October	47.3	47.2	43.3	55.1	50.8	46.9	45.7	49.3	49.6	48.0	48.3
November	35.5	35.6	31.0	43.9	39.0	34.5	33.2	37.3	37.1	35.0	36.3
December	26.7	25.9	21.2	34.5	28.5	21.8	22.2	28.4	28.3	25.8	26.3
Average	44.8	44.7	40.3	50.8	48.4	43.2	42.8	46.0	47.0	45.2	45.4

a From fifth annual report of the State weather bureau.

The intimate relation which exists between air circulation and precipitation in New York is one of the most interesting facts to be noted. Owing to lack of moisture in the continental interior, northwest winds in the spring, summer, and fall are essentially dry. In winter their dryness proceeds from low temperature and consequent small vapor-carrying capacity. The winter precipitation is due almost entirely to storm areas passing either actually across or in the vicinity of this State and deriving their supply of vapor from the inflow of moist air which they induce, either from the Atlantic Ocean or from the Gulf Region.

The winter months—December, January, and February—have somewhat less precipitation than either of the other seasons, although in the vicinity of the Atlantic coast, on the southwestern highlands of the State, and in the region of the Great Lakes the winter precipitation is relatively large.

In the spring rising temperature produces a modification and shifting of pressure systems, the winds decreasing in velocity and their directions being more variable than in winter. The frequent showers occurring in April and May appear to be due more than at any other time to the effect of an admixture of air having different temperatures.

In summer the Gulf of Mexico and the Atlantic Ocean contribute large supplies of moisture to northward-moving air currents, and, although cyclonic depressions are less frequent than at any other season, the rainfall accompanying each storm is heavy, and in New York the maximum seasonal precipitation, amounting as an average for the whole State to 10.96 inches, occurs in this season.

As regards the fall months, the rainfall of September is usually light in the region east of the Great Lakes, while in October the maximum general rainfall occurs. As regards meteorological conditions, winter may be considered as beginning in November.

Average precipitation in New York State, in inches.

	Western Plateau.	Eastern Plateau.	Northern Plateau.	Coast region.	Hudson Valley.	Champlain Valley.	St. Lawrence Valley.
Altitude (feet) *a*	1,307	1,056	973	132	230	262	414
January	2.52	2.52	3.11	3.47	2.89	1.73	2.19
February	2.23	2.34	2.78	3.22	2.26	1.35	2.15
March	2.51	2.46	3.06	3.74	2.88	1.94	2.49
April	2.68	2.80	2.66	3.50	2.82	1.88	2.21
May	3.36	3.54	3.45	3.90	3.53	2.63	2.82
June	4.23	4.16	3.28	3.53	3.68	3.16	3.54
July	3.25	4.04	4.09	4.20	4.24	3.24	3.39
August	3.13	3.50	3.50	4.54	3.69	3.39	2.75
September	2.90	3.13	3.19	3.59	2.90	3.09	3.26
October	3.28	3.31	3.47	3.93	3.52	3.12	3.44
November	2.76	2.81	3.48	3.87	3.15	2.61	2.71
December	2.73	2.82	2.90	3.44	2.89	1.92	2.57
Annual	35.58	37.43	38.97	44.93	38.46	30.06	33.52
Storage period	16.03	16.49	17.96	21.29	17.27	11.44	14.43
Growing period	10.61	11.69	10.87	12.27	11.62	9.79	9.68
Replenishing period	8.94	9.26	10.14	11.37	9.57	8.83	9.41

a Average altitude of stations considered.

A study of the data shows that there are a number of contending forces which are distinctively operative in New York, and which by modifying one another tend to produce numerous irregularities of the rainfall. So irregular indeed is the precipitation that frequently places only a short distance apart show wide variations.

In a general way it may be said that the amounts of annual rainfall in different sections of New York are mainly determined by proximity to sources of vapor or to vapor-laden air currents, and by the character of the local topography. As regards the latter statement, a more definite form would be that under similar conditions the precipitation is in some degree proportionate to the altitude. This rule, while generally true, does not apply to the valley of Hudson River, where the upper portion, including the Champlain Valley, receives a somewhat deficient rainfall as compared with the State as a whole. To the west, the Adirondack Plateau receives a marked increase of rainfall, while farther northwest there is a decrease in the valley of the St. Lawrence. This is also true of the elevated region in the vicinity of Hemlock Lake, which, although several hundred feet higher, has a rainfall considerably less than that at Rochester.

In the southeastern portion of the State the ocean winds find no obstruction along the coast, but, passing inland and meeting the abrupt ranges of the southeastern counties, give a copious rainfall, as compared with that of the intervening regions.

Western New York, on account of the frequent southwesterly direction of the winds, receives an appreciable portion of its vapor supply from the Gulf of Mexico. The rainfall in central New York, although less than that of the southeastern and southwestern highlands, is generally abundant. The principal valleys of the Susquehanna system, and also the depression of the central lakes tributary to Oswego River, show a deficiency as compared with the average of the State.

A knowledge of the snowfall is important in a study of the water resources, because by reason of the snow lying on the ground continuously for several months it is a great source of loss in open regions subject to severe winds, the evaporative effect of the winds tending to carry away large quantities of moisture which would otherwise be available to maintain stream flow. Thus far the only data relating to depth of snow are those derived from the reports of the State meteorological bureau. The following are a few figures so derived: In the winter of 1891–92 the total depth of snow at Humphrey, in the Western Plateau, was 119.8 inches; in 1890–91 the total depth at Cooperstown, in the Eastern Plateau, was 110 inches; in 1891–92 the total depth at Constableville, in the Northern Plateau, was 170.7 inches; in the winter of 1890–91, at Utica, in the Mohawk Valley, the total depth was 165 inches, and in 1891–92, at the same place, 151.6 inches. The records show that at the places where these large snowfalls occurred the ground was continuously covered with snow for several months. If the winds were of high velocity at the same time the evaporation loss must have been very great.

ROCKS AND STREAM FLOW.

Among the principal factors affecting stream flow should be noted the structure and texture of the rocks, especially those of the surface. For example, in regions with stiff, heavy, compact soils a much larger proportion of the rainfall runs off on the surface, passing immediately into the streams, than is the case in regions with open, porous soils or extensive sandy areas. A general knowledge of the surface geology is therefore desirable in a study of the water resources of the State. The relative position and area of the different geologic formations are best shown on the large geologic map of New York prepared under the direction of James Hall, State geologist, by W. J. McGee, and printed by the United States Geological Survey in 1894 (scale, about 5 miles to the inch). A similar but smaller map showing essentially the same features was also printed in the same year under authority of the regents of the university to accompany the report on the mineral exhibit of New York at the World's Columbian Exposition, this being on the scale of approximately 14 miles to an inch. On examining either of these maps one will note the preponderance, so far as area is concerned, of two classes of rocks—the ancient crystallines, which cover a large area in the northern part of the State, and the conglomerates, sandstones, and shales of the Devonian, which form the greater part of the Appalachian Plateau, stretching from Lake Erie across the State to within a short distance of Hudson River, this being the area classified by the State weather bureau as the Eastern and Western plateaus. The streams from the northern crystalline area undoubtedly furnish the best water supply of the State. This may not be due wholly to the character of the rocks, as many other factors contribute to this result.

The sandstones of the Upper Devonian along the northern boundary of Pennsylvania are bounded on the north by the long narrow belts of outcrop of the underlying rocks stretching in a general easterly and westerly direction. The streams pursuing a general northerly course pass in succession across these. As a rule, the soils of the region are heavy, with considerable clay, and the rainfall being absorbed somewhat slowly, a considerable portion of it flows directly into the water courses. The primeval forest has for the most part been cut away and heavy floods are common, such as those of the Genesee and Chemung rivers, described more fully on a later page.

The only streams of this region on which extensive discharge measurements have been made are Genesee River and its tributary, Oatka Creek. Streams of similar character in western Pennsylvania, however, have been measured for a number of years by the Philadelphia water department, and the results of these measurements are available for comparison and discussion. The results obtained on the Pennsylvania streams, the Neshaminy, Tohickon, and Perkiomen, are applicable particularly in estimates of the flow of the tributaries of Delaware River, rising in New York State, and to the more easterly streams which form the Susquehanna.

The drainage basins of the Oswego, Mohawk, and Hudson rivers are so highly composite as regards geologic formations and embrace such a wide variation in topography and surface geology that no definite deductions concerning the effect of the formations on water flow have been drawn. The streams of Long Island, rising among the sands, tills, and gravels of comparatively recent, unconsolidated formations, offer peculiar conditions, which are discussed on a later page.

RIVER SYSTEMS.

The rivers of the State may be classified into seven general systems, whose relative position is shown by the accompanying index map, fig. 1. These are:

(1) St. Lawrence system, which includes all waters draining to Lakes Erie and Ontario, and Niagara and St. Lawrence rivers.

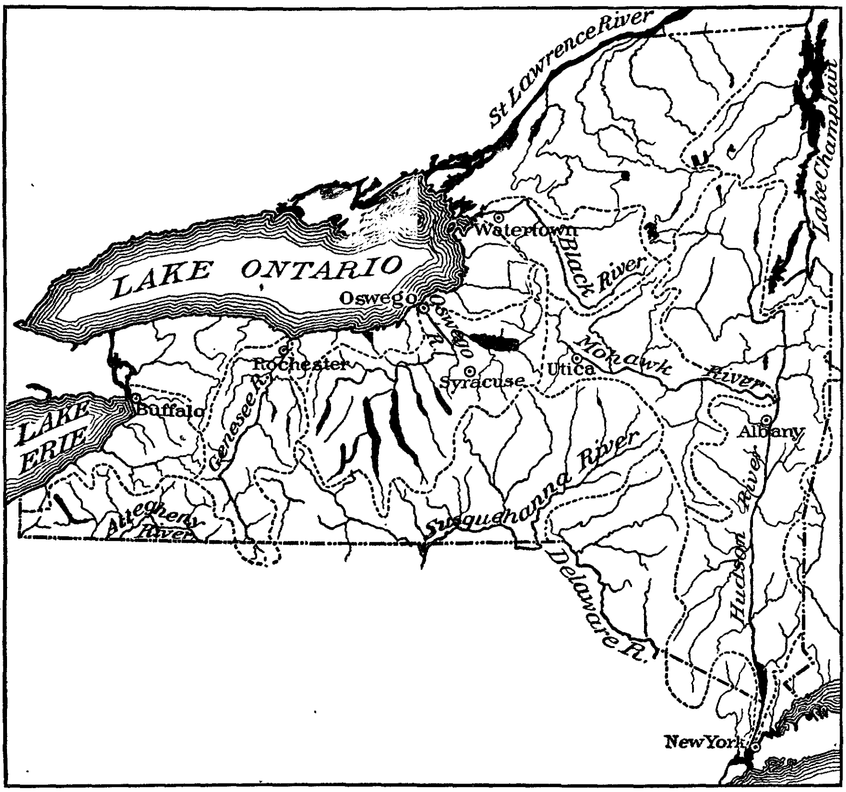


FIG. 1.—Index map of rivers of New York.

(2) Champlain system, including all streams in the State tributary to Lakes Champlain and George. The Champlain system is in reality a subdivision of the St. Lawrence, but made separate here merely for convenience in discussing the river systems of the State.

(3) Hudson River system, including all streams tributary to the Hudson and its main branch, the Mohawk.

(4) Allegheny River system.

(5) Susquehanna River system.

(6) Delaware River system.

(7) The streams of Long Island tributary to Long Island Sound and the Atlantic Ocean.

The head waters of the branches of Housatonic River in Connecticut flow out of the State to the east, while the head waters of Ramapo River, in Rockland County, flow from New York into New Jersey. These latter are of possible future importance by reason of the necessity of water for the supply either of Greater New York or, in the case of Ramapo River, also for the municipalities of northern New Jersey. Chateaugay River, a tributary of the St. Lawrence, also flows northward into the Dominion of Canada.

ST. LAWRENCE RIVER SYSTEM.

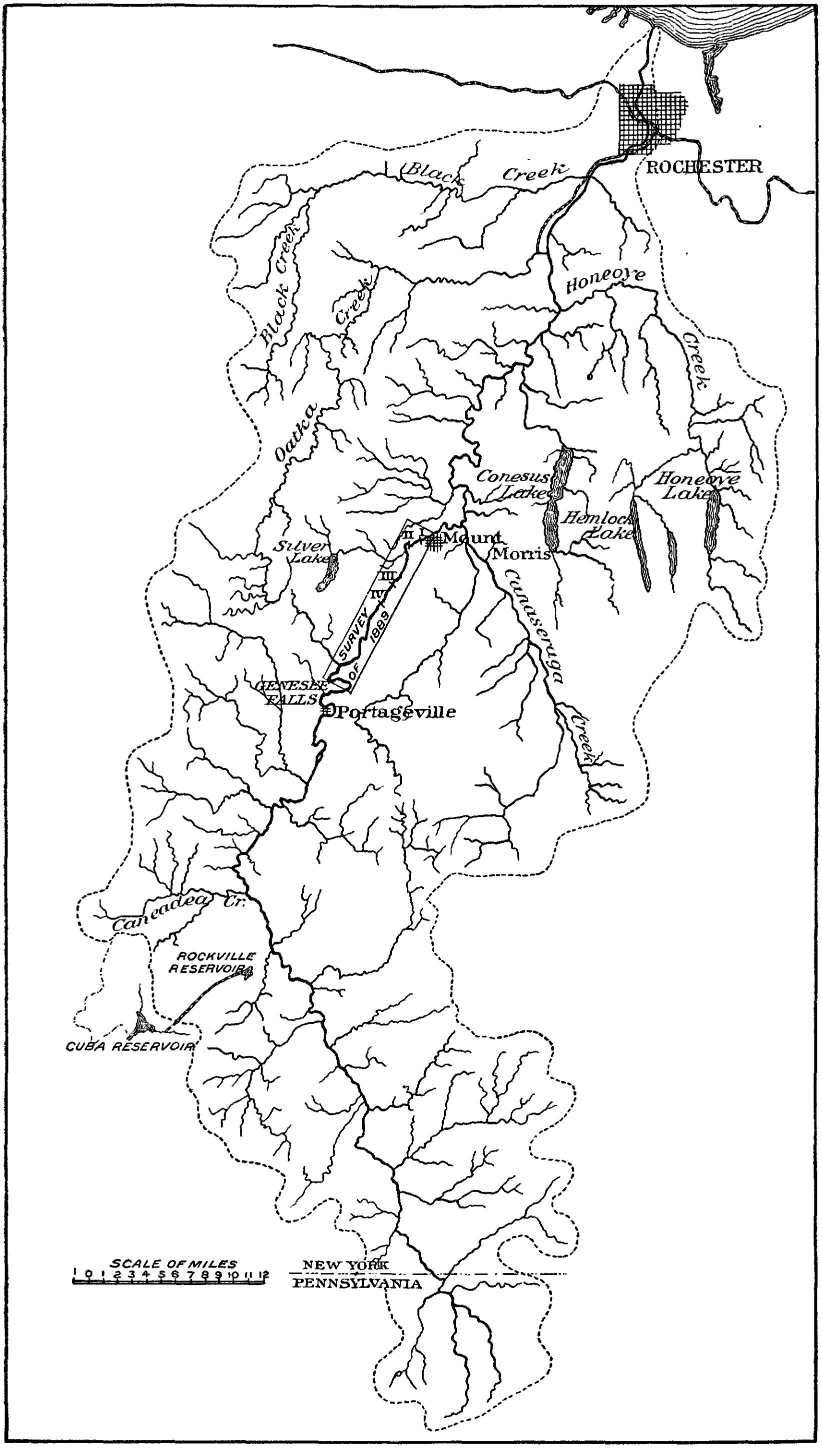
This group embraces the streams tributary to Lake Erie, Niagara River, Lake Ontario, and St. Lawrence River. On the extreme southwest, in Chautauqua County, the watershed line approaches within a few miles of Lake Erie, but at an elevation of several hundred feet above, and as a consequence the streams are short and rapid. A small amount of power is developed on Chautauqua Creek at Westfield, and on Canadaway Creek near Fredonia. Cattaraugus, Buffalo, Tonawanda, and Oak Orchard creeks may also be mentioned as tributaries of Lakes Erie and Ontario and Niagara River in western New York. Buffalo Creek is important as forming a large portion of Buffalo Harbor at its mouth. Tonawanda Creek, which flows into Niagara River at Tonawanda, is used for several miles as a part of Erie Canal. This stream is sluggish throughout nearly its whole course and affords only a small amount of power. The water supply of the village of Attica is taken from its head waters.

NIAGARA RIVER.

Niagara River forms a portion of the boundary between the Dominion of Canada and the State of New York. The difference in elevation between Lakes Erie and Ontario is, approximately, 336 feet, of which about 160 feet are at Niagara Falls. Between Lake Erie and Niagara Falls the river divides into two channels around Grand Island, which is 10 miles long and 4 or 5 miles wide. The general course of the river is from south to north, but in passing around Grand Island the eastern channel bends westward, and for 3 miles from the foot of the island the course of the river is west.

Goat Island lies at the foot of this westerly stretch. On the New York side the American channel finds its way around the island to the American Falls, which break over the rough ledge at right angles to the main river. The Horseshoe Falls, on the Canadian side, are about 3,000 feet higher up and lie between the west end of Goat Island and the Canadian shore. At the Canadian Falls the main river again turns to the north and pursues that general course to Lake Ontario.

The elevation of the water surface at the head of the rapids above the falls is 560 feet above tide water, thus giving a fall from the Lake



DRAINAGE AREA OF THE GENESEE RIVER.

Erie level to that point of from 12 to 13 feet, of which from 4 to 5 feet are included in the rapids at the city of Buffalo, in front of and just below Fort Porter. The descent in the river from the head of the rapids to the brink of the falls is about 50 feet. At the narrows, half a mile above the whirlpool, the elevation of the water surface is 300 feet, while that of the surface of the still water opposite Lewiston is 249 feet; the fall in this section, which is from 4 to 4.5 miles in length, may therefore be taken at 51 feet, while from Lewiston to the mouth at Fort Niagara the fall is only 2 feet in a distance of 7 miles. The total length of Niagara River is about 37 miles.

On account of the immense water-power developments now taking place at Niagara Falls the run-off of Niagara River must necessarily receive extended discussion in a complete account of the water resources of New York.

GENESEE RIVER.

Genesee River, as shown on Pl. III, issues from the highlands of the Allegheny Plateau in Potter County, Pennsylvania, a few miles south of the New York State boundary. Entering Allegany County, it first runs northwesterly for upward of 30 miles to near the village of Canadea, at which point it turns northeasterly, this direction being generally maintained to the mouth. It flows entirely across the county of Allegany and then for several miles forms the boundary between Livingston and Wyoming counties, after which it crosses the northeast part of Livingston into Monroe County, through which it continues to its mouth at Charlotte. Above Portage its course from the State line is chiefly through an alluvial valley.

From Portage to Mount Morris the river flows through a deep and in some places narrow canyon for a distance of over 20 miles. The Portage Falls, with a total descent including the intervening rapids of about 330 feet, are at the head of this canyon. The Upper Portage Falls have a descent, including the rapids, of about 70 feet. Half a mile below are the Middle Falls, shown on Pl. IV, with a descent of 110 feet; while 2 miles below begin the Lower Falls, consisting of a series of rapids about half a mile long with an aggregate fall of 150 feet. These three falls may be taken as aggregating about 270 feet, exclusive of the rapids. At present no power developments exist. Formerly a sawmill was located at the Middle Falls, but on account of the extinction of the lumber business on the stream it has not been operated for many years.

At Mount Morris, Genesee River issues into a broad, level, alluvial valley from 1 to 2 miles wide, which continues to near Rochester, where there is a descent of 263 feet in about 3 miles. The Upper Falls at Rochester, 90 feet in height, are a cataract in the Niagara limestone, while at the Lower Falls, 94 feet in height, shown on Pl. V, the Medina sandstone appears.

The principal tributaries of Genesee River are Canaseraga, Honeoye, and Conesus creeks from the east, and Oatka, Black, and Wiscoy creeks from the west. Honeoye, Canadice, and Hemlock lakes are tributary to the Honeoye Creek, and Conesus Lake to Conesus Creek. Silver Lake is another small body of water in the Genesee Basin and tributary to the river by the Silver Lake outlet. Canaseraga Creek joins Genesee River near Mount Morris. From Dansville to its mouth, a distance of 16 miles, this creek flows through a broad alluvial valley with very little fall. Above Dansville the stream is more rapid, but the comparatively small, deforested drainage area limits its value for water power. Honeoye Creek, which is the outlet of Honeoye, Canadice, and Hemlock lakes, furnishes some water power. There are also several mills on the outlet of Conesus Lake.

Formerly there were a number of mills on the Silver Lake outlet, but changed business conditions have led to their decay. The other tributaries of the Genesee have little significance as mill streams. It appears, then, that the two places of importance on Genesee River, from the water-power point of view, are Portage and Rochester. These will be discussed in detail farther on.

The following table gives the detail of the several subdivisions of the drainage area of Genesee River:

Drainage areas, in square miles, of tributaries of Genesee River.

Creek.	Drainage area.	Area above mouth.	Area below mouth.
Cryder	43.3	99.9	143.2
Chenunda	30.0	181.0	211.0
Dykes	68.3	214.0	282.3
Vandemarck	21.6	301.3	322.9
Knights	22.3	323.9	346.2
Phillips	32.3	372.8	405.1
Van Campens	55.7	410.4	466.1
Angelica	82.1	481.1	563.2
White	15.9	569.2	585.1
Black	31.1	595.5	626.6
Crawford	11.8	637.6	649.4
Caneadea	63.3	651.0	714.3
Cold	41.0	745.3	786.3
Rush	35.3	787.0	822.3
Wiscoy	108.6	833.6	942.2
Wolf	19.3	974.9	994.2
Silver Lake	30.4	1,029.2	1,059.6
Coshaqua	82.0	1,059.6	1,141.6
Canaseraga	258.7	1,148.4	1,407.1
Beards	41.3	1,423.1	1,464.4
Conesus Lake	88.8	1,555.5	1,643.9
Honeoye	262.6	1,675.9	1,938.5
Allens	198.1	1,947.1	2,145.2
Black	211.8	2,168.5	2,380.0

The total drainage area of Genesee River at its mouth is 2,445.6 square miles.

A. UPPER AND MIDDLE FALLS OF GENESEE RIVER AT PORTAGE.

B. GENESEE RIVER CANYON BELOW MIDDLE FALLS AT PORTAGE.

The following tabulation gives the elevation of Genesee River at various points.

Elevation above tide water of Genesee River at various points.

	Feet.
Mean surface of Lake Ontario	247
Crest of the feeder dam in south part of the city of Rochester	510
Low-water surface of river at New York, Lake Erie and Western Railway bridge near Avon	538
Crest of old Mount Morris power dam	605
Water surface just above Upper Falls at Portage	1,080
Water surface at New York, Lake Erie and Western Railway bridge near Belvidere	1,333

The extreme head waters in Potter County, Pennsylvania, are stated to be considerably over 2,000 feet above tide.

OSWEGO RIVER.

Oswego River flows into Lake Ontario at the city of Oswego. Its basin includes the more important of the inland lakes of western New York. Taking the lakes of the Oswego River Basin in order from west to east, their names, elevations above tide, area of water surface, and tributary drainage area at the foot of each lake are as follows:

Elevation and area of lakes of the Oswego River Basin.

Lake.	Elevation above tide.	Area.	Drainage area.
	Feet.	*Sq. miles.*	*Sq. miles.*
Canandaigua	687.0	18.6	175.0
Keuka	720.0	20.3	187.0
Seneca	443.0	66.0	707.0
Cayuga	380.0	66.8	1,593.0
Oswaco	710.0	12.4	208.0
Skaneateles	867.0	12.8	73.0
Otisco	784.0	3.0	41.0
Onondaga	364.0	4.0	267.0
Cazenovia	900.0	2.8	9.0
Oneida	370.0	80.9	1,300.0

The following are the drainage areas of Oswego River and its principal tributaries:

Drainage areas of Oswego River and principal tributaries.

	Sq. miles.
Oswego River at mouth	5,013
Below junction of Seneca and Oneida rivers	4,868
Oneida River	1,420
Seneca River	3,450

The subdivisions of the dainage area of Seneca River are as follows:

Subdivisions of drainage area of Seneca River.

	Sq. miles.
At junction with Oneida River	3,450
At Baldwinsville	3,136
At Montezuma	2,472
Below Cayuga Lake	1,593
At entrance to Cayuga Lake	780
At Seneca Falls	771
Waterloo	745
At foot of Seneca Lake	707
Keuka Lake Outlet	213
Catherines Creek	94

The drainage areas of Cayuga Lake and its tributaries are as follows:

Drainage areas of Cayuga Lake and tributaries.

	Sq. miles.
At outlet	813
Cayuga Inlet, including Cascadilla Creek	173
Fall Creek, not including Cascadilla Creek	152
Salmon Creek	90
Taughanic Creek	60

Clyde River, a tributary of Seneca River, is formed by the junction of Canandaigua Outlet and Mud Creek. The latter stream rises in the southern part of Ontario County and flows first north and then east, uniting with Canandaigua Outlet at Lyons. Clyde River joins Seneca River at Montezuma. The following are the drainage areas of Clyde River and tributaries:

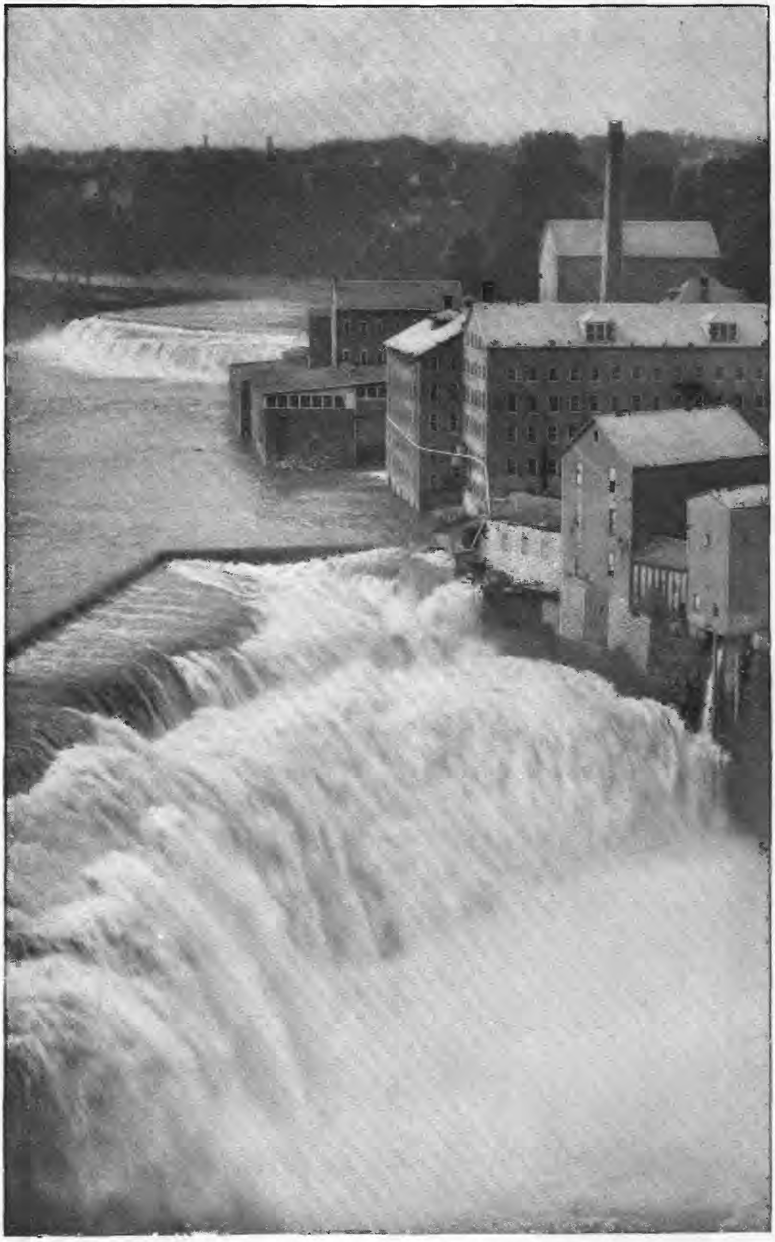
Drainage areas of Clyde River and tributaries.

