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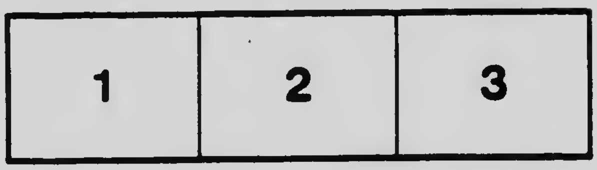
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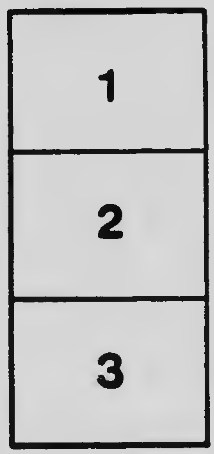
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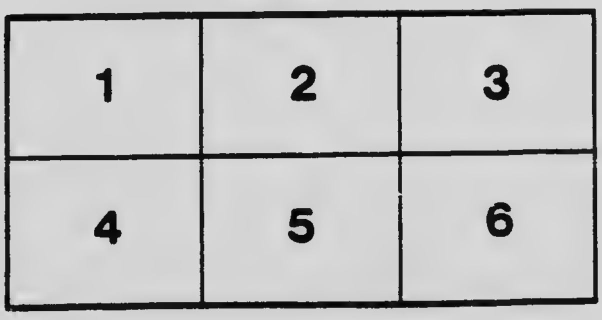
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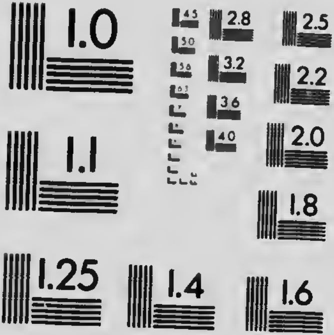

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DEPARTMENT OF THE INTERIOR
DOMINION WATER POWER BRANCH
OTTAWA, CANADA

WATER RESOURCES PAPER No. 3
VOLUME I

WINNIPEG RIVER POWER
AND
STORAGE INVESTIGATIONS

BY

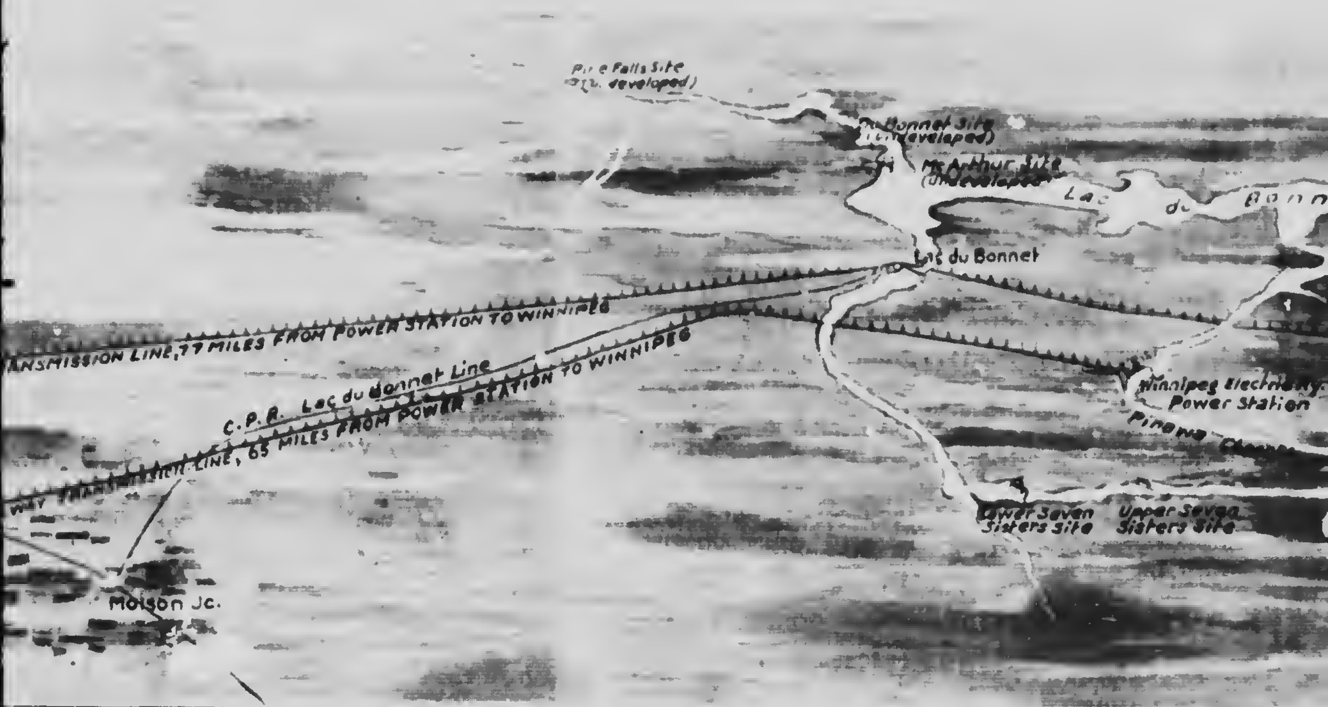
J. T. JOHNSTON, B.A. Sc.
Chief Hydraulic Engineer.

Prepared under the direction of the Superintendent of Water Power.

OTTAWA
GOVERNMENT PRINTING BUREAU
1915.


N Selkirk
Parkview
Red River
C. P. R.
C. N. R.
C. P. R.
WINNIPEG
G. T. P.
C. P. R.
C. P. R. Main Line
C. P. R. Molson Cut off
C. P. R.
C. N. R.
G. T. R.

