POWER POSSIBILITIES

ON THE

OSWEGATCHIE RIVER

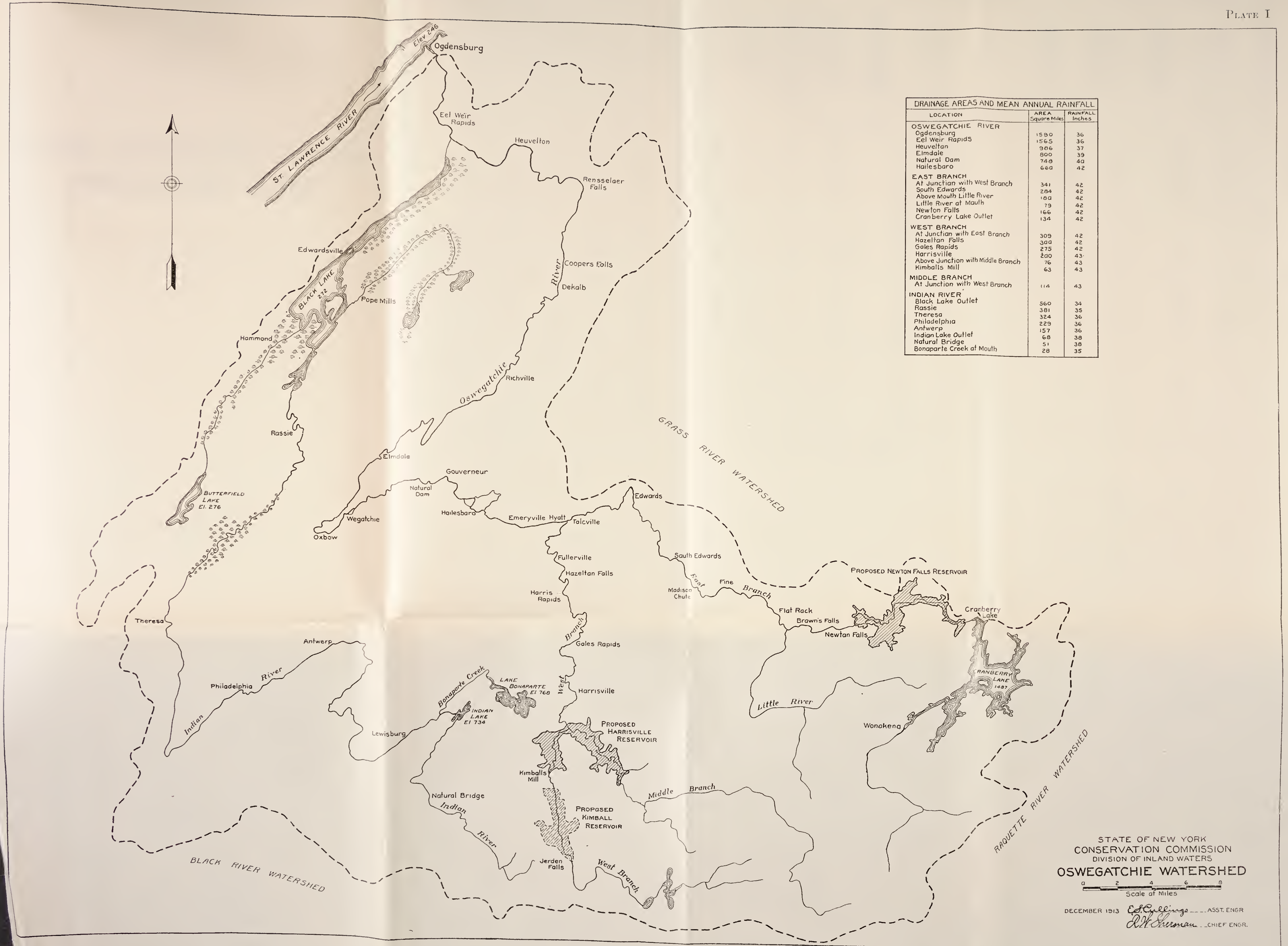
STATE OF NEW YORK

CONSERVATION COMMISSION

ALBANY

STATE OF NEW YORK

CONSERVATION COMMISSION



DRAINAGE AREAS AND MEAN ANNUAL RAINFALL		
LOCATION	AREA Square Miles	RAINFALL Inches
OSWEGATCHIE RIVER		
Ogdensburg	1590	36
Eel Weir Rapids	1565	36
Heuveltan	986	37
Elmdale	800	39
Natural Dam	748	40
Hailesbaro	660	42
EAST BRANCH		
At Junctian with West Branch	341	42
South Edwards	284	42
Above Mouth Little River	180	42
Little River at Mauth	79	42
Newton Falls	166	42
Cranberry Lake Outlet	134	42
WEST BRANCH		
At Junctian with East Branch	309	42
Hazeltan Falls	300	42
Gales Rapids	275	42
Harrisville	200	43
Above Junction with Middle Branch	76	43
Kimballs Mill	63	43
MIDDLE BRANCH		
At Junction with West Branch	114	43
INDIAN RIVER		
Black Lake Outlet	560	34
Rassie	381	35
Theresa	324	36
Philadelphia	229	36
Antwerp	157	36
Indian Lake Outlet	68	38
Natural Bridge	51	38
Bonaparte Creek at Mouth	28	35

STATE OF NEW YORK

CONSERVATION COMMISSION

POWER POSSIBILITIES ON THE OSWEGATCHIE RIVER

ALBANY

J. B. LYON COMPANY, PRINTERS

1914

REPORT ON THE POWER POSSIBILITIES OF THE OSWEGATCHIE RIVER.

Provisions of Conservation Law Covering Water Power Investigations.

The Conservation Law, among other things, provides for the systematic investigation of the power resources of the state as follows:

"§ 21. Systematic plan. It shall be the duty of the commission to continue investigations of the water resources of the state, including the systematic gaging of rainfall and stream flow throughout the state, so as to complete a comprehensive system for the entire state, for the conservation, development, regulation and use of the waters in each of the principal watersheds of the state with reference to the accomplishment of the following public uses and purposes:

1. The prevention of floods and the protection of the public health and safety in the watershed.

2. The supply of pure and wholesome water from the watershed to municipalities and the inhabitants thereof and the disposal of sewage.

3. Drainage and irrigation.

4. The development, conservation and utilization of water power in the watershed and to create a revenue for the state.

5. The protection of the public right of navigation.

It shall be the duty of the commission to investigate the possibilities of improving and extending navigation in rivers, lakes and other water courses and bodies of water, outside the canal system in each such watershed, including an investigation into the character of such waters and the use thereof for navigation and with the view of collecting data to determine the upstream limits of the public right of navigation, and to report from time to time the result of such investigations to the end that a complete plan will be presented for the economical and comprehensive development of all the water resources, for all the aforesaid purposes, in each of the principal watersheds of the state; and each of said purposes is hereby declared to be a public use or is continued as a public use. It shall investigate and report as to the privileges heretofore granted affecting the use of the waters aforesaid and as to the terms of such privileges and whether the conditions thereof have been complied with or the terms expired or whether revocable and investigate and report as to the diversion rights in streams heretofore acquired by the state and as to the use being made of the waters affected thereby.

Each such plan for any watershed shall set forth the developments already made and authorized to be made in such watershed for one or more such purposes, whether by the state or otherwise, and the extent to which any such existing or authorized development may be improved, enlarged or extended so as to increase or extend its efficiency for any of the aforesaid purposes, to the end that all developments in each watershed for all such purposes may be co-ordinated and unified, the rights of the state asserted and utilized so as to combine the most economical construction, maintenance and operation, and the most efficient service, with the production of the largest net revenue and public benefit to the state which may be practicable."

In compliance with these provisions of the Conservation Law the Commission has, as funds appropriated by the Legislature have permitted, been gathering data and making investigations regarding the power possibilities of the principal streams of the State. The results of such investigations and studies are made available to the public through publication thereof in the annual reports of the Conservation Commission.

Because of its importance as a power-producing stream and its undeveloped power possibilities, the Oswegatchie river was in the spring of 1912 selected as the next in order for surveys, investigations and report. A complete power survey of the river and its main tributaries was made, including an accurate profile of the river channel, detailed topographic surveys of the most desirable reservoir sites, and an examination into the various conditions affecting the development of power at each of the present plants, as well as at undeveloped power sites. The head in use at each plant was measured, and data secured as to pondage, hydraulic installation, use of power, probable future needs, etc. Some of the data secured from owners regarding existing plants must be treated as confidential, and therefore cannot be published, but the principal physical conditions affecting the development of power

PLATE II


PROFILE INDIAN RIVER
PROFILE OSWEGATCHIE RIVER
PROFILE EAST BRANCH
PROFILE WEST BRANCH
ELEVATION
DISTANCE IN MILES FROM OGDENSBURG
Black Lake El 272
ROSSIE
THERESA
PHILADELPHIA
ANTWERP
WOODS MILL
LEWISBURG
INDIAN LAKE
OGDENSBURG
EEL WEIR RAPIDS
BLACK LAKE OUTLET
HEUVELTON
RENSSELAER FALLS
COOPERS FALLS
RICHVILLE
ELMDALE
WEGATCHIE
NATURAL DAM
GOUVERNEUR
HAILESBORO
EMERYVILLE
HYATT
TALCVILLE
EDWARDS
SOUTH EDWARDS
MADISON CHUTE
FINE
FLAT ROCK
BROWNS FALLS
NEWTON FALLS
CRANBERRY LAKE
Junction of East and West Branches
FULLERVILLE
HAZELTON FALLS
HARRIS RAPIDS
GALES RAPIDS
HARRISVILLE
Proposed Reservoir
STATE OF NEW YORK
CONSERVATION COMMISSION
DIVISION OF INLAND WATERS
PROFILES OF OSWEGATCHIE RIVER AND TRIBUTARIES
DECEMBER 1913
ASST ENGR
CHIEF ENGR

at both the present plants and the undeveloped power sites are set forth and discussed in the following pages.

Oswegatchie Watershed. The Oswegatchie river has its source in the lakes and ponds on the westerly side of the Adirondack plateau, in the southern part of St. Lawrence county and the northern parts of Herkimer and Lewis counties. The main stream, known as the East Branch, forms the outlet of Cranberry lake and flows in a generally northwesterly direction, joining the West Branch near Talcville and emptying into the St. Lawrence river at Ogdensburg. The Indian river, one of the largest tributaries, rises in the sparsely wooded hills of northern Lewis county, flows in a northerly direction across an extensive sandy plain, into and through Black lake, and joins the Oswegatchie just above Eel Weir bridge, about five miles from the city of Ogdensburg. The upper reaches of the watershed are mountainous and densely wooded; the middle portion is a hilly region entirely denuded of marketable timber and not suitable for farming purposes; the lower section consists mainly of rolling farm lands, but includes a considerable area of swamp land in the vicinity of Black lake. The prevailing rock is Adirondack gneiss, with deposits of limestone and sandstone on the lower reaches of the watershed. The drainage area at Ogdensburg is 1,590 square miles, and the mean annual rainfall about 36 inches.

With the exception of the Indian river, which is lacking in desirable storage sites, the Oswegatchie river and its main tributaries are to a remarkable degree naturally adapted to economical power development. Nearly one-third of the total drainage area lies from 1,000 to 1,500 feet above sea level, and has an annual rainfall in excess of 40 inches. The fall of the river channel is concentrated by a series of comparatively quiet pools separated by low waterfalls and short rapids. In nearly every case, dams can be located on foundations of solid rock. Adequate storage is obtainable on the headwaters of the stream above the highest power developments, thus allowing the use of the stored water at all the power plants below, covering a remarkably high percentage of the total fall of the river; astonishingly near to all of it being economically available. As shown on the profile of the river, Plate II, and in Table III, the stored water from the proposed

Newton Falls and Cranberry Lake reservoirs can be made available through a total working head of 1,048 feet, and the water from the proposed Harrisville reservoir can be used through 523 feet of working head.

Present Plants.

The majority of the present plants are low-head developments supplying power for pulp grinding, talc mining and milling, grist-mills, small sawmills, electric lighting plants and other small shops and factories. Many of these plants are using old obsolete wheels which utilize but a small percentage of the power available thereat; consequently the average efficiency is extremely low. There are, however, several modern and up-to-date plants on the river, and others are in process of construction or under consideration, but there still remains a large field for future developments, both in sites not heretofore developed, and in the improvement of existing plants and plants that have been abandoned but which can now be profitably developed if sufficient storage is made available.

As most of the present plants and undeveloped possibilities are separately too small, without a comprehensive transmission system to which all might be connected, to allow of economical transmission to distant centers of population, it is probable that a local market must be developed before the power possibilities of the river can be fully utilized. That such a market will soon be fund there is no doubt.

Mineral Resources of Northern New York.

The mineral resources of Northern New York are rich and varied. In 1912, 61,619 tons of talc (over 40 percent. of the total production of the United States) were produced in St. Lawrence county; the production of iron ore at Benson Mines is being greatly increased, and other ore-beds are being developed; a rich deposit of zinc ore is being developed at Edwards, and recent prospecting has resulted in the discovery of additional deposits in different localities; pyrite, used chiefly in acid manufacture, is produced in considerable quantities; large marble and limestone quarries in the vicinity of Gouverneur and Natural Bridge have been operated for a number of years. With the decline in the lumber and paper industry due to the scarcity of timber, it is believed that the exploitation of these mineral resources will be actively prosecuted if a sufficient quantity of economical power is available. From the investigations and studies hereinafter discussed, it is believed that with proper regulation, the Oswegatchie river will be capable of supplying such power at a price which will permit the full development of all the natural resources of this region.

Streamflow Studies.

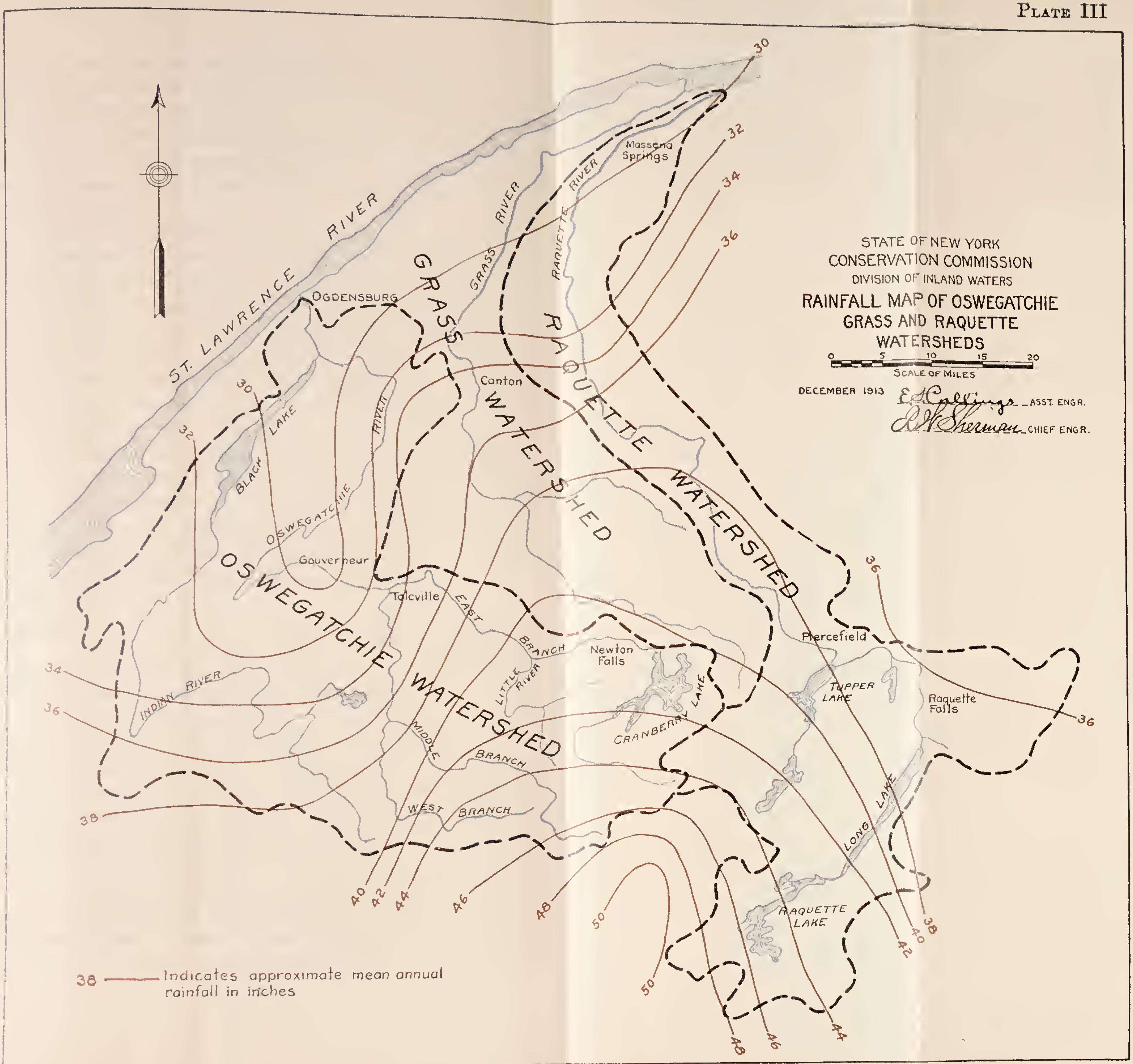
Data Available. The first requisite in the investigation of a storage or power project is a knowledge of the flow of the stream under consideration, both as to its mean annual runoff, and its variation during the different seasons of the year. Streamflow data on the Oswegatchie river are extremely limited; until the fall of 1912, the only gaging station on the river was that at "Eel Weir Bridge," just below the outlet of Black lake. This station has been maintained since 1903. In October, 1912, a gaging station was established at Newton Falls, on the East Branch, and in June, 1913, another at the power plant of the Uniform Fiberous Talc Company at the mouth of the West Branch, near Talcville. The records from the last two stations cover so short a period that they are not yet of much value in estimating the average flow of the river, and the discharge at the Eel Weir Bridge station is so modified by artificial storage in Cranberry lake and by natural storage in Black lake and the surrounding swamps that these records, too, are of rather limited value in estimating the probable runoff at points above the outlet of Black lake. Since 1895, the gate-keeper at Cranberry lake has made weekly reports of the number of "blocks" in the outlet sluiceways and of the depth of water flowing over each block, but there is so much variation in these records that it has been found impossible to compute from them a continuous estimate of discharge.

Because of this lack of direct measurements at most of the points under consideration the probable runoff must at present be deduced from the records of an adjacent watershed having similar characteristics as to topography and climate. This is done by means of a "conversion factor" as explained in Appendix I. For this purpose, the records of the Raquette river promise the most accurate results. The physical and climatic characteristics of both watersheds are very much alike; both rivers have their headwaters on the northwesterly side of the Adirondack Plateau at about the same altitude; both have similar topography and about the same relative proportion of wooded and cleared lands; and both have about the same mean annual temperature and mean annual rainfall. The only material difference between the two watersheds is that the Raquette has a somewhat larger ratio of natural lake surface to drainage area. This condition would probably make the computed flow of the Oswegatchie somewhat less "flashy" than the natural flow, though existing records of floods indicate that this difference is very slight. Good streamflow records are available at the following points on the Raquette river: at Massena Springs a gaging station has been maintained since 1904; at Piercefield, since 1908; and at Raquette Falls since 1908, except during the winter months. Rainfall records covering both watersheds have been maintained for various periods at the following points:

Watertown	50	years
Theresa	6	"
Ogdensburg	20	"
Gouverneur	27	"
Canton	24	"
Potsdam	20	"
Malone	15	"
Tupper Lake	12	"
Forked Lake	18	"

From these records the mean annual rainfall can be computed with a fair degree of accuracy. The accompanying rainfall map, Plate III, showing lines of equal rainfall was plotted from these records.