	Sq. miles.
At mouth	869
At Clyde	807
At Lyons, at junction of Canandaigua Outlet and Mud Creek	729
Mud Creek at Lyons	298
Canandaigua Outlet at junction with Mud Creek	431
Canandaigua Outlet at Phelps	390
Canandaigua Lake at foot	175
Canandaigua Inlet	85

Owasco Lake discharges into Seneca River through an outlet 15 miles in length. The following are the drainage areas of Owasco Outlet:

Drainage areas of Owasco Outlet.

	Sq. miles.
At mouth	230
At Auburn	212
Owasco Lake at foot	208
Owasco Inlet	120



MIDDLE AND LOWER FALLS OF GENESEE RIVER AT ROCHESTER.

The drainage areas of Oneida River and its principal tributaries are as follows:

Drainage areas of Oneida River and principal tributaries.

	Sq. miles.
Oneida River at mouth	1,420
Oneida Lake at foot	1,300
Fish Creek	480
Chittenango Creek, including Cazenovia Lake	306
Oneida Creek	128

The Oswego River and its tributaries furnish a large number of water powers, the detail of which may be obtained from the Report on Water Power of the United States, Tenth Census of the United States, 1880. Very little can be added to the statements in that report.

The next stream of any importance tributary to Lake Ontario is Big Salmon River, which rises in the highlands of Lewis County and flows westerly into Lake Ontario. This stream was extensively considered several years ago as the source of water supply for the city of Syracuse, the water to be taken at a point about 40 miles distant from the city. Its watershed above the proposed point of diversion comprises 70 square miles of forest land at an elevation of from 1,000 to 1,500 feet above tide water.

BLACK RIVER.

Between Big Salmon River and the mouth of Black River there are a number of small streams flowing into Lake Ontario, none of which are of special importance. We may therefore pass to a brief description of Black River. This stream rises in the western part of Hamilton County and pursues a southwesterly direction, passing across Herkimer County into Oneida County; it then bends to somewhat west of north through Lewis County, but soon after passing the northwesterly boundary of that county it changes to a general westerly course, flowing into Black River Bay at the extreme eastern end of Lake Ontario. Extensive water-power developments are in use on this stream and its tributaries, at Watertown, Lyons Falls, Carthage, Black River, Brownville, Dexter, and other points. There are also a number of State reservoirs on the head waters which will be discussed in detail later. The following gives the elevation in feet of the main points on Black River above tide water, according to the best available information.

Altitude of points along Black River.

	Feet.
At mouth	247
Watertown, west line of city	370
Watertown at head of falls	492
Carthage at foot of rapids	669
Carthage at crest of State dam	724

Altitude of points along Black River—Continued.

	Feet.
Lyons Falls at foot	733
Lyons Falls, crest of State dam	802
Forestport, crest of State dam	1,129
North Branch reservoir	1,821
Chub Lake	1,599
Woodhull reservoir	1,854
South Branch reservoir	2,019
Moose River at mouth	802
First Lake, Fulton Chain	1,684
Second Lake	1,684
Third Lake	1,685
Fourth Lake	1,687
Fifth Lake	1,691
Sixth Lake	1,760
Seventh Lake	1,762
Eighth Lake	1,803
Little Moose Lake	1,772
Big Moose Lake	1,787
Beaver River at mouth	724
Beaver Lake at Number Four	1,436

The drainage areas of Black River and its tributaries, in square miles, are as follows:

Drainage areas of Black River and tributaries.

	Sq. miles.
Black River at mouth	1,860
At Watertown	1,820
At Carthage	1,741
At Lyons Falls below Moose River	810
Forestport	275
Above mouth of Sawmill Creek	174
Deer River	107
Beaver River	365
Lovell Creek	34
Independence Creek	90
Martins Creek	29
Otter Creek	60
Moose River	349
Sugar River	66

STREAMS FLOWING INTO ST. LAWRENCE RIVER.

Proceeding along St. Lawrence River we find a number of streams, such as the Oswegatchie, which flows into the St. Lawrence at Ogdensburg; the Grass, which enters the St. Lawrence near the north line of the State; the Raquette and St. Regis, flowing into the St. Lawrence a short distance below the Grass, and finally the Chateaugay, which flows from this State into the Dominion of Canada and thence into the St. Lawrence. These streams all head in and about the Adirondack Plateau and, as a rule, fall rapidly from their sources to near their mouths, affording large water powers, which thus far have been chiefly utilized for pulp grinding, paper making, and sawing lumber.

There is a lack of definite information in regard to all the streams of the northern part of the State. No detailed surveys of this region have been made. Partial reservoir systems have been constructed on Oswegatchie, Grass, and Raquette rivers. Some of the economic questions involved in the construction of these reservoirs will be discussed in Part II of this paper, Water-Supply Paper No. 25.

So far as can be learned, no measurements have been made of any of the streams tributary to St. Lawrence River proper. It is probable, however, that they are the best water-yielding streams of the State, because they flow from the great northern forest, and because their head waters are in the extensive lake region which lies immediately west of the main Adirondack Mountains, and which extends westward from the base of the main range to the borders of the forest, a distance of nearly 50 miles. This portion of the Adirondack Plateau is comparatively level. As regards geographic distribution, these lakes are most numerous in the northern parts of Herkimer and Hamilton counties and the southern parts of St. Lawrence and Franklin counties. Those in Herkimer County flow into Moose and Beaver rivers, tributaries of Black River. The following are the elevations of a few of the more important lakes of Hamilton, St. Lawrence, and Franklin counties, which are tributary to streams flowing northward into the St. Lawrence:

Elevations of important lakes of Hamilton, St. Lawrence, and Franklin counties.

Lake.	Feet.
Cranberry	1,540
Raquette	1,774
Forked	1,753
Long	1,630
Little Tupper	1,728
Big Tupper	1,552

LAKE CHAMPLAIN SYSTEM.

Lake Champlain has a water area of 400 square miles. The area of its watershed in New York State amounts to 2,950 square miles, in Vermont to 4,270 square miles, and in the Province of Quebec to 740 square miles. The total area of watershed, not including water surface, is 7,960 square miles, or the total area of the drainage basin, including water surface, is 8,360 square miles. Lake Champlain is considered as beginning at Whitehall and terminating at St. Johns, on the Richelieu. Its length is 125 miles and its breadth in the northern portion about 13 miles. The standard low-water elevation is given at 95.03 feet, and standard high water at 103.78 feet, above tide.

The streams tributary to Lake Champlain are Big Chazy, Little Chazy, Saranac, Salmon, Little Ausable, Big Ausable, and Bouquet rivers and the outlet of Lake George. There are also a few small streams of no special importance.

The streams tributary to Lake Champlain are, as a rule, not of great length, but rising, as they nearly all do, in or near the high mountains of the Northern Plateau they have a rapid descent with an abundant fall. For illustration we may refer to the Saranac River, which has, by the county maps of Bien's Atlas, a length of about 55 miles from its mouth to Lower Saranac Lake. The elevation of Lake Champlain above tide water is 101 feet, while that of Lower Saranac Lake is given at 1,539 feet. Hence the fall in 55 miles of river course is 1,438 feet. Middle Saranac Lake lies at an elevation of 1,542 feet and Upper Saranac at 1,557 feet.

In the case of Ausable River we find a distance by the course of the river of about 40 miles from its mouth to Lake Placid, the elevation of that body of water being 1,864 feet above tide, or 1,763 above Lake Champlain; or, taking the distance by that fork of Ausable River which leads to Ausable Lakes, the distance is about 42 miles to Lower Ausable Lake, the elevation of which is 1,961 feet above tide; hence we have a fall in this stream of 1,860 feet in a little over 40 miles. The water power of the several streams tributary to Lake Champlain has been extensively developed at Plattsburg and other points, as indicated by the tabulations relating to pulp, paper, and lumber interests.

The most southerly tributary of Lake Champlain of any importance for water purposes is the outlet of Lake George, which in about 2 miles has a fall of 222 feet. The greater portion of this is concentrated in the first mile from the lake. The elevation of Lake George above tide water is 323 feet. The area of the lake surface is stated at 50 square miles, and the tributary drainage area above the foot of the lake at 238 square miles. In the absence of accurate topographic maps the drainage area of Lake George, like that of most of the other streams considered, can be given only approximately.

As will be shown later, the streams in eastern New York can not be depended on to furnish a natural flow of more that about 0.3 cubic foot per square mile per second as a minimum in a dry year. On account of the large water surface of Lake George in proportion to the drainage area, it is possible, by utilizing the storage on the lake surface, to realize a much larger quantity. From 0.7 to 0.8 cubic foot per second per square mile may be assumed as a conservative estimate, the results being based on allowing the water to flow out of the lake 24 hours per day for only 310 days in the year. On this basis we may assume a mean flow for minimum dry years of about 200 cubic feet per second. Since the entire 222-foot fall of the Lake George Outlet is now utilized, we may place the permanent power in a dry year at about 5,000 gross horsepower. The village of Ticonderoga, at which this power is all utilized, had a population in 1890 of 2,267.

Wood Creek, the most southerly tributary of Lake Champlain, is of interest in a study of the water resources of New York, chiefly because of its relations to Champlain Canal, its channel being utilized for several miles as part of the canal. At Fort Ann there is considerable power developed on one of its tributaries, used at present for grinding pulp.

HUDSON RIVER SYSTEM.

Hudson River, with its principal tributary, the Mohawk, is the most important river of the State. From its mouth to Troy, a distance of over 150 miles, it is a great inland estuary subject to tidal action, and because of its great length and the large fresh-water inflow it is unique among inland estuaries. From the first landing of the Dutch on Manhattan Island to the present time it has been an important channel of commerce. On his voyage of discovery in 1609, Hendrik Hudson ascended to the head of tide water, and doubtless discerned the possibilities of future settlement which were so soon realized at Albany, Waterford, and Schenectady. The tidal action of Hudson River originally terminated at the rapids above Troy, but its present termination is a few miles below, at the Troy dam, a structure erected about 1820 as a part of the State canal system. There is a lock at the east end of this dam through which canal boats pass into the pool above, thus enabling them to reach Lansingburg on the east side of the river, or Waterford on the west side, where they may enter Champlain Canal.

Below Troy the tributaries of Hudson River are mostly small and generally not of very great importance, although some of them have considerable power development. One of them, Croton River, is the principal source of water supply of the city of New York. On this part of the river the drainage basin is rather narrow, and many of the streams issuing from the highlands at either side have such small drainage areas as to carry only moderate quantities of water. In descending the river from Troy the principal streams are, on the west side, Normankill, Catskill, Esopus, and Rondout creeks, and on the east side Kinderhook, Wappinger, and Fishkill creeks and Croton River. Harlem River, connecting the Hudson with East River, may be mentioned, in view of its value to navigation interests, as an important feature of the water resources of New York.

The following are the elevations of mean tide, mean low tide, and mean high tide above mean sea level at New York, and the mean rise and fall of tides at various points along the tidal estuary between New York Bay and the Troy dam:

Mean tidal elevations in feet at various points between New York Bay and Troy dam.

Locality.	Mean tide.	Mean low tide	Mean high tide.	Mean rise and fall.
Sandy Hook	----- ----	----------	----------	4.70
Governors Island	0.00	2.20	2.20	4.40
Dobbs Ferry	0.18	1.62	1.98	3.60
Coxsackie light-house	1.68	0.17	3.53	3.70
New Baltimore	1.73	0.02	3.44	3.42
Colymans	1.88	0.44	3.31	2.87
Castleton	2.09	0.82	3.35	2.53
Van Wies	2.13	0.82	3.29	2.33
Albany	2.43	1.27	3.59	2.32
Nail works	2.78	1.81	3.75	1.94
Troy dam	3.77	3.37	4.17	0.80

The most important tributaries begin above Troy. Ascending on the west side we find Mohawk River, the outlet of Saratoga Lake, Sacundaga River, Stony and North creeks, and Indían and Cedar rivers. On the east side there are Hoosic, Battenkill, Schroon, and Boreas rivers. Above the mouth of Cedar River the main North or Hudson River is considered to extend to and beyond Lake Sanford, including Opalescent River and the streams issuing from the high Adirondacks.

The following gives the height above tide water at New York of a number of points on Hudson River.

Height above tide water at New York of points on Hudson River.

	Feet.
New York (at mouth)	0.0
Troy	3.8
Saratoga dam (crest)	102.0
Fort Edward (below dam)	118.0
Glens Falls (crest of feeder dam)	284.0
Mouth of Sacundaga River	556.0
Mouth of Stony Creek	584.0
Mouth of Schroon River	608.0
At Glen Bridge	728.0
At Riverside Bridge	875.0
At North Creek Bridge	998.0
At North River	1,050.0
Mouth of Boreas River	1,140.0
Mouth of Indian River	1,415.0
Mouth of Cedar River	1,460.0
Lake Sanford	1,723.0

MOHAWK RIVER.

Mohawk River, the most important tributary of the Hudson, rises in the western-central part of the State, near the Lewis and Oneida county line. It flows in a southerly direction to the city of Rome, from which it takes an easterly course across the State, emptying into the Hudson a little above Troy. The principal tributaries are Schoharie, East Canada, West Canada, and Oriskany creeks.

The following are the elevations above tide water of a number of points along Mohawk River:

Elevations of points along Mohawk River.

	Feet.
At mouth	12
Lower Mohawk Aqueduct	162
Schenectady	214
Mouth of Schoharie Creek	270
At Rome, above feeder dam	431

There are two principal falls of Mohawk River, the Great Falls at Cohoes and the Little Falls at the city of the same name, where are found the only important water powers thus far developed on this stream. At Cohoes are the Great Falls, about 120 feet in height, on which the Cohoes Company has developed about 105 feet. At Little Falls there is a total fall of about 45 feet occurring in a little over half a mile. Of this, from 38 to 40 feet are utilized by three dams. Aside from a small amount of power developed below Cohoes, just above the "sprouts" of the Mohawk, there are no water-power developments on the stream other than those of Cohoes and Little Falls, except a few unimportant mills on the extreme head waters. The waterworks of the city of Rome, at Ridge Mills, 2 miles north of Rome, where a water-power pumping system is in use, may, however, be mentioned.

The following are the principal subdivisions of the drainage areas of Mohawk River:

Subdivisions of drainage area of Mohawk River.

	Sq. miles.
At mouth	3,400
Below mouth of Schoharie Creek	3,100
At Little Falls	1,275
At Utica	524
At Rome	184

SCHOHARIE CREEK.

Schoharie Creek rises in the southern part of Greene County, whence it flows 18 miles northwesterly and then northerly about 50 miles to the Mohawk. The principal subdivisions of the drainage area are as follows:

Subdivisions of drainage area of Schoharie Creek.

	Sq. miles.
At mouth	947
Central Bridge	684
Gilboa	308

The drainage area of Schoharie Creek comprises the greater part of Schoharie County and portions of Greene, Albany, Delaware, Otsego, Montgomery, and Schenectady counties. Its head waters drain the western and northern slopes of the Catskill Mountains. At Central Bridge, about 19 miles from the mouth of the creek, the water surface is 560 feet above tide water; at the mouth the elevation is 274 feet. In spite of this large fall Schoharie Creek is not considered especially valuable for water-power development. It is subject to great extremes of flood and low-water flow. This is probably explainable by the nearly complete cutting off of the forests from the drainage area many years ago. The water powers thus far developed in the Schoharie Creek Basin are nearly all small and unimportant.

EAST CANADA CREEK.

The second important tributary of the Mohawk is East Canada Creek, which rises in the southwestern part of Hamilton County and flows southerly, joining the Mohawk at East Creek, about 7 miles from Little Falls. According to a map furnished by Stephen E. Babcock, of Little Falls, the total drainage area of East Canada Creek is 285.7 square miles, of which 58.2 square miles are in Hamilton County, 98.4 square miles in Herkimer County, 128 square miles in Fulton County, and 1.1 square miles in Montgomery County. Following are the elevations of principal points on East Canada Creek:

Elevations of principal points on East Canada Creek.

	Feet.
Bottom of Beardslee Falls near mouth	0
Top of Beardslee Falls	105
Bottom of High Falls	327
Top of High Falls	379
Crest of dam at Dolgeville	445
Mouth of Spruce Creek	477
Mouth of Fish Creek	559
Emmonsburg	646
Stratford	720
Oregon	1,140

The distance from the mouth of the stream to Oregon is about 25 miles.

The principal tributary of East Canada Creek is Fish Creek, which is the outlet of the East Canada lakes. The distance from its point of junction with East Canada Creek to the mouth of the Canada lakes outlet is about 9 miles, and the total rise in this distance 635 feet. The outlet of the lakes, which is nearly level, is about 3.5 miles long. There are no falls of any magnitude on this creek. For the first 5 miles from its mouth Fish Creek rises 245 feet, and from that point to the mouth of the outlet of the East Canada lakes, a distance of 4 miles, the rise is 390 feet.

The second tributary of East Canada Creek is Spruce Creek, which has a total length from its mouth to its head in the Eaton Millpond of about 8.7 miles, the total rise in this distance being about 550 feet. Just below the Eaton Millpond there is a fall of 180 feet in 2,000 feet. At Salisbury Center, Spruce Creek falls 85 feet in about 900 feet. Aside from the development at Dolgeville, and small developments at Beardslee Falls and at one or two other points, very little use has thus far been made of the water power of East Canada Creek. It is probable, however, that within a few years the water power of this stream will be nearly all utilized.

According to a manuscript report on the water power of East Canada Creek, by S. E. Babcock, the fall in this stream for the first 1,500 feet from its junction with Mohawk River is very slight. At this point the first rapids are encountered, where it has been proposed to develop a water power, with a head of about 60 to 70 feet. About 1,000 to 1,200 feet farther upstream there is an additional fall of from 30 to 40 feet. This takes us to the top of the so-called Beardslee Falls, referred to above.

It has also been proposed to construct an extensive system of power development by a series of dams on East Canada Creek, some of the details of which may be gathered from the following table:

Plan of power development on East Canada Creek.

Location.	Head (in feet).	Horse-power.	Estimated cost.	Cost per horse-power.
Twin Bridges	43	1,172	$108,427	$92.51
Green street	26	1,023	73,667	72.01
Factory	29	1,141	30,910	27.10
Intermediate	22	865	46,090	53.28
High Falls	72	2,700	56,320	20.86
No. 1 (below High Falls)	74	2,956	125,092	42.40
No. 2 (below High Falls)	34	1,360	56,408	41.40
No. 1 (Ingham's mill)	44	1,778	135,410	76.16
No. 2 (Ingham's mill)	44	1,778	129,800	73.00
Beardslee Falls	105	5,112	128,326	25.10
Totals and mean	423	19,885	890,450	44.80

This plan of power development further includes the construction of a storage of 1,250,000,000 cubic feet, which is estimated to cost $148,000, making a total for the whole development of $1,038,450. With these figures the final cost per net horsepower becomes $52.22. The estimates leading to this result include cost of land to be flooded, masonry of dams and head works, turbine water wheels, flumes and head feeders, tail raceways, waste gates, power stations, racks, engineering and superintendence, etc. So far as the actual power developments are concerned, the work can probably be constructed for the estimates, but the cost of the storage is, in the author's opinion, somewhat too low. The total number of dams which it is proposed to build is stated at 40, thus giving an average of only $3,700 per dam. This sum would only build timber dams of the most temporary character. The proper operation and repairs of this number of dams, scattered over an area of 200 square miles, would entail in the end an annual expense of $30,000, which is the annual interest at 5 per cent on $600,000. To obtain the real capitalized cost we need then to add $600,000, which gives an amended total of $1,638,450, whence the cost per net horsepower for the entire system would become $82.40.

At present an electric-power station is in process of installation by the Dolgeville Electric Light and Power Company at the high falls just below Dolgeville, shown on Pl. VI, by which it is expected to develop 1,200 net horsepower. The wheels to be set are two twin horizontal 36-inch Victor special wheels, to work under a 72-foot head, and which are claimed by the manufacturers to yield, at full capacity, 600 net horsepower each. A portion of the power generated at this station is to be used at Dolgeville for manufacturing, and the balance, it is stated, will be transmitted to Little Falls, 8 miles distant.

Dolgeville is the seat of the piano-felt and other industries established by Alfred Dolge & Son. The power for the establishments now in operation is derived from two 35-inch Victor turbines, working under a 25-foot head, and rated by the manufacturers to furnish, when running at full capacity, 229 net horsepower each, or a total of 458 horsepower. According to the manufacturer's catalogue, these wheels will consume 197 cubic feet per second when working at full capacity, and the statement is made that they are ordinarily so worked. The drainage area of East Canada Creek above Dolgeville is about 250 square miles; hence the present development is based upon a minimum flow of 0.79 cubic foot per second per square mile. As there is very little pondage at Dolgeville, it may be assumed that the power is sometimes short in a dry season, although the effect of the pondage of the large number of lakes and ponds on the head waters of East Canada Creek will undoubtedly be to increase considerably the minimum flow.

WEST CANADA CREEK.

West Canada Creek, the third important tributary of the Mohawk, rises near the center of Hamilton County and flows southwesterly about 40 miles, by general course, to the eastern edge of the town of Trenton, in Oneida County, where it turns and first runs southeasterly and then southerly for a total distance of 20 miles, finally empty-

A. DAM AT HIGH FALLS OF EAST CANADA CREEK.

B HIGH FALLS AT TRENTON, ON WEST CANADA CREEK.

ing into the Mohawk at the village of Herkimer. The total drainage area above Herkimer is given as 548 square miles. This creek has its source in the Canada lakes, which are about 40 miles northeast from the village of Prospect. These lakes are known separately as the West, Middle, and East Canada. The principal lake of this series has an elevation of 2,348 feet above tide water. The drainage area at the village of Prospect, where there is a natural fall of about 22 feet, is 375 square miles. At Trenton Falls, 3 miles below, the stream descends about 200 feet in half a mile. Ascending the stream, the principal falls, in order, are: Sherman Falls, 24 feet; High Falls (shown in Pl. VI), 105 feet; Mill Dam Falls, 14 feet; Suydam Falls, 12 feet.

According to a report made by Wallace C. Johnson, under date of March 17, 1896, to the Trenton Falls Power Company, it appears that of the 375 square miles of drainage area above Prospect about 175 square miles lie at an elevation of between 2,000 and 3,000 feet above tide water, the average elevation of this portion being about 2,500 feet. Of the remaining 200 square miles above Prospect the average elevation is placed at not less than 1,600 feet. The Trenton Falls Power Company is reported as intending to develop an extensive storage on the head waters of this stream, thus enabling it to produce several thousand electrical horsepower at Trenton Falls for transmission to Utica, Rome, and other towns in the vicinity. General plans have been prepared by Mr. Johnson, but the details of the project are not at hand. Judging from the data at hand, the author is disposed to place the minimum flow of West Canada Creek at from 0.30 to 0.35 of a cubic foot per square mile per second.

Water powers are now in use on West Canada Creek at Herkimer, Middleville, Newport, and Prospect, as well as at a few points higher up.

Parties interested in the development of an extensive power project at Trenton Falls have claimed that a very large storage reservoir could be constructed in the main valley of West Canada Creek a short distance above Prospect, and at very low cost per unit volume stored. The data are not at hand for accurately determining the cost of a reservoir at this place. However, casual inspection of the Remsen sheet of the topographic map of the State, made in 1897, shows that such a reservoir would probably be expensive in proportion to the storage gained. A trial estimate shows that with a dam from 80 to 100 feet in height a storage of about 2,000,000,000 cubic feet may be obtained. The cost of the dam necessary to store this quantity of water can hardly be placed as an experimental figure at less than $1,000,000, whence the cost per 1,000,000 cubic feet stored would become $500. This approximate estimate has no other significance than to indicate the importance of studying large reservoir projects in detail before deciding as to their feasibility.

OTHER TRIBUTARIES OF MOHAWK RIVER.

As less important tributaries of the Mohawk, Sauquoit and Oriskany creeks may be mentioned. Sauquoit Creek rises in the southeastern part of Oneida County and runs northerly, emptying into the Mohawk about 2 miles west of Utica. Its drainage area is given as 62 square miles. Oriskany Creek rises in the eastern-southerly portion of Madison County and flows northerly into the Mohawk 6 miles west of Utica. Its drainage area is given as 135 square miles. There is considerable water power developed on both Sauquoit and Oriskany creeks.

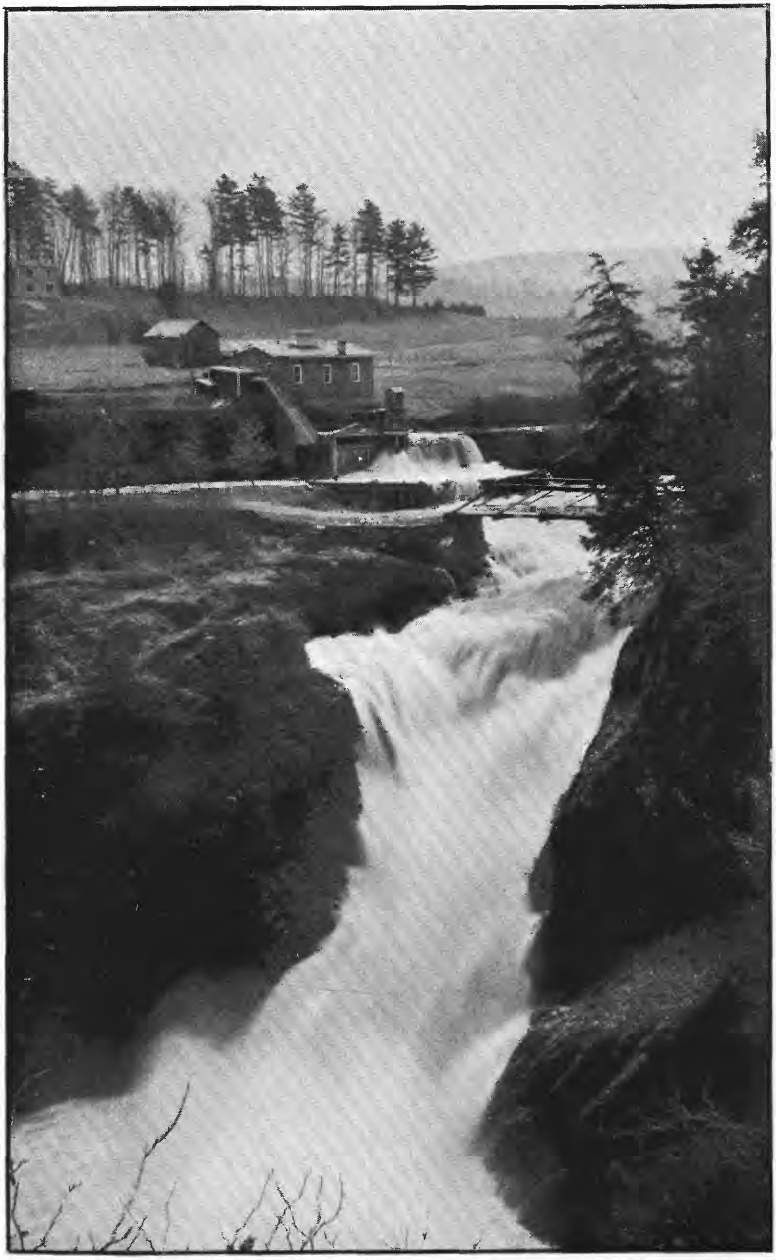
HOOSIC RIVER.

The most important tributary of the Hudson from the east is Hoosic River, which rises in the mountains of Berkshire County, Massachusetts. It first runs northwesterly, passing from Massachusetts into the extreme southwestern corner of Vermont and thence into Rensselaer County, in New York. At the northern boundary of Rensselaer County it turns and pursues a westerly course to the Hudson opposite the village of Stillwater. Its drainage area at the mouth is taken at 730 square miles. Its principal tributaries are Little Hoosic River, Walloomsac River, and Tomhannock Creek. The country drained is mainly mountainous, the summits attaining an elevation of from 1,000 to 2,000 feet above tide. The principal water powers developed on Hoosic River, in New York, are at Schaghticoke and Hoosic Falls, with a few at intermediate points. At Schaghticoke there is from 97 to 98 feet fall, broken into falls of 8, 7.5, 24.5, 34.5, and 23 feet. The available statements as to the power at Hoosic Falls are so conflicting that it is thought best to omit them.

Hoosic River is of considerable interest to persons concerned in water-power development on the Hudson below its mouth, because there are two reservoirs on its headwaters which have been constructed by manufacturers in Massachusetts in order to maintain a more equable summer flow. The first of these is the Clarksburg reservoir, on the North Branch of Hoosic River, and at a distance of about 2½ miles above North Adams. The second reservoir is on the South Branch, and is known as the Cheshire reservoir, being situated in the town of that name. The Clarksburg reservoir is stated to flow 156 acres and to have a depth of 22 feet. The Cheshire reservoir flows about 650 acres and can be drawn down about 8 feet. Both these reservoirs are controlled by an association of mill owners on the Hoosic and its branches in the State of Massachusetts.