AEROPLANE VIEW OF SOUTHEASTERN MANITOBA



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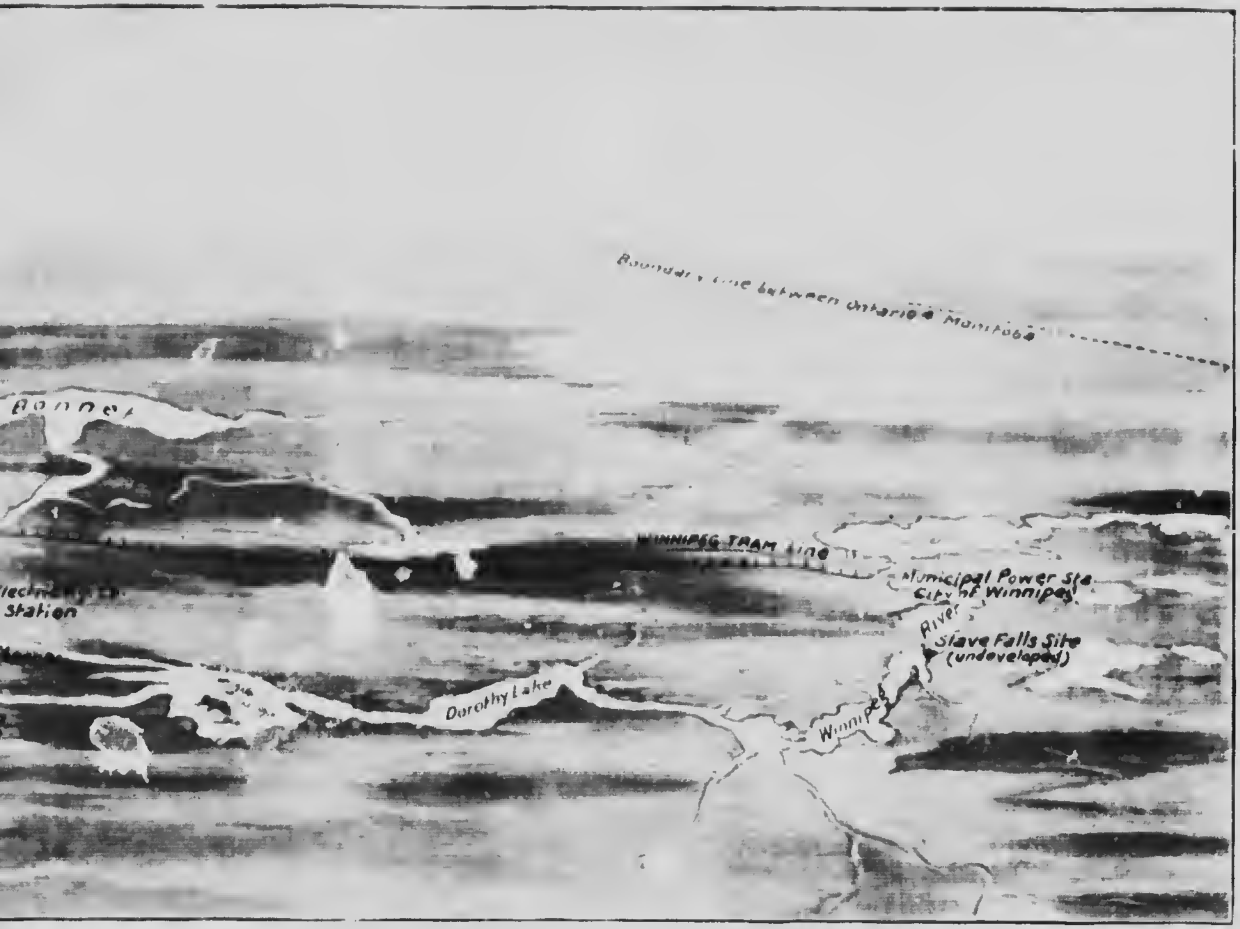

Dorothy Lake
WINNIPEG TRAM LINE
Municipal Power Sta.
City of Winnipeg
River
Slave Falls Site
(undeveloped)
Station

DEPARTMENT OF THE INTERIOR—CANADA

Hon. W. J. ROCHE, Minister, W. W. CORY, C.M.G., Deputy Minister.

DOMINION WATER POWER BRANCH,

J. B. CHALLIES, C.E., Superintendent.

WATER RESOURCES PAPER No. 3

VOLUME I

REPORT

ON THE

WINNIPEG RIVER POWER

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STORAGE INVESTIGATIONS

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Prepared under the direction of the Superintendent of Water Power.

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GOVERNMENT PRINTING BUREAU
1915.

86376—A

To Field Marshal, His Royal Highness Prince Arthur William Patrick Albert, Duke of Connaught and of Strathearn, K.G., K.T., K.P., etc., etc., etc., Governor General and Commander in Chief of the Dominion of Canada.

MAY IT PLEASE YOUR ROYAL HIGHNESS:

The undersigned has the honour to lay before Your Royal Highness a report on the Winnipeg River Power and Storage Investigations.

Respectfully submitted,

W. J. ROCHE,

Minister of the Interior.

OTTAWA, July 20, 1915.

DEPARTMENT OF THE INTERIOR,

OTTAWA, July 20, 1915.

The Honourable W. J. ROCHE,
Minister of the Interior.

SIR,—I have the honour to submit a report on the Winnipeg River Power and Storage Investigations, and to recommend that it be published as Water Resources Paper No. 3 of the Dominion Water Power Branch.

I have the honour to be, sir,
Your obedient servant,
W. W. CORY,
Deputy Minister of the Interior.

OTTAWA, July 17, 1915.

W. W. CORY, ESQ., C.M.G.,
Deputy Minister of the Interior,
Ottawa, Canada.

SIR,—The people of the province of Manitoba have a keen interest in the important economic problems now brought so forcibly to the attention of the Canadian people as a result of "the conservation movement." That interest is particularly manifested at this time because probably no province in the Dominion is endowed with conditions so favourable and opportunities so promising for the early accomplishment of material progress from practical and sane conservation of one of its most valuable natural resources.

Water is practically the only natural resource within the province for the development of power, that great and fundamental requisite for the prosperity and comfort of a civilized community. This condition is compensated for by the fact that in addition to the existence of an abundance of water, the general topography and the forest cover of a large portion of the province is naturally favourable for the establishment of hydraulic power developments, and also for the construction of storage reservoirs for flow regulation.

Historically considered, the utilization of our power resources has passed through three distinct phases. The first pertained to the production of power directly and from natural sources as water and wind, and its use was necessarily limited to their location. Early manufacturing communities were consequently grouped about easily available water power sites. This phase might be called the water power period in manufacturing industries

The second phase was characterized by the gradual development of the steam engine which rendered possible the utilization of fuel as a source of power, and at locations where it was required. During this period the development of coal mines and the rapid extension of railway systems imparted a tremendous stimulus to commercial and industrial enterprise. Proximity of water powers was no longer the controlling factor, and industrial communities were established wherever availability of raw material, labour, transportation facilities, markets and fuel power would allow.

The third phase of power development in this country synchronizes with the advancement of the art of high voltage transmission which permits the development of power generated by water or by steam at the most convenient and economical points, and its transmission many miles away to the desired location of use, in a form adapted to a great variety and convenience of use.

This later phase of development and use of power has called for a re-appraisement of all sources from which power is derived. The size of the power plant is no longer limited to requirements of any particular purpose or use, but the power for entire communities, and for an infinite variety of use, civil and commercial, can be supplied from a single station or power site many miles distant.

Extension of the field of use opened by the perfection of the art of electric transmission of power from great distances, has been marvellous. As a result, rapid and revolutionary changes are constantly taking place in the use of power. As the circle of electrical application circumscribes new fields, the opportunities for power development grow proportionately. The tremendous advance to date in the practicable application of the use of electric power in industry and the further accomplishments that are assured, have rendered the conservation and utilization of our power resources, (more especially our water powers), one of the most important problems in Canadian political economy.

The solution of this problem involves complex questions of law and regulation relating to various uses of water for domestic supply, irrigation, power, logging and navigation; of adequate administration under such legislation; of essential engineering and economic investigation of water resources to meet the necessities of administration, and to determine the most efficient and effective method of power development, so that the permanent public interest will be best served; and probably most difficult of all, determinations of economic questions relating to adequate rentals, and reasonable rates.

Canadian water power laws are in the main quite adequate, encouraging to development, with due regard to the public interest, present and future. While in some parts of the Dominion former conditions have been outgrown, and in such parts the evolution of governmental machinery and laws with respect to water powers has not advanced as fast as might be desired, it must be remembered that there is but a short distance in time from the 50 h.p. overshot mill wheel of small efficiency, crude apparatus, local use and of little general importance to the community at large, to the 20,000 h.p. turbine of over 90% efficiency and 200 mile transmission radius of to-day, of such widespread importance owing to the present universality of the electrical industry and the consequent infinite ramifications of power use in respect of the body politic.