In the following estimates of streamflow, the above rainfall and runoff records have accordingly been used for all points above the outlet of Black lake. An estimate computed in this manner is not to be considered as an actual record of the discharge at the given points, but rather as a prediction of the most probable runoff to be expected in the future. Due to local rainfalls and local topo-


STATE OF NEW YORK
CONSERVATION COMMISSION
DIVISION OF INLAND WATERS
RAINFALL MAP OF OSWEGATCHIE GRASS AND RAQUETTE WATERSHEDS
0 5 10 15 20
SCALE OF MILES
DECEMBER 1913
E. S. Cullings ASST. ENGR.
R. W. Sherman CHIEF ENGR.
ST. LAWRENCE RIVER
GRASS RIVER
RAQUETTE RIVER
Massena Springs
Ogdensburg
Canton
BLACK LAKE
OSWEGATCHIE RIVER
Gouverneur
Talcville
EAST BRANCH
LITTLE RIVER
Newton Falls
CRANBERRY LAKE
INDIAN RIVER
MIDDLE BRANCH
WEST BRANCH
Piercefield
TUPPER LAKE
Raquette Falls
LONG LAKE
RAQUETTE LAKE
GRASS WATERSHED
RAQUETTE WATERSHED
OSWEGATCHIE WATERSHED
30
32
34
36
38
40
42
44
46
48
50
38 Indicates approximate mean annual rainfall in inches

graphical conditions, the actual discharge for any given month at a given point may differ considerably from the computed discharge for that month, but the average for a term of years should be reasonably accurate. These figures are therefore subject to revision when more precise data become available. Existing data are, however, as complete as are ordinarily found when a new development is being considered.

To determine the resulting streamflow due to the present regulation from the Cranberry Lake reservoir, a depletion curve (Plate IV), showing the stage of the lake from 1904 to 1912 was plotted from the gate-keeper's records for that period. From this curve and an approximate capacity curve of the reservoir, the monthly depletion (or storage, considered as negative depletion) was computed and added, algebraically, to the previously computed natural flow for each month covered by the Raquette River records. Owing to some uncertainty as to the actual capacity of the Cranberry Lake reservoir (see page 12) and to the crude method of operating the gates, the estimated depletion for any particular month may be subject to a considerable error. The line representing this regulation is plotted on the power-percentage-of time curves only to indicate in a general way the benefits derived from the lake under the present method or regulation.

Indian River. On this river no streamflow records of any kind are available, and due to the great difference between the physical characteristics of this watershed and the surrounding watersheds, it is extremely difficult to make even a rough estimate of the runoff. The river rises in the wooded hills above Natural Bridge, flows through an extensive sandy plain between Lewisburg and Theresa, and through large swamps below Theresa and around Black lake. The runoff from the headwaters is probably comparable with that of West and Middle Branches of the Oswegatchie, but from the sand plain it is certainly much less, while from the swamp areas it is impossible to make a reliable estimate of runoff without actual gagings. Between Theresa and the outlet of Black lake there are over twenty square miles of lake and swamp surface. During the summer months the evaporation of these areas is extremely high; from the data at hand it seems probable that at certain times this evaporation may equal or even exceed the yield of the Indian river. The latter case would cause a back-flow from the Oswegatchie river into Black lake, although there are not sufficient data at hand to show that this has actually occurred. Because of these conditions it is considered inadvisable to attempt an estimate of the flow of the Indian river until more definite data are available.

Storage Reservoirs.

Reservoirs Necessary. As the value of any hydraulic power development is, to a great extent, dependent on the amount of flow which can be constantly maintained, the location of storage reservoirs on the headwaters of a stream subject to any considerable fluctuation in discharge is of prime importance. In common with most other rivers of the state, the Oswegatchie exhibits, in its natural state, such an irregularity of flow that the power obtainable from minimum discharge is far below that which can be obtained by means of scientific regulation. That this condition was early realized is shown by the construction nearly fifty years ago of the Cranberry Lake reservoir for storage purposes.

The investigation of the storage possibilities of the Oswegatchie watershed was accordingly made one of the principal features of the surveys and studies of 1911 and 1912. All promising storage sites were thoroughly investigated and in several cases detailed topographic surveys were made. The topography of the headwaters of the river fortunately presents opportunities for the creation of storage reservoirs of sufficient capacity to effect a high degree of regulation, and at a very reasonable cost, considering the fall through which such regulation will be effective.

Cranberry Lake Reservoir. This lake is the highest of the available storage basins. It is situated in the southeasterly corner of St. Lawrence county at an elevation of 1,487 feet above sea level, and forms the source of the east branch of the Oswegatchie river. Its distance from Ogdensburg is about 46 miles in a straight line, or 110 miles along the course of the river. At the outlet of the lake the drainage area is 134 square miles, and the mean annual rainfall about 42 inches. The entire catchment area is mountainous and densely wooded.

Dam at Outlet of Cranberry Lake.

Proposed Newton Falls Reservoir.
Site for Regulating Dam.

The present reservoir was built in 1867 by a commission of power owners acting under authority of an act of legislature. Definite information as to original conditions is lacking, but from the data at hand it appears that the lake in its natural condition, prior to 1867, had an area of 5.5 square miles, and that the original dam raised the surface between 12 and 13 feet, increasing its area to 11 square miles. It also appears that in 1889, the crest of the dam was lowered one foot to prevent the water from flowing over the divide between Cranberry lake and Silver pond. Assuming this to be true, and that the original surface of the lake was raised at least 12 feet, the present area is about 10.5 square miles, and the present capacity about 2.5 billion cubic feet. The gate-keeper's records for the past 10 years (see Plate IV) would indicate, however, that in the ordinary year not more than 1.5 billion cubic feet of this storage is utilized. Only once during this time is there any record of the reservoir being entirely emptied and that was during the fall of 1908, while the outlet sluiceways were being repaired. Objections from cottage owners have also had considerable influence in preventing the complete utilization of this storage.

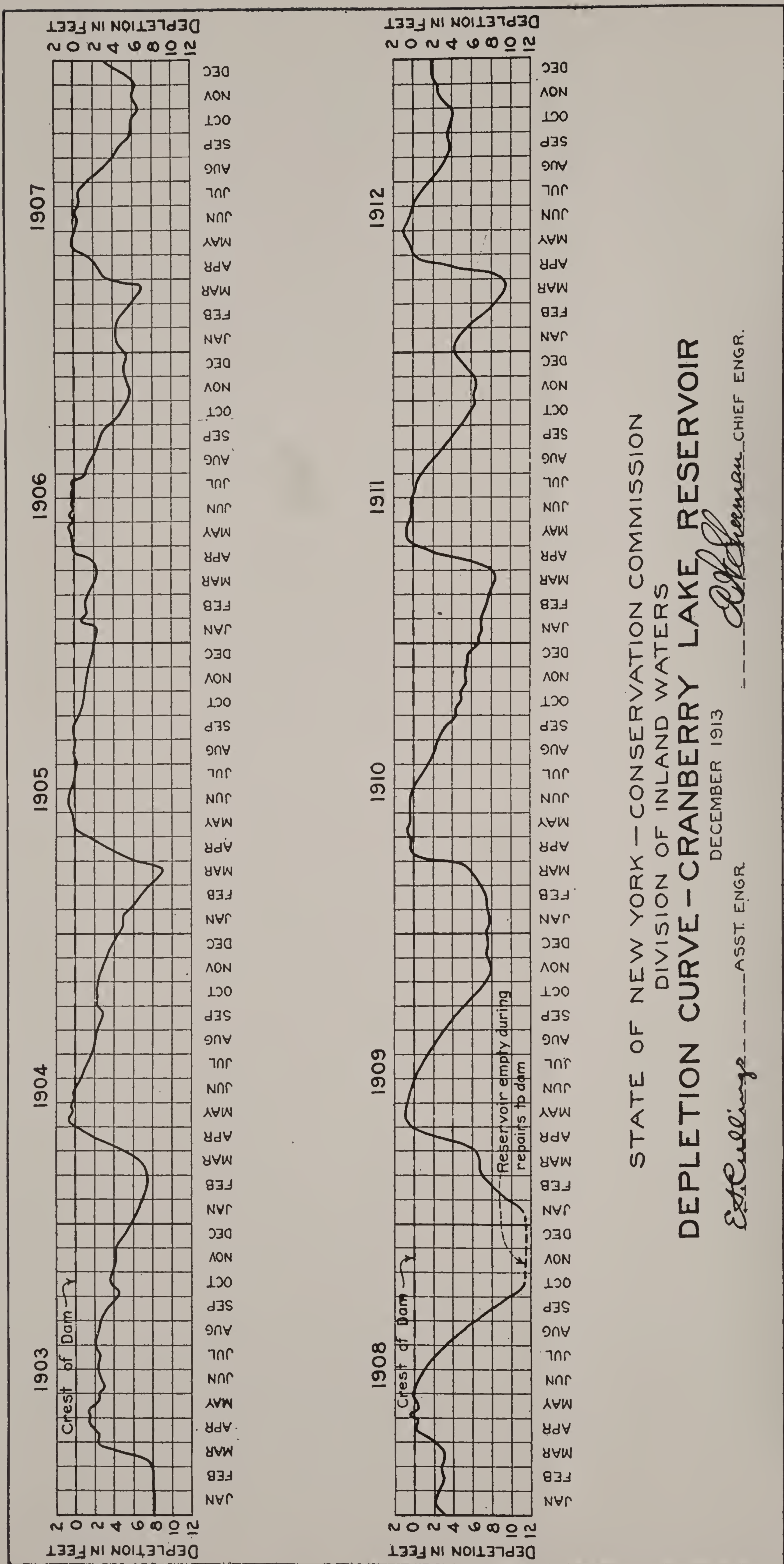
The regulating dam is a timber crib structure about 13 feet high, having a spillway 80 feet long, a logway 5 feet wide and 4 feet deep, and four outlet sluiceways each about 6 feet, 9 inches wide and 13 feet, 6 inches deep. The sides of these sluiceways are provided with vertical grooves into which 12-inch stop-logs are placed. The discharge from the reservoir is controlled by dropping in, or removing, one or more of these stop-logs. This method of regulation, as shown on the accompanying power-percentage-of-time curves is extremely crude and inefficient. The exact capacity of the reservoir is unknown, and there is no way of measuring the amount of water which is being drawn from the lake, or of how much should be drawn to maintain a given flow at any point on the stream below. Due to these conditions, but a small percentage of the benefit which should be obtained from the reservoir is at present realized. The dam leaks badly, and is in a very poor state of repair; several serious leaks have occurred within the last few years. In the near future the dam will have to be entirely rebuilt. When the original dam was built no attempt to clear the flowed land was made; in several places even standing timber was allowed to remain. Consequently the shores are now covered with dead and decaying trees and stumps, endangering navigation and detracting greatly from the beauty of the lake.

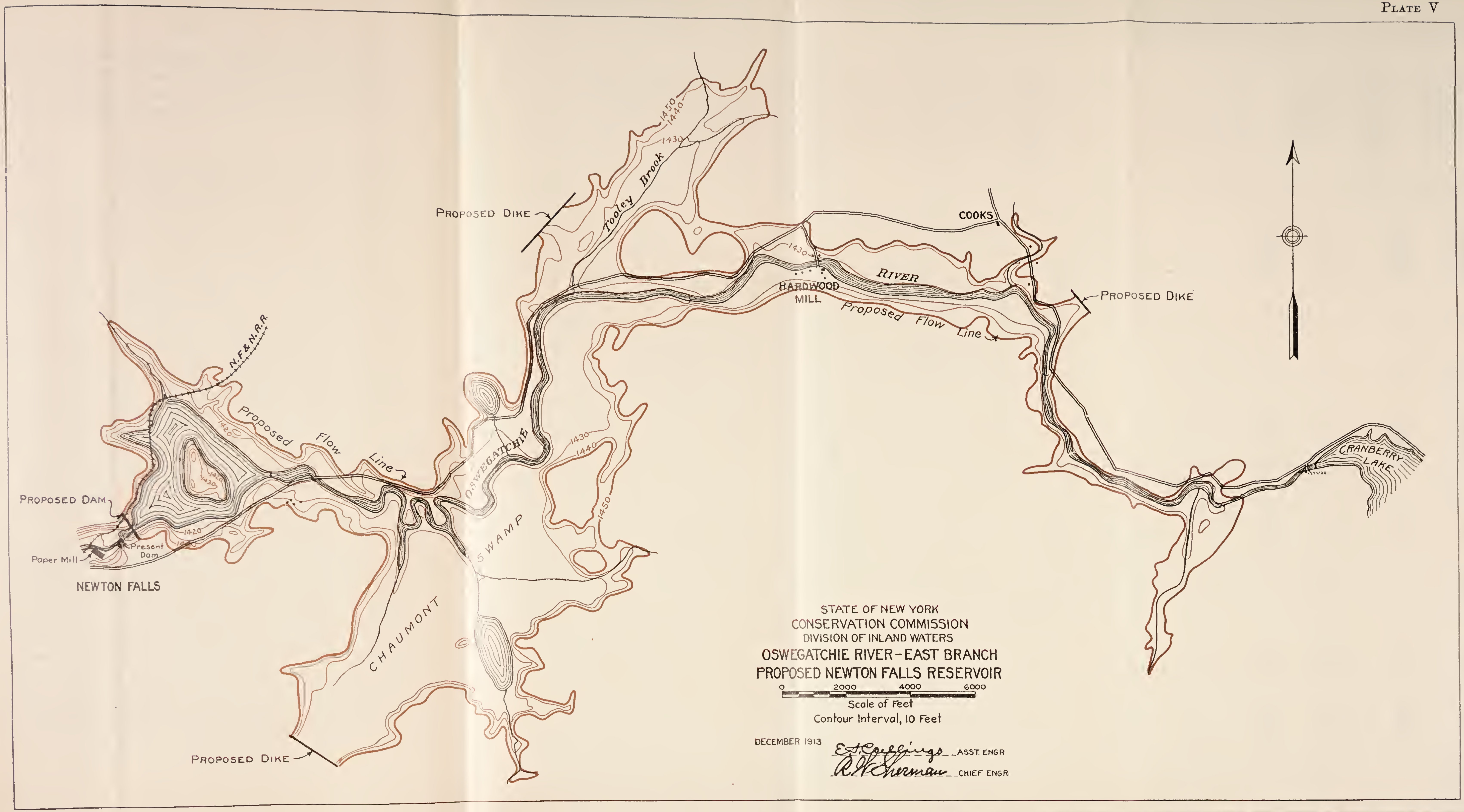
From the investigations and surveys made in 1912 it appears, after giving due consideration to the use of the lake for both storage and recreation purposes, that the greatest benefit from this reservoir can be obtained by operating it in conjunction with the proposed reservoir above Newton Falls, hereinafter considered in detail. The Newton Falls reservoir will back water to within a half-mile of the Cranberry Lake dam, and as there are no valuable power sites between the two reservoirs, there appears to be no reason why they should not be operated together. If this were done, it would be unnecessary to draw from Cranberry lake until late in the fall, and the lake surface could be maintained at spillway level until after the close of the summer season.

Proposed Cranberry Lake Reservoir.

From the data at hand, the most feasible plan for the utilization of this storage seems to be to replace the present dam with a masonry structure (perferably of reinforced concrete, unless ledge rock is found near the surface) having the same spillway elevation as at present, but with provision for 12-inch flashboards to increase the storage depth by one foot. As the original dam was lowered one foot in 1889 there appears to be no reason why this height should not be restored at the present time. No damage would be done to existing structures on the lake shores, and a low earth dike would prevent the water from spilling over into Silver pond. A small amount of dredging at the outlet would permit a depletion of 14 feet. This would provide a total storage capacity of about 3.0 billion cubic feet. The total cost of rebuilding this dam including the earth dike above mentioned is estimated at $79,000. This estimate is based on a reinforced concrete structure founded on gravel, with a deep cut-off wall. If further sub-surface exploration shows the existence of ledge rock near the surface the cost may be materially reduced.

The proposition to increase the height of the regulating dam by four feet was also investigated. This increase would provide a total storage capacity of 4.0 billion cubic feet. But the additional


STATE OF NEW YORK — CONSERVATION COMMISSION
DIVISION OF INLAND WATERS
DEPLETION CURVE - CRANBERRY LAKE RESERVOIR
DECEMBER 1913
ASST. ENGR.
CHIEF ENGR.
DEPLETION IN FEET
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
Crest of Dam
Reservoir empty during repairs to dam
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC


PROPOSED DIKE
Tooley Brook
1450
1440
1430
COOKS
HARDWOOD
MILL
RIVER
Proposed Flow Line
PROPOSED DIKE
N.F.&N.R.R.
Proposed Flow Line
1420
OSWEGATCHIE
1430
1440
1450
CRANBERRY LAKE
PROPOSED DAM
Present Dam
Paper Mill
NEWTON FALLS
SWAMP
CHAUMONT
PROPOSED DIKE
STATE OF NEW YORK
CONSERVATION COMMISSION
DIVISION OF INLAND WATERS
OSWEGATCHIE RIVER - EAST BRANCH
PROPOSED NEWTON FALLS RESERVOIR
0 2000 4000 6000
Scale of Feet
Contour Interval, 10 Feet
DECEMBER 1913
ASST. ENGR
CHIEF ENGR

cost of structures and the damage to property on the lake shores would be so great that the cost of the additional storage would be prohibitive. The same amount of storage can be more economically obtained by increasing the capacity of the proposed Newton Falls reservoir.

Proposed Newton Falls Reservoir.

From Cranberry lake to Newton Falls, a distance of about 10 miles, the river flows through a flat swampy area having an average elevation of about 1,425 feet above sea level. It is proposed to flood this area by constructing a dam at Newton Falls with a crest 34 feet higher than that of the existing dam. This would flood an area of 5.25 square miles and provide a storage capacity of 3.0 billion cubic feet. The capacity of the reservoir is limited by the yield of the catchment area rather than by the topographical features of the basin. At Newton Falls the drainage area is 166 square miles, and the mean annual rainfall about 42 inches. It is estimated that in ordinary years, the proposed storage capacity of 6.0 billion cubic feet (including Cranberry lake) will completely regulate the discharge at Newton Falls. In wet years the capacity of this reservoir might be increased by about 0.3 billion cubic feet by the use of 24-inch flashboards.