BATTENKILL RIVER.

Battenkill River, another important tributary of the Hudson, rises in the southwestern part of Vermont, in Bennington County. It first



BIG FALLS OF BATTENKILL RIVER.

flows southwesterly and then westerly irregularly across Washington County, New York, to the Hudson at a point about a mile above Schuylerville. The drainage area is taken at 460 square miles. The elevation above tide at the mouth of the river is 82 feet, and at the Delaware and Hudson Railway crossing, a little south of Shushan, the elevation is 437 feet. This gives a descent of 355 feet in 22 miles, about one-half of which is concentrated within the last 4 or 5 miles of the river's course.

The following is a brief statement of the water powers on the lower section of the Battenkill, in ascending order from the mouth:

Water powers on the lower section of the Battenkill.

At Clark Mills, the American Woodboard Company, 24 feet head.

At Big Falls (shown on Pl. VII), the dam at the head of the falls gives 106 feet head, divided into Bennington Falls Pulp Company, 32 feet; Ondawa Pulp and Paper Company, 30 feet; not utilized, 44 feet.

At Middle Falls, the dam at the head of the falls gives 55 feet head. Here there are a leather-board mill, shank mill, sawmill, plaster mill, gristmill, and electric-light station.

At Greenwich, Dunbar, McMaster & Co., 8 feet head; Palmer's lower dam, 9 feet head, furnishes power for gristmill, paint works, shirt manufacturing, scale manufacturing, and plow works; Palmer's upper dam, 6 feet head, furnishes power for a cotton mill and a paper mill.

At Center Falls, Angel & Langdon Paper Mill, 25 feet head.

At Battenville, Phœnix Paper Company, 10 feet head.

At Rexleigh there is a cotton mill with 6 feet head; at Shushan a gristmill, shirt factory, electric-light station, and foundry, all receiving power from about 14 feet head.

In addition to the foregoing there are stated to be undeveloped water powers on the Battenkill as follows: Between Clark Mills and Big Falls, 27 feet; between Greenwich and Center Falls, 8 feet; between Center Falls and Battenkill, 10 feet.

It is stated that the utilized powers on the Battenkill are developed up to about 30 horsepower per foot fall. They are, however, sometimes short of water in dry weather. With a drainage area of 460 square miles, a minimum flow of 0.3 of a cubic foot per square mile per second would give only about 15.3 gross horsepower per foot of fall. It is inferred, therefore, that the Battenkill is an exceedingly good water yielder, although definite data derived from stream measurements are entirely lacking.

FISH CREEK.

Fish Creek, a stream tributary to the Hudson at Schuylerville, is the outlet of Saratoga Lake. Its chief tributary is the Kayaderosseras Creek, which drains the central part of Saratoga County. The drainage area of Fish Creek at its junction with the Hudson is estimated at 253 square miles. Both Fish Creek and Kayaderosseras Creek are extensively utilized for water power.

SACUNDAGA RIVER.

Sacundaga River, a view of which is given on Pl. VIII, is the next important tributary of the Hudson in the ascending order. It has three principal branches, which unite to form the main river in the southeastern part of Hamilton County. The West Branch is the outlet of Piseco Lake; the Middle Branch is the outlet of Sacundaga and Pleasant lakes, while the East Branch issues from a series of small ponds and lakes in the southwestern part of Warren County, not far from Bakers Mills. The East and Middle branches unite a few miles to the north of Wellstown, and West Branch joins a few miles south of Wellstown. The river then flows southeasterly to about 5 miles below Northville, where it turns rather more than a right angle and flows irregularly northeast to the main Hudson at Hadley. The principal tributary of the Sacundaga, aside from its several branches, is East Stony Creek.

The following are the several subdivisions of the drainage area of Sacundaga River:

Subdivisions of the drainage area of Sacundaga River.

	Sq. miles.
Total drainage area at mouth	1,040
South Branch	240
Middle Branch	115
East Branch	124
Stony Creek	212
Main river below Stony Creek	223

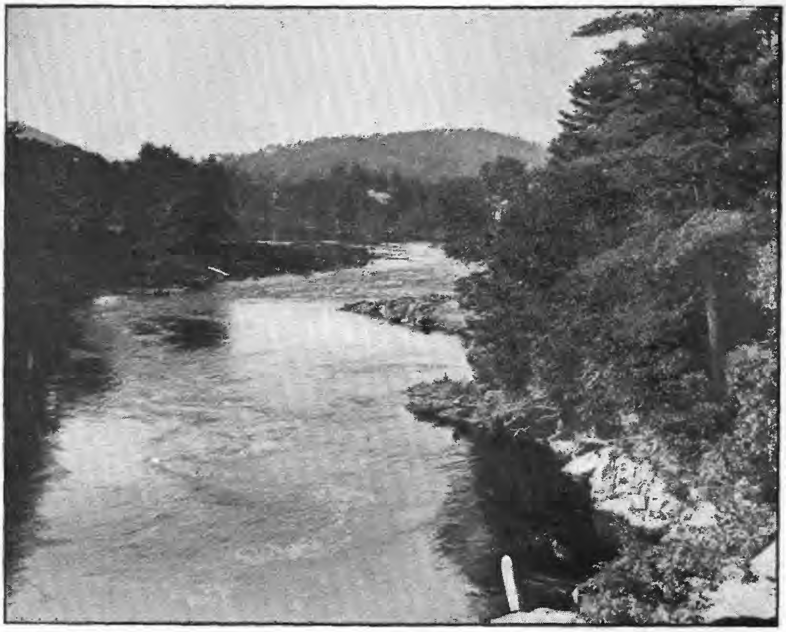
The following are elevations above tide at a number of principal points:

Elevations above tide of points along Sacundaga River.

	Feet.
At mouth of river	556
Above dam at Conklinville	697
Northville	732
Hope Center	763
Wellstown	902
East Branch at old tannery	958
East Branch at foot of High Falls	1,205
East Branch at head of High Falls	1,337
East Branch at Brighams Pond	1,706
Piseco Lake	1,648
Lake Pleasant	1,706
Sacundaga Lake	1,706

From Conklinville to the mouth of the river, a distance of a little over 5 miles, the river falls 141 feet. At present this section of the river is entirely unutilized except by two powers, one at Conklinville and the other about 2 miles from Hadley.

Thus far there are no detailed measurements of the Sacundaga, but since the drainage area is still largely in primeval forest it is without doubt an excellent water yielder.



A. HUDSON RIVER ABOVE LUZERNE

B. SACUNDAGA RIVER NEAR LUZERNE.

SCHROON RIVER.

Schroon River rises in Essex County, along the southern slopes of the highest mountains of the Adirondack group. As shown by the map (Pl. IX), it flows in a general southerly direction for about 45 miles, through Essex and Warren counties, and joins the Hudson just above Thurman. On the boundary between Essex and Warren counties the river flows through Schroon Lake, a body of water nearly 9 miles long and from a little less than 0.5 to 1.5 miles in width.

The following are some of the important subdivisions of the drainage area of Schroon River:

Subdivisions of the drainage area of Schroon River.

	Square miles
At mouth	550
Warrensburg	535
Tumblehead Falls	502
Foot of Schroon Lake	479

Some of the elevations on Schroon River are as follows:

Elevations on Schroon River.

	Feet.
At mouth	610
Schroon Lake	807
Paradox Lake	820
Schroon Falls	840
Elk Lake	1,986

There is no developed water power on Schroon River except that at Warrensburg.

TRIBUTARIES SOUTH OF MOHAWK RIVER.

Kinderhook Creek and Croton River are the chief tributaries of the Hudson south of the Mohawk requiring special mention at this time. Brief consideration of the run-off of Croton River will be given further on. The Columbia Electric Light Power Company, of Valatie, was incorporated by the laws of 1897 to construct reservoirs and create extensive power developments on Kinderhook Creek and its tributaries in Columbia and Rensselaer counties. The surveys for this work are now in process under the direction of L. L. Tribus, chief engineer of the company.

Wallkill River, a branch of Rondout Creek, may be mentioned. This stream rises in New Jersey and flows north, joining Rondout Creek near Rondout. It is proposed to take an additional water supply for Brooklyn Borough of Greater New York from the head waters of this stream in New Jersey. The drainage area south of the New York State line is 210 square miles.

ALLEGHENY RIVER SYSTEM.

The Allegheny River enters the State of New York from Pennsylvania in the southeastern corner of Cattaraugus County and, flowing in nearly a semicircle with its outward curve to the north, passes out of the State in the southwestern part of Cattaraugus County, again entering Pennsylvania. Its principal tributary from the north is Conewango Creek, which receives the outlet of Chautauqua Lake and of Cassadaga Creek as tributaries. Little Valley, Great Valley, and Olean creeks are also tributaries in New York. None of these streams is of especial importance for water power.

Chautauqua Lake, 20 miles in length and from 1 to nearly 2 miles in width, is distant from Lake Erie at its northern extremity only about 9.5 miles. Its elevation above tide water is 1,297 feet, while that of Lake Erie is 573 feet. Hence Chautauqua Lake is 724 feet above Lake Erie. The Conewango Creek, at the south line of the State, has an elevation of 1,243 feet. The fall from Chautauqua Lake to the southern boundary of the State along the drainage line is therefore only 54 feet. The drainage area of the Chautauqua outlet at the foot of Chautauqua Lake is 178 square miles, and of the Chautauqua outlet below Cassadaga Creek 343 square miles.

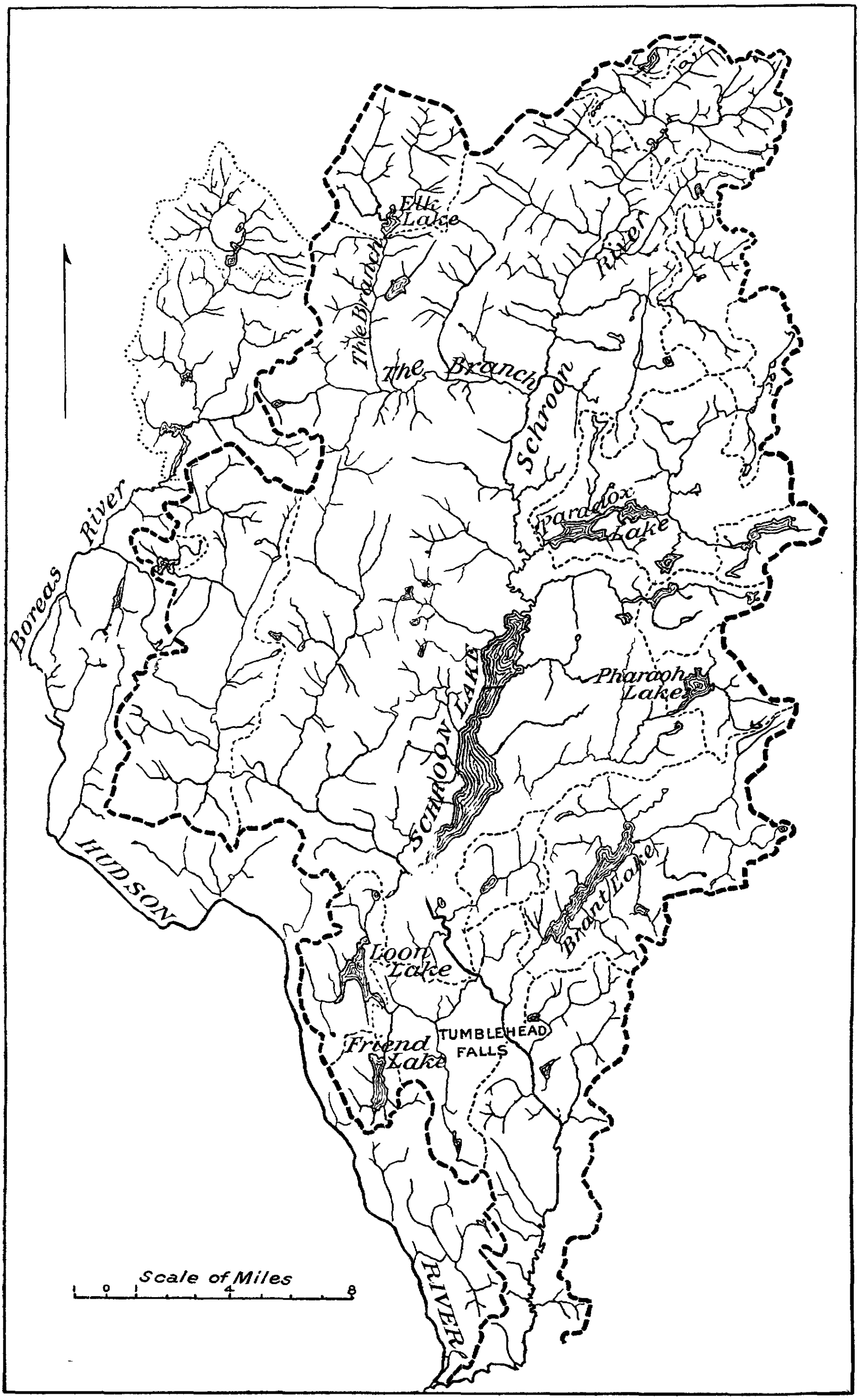
SUSQUEHANNA RIVER SYSTEM.

The head waters of the North Branch of Susquehanna River lie chiefly in the State of New York, the drainage area in this State being taken at 6,267 square miles. The main stream is considered as rising in Otsego Lake, from which it flows first southwesterly, then westerly with a short portion of its course south of the Pennsylvania line. It finally leaves New York State in Tioga County. The Susquehanna, while one of the large rivers of New York, is not at all important as regards water power. The main river and most of its tributaries in New York flow through a rolling country with fairly uniform declivity. While utilized for small powers in many places, thus far there are no extensive developments on either the main stream or its branches, except at Binghamton, where considerable water power is utilized. The slope of the stream in New York State is shown by following elevations, in feet, above tide water:

Elevations along Susquehanna River in New York State.

	Feet.
At Towanda, a few miles south of the State line	700
At Athens, on Chemung River, near the State line	744
At Otsego Lake	1,193

So far as known, no discharge measurements of this stream have ever been made.



DRAINAGE AREA OF SCHROON RIVER.

As one of the important tributaries of the North Branch of Susquehanna River in New York may be mentioned Chenango River, which rises in Madison County, and flows south through Madison, Chenango, and Broome counties, emptying into the Susquehanna at Binghamton. Chemung River, the chief tributary of the North Branch, is formed in Steuben County, New York, near Painted Post, by the junction of the Tioga and Cohocton Rivers, whence it pursues a southeasterly course, joining the Susquehanna near Athens, in Bradford County, Pennsylvania, just south of the State line. Tioga River rises in Tioga County, Pennsylvania, and flows north to join the Cohocton at Painted Post. Canisteo, the principal New York State tributary of the Tioga, joins the main stream 5 miles south of Painted Post. Cohocton River, which rises in Livingston County, and flows southeast to join the Tioga at Painted Post, is utilized for small powers at a number of places. The area drained by the Cohocton and Canisteo is almost entirely denuded of forest and the streams are in consequence much less valuable for power than formerly. For a considerable length of time, in the fall of 1895, the natural yield of these streams was probably considerably less than one-tenth of a cubic foot per second per square mile.

Other tributaries of the Susquehanna in New York State are Owego and Cuyuta creeks, neither of which, although formerly extensively utilized for small powers, is now of great value, largely because of the exceedingly slight summer flows.

The following are the drainage areas of the Susquehanna and its tributaries in the State of New York:

Drainage areas of Susquehanna River and its tributaries in New York.

	Square miles.
Main river below mouth of Chemung River (south of Pennsylvania line)	7,463
Total area north of Pennsylvania line	6,267
Above mouth of Chemung River	4,945
At Binghamton	2,279
At Susquehanna	2,024
At Nineveh	1,789
Below mouth of Unadilla River	1,638
Below mouth of Oak Creek	212
Above mouth of Oak Creek	97
Oak Creek	115
Cherry Valley Creek	121
Chenevas Creek	127
Charlotte River	178
Otego Creek	106
Oaliout Creek	115
Unadilla River	561
Butternut Creek	123
Chenango River at mouth	1,540
Chenango River above Tioughnioga	685
Chenango River above Canasawacta Creek	297
Tioughnioga River at mouth	735

Drainage areas of Susquehanna River and its tributaries in New York—Cont'd.

	Square miles.
Tioughnioga River above mouth of Otselic River	428
Otselic River	259
West Branch of Tioughnioga River	103
East Branch of Tioughnioga River	164
Owego Creek	391
Cayuta Creek	148
Chemung River at junction of Canisteo and Cohocton rivers	1,941
Chemung River at Elmira	2,055
Chemung River at mouth	2,518
Cohocton River at mouth	425
Tioga River at mouth	1,530
Tioga above mouth of Canisteo	750
Canisteo at mouth	780
Tuscarora Creek at mouth	120

DELAWARE RIVER SYSTEM.

The extreme head waters of Delaware River, in New York, are a series of small ponds in Schoharie County, a little north of the village of Stamford. From this point the stream flows southwesterly to Deposit, on the line between Broome and Delaware counties, where it turns south, on which general course it continues until near the Pennsylvania line, whence its course is southwesterly to Port Jervis. This portion of the river is the boundary line between New York and Pennsylvania. At Port Jervis the river passes from New York State, making a sharp turn to the southwest. The declivity of Delaware River is shown by the following elevations above tide water:

Elevations along Delaware River in New York State, showing declivity of the stream.

	Feet.
At Lackawaxen	600
At Deposit	984
At head waters	1,886

The principal tributary in New York State is Pepacton River, which rises in the eastern part of Delaware and Greene counties and flows southwest in a course generally parallel to the main stream. Neversink Creek, the next important tributary in the State, joins the main stream at the State line a mile south of Port Jervis. Neither of these streams has thus far developed any large amount of water power, although there are a number of places where good powers could be developed. The cutting off of the forests of the Delaware drainage area has undoubtedly greatly injured the tributary streams for mill purposes.

The following are the more important drainage areas on the Delaware and its tributaries in New York State:

Drainage areas on Delaware River and tributaries in New York State.

	Square miles.
Total area in New York State	2,580
Main stream below mouth of Neversink River	3,600
Main stream below Port Jervis	3,252
Main stream below junction of East and West branches	1,604
West Branch at mouth	685
West Branch at Deposit, below Oquaga Creek	519
Pepacton River at mouth	919
Above mouth of Beaverkill	520
Beaverkill Creek	322
Oquaga Creek	82
Little Delaware Creek	53
Neversink River at mouth	346

By way of concluding the general discussion of the Allegheny, Susquehanna, and Delaware river systems in the State of New York, it may be remarked that these have all been extensively used, either for floating logs or for propelling sawmills, or for both. The clearing up of the drainage areas has, however, long since reduced the lumbering business to nothing. These streams are, therefore, much less extensively utilized than formerly. At present, aside from one or two points, their use is chiefly for propelling small sawmills and gristmills and for other moderate-sized industries. With one or two exceptions, there are no large power developments throughout the whole region.

STREAMS OF LONG ISLAND.

Long Island is chiefly a sandy plain, about 120 miles in length, with a total area of 1,682 square miles. A considerable portion is below an elevation of 100 feet above tide water, although in places it rises to elevations of 300 feet and more. The streams are all small and only a few miles in length, running down from the high land of the middle section to the Atlantic Ocean on the south and to Long Island Sound on the north. As regards water power, the water resources of Long Island have little significance, although there are many places where small powers are utilized for gristmills and other similar uses. The chief value of the inland water of Long Island is for the water supply of the city of Brooklyn.

East River, which connects Long Island Sound with New York Bay, may also be referred to for convenience as a Long Island water resource. The great value of the stream to the commerce of New York is so obvious as to hardly require mention.

The foregoing description of the river systems of New York has been made as brief as possible, because very complete descriptions have been given in the several monographs relating to New York State which appear in the report on the Water Power of the United States, Tenth Census, 1880. In these reports may be found full details of the several river valleys, with statements as to agricultural production, population, geology, climatology, and many other subjects not touched on here.

AVAILABLE WATER SUPPLY.

RUN-OFF OF NIAGARA RIVER.

The great developments of the Niagara Falls Power Company, authorized by the laws of 1886, have been in part completed, while at the same time the original Niagara Falls power development, now owned by the Niagara Falls Power and Manufacturing Company, has increased greatly in capacity. The laws of 1886, and amendments thereto, have also authorized the taking from Niagara River of large quantities of water for the purpose of creating a water power near the city of Lockport. A ship canal is projected connecting Lakes Erie and Ontario, and the Canadian Government has made a concession for extensive power developments on the Canadian side of the river. Hence it is evident that the future demands for water to be taken from Niagara River and delivered either into the lower river below the Falls or into Lake Ontario independent of the river are very large, and the interest which the people of the State of New York have in the run-off of Niagara River becomes exceedingly important.

The most recent determination of the area of the basin drained by the Great Lakes and of the water surfaces of the lakes themselves is that given in the report of the United States Deep Waterways Commission, from which the following general summary is taken:

Water surface and watershed areas of the basin drained by the Great Lakes.

Lake.	Area of water surface.	Area of watershed.	Total area of basin.
	Square miles.	*Square miles.*	*Square miles.*
Superior	31,800	48,600	80,400
Michigan	22,400	45,700	68,100
Huron	23,200	52,100	75,300
St. Clair	495	6,320	6,815
Erie	10,000	24,480	34,480
Total	87,895	177,200	265,095

That portion of the drainage area of Lake Erie lying within the State of New York is given as 2,210 square miles. The area of islands in Niagara River is given as 29 square miles. That portion of the watershed of Niagara River lying within the State of New York has an area of 789 square miles. The area of the river itself, from its head at Lake Erie to the Falls, is 21 square miles.[1]

The accompanying table gives the precipitation within and in the vicinity of the drainage area of the Great Lakes for the years from 1892 to 1895, inclusive. In this table a few only of the many precipitation records which are now available have been used. The records there appearing are, it is believed, sufficient to show the mean precipitation of the basin of the Great Lakes for the years indicated. In this and subsequent tables the water year[2] is considered as beginning with the month of December of the preceding year. Thus the water year of 1879 extends from December, 1878, to November, 1879, inclusive. The months from December to May constitute what may be termed the storage period. During this time vegetation is inert, the temperature low, with consequent light evaporation. Usually from 70 to 80 per cent of the precipitation of this period runs off in the streams.

June to August, inclusive, is the growing period. Then the temperature is at its highest for the year and vegetation is active. For this period only about 20 per cent of the rainfall appears in the streams, and some of that is usually the stored ground water of the preceding period.

September to November, inclusive, is the replenishing period. The temperature is again relatively low, vegetation inert, and the rainfall goes to replenish the stock of ground water, depleted during the growing period, or, after the ground again becomes full, appears as direct run-off in the streams. In the table the monthly precipitation has been omitted, as it can readily be found in the annual reports of the United States Weather Bureau, and the data have been condensed to show the total quantities for the storage, growing, and replenishing periods, together with the total annual amounts.

[1] Report of the United States Deep Waterways Commission, by the commissioners, James B. Angell, John E. Russell, Lyman E. Cooley. Accompanied by the report on technical work and the several topical reports and drawings pertaining thereto. Printed as House Document No. 192, Fifty-fifth Congress, second session, Washington, 1897, pp. 146, 147.

For the drainage area of the Great Lakes in detail reference may be made to an excellent map of the basin of the Great Lakes and of St. Lawrence and Hudson rivers in relation to the surrounding drainage systems accompanying the report of the Deep Waterways Commission.

[2] Report of the State Engineer and Surveyor of New York, 1895, p. 99.

Precipitation, in inches, within and in the vicinity of the drainage area of the Great Lakes, 1892 to 1895, inclusive.

Locality and year.	December to May.	June to August.	September to November.	Annual.
Pokegama Falls, Minn.:				
1892	11.76	6.99	2.86	21.61
1893	9.64	13.06	2.84	25.54
1894	14.72	8.04	9.01	31.77
1895	9.14	12.49	5.70	27.33
Mean				*26.56*
Duluth, Minn.:				
1892	17.96	11.78	2.39	32.13
1893	11.08	6.86	3.64	21.58
1894	19.44	3.80	8.51	31.75
1895	6.44	9.32	7.70	23.46
Mean				*27.23*
Minneapolis, Minn.:				
1892	13.78	23.32	2.33	39.43
1893	12.80	9.79	5.68	28.27
1894	15.66	1.73	6.46	23.85
1895	7.72	9.96	5.01	22.69
Mean				*28.56*
Green Bay, Wis.:				
1892	14.95	12.47	7.95	35.37
1893	14.85	8.12	7.15	30.12
1894	19.65	8.52	10.46	38.63
1895	10.06	7.52	3.14	20.72
Mean				*31.21*
Madison, Wis.:				
1892	18.89	13.34	4.89	37.12
1893	13.37	12.75	5.82	31.94
1894	10.96	6.23	7.61	24.80
1895	5.54	3.88	2.57	11.99
Mean				*26.46*
Milwaukee, Wis.:				
1892	18.17	11.00	5.71	34.88
1893	15.69	10.14	6.06	31.89
1894	15.94	4.81	8.79	29.54
1895	10.34	7.45	5.33	23.12
Mean				*29.86*

Precipitation, in inches, within and in the vicinity of the drainage area of the Great Lakes, 1892 to 1895, inclusive—Continued.

Locality and year.	December to May.	June to August.	September to November.	Annual.
Chicago, Ill.:				
1892	16.03	14.66	5.56	36.25
1893	13.93	6.85	6.18	26.96
1894	14.48	3.16	10.30	27.94
1895	9.58	10.70	7.00	27.28
Mean				*26.61*
Logansport, Ind.:				
1892	27.26	10.91	6.97	45.14
1893	24.45	4.52	8.92	37.89
1894	21.11	4.58	7.82	33.51
1895	9.08	6.40	8.56	24.04
Mean				*35.15*
Ann Arbor, Mich.:				
1892	14.52	8.18	7.70	30.38
1893	20.54	7.18	10.33	38.05
1894	16.63	2.76	7.21	26.60
1895	8.92	5.40	4.70	19.02
Mean				*28.51*
Grand Haven, Mich.:				
1892	16.57	8.93	4.97	30.47
1893	19.02	6.79	8.68	34.49
1894	19.84	4.07	11.08	34.99
1895	10.89	4.88	6.17	21.94
Mean				*30.47*
Marquette, Mich.:				
1892	16.03	3.53	8.89	28.45
1893	14.81	9.16	7.41	31.38
1894	24.65	5.25	9.31	39.21
1895	16.35	7.04	8.89	32.28
Mean				*32.83*
St. Ignace, Mich.:				
1892	12.39	10.30	6.43	29.12
1893	15.61	7.94	8.31	31.86
1894	17.80	6.83	9.80	34.43
1895	11.66	4.59	8.98	25.23
Mean				*30.16*

Precipitation, in inches, within and in the vicinity of the drainage area of the Great Lakes, 1892 to 1895, inclusive—Continued.

Locality and year.	December to May.	June to August.	September to November.	Annual.
Traverse City, Mich.:				
1892	17.65	10.87	8.61	37.13
1893	17.88	7.07	11.41	36.36
1894	20.62	5.61	9.72	35.95
1895	16.69	4.53	7.85	29.07
Mean				*34.63*
Cleveland, Ohio:				
1892	19.84	11.91	5.90	37.65
1893	19.09	5.46	7.45	32.00
1894	15.28	5.55	7.77	28.60
1895	9.29	7.59	7.91	24.79
Mean				*30.76*
Toledo, Ohio:				
1892	17.77	12.76	6.47	37.00
1893	10.17	4.81	6.92	21.90
1894	14.93	2.78	5.23	22.94
1895	9.23	6.24	7.11	22.58
Mean				*26.10*
Buffalo, N. Y.:				
1892	22.62	16.93	8.32	47.87
1893	20.65	8.00	7.87	36.52
1894	22.47	5.82	12.50	40.79
1895	14.17	6.23	8.85	29.25
Mean				*38.61*
Rochester, N. Y.:				
1892	17.75	13.41	5.94	37.10
1893	18.05	9.36	6.02	33.43
1894	21.26	7.05	7.14	35.45
1895	16.16	6.84	7.15	30.15
Mean				*34.03*
Oswego, N. Y.:				
1892	15.22	15.33	6.82	37.37
1893	14.63	9.83	8.01	32.47
1894	19.55	6.46	11.13	37.14
1895	15.06	6.25	9.08	30.39
Mean				*34.34*

Precipitation, in inches, within and in the vicinity of the drainage area of the Great Lakes, 1892 to 1895, inclusive—Continued.