So far as the prairie provinces of Manitoba, Saskatchewan and Alberta are concerned, the problems above referred to have been given fairly adequate consideration and the regulations, administration and investigations which have been evolved by the Department of the Interior in the short space of seven or eight years, have marked a creditable achievement The existing water power regulations (see appendix IV) are admittedly, in some respects, imperfect. At the same time the imperfections and undesirable features are thoroughly well realized, and it is only a matter of time and opportunity when they will be corrected. The regulations now in force afford every reasonable protection to the public in the way of limited grants, rentals and control of rates, both subject to periodic revision, continuous and beneficial use of the power privileges, and at the same time provide sufficiently attractive opportunities for investment to actively interest the capitalist. The departmental administration, is as progressive as the regulations and the Parliamentary appropriations will permit.

The two most important water power situations within the three prairie provinces, that on the Winnipeg river in Manitoba, and that on the Bow river in Alberta, important on account of their strategic location close to important existing commercial centres, and on account of the great and urgent demand for power within these centres, and also important on account of the complicated problems involved in realizing the best use of the potential power possibilities in a manner consistent with the interests of irrigation, navigation and water supply; have been exhaustively covered by extensive engineering and economic investigations in the field, and by thorough study in the office.

The power and storage investigations of the Bow river were completed over a year ago and published in the form of a report as Water Resources Paper No. 2.

The Winnipeg river power situation in the province of Manitoba within easy transmission radius (about seventy-five miles) of the city of Winnipeg, a city on the eastern threshold of the great prairie country, which competent experts claim will have a future in population, banking, commercial and industrial importance equal to that of Chicago, has also been thoroughly investigated.

These investigations were commenced in 1911 following a report from the undersigned, then Hydraulic Engineer of the Department, to the late Robert Evans Young, D.L.S., then Chief Geographer, and in responsible administrative charge of water power matters in the western provinces. No one in the Canadian service had a deeper appreciation for the importance of the undeveloped natural resources of the west, or a more thorough realization of their tremendous import to the future progress of the prairie provinces. With his boundless enthusiasm for all matters relating to western Canada he determined that this department should, with respect to water powers, have not only an efficient and effective administration, but should obtain by every reasonable means, a thorough knowledge of their nature, extent and value, especially those powers within zones of "reasonable commercial availability." In order that the Winnipeg river water power investigations might be commenced under proper auspices and on a thoroughly satisfactory basis, Mr. Young, early in 1911, conferred with two prominent consulting engineers, eminent in hydro-electric practice, Mr. John R. Freeman of Providence and New York, and Mr. J. B. McRae of Ottawa. Accompanied by Mr. J. T. Johnston, then Assistant Hydraulic Engineer of the department, and Mr. D. L. McLean, these engineers, in the month of September of the same year, made a reconnaissance trip down the Winnipeg river from Kenora at the outlet of the lake of the Woods to lake Winnipeg. After the completion of this investigation, these engineers submitted reports which were so emphatic as to the potential power possibilities of the river, and so strongly recommended that a complete power survey be commenced at once, that arrangements were immediately perfected for the work to be commenced under the immediate direction of Mr. J. T. Johnston.

Up to the time of his resignation in September, 1913, Mr. McLean ably acted as chief engineer of the field operations. Between September 1913 and June 1914 Mr. S. S. Scovil assumed complete charge of the field work to the entire satisfaction of the Department. Since June 1914 Mr. M. C. Hendry has been responsible for the continuation of the field studies. To these three engineers in conjunction with Mr. Johnston, under whose direction from Ottawa the work was carried on, great credit is due for their efficient and satisfactory completion. Mr. Johnst n is wholly responsible for the comprehensive power scheme developed in the report attached hereto, and for the unusually satisfactory presentation of the results of the investigations.

These investigations show that at nine distinct power sites, by means of storage easily and cheaply accomplished at the Lake of the Woods, at Lac Seul and other lakes in the province of Ontario, it is possible and economically feasible to develop over 418,000 continuous 24-hour horse-power, all within seventy-five miles of the city of Winnipeg and within feasible transmission distance of all commercial centres of the present settled portions of the province.

Of the nine possible power sites on the Winnipeg river, there are three now under development, representing a total power capacity of 200,000 24-hour horse-power. One site is completely developed by the Winnipeg Electric Railway Company on the Pinawa channel, and produces about 28,000 horse-power. Another site at Point du Bois falls, developed by the city of Winnipeg produces at the present time about 25,000 continuous horse-power, but is capable of extensions to a maximum of 77,000 24-hour horse-power. Development the third power site at Great or du Bonnet falls, having a maximum possible development of 95,000 24-hour horse-power, is about to be commenced by the Winnipeg River Power Company.

There is, therefore, at the present time about 53,000 continuous horse power produced, and transmitted for use in and around the city of Winnipeg, which can, with the two present plants, be increased to 200,000 24-hour horse-power.

The six remaining power sites are under the control of the Dominion Government, and can furnish a further amount of 24-hour power to a maximum extent of 218,000 horse-power.

In addition, there are several important power sites on the Winnipeg and English rivers within the province of Ontario, which are within easy transmission distance of Winnipeg.

Experience has abundantly proved the advisability of such investigations as a necessary preliminary to the authorization of all important power or storage projects, and furthermore, that proper government supervision and control of the construction and maintenance of all developments, is the only safe method of intelligently initiating construction and maintaining an adequate system of river improvement for power purposes that will allow of the most advantageous use of the resources of a river from both an engineering and an economic standpoint. Such investigation, supervision and control by government engineers of recognized competence and character, not only secures the scientific treatment of power rivers as a whole, but the safe and economic execution of the various component parts of a comprehensive system of improvement.

Development under the immediate direction of the Government makes certain the fullest possible utilization of the power possibilities of each stream whereas development by private enterprise almost invariably involves waste of natural resources. Private capital is seeking the greatest possible immediate return on investment and naturally [illegible] its attention to the most concentrated and easily developed portion [illegible] stretch of a river. The least precipitous portions of the river above and below a concentrated stretch involving a large unit outlay in development, are consequently apt to be neglected and permanently wasted because no other enterprise is likely or able to undertake the subsequent development. On the other hand the Government with its greater power and scope can compel the construction of the more extensive works necessary to develop to the fullest feasible extent so that every foot-pound of energy represented by the falling waters of the province may be given up when necessary to the service of man.

"The prime reason for the exercise of government authority over the "control of stream flow for power development, is that under modern social "and economic conditions, this step is necessary to insure the equal participation "of all citizens in this form of natural wealth which is peculiarly the heritage of "the whole people[illegible]

In the case of [illegible] innipeg river the anticipated advantages of such investigations as de[illegible] herein have [illegible] en realized to the full. Not only is the Government now [illegible] sition to di[illegible] te developments in connection with storage and powe[illegible] which will st[illegible] tly conform to the comprehensive scheme worked out, [illegible] s also been possible to compel a course of development which will con[illegible] th the strictest economic considerations, not only in connection with engineering problems directly involved, but problems indirectly allied and relating to the present and anticipated necessities of the market to be served.

As a direct result of th[illegible] investigations the Department of the Interior has been able to authorize a[illegible] at new power project at Great falls, and at the same time to have the [illegible] existing developments of the city of Winnipeg and the Winnipeg Electric Railway Company, conform to and be consistent with the comprehensive co[illegible] scheme worked out as described in detail in this report. T[illegible] ght[illegible] gr[illegible] these three projects are wholly consistent with the ultim[illegible] realiza[illegible] comprehensive scheme and conform strictly to the policy of water powe[illegible] istration under the Water Power Regulations. Constructive conservatio[illegible] with the best permanent public interest has been realized to a deg[illegible] equalled, and not surpassed in present day water power administration. [illegible] department now has at hand all essential data respecting the water power [illegible] ation on the Winnipeg river to enable it to work out a comprehensive scheme of development realizing the most advantageous use of the whole river for power and other purposes: to enable all new developments to be commenced with a minimum of physical investigation and therefore of delay; to insure that all developments will fit in and be component parts of the whole project. Not only has future administration been simplified and power development to keep pace with all demands been made certain, but present and future developments have been properly co-related as parts of a comprehensive scheme to realize the best possible use of the river for power.