In the construction of the reservoir, a masonry dam having a maximum height of 62 feet, and a length, at spillway level, of about 950 feet, will be required at a point about 400 feet above the present Newton Falls dam. At this point the valley is quite narrow and an outcrop of hard granitic rock is found on both sides of the river. Additional work is needed in the way of borings and test pits to locate the surface of this rock at all points in the section. Good sand and stone for concrete and cyclopean masonry can be found near the proposed site of the dam. In addition to this dam, three earth dikes will be required to prevent the water from spilling over into adjacent watersheds. The largest of these dikes, across the Chaumont swamp, will have a maximum height of 46 feet and a top length of about 1,750 feet. The bed of the swamp at this point is composed of from 4 to 8 feet of muck underlaid by a bed of fine gray sand and rock flour. Good material for an embankment can be found within half a mile of

STATE OF NEW YORK
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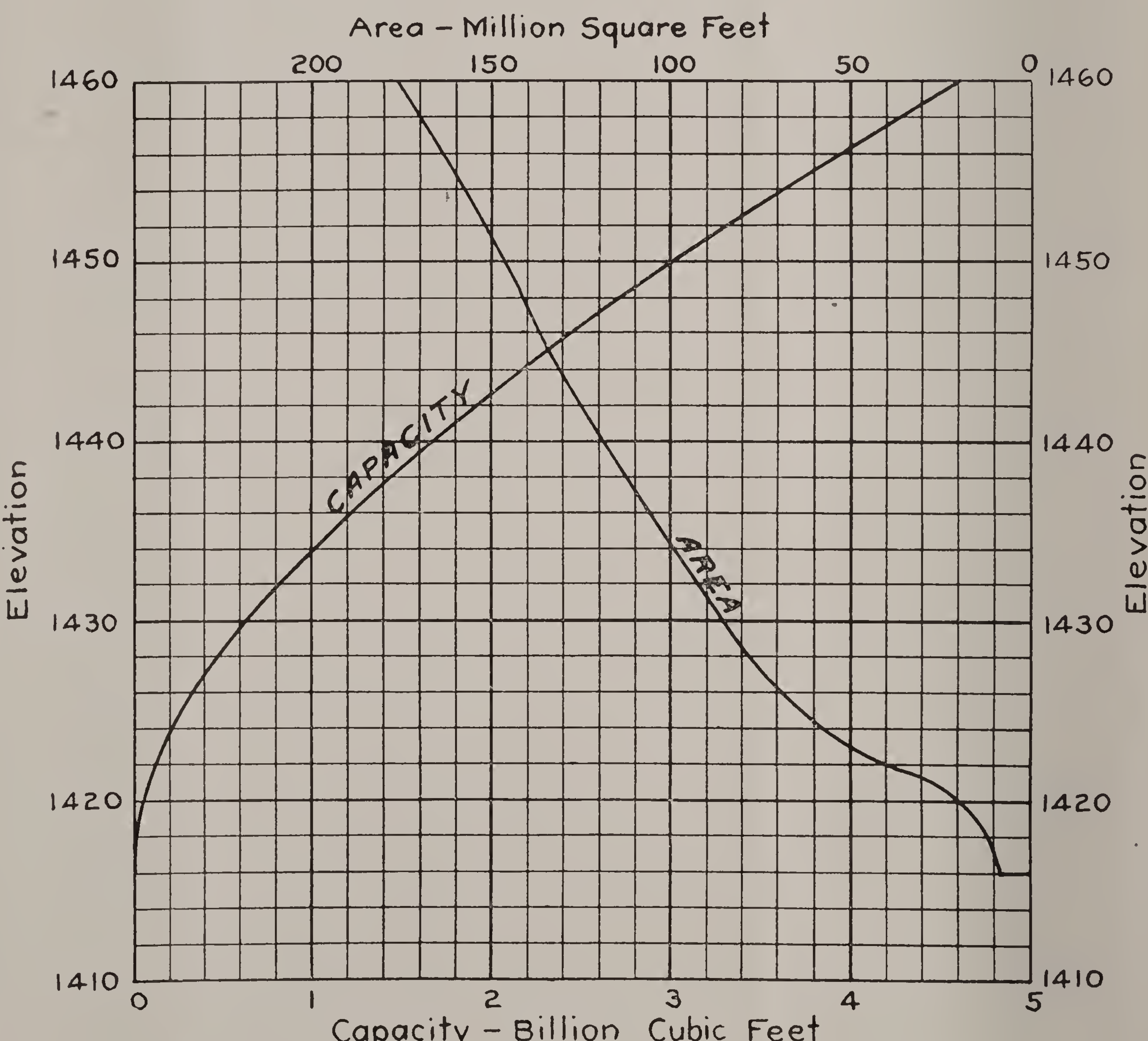
OSWEGATCHIE RIVER—EAST BRANCH

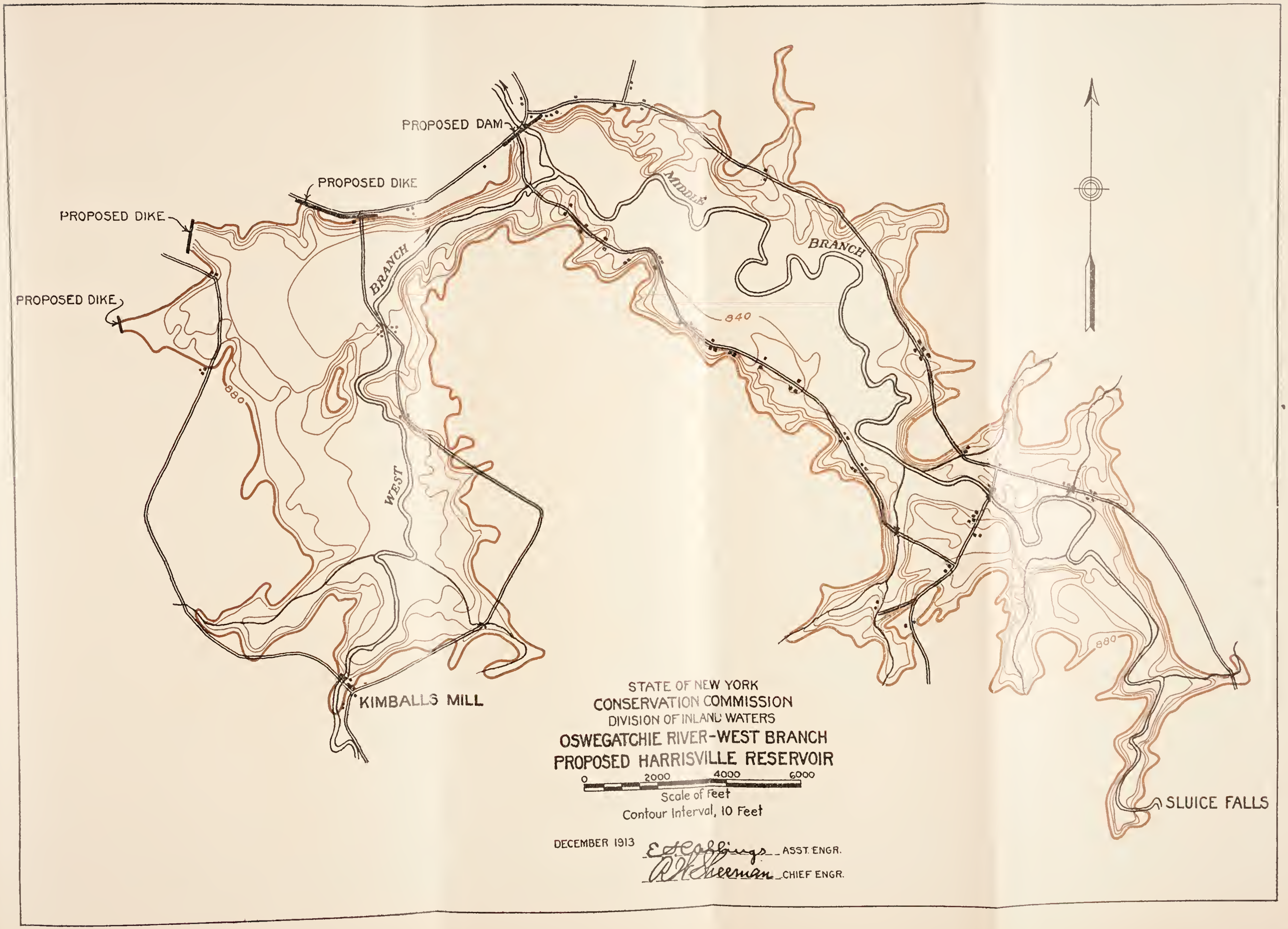
AREA AND CAPACITY CURVES

PROPOSED NEWTON FALLS RESERVOIR

DECEMBER 1913 ______ ASST. ENGR
R. W. Sherman CHIEF ENGR.

Crest of present dam, elevation 1416.
Proposed flow line, elevation 1450.
Capacity, 3.0 billion cubic feet.




PROPOSED DAM
PROPOSED DIKE
PROPOSED DIKE
PROPOSED DIKE
MIDDLE
BRANCH
BRANCH
WEST
840
880
880
KIMBALLS MILL
SLUICE FALLS
STATE OF NEW YORK
CONSERVATION COMMISSION
DIVISION OF INLAND WATERS
OSWEGATCHIE RIVER-WEST BRANCH
PROPOSED HARRISVILLE RESERVOIR
0 2000 4000 6000
Scale of Feet
Contour Interval, 10 Feet
DECEMBER 1913
ASST. ENGR.
CHIEF ENGR.

the proposed site. The second dike, across Tooley swamp, will have a maximum height of 24 feet and a top length of about 1,900 feet. The third, across Cook's swamp, will be 20 feet in height and will have a top length of about 860 feet.

The land included within the flow line of the proposed reservoir is chiefly worthless swamp land and rocky hillsides from which practically all valuable timber has been removed. Much of it has been burned over within recent years and is now covered with dead trees and stumps and a thick growth of underbrush. The only buildings included within the reservoir basin are a few cheap cabins and an abandoned hardwood mill. There is no State land within the limits of the proposed reservoir. Nearly the whole of the highway between Newton Falls and Cranberry Lake will have to be relocated, but a convenient and economical route can be obtained by crossing the Oswegatchie river just below the Cranberry Lake dam, following the old Benson Mines road to a point near the Chaumont Swamp dike, and then cutting across at the foot of the dike to the present road from Newton Falls to Benson Mines at a point about one mile south of Newton Falls. About 10 miles of highway will have to be relocated. No new bridges will be necessary. About 3.4 miles of the Newton Falls and Northern Railroad, a private line running from Newton Falls to a hardwood mill on the Grass river, will have to be relocated. This, however, is a very cheaply constructed line, and its relocation will offer no great difficulty. The present bridge across the river can be used.

A detailed topographic survey of this basin was made in the fall of 1911, but owing to the lateness of the season and lack of equipment, only a very limited amount of sub-surface investigation at the dam sites could be made. Additional borings will be necessary before final plans can be prepared. Following is an approximate estimate of the cost of this reservoir:

Land and buildings	$23,000
Clearing reservoir basin	60,000
Relocating highway	30,000
Relocating railroad	51,000
Regulating dam	163,800
Chaumont dike	260,500

Tooley dike	$35,500
Cook's dike	22,200
Engineering and contingencies, 15 per cent.	97,000
Total	$743,000
Storage capacity — 3,000,000,000 cubic feet.	
Cost per million cubic feet.	$248.67

As before stated, the Newton Falls and Cranberry Lake reservoirs should be operated together, drawing from the Newton Falls reservoir during the summer and early fall and from Cranberry Lake during the late fall and winter. In this way it is believed that all interests can best be conserved.

Proposed Harrisville Reservoir.

On the West Branch of the Oswegatchie river the most feasible storage basin lies about two miles above the village of Harrisville at the junction of the Middle and West Branches. By building a dam 70 feet high across the valley at a point near the highway bridge locally known as the Woodward bridge, an area of 6.25 square miles can be flooded to a depth of from 20 to 50 feet, providing a storage capacity of 5.0 billion cubic feet. This reservoir, with flow line at an elevation of 880 feet above sea level, will include practically all the farm lands and buildings in the river valley between Kimball's Mill on the West Branch and Sluice Falls on the Middle Branch. A considerable portion of this land is swampy, and the rest of moderate value and fertility. About 5 miles of highway will have to be relocated.

For the regulating dam an earth structure with masonry spillway and corewall is proposed. The earth section will have a top length of about 900 feet and a maximum height of 70 feet. On the downstream side, a slope of 1 on 2 is proposed, while the upstream slope is reduced to 1 on 3 and paved with rough stone to a depth of 2 feet. A concrete corewall extending from maximum flood line to bed rock is provided. The spillway, 250 feet long, will be of cyclopean masonry founded on rock at the southerly end of the dam. With a depth of 5 feet on the crest,

STATE OF NEW YORK
CONSERVATION COMMISSION
DIVISION OF INLAND WATERS

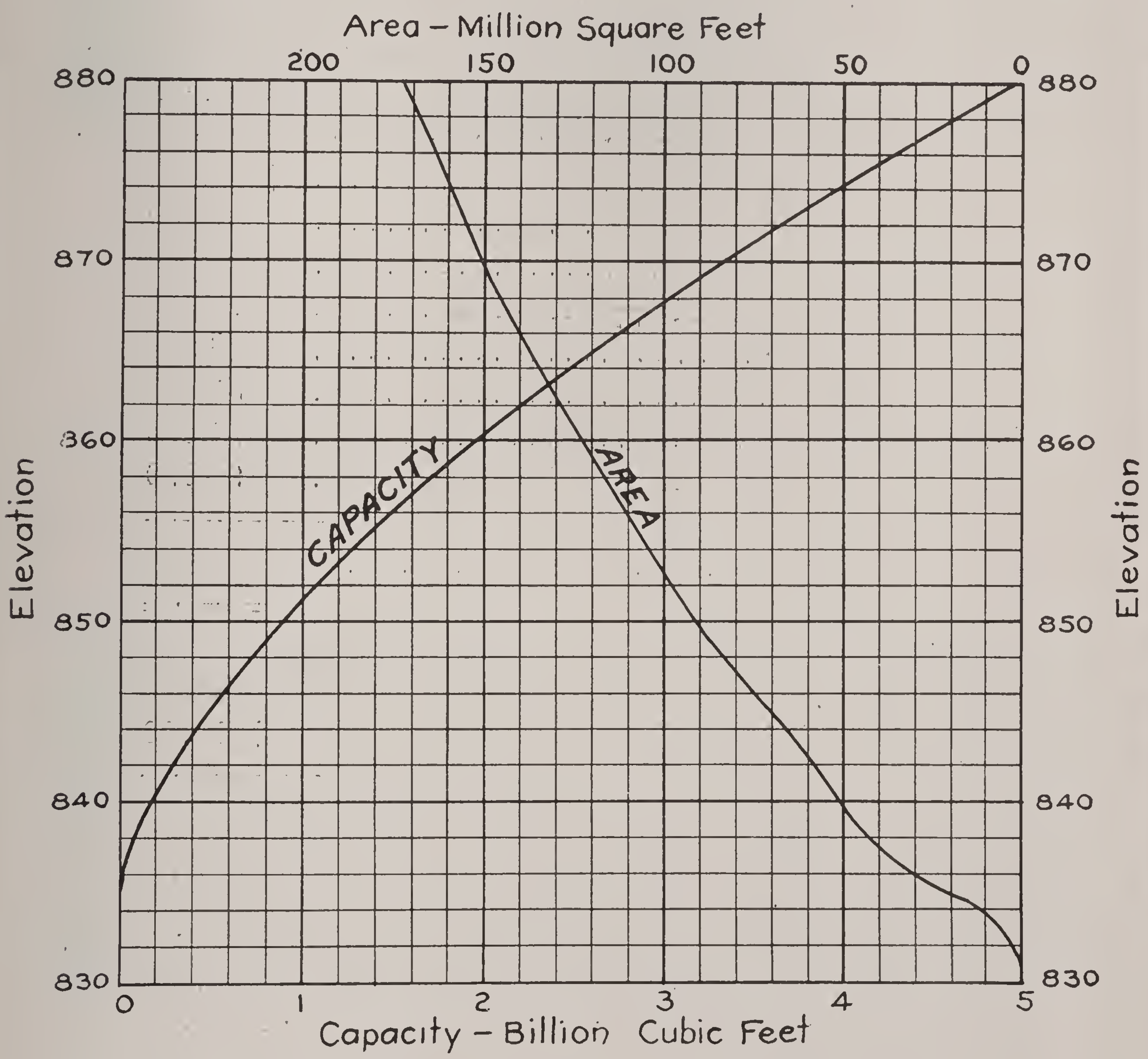
OSWEGATCHIE RIVER–WEST BRANCH

AREA AND CAPACITY CURVES

PROPOSED HARRISVILLE RESERVOIR

DECEMBER 1913 E. S. Cullings ASST. ENGR.
R. W. Sherman CHIEF ENGR.

Proposed flow line, elevation 880.
Maximum depletion line, elevation 835.
Capacity, 5.0 billion cubic feet.



the proposed spillway will have a discharging capacity of about 10,000 second-feet. The outlet works are located at the middle of the earth section. Water is carried through the dam in a reinforced concrete culvert. In addition to the main dam, three earth dikes will be required to prevent the water from spilling over into the Indian River watershed. The first of these dikes, across the lands of Simmons and Marsha, will be about 2,600 feet long and from 5 to 18 feet high. The second, on the lands of Carley and Sprague will have a top length of about 700 feet and a maximum height of 50 feet. The third dike will be located on the land of A. B. Peryer and will have a length of 500 feet and a maximum height of 19 feet. Good material for these dams lies close at hand, in each case. Owing to the lack of suitable equipment, only a very limited sub-surface investigation could be made. Additional borings must be made before final plans can be prepared. Following is an approximate estimate of the cost of the reservoir:

Land and buildings	$131,000
Clearing reservoir basin	50,000
Relocating highways	18,000
Regulating dam and appurtenances	279,000
Simmons dike	26,500
Carley dike	85,700
Peryer dike	14,800
Engineering and contingencies, 15 per cent	91,000
Total	$696,000
Storage capacity — 5,000,000,000 cubic feet.	
Cost per million cubic feet	$139.20

The drainage area at this point is 190 square miles, and the mean annual rainfall about 43 inches. While a storage capacity of 5.0 billion cubic feet will not entirely control this drainage area, it is believed that until the market for power is greatly increased, this storage, with 6.0 billion cubic feet on the East Branch above Newton Falls, will be sufficient for present needs. If, however, a future demand for power should warrant the expense, a

Proposed Harrisville Reservoir.
Site for Regulating Dam.

Proposed Harrisville Reservoir.
Lower End of Basin.

second reservoir may be located on the West Branch between Kimball's Mill and Jerden Falls.

Proposed Kimball Reservoir. By building a dam 40 feet high at a point one mile above Kimball's mill, and about 700 feet above the present log sluice, a flat swampy area about two miles long and one-half mile wide may be flooded to a depth of from 15 to 25 feet, thus providing a storage capacity of about 2.3 billion cubic feet. A topographic survey of this basin was begun late in the fall of 1912, but after the northerly half of the basin had been covered, the survey was discontinued on account of bad weather. The topography of the southerly half was filled in from data furnished by the United States Geological Survey.

In addition to the regulating dam, about 1,100 feet long, four dikes having a total length of 2,200 feet will be required. Most of the land in this basin is worthless swamp land and rocky hillsides from which all valuable timber has been removed, though there are several hundred acres of wild-hay land which is quite highly value by the owners. The tributary drainage area is 63 square miles, and the mean annual rainfall about 43 inches. Following is an approximate estimate of the cost of this reservoir:

Land and buildings	$38,000
Clearing reservoir basin	32,000
Relocating highways	6,000
Regulating dam and appurtenances	114,000
Four dikes	131,000
Engineering and contingencies, 15 per cent.	49,000
Total	$370,000
Storage capacity — 2,300,000,000 cubic feet.	
Cost per million cubic feet	$160.87

The above estimate is to be considered provisional only, and is subject to correction at a later date when more precise data are available. Considering the nearly complete regulation of this watershed afforded by the proposed Harrisville reservoir, the project can hardly be considered feasible until the demand for power is much greater than at the present time.

Alder Beds Reservoir Site. Another reservoir site on the headwaters of the Middle Branch about 16 miles above the junction of the Middle and West Branches at a point locally known as the "Alder Beds" was investigated during the fall of 1912. For several years a small reservoir for logging purposes has been maintained at this point, but as the reservoir is emptied at the close of the driving season, it is at present of no use for storage purposes. The present dam, a crib structure about 15 feet high and 125 feet long, floods about 200 acres of swamp land. The tributary drainage area is about 30 square miles, and the mean annual rainfall about 43 inches. A new dam about 40 feet high would provide a storage capacity of not more than 300,000,000 cubic feet, but the cost would be prohibitive. The project, therefore, need not be considered further.

Reservoir Site on Little River. On the Little river, at a point just above Aldrich, there is a low swampy area which has been suggested as a possible location for a storage reservoir. This site also was investigated during the fall of 1912. The swamp in question has an area of approximately 300 acres, and by building a dam about 40 feet high just above the present dam a storage capacity of about 450,000,000 cubic feet could be obtained. The cost of the dam, however, would be prohibitive, and the project need not be given further consideration.

Black Lake Storage Not Practicable. For a number of years Black lake has been persistently suggested as offering storage possibilities of great value. Therefore, in course of the Oswegatchie river surveys, this matter was thoroughly investigated. Black lake is a long narrow body of water lying in the westerly part of St. Lawrence county parallel with the St. Lawrence river and distant therefrom about 5 miles. It has a length of about 13 miles, a width of from one-quarter to two miles, and an area of 11.7 square miles. Its low water elevation is 272 feet above sea level, or about 26 feet above the St. Lawrence river at Ogdensburg. The banks on the westerly side of the lake are steep and rocky, but on the southerly and easterly sides, low and swampy. The tributary drainage area at the outlet is 560 square miles, and the mean annual rainfall about 34 inches.