Locality and year.	December to May.	June to August.	September to November.	Annual.
Winnipeg, Manitoba:				
1892	6.65	8.70	3.96	19.31
1893	8.25	10.81	4.35	23.41
1894	8.55	3.80	5.84	18.19
1895	8.18	6.62	2.42	17.22
Mean				*19.53*
Port Arthur, Ontario:				
1892	8.84	7.35	5.31	21.50
1893	8.48	7.39	6.50	22.37
1894	8.20	5.57	8.30	22.07
1895	8.76	7.86	6.05	22.67
Mean				*22.15*
Toronto, Ontario:				
1892	12.21	12.29	6.65	31.15
1893	18.64	9.85	7.86	36.35
1894	19.90	3.07	8.44	31.41
1895	11.93	6.24	7.76	25.93
Mean				*31.21*

These precipitation data are of special interest because the year 1895 was the culmination of a period of exceedingly low water. They show that for a period of four years the precipitation of this basin was low, and in consequence the run-off of the tributary streams must have been exceedingly small. As illustrating this proposition, we may first refer to the run-off of the Upper Mississippi,[1] where there is a reservoir system controlling a drainage area of 3,265 square miles, first operated about 1885. The rainfall of the area tributary to these reservoirs, as indicated by records kept at Leech Lake, Lake Winibigoshish, and Pokegama Falls from 1885 until the present time is, as an average, from 24 to 26 inches per year. The highest recorded yearly precipitation is 31.87 inches, at Pokegama Falls in 1894. The rainfall of the area tributary to the Upper Mississippi reservoirs is found to be quite similar to that of the region tributary to Lake Superior. Hence the run-off of this reservoir system may be considered as representing the run-off of the drainage area of Lake Superior and the northern portion of Lakes Michigan and Huron.

[1] Annual Report of Chief of Engineers U. S. Army for 1896, Part III, p. 1843; also for 1897, Part III, p. 2169.

The following gives the discharge from these reservoirs for the years 1892 to 1895, inclusive, corresponding with the years of precipitation shown in the table on pages 50 to 53:

Mean rainfall, run-off, and proportion of run-off to rainfall of the area tributary to the Upper Mississippi reservoirs.

Water year.	Mean rainfall on water shed.	Run-off of watershed.	Proportion of run-off to rainfall.
	Inches.	*Inches.*	*Per cent.*
1892	21.33	4.43	20.8
1893	25.42	3.61	14.2
1894	26.63	3.62	13.6
1895	25.11	2.79	11.1
Total	98.49	14.45	
Mean	24.62	3.61	14.7

The table shows that during the years 1892 to 1895, inclusive, the mean run-off of the Upper Mississippi watershed was only 3.61 inches on the total watershed. These figures, however, are subject to correction because the state of the reservoirs at the beginning and ending of the four-year period is not given in the report of the United States engineers, from which these data are taken. This correction, however, can not be very large, because the reservoirs are so operated as to be emptied, generally speaking, each year. In considering the run-off of these Upper Mississippi reservoirs, due consideration should be given to the fact that the water area of the reservoirs is 585 square miles, or nearly 18 per cent of the whole. For Lakes Superior, Michigan, Huron, St. Clair, and Erie we have a total water surface of 87,895 square miles, with a total drainage area, including the surface of the lakes, of 265,095 square miles. The water surface of these several lakes is, therefore, about 33 per cent of the entire area of the basin, or nearly double the relative area of water surface and drainage area for the Upper Mississippi reservoirs. With other conditions the same, this fact would probably lead to a somewhat greater proportion of run-off from the Great Lakes.

By way of further illustrating the yield of streams in the vicinity of the Great Lakes drainage area, we may refer to the run-off of the Des Plaines River as given in the table on page 64. This stream has been measured by the Chicago drainage commission, with certain intermissions, as shown by the table, since January, 1886, the drainage area above the point of measurement being 633 square miles. The drainage area comprises a long and narrow, flat region extending from near Chicago to a few miles north of Milwaukee, the eastern line being for the entire distance nearly parallel to Lake Michigan and in places only 2 or 3 miles distant therefrom. The area drained by the Des Plaines River is large enough to give a fair idea of the average yield of streams tributary to Lake Michigan in northern Illinois and Indiana, western Michigan, and southern and central Wisconsin. In 1893, with a mean rainfall on the drainage area of 39.96 inches, the total run-off was 10.14 inches, of which 8.61 inches occurred during the storage period from December to May, inclusive. In 1894, with a total rainfall of 27.94 inches, the total run-off was 7.70 inches, of which 7.54 inches occurred in the storage period. For the year 1895 the total rainfall was 27.28 inches. The run-off data of this year are unfortunately incomplete, but taking into account the sequence of the rainfall it is clear that the total run-off for that year did not exceed about 2.0 to 2.5 inches. The effect of the three dry years 1893, 1894, and 1895 in the Des Plaines drainage area is shown by the record of 1896, where, with a total rainfall of 39.58 inches, the total run-off was only 6.69 inches, of which 5.39 inches occurred in the storage period. These figures indicate that the ground water of the Des Plaines area must have been so low at the end of 1895 as to absorb a large portion of the heavier rainfall of 1896 before any great amount could appear as run-off.[1]

Rainfall, run-off, evaporation, and mean temperature of Muskingum River, as measured by the United States engineers, from 1888 to 1895, inclusive.

[In inches on the watershed.]

Month.	1888.				1889.				1890.			
	Rainfall.	Run-off.	Evaporation.	Temperature.	Rainfall.	Run-off.	Evaporation.	Temperature.	Rainfall.	Run-off.	Evaporation.	Temperature.
December	1.94	0.18	......	°30.8	1.50	0.84	......	°31.5	3.01	1.48	......	°41.1
January	3.96	1.24	......	23.5	3.63	1.89	......	31.7	4.52	3.53	......	37.0
February	1.91	1.12	......	29.4	1.55	1.42	......	24.0	5.84	3.73	......	37.5
March	4.05	1.38	......	32.5	1.71	0.71	......	39.0	4.38	4.23	......	32.0
April	1.75	0.80	......	46.9	2.23	0.88	......	47.9	3.41	2.00	......	48.8
May	3.55	0.45	......	58.4	2.90	0.28	......	59.1	6.61	3.10	......	56.9
	17.16	*5.17*	*11.99*	*36.9*	*13.52*	*6.02*	*7.50*	*38.9*	*27.77*	*18.07*	*9.70*	*42.2*
June	2.66	0.29	......	68.4	4.79	0.47	......	65.7	5.27	1.64	......	70.7
July	5.81	0.81	......	70.4	5.35	0.55	......	71.7	3.06	0.51	......	70.9
August	5.84	0.67	......	68.8	1.98	0.22	......	67.0	5.35	0.49	......	66.6
	14.31	*1.77*	*12.54*	*69.2*	*12.12*	*1.24*	*10.88*	*68.1*	*13.68*	*2.64*	*11.04*	*69.4*
September	3.28	0.61	......	58.0	4.17	0.14	......	61.3	6.86	2.28	......	60.6
October	3.25	0.77	......	45.6	2.35	0.14	......	46.5	6.20	2.01	......	51.1
November	4.61	2.01	......	41.1	3.72	0.68	......	40.2	2.46	1.84	......	42.0
	11.14	*3.39*	*7.75*	*48.2*	*10.24*	*0.96*	*9.28*	*49.3*	*15.52*	*6.13*	*9.39*	*51.2*
Year	42.61	10.33	32.28	47.8	35.88	8.22	27.66	48.8	56.97	26.84	30.13	51.3

[1] For details of the measurements of the Des Plaines River see data pertaining to rainfall and stream flow, by Thomas T. Johnston, Journal Western Soc. C. E., Vol. I (June, 1896).

Rainfall, run-off, evaporation, and mean temperature of Muskingum River, as measured by the United States engineers, from 1888 to 1895, inclusive—Cont'd.

Month.	1891.				1892.				1893.			
	Rainfall.	Run-off.	Evaporation.	Temperature.	Rainfall.	Run-off.	Evaporation.	Temperature.	Rainfall.	Run-off.	Evaporation.	Temperature.
December	2.45	0.91	......	°29.3	2.62	1.03	......	°37.8	1.62	0.24	......	°28.1
January	2.52	2.40	......	31.2	2.40	0.74	......	22.8	3.01	0.37	......	18.0
February	4.43	4.56	......	34.8	2.76	2.40	......	33.0	6.38	4.70	......	28.3
March	3.19	2.52	......	33.5	3.10	1.26	......	32.7	2.31	2.55	......	36.9
April	1.74	1.58	......	49.8	2.24	1.38	......	46.0	5.94	2.22	......	49.6
May	2.39	0.45	......	55.8	7.27	2.25	......	57.9	5.78	4.05	......	57.0
	16.72	*12.42*	*4.30*	*39.1*	*20.39*	*9.06*	*11.33*	*38.4*	*25.04*	*14.13*	*10.91*	*36.3*
June	7.56	0.91	......	69.0	7.05	2.30	......	71.6	3.08	0.78	......	70.2
July	3.92	0.51	......	67.6	5.44	0.75	......	70.9	2.92	0.28	......	73.6
August	2.08	0.35	......	68.7	4.05	0.60	......	70.0	2.31	0.16	......	69.5
	13.56	*1.77*	*11.79*	*68.4*	*16.54*	*3.65*	*12.89*	*70.8*	*8.31*	*1.22*	*7.09*	*71.1*
September	1.08	0.17	......	66.5	2.33	0.28	......	62.2	1.56	0.14	......	63.4
October	1.25	0.26	......	49.7	0.80	0.20	......	50.1	5.51	0.46	......	52.4
November	4.75	0.94	......	38.6	1.68	0.19	......	37.8	1.94	0.25	......	38.4
	7.08	*1.37*	*5.71*	*51.6*	*4.81*	*0.67*	*4.14*	*50.0*	*9.01*	*0.85*	*8.16*	*51.4*
Year	37.36	15.56	21.80	49.5	41.74	13.38	28.36	49.4	42.36	16.20	26.16	48.8

Month.	1894.				1895.				Mean.			
	Rainfall.	Run-off.	Evaporation.	Temperature.	Rainfall.	Run-off.	Evaporation.	Temperature.	Rainfall.	Run-off.	Evaporation.	Temperature.
December	2.59	1.54	......	°31.7	3.01	0.36	......	°33.2	......	......	......	°......
January	2.11	1.00	......	33.2	3.99	1.67	......	22.4	......	......	......	......
February	2.95	2.19	......	27.6	0.89	0.12	......	19.1	......	......	......	......
March	2.20	1.41	......	43.9	1.87	1.20	......	33.2	......	......	......	......
April	2.45	0.75	......	49.8	1.76	0.59	......	50.6	......	......	......	......
May	4.63	0.74	......	58.3	1.52	0.10	......	60.5	......	......	......	......
	16.93	*7.63*	*9.30*	*40.7*	*13.04*	*4.04*	*9.00*	*36.5*	*18.82*	*9.57*	*9.25*	*38.6*
June	2.12	0.42	......	70.6	2.87	0.17	......	71.6	......	......	......	......
July	1.77	0.13	......	73.1	2.52	0.21	......	69.6	......	......	......	......
August	0.67	0.11	......	70.1	3.75	0.11	......	71.7	......	......	......	......
	4.56	*0.66*	*3.90*	*71.3*	*9.14*	*0.49*	*8.65*	*71.0*	*11.53*	*1.68*	*9.85*	*69.9*
September	4.12	0.15	......	67.2	2.39	0.13	......	67.2	......	......	......	......
October	2.19	0.10	......	53.3	1.38	0.08	......	45.3	......	......	......	......
November	2.71	0.16	......	36.8	3.89	0.16	......	40.8	......	......	......	......
	9.02	*0.41*	*8.61*	*52.4*	*7.66*	*0.37*	*7.29*	*51.1*	*9.31*	*1.77*	*7.54*	*50.7*
Year	30.51	8.70	21.81	51.3	29.84	4.90	24.94	48.8	39.66	13.02	26.64	49.5

In the table is given the rainfall and run-off record for Muskingum River, in Ohio, as measured at Zanesville[1] for the years 1888 to 1895, inclusive, the area of the watershed above the point of measurement being 5,828 square miles. The head waters of the stream are not far from Lake Erie and on the dividing line between the hill country of the east and the prairie country of the Mississippi Valley. Hence this stream represents conditions applicable to the run-off of the Ohio streams tributary to Lake Erie. The rainfall record as used in this table is the mean of the records kept at Akron, Canton, Newcomerstown, and Wooster, and may be considered to represent fairly well the mean precipitation of the Muskingum drainage area. For the year 1892 the total rainfall was 41.74 inches and the total run-off 13.38 inches, of which 9.06 occurred in the storage period. In 1893 the total rainfall was 42.36 inches, with a total run-off of 16.20 inches, the run-off of the storage period being 14.13 inches. In 1894 the rainfall dropped to a total of 30.51 inches and the run-off to a total of 8.70 inches, of which 7.63 inches occurred in the storage period. In 1895 the total rainfall was 29.84 inches and the total run-off 4.90 inches, of which 4.04 inches occurred during the storage period.

Genesee River, while not tributary to the Great Lakes above Niagara River, may still be cited as showing that at times the run-off of streams tributary to the Great Lakes is quite low. Referring to the table on page 70, giving the rainfall and run-off of Oatka Creek, a tributary of the Genesee, we learn that in the water year 1891, with a rainfall of 38.12 inches, the run-off was 14.05 inches. In 1892, with a rainfall of 41.69 inches, the run-off was 15.42 inches.

Taking the record of Genesee River proper, as given in the table on page 58, we learn that for the water year 1894, with a mean precipitation above the point of measurement of 47.79 inches, the run-off was 19.38 inches, of which 15.73 inches occurred in the storage period. In 1895 the rainfall dropped to 31 inches and the total run-off to 6.67 inches. In 1880 Hemlock Lake, a tributary of Genesee River, with a drainage area of 43 square miles and a total rainfall of 21.99 inches, gave a run-off of only about 3.4 inches.

[1] Survey of the Miami and Erie Canal, the Ohio Canal, etc. Report of Capt. Hiram M. Chittenden, Corps of Engineers, U. S. Army, January 20, 1896, printed as House Document No. 278, Fifty-fourth Congress, first session, p. 42.

Rainfall, run-off, evaporation, and mean temperature of Genesee River from December, 1893, to November, 1896, inclusive.

[In inches on the watershed.]

Month.	1894.				1895.				1896.			
	Rain-fall.	Run-off.	Evap-ora-tion.	Mean tem pera ture	Rain-fall.	Run-off.	Evap ora tion.	Mean tem-pera-ture.	Rain-fall.	Run-off.	Evap-ora-tion.	Mean tem-pera-ture.
				°				°				°
December	3.39	2.34	......	26.8	2.47	0.61	......	29.0	3.80	1.32	......	30.1
January	3.91	1.40	......	28.4	3.26	0.66	......	1.91	2.29	0.47	......	22.4
February	2.93	0.86	......	20.1	1.22	0.22	......	14.5	3.56	0.91	......	22.9
March	1.62	3.31	......	37.9	1.72	1.94	......	28.0	4.00	3.00	......	22.7
April	7.22	3.39	......	42.1	2.10	2.01	......	44 2	1.62	3.38	......	47.7
May	8.64	4.43	......	54.5	2.43	0.19	......	57.8	2.57	0.17	......	60.7
	27.71	*15.73*	*11.98*	*35.0*	*13.20*	*5.63*	*7.57*	*32.1*	*17.84*	*9.25*	*8.59*	*34.4*
June	2.51	1.10	......	64.6	4.57	0.13	......	67.5	3.52	0.39	......	62.1
July	3.70	0.14	......	67.9	2.57	0.11	......	64.1	4.90	0.24	......	67.3
August	1.74	0.22	......	63.4	3.99	0.12	......	66.5	1.86	0.20	......	65.0
	7.95	*1.46*	*6.49*	*65.3*	*11.13*	*0.36*	*10.77*	*66.0*	*10.28*	*0.83*	*9.45*	*64.8*
September	6.97	0.93	......	61.6	1.96	0.10	......	61.7	5.22	0.16	......	57.5
October	3.50	0.44	......	49.5	1.30	0.11	......	41.8	4.08	1.74	......	43.6
November	1.66	0.82	......	32.1	3.41	0.47	......	38.0	3.26	0.82	......	41.6
	12.13	*2.19*	*9.94*	*47.7*	*6.67*	*0.68*	*5.99*	*47.2*	*12.56*	*2.72*	*9.84*	*47.6*
Year	47.79	19.38	28.41	45.7	31.00	6.67	24.33	44.3	40.68	12.80	27.88	45.3

These figures are cited to show that in years of low rainfall the run-off of streams tributary to the Great Lakes is very low, and as a consequence the run-off of Niagara River will probably be affected thereby. At present the data are insufficient for showing what the run-off of Niagara River really is.

The most elaborate measurements thus far made are those of the Lake Survey in 1867 and 1868, which are, however, extremely unsatisfactory. According to these measurements the mean discharge, rainfall, and evaporation from the Great Lakes for the year 1868, in cubic feet per second, were as follows:[1]

Mean discharge, rainfall, and evaporation from the Great Lakes for the year 1868, in cubic feet per second.

Lakes.	Mean discharge.	Total rainfall on basin.	Evaporation from surface.
Superior	86,000	171,430	27,690
Huron and Michigan	225,000	251,450	59,890
Erie	265,000	100,540	14,310
Total	....	523,220	101,890

[1] These figures are derived from Mr. Cooley's Lakes and Gulf Waterways, as corrected and given in the Journal of the Assoc. of Eng. Soc., Vol. VIII (March, 1889), p. 132.

According to the Deep Waterways Commission's tabulations of available records of heights of the Great Lakes, it appears that the water levels fluctuate through a series of years to the extent of about 4.5 feet. For the present discussion we are chiefly concerned with the fluctuations of Lake Erie, which control the discharge of Niagara River. By examination of the records of mean monthly elevation of Lake Erie at Buffalo from 1887 to 1897, as kept by the United States engineer's office at Buffalo, it appears that the highest mean monthly elevation during these years was for June, 1887, when the mean lake surface was +0.92. The lowest mean monthly elevation for the period was for March, 1896, when the mean for the month was —2.36. The range in the mean monthly elevations for this period was 3.28 feet.

Mean monthly elevation of Lake Erie at Buffalo.

[In feet with reference to datum.]

Month.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.
December	......	—0.26	—0.31	—0.71	—0.31	—1.35	—1.01	—0.92	—1.23	—2.08	—1.82
January	......	—0.48	—0.49	—0.13	—0.57	—1.44	—1.78	—0.92	—1.36	—1.93	—1.47
February	......	—1.09	—0.71	—0.31	—0.69	—2.13	—1.83	—1.30	—2.05	—2.00	—1.90
March	+0.60	—1.02	—1.10	—0.07	—0.55	—1.93	—1.52	—1.19	—2.13	—2.36	—1.39
April	+0.56	—0.36	—0.72	+0.18	—0.43	—1.09	—0.86	—1.00	—1.92	—1.83	—0.87
May	+0.78	—0.21	—0.56	+0.54	—0.65	—0.65	—0.14	—0.50	—1.57	—1.38	—0.45
	+0.64	*—0.57*	*—0.65*	*—0.08*	*—0.53*	*—1.43*	*—1.19*	*—0.97*	*—1.71*	*—1.93*	*—1.32*
June	+0.92	—0.04	—0.09	+0.87	—0.67	+0.16	+0.21	—0.11	—1.47	—1.37	—0.46
July	+0.76	+0.18	—0.05	+0.59	—0.49	+0.37	+0.08	—0.24	—1.49	—1.19	—0.48
August	+0.36	+0.07	—0.14	+0.12	—0.78	+0.00	—0.51	—0.71	—1.63	—0.96	—0.96
	+0.68	*+0.07*	*—0.09*	*+0.53*	*—0.65*	*+0.18*	*—0.07*	*—0.36*	*—1.53*	*—1.18*	*—0.63*
September	+0.05	—0.27	—0.52	—0.23	—0.95	—0.27	—0.76	—0.08	—1.61	—1.38	—1.40
October	+0.11	—0.46	—1.03	—0.25	—1.32	—0.60	—0.87	—0.88	—1.85	—1.64	—1.36
November	—0.44	—0.61	—1.03	—0.05	—1.38	—0.98	—0.88	—1.06	—2.34	—1.61	—1.24
	—0.09	*—0.45*	*—0.86*	*—0.17*	*—1.22*	*—0.62*	*—0.84*	*—0.67*	*—1.93*	*—1.54*	*—1.33*
Year	*a*+0.41	—0.38	—0.56	+0.05	—0.73	—0.83	—0.82	—0.74	—1.72	—1.64	—1.15

a Mean of nine months.

Temporarily much greater fluctuations have been experienced, due largely to wind action, to which Lake Erie, on account of its shallowness, and the fact that its general direction is favorable for the sweep of the prevailing winds, is peculiarly subject. In regard to the measurements of the Lake Survey, it may be remarked that they indicate large variations in discharge from all of the lakes, from the effects of winds and other disturbing causes, but give little clew to the quantities at either of the extremes of high or low water. According to Lyman E. Cooley the extreme low-water discharge is probably 20 to 30 per cent less than the Lake Survey figures, and extreme high water 20 to 30 per cent more.

Measurements of the amount of water flowing in Niagara River were begun in December, 1891, at a time when the water in Lake Erie was very low and the conditions were considered especially favorable for minimum discharge. The results are given in the Annual Report of the Chief of Engineers, United States Army, for 1893, Part VI, pp. 4364–4371. The point selected was about 1,000 feet below the International Bridge at Black Rock, near the foot of Squaw Island, at which point the river is free from eddies. Niagara River, on leaving Lake Erie, has a nearly straight channel about 2,000 feet wide for the first 2 miles. The fall in this section is from 4 to 5 feet, and the velocity ranges from 7 miles per hour at the upper end to about 5 miles at the lower end. The point was chosen, after careful consideration, as the point in that vicinity least subject to disturbance. In taking the cross sections, the width, which varies slightly with different stages of the river, was actually determined for gage readings 1 foot apart, and for extreme points the width was determined by interpolating values derived from the known slope of the river banks. A local gage was established at the draw pier of the International Bridge by setting gage boards on each side of the pier, with the zeros of the gages on the same level. The local gage was read at the beginning and close of all velocity observations, and the gage at Buffalo was read at 7 a. m. and 1 and 7 p. m. The zero of this latter gage is at the mean level of Lake Erie, or 572.23 feet above mean tide at New York, in the Erie Canal levels, or as used by the Government engineers, 572.96 feet. During the velocity observations in December, 1891, Lake Erie was about 1.5 feet below its mean level, and is stated not to have been seriously affected by strong winds. Still the daily record shows that there must have been some wind action. The current velocities were obtained after the methods used by the Mississippi River Commission and described in their reports, all velocity observations being taken with a current meter, with electrical appliances for recording the number of revolutions. The following are some of the results obtained:[1]

Mean heights and discharge of Niagara River.

Date.	Mean height on local gage.	Mean height on Buffalo gage.	Discharge per second.
1891.	*Feet.*	*Feet.*	*Cu. feet.*
December 24	0.05	−2.95	164,648
December 14	0.65	−1.85	191,822
December 21	0.735	−1.75	193,522
December 20	0.835	−1.75	201,433
December 22	1.125	−1.45	208,597
December 10	1.33	−0.50	218,353
1892.			
May 19	1.562	−0.80	213,180
May 7	1.750	−0.85	218,988
May 24	2.292	+0.15	236,762

[1] Annual Report of Chief of Engineers, United States Army, 1893, Part VI, p. 4367.

The table shows (1) a variation in lake elevation, as indicated in the Buffalo gage, from —2.95 on December 24, 1891, to +0.15 on May 24, 1892, a range of 3.10 feet; (2) a variation in discharge of 72,114 cubic feet per second. There are some discrepancies in the results which it is not necessary to discuss at length; but in the absence of more satisfactory data we may assume, in view of the foregoing evidence as to the small run-off of streams tributary to and in the vicinity of the Great Lakes, that the figures obtained in the fall of 1891 and spring of 1892 are probably more nearly correct than the larger figures of the Lake Survey. By plotting the observed discharges a mean discharge curve has been obtained, from which the discharge of the river at points within the range of the observation can be taken off, when one has the tabulated heights of the Buffalo gage before him. At present these measurements are, on the whole, not considered sufficiently exact to justify the labor of preparing a tabulation of this character.[1]

Referring to the table on page 58, it is learned that the rainfall in that portion of the basin of the Great Lakes tributary to Niagara River was, for 1868, 523,220 cubic feet per second, and the evaporation from the water surface of the lakes tributary to Niagara River was 101,890 cubic feet per second. Hence the evaporation from the lake surfaces was nearly 20 per cent of the rainfall on the whole basin. Assuming for the moment the truth of these figures, we have 80 per cent of the total rainfall from which the land evaporation must be deducted before anything can run off. Again assuming the land evaporation at 1.70 feet, there results a loss from this source alone of 298,000 cubic feet per second; adding to this the evaporation loss from the water surfaces gives a total evaporation loss of 399,890 cubic feet per second. The run-off is the difference between rainfall and total evaporation losses. If, therefore, the land evaporation was 1.7 feet for the year 1868, the run-off would have been in reality only 123,330 cubic feet per second instead of 265,000 cubic feet per second, as

[1] There have been a number of independent measurements of volume of the Niagara, and though the results differ widely, they probably do not differ more than the actual volume of the river at various stages of Lake Erie.

Lyell (1841 ?) quotes Ruggles as authority for a volume of 250,000 cubic feet per second.

E. R. Blackwell, computed by Allen (Am. Jour Sci., 1841), obtains 374,000 cubic feet per second. His work was afterwards recomputed by D. F. Henry, who obtained 244,797 cubic feet per second.

In the annual report of the Chief of Engineers, United States Army, for 1867-68, D. F. Henry gives as a result of observations in August and September, 1867, 242,494 cubic feet per second. A year later he recomputed from the same data, and obtained 240,192 cubic feet per second. He also made a new measurement by a different method (see Report for 1868-69) from which he obtained two results, 304,307 and 258,586 cubic feet per second.

W. F. Reynolds (annual report of the Chief of Engineers, United States Army, 1870?), gives the result of observations from June to September, 1869, 212,860 cubic feet per second.

In the annual report of the Chief of Engineers, United States Army, for 1871, there is mention of a result, without date of measurement, 245,296 cubic feet per second.

In the annual report of the Chief of Engineers, United States Army, for 1891-92, Quintus, as a result of gaging, gives the volume, reduced to mean stage, as 232,800 cubic feet per second.

Sir Casimir S. Gzowski, from continuous observations at the International Bridge, 1870-1873, gives an average discharge for that period of 246,000 cubic feet per second.

determined by the Lake Survey. These figures, while not conclusive, are suggestive, so much so, indeed, that taking into account all the conditions it seems clear that in a series of years of minimum rainfall the run-off of the Great Lakes, tributary to Niagara River, may be as low as from 6 to 9 inches a year on the watershed. At the former figure the mean discharge would be about 177,700 cubic feet per second.[1]

As an additional source of loss from the Great Lakes the proposed ultimate diversion of 10,000 cubic feet per second through the Chicago drainage canal to the head waters of Illinois River may be referred to. Thus far the discussion of such loss has been mainly conducted on the supposition that the mean discharge of the Great Lakes at Niagara was about 265,000 cubic feet per second. If this were true the ultimate injurious effect of such diversion could only appear during a series of extremely dry years. The author can not but think that this whole question of the run-off of Niagara River has become fogged by a discussion based thus far purely on averages. What we really want to know is the run-off of a cycle of dry years. With such data we can compute the effect of a given diversion more satisfactorily than when dealing with means.

With a cycle of rainfall years, either high or at about the average, it is probable that very little effect from such diversion will be observed, the consensus of opinion at the present time apparently being that it will not exceed about 0.3 to 0.4 foot in depth over the areas affected. Owing to the balancing of conditions due to the immense pondage of the Great Lakes, and which requires years in order to complete a cycle, it is uncertain whether the abstraction of 10,000 cubic feet per second at Chicago would be especially detrimental at Niagara Falls, although in years of extreme low flow it is probable that it would be easily apparent. If, however, the minimum flow of Niagara River is really as low as 150,000 to 180,000 cubic feet per second, it is clear that the loss of 10,000 cubic feet per second will be a matter worth taking into account.