As these investigations conclusively show, there is no more fortunate power situation on the continent than that on the Winnipeg river. Situated as it is within a few miles of the present city of Winnipeg and at the threshold of the western prairie provinces, there can be no doubt about the gradual development of these various water powers to their maximum possible capacity. The industrial and commercial future of the city of Winnipeg and indeed the province of Manitoba, is assured beyond peradventure and quite independent of outside sources of power-producing agencies.

In view of the great importance of the Winnipeg river power situation to the future development of the city of Winnipeg, the province of Manitoba, and of western Canada, I would recommend that Mr. Johnston's report be sent to the King's Printer for publication as No. 3 of the series of Water Resources Papers of the Dominion Water Power Branch.

Respectfully submitted,

J. B. CHALLIES,
Superintendent,
Dominion Water Power Branch.

July 16, 1915.

J. B. CHALLIES, Esq., C.E.,
Superintendent,
Dominion Water Power Branch,
Department of the Interior,
Ottawa.

SIR,—I have the honour to submit a report on the Winnipeg River Power and Storage Investigations covering the Field and Office Studies carried on by the Dominion Water Power Branch, with a view to ensuring a full measure of conservation of the power resources of the river, and to providing a definite and permanent basis for the proper administration of these resources.

In submitting this report I wish to make due acknowledgment of the efficient and hearty co-operation of the staff of the Manitoba Hydrographic Survey under the direction of Mr. D. L. McLean as Chief Engineer during the early stages of the work, of Mr. S. S. Scovil as Assistant Chief Engineer since August, 1912, and as acting chief from October, 1913, to June, 1914, and of Mr. M. C. Hendry as Chief Engineer since July, 1914.

I have the honour to be, sir,

Your obedient servant,

J. T. JOHNSTON,

Chief Hydraulic Engineer.

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REPORT

ON

THE WINNIPEG RIVER POWER AND STORAGE INVESTIGATIONS

CHAPTER I.

SUMMARY OF INVESTIGATIONS

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CHAPTER I.

SUMMARY OF INVESTIGATIONS.

In the province of Manitoba, richly endowed as it is with natural wealth, no one resource offers to the community such assured prospects of present prosperity and of future commercial and industrial progress as does the enormous reserve of dependable and economically developable water-power, lying ready for use, awaiting a market. Vast plains of unexcelled agricultural lands, lying in the immediate vicinity or within easy transmission distance, of almost unlimited resources of water-power, present a combination rarely found, and one which is conducive to exceptional opportunities for industrial development.

Lake Winnipeg, the great central reservoir of the province, receives from the west the entire drainage of the prairies, collected and conveyed by the Saskatchewan river from the far-distant Rocky mountains; from the south comes the run-off from the Red river carrying the surplus waters of southern Manitoba and northern Dakota; while from the east flows the Winnipeg river, draining the western section of the province of Ontario. The enormous run-off from this basin, varying vastly in volume in different seasons and at different times, is collected and conserved in the great natural bal[illegible]ncing reservoir of lake Winnipeg; the outflow therefrom, largely modif[illegible] naturally regulated, discharges down the 700-foot drop of the Nelson r[illegible]ries of magnificent falls, cataracts, and rapids, finally entering into H[illegible].

Before the era of the railroad, this great syste[illegible]ays formed the natural route of trade and commerce throughout th[illegible]on. The Nelson, Winnipeg, Red, and Saskatchewan rivers were the main arteries of traffic, and the boats and canoes of fur trader and pioneer found their way to the most distant parts of the basin. Even to-day these waterways have not entirely lost th[illegible] former high repute as avenues of transport, while prospective navigation improvements may renew to a large extent their old pre-eminence.

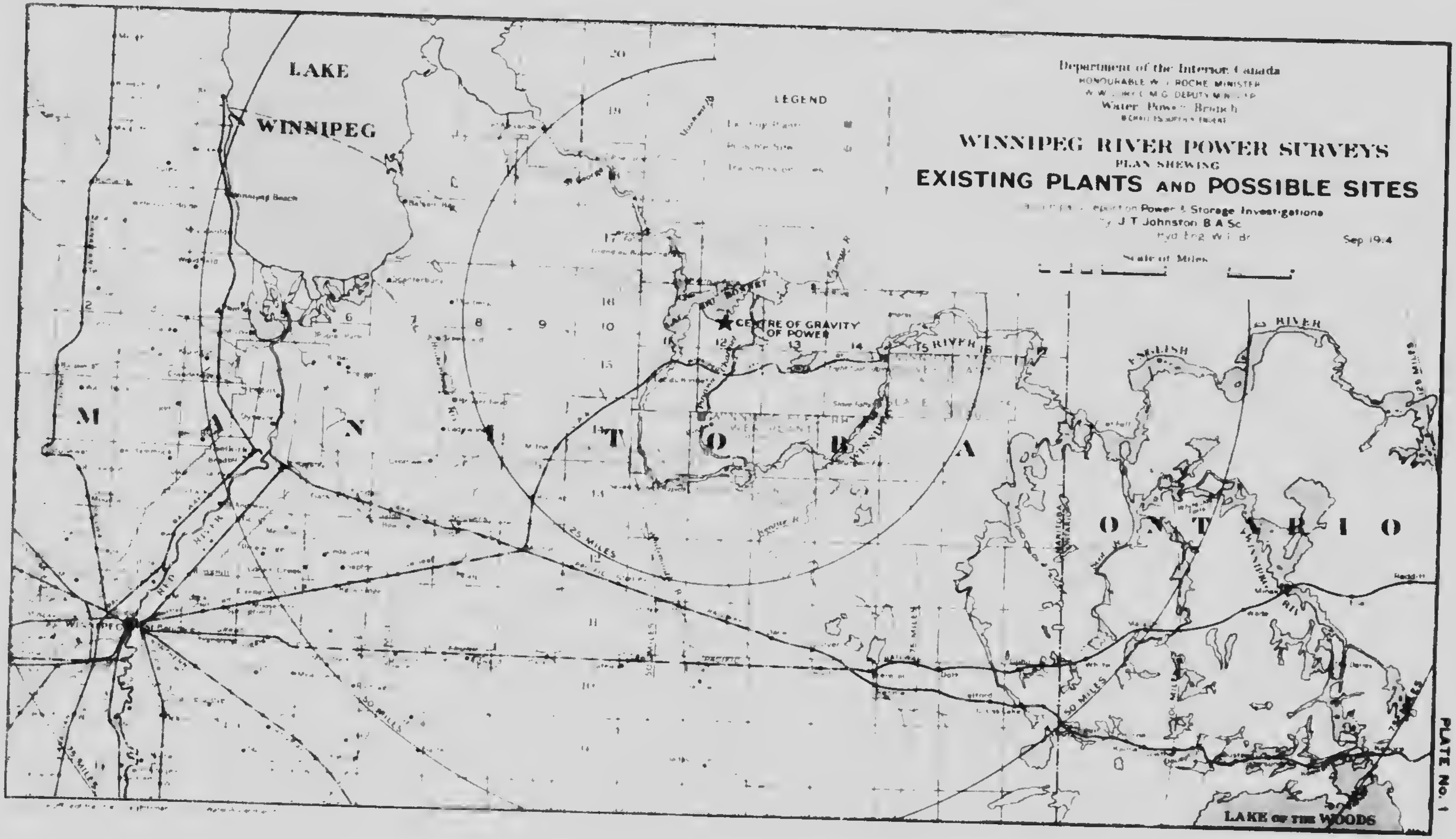
In the province of Manitoba, and following the construction of the main line of the Canadian Pacific railway, the city of Winnipeg grew with unexampled rapidity in population, wealth, and industry; and engineers, ever in search of possibilities of using the forces of nature to supply the needs of man, soon began to explore the province for sources of power to supply the urgent municipal and industrial requirements of the growing community. The Winnipeg river, owing to its general familiarity to a large section of the population and to the many and obvious advantages it offered in respect to power development, received early consideration. Hydro-electric practice no longer confined the use of power generated from water to the actual power sites. Long-distance transmission made the energy of the many waterfalls of the Winnipeg river easily available in the city of Winnipeg, many miles away.