There is no feasible site for a dam on the outlet of the lake, but at the "Eel Weir Rapids" on the Oswegatchie river about 1.5 miles below the outlet, a dam 22 feet high across a rock gorge would raise the surface of the lake by 10 feet. This would submerge an area of 32 square miles, and provide a storage capacity of 6.0 billion cubic feet. Great damage would, however, be done to existing water powers and other property; practically the entire head of 9 feet at Heuvelton would be destroyed, several farm houses between Heuvelton and Eel Weir Bridge would be flooded, and about one mile of the highway would have to be relocated. At Edwardsville the bridge across the lake would have to be raised, and several houses moved back to higher ground. The water power from Fish creek at Pope Mills would be partially destroyed, and nearly a score of buildings including the hotel, town hall, one store and several dwellings would be flooded. At Rossie the highway bridge would have to be raised, nearly one-half the available water power would be destroyed, and several dwellings and stores would be flooded. About 3,000 acres of farm land, 2,000 acres of wild-hay land, and 5,000 acres of rough pasture land would be submerged, and 1.5 miles of the railroad near Redwood would have to be relocated. Following is a conservative estimate of the cost of this reservoir, exclusive of the value of the water power destroyed at Heuvelton, Rossie and Pope Mills:

Land	$176,000
Clearing reservoir basin	120,000
Relocating highways and raising bridges	43,000
Relocating railroad	28,000
Dwellings and other buildings	58,000
Regulating dam (61 per cent. chargeable to reservoir)	80,000
Engineering and contingenices, 15 per cent.	75,000
Total	$580,000
Reservoir capacity, 6,000,000,000 cubic feet.	
Cost per million cubic feet	$96.67

When compared with other reservoirs, the unit cost of this storage appears low, but the total head through which it could be used would be only 30 feet, 18 feet (average) at the dam site, and 12 feet at Ogdensburg. The total amount of power added to the present output of the river would be not more than 450 horsepower-years per annum, while the present output at Heuvelton alone is about 180 horsepower-years per annum. Therefore, while this storage would afford almost ideal regulation at Eel Weir Rapids and Ogdensburg it is readily apparent that such a small gain in power would not warrant so large an expenditure. The proposed reservoirs at Newton Falls and Harrisville, due to their location on the headwaters of the river, will add an even greater amount of power (see Table III) at only a fraction of the cost of the Black Lake reservoir. With the proposed regulation from the reservoirs at Newton Falls and Harrisville, the available power at Heuvelton with the present 9-foot head will amount to about 750 continuous 24-hour horsepower. Under these conditions the Black Lake reservoir would destroy more power than it would create.

Proposed Theresa Reservoir. Between Rossie and Theresa lies a low swampy area of about 8 square miles which might be flooded to a depth of from 15 to 25 feet by building a dam 35 feet high, above the stream bed, at a point one mile above the village of Rossie. A storage capacity of 5.0 billion cubic feet could thus be obtained, but, as in the case of the Black Lake reservoir, the cost would be prohibitive. About 6,000 acres of land of moderate value would be required; about 6 miles of highway and 2 miles of railroad, including the passenger station and freight house at Theresa, would have to be relocated; and the power plant of The Hydro-Electric Company and about 30 dwellings in the village of Theresa would be submerged. A cemetery near the village of Rossie would also be flooded. The following is a conservative estimate of the cost of this reservoir. It does not include the value of the water power destroyed at Theresa:

Land	$97,000
Clearing and grubbing	40,000
Relocating railroad and highways	70,000
Moving cemetery	6,000
Dwellings and other buildings	66,000
Regulating dam and appurtenances	105,000
Engineering and contingencies, 15 per cent.	58,000
Total	$442,000

This storage would be effective through a total head of 50 feet, and would add to the power output of the stream about 640 horsepower-years per annum. It would, however, destroy not less than 500 horsepower-years per annum at Theresa. Of course the power added by this reservoir would, to a certain extent, replace steam or other auxiliary power, while probably two-thirds of the power destroyed at Theresa is second-class power, that is, power which is not continuous throughout the year. Therefore, the power added by the reservoir would be more valuable than that which would be destroyed. But even under the most favorable conditions, the gain in power is too small to make this reservoir a desirable proposition.

Proposed Indian Lake Reservoir.

A dam 20 feet high across a rock gorge at the outlet of Indian lake would raise the lake surface about 16 feet and flood an area of about 2.25 square miles, thus providing a storage capacity of about 560,000,000 cubic feet. The tributary drainage area at Indian lake is 68 square miles, and the mean annual rainfall about 38 inches. The land which would be flooded is chiefly worthless swamp land and rocky hillsides entirely denuded of marketable timber. An electric power plant at Natural Bridge would, however, be partially submerged, and a large part of the power would be destroyed.

The cost of the reservoir, exclusive of the damage to the power plant above mentioned, is estimated at approximately $107,000. The storage could be effectively used through about 280 feet of head, including plants not in use at present. It would add to the power output of the stream not more than 600 horsepower-years per annum. To determine whether the cost of this reservoir is justifiable will require detail surveys and careful estimates of the value of storage to the plants benefited, as well as of the damage to the power plant at Natural Bridge. From the data at hand, the project does not appear desirable.

Lake Bonaparte.

A small amount of storage has been obtained from Lake Bonaparte by private enterprise, but owing to the objections of cottage owners and to the difficulty of securing adequate compensation from power owners on the stream below, little use has been made of this storage in recent years. The low divide between Lake Bonaparte and the Oswegatchie river, and the damage which would be caused to existing property on the lake shores prohibit the raising of the lake surface by an appreciable amount, and the lowering of its surface by more than a foot or two would seriously interfere with navigation. Therefore, it seems that no further consideration need be given to this proposition.

Just below the outlet of Lake Bonaparte is a small basin which might be flooded by building a dam across Bonaparte creek at a point about one mile below the outlet of the lake. The amount of storage obtainable, however, is so small that its cost would be out of all proportion to its value.

Reservoir Site Above Natural Bridge.

About three miles above the village of Natural Bridge is a swampy area of several hundred acres, which might be flooded to a depth of about 20 feet by building an earth dam about 2,500 feet long and from 20 to 30 feet high. The cost, however, would be prohibitive, and the tributary drainage area is so small that no material amount of storage capacity could be fully utilized.

No Practicable Reservoir Site on Indian River.

On the Indian river nearly the whole head susceptible of economic development has been utilized, though several plants have been abandoned within recent years. The flow of the river is extremely variable, and is badly in need of regulation, but the topographic conditions of the watershed are such that there is no reservoir site where storage of adequate volume can be combined with sufficient head to make its development profitable.

Regulation.

A careful study of the cost of the regulation obtainable from the above named reservoirs and of the present needs of the river indicates that the proposed reservoirs at Cranberry lake and Newton Falls on the East Branch, and at Harrisville on the West Branch, having a total storage capacity of 11.0 billion cubic feet, will provide sufficient regulation to supply all demands for power likely to occur in the near future. If at a later date, the demand for power shall warrant the expense, the storage capacity on the West Branch can be increased by about 2.0 billion cubic feet by utilizing the basin between Kimball's Mill and Jerden Falls, but it is probable that such increase will not become necessary for a considerable number of years.

The following discussion is therefore limited to the regulation obtainable from:

1. A total storage of 3.0 billion cubic feet in Cranberry lake.

2. An additional storage of 3.0 billion cubic feet in the proposed Newton Falls reservoir to be operated in conjunction with Cranberry lake, so that the lake surface may be maintained at spillway level until the early fall.

3. A storage of 5.0 billion cubic feet in the proposed Harrisville reservoir on the West Branch.

These reservoirs will provide a very high degree of regulation at all points above Hailesboro, and sufficient regulation for present needs at all points below that place. The complete regulation of the lower reaches of the stream is impracticable on account of the lack of suitable storage basins which can be profitably utilized.

In the use of stored water through a number of plants at various distances from the reservoir, it is obvious that equal regulation cannot be secured at all points. Each reservoir must be so regulated as to provide, as nearly as possible, an equal year-round flow at some definte point on the stream. Under ordinary conditions this point should be so selected that, within the economic wheel installations at the various plants, a maximum amount of energy will be added to the stream as a whole. If, however, this plan is strictly followed, it may be necessary at certain times, while the reservoir is filling, to completely close the outlet gates, and thus entirely, or very nearly, shut off all flow from a plant located at, or near, the reservoir. Such would be the case with both the Newton Falls and Harrisville reservoirs here proposed. It will therefore be necessary to determine a just and equitable minimum flow which should be maintained while the reservoir is filling, even though some plants at points further down stream have more water than they can use.

A careful study of the profiles of the Oswegatchie river and its main branches, and of the power developments thereon, indicates that the storage above Newton Falls should be so regulated as to give, as nearly as may be, an even flow at a point near South Edwards, and that the Harrisville reservoir should be regulated for a point near the mouth of the West Branch. Therefore, in the following studies of the benefits due to regulation, it has been assumed that the Cranberry Lake and Newton Falls reservoirs will be operated together for a point near South Edwards, and that a minimum flow of 200 second-feet will be maintained at Newton Falls while the reservoirs are filling. It is also assumed that the Harrisville reservoir will be regulated for the mouth of the West Branch. Due to the somewhat larger drainage area tributary to this reservoir, and to its somewhat smaller storage capacity, it will be practicable to maintain a minimum flow of 300 second-feet at Harrisville while this reservoir is filling. On this basis mass curves and the resulting power-percentage-of-time curves have been computed and plotted, and from these the resulting benefits at each of the existing plants and at all undeveloped power sites have been deduced.

Power Developments and Possibilities.

Basis of Comparison. The economic development of a water power usually requires a wheel capacity considerably in excess of that required for the minimum flow of the stream. Depending somewhat on the purpose for which the power is used, a turbine installation of sufficient capacity to utilize the whole flow of the stream for from 6 to 8 months each year is usually economical; if continuous year-round power is required, the deficiency during the low-water period is supplied by an auxiliary plant. For the purpose of reducing all plants and undeveloped power sites to a common basis of comparison in this discussion, a wheel installation which can run at full capacity 60 per cent. of the average year (7.2 months) has in each case been adopted as the economic development for either natural or regulated flow.

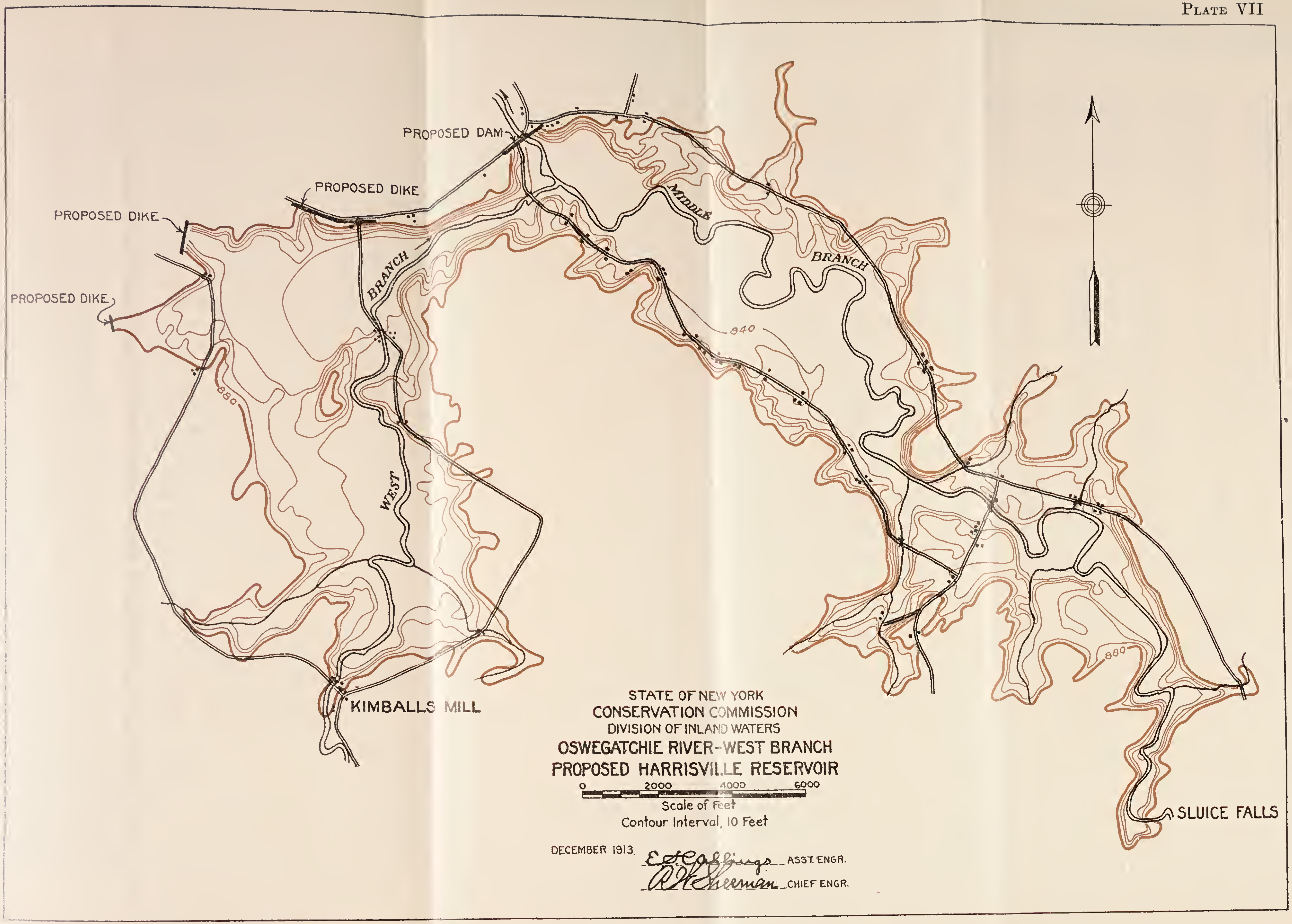
All estimates of stream flow are based on mean monthly discharges. These flows will, of course, be subject to certain daily or weekly variations caused by the manipulation of pondage at plants further up stream, but in most cases, particularly at the undeveloped power sites, sufficient pondage can be obtained to eliminate, to a great extent, the effects of such manipulation.

Owing to the impossibility of making, within the time allotted to this work, a thorough sub-surface investigation at each of the undeveloped power sites, it has been possible to prepare only rough estimates of the cost of developing these powers, but liberal assumptions have been made, and it is believed that these estimates are sufficiently accurate to form a reliable basis of comparison of the relative merits of the various projects. Hydro-electric development has been assumed in each case, but the estimates for electrical apparatus do not include transformers or transmission lines. The cost of acquiring riparian rights is not included.

The following statements briefly summarize the principal physical conditions at each of the existing plants and at undeveloped power sites. The details of both present and proposed developments are shown in Table II, page 59, and Table III, following page 65.

Ogdensburg. The first water power on the Oswegatchie river is at Ogdensburg, where a masonry dam creates an average gross head of twelve feet, and supplies power to the pumping plant of the city water works at the northerly end of the dam, and to several mills and factories grouped about an artificial forebay or " basin " near the southerly end of the dam (see Plate IX). The present dam was built in 1910, replacing an old timber structure. It is 12 feet high, 347 feet long and founded on rock. The elevation of the spillway crest is 258 feet above sea level. At the southerly end of the dam a short canal connects with the aforesaid basin, around which are grouped the head-gates of various mills and factories. At the head of the forebay another canal diverts a portion of the water to other mills and factories south of Lake street.

The power is partitioned into 101 privileges or " rights," of which 26 are termed first-class and 75 second-class. In 1872 the Supreme Court was called upon to define the rights of the several claimants. A right was defined as follows: " That the quantity of water which constitutes a run of water under the provisions of Exhibits Nos. 6, 7, 8, 9, 10, 11 and 12, being such quantity as was sufficient with the most approved wheels and water saving machinery, to propel a run of stone with the necessary bolts and


PROPOSED DAM
PROPOSED DIKE
PROPOSED DIKE
PROPOSED DIKE
MIDDLE
BRANCH
BRANCH
WEST
BRANCH
840
880
880
KIMBALLS MILL
SLUICE FALLS
STATE OF NEW YORK
CONSERVATION COMMISSION
DIVISION OF INLAND WATERS
OSWEGATCHIE RIVER-WEST BRANCH
PROPOSED HARRISVILLE RESERVOIR
0 2000 4000 6000
Scale of Feet
Contour Interval, 10 Feet
DECEMBER 1913.
ASST. ENGR.
CHIEF ENGR.

End of Power Canal or "Basin" at Ogdensburg.
Filled with Mud and Overgrown with Water Plants.

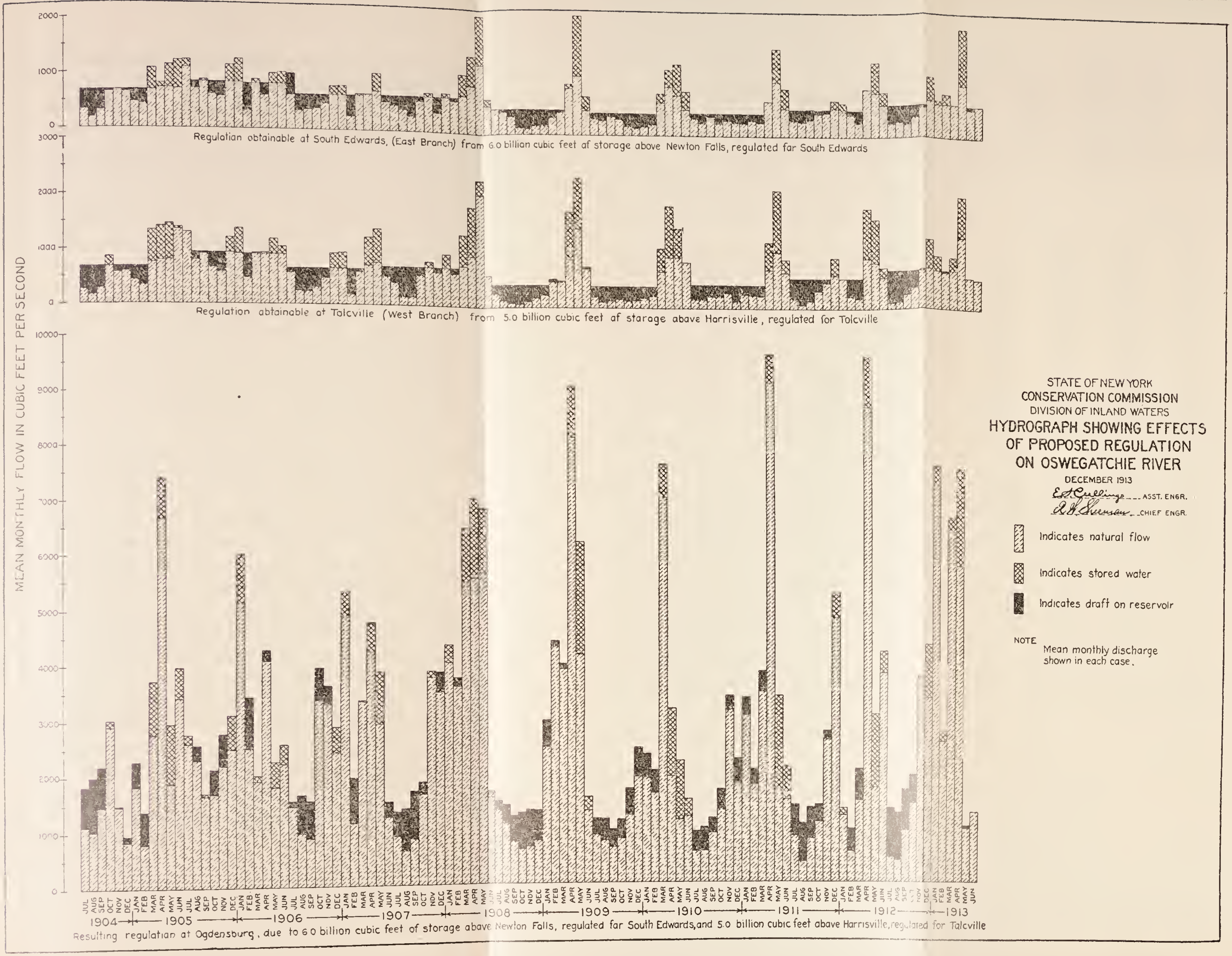
Proposed Dam Site at Eel Weir Rapids.
An Undeveloped Head of Thirteen Feet Within Five Miles of the City of Ogdensburg.

machinery of a flour mill, at the time said conveyances were executed, is twenty-five cubic feet per second when the fall is nine feet, or water enough to produce an equivalent power when the fall is more or less, to wit:

32	cubic feet per second when fall is	7 feet.
28	" " " " " " "	8 "
22.5	" " " " " " "	10 "
20.5	" " " " " " "	11 "

The said quantity being nearly equal to twenty-five horsepower, and such quantity is the amount hereinafter specified as the standard quantity for a run." (To produce 25 horsepower with the quantities and heads specified above, requires a wheel efficiency of about 98 per cent.) In accordance with this decree a system of weirs with movable crests was established. These weirs are of standard form, 4 feet wide and 5 feet deep, one being placed at the entrance to each penstock. All rights, both first- and second-class, are entitled to an equal share of the water as long as it is flowing over the dam, and until it has fallen one foot below the crest, when the second-class rights are shut off by raising the movable crests of the weirs. The whole of the available water is then divided among the first-class rights. The second-class rights can not again begin to use water until the surface of the pool above the dam has risen to within six inches of the crest.