In the discussion of the effect of diverting 10,000 cubic feet per second at Chicago on the levels of the Great Lakes, by Lyman E. Cooley, which appears in the proceedings of the annual convention of the International Deep Waterways Association, held at Cleveland in September, 1895, it is stated that assuming the correctness of the

[1] By way of illustrating further the probable inaccuracy of the Lake Survey figures, it may be pointed out that if the determination of evaporation from the water surfaces at 101,890 cubic feet per second and run-off at 265,000 cubic feet per second for the year 1868 is correct, the total outgo from these two sources was 368,890 cubic feet per second, leaving the land evaporation for that year at 156,330 cubic feet per second, or at 0.9 foot over the watershed.

By studying the evaporation of the Upper Mississippi reservoirs, the Des Plaines and Muskingum rivers, and other streams herein referred to, it will readily be seen that it is exceedingly improbable that a land evaporation as low as 0.9 foot ever occurred over the whole watershed of the Great Lakes.

figures derived from the Lake Survey placing the mean discharge of St. Clair River at 225,000 cubic feet per second, the abstraction of 10,000 cubic feet per second would diminish the mean outflow in St. Clair River by nearly 4.5 per cent and in Niagara River by about 3.75 per cent. Mr. Cooley says that, reasoning on lines obvious to those unacquainted with hydraulic principles, it is apparent that the ruling depth in the rivers at mean level can not be lessened by an amount greater than the percentages just stated; but if we consider the question as an hydraulic proposition, taking into account the relation of mean radius to area and perimeter, it is apparent that the effect on lake levels would be only a fraction of that indicated by the reduction in volume.

The literature of the discharge of Niagara River and of the probable effect on the lake levels of abstracting 10,000 cubic feet per second at Chicago has now grown so extensive as to preclude further discussion of the question here. Those wishing to pursue the subject further may consult the references given in the footnote. Concluding the subject, it may be stated that the studies of the Lake Survey indicate a mean discharge of Niagara River of about 265,000 cubic feet per second, with a range above and below the mean of from 20 to 30 per cent. The only measurements since made were those of December to May, 1891–92, which indicate a minimum discharge as low as or even lower than 141,000 cubic feet per second, this latter figure agreeing fairly well with theoretical considerations derived from present knowledge of the actual minimum run-offs of contiguous drainage areas.[1]

[1] For literature of discharge of Great Lakes and allied questions see (1) Repts. Chief of Engnrs. 1868, 1869, 1870, and 1882; (2) Repts. Chief of Engnrs., 1893; (3) Eng. News, Vol. XXIX (March 2, 1893); (4) The Lakes and Gulf Waterways, by L. E. Cooley; (5) The level of the Lakes as affected by the proposed Lakes and Gulf waterway, a discussion before the Western Society of Engineers, in Jour. of the Assn. of Eng. Socs., Vol. VIII (Mch., 1889); (6) An enlarged waterway between the Great Lakes and the Atlantic seaboard, by E. L. Corthell, with discussion, in Jour. of the Assn. of Eng. Socs., Vols. X and XI (April, June, and December, 1891, and July, 1892); (7) Lake level effects on account of the sanitary canal at Chicago, by L. E. Cooley, in Proc. Internat. Deep Waterways Con., at Cleveland, Sept., 1895; (8) A technical brief, by Thomas T. Johnston, covered by the preceding reference; (9) Papers by William Pierson Judson, on an Enlarged waterway between the Great Lakes and the Atlantic seaboard, pamphlets, 1890 and 1893.

Rainfall and run-off of Des Plaines River, as determined by the Chicago drainage commission, from 1886 to 1897.

[Inches on watershed.]

Months.	1886.		1887.		1888.		1889.		1890.		1891.	
	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.
December	......	......	1.76	0.00	3.67	......	1.94	0.00	1.90	......	......	......
January	......	......	3.13	0.89	1.56	1.37	1.64	0.29	......	......	......	......
February	......	......	5.10	5.59	1.51	2.50	1.31	0.01	......	......	......	......
March	......	......	0.89	2.64	2.99	4.84	1.43	0.43	......	......	......	......
April	......	......	0.46	0.52	......	......	2.35	1.13	......	......	......	......
May	......	......	1.38	0.13	......	......	5.38	0.39	......	......	......	......
			12.72	*9.77*	......	......	*14.05*	*2.25*	......	......	......	......
June	0.94	0.16	1.63	0.02	......	......	2.93	1.26	......	......	......	......
July	1.53	0.14	1.05	0.33	......	......	9.56	1.09	2.57	......	......	......
August	3.38	0.01	3.35	0.18	......	......	0.39	0.45	2.58	0.02	......	......
	5.85	*0.31*	*6.03*	*0.53*	......	......	*12.88*	*2.80*	......	......	......	......
September	6.93	0.03	4.03	0.22	0.98	......	2.75	0.00	1.39	0.01	......	......
October	1.42	0.01	2.03	0.63	2.95	0.00	1.82	0.00	4.20	0.02	......	......
November	1.66	0.00	2.41	......	2.89	0.00	3.49	0.01	1.59	0.04	......	......
	10.01	*0.04*	*8.47*	......	*6.82*	......	*8.06*	*0.01*	*7.18*	*0.07*	......	......
Year	......	......	27.22	......	......	......	34.99	5.06	......	......	......	......

Months.	1892.		1893.		1894.		1895.		1896.		1897.	
	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain. fall.	Ruu-off.	Rain-fall.	Run-off.
December	......	......	1.63	0.04	2.14	0.27	1.66	......	6.76	1.80	0.16	0.19
January	......	......	2.08	0.01	1.55	0.50	2.15	......	1.12	0.26	4.53	......
February	......	......	2.44	0.31	2.13	1.06	1.60	0.21	3.48	1.06	2.22	1.39
March	......	......	1.69	5.15	2.66	3.05	1.32	0.71	1.26	1.11	3.56	4.61
April	......	......	4.16	1.79	2.65	0.76	0.86	0.29	2.79	0.77	2.23	1.88
May	6.77	4.24	1.93	1.31	3.35	1.90	1.99	0.11	4.16	0.39	0.84	0.60
			13.93	*8.61*	*14.48*	*7.54*	*9.58*	......	*19.57*	*5.39*	*13.54*	......
June	10.58	6.04	3.59	1.37	1.96	0.08	1.79	0.00	2.82	0.09	......	......
July	2.23	0.79	3.08	0.14	0.60	0.01	2.42	0.00	3.61	0.02	......	......
August	1.85	0.03	0.18	0.00	0.60	0.00	6.49	0.01	3.52	0.06	......	......
	14.66	*6.86*	*6.85*	*1.51*	*3.16*	*0.09*	*10.70*	*0.01*	*9.95*	*0.17*	......	......
September	1.34	0.02	1.98	0.00	8.28	0.06	0.89	0.06	6.54	0.32	......	......
October	1.54	0.00	1.75	0.02	0.84	0.00	0.51	0.00	1.36	0.33	......	......
November	2.68	0.02	2.45	0.00	1.18	0.01	5.60	0.00	2.16	0.48	......	......
	5.56	*0.04*	*6.18*	*0.02*	*10.30*	*0.07*	*7.00*	*0.06*	*10.06*	*1.13*	......	......
Year	......	......	26.96	10.14	27.94	7.70	27.28	......	39.58	6.69	......	......

Evaporation from the Des Plaines watershed, as given by differences between rainfall and run-off in the preceding table.

[Inches on watershed.]

Water year.	December to May.	June to August.	September to November.	Total.
1886	....	5.54	9.97	....
1887	2.95	5.50	....	....
1889	11.80	10.08	8.05	29.93
1890	....	....	7.11	....
1892	....	7.80	5.52	....
1893	5.32	5.34	6.16	16.82
1894	6.94	3.07	10.23	20.24
1895	....	10.69	6.94	....
1896	14.18	9.78	8.93	32.89

RUN-OFF OF ST. LAWRENCE RIVER.

According to the report of the Deep Waterways Commission, the area of the water surface of Lake Ontario is 7,450 square miles, and the area of the tributary watershed, exclusive of the area of the lake itself, 25,530 square miles. The total area of the drainage basin, including both land and water surfaces, is 32,980 square miles. The area of the water surface of St. Lawrence River from Gallops Rapids to Montreal[1] is given at 220 square miles, and the area of the tributary watershed at 5,710 square miles; hence the total area of the basin of the St. Lawrence from Gallops to Montreal becomes 5,930 square miles.

In the foregoing figures Lake Ontario is considered as beginning in Niagara River, at the foot of Niagara Falls and terminating at the head of Gallops Rapids, whence the following subdivisions of water-surface area are derived: Niagara River, 5 square miles; Lake Ontario proper, 7,260 square miles; St. Lawrence River, 185 square miles; giving a total, as above, of 7,450 square miles.

Of the total area of watershed of 25,530 square miles, 14,275 square miles lie within the State of New York and 11,255 square miles in the Province of Ontario. The standard low-water elevation of Lake Ontario is taken as 244.53 feet, and the standard high-water elevation as 249.04 feet above tide.

St. Lawrence River is considered as beginning at Gallops Rapids. The following table gives the elevation of water surface at a number of points.[2]

[1] Report of U. S. Deep Waterways Commission, 1897, House Document No. 192, Fifty-fourth Congress, second session, pp. 151-153.

[2] Report of U. S. Deep Waterways Commission, 1897, p. 152.

Elevation above tide of low-water and high-water surface of St. Lawrence River.

Locality.	Standard low water.	Standard high water.
	Feet.	*Feet.*
Ogdensburg	244.28	248.57
Lake St. Francis, at Valleyfield	153.50	155.94
Lake St. Louis, at Melicheville	70.0	77.50
Montreal	23.10	35.78

The area of water surface of the St. Lawrence from Gallops Rapids to Montreal is 220 square miles, and the total area of watershed not included in the surface of the river is 5,710 square miles, of which 3,800 square miles lie in New York, 620 in Ontario, and 1,290 in Quebec. The total area of the drainage basin, including water surface of the river, is 5,930 square miles.

The only measurements as to the discharge of St. Lawrence River thus far made are those of the Lake Survey, which give a mean discharge of 300,000 cubic feet per second. The recent data would indicate that this figure is somewhat too large, as in the Lake Survey discharge of Niagara River. The streams tributary to Lake Ontario, however, issue from a region of heavier rainfall than those tributary to the Upper Great Lakes and, as shown by the run-off tables of this report, are generally much better water yielders. Taking everything into account, it is probable that the minimum discharge of St. Lawrence River will not be less than from 8 to 10 inches over the entire watershed per year. A run-off of 12 inches per year over the entire drainage basin would give a mean discharge of 234,300 cubic feet per second, or a discharge of 0.884 cubic foot per square mile per second. A mean discharge of 300,000 cubic feet per second, as measured by the Lake Survey, would give 1.13 cubic feet per square mile per second. These figures are for the minimum discharge; for years, or cycles of years, of average rainfall the run-off would be more.

RUN-OFF OF INLAND STREAMS OF NEW YORK.

The data for determining the run-off of the inland streams of New York are included in the tables given on pages 67 to 85 and others following. The results of measurements on Oatka Creek, a tributary of Genesee River, with a drainage area of 27.5 square miles above the point of measurement, from April, 1890, to November, 1892, are given on page 70. The discharge of Genesee River at Mount Morris, above which point the drainage area is 1,070 square miles, from December, 1893, to November, 1896, is given on page 58. The table on pages 76 and 77 shows the quantity of water drawn from Hemlock Lake, also a tributary of Genesee River, and with a drainage area above the point of measurement of 43 square miles, for the water years 1880 to 1884, inclusive. The table on page 78 gives a similar tabulation of water drawn from Skaneateles Lake for the months indicated from October, 1890, to November, 1897, inclusive. The tables on page 82 give the run-off of Hudson River as measured at Mechanicville, where the drainage area is 4,500 square miles, from October, 1887, to November, 1896, inclusive. The table on pages 83 to 85 gives the run-off of Croton River, as measured at the Croton dam, where the drainage area is 338 square miles, for the water years from 1870 to 1896, inclusive. The table on page 72 presents measurements at Rochester in comparison with those at Mount Morris. So far as the author can learn, the foregoing include all the systematic measurements of streams, for considerable periods, thus far made in the State of New York, except those by John B. Jervis of the Madison and Eaton brooks in 1835, the results of which are presented in his report for that year to the canal commissioners.[1]

DISCHARGE MEASUREMENTS OF EATON AND MADISON BROOKS.

Eaton and Madison brooks, of which measurements were made by Mr. Jervis in 1835, are in the central-eastern part of Madison County and tributary to Chenango River. The drainage area of Eaton Brook is given by Mr. Jervis at 6,800 acres, or 10.6 square miles; and that of Madison Brook as 6,000 acres, or 9.4 square miles.

Rainfall and run-off of Eaton Brook.

Month.	Rainfall.	Rainfall for 6,800 acres.	Run-off from 6,800 acres.	Percentage of run-off to rainfall.
1835.	*Inches.*	*Cubic feet.*	*Cubic feet.*	
June	6.72	165,876,480	59,407,394	35.8
July	2.74	67,634,160	27,994,240	41.4
August	2.86	70,596,240	13,547,058	19.2
September	1.34	33,076,560	9,586,513	29.0
October	3.0	74,052,000	20,694,651	27.2
November	2.20	54,304,800	23,772,620	43.8
December	0.96	23,696,640	36,525,544	54.1
June to December, inclusive	19.82	489,236,880	191,528,020	39.2
June to October, inclusive		411,235,440	131,229,856	31.9

[1] The measurements for short periods of several streams and of the water supply of Brooklyn are not overlooked in this statement, which is intended to apply to measurements extending over a year or more.

Rainfall and run-off of Madison Brook.

Month.	Rainfall.	Rainfall for 6,000 acres.	Run-off from 6,000 acres.	Percentage of run-off to rainfall.
1835.				
Snow of November-December, 1834, on ground	*Inches.*	*Cubic feet.* 87,120,000	*Cubic feet.*	....
January	2.17	47,262,600	23,192,079	49.1
February	2.50	54,450,000	35,377,594	64.9
March	1.03	22,443,400	43,284,656	192.8
April	5.0	108,900,000	80,776,974	74.1
May	1.98	43,124,400	58,013,176	134.5
June	8.05	175,329,000	20,138,006	11.5
July	3.87	84,288,600	23,141,302	27.4
August	3.06	66,646,800	23,725,060	35.6
September	0.88	19,166,400	19,158,957	99.9
October	3.86	84,070,800	19,544,880	23.2
November	2.10	45,738,000	18,232,372	39.9
December	0.76	16,552,800	19,401,364	117.2
January to December, inclusive	35.26	855,092,800	383,986,420	44.9
January to May, inclusive	....	363,300,400	240,644,479	66.2
June to October, inclusive	....	429,501,600	105,708,205	24.6

The following statements in regard to these measurements are abstracted from Mr. Jervis's report:[1] From the Eaton Brook results it appears that the average run-off from June to December, inclusive, was 39.2 per cent of the rainfall and from June to October, inclusive, 31.9 per cent of the rainfall. The minimum monthly run-off was in August, which shows only 19.2 per cent of the rainfall. The rainfall in the month of June, 1835, on Eaton Brook was 6.72 inches and in July 2.74 inches. The percentage of run-off to rainfall for June was 35.8, whereas for July it was 41.4, which would indicate that the bulk of the June rain must have been at the end of the month.

[1] For Mr. Jervis's original report see Appendix F to Ann. Rept. Canal Com., 1835, Ass. Doc. No. 65, pp. 55-60. Mr. Jervis's tables, with extracts from the report, are also quoted in the following documents:

(1) Report of F. C. Mills, chief engineer Gen. Val. Can., in Appendix D to Ann. Rept. Can. Com., 1837, Ass. Doc. No. 80, p. 81.

(2) Report of W. H. Talcott, Res. Eng. Gen. Val. Can., 1840, Ass. Doc. No. 96, p. 51.

(3) Report of the Regents of the University, 1838, Sen. Doc. No. 52, pp. 208-211.

(4) Documentary History of the New York State Canals. By S. H. Sweet, Dep. State Eng. and Sur., 1863, Ass. Doc. No. 8, pp. 203-204.

From the measurements of Madison Brook it appears that in 1835 the average run-off for the whole year, including the snow on the ground on January 1, was 44.9 per cent, or nearly one-half of the rainfall. Mr. Jervis points out that on account of the storage of the reservoir Madison Brook record can not be taken for the summer months, but that the year should be divided into two periods. For the first period he gives the results from January to May, inclusive, during which the run-off was 66.2 per cent of the rainfall, and for the second from June to October, during which the run-off was 24.6 per cent of the rainfall. During the second period, June to October, inclusive, Eaton Brook gave a run-off of 31.9 per cent of the rainfall. Mr. Jervis explains these different results by the different characters of the two districts drained. Eaton Brook Valley is very narrow and the area drained quite steep, with a very close-textured soil. Madison Brook Valley, on the other hand, is much wider, with easy slopes, and the soil in a portion of it is more porous than that on Eaton Brook. Mr. Jervis concludes his discussion with the remark that Eaton Brook Valley would afford more than an average run-off over a large district of country including the usual varities of soil, while Madison Brook would probably not differ materially from the general average in this State.

In his documentary history of the New York State canals, which is included in the annual report of the State engineer and surveyor for the fiscal year ending September 30, 1862, S. H. Sweet analyzes Mr. Jervis's measurements of discharge of Eaton and Madison brooks and points out several probable errors, especially in the Madison Brook result, where, because the measurements indicate only what was actually discharged through the sluice pipes each day instead of what drained off from the valley, he concludes that the real drainage of the Madison Brook area in 1835 was about 0.518 of the rainfall, instead of 0.449, as given by Mr. Jervis. Inasmuch as the Eaton Brook and Madison Brook measurements have only historical interest at the present time, this branch of the subject is not here pursued at length. So far as can be learned, the measurements of these two streams by Mr. Jervis, in 1835, were the first systematic measurement of the run-off of streams in the United States. Geologically these streams lie in the horizon of the Hamilton shales.

DISCHARGE MEASUREMENTS OF OATKA CREEK.

The measurements of Oatka Creek, recorded in the following table, were made at the milldam in the south part of the village of Warsaw, in Wyoming County. The dam was new, practically tight, and well adapted for securing accurate results. Measurements were also made of the outflow of the head race way leading from the dam for different elevations of water on the dam, and a curve prepared from which the discharge of the race way was read off and added to the discharge over the dam as computed by Francis's weir formula. It is believed that the results are accurate within a very small per cent.

Rainfall, run-off, evaporation, and mean temperature of Oatka Creek drainage area.

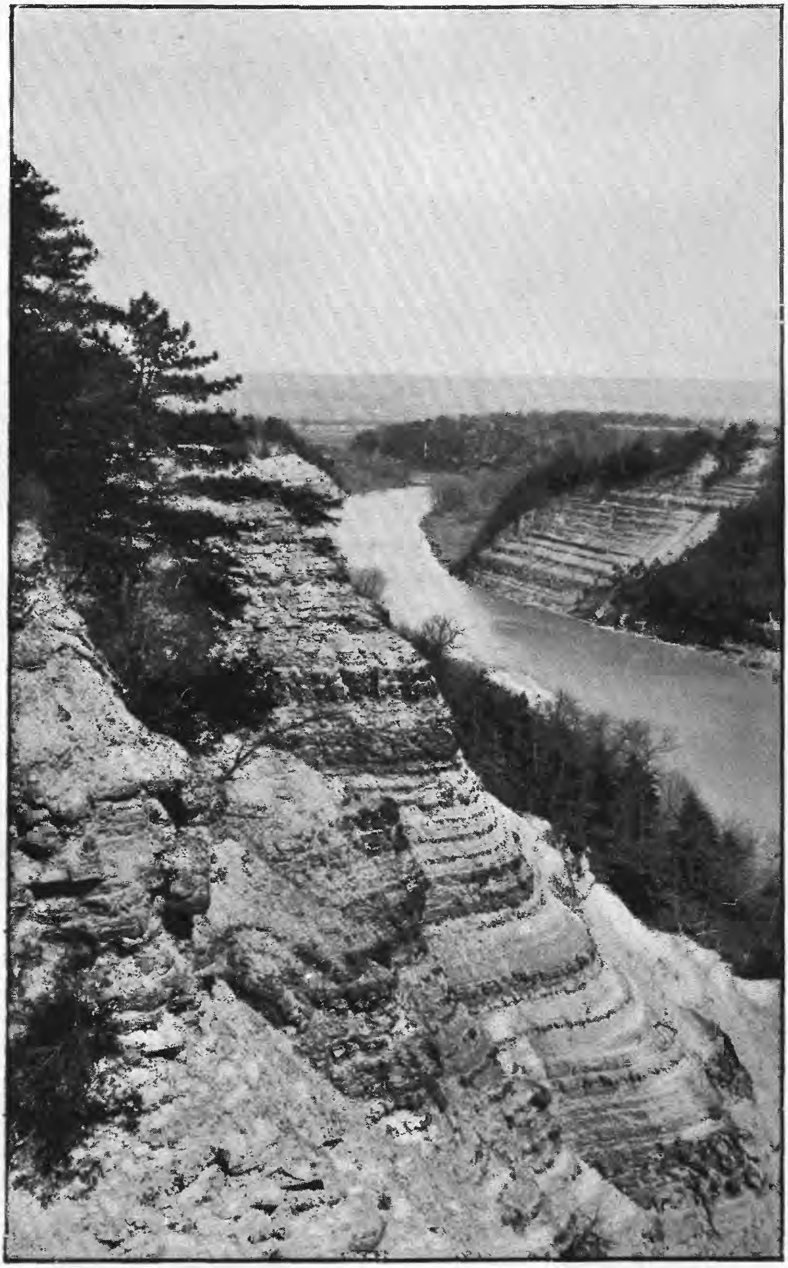
[In inches on the watershed.]

Months.	1890.				1891.				1892.			
	Rainfall.	Run-off.	Evaporation.	Mean temperature.	Rainfall.	Run-off.	Evaporation.	Mean temperature.	Rainfall.	Run-off.	Evaporation.	Mean temperature.
				°				°				°
December	3.33	......	......	37.0	2.61	0.97	......	24.6	3.80	1.04	......	34.9
January	4.36	......	......	32.7	4.12	2.62	......	26.1	3.82	0.78	......	21.0
February	3.63	......	......	31.5	4.67	3.40	......	29.0	3.71	1.66	......	26.9
March	2.72	......	......	29.5	3.70	2.87	......	29.9	1.73	1.94	......	26.1
April	2.82	2.17	......	44.7	1.52	1.39	......	45.7	1.04	2.21	......	42.1
May	6.15	3.16	......	52.8	1.60	0.63	......	52.8	5.74	1.75	......	50.0
	23.01	......	......	*38.0*	*18.22*	*11.88*	*6.34*	*34.7*	*19.84*	*9.38*	*10.46*	*31.8*
June	4.12	1.85	......	67.4	4.01	0.44	......	65.2	6.67	1.41	......	67.2
July	3.18	0.38	......	70.2	4.52	0.37	......	63.9	4.18	2.06	......	68.1
August	3.22	0.28	......	66.8	4.25	0.25	......	65.4	4.45	1.43	......	67.1
	10.52	*2.51*	*8.01*	*68.1*	*12.78*	*1.06*	*11.72*	*64.8*	*15.30*	*4.90*	*10.40*	*67.5*
September	6.59	1.35	......	60.3	1.72	0.46	......	62.5	1.62	0.24	......	59.0
October	4.52	2.27	......	50.2	2.49	0.24	......	46.6	2.19	0.33	......	47.2
November	2.90	2.13	......	39.3	2.91	0.41	......	36.5	2.74	0.57	......	35.0
	14.01	*5.75*	*8.26*	*49.9*	*7.12*	*1.11*	*6.01*	*48.5*	*6.55*	*1.14*	*5.41*	*47.1*
Year	47.54	......	......	48.5	38.12	14.05	24.07	45.7	41.69	15.42	26.27	45.4

The drainage area of Oatka Creek above Warsaw includes 27.5 square miles of rolling semimountainous country. The valley of the creek is deep cut, with numerous springs at the head waters. The drainage area is mostly deforested and in a high state of cultivation, the soil inclining to clay for a considerable portion. Geologically the stream lies in the rocks of the Portage formation, as developed in western New York. The run-off from this area may be taken as fairly typical of many small streams in western New York.

DISCHARGE MEASUREMENTS OF GENESEE RIVER.

The measurements of Genesee River proper, presented in the table on page 58, were made at the timber dam of the Mount Morris Hydraulic Power Company from September, 1893, to November, 1896, inclusive. The crest of this dam is quite irregular, and, in order to apply weir formulæ to it, an accurate profile was taken and the dam divided into a number of approximately level sections, with each section computed separately for various heights and advancing by 0.1 of a foot up to 10 feet. Working on this plan, the flow over the entire dam, which is 337 feet in length, was obtained by adding together the sums of the several sections at the corresponding heights and tabulating these. A gage graduated to 0.05 foot was erected on the river bridge



CANYON OF GENESEE RIVER BETWEEN MOUNT MORRIS AND PORTAGE.

a short distance away, with its zero level coinciding with the lowest point of the dam. During ordinary stages of the river readings of this gage were taken twice each day, but in time of high water, in order to obtain the movement of floods as accurately as possible, readings were taken several times a day. In order to compute the flow readily a curve was projected, embodying the data of the tabulation previously referred to, and from which, with the given gage heights, the flows in cubic feet per second could be quickly read off.

When the measurements were first begun, it was considered that the formula $Q=1142\ H^{\frac{3}{2}}$ was best suited to the form of the dam, but after more careful consideration it was apparent that the results given by this formula were somewhat in excess of the actual discharge, especially for the low-water flows. Accordingly a weir was constructed during the summer of 1896, at a point 2.5 miles above the Hydraulic Power Company's dam, where rock bottom clear across the river offered a convenient opportunity for such construction without heavy expense. This weir was made perfectly tight.

In order to correlate the measurements at the Mount Morris Hydraulic Power Company's dam with those of the weir, two observations a day were taken at each place, nearly at the same time; that is to say, they were both taken by the same man, who passed immediately from the weir to the dam and vice versa. Observations on the weir were obtained up to a head of 4 feet, and the corresponding discharge computed with the proper allowance for velocity of approach, etc. The depths on the Hydraulic Power Company's dam corresponding to the given depths on the weir were so plotted on the diagram as to give at once the relation between the flow at the weir and the depth on the crest of the Hydraulic Power Company's dam. By proceeding in this way the dam was accurately rated up to a discharge of 5,000 cubic feet per second. For discharges beyond 5,000 cubic feet per second the original determination has been used. An extension of the plotted curves shows that some little distance above 5,000 cubic feet per second discharge the results of the two methods are substantially the same. The two curves crossed at the point of about 6,000 cubic feet per second discharge. For discharges above 10,000 or 15,000 cubic feet per second there is probably an error in the results of from 5 to 10 per cent. Below 5,000 cubic feet per second it is believed that the results are now accurate within 2 or 3 per cent. Francis's formula, $Q=3.33\ L\ H^{\frac{3}{2}}$ has been used for the weir computations.

The measurements taken previously to the construction of the weir and the rating of the dam, as aforesaid, have all been corrected to conform to the new determinations; hence all the data of the Genesee measurements of this table may be considered as accurate within the limits stated.

Discharge measurements of Genesee River have also been kept for the last three years at Rochester, where the drainage area is about 2,400 square miles. From data obtained during the summer of 1895 it was apparent that these measurements also require a correction in order to give the approximate true flow of the stream during the period covered. Without going into detail it may be stated that the Rochester measurements in the following table give the corrected results, which are now probably accurate within from 5 to 10 per cent:

Comparison of the measurements of Genesee River at Rochester with those at Mount Morris for the water years 1894 to 1896, inclusive.

[In cubic feet per second, and with yearly means also in inches on the watershed.]

Month.	1894.			1895.			1896.		
	As per record.	Corrected.	Estimated from measurements at Mount Morris. *a*	As per record.	Corrected.	Estimated from measurements at Mount Morris. *a*	As per record.	Corrected.	Estimated from measurements at Mount Morris. *a*
December	3,914	3,914	4,797	1,459	1,100	1,256	1,839	1,700	2,710
January	2,841	2,841	2,867	1,619	1,200	1,335	1,645	1,400	964
February	2,584	2,584	1,954	977	700	495	2,702	2,702	2,005
March	6,008	6,008	6,794	4,035	4,035	3,985	3,725	3,725	6,158
April	5,646	5,646	7,172	3,083	3,083	4,257	7,623	7,623	7,172
May	6,304	6,304	9,080	1,309	900	385	1,576	1,300	347
	4,576	*4,576*	*5,477*	*2,099*	*1,848*	*1,958*	*3,181*	*3,054*	*3,218*
June	2,951	2,800	2,321	885	535	283	1,317	1,000	654
July	1,055	792	292	645	390	232	854	645	501
August	973	732	442	600	400	254	585	440	416
	1,656	*1,426*	*1,003*	*728*	*440*	*256*	*977*	*692*	*522*
September	1,664	1,500	1,963	407	250	221	324	240	327
October	1,226	920	899	366	220	230	2,271	2,000	3,667
November	1,782	1,600	1,729	834	500	993	993	745	1,728
	1,573	*1,335*	*1,523*	*534*	*333*	*478*	*1,353*	*1,006*	*1,926*
Year	3,088	2,978	3,370	1,364	1,116	1,163	2,174	1,951	2,220
Inches on watershed	19.20	18.35	19.38	8.48	6.41	6.67	12.48	11.20	12.80

a Increased in proportion to increased drainage area at Rochester.