For exceptional natural power and storage advantages the Winnipeg river is probably unequalled in Canada and possibly on this continent. It drains an almost circular area of 53,500 square miles, dotted in all directions with innumerable lakes. The balance of the basin is fairly well forested, the precipitation is regular and well distributed, and the run-off is, in consequence, remarkably uniform from season to season, the maximum high water in a normal year seldom exceeding four times the minimum flow. Owing to its strategic location close to the city of Winnipeg, on the threshold of the western prairies, it soon became the Mecca of hydraulic and civil engineers seeking out suitable power sites for development in the interests of the various municipal and commercial centres. Mr. James C. Kennedy, Consulting Hydraulic Engineer of Montreal, in 1895 made the first comprehensive reconnaissance survey of this river for power. The results of this survey are unique and interesting as they, even at that time, brought out the promising and unequalled power possibilities of this river. In the year 1907, Mr. W. Thibaudeau, C.E., made, on behalf of the department, a reconnaissance investigation of the Winnipeg River powers, and submitted an interesting and valuable report on the river's resources. Many other investigations were made by various hydraulic and civil engineers in connection with special or particular power sites. Following these investigations, two developments on the Winnipeg river were undertaken, the first being that of the Winnipeg Electric Railway Company on the Pinawa channel, the pioneer power project of the west. This company has, since 1906, furnished the power necessary for the operation of the street car system and many other industries in the city of Winnipeg. In the year 1911, the city of Winnipeg authorities, largely on the initiative of Controller J. W. Cockburn, of the City Council, who has ever since been one of the pioneer movers in the power situation in Winnipeg, completed the initial installation of an ultimate 76,000-horsepower municipal power station.

Following the successful development of these two plants, and in view of the rapidly increasing demand for further power which students of the power situation at Winnipeg at once realized could not be met by the two existing plants, even when extended to their maximum capacity, many capitalists interested in the power and industrial situation in Winnipeg became actively interested in the question of power development on this river, and many separate and conflicting power schemes were submitted to the Dominion Government for authorization.

These schemes were frequently supported by fairly complete plans and specifications from eminent and experienced hydro-electric engineers, and the conflict of interests involved in the various projects soon emphasized the necessity of an independent investigation, by the Dominion Government, of the whole river. Such an investigation was the only means of ensuring the conservation of the river's power resources in the interests of the investor, the consumer, and the general public. It was considered by the engineers of the Dominion Water Power Branch that private, municipal, and provincial enterprise in hydro-electrical development on the Winnipeg river could best be ensured and safeguarded by furnishing the prospective power user with thoroughly reliable data upon which the economic and engineering features of the prospective sites could be properly and accurately judged and compared. That such definite and dependable information should be secured, and made available in reliable form, is considered essential for attracting and securing the confidence of capital.

PLATE No. 1


Department of the Interior, Canada
Water Power Branch
WINNIPEG RIVER POWER SURVEYS
PLAN SHEWING
EXISTING PLANTS AND POSSIBLE SITES
Power & Storage Investigations
J. T. Johnston B.A.Sc.
Sep 1914
Scale of Miles
LEGEND
LAKE WINNIPEG
CENTRE OF GRAVITY OF POWER
MANITOBA
ONTARIO
ENGLISH RIVER
WINNIPEG RIVER
LAKE OF THE WOODS
25 MILES
50 MILES

The conservation of natural resources is one of the most important public problems which has in recent years confronted the people of Canada. The widespread publicity given to this question in the press and on the platform during recent years has met with an enthusiastic response from the public, and has resulted in an active interest being taken in all forms of governmental activity respecting water-power.

Of the many phases of conservation proposed and practised, that having to do with the conservation of water for power is probably the most productive of direct and immediately favourable results. The situation in the Winnipeg River watershed offered exceptional opportunities for the practical realization of the best principles of conservation as applied to the preservation and utilization of water-power resources.

Among the power investigations of the Dominion Water Power Branch extending over the provinces of Manitoba, Saskatchewan, and Alberta, and the Railway Belt of British Columbia, none have been so comprehensive, complete, and consequential as those of the power and storage possibilities of this river, commencing in the year 1911 and now completed in so far as data pertinent to this report are concerned, but to be continued so far as basic hydraulic data are required for the absolutely final and complete investigation of the power and storage resources of the whole watershed.

The principal objective kept in view in the investigations was the institution of a system of power installation which would utilize without waste the entire available and unutilized power resources of the river in Manitoba. In order to render this study complete and comprehensive, it was necessary that it should be supplemented by a thorough investigation into the storage possibilities of the watershed. Systematic discharge measurements and the collation and analysis of all existing run-off data and gauge records, formed a necessary complement to the information to be gathered.

Summary of Power and Storage Studies.

The principal result of the power and storage investigations can be briefly summarized by stating that it has been determined that a minimum flow of 20,000 cubic feet per second is feasible at all seasons, with an efficient and systematic control of the river run-off, and that it is possible to concentrate practically the entire unused river fall in Manitoba into seven economic power concentrations with a minimum output of 175,000 continuous 24-hour power under present conditions of flow, and of 313,000 horse-power with the river regulated to a 20,000 second-foot minimum. These power concentrations, together with the existing plants, will conserve to the utmost the power resources of the river in Manitoba, and will supply a total ultimate output of over 420,000 continuous horse-power. (Plates 1 and 2.)