This method of operation has become extremely wasteful and inefficient. During the low-water period, there is seldom enough water to satisfy the claims of the holders of the 26 first-class rights (about 650 second-feet), consequently in order to shut off the second-class rights the pond level is quickly drawn down to the point one foot below the spillway crest, and is not allowed to rise above that point while the first-class rights are in use, or until the stream flow exceeds 650 second-feet. This practice causes a direct loss of about 10 per cent. of the available power of the stream. A large part of the remaining power is lost through leakage of the basin walls, and the loss of head due to the clogging of the basin and tail-races with weeds and other debris. The heads actually in use at the various plants on July 1, 1912, varied from 7.5 to 10.2 feet, as shown in Table I.


STATE OF NEW YORK
CONSERVATION COMMISSION
DIVISION OF INLAND WATERS
HYDROGRAPH SHOWING EFFECTS OF PROPOSED REGULATION ON OSWEGATCHIE RIVER
DECEMBER 1913
ASST. ENGR.
CHIEF ENGR.
Indicates natural flow
Indicates stored water
Indicates draft on reservoir
NOTE Mean monthly discharge shown in each case.
MEAN MONTHLY FLOW IN CUBIC FEET PER SECOND
Regulation obtainable at South Edwards, (East Branch) from 6.0 billion cubic feet of storage above Newton Falls, regulated for South Edwards
Regulation obtainable at Talcville (West Branch) from 5.0 billion cubic feet of storage above Harrisville, regulated for Talcville
Resulting regulation at Ogdensburg, due to 6.0 billion cubic feet of storage above Newton Falls, regulated for South Edwards, and 5.0 billion cubic feet above Harrisville, regulated for Talcville
1904 1905 1906 1907 1908 1909 1910 1911 1912 1913

The most feasible plan for increasing the power output at this place appears to be to abandon the basin and canals leading to the various plants, and to develop the whole available power at a single hydro-electric plant. In this way the entire head of from 12 to 13 feet could be fully utilized, and electric power could be distributed to the various factories in proportion to the number of rights owned. At the south end of the dam there is an especially favorable location for such a plant. The present dam and head-works could be used, and only a small amount of excavation would be necessary for a suitable tail-race. It would be no difficult matter to determine the amount of power which should be allotted to the owner of each first- and second-class right.

The elevation of the water surface of the St. Lawrence river at Ogdensburg, as shown by the records of the War Department, varies approximately from 245 to 247 feet above sea level (U. S. G. S. datum), with a mean of 246. The elevation of the crest of the Ogdensburg dam is 258.0 and on July 1, 1912, the water surface of the St. Lawrence river was 246.2. The gross available head, without flashboards, therefore, varies from 11 to 13 feet, with a mean of about 12 feet. By using 12-inch flashboards and allowing a daily pondage depletion of not more than 2 feet, an average working head of 12 feet would be available.

The power-percentage-of-time curve (Plate XI) shows in graphic form the available power from the natural stream flow, from the present flow as regulated by the Cranberry Lake reservoir, and from the proposed regulation due to 6.0 billion cubic feet of storage above Newton Falls, regulated for South Edwards, and 5.0 billion cubic feet above Harrisville, regulated for the mouth of the West Branch. A tabulation of these flows and the resulting power is also shown in Table III. It is here seen that with the proposed regulation the low-water flow of Ogdensburg would be practically doubled, thus obviating, to a great extent, the necessity for auxiliary power. (The hydrograph, Plate IX, shows the result of this regulation at Ogdensburg, and also at Talcville and South Edwards.)

TABLE I.

HEAD IN USE AT THE VARIOUS PLANTS IN THE CITY OF OGDENSBURG, JULY 1, 1912.

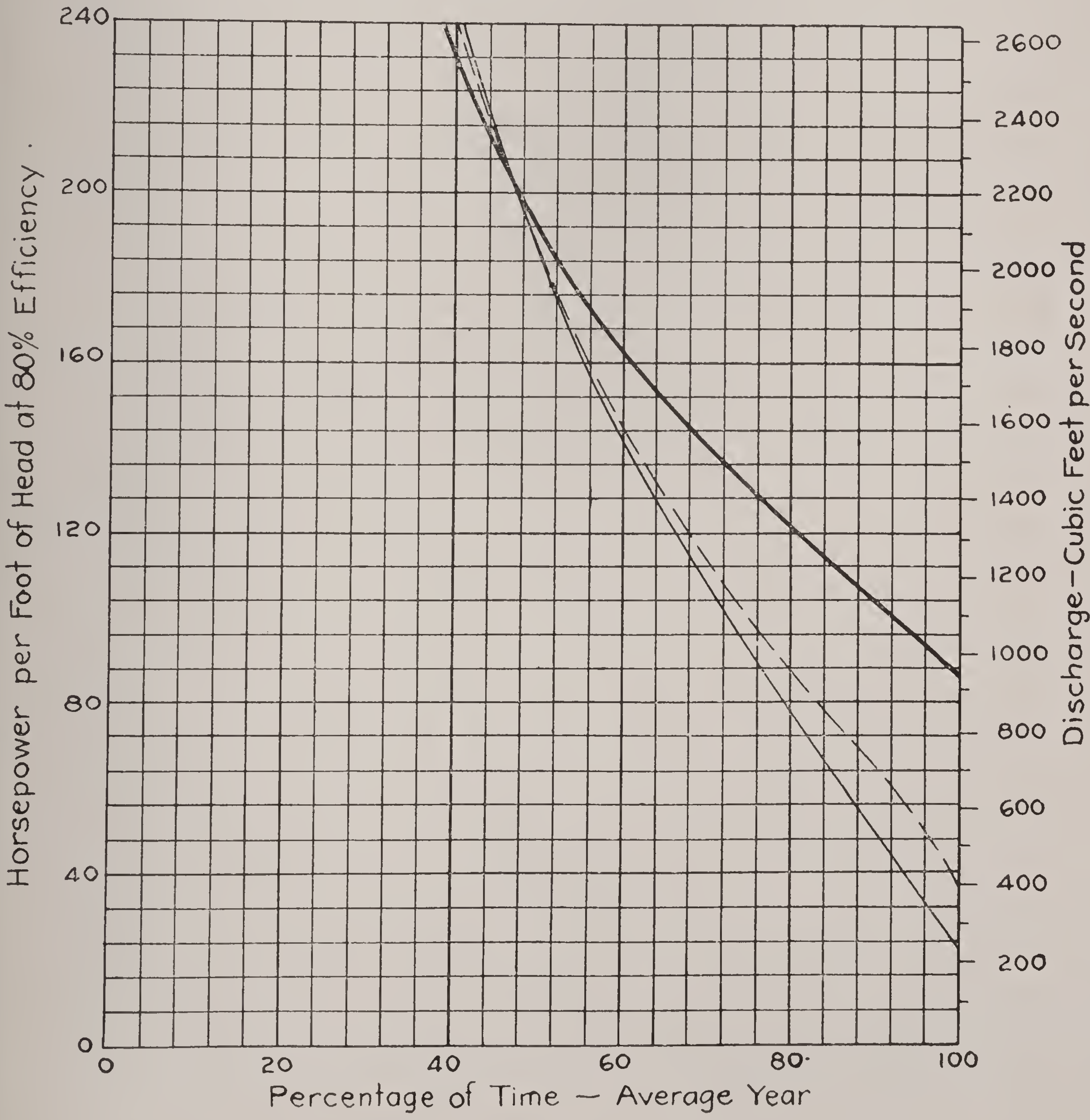
City of Ogdensburg	10.2	feet
Burt Wool and Leather Co	7.5	"
J. E. Fell	7.5	"
John Glass	7.5	"
H. N. Brown	7.4	"
L. A. Green	10.2	"
James McCasland	8.0	"
Proctor Manufacturing Co	9.8	"
Maple City Milling Co	10.2	"
A. A. Babcock Pump Co	7.4	"
Hackett Hardware Co	7.4	"
Ogdensburg Roller Mills	9.9	"
Bill, Bell & Co	9.9	"
Ogdensburg Light & Power Co	9.4	"
Elevation of crest of dam	258.0	"
Elevation of pool below dam July 1, 1912	246.2	"
Elevation of pool above dam July 1, 1912	256.4	"
Available head (without flashboards) July 1, 1912	11.8	"

Eel Weir Rapids. At the foot of this rapids, about four miles above the city of Ogdensburg, a dam 13 feet high above the present stream bed would concentrate all the available head between the Ogdensburg dam and Black lake. The dam would be founded on solid rock, with spillway crest at elevation 272, the low water elevation of Black lake. The power plant would be located at the northerly end of the dam, using the present river channel as a tail-race. Suitable materials for concrete and cyclopean masonry are to be found at or near the site. With the proposed regulation due to 11.0 billion cubic feet of storage, it is estimated that a minimum flow of 950 second-feet could be maintained, and for 60 per cent. of the average year a flow of about 1,780 second-feet. With a working head of 13 feet this would make available 1,120 continuous 24-hour horsepower, and from 7 to 8 months each year, about 2,100 horsepower.

STATE OF NEW YORK
CONSERVATION COMMISSION
DIVISION OF INLAND WATERS
POWER-PERCENTAGE-OF-TIME CURVES
OSWEGATCHIE RIVER AT OGDENSBURG

DECEMBER 1913 E. S. Cullings ASST. ENGR.
R. W. Sherman CHIEF ENGR.

——— Indicates computed natural flow
– – – – Indicates regulated flow due to present storage in Cranberry Lake
━━━ Indicates regulated flow due to 6.0 billion cubic feet of storage above Newton Falls and 5.0 billion cubic feet above Harrisville



Based on regulated flow and an installation of 2,200 horsepower, the approximate cost of this development is estimated as follows:

Dam and appurtenances	$61,900
Power house	16,000
Hydraulic and electrical machinery	53,000
Engineering and contingencies, 15 per cent.	19,600
Total	$150,500
Cost per horsepower of installation	$68.41

Heuvelton. A timber dam at this place creates a working head of 9 feet, which, during the low water period, might be increased by one or two feet by means of flashboards. The present installation of about 180 horsepower is used to operate a grist-mill and a small electric plant. A new dam at a point about midway between the present dam and the highway bridge would make available a total head of 12 feet. With regulation from the proposed reservoirs and a working head of 11 feet, about 950 continuous horsepower, and 1,540 horsepower for 60 per cent. of the average year would be available.

Rensselaer Falls. An average working head of 7 feet is here obtained by means of a timber dam. Power is used by four small factories having a total installation of 330 horsepower. An extensive area of swamp land a short distance up stream prevents the use of flashboards or an increase in the height of the dam, but by deepening the tail-races slightly a total head of 8 feet might be obtained.

Cooper's Falls. A low dam of inexpensive construction would here make available a gross head of from 6 to 7 feet, but until there is a greater demand for power it will probably not be found economical to develop this fall.

Elmdale. At this point a timber crib dam across a rock gorge creates a head of 9 feet and furnishes power to operate a small sawmill. A new dam having a maximum height of 23 feet above the present stream bed, and a total length of about 600 feet, would provide a working head of 22 feet and a pondage area of from 6,000,000 to 8,000,000 square feet. A new highway bridge would be required, and about 2,000 feet of new State road would have to be relocated; also about 100 acres of pasture land and four or five dwellings would be flooded. The proposed regulation due to 11.0 billion cubic feet of storage above Newton Falls and Harrisville would in the average year maintain a continuous flow of about 850 second-feet, and for from 7 to 8 months each year, a flow of about 1,380 second-feet. The estimated cost of this development, based on regulated flow and a wheel installation of 2,800 horsepower, exclusive of riparian rights, is as follows:

Dam and appurtenances	$55,600
New bridge and relocation of highway	30,000
Buildings and property damage	10,000
Power house	19,000
Hydraulic and electrical machinery	43,000
Engineering and contingencies, 15 per cent.	23,000
Total	$181,000
Cost per horsepower of installation	$64.79

Wegatchie. Power to operate a small sawmill is here obtained by means of a timber dam utilizing a head of 9 feet. About 2,000 feet up stream from the present dam, a small island in a rock gorge divides the river into two channels. At the head of this island a dam from 15 to 20 feet high and not more than 400 feet long would provide a working head of 23 feet and a pondage area of over 2,000,000 square feet. In addition to the diversion dam, this development would require an outlet tunnel about 300 feet long across the head of the island. The power plant would be located on the westerly side of the island at the foot of a short rapids. It would also be necessary to raise the Carney highway bridge about 10 feet and about 500 feet of the highway from 5 to 10 feet. With the proposed regulation it would be possible to maintain a continuous flow of about 830 second-feet, or for 60 per cent. of the average year, a flow of about 1,360 second-feet. The approximate cost of this development, based on regulated flow and a wheel instal-

Part of Proposed Dam Site Above Hailesboro.

Proposed Dam Site at Wegatchie.

lation of 2,900 horsepower, exclusive of riparian rights, is estimated as follows:

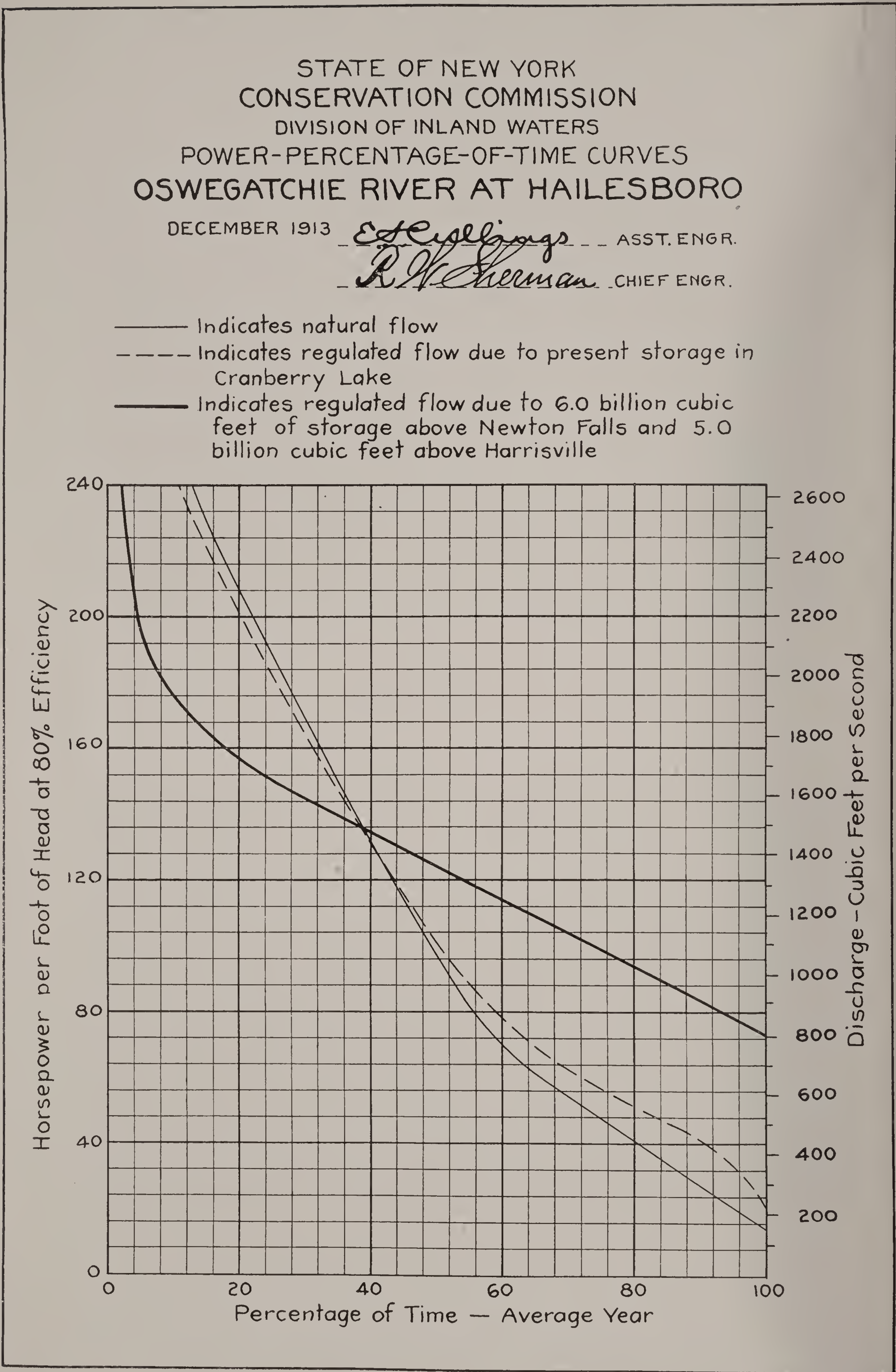
Dam and appurtenances, including outlet tunnel	$80,500
Raising bridge and highway	5,000
Power house	19,000
Hydraulic and electrical machinery	44,500
Engineering and contingencies, 15 per cent.	22,000
Total	$171,000
Cost per horsepower of installation	$58.96

Natural Dam Lower Plant. A working head of 9 feet is here available. The power was formerly utilized in the operation of a talc mill, but the mill has been standing idle for a number of years, and at present the power is not in use.

Natural Dam Upper Plant. The entire available head of 20 feet between Gouverneur and the above described plant is here made use of in the operation of a pulp and paper mill. Regulation of the stream flow appears to be the only feasible means of increasing the power output at this plant.

Gouverneur. Power from an average head of about 7 feet is here divided among eight small mills and factories. Most of these plants are using old obsolete wheels of extremely low efficiencies, consequently a large percentage of the available power of the stream is wasted. To obtain the best results, the entire development should be concentrated in one plant, and electrical energy distributed to the various users.

Hailesboro. This village is the center of the talc industry of New York State, and the power here developed is used almost exclusively in the grinding of talc. At a point about one mile above the village the river divides into two branches and flows around an island having an area of about one square mile. It is estimated that under ordinary conditions the south channel carries about 75 per cent., and the north channel about 25 per cent. of the flow of the stream. In a series of falls and rapids covering a distance of about two miles the river has a


STATE OF NEW YORK
CONSERVATION COMMISSION
DIVISION OF INLAND WATERS
POWER-PERCENTAGE-OF-TIME CURVES
OSWEGATCHIE RIVER AT HAILESBORO
DECEMBER 1913
ASST. ENGR.
R. W. Sherman CHIEF ENGR.
Indicates natural flow
Indicates regulated flow due to present storage in Cranberry Lake
Indicates regulated flow due to 6.0 billion cubic feet of storage above Newton Falls and 5.0 billion cubic feet above Harrisville
Horsepower per Foot of Head at 80% Efficiency
0
40
80
120
160
200
240
Discharge - Cubic Feet per Second
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
0
20
40
60
80
100
Percentage of Time — Average Year

fall of 140 feet, about half of which is now developed by nine small plants utilizing heads of from 7 to 25 feet, and having a total installation of about 3,840 horsepower. None of these plants has any considerable amount of pondage, and their efficient operation is materially interfered with by the ponding of water at plants further up stream. It is estimated that under ordinary conditions the total power output from these plants does not exceed 3,500 horsepower-years per annum.