As interesting data from Genesee River measurements, we may discuss the flood of May 20–23, 1894, at which time the approximate discharge of the stream at Mount Morris, from a drainage area of 1,070 square miles, was as follows:

Discharge of Genesee River at Mount Morris during the flood in May, 1894.

	Cubic feet per second.
May 18, 7 a. m	600
May 18, 6 p. m	3,090
May 19, 7 a. m	5,530
May 19, 6 p. m	5,090
May 20, 7 a. m	16,580
May 20, 12 m	22,210

Discharge of Genesee River at Mount Morris during the flood in May, 1894—Cont'd.

	Cubic feet per second.
May 20, 6 p. m	28,000
May 21, 3.30 a. m	42,000
May 21, 7 a. m	33,000
May 21, 12 m	30,730
May 21, 6 p. m	26,500
May 22, 7 a. m	15,650
May 22, 12 m	13,650
May 22, 6 p. m	10,720
May 23, 7 a. m	7,300
May 23, 12 m	6,700
May 23, 6 p. m	5,690
May 24, 7 a. m	5,390

The total run-off from 7 a. m. of May 19 to 7 a. m. of May 24 was nearly 6,900,000,000 cubic feet.

On the morning of May 21 the flats in the broad, level valley of

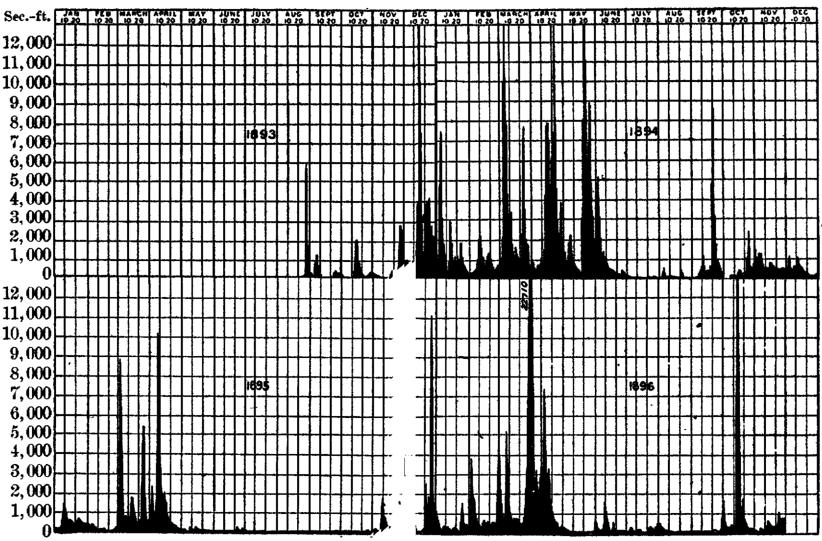


FIG. 2.—Discharge of Genesee River at Mount Morris, New York, 1893 to 1896.

Genesee River and Canaseraga Creek, between Dansville, Mount Morris, and Rochester, and which have an area of from 60 to 80 square miles, were nearly flooded, in some localities to a depth of from 4 to 6 feet. On account of the large pondage by these flats, although the maximum run-off at Mount Morris was 42,000 cubic feet per second at 3.30 a. m. on the morning of May 21, at Rochester the maximum flow did not at any time exceed about 20,000 cubic feet per second. We have, then, a case where a large pondage has, by prolonging the time of run-off, modified a flood flow over 50 per cent. As further illustrating the effect of a large reservoir, or, what is the same thing, the effect of a large pond area in modifying the effect of an extreme flood, reference may be made to fig. 3, in which, with time as abscissas and run-off as ordinates, the run-off record of Genesee River for May 18–24, 1894, has been plotted. The lower curve of that figure may be taken as representing approximately the law of the run-off of any generally distributed heavy rainfall on the catchment area of this stream. In making this statement it is not overlooked that flood flows at other seasons of the year may differ somewhat in their movement from that of May, 1894. Inasmuch as the rapidity and intensity of the run-off of any given stream depend largely upon the topography, the statement may be made that the general law of movement of floods in Genesee River is indicated by the lower curve of fig. 3. With this understanding we may assume any other run-off and construct the approximate curve by drawing it generally parallel to the curve of the actually observed case. In this way the upper curve of fig. 3, representing the curve of a flood one and one-half times greater than that of May, 1894, has been produced, slight irregularities of the lower curve having been neglected in projecting the upper one.

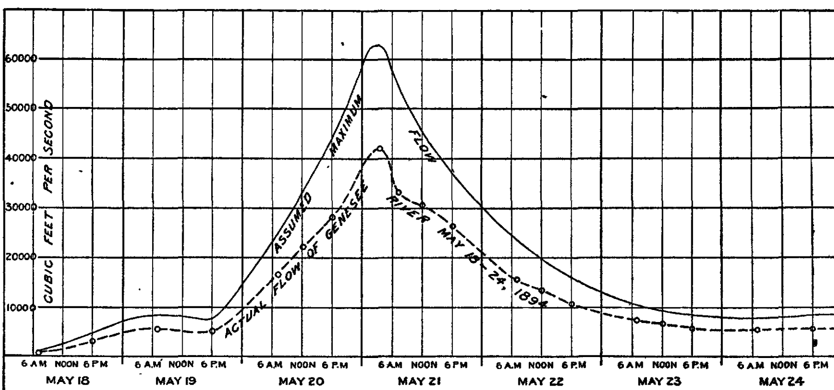


FIG. 3.—Flood flow of Genesee River, May 18-24, 1894.

A flood flow one and one-half times as great as that of May, 1894, which culminated in a maximum of about 42,000 cubic feet per second at 2.30 a. m. of May 21, gives a maximum of 63,000 cubic feet per second, the movement of which would be, under the assumptions, substantially as in the upper curve of fig. 3. As to the probability of a maximum flood flow of 63,000 cubic feet per second on the upper Genesee drainage area, the case of the neighboring Chemung River may be cited, where a flood flow of 67.1 cubic feet per second per square mile occurred in June, 1889. This figure applied to the upper Genesee would give a possible maximum run-off of 71,126 cubic feet per second.

Geologically, the drainage area of Genesee River above Mount Morris, the point of measurement, lies in the shales, sandstones, etc., of the Portage and Chemung groups. Its extreme head waters south of the Pennsylvania line issue from the lower Carboniferous. Generally the soils throughout the whole basin are heavy and tenacious, inclining to clay. Their capacity for absorbing and retaining water must, therefore, be considered as small.

DISCHARGE MEASUREMENTS OF HEMLOCK LAKE.

Measurements of the run-off of the Hemlock Lake drainage area for the water years 1880 to 1884, inclusive, were made by the Rochester Waterworks. Hemlock Lake lies at an elevation of 896 feet above tide, and has a length of 6.5 miles, with an average width of about 0.5 of a mile. The area of the surface at low water is 1,828 acres. The total drainage basin, including the area of the lake, is 27,554 acres, or about 43 square miles. The shores are bold, and on the east side rise to a height of several hundred feet above the lake in a distance of 2 or 3 miles. At the head of the lake there is a swamp of 118 acres, partially covered at high water.

The outflow of the lake during the period covered by the measurements included in the following table may be considered as having taken place at three points: (1) At the natural outlet of the lake; (2) at an artificial channel through which water was discharged at will for the benefit of the millers on the outlet; and (3) through the conduit of the Rochester waterworks. The run-offs given are the sums of these several outgoes. In order to determine the outflow of the natural outlet, a weir was constructed and the discharge observed at different heights of the lake surface. The discharge into the artificial channel was through submerged orifices of known dimensions, and has been computed from standard formulæ for the discharge of such orifices, the size of the openings and the difference of level of water surfaces above and below being known.

The discharge of the conduit of the Rochester waterworks is as computed from standard formulæ for discharge through pipes. Measurements made by the author and others during the last few years show that the computed quantities passing through the conduit were not far from correct. As a whole, it is believed that the Hemlock Lake results are accurate within from 5 to 8 per cent.

Water drawn from Hemlock Lake for the water years 1880 to 1884, inclusive.

[In inches on the watershed.]

Month.	1880.					1881.				
	Mean monthly elevation of lake surface.	Rainfall.	Water drawn.	Rainfall, less the water drawn.	Temperature.	Mean monthly elevation of lake surface.	Rainfall.	Water drawn.	Rainfall, less the water drawn.	Temperature.
December	−1.67	1.26	0.16	....	*a* 31.4	−1.33	0.72	0.49	....	27.3
January	−0.91	1.37	0.15	....	*a* 25.5	−1.47	2.24	0.44	....	24.7
February	−0.11	1.45	0.16	....	*a* 27.3	−0.11	1.08	0.54	....	29.7
March	+0.21	1.47	0.15	....	*a* 31.8	+1.20	1.92	1.73	....	39.1
April	+0.79	1.25	0.15	....	*a* 45.7	+1.47	0.52	1.24	....	45.2
May	+0.87	2.08	0.17	....	71.8	+1.32	2.23	1.11	....	69.7
	−0.14	*8.88*	*0.94*	*7.94*	*38.9*	*+0.18*	*8.71*	*5.55*	*3.16*	*39.3*
June	+0.45	1.66	0.36	....	76.5	+1.08	3.13	0.76	....	73.9
July	−0.15	1.93	0.41	....	77.1	+0.58	3.71	0.43	....	75.6
August	−0.70	3.46	0.35	....	74.4	....	0.95	0.50	....	80.0
	−0.13	*7.05*	*1.12*	*5.93*	*76.0*	*+0.55*	*7.79*	*1.69*	*6.10*	*76.5*
September	−1.13	1.35	0.31	....	69.7	−0.69	1.73	0.35	....	77.9
October	−1.57	3.85	0.31	....	53.4	−0.81	4.23	0.33	....	59.1
November	−1.24	0.86	0.39	....	37.1	−0.71	1.81	0.46	....	44.8
	−1.31	*6.06*	*1.01*	*5.05*	*53.4*	*−0.74*	*7.77*	*1.14*	*6.63*	*60.6*
Year	−0.43	21.99	3.07	18.92	51.8	+0.04	24.27	8.38	15.89	53.9

a Interpolated from average of fifteen years.

Month.	1882.					1883.				
	Mean monthly elevation of lake surface.	Rainfall.	Water drawn.	Rainfall, less the water drawn.	Temperature.	Mean monthly elevation of lake surface.	Rainfall.	Water drawn.	Rainfall, less the water drawn.	Temperature.
December	−0.05	4.02	0.66	....	39.8	−1.51	0.91	0.19	....	31.0
January	+1.63	1.03	2.04	....	29.4	−1.56	0.84	0.21	....	25.7
February	+1.39	1.07	1.40	....	37.0	+0.03	3.11	0.28	....	30.6
March	+1.67	1.47	2.82	....	38.7	+0.95	0.90	0.68	....	33.3
April	+1.51	2.49	1.53	....	48.5	+1.57	2.43	1.58	....	47.8
May	+1.61	5.29	1.74	....	57.4	+1.59	9.54	2.59	....	59.1
	+1.29	*15.37*	*10.19*	*5.18*	*41.8*	*+0.18*	*17.73*	*5.53*	*12.20*	*37.9*
June	+1.45	2.31	1.85	....	71.9	+1.38	4.52	1.65	....	74.2
July	+0.81	1.42	0.62	....	78.0	+1.29	2.13	1.08	....	75.7
August	+0.15	2.17	0.41	....	76.8	+0.64	2.86	0.45	....	73.7
	+0.80	*5.90*	*2.88*	*3.02*	*75.6*	*+1.10*	*9.51*	*3.18*	*6.33*	*74.5*
September	−0.44	1.78	0.43	....	69.4	+0.25	2.36	0.21	....	65.1
October	−0.99	1.00	0.65	....	61.4	+0.07	1.62	0.18	....	55.7
November	−1.38	1.41	0.36	....	41.8	+0.17	2.02	0.19	....	45.1
	−0.94	*4.19*	*1.44*	*2.75*	*57.5*	*+0.16*	*6.00*	*0.58*	*5.42*	*55.3*
Year	+0.61	25.46	14.51	10.95	54.2	+0.41	33.24	9.29	23.95	51.4

Water drawn from Hemlock Lake for the water years 1880 to 1884, etc.—Cont'd.

Month.	1884.				
	Mean monthly elevation of lake surface.	Rainfall.	Water drawn.	Rainfall, less the water drawn.	Temperature.
December	+0.44	2.01	0.54	....	34.0
January	+0.46	1.78	1.01	....	24.7
February	+1.28	2.17	2.70	....	30.2
March	+1 47	3.18	2.71	....	30.5
April	+1.56	2.21	1.47	....	42.7
May	+1.62	3.30	1.69	....	56.7
	+1.14	*14.65*	*10.12*	*4.53*	*36.5*
June	+1.01	2.44	0.75	....	70.4
July	+0.58	3.98	0.37	....	68.4
August	+0.27	1.08	0.24	....	70.8
	+0.62	*7.50*	*1.36*	*6.14*	*69.9*
September	−0.26	2.24	0.71	....	66.9
October	−0.70	1.34	0.20	....	52.3
November	−1.17	1.01	0.18	....	38.9
	−0.71	*4.59*	*1.09*	*3.50*	*52.7*
Year	+0.55	26.74	12.57	14.17	48.9

The drainage area of Hemlock Lake is, as stated, 27,554 acres, and the area of the lake itself at the elevation ±0.0 is 1,828 acres; hence the lake surface is 6.6 per cent of the total drainage area, or the drainage area is 15.1 times the area of the lake surface. On this basis 1 inch on the whole area is 15.1 inches on the lake. Taking into account these statements, it is clear that the data of the table give approximately the natural run-off, although for exact figures corrections for actual elevations of lake surface at the beginning, as well as at the end of each year, should be applied. On this point see the discussion on the minimum flow of Hemlock Lake, on pages 92 and 93. Geologically, the Hemlock Lake Basin proper is in the Hamilton and Marcellus shale, with the hills at the side rising into the rocks of the Portage group.

DISCHARGE MEASUREMENTS OF SKANEATELES LAKE.

The measurements of the run-off of Skaneateles Lake drainage area, as given in the following table, have been made by the Syracuse waterworks over a dam at the foot of the lake or over a weir a short distance below since October, 1890. Previous to 1886 this lake was the principal feeder of the Jordan level of Erie Canal, but in that year Otisco and Owasco lakes were also made feeders. The Skaneateles Lake dam was reconstructed 9 feet high by the State in 1887, and in 1893 was again rebuilt by the Syracuse water board with its spillway 2 feet higher than the crest of the old dam. The area of the water surface of Skaneateles Lake is 12.75 square miles, and the area of the watershed, including the area of the lake, is 73 square miles.

The elevation above tide is 867 feet. The lake lies in a deep valley, with bold shores rising several hundred feet at either side. The figures given in the following table do not represent in any degree the natural run-off of this drainage area, but merely the water yield during the years indicated, in which there was large storage.

In March, 1895, the city of Syracuse began to draw water through its new conduit to Skaneateles Lake. Since that time the results given in the table are the quantity flowing in the outlet as measured on the weir located at Willow Glen plus the outflow through the conduit. Previous to March, 1895, the results are from measurements at the dam at the foot of the lake. The earlier results are possibly affected by errors of from 12 to 15 per cent, while the latter are probably accurate within from 2 to 5 per cent. Geologically the drainage basin of Skaneateles Lake is in the Hamilton group of rocks.

Water drawn from and monthly elevatians of Skaneateles Lake for the months indicated for the water years 1890 to 1897, inclusive.

[Water drawn in inches on the watershed.]

Year, etc.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Total.
1890:													
Mean lake surface	−1.92	−2.08	−2.25	+0.33	+0.33	+0.25	+0.37	+0.50	−0.42	−1.33	−1.08	−1.16	----
Water drawn	------	------	------	------	------	------	------	------	------	------	1.59	1.67	-----
1891:													
Mean lake surface	−1.00	−1.50	−1.00	+0.16	+0.50	0.0	−0.75	−1.42	−2.21	−3.25	−4.12	−5.25	-----
Water drawn	1.62	1.63	1.52	2.42	2.57	*a*1.90	1.23	1.33	1.93	1.79	1.61	1.21	20.76
1892:													
Mean lake surface	−5.79	−5.50	------	−5.0	−3.67	−1.83	−0.67	−0.33	−0.67	−1.08	−1.83	−2.58	-----
Water drawn	------	------	------	------	------	------	------	------	------	1.35	1.24	1.13	-----
1893:													
Mean lake surface	−2.56	−2.71	−2.92	−2.75	−1.33	0.0	+0.33	−0.67	−1.42	−2.17	−3.00	−3.83	-----
Water drawn	1.09	0.87	0.87	1.10	1.18	3.06	2.10	1.98	1.53	1.08	1.58	1.58	20.02
1894:													
Mean lake surface	−4.75	−4.48	------	------	------	−2.50	−1.27	+0.25	−0.06	−0.88	−1.00	−1.21	-----
Water drawn	1.38	0.86	------	------	------	0.26	0.15	0.57	1.07	1.39	1.46	1.44	-----
1895:													
Mean lake surface	−1.58	−1.20	−1.75	−0.37	−0.17	+0.14	−0.40	−0.92	−1.67	−2.18	−3.12	−4.14	-----
Water drawn	0.32	0.24	0.22	1.29	2.55	2.14	1.64	1.77	1.87	1.64	1.85	1.75	17.28
1896:													
Mean lake surface	−4.56	−4.33	−4.60	−4.08	−2.42	−1.35	−1.58	−1.94	−2.23	−2.94	−3.42	−3.85	-----
Water drawn	1.58	1.51	1.46	1.61	1.50	1.59	1.61	1.51	1.50	1.51	1.50	1.38	18.26
1897:													
Mean lake surface	−3.92	−4.12	−4.29	−4.56	−3.46	−2.67	−2.50	−2.65	------	------	------	------	-----
Water drawn	1.35	1.25	1.08	1.06	0.26	1.12	1.34	1.45	2.21	1.41	1.61	1.47	15.61

a Interpolated. No record. Mean of preceding and following months used.

DISCHARGE MEASUREMENTS OF HUDSON RIVER.

Measurements of the flow of Hudson River have been made over the dam of the Duncan Company, at Mechanicville. In 1887 this company began daily measurement of the amount of water flowing in Hudson River at their mill.[1] With the exception of one or two days this record has been kept for every working day since October 1, 1887. A record has also been kept of the number, size, and kind of turbine water wheel in use for the same period. The Duncan Company placed all this material at the disposal of the survey of the Upper Hudson Valley, of which the author has had charge, thus enabling him to compute the mean daily flow of the river for each working day from October 1, 1887, to November 30, 1896. The flow of Sundays and holidays, when no observations were taken, has been assumed as a mean between the preceding Saturday and the following Monday, etc. The dam is a substantial structure of masonry 16 feet high, with a length of 794 feet between the abutments. The crest is stated by John R. Kaley, the constructing engineer, to be perfectly level, and from all that can be learned it appears that the daily observations have been taken with such care as to leave no reason for doubting that this is a fairly accurate exhibit of the daily flow of the stream for the period covered. This record is therefore considered to be accurate within from 5 to 8 per cent.

The greatest depth on this dam in the nine-year period, 1888 to 1896, inclusive, occurred May 5, 1893, when the gage showed a depth of 7.83 feet and the mean flow of the day was over 53,000 cubic feet per second. The drainage area of Hudson River above the Mechanicville dam is taken at 4,500 square miles.

Experience in flows over dams of this length and with depths as great as from 7 to 8 feet is as yet rather limited in this country, and the question was raised as to the best method of computing the discharge for a case like the one under discussion. The engineers of the British Government in India have had, in connection with their large irrigation works, perhaps more experience in this class of measurement than all others combined, and the formulæ used by them appear more rational in form than those commonly used in the United States for such computations, and after some study it was decided to use these. As many American engineers may not be familiar with these formulæ they are here reproduced. They take the following form:

$$Q = \tfrac{2}{3} L C \sqrt{2 g d^3}, \tag{1}$$

in which—

Q = the discharge over a thin-edged clear overfall, in cubic feet per second,

L = the length of the dam in linear feet,

[1] Annual Report of the State Engineer and Surveyor of New York, 1895, p. 104.

C = coefficient depending for its value on d,
g = acceleration of gravity = 32.2,
d = depth on crest, in linear feet.

Equation (1) may also take the form—

$$Q = 5.35 \text{ L C } \sqrt{d^3}. \quad (2)$$

To find C for different values of d, we have—

$$C = 1 - \left(\frac{0.04\ (34.6 + d)}{4}\right). \quad (3)$$

This gives a series of values of C corresponding to d. For instance, for $d = 0.25$ foot, C = 0.651; for $d = 0.50$ foot, C = 0.649, and so on.

For a wide-crested dam the coefficient is further modified to suit the actual width of the crest. For this we have given the expression—

$$C' = C - \left(\frac{0.025\ C\ (B + 1)}{1 + d}\right), \quad (4)$$

in which—
B = the width of the crest in linear feet;
C = the coefficient for a thin-edged weir, corresponding to a depth d, as per equation (3), and
C′ = the adjusted coefficient corresponding to a given breadth B and a depth d.[1]

In the case of the Mechanicville dam we have a stone crest 7 feet in width and slightly inclined upstream. The width of the river a short distance above the dam is considerably over 800 feet; the depth for some distance back is from 16 to 20 feet. In order to avoid a correction for velocity of approach, a crest was assumed 5 feet wide and values of C′ were computed on that basis.

Having obtained values of C′ for d = 0.25, 0.50, 0.75, 1.00, 1.25, 1.50, 1.75 feet, and so on up to 8 feet, corresponding values of Q were computed and plotted at a large scale as a curve with values of d as abscissas and the corresponding flows as ordinates. From this curve intermediate values of Q have been read off.

[1] The method of deducing equations (3) and (4) may be found in Mullin's Irrigation Manual, 1890, pp. 11, 12, 138, 139, 171, 172.

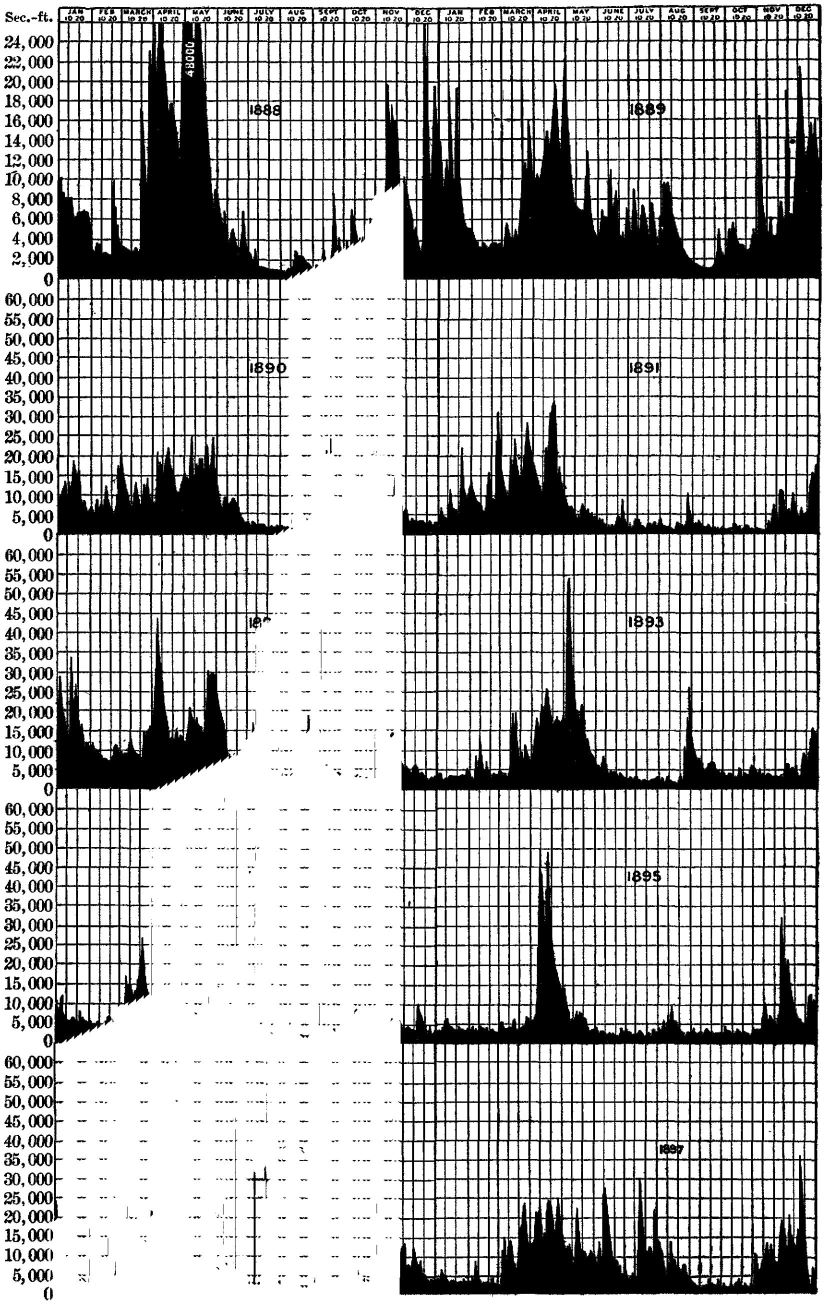


FIG. 4.—Discharge of Hudson River at Mechanicville, New York, 1888 to 1897.

Run-off of Hudson River at Mechanicville from October, 1887, to November, 1896, inclusive. (*a*)

[In cubic feet per second.]

Month.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.
December	....	8,018	10,014	13,226	3,244	8,577	4,031	7,217	4,367	10,899
January	....	6,367	10,983	11,272	8,284	18,857	3,192	6,757	3,876	6,787
February	....	3,714	3,790	7,913	11,664	9,263	4,805	4,836	3,543	4,668
March	....	6,845	8,280	11,129	17,736	10,929	8,250	14,738	4,204	13,600
April	....	21,200	13,690	15,053	20,021	21,554	17,889	11,135	23,822	24,972
May	....	21,420	8,871	17,931	5,533	19,622	22,285	7,566	6,850	4,610
Mean	....	*11,289*	*9,337*	*12,821*	*11,021*	*14,831*	*10,114*	*8,759*	*7,759*	*10,921*
June	....	4,917	6,869	7,392	3,200	12,395	4,801	7,097	2,816	4,738
July	....	1,537	5,727	1,950	2,337	9,287	2,521	3,168	2,559	2,772
August	....	1,725	4,272	2,019	2,666	5,485	5,005	2,456	3,901	2,442
Mean	....	*2,703*	*5,718*	*3,748*	*2,957*	*9,019*	*4,102*	*4,209*	*3,095*	*3,317*
September	....	2,851	1,963	8,844	2,040	4,448	6,870	1,889	2,629	2,879
October	2,365	4,608	3,740	9,215	1,472	2,819	3,865	3,649	2,631	4,106
November	4,190	10,642	7,888	9,121	4,088	7,604	3,639	6,379	8,421	11,352
Mean	....	*6,018*	*4,522*	*9,061*	*2,521*	*4,934*	*4,781*	*3,969*	*4,539*	*6,112*
Yearly mean	....	7,820	7,197	9,597	6,867	10,909	7,271	6,418	5,780	7,818

[In inches on the watershed.]