The main features of the investigations are summarized below:—

(1) A complete contour survey has been made of the Winnipeg river in Manitoba from the mouth of the river to the headwaters of the city of Winnipeg municipal plant at Point du Bois. This survey has been supplemented by detail cross-sections and soundings at all falls and rapids

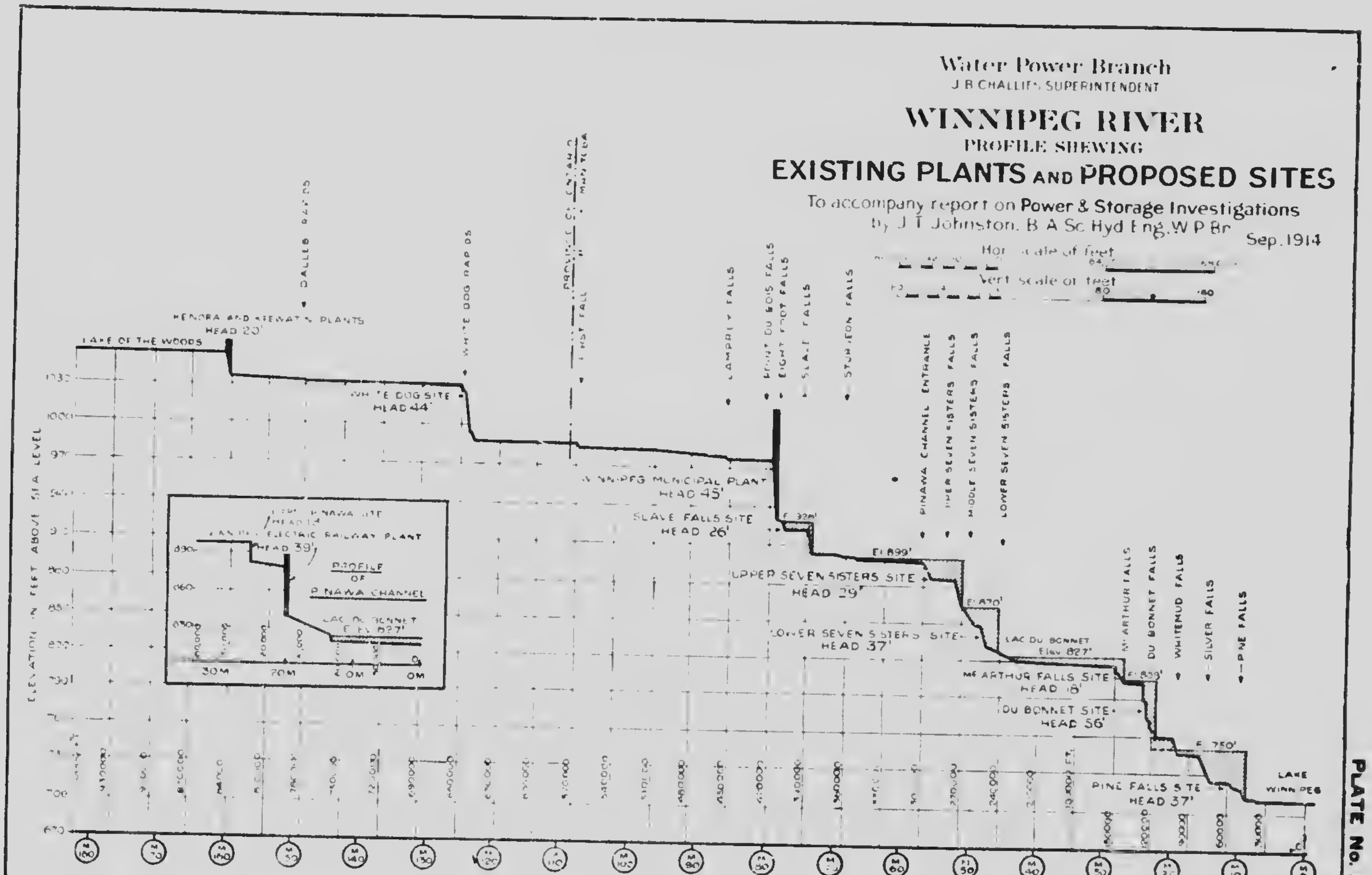

Water Power Branch
J B CHALLIES SUPERINTENDENT
WINNIPEG RIVER
PROFILE SHEWING
EXISTING PLANTS AND PROPOSED SITES
To accompany report on Power & Storage Investigations
by J T Johnston, B A Sc Hyd Eng. W P Br
Sep. 1914
Hor. scale of feet
Vert. scale of feet
LAKE OF THE WOODS
KENORA AND KEEWATIN PLANTS HEAD 20'
DALLES RAPIDS
WHITE DOG SITE HEAD 44'
WHITE DOG RAPIDS
FIRST FALL
LAMPREY FALLS
POINT DU BOIS FALLS
EIGHT FOOT FALLS
SLATE FALLS
STURGEON FALLS
WINNIPEG MUNICIPAL PLANT HEAD 45'
SLAVE FALLS SITE HEAD 26'
UPPER SEVEN SISTERS SITE HEAD 29'
LOWER SEVEN SISTERS SITE HEAD 37'
PINAWA CHANNEL ENTRANCE
UPPER SEVEN SISTERS FALLS
MIDDLE SEVEN SISTERS FALLS
LOWER SEVEN SISTERS FALLS
LAC DU BONNET Elev. 827'
McARTHUR FALLS SITE HEAD 18'
DU BONNET SITE HEAD 56'
McARTHUR FALLS
DU BONNET FALLS
WHITEMUD FALLS
SILVER FALLS
PINE FALLS
PINE FALLS SITE HEAD 37'
LAKE WINNIPEG
PROFILE OF PINAWA CHANNEL
WINNIPEG ELECTRIC RAILWAY PLANT HEAD 39'
LAC DU BONNET Elev. 827'
30M
20M
10M
0M
ELEVATION IN FEET ABOVE SEA LEVEL

PLATE No. 2

where power concentration is in prospect. All existing dams, weirs, bridges, and permanent works have been tied in to the basic field survey lines.

(2) A permanent system of bench-marks, located on the bedrock and tied in to sea-level datum, has been established throughout the entire power reach.

(3) The complete survey notes have been plotted on standard topographic sheets, and are appended to this report.

(4) Seven points of concentration have been selected as the prospective sites of future power development. These sites will develop practically the entire remaining drop of the Winnipeg river in Manitoba, unutilized by the present existing power plants on the river.

(5) At each of these seven sites, detail layouts and designs covering a feasible method of development have been prepared, and the estimated cost of development, maintenance, and operation has been deduced, for the double purpose of comparing their individual engineering features and their commercial possibilities. The plans upon which the estimates were based are appended.

(6) The seven proposed power concentrations, with estimated capital and operating costs, are listed in table I.

(7) The total dependable power on the river in Manitoba, based on a regulated minimum flow of 20,000 cubic feet per second, including that available at the two power stations already in operation, is 418,000 horsepower in terms of 24-hour continuous power.

(8) Permanent metering stations have been established at Slave falls on the power reach in Manitoba; at the head of the Pinawa channel; at the outlets of the Lake of the Woods; and on the Whitemouth river. Miscellaneous measurements have been secured throughout the basin. All early run-off records, and all records secured by other organizations, such as the Dominion Department of Public Works, the Ontario Hydro-electric Commission, and the United States Geological Survey, have been collated and are appended.

(9) The power station of the Winnipeg Electric Railway Company, and the Kenora municipal power station have been rated.

(10) Existing records of lake levels, of head and tailwater elevations, of power loads, and of precipitation and temperature have been collated and studied.

(11) A fully equipped evaporation station has been established on the Lake of the Woods.

(12) The storage necessities and possibilities of the watershed have been exhaustively analysed, and the steps necessary to ensure an adequate minimum flow at the various vital points on the river determined.

(13) A study has been made of existing water rights throughout the basin and of international questions which have arisen in connection with the boundary waters.

Table 1.—Summary of the Power Sites available for development on the Winnipeg River in Manitoba.