By building a diversion dam 10 feet high above the present water surface, at a point about one-half mile above the head of the island above mentioned, and conducting the water to the foot of the island through a 17-foot tunnel 6,600 feet long, a gross head of 150 feet can be secured, and the entire available power concentrated at one plant. With the proposed regulation due to 11.0 billion cubic feet of storage it would be possible to maintain a continuous flow of at least 800 second-feet, and for 60 per cent. of the average year, a flow of about 1,250 second-feet. These flows through a working head of 140 feet would produce, at 80 per cent. efficiency, 10,200 continuous horsepower, or 15,900 horsepower for 60 per cent. of the average year. Following is the estimated cost of this development, based on regulated flow and a wheel installation of 18,000 horsepower:

Dam and head-works	$57,000
17-foot tunnel, including shafts	657,000
Surge tank, penstocks, valves, etc	76,000
Power house	35,000
Hydraulic and electrical machinery	158,000
Engineering and contingencies, 15 per cent.	147,000
Total	$1,130,000
Cost per horsepower of installation	$62.77

Emeryville. At this place a low crib dam at the crest of a small waterfall creates a 31-foot head, power from which is used in the operation of a pulp mill. There is apparently no way of increasing the power output at this plant, except by regulation of the stream flow.

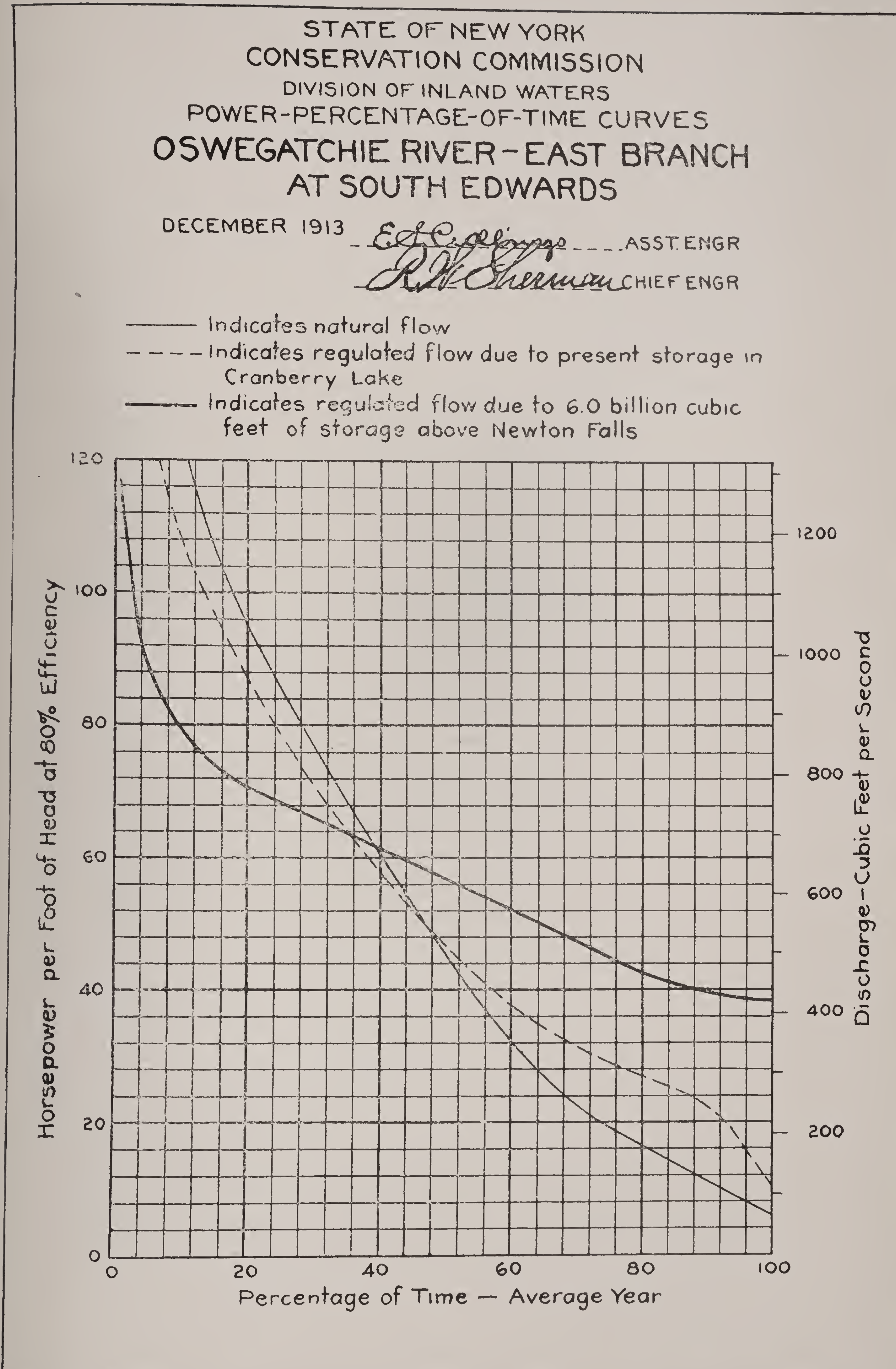
Hyatt. Two low timber dams, one on either side of a small island about one-half mile below the junction of the East and West Branches, concentrate the available head of 24 feet between the crest of the Emeryville dam and the tail-water of the power plant at the mouth of the West Branch. This power was formerly used in the operation of a talc mill, but since the mill was burned, two or three years ago, the power has not been in use. A moderate sum would place this plant again in service.

East Branch.

Talcville. Power from a 16-foot head created by a crib dam and timber flume 260 feet long is here used in the talc mines on the west bank of the river. The head might be increased by one or two feet by deepening the tail-race and using low flashboards during the low-water period.

Talcville Undeveloped Site. A short distance above the village of Talcville the river flows through a rock gorge, and in a distance of about one-quarter mile has a total fall of 15 feet. A dam 14 feet high above the present stream bed and not more than 200 feet long would utilize all that is practicable of the fall between the crest of the dam last mentioned and the tail-water of the plant at Edwards. With the proposed regulation due to 6.0 billion cubic feet of storage above Newton Falls, it would be possible to maintain a continuous flow of about 400 second-feet, and for from 7 to 8 months each year, a flow of about 660 second-feet. With a working head of 14 feet the latter flow would make available about 840 continuous 24-hour horsepower for 60 per cent. of the average year. Following is the estimated cost of this development, based on regulated flow and an installation of 850 horsepower:

Dam and appurtenances	$17,300
Power house	8,000
Hydraulic and electrical machinery	19,000
Engineering and contingencies, 15 per cent.	6,700
Total	$51,000
Cost per horsepower of installation	$60.00


STATE OF NEW YORK
CONSERVATION COMMISSION
DIVISION OF INLAND WATERS
POWER-PERCENTAGE-OF-TIME CURVES
OSWEGATCHIE RIVER-EAST BRANCH
AT SOUTH EDWARDS
DECEMBER 1913
ASST. ENGR
R. W. Sherman CHIEF ENGR
Indicates natural flow
Indicates regulated flow due to present storage in Cranberry Lake
Indicates regulated flow due to 6.0 billion cubic feet of storage above Newton Falls
Horsepower per Foot of Head at 80% Efficiency
Discharge-Cubic Feet per Second
Percentage of Time — Average Year
0
20
40
60
80
100
120
200
400
600
800
1000
1200

This estimate is for a solid masonry dam. By the use of a reinforced concrete or other hollow type of dam, the cost might be materially reduced. The bed and banks of the river at this point are of solid rock.

Edwards. A small island at this place divides the river into two branches. In the southerly channel a short timber dam creates a head of 10 feet, and provides power for the operation of a grist-mill and a small lighting plant. A similar dam in the northerly channel formerly supplied power to a sawmill and an excelsior plant, but since these mills were destroyed by fire a few months ago, the power has not been used. During the low-water period the head at these dams might be increased by one or two feet by the use of flashboards.

South Edwards Lower Plant. At the head of a series of falls and rapids a low timber dam, with a head-race and flume about 100 feet long, concentrates a head of 37 feet. This power was until recently used in the operation of a pulp mill, but on the exhaustion of the local timber supply the pulp machinery was removed, and an electric generator was installed in its place. Provision has been made for the installation of an additional unit at a future date.

By means of a steel penstock or other conduit about 6,500 feet long, carrying the water to the foot of the "Cotton Rapids," a gross head of 87 feet could be made available. The proposed storage of 6.0 billion cubic feet of water in the Newton Falls and Cranberry Lake reservoirs would be sufficient to maintain a continuous flow of about 400 second-feet, or for 60 per cent. of the average year a flow of about 570 second-feet.

South Edwards Upper Plant. This plant utilizes a gross head of 84 feet. A masonry dam 54 feet high across a rock gorge diverts water into a 10-foot riveted steel penstock, which delivers it to the power house 1,150 feet down stream. Two 1,600-horsepower turbines direct-connected to 1,200 kv-a. generators develop electrical energy which is transmitted to Harrisville, 10 miles distant, and used in the mills at that place. During the low-water period a small increase of head might be obtained by the use of flashboards.

Madison Chute. About two miles below the village of Fine the river has cut its way through a ridge of hard granitic rock, forming a narrow gorge known as Madison Chute. A dam 25 feet high above the present water surface and not over 160 feet long at spillway level, with a steel penstock or other conduit about 5,000 feet long, would provide a gross head of 103 feet, and utilize practically all the available fall between the pool of the upper plant at South Edwards and the tail-water of the tannery dam at Fine. This development would submerge a 7-foot head created by an old crib dam at a point about one mile up stream from the proposed dam site. This power, however, has not been in use for several years.

The regulated stream flow would be practically the same as at South Edwards. With a net working head of 95 feet, the proposed regulation would make available a minimum of about 3,450 horsepower, and for 60 per cent. of the average year, about 4,900 continuous 24-hour horsepower. Based on regulated flow and an installation of 5,000 horsepower, the approximate cost of this development is estimated as follows:

Dam and outlet works	$47,700
Twelve-foot riveted steel conduit 5,000 feet long	170,000
Surge tank, penstock, valves, etc	39,000
Power house	22,000
Hydraulic and electrical machinery	57,000
Engineering and contingencies, 15 per cent.	50,300
Total	$386,000
Cost per horsepower of installation	$77.20

The cost of the dam might be reduced somewhat by using a reinforced concrete or arched type of dam.

Fine. Just above this village a head of 13 feet was formerly utilized by a tannery, but since the tannery was closed down several years ago the power has not been in use. The dam, a timber structure, is now in very poor state

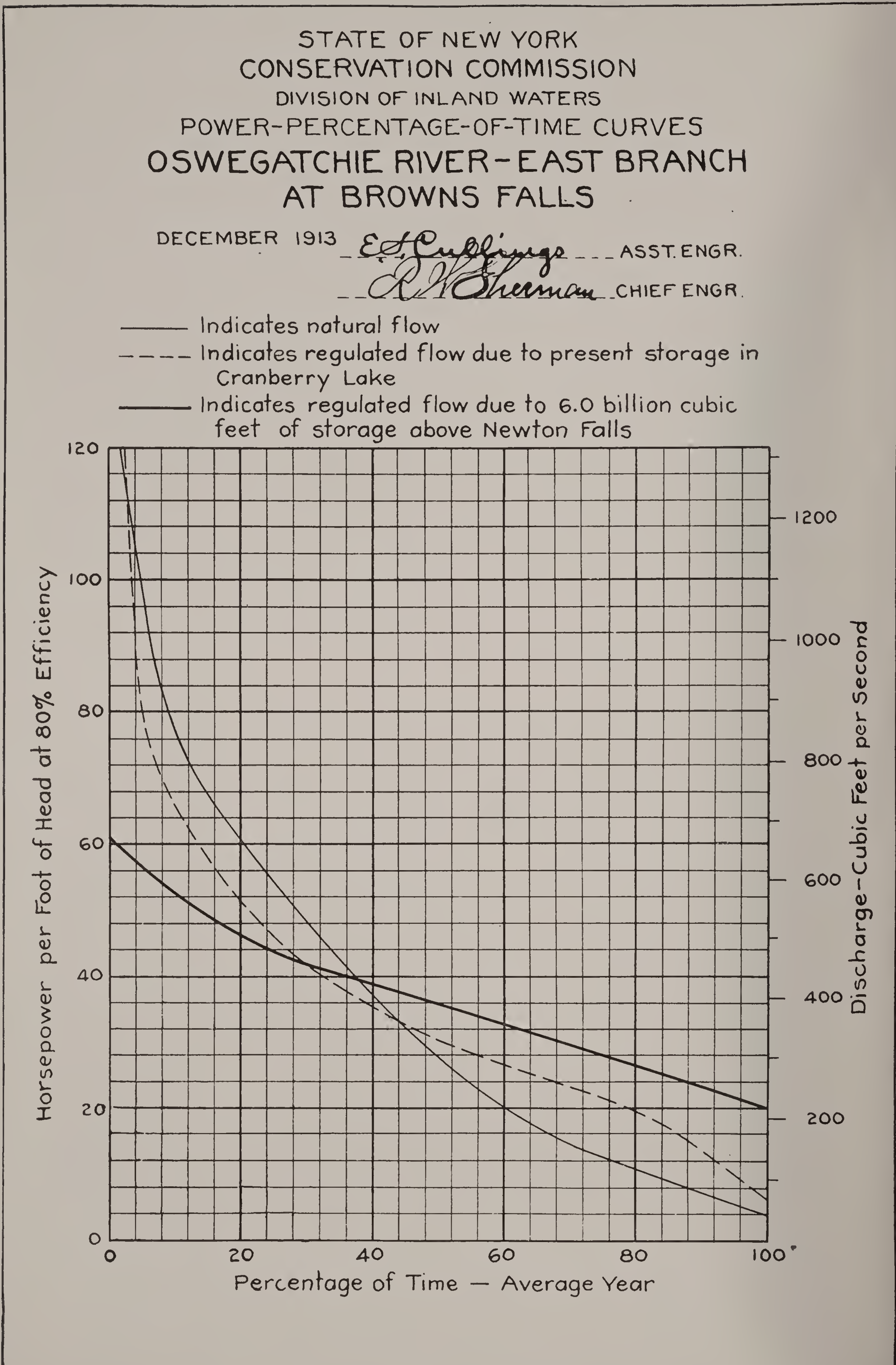
Proposed Dam Site at Madison Chute.

Rock Dam — Included in Madison Chute Power Project.

of repair. About 400 feet above this dam, at the head of a short rapids, is a small veneer mill which secures power from a 12-foot head created by a low crib dam and a short timber flume. The combination of these two powers offers a favorable opportunity for the creation of a 60-foot head at a very reasonable cost. The proposed dam would be located just below the highway bridge midway between the aforesaid dams. It would have a maximum height of 50 feet above stream bed and a total length of about 1,250 feet. The power house would be located on the southerly bank of the river just below the tannery dam. This development would make necessary the relocation of about 2 miles of highway and 2 bridges. It would also flood 4 or 5 farm houses and 100 acres of farm land. With the proposed regulation from the Newton Falls and Cranberry Lake reservoirs it would be possible to maintain a continuous flow of about 390 second-feet, and for 60 per cent. of the average year, a flow of about 550 second-feet. Based on regulated flow and an installation of 3,000 horsepower, the approximate cost of this development is estimated as follows:

Dam and appurtenances................	$137,500
Relocating highway and bridges.........	12,000
Farm land and buildings..............	13,000
Power house	11,000
Hydraulic and electrical machinery.......	32,000
Engineering and contingencies, 15 per cent	30,500
Total	$236,000
Cost per horsepower of installation.......	$78.67

Flat Rock. This project contemplates a masonry dam of freeboard section across the present stream bed, and a spillway 300 feet long on the northerly bank of the river. The dam would have a total length of about 600 feet and a maximum height above stream bed of 50 feet. It would make available a working head of 50 feet. The bed and banks of the


STATE OF NEW YORK
CONSERVATION COMMISSION
DIVISION OF INLAND WATERS
POWER-PERCENTAGE-OF-TIME CURVES
OSWEGATCHIE RIVER-EAST BRANCH
AT BROWNS FALLS
DECEMBER 1913
ASST. ENGR.
CHIEF ENGR.
Indicates natural flow
Indicates regulated flow due to present storage in Cranberry Lake
Indicates regulated flow due to 6.0 billion cubic feet of storage above Newton Falls
Horsepower per Foot of Head at 80% Efficiency
0
20
40
60
80
100
120
Discharge-Cubic Feet per Second
200
400
600
800
1000
1200
Percentage of Time — Average Year

river are of hard granitic rock. The power house would be located at the southerly end of the dam, using the present channel as a tail-race. The regulated stream flow at this point would be practically the same as at Fine. Based on regulated flow and an installation of 2,500 horsepower, the approximate cost of this development is estimated as follows:

Dam and appurtenances................	$159,000
Power house	9,000
Hydraulic and electrical machinery.......	27,000
Engineering and contingencies, 15 per cent.	29,000
Total	$224,000
Cost per horsepower of installation.......	$89.60

Brown's Falls. A working head of 53 feet is here utilized by means of a low crib dam and a 10-foot riveted steel penstock about 450 feet long, which delivers water to two 660-horsepower turbines direct-connected to 350 kw. generators. Power is transmitted to Benson Mines, four miles distant, and used in the iron mines at that place. A new dam at the head of the falls, and a larger power plant are now under construction.

In this series of falls and rapids there is available a gross head of 272 feet, which could be secured by means of a dam about 70 feet high at the crest of the upper falls, and a penstock about 7,000 feet long, carrying the water to the foot of the rapids just above the mouth of the Little river. With the proposed regulation due to 6.0 billion cubic feet of storage, regulated for South Edwards, it would be possible to maintain at this place a minimum flow of about 220 second-feet, and for 60 per cent. of the average year, a flow of about 360 second-feet.

Newton Falls. Two plants are in operation at this place. The lower plant, a pulp mill, utilizes a 21-foot head created by a timber dam. At the upper plant, power from a 32-foot head, secured by means of a low masonry dam and a 10-foot riveted steel penstock about 500 feet long, is used in the operation of a paper mill. A penstock 3,500 feet long, carrying water from the upper dam to the lower plant, would make it possible to utilize at one plant the whole available head of 60 feet.

West Branch.

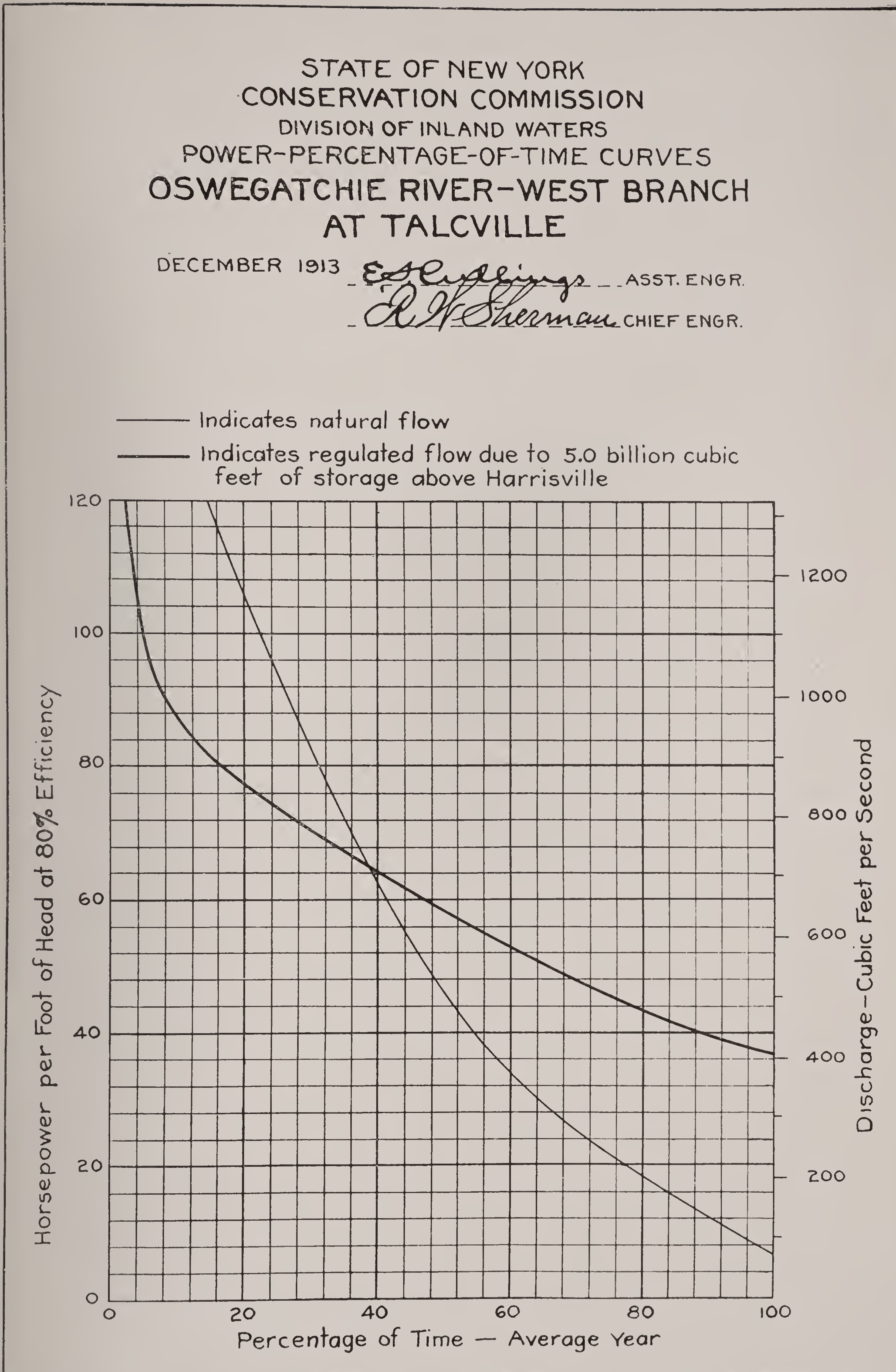
Talcville. A reinforced concrete dam at a point about 2,000 feet above the mouth of the West Branch utilizes the total available head of 19 feet. Electric power is generated and transmitted to a talc mine and mill about two miles away. Regulation offers the only means of increasing the power output at this plant.