Month.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.
December	....	2.05	2.57	3.39	0.83	2.27	1.03	1.85	1.12	2.79
January	....	1.62	2.81	2.89	2.12	4.83	0.82	1.73	0.99	1.74
February	....	0.89	0.88	1.83	2.70	2.22	1.09	1.12	0.82	1.12
March	....	1.75	2.12	2.85	4.55	2.80	2.11	3.78	1.08	3.49
April	....	5.26	3.39	3.73	4.97	5.35	4.44	2.76	5.91	6.20
May	....	5.49	2.27	4.59	1.42	5.03	5.71	1.94	1.76	1.18
Total	....	*17.06*	*14.04*	*19.28*	*16.59*	*22.50*	*15.20*	*13.18*	*11.68*	*16.52*
June	....	1.22	1.70	1.83	0.79	3.08	1.19	1.76	0.70	1.18
July	....	0.39	1.47	0.50	0.60	2.38	0.65	0.81	0.66	0.72
August	....	0.44	1.09	0.52	0.68	1.41	1.28	0.63	1.00	0.63
Total	....	*2.05*	*4.26*	*2.85*	*2.07*	*6.87*	*3.12*	*3.20*	*2.36*	*2.53*
September	....	0.71	0.49	2.19	0.51	1.10	1.70	0.47	0.65	0.71
October	0.61	1.18	0.96	2.36	0.38	0.72	0.99	0.94	0.69	1.05
November	1.04	2.64	1.96	2.26	1.01	1.89	0.90	1.58	2.08	2.82
Total	....	*4.53*	*3.41*	*6.81*	*1.90*	*3.71*	*3.59*	*2.99*	*3.42*	*4.58*
Yearly total	....	23.64	21.71	28.56	20.56	33.08	21.90	19.37	17.46	23.63

a Annual Report of the State Engineer and Surveyor of New York, 1895, pp. 107, 120.

DISCHARGE MEASUREMENTS OF CROTON RIVER.

The record of the run-off of Croton River as measured at the old Croton dam for the watei years 1870 to 1896, inclusive, is given in the table on pages 83 to 85. The watershed of the Croton consists of a broken, hilly country with its surface soil composed principally of sand and gravel. Clay, hardpan, and peat, while found in a few localities, are for the whole area only present to a limited extent. The rock formation consists generally of gneiss, although strata of limestone, some micaceous and talcose slates, with veins of granite, serpentine, and iron ore, occur in a few places. The drainage area lies almost entirely in the State of New York, only a small portion being in Connecticut. It amounts to about 338 square miles above the old Croton dam and to 360 square miles above the new Croton dam under construction. The main river is formed by three branches, known, respectively, as East, Middle, and West branches, which, rising in the southern part of Dutchess County, flow south through Putnam County and unite near its south boundary. The river then flows across Westchester County to Hudson River, into which it empties at Croton Point, about 30 miles north of the city of New York. The principal tributaries aside from East, Middle, and West branches are Kisko, Titicus, Cross, and Muscoot rivers. The monthly and annual rainfall of the Croton watershed, as well as the run-off of the water years, from 1870 to 1896, inclusive, are given in the following table. The average annual rainfall for this period was 48.10 inches and the run-off 24.65 inches.[1]

Rainfall and run-off of Croton River drainage area from 1870 to 1896, inclusive.

[In inches on the watershed.]

Month.	1870.		1871.		1872.		1873.		1874.		1875.	
	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.
December	5.96	3.07	1.49	0.64	2.59	2.11	3.68	1.45	4.13	3.38	1.78	0.98
January	4.51	3.99	3.80	0.59	1.44	2.08	5.66	4.29	6.96	8.22	2.74	0.65
February	6.40	4.28	3.81	2.21	1.22	1.25	3.09	1.72	2.78	2.79	3.47	4.09
March	3.80	3.56	4.27	3.52	2.59	1.75	3.08	4.03	1.57	3.03	4.99	3.24
April	5.45	4.11	3.01	2.02	3.04	3.11	3.77	7.12	6.31	3.63	3.04	5.58
May	2.30	1.86	3.45	2.06	3.69	1.29	2.91	2.19	1.99	3.19	1.08	1.86
	28.42	*20.87*	*19.83*	*11.04*	*14.57*	*11.59*	*22.19*	*20.80*	*23.74*	*24.24*	*17.10*	*16.40*
June	2.06	0.83	5.73	1.43	4.00	1.22	0.71	0.54	3.57	0.92	3.02	0.59
July	3.43	0.51	5.07	0.73	4.34	0.61	2.21	0.49	5.98	1.43	3.10	0.58
August	5.10	0.51	5.24	0.85	5.99	1.64	5.73	0.71	2.75	0.89	10.33	5.80
	10.59	*1.85*	*16.04*	*3.01*	*14.33*	*3.47*	*8.65*	*1.74*	*12.30*	*3.24*	*16.45*	*6.97*
September	2.85	0.35	1.44	0.63	3.69	1.25	3.73	0.52	3.56	0.58	2.11	0.90
October	4.73	0.42	6.18	1.92	2.15	1.13	5.13	1.45	2.40	0.81	3.61	0.85
November	2.51	0.62	4.35	3.41	4.91	2.67	3.72	1.81	2.72	0.74	4.61	2.05
	10.09	*1.39*	*11.97*	*5.96*	*10.75*	*5.05*	*12.58*	*3.78*	*8.68*	*2.13*	*10.33*	*3.80*
Total	49.10	24.11	47.84	20.01	39.65	20.11	43.42	26.32	44.72	29.61	43.88	27.17

1 See Wegmam's History of the Water Supply of the City of New York, Chap. IX, The Croton watershed.

Rainfall and run-off of Croton River drainage area from 1870 to 1896, etc.—Cont'd.

Month.	1876.		1877.		1878.		1879.		1880.		1881.	
	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.
December	1.56	1.84	2.35	1.19	1.52	1.97	8.74	7.23	4.26	2.03	2.49	0.54
January	1.42	1.59	2.68	0.84	4.49	2,85	2.52	1.45	4.00	2.75	4.19	0.76
February	4.91	3.65	0.80	1.55	3.65	3.92	2.85	2.77	2.92	2.99	5.28	4.32
March	6.33	7.16	7.66	6.97	3.10	3.89	4.96	4.30	4.51	3.01	6.14	6.09
April	4.43	6.39	2.35	3.02	2.85	1.69	5.10	5.12	3.99	2.09	1.67	1.88
May	3.99	2.03	0.85	0.89	4.97	1.57	2.45	1.77	1.17	0.98	3.74	1.39
	22.64	*22.66*	*16.69*	*14.46*	*20.58*	*15.89*	*26.62*	*22.64*	*20.85*	*13.85*	*23.51*	*14.98*
June	2.52	0.71	4.95	0.62	4.65	1.52	5.29	0.94	1.28	0.52	5.72	1.67
July	3.42	0.55	4.65	0.51	4.28	0.74	5.95	0.73	5.65	0.54	2.45	0.58
August	1.20	0.50	2.54	0.49	2.66	0.68	5.83	1.48	3.60	0.52	1.71	0.52
	7.14	*1.76*	*12.14*	*1.62*	*11.59*	*2.94*	*17.07*	*3.15*	*10.53*	*1.58*	*9.88*	*2.77*
September	5.21	0.37	1.49	0.34	6.61	2.13	3.43	1.09	2.69	0.50	0.75	0.51
October	1.50	0.38	8.38	1.14	3.78	0.93	0.95	0.67	3.25	0.51	3.65	0.52
November	3.40	0.71	8.16	4.18	4.36	2.09	2.49	0.82	2.97	0.57	4.50	0.48
	10.11	*1.46*	*18.03*	*5.66*	*14.75*	*5.15*	*6.87*	*2.58*	*8.91*	*1.58*	*8.90*	*1.51*
Total	39.89	25.88	46.86	21.74	46.92	23.98	50.56	28.37	40.29	17.01	42.29	19.26

Month.	1882.		1883.		1884.		1885.		1886		1887.	
	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.
December	6.53	1.73	2.68	1.29	3.45	0.64	7.34	3.78	3.84	2.09	4.29	1.19
January	4.41	2.40	2.80	1.06	5.07	2.14	5.59	4.12	5.24	3.42	5.68	2.74
February	5.96	4.23	5.21	3.81	6.31	4.95	4.66	2.44	5.20	4.89	6.01	4.98
March	4.58	4.74	1.67	3.03	4.82	5.01	1.29	2.05	3.86	2.50	3.60	3.69
April	1.36	1.43	3.94	2.73	2.96	3.00	2.09	2.62	3.61	4.51	3.47	3.26
May	6.30	2.20	2.86	1.38	4.33	1.91	2.44	1.58	4.54	2.15	0.32	1.30
	29.14	*16.73*	*19.16*	*13.30*	*26.94*	*17.65*	*23.41*	*16.59*	*26.29*	*19.56*	*23.37*	*17.16*
June	3.04	1.70	5.64	0.63	2.04	0.70	1.19	0.59	3.09	0.78	7.70	1.16
July	3.63	0.69	4.26	0.52	6.54	0.81	5.27	0.52	4.40	0.61	13.32	2.63
August	3.92	0.52	2.09	0.52	4.50	1.18	7.35	0.58	3.21	0.58	7.06	3.56
	10.59	*2.91*	*11.99*	*1.67*	*13.08*	*2.69*	*13.81*	*1.69*	*10.71*	*1.97*	*28.08*	*7.35*
September	14.33	3.25	2.45	0.51	1.69	0.74	1.09	0.42	2.30	0.51	2.00	0.90
October	3.33	2.27	6.99	0.66	3.74	0.57	5.19	0.55	2.28	0.52	3.12	1.03
November	1.66	0.96	1.79	0.69	4.37	0.98	5.99	2.19	5.57	0.88	2.69	0.95
	19.32	*6.48*	*11.23*	*1.86*	*9.80*	*2.29*	*12.27*	*3.16*	*10.15*	*1.91*	*7.81*	*2.88*
Total	59.05	26.12	42.38	16.83	49.82	22.63	49.49	21.44	47.15	23.44	59.26	27.39

Rainfall and run-off of Croton River drainage area from 1870 to 1896, etc.—Cont'd.

Month.	1888.		1889.		1890.		1891.		1892.		1893.	
	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.	Rain-fall.	Run-off.
December	6.71	2.48	6.13	5.26	2.94	4.55	3.71	1.65	5.65	1.64	1.11	1.48
January	5.56	4.01	5.14	4.41	2.03	2.34	9.76	6.84	5.95	5.07	3.29	1.70
February	5.07	4.95	2.33	2.36	4.94	3.19	6.02	5.73	1.22	1.54	4.60	3.27
March	6.44	4.69	1.86	2.10	5.66	4.72	3.36	4.37	2.90	2.10	4.52	7.21
April	2.68	4.85	4.42	2.58	3.03	3.29	3.77	2.90	1.08	1.42	3.55	3.57
May	6.27	2.67	3.22	1.76	5.74	2.73	1.36	0.89	5.74	1.62	8.18	6.06
	32.73	*23.65*	*23.10*	*18.47*	*24.34*	*20.82*	*27.98*	*22.38*	*22.54*	*13.39*	*25.25*	*23.29*
June	2.00	1.39	4.51	1.43	3.56	1.53	1.81	0.63	3.84	1.15	2.43	0.96
July	2.43	0.67	7.74	1.63	5.46	0.71	2.97	0.40	5.05	0.70	2.38	0.40
August	6.87	1.11	2.90	4.03	4.70	0.59	5.61	0.31	6.12	0.90	7.06	0.72
	11.30	*3.17*	*15.15*	*7.09*	*13.72*	*2.83*	*10.39*	*1.34*	*15.01*	*2.75*	*11.87*	*2.08*
September	10.77	3.11	6.13	2.27	6.86	2.04	1.87	0.38	2.65	0.51	2.65	0.53
October	4.80	2.58	4.85	1.93	7.63	3.36	2.15	0.41	0.92	0.17	6.42	1.17
November	4.49	3.04	8.45	5.29	1.12	2.09	3.86	0.64	7.85	1.58	3.32	2.08
	20.06	*8.73*	*19.43*	*9.49*	*15.61*	*7.49*	*7.88*	*1.43*	*11.42*	*2.26*	*12.39*	*3.78*
Total	64.09	35.55	57.68	35.05	53.67	31.14	46.25	25.15	48.97	18.40	49.51	29.15

Month.	1894.		1895.		1896.		Mean.	
	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.
December	5.34	4.12	4.43	2.57	4.88	1.30		
January	3.40	1.77	3.63	3.42	1.52	2.06		
February	5.01	2.15	3.34	1.04	6.65	4.33		
March	1.62	5.21	1.88	3.87	8.20	7.90		
April	3.07	2.44	5.63	4.22	0.96	3.05		
May	6.67	1.88	2.41	1.33	3.09	0.87		
	25.11	*17.57*	*21.32*	*16.45*	*25.30*	*19.51*	*23.44*	*18.00*
June	1.69	1.48	1.89	0.49	3.79	0.97		
July	1.75	0.45	3.95	0.44	3.98	0.86		
August	1.45	0.71	3.10	0.62	4.56	0.76		
	4.89	*2.64*	*8.94*	*1.55*	*12.33*	*2.59*	*12.54*	*2.90*
September	7.49	0.57	1.16	0.09	6.50	0.65		
October	5.94	0.75	3.55	0.40	2.17	0.88		
November	4.44	3.37	2.91	0.82	3.96	1.73		
	17.87	*4.69*	*7.62*	*1.31*	*12.63*	*3.26*	*12.12*	*3.14*
Total	47.87	24.90	37.88	19.31	50.26	25.36	48.10	24.65

The run-off as given is stated by A. Fteley, chief engineer of new Croton aqueduct, to have been corrected as far as necessary for the storage, and accordingly represents approximately the natural run-off of the stream.

Evaporation from the Croton River watershed as given by differences between rainfall and run-off in preceding table.

[Inches on watershed.]

Year.	December to May.	June to August.	September to November.	Total.	Year.	December to May.	June to August.	September to November.	Total.
1870	7.55	8.74	8.70	24.99	1885	6.82	12.12	9.11	28.05
1871	8.79	13.03	6.01	27.83	1886	6.73	8.74	8.24	23.71
1872	2.98	10.86	5.70	19.54	1887	6.21	20.73	4.93	31.87
1873	1.39	6.91	8.80	17.10	1888	9.08	8.13	11.33	28.54
1874	*a* 0.50	9.06	6.55	15.11	1889	4.63	8.06	9.94	22.63
1875	0.70	9.48	6.53	16.71	1890	3.52	10.89	8.12	22.53
1876	*a* 0.02	5.38	8.65	14.01	1891	5.60	9.05	6.45	21.10
1877	2.23	10.52	12.37	25.12	1892	9.15	12.26	9.16	30.57
1878	4.69	8.65	9.60	22.94	1893	1.90	9.79	8.61	20.36
1879	3.98	13.92	4.29	22.19	1894	7.54	2.25	13.18	22.97
1880	7.00	8.95	7.33	23.28	1895	4.87	7.39	6.31	18.57
1881	8.53	7.11	7.39	23.03	1896	5.79	9.74	9.37	24.90
1882	12.41	7.68	12.84	32.93	Mean	5.44	9.64	8.38	23.46
1883	5.86	10.32	9.37	25.55					
1884	9.29	10.39	7.51	27.19					

a During this period the run-off exceeded rainfall.

This stream is an exceedingly good water yielder. The minimum yield for a complete water year for the whole period from 1870 to 1896 was in 1883, in which water year, from December to November, inclusive, the total run-off was 16.83 inches.

The Croton watershed contains 31 lakes and ponds, many of which have been utilized as natural storage basins by constructing dams at their outlets. The following tabulation gives the entire natural and artificial storage, either actually carried out or now under construction, in the Croton watershed:

Storage capacity in the Croton watershed.

	U. S. gallons.
Boyds Corners reservoir	2,727,000,000
Middle Branch reservoir	4,004,000,000
Lake Mahopac *a*	575,000,000
Lake Kirk *a*	565,000,000
Lake Glenida *a*	165,000,000
Lake Gilead *a*	380,000,000
Lake Waccabuc *a*	200,000,000
Lake Tonnetta *a*	50,000,000
Barretts Pond *a*	170,000,000
China Pond *a*	105,000,000
White Pond *a*	100,000,000
Pine Pond *a*	75,000,000
Long Pond *a*	60,000,000

a The lakes and ponds marked thus are owned by the city. Those not marked are city reservoirs.

Storage capacity in the Croton watershed—Continued.

	U. S. gallons.
Peach Pond *a*	230,000,000
Cross Pond *a*	110,000,000
Haines Pond *a*	25,000,000
East Branch reservoir	9,028,000,000
Titticus reservoir	7,000,000,000
Caramel reservoir	9,000,000,000
New Croton reservoir	32,000,000,000
Amawalk reservoir	7,000,000,000
Total storage	73,569,000,000

a The lakes and ponds marked thus are owned by the city. Those not marked are city reservoirs.

The drainage area above the new Croton dam now constructing is 360 square miles. It is considered by the Croton aqueduct officials that the storage afforded by this reservoir system will furnish a daily supply of at least 280,000,000 gallons. At this rate the utilization from this drainage area of 360 square miles will become 778,000 gallons per square mile per day, or 1.20 cubic feet per square mile per second.

MAXIMUM AND MINIMUM FLOW OF STREAMS IN NEW YORK.

The data relating to floods in Genesee River, given on pages 72 to 74, as well as the following facts, may be taken as indicating some of the maximum flows of streams in New York.

FLOODS IN CHEMUNG RIVER.

Severe floods have occurred in this stream several times during the historical period, the most severe being the great flood of June, 1889, which caused serious damage to property at Elmira and Corning. Chemung River is formed by the junction of Tioga and Cohocton rivers at Painted Post, a few miles above Corning, the principal tributary of the Tioga in this State being the Canisteo. Tioga River rises near Blossburg, in Tioga County, Pennsylvania, in an elevated region from 1,500 to 2,500 feet above tide. The descent from the extreme head waters near the Fall Brook Coal Company's mines to Blossburg is at the rate of about 22 feet per mile, after which it descends at the rate of about 11 feet to the mile. The streams tributary to the Tioga are also very rapid; they flow mainly through deep, narrow rock valleys, with their heads generally at an elevation of nearly 2,000 feet above tide. Recently the hill slopes have been largely denuded of timber, thus permitting a rapid descent of the rainfall or melted snow. Hence it results that Tioga River not only naturally rises quickly, but its freshet flows have very high velocities. Canisteo River, joining the Tioga from the west, has an average slope of about 5.5 feet per mile. The slope of the Chemung from Painted Post to Elmira is at the rate of 5.9 feet per mile; thence through the city of Elmira for 3 miles at the rate of 3.5 feet per mile; from Elmira to Chemung, 5.5 feet per mile, and thence to Athens, where it joins the main East Branch of the Susquehanna, 3.4 feet per mile. Cohocton River is also a stream of comparatively low slope.

The foregoing facts indicate that the floods will be slower in rising on Canisteo and Cohocton rivers than on the Tioga. In a general storm, where other conditions are equal, the first flood water to reach Corning and Elmira will come from the Tioga, to be followed later by large flows from the Canisteo and the Cohocton. The areas drained by these streams are approximately as follows:

Areas drained by tributaries of Chemung River.

	Square miles.
Tioga, aside from the Canisteo	750
Canisteo	780
Cohocton	425
Chemung above Elmira	100
Total	2,055

On May 31, 1889, the region tributary to Chemung River above Elmira was visited by a phenomenally heavy rainfall, amounting in many places to nearly 10 inches. The center of this downpour was located about 10 miles south and 15 miles west of Elmira. At Elmira the rainfall was not unusual, 1.5 inches being recorded from 8 p. m. of May 31 to 7 a. m. of June 1; but at Wellsboro, 36 miles southwesterly from Elmira, the total precipitation was 9.8 inches, of which 7.45 inches occurred after 9 p. m. of May 31 and before 7 a. m. of June 1. At South Canisteo, 45 miles westerly from Elmira, a total fall of 6.25 inches was recorded, of which 4.5 inches fell between midnight and 3 a. m. of June 1. Farther up the valley 6 inches were measured between the same hours. At Painted Post a total fall of about 8 inches was reported. At Savonia, on the Cohocton, 5 inches fell, but the fall grew gradually less to the north. At a number of points to the south and southwest rainfalls of from 6 to 8 inches were recorded for May 31, heavy rains occurring as far south as Virginia.

It will be noticed from the preceding statement of the rainfall of May 31 and June 1, 1889, that the heaviest precipitation was practically at the same time over the entire watershed. The following indicates the heights of the flood wave at several points: At Tioga the river was highest about 6.30 a. m. on June 1; Canisteo River was at its highest a little before noon of June 1; at Painted Post the local creeks reached their highest points at 5 a. m., and the Tioga began to rise rapidly about the same time; the Chemung reached a height at this place of 18 feet above low water; at Elmira the river began to rise rapidly about 9 a. m. of June 1 and was at its highest at about 7 p. m.

According to Francis Collingwood,[1] who investigated the Chemung River flood of 1889, for the city of Elmira, the foregoing data indicate that in a flood coming more from the south than from the west the highest water in Chemung River may be looked for about twelve hours after the highest water has passed the Tioga, and at a somewhat later period when the water comes more from the Canisteo and Cohocton rivers. Mr. Collingwood concludes that the flood flow at Elmira will usually be not less than fourteen hours after a heavy rain on the head waters of these streams.

The surveys made by Mr. Collingwood, in which a considerable number of flood elevations were fixed and plotted, show that the discharge of Chemung River at its maximum was about 138,000 cubic feet per second, and the mean velocity 12.72 feet per second. A maximum of 138,000 cubic feet per second, gives 67.1 cubic feet per second per square mile. By the way of comparison, it may be noted that a maximum has been recorded on the Croton watershed of 74.87 cubic feet per second per square mile; also that Genesee River at Mount Morris gave in the flood of 1894 the maximum discharge of 42,000 cubic feet per second, or 48.6 cubic feet per second per square mile.

The Chemung flood of 1889 did considerable damage both at Corning and at Elmira, and the investigations of Mr. Collingwood were with reference to plans for protecting the latter city from devastation by future floods. Several plans were proposed, all including the rectification, clearing, and lowering of the river through the city with such dikes at the side as might be necessary for special protection at exposed points. The estimated cost of these various projects varied from $336,000 to $700,000. So far as known, nothing in the way of constructing the work at Elmira has yet been done.

The city of Corning, which is situated on the banks of Chemung River a few miles above Elmira, was also greatly damaged by the flood of June, 1889. In consequence, it was determined to construct protective works, and an act of the legislature was accordingly passed in 1892, creating a board of river commissioners, with authority to issue bonds for this purpose, under which enactment and amendments thereto bonds to the amount of $150,000 have been issued. The work began in June, 1896, and is now about completed. The plan adopted is to construct earthen dikes to confine the river at all points where it is subject to overflow. The total length of the dikes is about 25,800 feet, or 4.9 miles, and they vary in height from 4 to 19 feet. The river dikes were generally 8 feet wide on top, with a slope of from 3 to 1 (3 horizontal to 1 vertical) on the river side, and a slope of 2 to 1 on the land side.

Whatever the purpose for which an inland stream is to be utilized,

[1] Report on the Prevention of Floods at Elmira.

the first question asked by an experienced engineer is with regard to the minimum flow. If for power development, the minimum flow will determine the amount of power which can be insured on a given head; if for the water supply of a town, the minimum flow will indicate at once the number of people which may be supplied without storage. From every point of view, therefore, a knowledge of the minimum flow is a matter of the first importance. Below are given the minimum flows of the inland streams of the State of New York so far as information is at hand.

LOW-WATER FLOW OF OATKA CREEK.

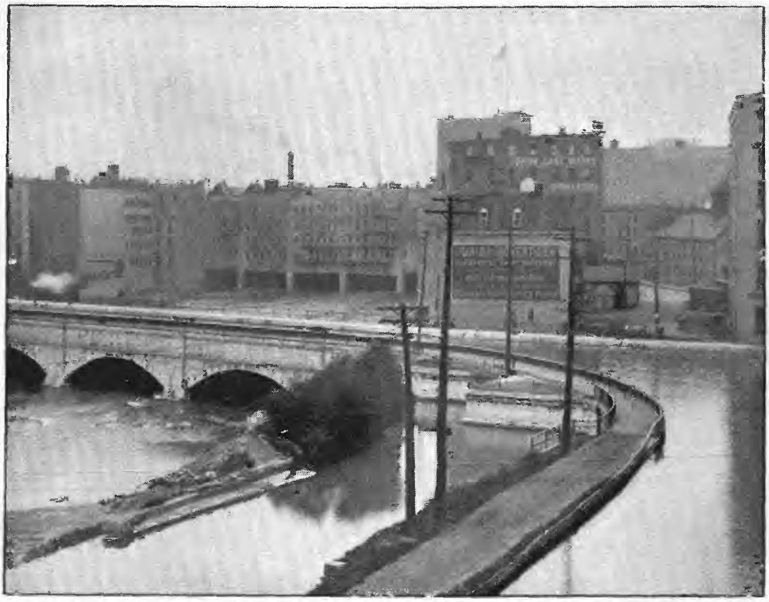
The drainage area of this stream above the point of measurement is 27.5 square miles. The mean flow for the month of August, 1891, was 6 cubic feet per second; for September, 5.83 cubic feet per second; for October, 5.8 cubic feet per second. Expressed in cubic feet per second per square mile, the foregoing results are 0.218 cubic foot for August, 0.212 cubic foot for September, and 0.211 cubic foot for October. Expressed in inches on the watershed, the run-off of this stream for August to October, 1891, was from 0.24 to 0.25 inch per month. For several days during the months of August to October, 1891, the flow of Oatka Creek was down to about 4.2 cubic feet per second, or to about 0.151 cubic foot per square mile per second. On September 26, 1891, the recorded mean flow for the the day was 3.77 cubic feet per second, or 0.137 cubic foot per square mile per second.

As a general proposition, statements of minimum flows of streams ought not to be based on the record of single days, especially on streams where there are mill ponds above the point of measurement, because such accidental circumstances as the holding back of the water may vitiate the result; from this point of view an average extending over as long a period as possible should be taken.

The measurements of Oatka Creek from August to October, 1891, illustrate well the nearly universal tendency of streams to run either at approximately a fixed rate or to decrease only very slowly after the tributary ground water has become well drawn down. For several days at a time the records show only slight variations.

LOW-WATER FLOW OF GENESEE RIVER.

The drainage area above Mount Morris, the first point of measurement, is 1,070 square miles; above Rochester, the second point, 2,365



A. ERIE CANAL AQUEDUCT AND SOUTH SIDE OF MAIN STREET BRIDGE, ROCHESTER

B. GREAT FLOOD OF 1865 AT ROCHESTER, SHOWING LUMBER LODGED AGAINST AQUEDUCT BRIDGE.

square miles. The following table gives the mean monthly flows at Mount Morris and Rochester for several low months of the year 1895:

Mean monthly flow of Genesee River at Mount Morris and Rochester.

Month.	Mount Morris.			Rochester.	
	Mean flow (cubic feet per second).	Cubic feet per second per square mile.	Inches on the water shed.	Mean flow (cubic feet per second.)	Cubic feet per second per square mile.
May	174	0.163	0.19	385	0.380
June	128	0.119	0.13	283	0.226
July	105	0.099	0.11	232	0.165
August	115	0.108	0.12	254	0.169
September	100	0.093	0.10	221	0.106
October	104	0.097	0.11	230	0.093

Comparing the foregoing figures for Mount Morris with those for Rochester for the month of October, 1895, it is seen that the proportion of run-off at Rochester was somewhat less for that month than at Mount Morris, although for the previous months it appears to have been larger. The explanation of this is that there are between Rochester, Mount Morris, and Dansville extensive flats aggregating from 60 to 80 square miles. The temporary ground-water storage of these flats acts to sustain a somewhat more equable flow at Rochester than at Mount Morris, above which point there are proportionately much smaller areas of flats.

The foregoing minimum flows of Genesee River show conclusively that in its present condition it is not a good mill stream. The great variations in run-off are conclusive on this point. The figures show that the run-off of the stream may be exceedingly slack during the summer and fall months.

In the summer of 1846 Daniel Marsh made a series of measurements in order to determine the low-water flow of that year. As the result of 9 measurements made at various times in July and August he placed the minimum flow at Rochester in 1846 at 412 cubic feet per second.

If we examine the meteorological records of western New York for the years 1844 to 1846, we find that the period covered was one of low rainfall. For instance, at Rochester the rainfall for the storage period of the year 1846 (from December, 1845, to May, 1846, inclusive) was only 11.57 inches; the rainfall of the growing period, 11.30 inches; for the replenishing period, 13.16 inches; the total for the water year 1846 being 36.03 inches. For 1845 the total was 34.66 inches. For 1844 the storage period rainfall was 10.52 inches; growing period, 8.23 inches; replenishing period, 7.68 inches; total for the year, 26.43 inches.

At Middlebury Academy, Wyoming County, in the drainage area of Oatka Creek, the rainfall for the water year 1845 was, for the storage period, 12.59 inches; growing period, 4.82 inches; replenishing period, 8.60 inches; total for the year, 26.01 inches. The record for the year 1846 at Middlebury is not given. It is clear, therefore, so far as we have any definite meteorological record, that the measurements made by Mr. Marsh in 1846 were at a time of very low water.