Site.	Distance from Winnipeg.	Head.	24-hour Power available at 75% Efficiency.		Capital Cost.				Annual Operative Cost.				Remarks.
					Total.		Per H.P. on basis of 24-hour power.		Per H.P. on basis of 24-hour power.		Per Kilowatt hour 100% load factor.		
			12,000 c.f.s.	20,000 c.f.s.	12,000 c.f.s.	20,000 c.f.s.	12,000 c.f.s.	20,000 c.f.s.	12,000 c.f.s.	20,000 c.f.s.	12,000 c.f.s.	20,000 c.f.s.	
	Miles	Feet.	H. P.	H. P.	$	$	$	$	$	$	Cents.	Cents.	
Pine Falls	64	37	37,900	63,100	3,057,000	4,407,000	80·66	69·84	8·00	7·08	0·122	0·108	Entire river flow available.
Du Bonnet Falls....	64	56	57,300	95,500	4,624,000	6,551,000	80·70	68·60	7·56	6·65	0·116	0·102	" "
McArthur Falls	62	18	18,400	30,700	2,031,000	2,740,000	110·38	89·25	10·82	8·86	0·166	0·136	" "
Lower Seven Sisters ..	52	37	12,600	37,900	....	3,409,000	....	89·95	....	8·65	....	0·132	On main channel.
Upper Seven Sisters...	55	29	9,900	29,600	....	2,724,000	....	92·15	....	9·05	....	0·138	" "
Upper Pinawa.........	58	18	12,300	12,300	1,280,000	1,280,000	104·07	104·07	10·40	10·40	0·159	0·159	On Pinawa Channel.
Slave Falls...........	74	26	26,600	44,400	2,327,000	3,436,000	87·50	77·39	8·58	7·62	0·131	0·117	Entire river flow available.

Note.—12,000 cubic feet per second is available under present conditions of regulation on the Winnipeg River, and 20,000 cubic feet per second is feasible under a properly controlled system of regulation.

[1](14) The possibilities of future navigation have been given full consideration. The limiting head and tailwater elevations proposed will permit of the ready canalization of the river, while provision has been made for the inclusion of lockage facilities in the provisional layouts, should the future canalization of the river ever become desirable.

(15) Existing power plants and all other vested interests along the river have been carefully studied.

(16) Present and future market conditions and possibilities for the utilization of the Winnipeg River power have been investigated.

(17) A consecutive policy looking to the full realization of the power resources of the river basin, according to the best principles of conservation, has been determined for the future guidance of hydro-electric development.

Conclusions from Investigations.

The detail study which has been given to the power and storage questions involved in the proper utilization of the resources of the Winnipeg River watershed has of necessity been extended to cover the ways and means by which the vast power resources, now lying dormant, can be made fully available for the public good. The conclusions evolving from these studies are discussed in detail throughout this report, in connection with the various subjects to which they are pertinent. The more important may here be summarized.

Full realization of the power resources of the Winnipeg river in Manitoba is only attainable by a power system in which each developed site forms a component link in a comprehensive scheme looking to the development of the entire river reach. Such a power scheme is outlined and discussed herein, and furnishes the basic principles for the guidance of future hydro-electric development.[2] Due to the interdependence of a series of hydro-electric plants such as is proposed, and to the conflict of head- and tailwater elevations, satisfactory operation can only be realized through an independent supervising control over local pond regulation.

Full realization of the power resources of the Winnipeg river in Manitoba is possible only through an exhaustive measure of run-off control, and feasible only through the establishment of storage reservoirs in the upper watershed. Due to the conflicting requirements of the lumbering, fishing, navigation, and power interests represented in the watershed, a proper run-off control, satisfactory to all, can best be insured by some central governmental authority possessing the full confidence of all interests affected, and having entire authority over all questions affecting lake, reservoir, and pond levels, and over all questions of river flow and of discharge requirements. This authority can only be properly exercised through government owned or operated storage reservoirs.

As a result of the exhaustive nature of the data gathered in the power and storage studies, the Dominion Water Power Branch is now in a position to

[1] In this connection it might be pointed out that the Department of Public Works has already approved the power layouts on the Winnipeg river as submitted in this report in so far as the navigation interests are concerned.

[2] Since the completion of the power studies along the river reach below Lac du Bonnet, the Winnipeg River Power Company has commenced operations on the Great falls development corresponding to the du Bonnet site in this report, and has adopted the limiting head- and tailwater elevations in keeping with the comprehensive river development scheme outlined herein. For full discussion of this development see Appendix II.

intelligently supervise a comprehensive power system such as is proposed for the development of the river in Manitoba, and to ensure the maximum utilization and preservation of its power resources.

The full conservation of the power resources of the watershed, requires also the institution throughout the watershed of a systematic policy looking to a proper preservation of the forest cover, which now so effectively assists in natural regulation of the river flow. Consistent steps have already been taken to this end by the Dominion Water Power Branch.

To realize the maximum power output of the Winnipeg river will require the most thorough and scientific control of the forest and water resources of the entire watershed, by an authority with sufficient power and breadth of view to ensure that all affected interests receive their just due.

Recommendations.

As a result of the power and storage studies now successfully completed in so far as is necessary to outline a comprehensive scheme of power development and to enunciate a policy suitable to the proper operation of such a system as is proposed, the following recommendations are appended:—

(1) All future hydro-electric, milling, or industrial undertakings acquiring power privileges on the power reach of the Winnipeg river in Manitoba, should be authorized only in accordance with the general scheme of power development outlined herein, or in accordance with such modifications of the same as may be considered advisable as a result of the further information and data being secured by the continuance of the present studies.

(2) Authority for all such undertakings should fully protect the head- and tailwater levels, not only of all existing interests on the river, but also of all sites of future power concentration.

(3) Authority for all such undertakings should retain to the Government a measure of supervising local pond control for the protection of other plants on the river.

(4) Authority for all such undertakings should call for the bearing by the lessee of the cost of reservoir construction and of storage control operation and maintenance in the upper watershed, in proportion to the benefits accruing to the lessee therefrom.

(5) The establishment of new regulating reservoirs should be undertaken by the Crown, and the cost of constructing the necessary dams and regulating works, as well as of maintaining and operating the same, should be apportioned among the various power undertakings benefiting therefrom, in proportion to the benefits accruing.

(6) An appraisal of the value of existing storage works throughout the watershed should be undertaken by the Government, with a view to their ultimate purchase or expropriation, the cost of such purchase or expropriation to be apportioned among the power users benefiting from the use of the storage, in proportion to the benefits accruing.

[1](7) All matters pertaining to the regulation of the lake and reservoir levels, and to questions of run-off and discharge requirements, should be under the joint control of the Dominion Water Power Branch, and the Hydro-electric Power Commission of the Province of Ontario, or, failing this, of a governmental board or commission. The controlling body must have the full confidence of all interests affected by questions of run-off and lake levels, and must possess entire authority and exercise its control actively and directly.

(8) Some definite measures of forest preservation should be instituted in the immediate future, and be continuously maintained. These measures should include scientific timber cutting and lumbering, systematic reforestation and effective protection from fire ravages,

(9) All lands which will be necessary for or affected by the future construction of power undertakings or of storage works, should be reserved to the Crown.

(10) The present studies should be aggressively continued, more particularly with respect to the storage requirements and possibilities of the basin. Among the various phases of activity which are essential to the proper future control of the water resources of the river basin are: continuous stream measurement records at all vital points; continuous surface level records of all prospective and existing reservoirs; continuous evaporation records in various parts of the watershed; the establishment of numerous precipitation stations; the prosecution of reconnaissance surveys for the investigation of storage possibilities; the rating of all power stations, mills, dams, and weirs in the watershed; a study of the relation between the various existing reservoirs and storage prospects, and the existing plants and possible power sites; continuous surface level records under all stages of flow at all vital points on the power reach of the river in Manitoba; and the maintenance of an efficient policy of forest preservation and protection.