Fullerville Lower Plant. A crib dam 11 feet high, with 24-inch flashboards, here creates a head of 13 feet and supplies power for the operation of a talc mill. No appreciable increase of head seems to be possible at this point.

Fullerville Undeveloped Fall. Just above the Fullerville highway bridge is a fall of 13 feet, which can be very economically developed. It is understood that this power is now being developed for use in the nearby talc mines.

Fullerville Upper Plant. At this point a crib dam in very poor state of repair creates a head of 18 feet, and supplies power to a talc mill. No increase of head appears practicable at this place.

Hazelton Falls. This falls offers a favorable opportunity for a low-head development at a very reasonable cost. At the crest of the falls a dam not over 8 feet high and 40 feet long would divert the water into a small channel on the easterly side of the river, which, with a small amount of excavation, could be utilized as a head-race. The power plant would be located at the junction of this channel and the main river near the foot of the falls. With the proposed regulation due to 5.0 billion cubic feet of storage in the Harrisville reservoir, it is estimated that in the ordinary year it would be possible to maintain a continuous flow of about 380 second-feet, and for from 7 to 8 months each year, a flow of about 550 second-feet. Based on this


STATE OF NEW YORK
CONSERVATION COMMISSION
DIVISION OF INLAND WATERS
POWER-PERCENTAGE-OF-TIME CURVES
OSWEGATCHIE RIVER-WEST BRANCH
AT TALCVILLE
DECEMBER 1913
ASST. ENGR.
CHIEF ENGR.
Indicates natural flow
Indicates regulated flow due to 5.0 billion cubic feet of storage above Harrisville
Horsepower per Foot of Head at 80% Efficiency
0
20
40
60
80
100
120
Discharge-Cubic Feet per Second
200
400
600
800
1000
1200
Percentage of Time — Average Year
0
20
40
60
80
100

regulation and an installation of 700 horsepower, the estimated cost of this development is as follows:

Dam and appurtenances, including head and tail-races	$19,700
Power house	8,700
Hydraulic and electrical machinery	15,600
Engineering and contingencies, 15 per cent.	6,600
Total	$50,600
Cost per horsepower of installation	$72.28

Harris Rapids. In this rapids the river has a total fall of 32 feet in a distance of about one mile. Near the lower end of the rapids a dam 200 feet long with spillway crest 22 feet above stream bed, and a head-race about 150 feet long, would provide a working head of 30 feet. With the proposed regulation from the Harrisville reservoir the minimum flow would be about 375 second-feet, and for 60 per cent. of the average year, about 530 second-feet. The estimated cost, based on regulated flow and an installation of 1,500 horsepower, is as follows:

Dam and appurtenances, including head-race	$43,700
Power house	12,600
Hydraulic and electrical machinery	28,500
Engineering and contingencies, 15 per cent.	12,700
Total	$97,500
Cost per horsepower of installation	$65.00

It might be possible to combine the last two projects by building a dam 30 feet high at the crest of Hazelton falls, but sufficient data are not at hand to determine the feasibility of this possibility. A total working head of 44 feet would be available and no valuable property would be flooded.

Gales Rapids. About 3.5 miles below the village of Harrisville is a rapids having a fall of 14 feet in a distance of about 1,000 feet. A working head of 16 feet could be obtained without flooding valuable property. The dam would be located at the middle of the rapids and would be about 200 feet long and 12 feet high above the stream bed. A head-race about 300 feet long would be required to carry the water to the power house at the foot of the rapids. The easterly bank and bed of the river are of rock; the westerly bank is of glacial drift, offering a favorable location for a head-race to the power plant. The minimum regulated flow in the ordinary year is estimated at 370 second-feet, and about 500 second-feet for from 7 to 8 months each year. Based on regulated flow and an installation of 750 horsepower, the estimated cost is as follows:

Dam and appurtenances, including head-race	$29,500
Power house	9,200
Hydraulic and electrical machinery	16,500
Engineering and contingencies, 15 per cent.	8,300
Total	$63,500
Cost per horsepower of installation	$84.67

Conditions are favorable for the erection of a multiple arch or reinforced concrete dam at this point. A considerable reduction in cost might be obtained in this way.

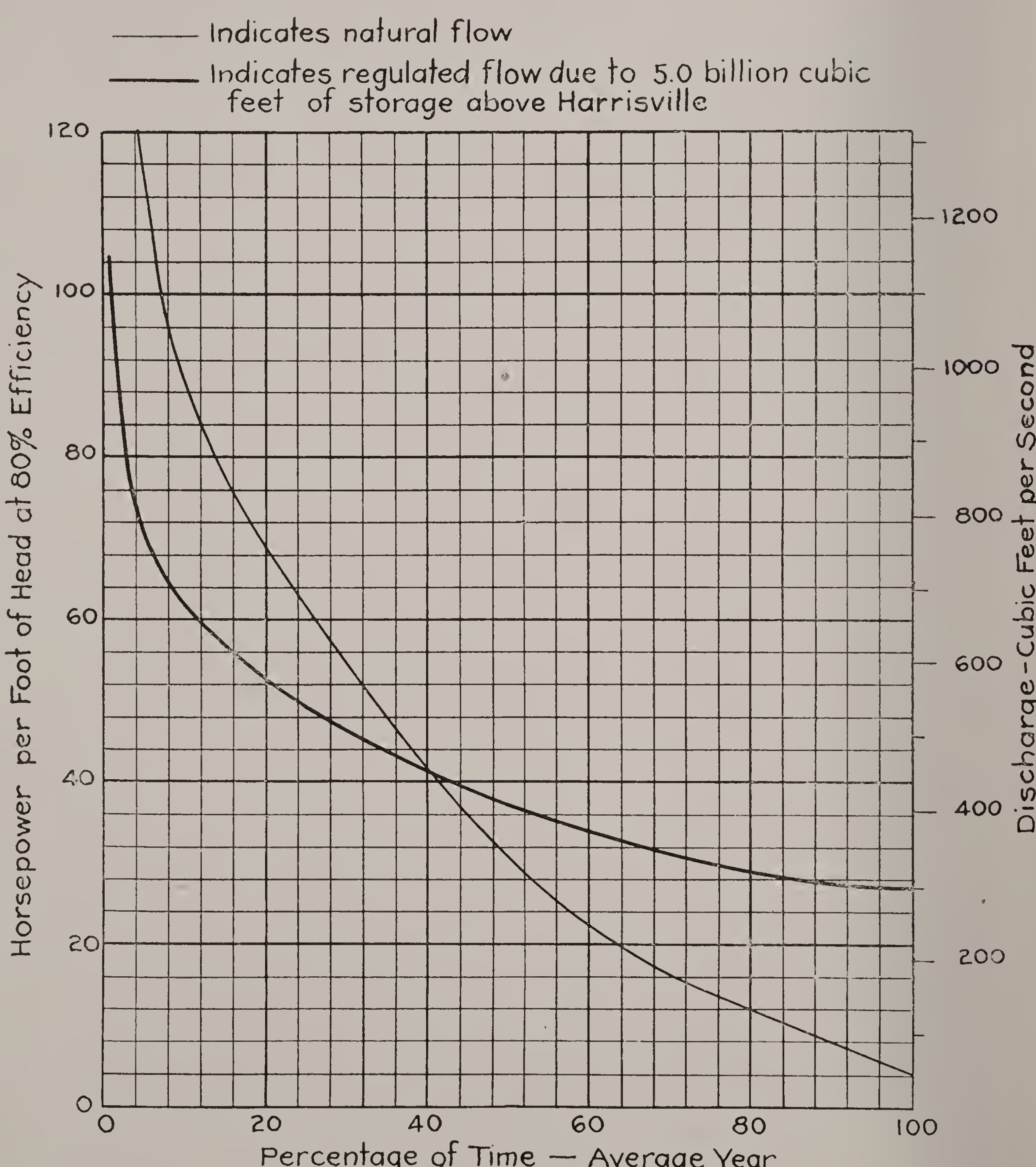
Harrisville Paper Mill. A masonry dam 20 feet high and a steel penstock 600 feet long here utilize the available head of 36 feet. Power is used in the operation of a pulp and paper mill. Regulation apparently offers the only means of increasing the power output at this plant.

Planing Mill. About one-half the stream flow under a head of 5 feet is here utilized in the operation of a planing mill and carpenter shop. The power output could be practically doubled by diverting the whole flow of the stream

STATE OF NEW YORK
CONSERVATION COMMISSION
DIVISION OF INLAND WATERS
POWER-PERCENTAGE-OF-TIME CURVES

OSWEGATCHIE RIVER–WEST BRANCH AT HARRISVILLE

DECEMBER 1913 E. S. Cullings ASST. ENGR.
R. W. Sherman CHIEF ENGR.



through the wheels of the plant, but the most efficient plan would be to combine this and the two plants next above under a single head using the entire flow of the stream.

Grist-mill and Sawmill. A 12-foot head is here created by a crib dam about 130 feet long. At the westerly end of the dam about one-half the stream flow is used by a grist-mill, while at the easterly end a small sawmill is operated by the remaining flow of the stream. The water discharged from the grist-mill is used by the planing mill above described. By combining these three plants a total working head of 17 feet would be available, and with the proposed regulation due to 5.0 billion cubic feet of storage it is estimated that a continuous flow of 300 second-feet could be maintained, and for 60 per cent. of the average year, a flow of about 375 second-feet would be available.

Undeveloped Site Above Harrisville. At a point immediately below the mouth of South creek a dam 31 feet high above low-water level would utilize the entire available fall between the crest of the grist-mill dam at Harrisville and the outlet works of the proposed reservoir. The dam would have a total length of 450 feet at spillway level and a maximum height of about 40 feet. The bed and banks of the river at this point are of granitic rock. The power house would be located at the easterly end of the dam. Under the proposed scheme of regulation a minimum flow of 300 second-feet would be maintained at this point during the filling of the reservoir. For 60 per cent. of the average year, a flow of about 375 second-feet would be available. The cost of developing this power would be rather high, and without regulation the project would probably not be feasible. Based on regulated flow and an installation of 1,000 horsepower, the approximate cost is estimated as follows:

Dam and appurtenances	$85,200
Power house	8,500
Hydraulic and electrical machinery	20,000
Engineering and contingencies, 15 per cent.	17,300
Total	$131,000
Cost per horsepower of installation	$131.00

Proposed Dam Site at Flat Rock.

Indian River — Water Power at Rossie.

The proposed dam would destroy a head of 8 feet at a sawmill about one mile upstream. This mill, however, is operated by steam, and the water power has not been used for several years. The above estimate of cost does not include the value of this water power, or of other riparian rights.

Kimball's Mill. On the West Branch about three miles above the mouth of the Middle Branch, a head of 15 feet created by a crib dam is utilized in the operation of a veneer mill. This head would be entirely destroyed by the proposed Harrisville reservoir, but at small expense the plant could be relocated at a point a few hundred feet upstream where a head of 17 feet is available.

Indian River.

Rossie. On the Indian river the feasible power sites have been quite fully developed. At Rossie a head of 23 feet, created by a low crib dam at the crest of the falls, formerly supplied power for the operation of a blast furnace and two or three small factories. These plants, however, have been in disuse for several years; only a grist-mill and a small sawmill now operate intermittently when water is available.

Theresa. A total fall of 81 feet is here developed, at three dams supplying power to four plants. At the lower plant a 50-foot head is utilized by means of a low masonry dam at the crest of a waterfall, and a short steel penstock connecting with the power house at the foot of the falls. Electric power is generated and used in a silk mill nearby.

A reinforced concrete dam a few hundred feet upstream creates a gross head of 18 feet. A grist-mill at the southerly end of the dam uses water under the full head of 18 feet. The pumping plant of the village water works is also located in this mill; it is operated chiefly at night, using power which would otherwise be wasted. At the northerly end of the dam but 9 feet of the available head is used in the operation of a sash and blind shop.

About one mile above the village is the municipal lighting plant, using power from a 13-foot head created by a masonry dam. This head could be increased by one or two feet by deepening the tail-race; during the low water period, 12- or 24-inch flashboards would be permissible.

Philadelphia. The municipal lighting plant of this village is located about one mile down stream from the village. A working head of 20 feet is created by a masonry dam of freeboard section and two small auxiliary dams which form the spillway. This head could be increased by three or four feet by deepening about 400 feet of the tail-race. Through the village of Philadelphia the river has a total fall of 57 feet, which is partially developed by two low timber dams. The first of these, at the crest of the lower falls, makes available a head of 40 feet, 16 feet of which is utilized in the operation of a grist-mill. The remaining 24 feet could be obtained at small expense by deepening the wheel-pit and lowering the wheels. At the upper dam the water is divided among two furniture factories and a grist-mill, using heads of from 10 to 12 feet. All three have to close down or use auxiliary power during the summer months.

The total head of 57 feet at this place could be utilized by combining these heads and developing power at a single plant at the foot of the falls, below the lower grist-mill. A considerable increase in the total power output could thus be secured.

Antwerp. At this place a head of 13 feet is developed by a masonry dam. Such power as is available is used in the operation of a lighting plant, a sash and blind shop, and a small sawmill. These plants are obliged to close down or use auxiliary power during the summer months.

Between Antwerp and Natural Bridge the river has a total fall of about 250 feet, but less than 40 feet of this head is now in use. About one mile above the village is a box factory using a 13-foot head created by a timber dam. Auxiliary power is used during the summer months. Half a mile further up stream is a small sawmill using a 15-foot head during the spring and early summer only. Another head of 17 feet was formerly utilized by a grist-mill, but both mill and dam are now in ruins. At "Wood's Mill" a grist-mill and a small sawmill are intermittently operated by power from a 9-foot head. There are also several falls and rapids, at which heads of from 10 to 20 feet could be very cheaply developed, but owing to the small tributary drainage area and the lack of storage facilities these possibilities are not at present considered practicable.

Natural Bridge. There are five low-head developments at this place, the first of which is a 22-foot head created by a crib dam recently built to supply power to a nearby talc mine. Next is a 15-foot head, power from which is used in a lime factory. A short distance further upstream is a grist-mill using a 20-foot head; and then a small custom sawmill with a 12-foot head. The last power development on the river is a 15-foot head just above the highway bridge, but this power is not at present in use. All these plants are obliged to use auxiliary power, or remain idle, during the summer months.

TABLE II.

Power Statistics — Indian River.

Location	Nature of business	Drainage area	Elevation of crest of dam	Working head	Rated h. p. of turbines
Rossie	Sawmill	381	295	23	20*
Rossie	Grist-mill	381	295	23	20*
Theresa	Power plant	324	354	50	1,480
Theresa	Grist-mill	324	374	18	250
Theresa	Sash and blinds	324	374	9	40*
Theresa	Lighting plant	324	389	13	168
Philadelphia	Lighting plant	229	418	20	240
Philadelphia	Grist-mill	229	458	16	20*
Philadelphia	Furniture factory	229	475	12	94
Philadelphia	Grist-mill	229	475	10	33
Philadelphia	Furniture factory	229	475	10	45
Antwerp	Lighting plant	157	495	15	194
Antwerp	Sawmill	157	495	13	30*
Antwerp	Sash and blinds	157	495	13	25*
Antwerp	Box factory	157	517	13	277
Antwerp	Sawmill	157	532	15	75*
Wood's Mill	Sawmill	125	610	9	25*
Wood's Mill	Grist-mill	125	610	9	25*
Natural Bridge	Power plant	60	......	22	200
Natural Bridge	Lime	60	......	15	40*
Natural Bridge	Grist-mill	51	......	20	143
Natural Bridge	Sawmill	51	......	12	35*
Natural Bridge	(Not in use)	51	......	15	35*
Total				282	3,514

* Estimated.

EXPLANATION OF TABLE III.

This table shows the principal details of head, installation, estimated stream flow, etc., at each of the present plants and at all undeveloped power sites affected by the proposed Cranberry

Lake, Newton Falls and Harrisville reservoirs. The first six columns are self-explanatory. Column VII shows the estimated minimum monthly flow, including the present regulation from Cranberry Lake. The flow at Ogdensburg and Eel Weir rapids is based on gagings at the Eel Weir Bridge station, but the estimates of discharge at all other points are based on the Raquette river records as explained on page 7. Column VIII shows the power available in the average year with the head shown in Column V and the flow in Column VII; turbine efficiency of 80 per cent. is assumed. Columns IX and X show the power available with the present installation and head, and that part of it supplied by the present Cranberry Lake reservoir. The estimates of power supplied by Cranberry Lake are intended only as rough approximations. Column XI shows the flow which can be depended on for about 60 per cent. of the average year, including the present regulation from Cranberry Lake. Column XII shows the required wheel installation to utilize the flows in Column XI, and Column XIII the average power output in horsepower-years per annum, including the power supplied by Cranberry Lake. Columns XV to XXX, inclusive, show conditions after regulation by 11.0 billion cubic feet of storage in the proposed Cranberry Lake, Newton Falls and Harrisville reservoirs. Columns XV shows the amount of power in horsepower-years per annum which would be added by these reservoirs with the present wheel installation and head. Columns XVI, XVII, XVIII, and XIX are similar to Columns IV, V, VII, and VIII, respectively, showing conditions after regulation. Columns XX, XXI, XXII, and XXIII are comparable with Columns XI, XII, XIII and XIV. Column XXIV shows the amount of energy added by the proposed regulation after economic development as shown in Column XXI. This is in addition to the power which would be supplied by the present storage in Cranberry Lake, shown in Column XXIII. Columns XXVI and XXVII show the auxiliary installation and the amount of auxiliary power required in the ordinary year to supply continuous year-round power to the full wheel capacity shown in Column XXI. Columns XXVIII, XXIX and XXX show the respective amounts of power in horsepower-years per annum supplied by each of the proposed reservoirs It is

TABLE No. III—Summary of Effects of Storage on Oswegatchie River.