The foregoing statements indicate that apparently the minimum summer flow of Genesee River has decreased from 462 cubic feet per second in 1846 to about 220 cubic feet per second in 1895. As to the reason for this decrease it is believed that the extensive deforestation of the drainage area which has taken place since 1846 offers full explanation. In 1846 the upper Genesee drainage area was still very largely in forest. Probably of the entire area above Rochester the virgin forest was from 65 to 70 per cent of the whole. We have, therefore, apparently a marked case where the deforestation of a large area has materially reduced the minimum run-off.

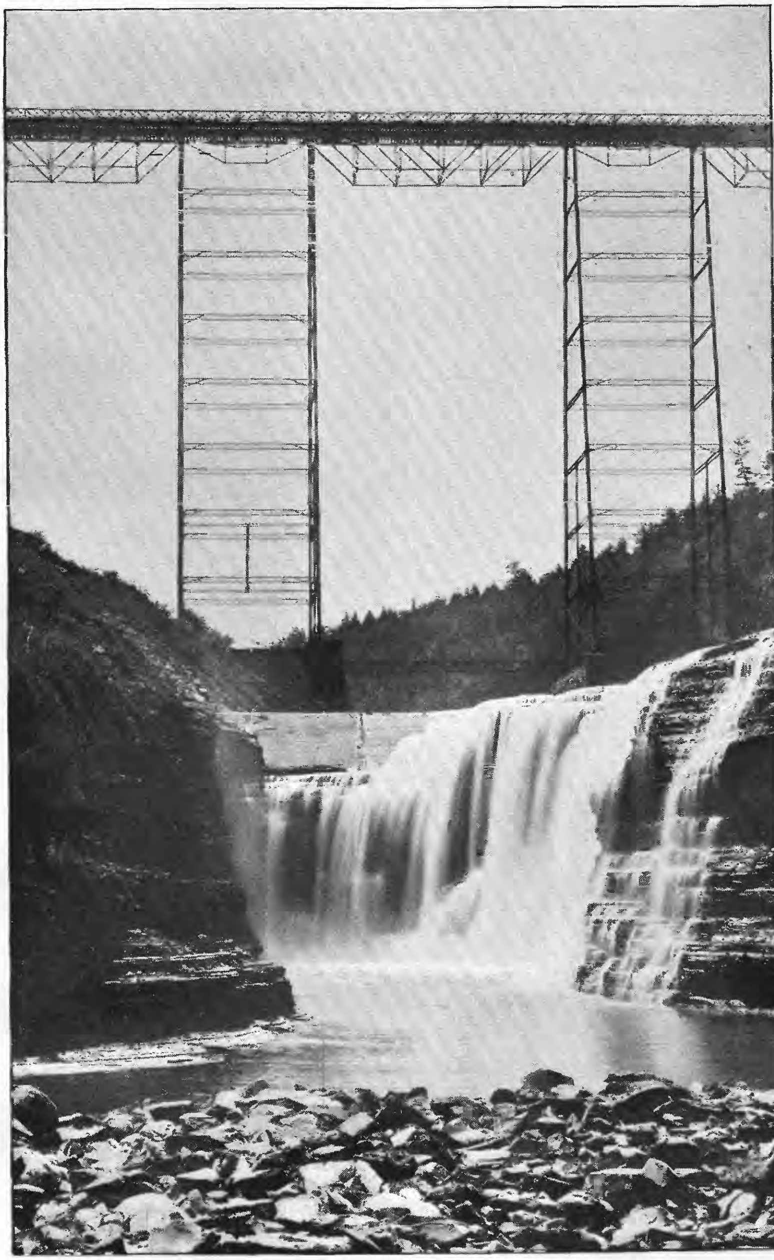
LOW-WATER FLOW OF HEMLOCK LAKE.

According to a report made by Henry Tracy, the minimum flow of Hemlock Lake (drainage area 43 square miles) is 5 cubic feet per second, or 0.116 cubic foot per square mile per second.[1]

The table on pages 76 and 77 gives, as previously stated, the quantity of water passing out of Hemlock Lake for the period covered and without reference to the natural flow. In order to obtain the approximate natural flow for the year we must take into account the mean elevations of lake surface. Thus, for the water year 1880 the mean elevation of the first month, December, was —1.67, while for the last month, November, it was —1.24. The difference (0.43 foot) represents the gain in depth of storage for the year. Computing for the value of this storage in inches on the drainage basin, we have 0.28 inch, which, added to the quantity of water passing out of the lake (3.07 inches), gives as the approximate total run-off for the year 3.35 inches. Since 1880 was a very dry year, we may compute the flow for the entire water year to be 10.3 cubic feet per second, which again amounts to 0.24 cubic foot per square mile per second. So far as known this is the lowest annual run-off thus far measured in the State of New York.

For the five-year period included in this table, the total rainfall and run-off are as follows:

[1] Report on the cost and policy of constructing reservoirs of Conesus, Hemlock, Honeoye, and Canadice lakes. Senate Document No. 40, 1850.



UPPER FALLS OF GENESEE RIVER AT PORTAGE.

Rainfall and run-off of Hemlock Lake.

Water year.	Rainfall.	Run-off.
	Inches.	*Inches.*
1880	21.99	3.07
1881	24.27	8.38
1882	25.46	14.51
1883	32.24	9.29
1884	26.74	12.57
Add for rise in level		0.40
Total	131.70	48.22

For the five-year period the total run-off was therefore only 36.6 per cent of the rainfall. In 1880 the run-off was only 15.2 per cent of the rainfall.

LOW-WATER FLOW OF MORRIS RUN.

The result of a measurement of Morris Run, a tributary of Oatka Creek, the source of a part of the water supply of the village of Warsaw, Wyoming County, made from July 4 to December 26, 1894, is shown by the accompanying table. The measured drainage area is 156 acres, but it may, by reason of the peculiar topography, be somewhat greater than this. The water issues along the thread of the short valley in the form of springs. The measurement was made by a thin-edged notched weir at a point just below the lowest spring. As may be observed, the flow varied greatly at different times, the minimum being 77,630 gallons per day or 7.2 cubic feet per minute, in October. On July 8 the discharge was 238,580 gallons, or 22.1 cubic feet per minute for twenty-four hours. There is a popular impression that springs do not vary their flow at different seasons. The measurements of Morris Run are valuable, therefore, as illustrating that even a spring-fed stream will gradually decrease during a dry season.

Daily mean discharge in cubic feet per minute of Morris Run near Warsaw, New York, in 1894.

Day.	July.	August.	September.	October.	November.	December.
1		16.0	10.4		10.9	
2		17.3				
3		16.7	8.3			10.0
4	19.4	18.3	8.0	7.8		
5	17.8		7.8	8.2		
6	19.5	16.2			9.4	
7	20.9	14.9		6.7		

Daily mean discharge in cubic feet per minute of Morris Run near Warsaw, New York, in 1894—Continued.

Day.	July.	August.	September.	October.	November.	December.
8	22.1					
9	21.2					
10	21.3					
11	20.8			9.4		21.9
12	20.6			7.8		
13	19.7					16.2
14	20.1					
15	19.7			8.8		14.9
16	19.3		8.8		8.2	
17	18.7		8.2	7.8		
18	18.3		19.0	7.8		13.4
19	17.5			7.2	8.2	
20	17.9					13.6
21	21.2		11.1	7.2	8.2	
22	20.6		8.8		8.8	
23	20.0			7.2		
24	20.4		8.8	53.8	8.2	13.6
25	18.7					
26	17.8			8.8	8.2	13.6
27	17.3			7.8		
28	17.1		8.8			
29	17.8		8.8	7.2		
30	16.3			7.2		
31	16.5	11.7		19.0		

LOW-WATER FLOW OF WEST BRANCH OF CANADAWAY CREEK.

In the summer of 1883 measurements were made of the West Branch of Canadaway Creek in Chautauqua County, from July 18 to September 2 of that year. This stream, which is the source of the water supply of the village of Fredonia, has a drainage area above the point of measurement of 4.3 square miles. The valley is deep cut for a distance of 3 miles from the measuring point to its extreme headwaters. Small springs issue frequently throughout the valley. On July 18, 1883, the stream was flowing at the rate of 541,620 gallons in 24 hours, or 50.2 cubic feet per second, and very gradually decreased to 270,000 gallons, or 25 cubic feet per minute, on July 22. Rains between July 22 and July 29 brought the stream up to a discharge of 1,319,000 gallons per day, or 122.1 cubic feet per minute, on the latter date. The flow then gradually decreased during the month of August until, on August 26, it was only 216,000 gallons per day, or 20 cubic feet per minute, which was the lowest point reached during the summer of 1883.

This stream can not be considered a good water yielder. A mean discharge of 216,000 gallons in twenty-four hours from a drainage area of 4.3 square miles represents a yield of 0.334 cubic foot per second, or, what is the same thing, 0.078 cubic foot per square mile per second. It is apparent, therefore, that even a spring-fed stream with a deep valley in Chautauqua County may at times furnish a very small outflow, though it should not be overlooked that the flow of 0.078 cubic foot per square mile per second was the extreme minimum for one day only. The relations of this extreme minimum to the daily flows during the period covered by the measurements may be easily gathered from an inspection of the table. The gradual falling in water yield from August 1 to 26 is the most interesting fact revealed by these measurements.

The following was the rainfall at the point of measurements during the month of August, 1883:

	Inches.
August 3	0.04
August 13	0.10
August 20	0.05
August 23	0.05
August 28	1.98

Daily mean discharge in cubic feet per minute of West Branch of Canadaway Creek, near Fredonia, New York.

[Drainage area, 4.3 square miles.]

Day.	July.	August.	September.	Day.	July.	August.	September.
1		56.5	47.6	17		31.7	
2		50.3	45.0	18	50.2	28.4	
3		46.2		19	49.3	29.3	
4		45.4		20	45.7	31.7	
5		39.8		21	44.0	33.2	
6		36.9		22	25.0	22.9	
7		36.0		23		25.6	
8		34.1		24			
9		34.1		25		22.1	
10		33.2		26		20.0	
11		31.7		27		21.3	
12		30.2		28		105.1	
13		30.2		29	122.1	321.9	
14		32.4		30		101.7	
15		27.0		31	62.4	60.0	
16		27.9					

LOW-WATER FLOW OF SKANEATELES LAKE.

So far as can be learned, no definite statements of the minimum flow from this drainage basin, having an area of 73 square miles, have ever been made. Before the taking of the waters of this lake for the supply of the city of Syracuse the supply was ample for the canal, and close estimates were not made. For the run-off of a water year we find by the table on page 78 that 1897 was the lowest thus far measured, the total of that year being 15.61 inches on the watershed. The indications of the table, so far as they go, are that the Skaneateles area is a good water yielder. Nevertheless, it is improbable that 1897 was a year of minimum flow.

LOW-WATER FLOW OF OSWEGO RIVER.

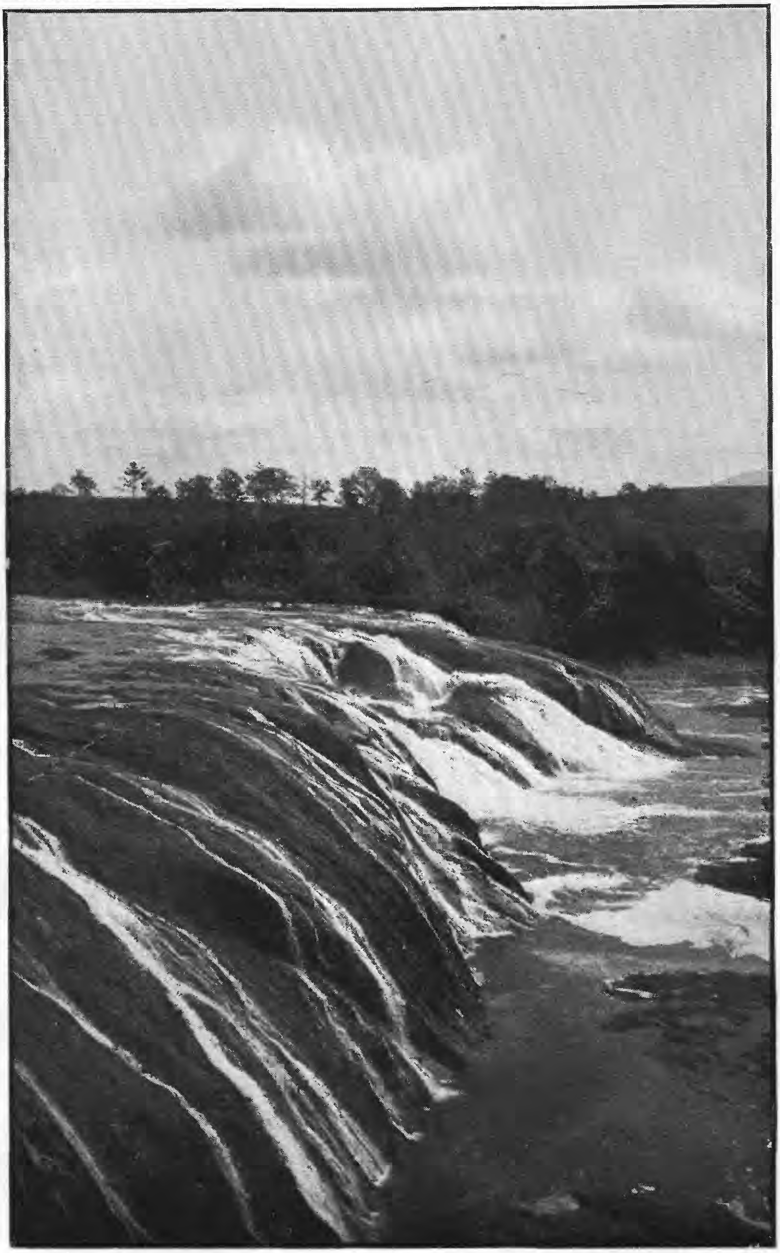
There are no records of any long-continued measurements of the discharge of Oswego River, whose drainage area at the mouth is 5,013 square miles. The minimum flow of this stream has been the subject of judicial inquiry. In August, 1875, in the case of Michael J. Cummings against owners and lessees of the water of the Varick Canal at Oswego, it was decreed:

> (1) That the average flow of water from the Oswego River into the Varick Canal in low water in the summer months is about 45,000 to 50,000 cubic feet per minute; (2) that in extreme low water in the summer, and which usually occurs in the month of July or August, it is about 35,000 cubic feet per minute; (3) that the average flow of the whole three summer months is about 75,000 cubic feet per minute.

Varick Canal is entitled to receive one-half the total flow of the river, less the amount of water required for navigation purposes. Hence the average summer flow, according to the decree, is from 90,000 to 100,000 cubic feet per minute (1,500 to 1,670 cubic feet per second). The extreme low-water flow is placed at 70,000 cubic feet per minute for the whole flow of the river, or at 1,170 cubic feet per second, while the average flow of the whole three summer months is given at about 150,000 cubic feet per minute, or 2,500 cubic feet per second. From the foregoing figures we deduce an extreme minimum of perhaps 0.23 of a cubic foot per square mile per second, with an average of low water in the summer months of about 0.30 to 0.33 of a cubic foot per square mile per second.

LOW-WATER FLOW OF BLACK RIVER.

The drainage area of this stream at Watertown is 1,820 square miles. There is very little definite information as to either the maximum or the minimum flow. Aside from a few measurements made by engineers in the employ of the State at the time of construction of Black River Canal and a few made by Frank A. Hines in 1875, there do not appear to be any measurements of flow. As stated in the Report on Water Power of the United States, Tenth Census, probably the minimum flow



HIGH FALLS OF MOHAWK RIVER AT TIME OF LOW WATER.

in an ordinarily dry season may be taken at from 1,000 to 1,100 cubic feet per second for 24 hours. By reasoning from the data of Hudson River, it may be assumed that in very dry years the minimum flow will be less than this. Taking into account the large surface storage on the numerous lakes at the head waters, it is doubtful if Black River in its natural state will, while present forestry conditions are maintained, ever go below about 0.4 of a cubic foot per square mile per second, although it is claimed to have been less than this in 1849. As is shown in detail in another place, there are a large number of reservoirs upon the upper waters of this stream, which, if properly operated, may be expected to keep the low-water flow at a considerably higher figure than 0.4 of a cubic foot per square mile per second, that figure relating to the natural flow of the stream only.

LOW-WATER FLOW OF MOHAWK RIVER.

The drainage area of this stream is 3,400 square miles. According to David H. Van Auken, the engineer of The Cohoes Company, at Cohoes, the minimum flow of Mohawk River does not exceed 800 cubic feet per second, or 0.235 cubic foot per square mile per second. Since considerable water is taken from Mohawk River for the supply of Erie Canal, probably Mr. Van Auken's statement relates to the amount realized for water power at Cohoes, and, in the absence of definite figures as to the amount abstracted for the canal, must be taken as somewhat general. There is, however, a well-defined feeling that the minimum flow of the Mohawk has been gradually decreasing during the last twenty or twenty-five years, due probably to decreasing deforestation of the drainage area.

LOW-WATER FLOW OF HUDSON RIVER.

The drainage area above Mechanicville is 4,500 square miles. Measurements have been made at Mechanicville since October, 1887, the record of which to November, 1896, is presented in the tables on page 82. The natural flow of this stream is somewhat obscured by the presence of a considerable number of lumbermen's reservoirs on its head waters, the total storage of which aggregates about 4,000,000,000 cubic feet. The month of minimum run-off for the whole period covered by the measurements was July, 1888, the mean for the month being 1,537 cubic feet per second, or 0.39 inch on the watershed. For short periods the mean flow has been less than this. Thus, from August 14 to 19, 1890, the mean flow was 1,080 cubic feet per second; also, from October 2 to 6, 1891, inclusive, the mean flow is given at 1,080 cubic feet per second. For 4,500 square miles drainage area this gives 0.24 cubic foot per second. Taking the diversion for the supply of Champlain Canal into account, we have about 0.29 cubic foot per square mile per second as the actually observed minimum flow.

The figures show, moreover, that the minimum of 0.29 of a cubic foot per second has occurred for only two periods, one of six days and the other of five days, a total of eleven days for the whole period covered by the measurements. For July, 1888, the mean flow, including the diversion which was then occurring for the supply of Champlain Canal, may be taken at 0.37 of a cubic foot per square mile per second. For October, 1891, the mean flow for the whole month was 1,472 cubic feet per second, or, including the diversion to the Champlain Canal, 0.36 of a cubic foot per square mile per second. In July, 1890, the mean flow for the month was 1,950 cubic feet per second, and in several other months, as July, 1893, July, 1895, and September and October, 1895, the mean monthly flow varied from about 2,600 to 2,700 cubic feet per second. Hence we may say that for any business where it is not absolutely indispensable to have permanent power, water power on Hudson River may be developed up to the limit of about 0.4 of a cubic foot per square mile per second, with a prospect of not being interrupted on account of low water more than a few days in each year. For electric power, however, or any application of water power requiring a permanent power every day in the year, the development ought not to be based, under present conditions, on more than about 0.24 to 0.25 of a cubic foot per square mile per second, these latter figures relating especially to that portion of the river from which water is diverted for the supply of Champlain Canal. At points above the Glens Falls feeder the indications of the available data are that permanent power developments may be made up to 0.3 of a cubic foot per square mile per second. As is shown in the section on the water power of Hudson River, nearly all of the plants on that stream are developed far beyond these figures.

LOW-WATER FLOW OF CROTON RIVER.

The drainage area above the point of measurement is 338 square miles. The minimum flow of the main Croton River above the point of measurement, as given by J. J. R. Croes, is 0.178 of a cubic foot per square mile per second. The minimum flow of West Branch of Croton River, with a drainage area of 20.4 square miles, is given at 0.02 cubic foot per square mile per second. The lowest mean monthly flow in the period from 1870 to 1896, covered by the table on pages 83 to 85, is for the month of September, 1870, in which month the average daily run-off was 69,401,200 gallons or 9,265,800 cubic feet in 24 hours. These figures give 7.5 cubic feet per second and 0.318 of a cubic foot per square mile per second.

SUMMARY OF KNOWLEDGE OF LOW-WATER FLOW.

Summarizing the present knowledge of the minimum flow of streams in New York, we may say that in western New York for streams like Genesee River, issuing from regions of heavy, compact soil, mostly deforested, the minimum flows are likely to run as low as 0.1 of a cubic foot per square mile per second, and even less. Spring-fed streams in that region, and those with considerable lake-surface pondage, may be expected to be somewhat greater than this. For the central part of the State the information is too limited to permit of making other than general statements. It is probable, however, that Oswego River, the main stream of the central region, has by reason of its lake pondage and swamp area a minimum flow not much less than 0.3 of a cubic foot per square mile per second. The Mohawk and the upper Hudson may also be placed, while their present condition of forestation is maintained, at a minimum of about 0.3 of a cubic foot per square mile per second. This figure also appears to apply to the Croton drainage area, where there are considerable sand areas, which compensate for the limited forestation. The streams of Long Island issuing from sand plains will give larger yields, the measurements showing a run-off of 0.58 cubic foot per second per square mile drained. The streams of the northern part of the State, which issue from denser forests than the others, may be expected to give minimum yields somewhat in excess of 0.3 of a cubic foot per square mile per second. Little is known as to the yield of streams tributary to the Allegheny, Susquehanna, and Delaware rivers aside from the measurements of Eaton and Madison brooks by Mr. Jervis, in 1835. Apparently no measurements of any other of these streams have been made. It is probable, however, that many of them are not specially different in water-yielding capacity from the Neshaminy, Tohickon, and Perkiomen creeks in Pennsylvania.[1]

In view of the vast importance of a detailed knowledge of stream flow in the State of New York, on account not only of the canal interests of the last seventy-five years, but also on account of the great possibilities of water-power developments, it is a matter of surprise that more extended measurements of the inland streams have not been made.

[1] For details of the measurements of the Neshaminy, Tohickon, and Perkiomen creeks, see a paper, Observations on rainfall and stream flow in eastern Pennsylvania, by John E. Codman. Proc. Eng. Club of Philadelphia, Vol. XIV (July to September, 1897).

[For index, see Part II of this report—Water-Supply Paper No. 25.]

1895.

Sixteenth Annual Report of the United States Geological Survey, 1894–95, Part II, Papers of an economic character, 1895; octavo, 598 pp.

Contains a paper on the public lands and their water supply, by F. H. Newell, illustrated by a large map showing the relative extent and location of the vacant public lands; also a report on the water resources of a portion of the Great Plains, by Robert Hay.

A geological reconnoissance of northwestern Wyoming, by George H. Eldridge, 1894; octavo, 72 pp. Bulletin No. 119 of the United States Geological Survey; price, 10 cents.

Contains a description of the geologic structure of portions of the Bighorn Range and Bighorn Basin, especially with reference to the coal fields, and remarks upon the water supply and agricultural possibilities.

Report of progress of the division of hydrography for the calendar years 1893 and 1894, by F. H. Newell, 1895; octavo, 176 pp. Bulletin No. 131 of the United States Geological Survey; price, 15 cents.

Contains results of stream measurements at various points, mainly within the arid region, and records of wells in a number of counties in western Nebraska, western Kansas, and eastern Colorado.

1896.

Seventeenth Annual Report of the United States Geological Survey, 1895–96, Part II, Economic geology and hydrography, 1896; octavo, 864 pp.

Contains papers on "The underground water of the Arkansas Valley in eastern Colorado," by G. K. Gilbert; "The water resources of Illinois," by Frank Leverett; and "Preliminary report on the artesian areas of a portion of the Dakotas," by N. H. Darton.

Artesian-well prospects in the Atlantic Coastal Plain region, by N. H. Darton, 1896; octavo, 230 pp., 19 plates. Bulletin No. 138 of the United States Geological Survey; price, 20 cents.

Gives a description of the geologic conditions of the coastal region from Long Island, N. Y., to Georgia, and contains data relating to many of the deep wells.

Report of progress of the division of hydrography for the calendar year 1895, by F. H. Newell, hydrographer in charge, 1896; octavo, 356 pp. Bulletin No. 140 of the United States Geological Survey; price, 25 cents.

Contains a description of the instruments and methods employed in measuring streams and the results of hydrographic investigations in various parts of the United States.

1897.

Eighteenth Annual Report of the United States Geological Survey, 1896–97, Part IV, Hydrography, 1897; octavo, 756 pp.

Contains a "Report of progress of stream measurements for the year 1896," by Arthur P. Davis; "The water resources of Indiana and Ohio," by Frank Leverett; "New developments in well boring and irrigation in South Dakota," by N. H. Darton; and "Reservoirs for irrigation," by J. D. Schuyler.

1898.

Nineteenth Annual Report of the United States Geological Survey, 1897–98, Part IV, Hydrography, 1899; octavo, 814 pp.

Contains a "Report of progress of stream measurements for the calendar year 1897," by F. H. Newell and others; "The rock waters of Ohio," by Edward Orton; and "Preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian," by N. H. Darton.

Water-Supply and Irrigation Papers, 1896–1899.

This series of papers is designed to present in pamphlet form the results of stream measurements and of special investigations. A list of these, with other information, is given on the outside (or fourth) page of this cover.

Survey bulletins can be obtained only by prepayment of cost, as noted above. Postage stamps, checks, and drafts can not be accepted. Money should be transmitted by postal money order or express order, made payable to the Director of the United States Geological Survey. Correspondence relating to the publications of the Survey should be addressed to **The Director, United States Geological Survey, Washington, D. C.**

WATER-SUPPLY AND IRRIGATION PAPERS.

1. Pumping water for irrigation, by Herbert M. Wilson, 1896.
2. Irrigation near Phœnix, Arizona, by Arthur P. Davis, 1897.
3. Sewage irrigation, by George W. Rafter, 1897.
4. A reconnoissance in southeastern Washington, by Israel C. Russell, 1897.
5. Irrigation practice on the Great Plains, by E. B. Cowgill, 1897.
6. Underground waters of southwestern Kansas, by Erasmus Haworth, 1897.
7. Seepage waters of northern Utah, by Samuel Fortier, 1897.
8. Windmills for irrigation, by E. C. Murphy, 1897.
9. Irrigation near Greeley, Colorado, by David Boyd, 1897.
10. Irrigation in Mesilla Valley, New Mexico, by F. C. Barker, 1898.
11. River heights for 1896, by Arthur P. Davis, 1897.
12. Water resources of southeastern Nebraska, by Nelson Horatio Darton, 1898.
13. Irrigation systems in Texas, by William Ferguson Hutson, 1898.
14. New tests of pumps and water lifts used in irrigation, by O. P. Hood, 1898.
15. Operations at river stations, 1897, Part I, 1898.
16. Operations at river stations, 1897, Part II, 1898.
17. Irrigation near Bakersfield, California, by C. E. Grunsky, 1898.
18. Irrigation near Fresno, California, by C. E. Grunsky, 1898.
19. Irrigation near Merced, California, by C. E. Grunsky, 1899.
20. Experiments with windmills, by Thomas O. Perry, 1899.
21. Wells of northern Indiana, by Frank Leverett, 1899.
22. Sewage irrigation, Part II, by George W. Rafter, 1899.
23. Water-right problems in the Bighorn Mountains, by Elwood Mead, 1899.
24. Water resources of the State of New York, Part I, by George W. Rafter, 1899.

In addition to the above, there are in various stages of preparation other papers relating to the measurement of streams, the storage of water, the amount available from underground sources, the efficiency of windmills, the cost of pumping, and other details relating to the methods of utilizing the water resources of the country. Provision has been made for printing these by the following clause in the sundry civil act making appropriations for the year 1896–97:

Provided, That hereafter the reports of the Geological Survey in relation to the gauging of streams and to the methods of utilizing the water resources may be printed in octavo form, not to exceed 100 pages in length and 5,000 copies in number; 1,000 copies of which shall be for the official use of the Geological Survey, 1,500 copies shall be delivered to the Senate, and 2,500 copies shall be delivered to the House of Representatives, for distribution. [Approved June 11, 1896; Stat. L., vol. 29, p. 453.]

The maximum number of copies available for the use of the Geological Survey is 1,000. This number falls far short of the demand, so that it is impossible to meets all requests. Attempts are made to send these pamphlets to persons who have rendered assistance in their preparation through replies to schedules or donation of data. Requests specifying a certain paper and stating a reason for asking for it are attended to whenever practicable, but it is impossible to comply with general requests, such as to have all of the series sent indiscriminately.

Application for these papers should be made either to members of Congress or to

THE DIRECTOR,

UNITED STATES GEOLOGICAL SURVEY,

Washington, D. C.