Location.	Nature of business.	Present Conditions. Drainage area.	Elevation of crest of dam or top of flash-boards. (Above sea level.)	Average working head.	Rated horse-power capacity of turbines.	Estimated minimum monthly flow in second-feet. (Includes present regulation from Cranberry Lake.)	Continuous 24-hour h. p. available with flow in Column VII at 80% efficiency.	Power available in average year with installation in Column VI h. p. years per annum. (Includes column X.)	Power supplied by present regulation from Cranberry Lake, h. p. years per annum.	Estimated available flow for 60% of average year in second-feet. (Includes present regulation from Cranberry Lake.)	Capacity of turbines at 80% efficiency for 24-hour power 60% of average year.	Power available with installation in column XII and flow in Column XI h. p. years per annum (Includes column XIV.)	Power supplied by present storage in Cranberry Lake with installation in Column XII h. p. years per annum.	Conditions After Regulation by 3.0 B. C. F. of Storage in Cranberry Lake Reservoir and 3.0 B. C. F. in Newton Falls Reservoir Regulated for South Edwards, and 5.0 B. C. F. of Storage in Harrisville Reservoir Regulated for Talcville; Turbine Installation Which Can be Operated at Full Capacity 60% of Average Year Assumed to be Economic Development in Each Case. Power added to present stream flow by proposed reservoirs with present installation and head h. p. years per annum.	Elevation proposed crest of dam or top of flash-boards. (Above sea level.)	Ultimate working head.	Minimum regulated flow in second-feet. (Based partly on Raquette river records).	Continuous 24-hour h. p. available with flow in Column XVIII at 80% efficiency.	Regulated flow available for 60% of average year. (Based partly on Raquette rivor records).	Capacity of turbines at 80% efficiency for 24-hour power 60% of average year.	Power supplied by present stream flow with installation in Column XXI h. p. years per annum (Includes Column) XXIII.	Power supplied by present storage in Cranberry Lake with installation in Column XXI h. p. years per annum.	Additional power afforded by proposed regulation in average year, after economic development. h. p. years per annum.	Total hydraulic power available in average year. (Sum of Columns XXII and XXIV.) h. p. years per annum.	Auxiliary Power Required to Maintain Continuous 24-hour Power With Installation in Column XXI. Rated horse-power.	Auxiliary Power Required to Maintain Continuous 24-hour Power With Installation in Column XXI. Horsepower years per annum.	Power Added to Natural Stream Flow by Proposed Reservoirs After Economic Development, H. P. Years Per Annum. Cranberry Lake reservoir 3.0 b. c. f. capacity.	Newton Falls reservoir 3.0 b. c. f. capacity.	Harrisville reservoir 5.0 b. c. f. capacity
I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI	XXII	XXIII	XXIV	XXV	XXVI	XXVII	XXVIII	XXIX	XXX
													DEVELOPED POWERS																
MAIN RIVER:																													
Ogdensburg	Small mills and factories	1,590	258	10	2,878	395	359	1,890	35	1,600	1,450	1,220	35	130	258	12	950	1,036	1,780	1,940	1,580	50	165	1,745	910	195	59	59	97
Heuvelton	Grist-mill aud electric plant	986	284	9	180	270	221	180	0	1,170	957	825	35	0	286	11	950	950	1,540	1,540	1,200	55	220	1,420	585	120	75	75	125
Rensselaer Falls	Small factories	950	301	7	330	265	168	310	10	1,130	720	640	25	6	301	8	935	680	1,500	1,090	840	40	160	1,000	400	90	55	55	90
Elmdale	Sawmill	800	324	9	50	245	200	50	0	1,000	818	675	35	0	339	22	850	1,700	1,380	2,760	2,100	105	440	2,540	1,060	220	148	148	249
Wegatchie	Sawmill	760	349	9	75	235	192	75	0	950	778	665	35	0	365	23	830	1,735	1,360	2,840	2,150	110	460	2,610	1,100	230	155	155	260
Natural Dam, lower plant	Talc mill (not in use)	748	374	9	200	235	192	200	0	930	760	660	35	0	374	9	830	678	1,360	1,120	850	45	180	1,030	430	90	61	61	103
Natural Dam, upper plant	Paper mill	748	395	20	3,160	235	427	2,140	90	930	1,690	1,475	80	465	395	20	830	1,510	1,360	2,470	1,870	95	400	2,270	960	200	135	135	225
Gouverneur	Small factories	745	402	7	285	235	149	270	10	930	591	515	30	6	402	7	830	528	1,360	865	660	35	140	800	330	65	48	48	79
Hailesboro — South channel	Talc mill (about 75% of stream flow)	660	429	19	525	165	285	520	20	640	1,105	965	60	1															
Hailesboro — South channel	Power plant (75% of stream flow)	660	454	25	892	165	375	860	40	640	1,452	1,270	75	10															
Hailesboro — South channel	Talc mill (37.5% of stream flow)	660	470	14	450	83	106	380	20	320	407	355	20	60															
Hailesboro — South channel	Sash and blind shop (18.75% of stream flow)	660	470	10	25	41	37	25	0	160	145	125	7	0															
Hailesboro — South channel	Grist-mill (18.75% of stream flow)	660	470	10	50	41	37	50	0	160	145	125	7	0	553	140	810	10,300	1,250	15,900	12,000	670	2,800	14,800	5,600	1,100	945	945	1,580
Hailesboro — South channel	Talc mill (75% of stream flow)	660	486	16	1,024	165	240	860	50	640	930	800	50	140															
Hailesboro — North channel	Sawmill (25% of stream flow)	660	418	7	10	55	35	10	0	210	134	120	7	0															
Hailesboro — North channel	Talc mill (25% of stream flow)	660	485	25	264	55	125	250	15	210	477	425	25	15															
Hailesboro — Main channel	Power plant	660	535	15	600	220	300	580	25	850	1,160	1,020	60	8															
Emeryville	Pulp null	650	586	31	2,440	210	592	2,100	130	850	2,390	2,100	125	340	586	31	810	2,280	1,250	3,520	2,640	150	630	3,270	1,240	250	213	213	355
Hyatt	Not in use	650	610	24	....	210	458	....	....	850	1,850	1,620	95	....	610	24	810	1,765	1,250	2,730	2,050	115	490	2,540	960	190	165	165	275
Sub-total	....	....	....	212	13,438	....	4,498	10,750	445	....	17,959	15,600	841	1,181	....	307	....	23,162	....	36,775	27,940	1,470	6,085	34,025	13,575	2,750	2,059	2,059	3,438
EAST BRANCH:																													
Talcville	Power plant	341	630	16	457	125	182	440	40	470	685	600	60	17	630	16	415	603	660	960	745	65	140	885	355	75	102	102	....
Edwards	Grist-mill and lighting plant	317	658	10	250	120	109	230	20	445	404	365	35	6	658	10	410	372	620	565	440	40	85	525	190	40	63	63	....
South Edwards, lower plant	Power plant	284	757	37	900	105	353	860	85	410	1,380	1,200	125	30	757	80	400	2,910	570	4,150	3,230	320	650	3,880	1,240	270	485	485	....
South Edwards, upper plant	Power plant	284	843	83	3,200	105	792	2,720	295	410	3,100	2,700	280	375	843	83	400	3,020	570	4,300	3,350	330	670	4,020	1,280	280	500	500	....
Fine	Veneer mill	275	984	12	150	100	109	150	5	400	436	385	40	0	1,010	58	390	2,055	550	2,900	2,260	230	450	2,710	845	190	340	340	....
Brown's Falls	Power plant	178	1,205	53	1,320	65	313	1,180	170	290	1,400	1,200	170	130	1,350	262	220	5,240	360	8,570	6,940	930	1,000	7,940	3,330	630	965	965	....
Newton Falls, lower plant	Pulp mill	166	1,374	21	600	60	115	480	75	270	515	460	65	50	1,416	60	200	1,090	335	1,830	1,490	210	155	1,645	740	185	182	182	....
Newton Falls, upper plant	Paper mill	166	1,416	32	1,900	60	175	1,000	65	270	785	700	100	80															
Sub-total	....	....	....	264	8,777	....	2,148	7,060	755	....	8,705	7,610	875	688	....	569	....	15,290	....	23,275	18,455	2,125	3,150	21,605	7,980	1,670	2,637	2,637	....
WEST BRANCH:																													
Talcville	Power plant	309	629	19	440	65	112	390	....	375	648	530	....	44	629	19	395	682	580	1,000	710	....	220	930	310	70	....	....	220
Fullerville, lower plant	Talc mill	300	645	13	393	65	77	325	....	340	402	330	....	65	645	13	385	455	550	650	460	....	150	610	195	40	....	....	150
Fullerville, upper plant	Talc mill	300	676	18	225	65	106	220	....	340	556	460	....	7	676	18	385	630	550	900	640	....	200	840	270	60	....	....	200
Harrisville, lower plant	Paper mill	200	781	34	2,160	45	140	1,200	....	240	740	620	....	216	781	34	300	927	375	1,160	840	....	265	1,105	240	55	....	....	265
Harrisville, middle plant	Carpenter shop (50% of stream flow)	200	786	5	30	23	10	30	....	120	55	45	....	0	799	17	300	463	375	580	420	....	130	550	120	30	....	....	130
Harrisville, upper plant	Grist-mill and sawmill	200	798	12	610	45	49	370	....	240	262	215	....	86															
Kimball's Mill	Veneer mill	63	876	15	132	15	20	100	....	75	102	75	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Sub-total	....	....	....	114	3,990	....	514	2,635	....	....	2,765	2,275	....	418	....	101	....	3,157	....	4,290	3,070	....	965	4,035	1,135	255	....	....	965
Total—Developed powers	....	....	....	....	26,205	....	7,160	20,445	1,200	....	29,429	25,485	1,716	2,287	....	....	....	41,609	....	64,340	49,465	3,595	10,200	59,665	22,690	4,675	4,696	4,696	4,403
													UNDEVELOPED POWERS																
MAIN RIVER:																													
Eel Weir Rapids	....	1,565	....	....	....	395	....	....	....	1,600	....	....	....	....	272	13	950	1,120	1,780	2,100	1,710	55	180	1,890	990	210	64	64	107
EAST BRANCH:																													
Talcville	....	341	....	....	....	125	....	....	....	470	....	....	....	....	647	14	415	528	660	840	650	55	125	775	310	65	90	90	....
Madison Chute	....	280	....	....	....	105	....	....	....	410	....	....	....	....	948	95	400	3,460	570	4,920	3,840	380	760	4,600	1,460	320	570	570	....
Flat Rock	....	268	....	....	....	100	....	....	....	400	....	....	....	....	1,072	50	390	1,770	550	2,500	1,945	190	390	2,335	730	165	290	290	....
Sub-total	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	159	....	5,758	....	8,260	6,435	625	1,275	7,710	2,500	550	950	950	....
WEST BRANCH:																													
Fullerville	....	300	....	....	....	65	....	....	....	340	....	....	....	....	658	13	385	455	550	650	460	....	145	605	195	45	....	....	145
Hazelton Falls	....	300	....	....	....	65	....	....	....	340	....	....	....	....	691	14	385	490	550	700	495	....	160	655	210	45	....	....	160
Harris Rapids	....	290	....	....	....	63	....	....	....	330	....	....	....	....	723	30	375	1,022	530	1,450	1,020	....	335	1,355	430	95	....	....	335
Gale's Rapids	....	275	....	....	....	60	....	....	....	315	....	....	....	....	743	16	370	538	500	730	500	....	180	680	190	50	....	....	180
Harrisville	....	200	....	....	....	45	....	....	....	240	....	....	....	....	830	29	300	790	375	990	720	....	225	945	205	45	....	....	225
Sub-total	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	102	....	3,295	....	4,520	3,195	....	1,045	4,240	1,230	280	....	....	1,045
Total — Undeveloped powers	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	10,173	....	14,880	11,340	680	2,500	13,840	4,720	1,040	1,014	1,014	1,152
Grand total — All powers	....	....	....	....	26,205	....	7,160	20,445	1,200	....	29,429	25,485	1,716	2,287	....	E. Br. 1,048 W. Br. 523	....	51,782	....	79,220	60,805	4,275	12,700	73,505	27,410	5,715	5,710	5,710	5,555

assumed the the Cranberry Lake and Newton Falls reservoirs will be operated together, and therefore, having equal capacities, will add equal amounts of power. Column XXVIII, Cranberry Lake, includes the amount of power which would be supplied by the present reservoir with the present method of regulation.

Comparing Columns IX and XXV, it is seen in Column IX that the total available power from the present stream, with the present wheel installations and heads, is slightly in excess of 20,000 horsepower-years per annum, but of this amount only about 7,160 horsepower (Column VIII) is continuous; Column XXV shows that the full economic development of existing plants and all undeveloped power sites will produce over 73,000 horsepower-years per annum, and of this amount nearly 52,000 horsepower (Column XIX) will be continuous in the driest year. Comparing the costs of the proposed reservoirs and the increase in power due to each, it is seen by referring to Columns XXIII and XXVIII that the proposed Cranberry Lake reservoir will add about 1,435 horsepower-years per annum over and above that which would be supplied by the present reservoir; the estimated cost of the proposed reservoir is $79,000; therefore, the storage investment amounts to about $55 per horsepower. The estimated cost of the Newton Falls reservoir is $743,000, and Column XXIX shows that it will supply about 5,710 horsepower-years per annum, making the storage investment $130 per horsepower. In the case of the Harrisville reservoir, the cost is estimated at $696,000, and Column XXX shows that it will supply about 5,555 horsepower-years per annum, making the storage investment $125 per horsepower.

APPENDIX I.

Methods Used in Making Steamflow Studies.

Location of Data. Nearly all of the steamflow data on New York State streams may be found in the annual reports of the Conservation Commission, the State Water Supply Commission (previous to 1911), the State Engineer and Surveyor, and in the United States Geological Survey water supply papers. Rainfall and temperature records are published in the monthly and annual reports of the U. S. Weather Bureau. Many valuable statistics are also to be found in the New York State Museum Bulletin No. 85, "Hydrology of the State of New York," by George W. Rafter. Following is a brief description of the methods used in the foregoing streamflow studies:

Conversion Factors and Curves. In the ordinary hydraulic development, reliable streamflow data at the power site are seldom available. It is only in the more thickly settled regions on such rivers as the Hudson, Genesee and Croton that gaging stations have been maintained for long periods. Therefore, in a new development it is usually necessary to estimate the probable runoff either: (1), entirely from rainfall records; (2), from rainfall records used in conjunction with streamflow records from an adjacent or near-by watershed; (3), from a short-term streamflow record at the site, and a long-term record at another point on the same stream or from a near-by watershed. In New York State it is no longer necessary to depend entirely on rainfall studies, as long-term streamflow records are available for most of the larger rivers, and short-term records for at least one point on many of the smaller streams. The first method above mentioned therefore need not be discussed.

When rainfall data are available for one watershed, only, while from an adjacent drainage area both rainfall and streamflow records can be obtained, the probable run-off to be expected from the first watershed can be quite accurately estimated from the records of the second by means of a "conversion factor." This method is based on the assumption that the discharges from two adjacent watersheds having similar physical and climatic characteristics are proportional to their respective drainage areas and mean annual rainfalls. That is, for example, if Watershed "A" has an area of 400 square miles and a mean annual precipitation of 50 inches, and Watershed "B" has an area of 600 square miles and a precipitation of 48 inches, the ratio:

$$\frac{\text{discharge A}}{\text{discharge B}} = \frac{400 \times 50}{600 \times 48} = 0.89$$

The resulting value (0.89 in this case) is called a "conversion factor." If the known monthly (or weekly or daily) discharges from Watershed B for a given period be successively multiplied by this factor, the resulting quantities will represent the most probable values of the discharge from Watershed A for the respective months. The accuracy of this method will depend on the similarity of the topographical and meteorological characteristics of the two watersheds.

In case there is available only a short-term streamflow record at the given point, while at another point on the same stream (or a near-by stream) a long-term record is available, the "conversion curve" offers a convenient method of computing a long-term estimate for the short-term station. This is accomplished by plotting as ordinates the monthly (or weekly or daily) flows at one station, and the corresponding flows for the same months at the other station as abscissas. An average curve drawn through these points is termed a "conversion curve," from which it is possible to reduce the long-term records to the short-term station. As in the preceding case, the accuracy of this method depends on the similarity of the characteristics of the two watersheds.

Mass Curves.

Some phases of a given streamflow can best be studied by the mass curve method. The computations are generally made in monthly increments. The method consists in adding up the totals of the yield in monthly (or daily) increments from month to month, for the whole period of gagings under consideration; then plotting these totals as ordinates over the corresponding time as abscissas. A line connecting these points forms the mass curve. Any desired rate of draft may then be assumed and plotted to the same scale. If a uniform rate is assumed, this draft curve forms a straight inclined line, and if it is made to start coincident with some point or summit on the mass curve, the divergence of the two curves at the end of any dry period serves to show the volume of storage that would have been required to have maintained the assumed draft up to that time. Conversely, any volume of storage may be assumed and plotted as an ordinate at the point on the mass curve at the end of the dry season, and the slope of the line drawn from the previous peak of the mass curve to this ordinate will give the regulated flow possible by the use of this volume of storage. The records giving the mean monthly flow in second-feet are converted into cubic feet per month by multiplying by the factor, 2,628,000, which is the number of seconds in an average month, i. e., a month of $\frac{365}{12} = 30.42$ days.

The results of river regulation with a given storage reservoir will not be the same at widely separated points below the reservoir, particularly if the flow of the river has been materially augmented by the entrance of streams between these points. Each point will require a different method of operation of the reservoir to give the best result at that point. The mass curve offers an easy method by which to determine the respective effects on the flow of the river at those more or less remote points, by release of the stored water in a prescribed manner. This is accomplished by plotting separate mass curves for the different points under consideration. Any point may be chosen as the one for which the best regulation is desired at the expense, to some extent, of the other places. The proposed draft line may then be drawn on the mass curve for this point, bearing in mind that the billions of cubic feet represented by the maximum ordinate-intercept must not exceed the reservoir capacity. Having done this, the incidental effect upon the flow at each of the other points may be readily found by superimposing these ordinate-intercepts on each of the other mass curves, thus making up new mass curves which represent the new flow of the river due to the presence of the regulating reservoir. This method has also proved efficient for determining the amount of pondage necessary to regulate for the unequal hourly draft due to a load factor of less than 100 per cent. A hydrograph is first made up from the load diagram, showing the mean hourly demand from the pond. These values are then integrated to make up a daily mass curve of draft. The steady river supply is represented by a straight line, and the maximum ordinate-intercept between the two lines represents the daily fluctuation in volume of water ponded. This is the inverse process of the ordinary storage-depletion method, where the river flow is unsteady and the draft is constant.

Power-Percentage-of-Time Curves.

This title has been given to certain curves which show on a percentage basis the period of time in an average year during which any given horsepower is available at a certain point, either from the natural flow of the stream or as a result of a certain amount of regulation due to storage reservoirs.

The natural flow curve is obtained by arranging the mean monthly stream-flow values in order of their magnitude and reducing them to horsepower at 80 per cent. efficiency by multiplying by the factor;

$$\frac{\text{Head in feet.}}{11} = \frac{\text{Head} \times 62.5 \times 80\%}{550}$$

If there is more than one fall in the vicinity to which this curve will apply, it may be well to compute and plot the curve on a one-foot-head basis as shown on Plates XI, XII, XIII, XIV, XV, XVI. The number of months during which any flow or a greater flow is available are then tabulated, and assuming the total number of months for the whole period for which records are available, as 100 per cent. of the time, the percentage of time during which any of the other flows are available is then computed. With the percentages of time as abscissas and corresponding horsepowers as ordinates, points can be plotted, through which a curve can be drawn. The regulated streamflow power-percentage-of-time curve is obtained in the same manner by substituting for the natural stream-flows the regulated flows obtained from the mass curve for a given volume of storage during the months they are maintained, converting them into horsepower, computing the corresponding percentages of time and plotting as in the previous case.

If the power-percentage-of-time curves for natural and regulated flow are plotted from the same set of axes, the area between the natural flow curve and the axes represents the amount of energy available from the natural flow of the stream. This area is reduced to horsepower-years as follows: Suppose the curves are plotted to a scale of 100 horsepower to the inch, ordinates, and 20 per cent. of the time to an inch, abscissas, then one square inch is equal to 20 horsepower-years. The area between the natural flow and regulated flow curves up to their intersection represents the energy added from storage; and the area between the regulated flow curve and any horizontal line above its lowest point and the axis, represents the auxiliary energy necessary for that installation.