Policy of the Department.

The policy of the Dominion Water Power Branch is, in brief: to encourage desirable development of water-power resources; to discourage and prevent the initiation and development of uneconomic and wasteful projects; to ensure that each site developed shall utilize or provide for the future utilization of the maximum available power; to ensure that river systems are developed along comprehensive lines wherein each unit is a component link in a system; to ensure adequate storage measures in the interests of all powers affected; to prevent unnecessary and costly duplication of expenditures on the part of competing plants; to protect the public from inadvisable power schemes and ill-designed plants and dams; to safeguard the public from monopolistic control, by regulation and periodical revision of rates; to see to the early carrying into effect of agreements issued by the Department for the development of power; to compel the development of existing plants to their limit when the market demands; and to promote in every way the fullest conservation of the power resources of the West.

[1]For fuller recommendations re storage control see chapter IV, page 133.

The regulations governing the granting of water-power rights in Manitoba, Saskatchewan, Alberta, and the Northwest Territories are attached to this report in full in Appendix IV. A careful study of the various clauses of the regulations, and of the conditions which are imposed upon, and the privileges conveyed to the applicant, will serve to make clear the measures which are deemed essential to the proper administration of the water-powers under control of the Department of the Interior, in the interests of both the investor and the consumer.

The initial steps taken by the department in dealing with an application for water-power privileges are largely dependent upon the character of the site applied for, and upon the detailed data submitted by the applicant. General information covering the project is required along the lines set out in section II of the regulations. Upon the character of the information supplied, further action is based. A consideration of the data submitted, in conjunction with whatever existing information may be on file in the department, determines whether further information is required and whether an inspection by one of the field engineers is necessary. This inspection is always required should the site applied for be one which has not been previously covered by the field investigations of the Dominion Water Power Branch. Based upon the field officer's report, or upon head office studies, the applicant may be advised that his project is unsound upon either engineering or economic grounds, or, should the scheme be feasible, he may be called upon for further details under section IV of the regulations.

When the department is convinced, after independent investigation, that the engineering features of the project are sound, and that it offers reasonable prospects of financial success, and has approved the scheme, an agreement is issued authorizing the construction of the plant. At no stage does the priority of application convey any rights to development. This is a necessary provision in order to forestall blanket applications made with a view to holding power sites for speculative purposes.

The principal clauses of the agreement are framed to protect the public from exploitation at the hands of interests which may have in view the sale of rights only, and not actual development. The more important features included are: a definite time within which the proposed works shall be begun; a stated minimum amount of expenditure to be made annually on actual construction of the works; a stated amount of water-power to be developed from the water applied for within a fixed period not exceeding five years; summary cancellation of the agreement by the minister if any of the above conditions have not been complied with; and provision for the issuing of a lease and a license to the applicant upon the fulfilment of the conditions of the agreement. The license covers the use for water-power purposes of a stated amount of water. The lease covers the use of the necessary land. Other clauses are included looking to the full protection of the public interests involved, and varying with the particular necessities of each project.

Before actual construction work is commenced on the ground, the general layout plans and the actual construction plans covering the plant must be submitted to the department for approval.

During the period of construction, the department maintains an inspecting engineer on the works whose duty is to see that all the terms of the agreement are observed and that the works are constructed according to plans which have been approved or revised by the department. Prompt weekly progress reports are forwarded direct to the department at Ottawa, and the head office is at all times directly in touch with all the construction being carried on under its jurisdiction. Pressing matters are dealt with by the inspecting engineer on the ground. Matters of vital importance or involving questions of policy are referred to head office, and are dealt with by correspondence or by wire as the case demands. Serious differences of opinion as to engineering questions are referred to the departmental Board of Consulting Engineers. In all phases of the construction the department endeavours to exercise the functions of an impartial authority mediating between the respective interests of the owner, the investor, and the public.

Upon the completion of the undertaking in accordance with the conditions of the agreement, a license for the use of the water is issued, incorporating the following principal clauses: terms of license, twenty-one years renewable for three further consecutive 21-year terms; schedule of rates and prices to be charged to the public for use of the power, to be submitted to the Board of Railway Commissioners of Canada for adjustment and approval, the same to be revised every seven years.

The procedure as outlined above is slightly altered in dealing with projects along a river whose resources have been thoroughly investigated by the field engineers of the Dominion Water Power Branch. Immediately such investigation is completed, and the conclusions determined, the department is in a position to dictate a scheme of development for the entire river, so that each individual project will form a component part of the whole. This policy is followed, and all hydro-electric undertakings on such rivers are carried out along these lines. The outstanding feature resulting from such administration is the greatly increased maximum output secured, over that obtainable from unguided and unrestrained private initiative.

This administrative policy can now be adopted along the Winnipeg river, and in fact has already been put into force in dealing with the power project which the Winnipeg River Power Company has at present under construction at the Du Bonnet falls, and which is discussed at length in Appendix II.

Water-power is readily subject to monopolistic control. This is largely due to the heavy capital expenditure necessary in the development of large hydro-electric undertakings and in the transmission of power to the consumer. Again, power obtained from river discharge is perpetual and at the same time limited. If, therefore, it is to be kept always available to the public at reasonable rates, its disposal must be carefully safeguarded and controlled.

The power situation on the Winnipeg river has an equalizing factor in the municipal plant of the city of Winnipeg at Point du Bois. This large and successful municipal undertaking, with its modern and extensive installation and with its great reserve of power, feeding into the city of Winnipeg over its own transmission system, will always serve to moderate and to regulate the rates chargeable for power in this territory. The department is also, as a result of the surveys just completed, in command of complete and detailed data as to the sources and extent of the power available, the larger portion of which is still vested in the Crown. Under these conditions, and with the control of rates provided by the regulations which govern the granting of water-power rights, there is no prospect of the southern portion of the province of Manitoba coming under a monopolistic power regime.

While the danger of single and unlimited private control must be guarded against, the question of unnecessary duplication of transmission systems must also be considered. Competition which involves carrying heavy overhead charges due to unnecessary duplication of transmission and distribution systems is unprofitable both to the investor and to the consumer; this phase of power development requires and receives careful consideration in the granting of water-power privileges. Crown supervision and control of rates allowing for reasonable financial returns on investment while guarding against extortion and overcharging, would appear to be the most satisfactory arrangement for all parties interested. Such a policy must recognize both the need for the utilization of the power and the dangers of monopolistic control, and must take effective action for the proper guidance and control of each.

Necessity for Crown Control over Hydro-Electric Investigation and Development.

An impartial governmental supervision of water-power development, from the initial stages to the final distribution and sale of the power, is to the mutual advantage of the investor, the general public, and the direct consumer. The truth of this is particularly evident in planning the proper and comprehensive utilization of the power resources of a river such as the Winnipeg, where but few vested interests interfere with hydro-electric development along lines of maximum beneficial use. The various phases which render a greater or less degree of Crown control essential to the true conservation both of the public interests and of capital can be summarized as follows:

(1) The selection of a hydro-electric site by private interests usually results in the utilization of the greatest drop which can be economically concentrated, without, as a rule, considering the requirements and the possibilities of the river as a whole. This has been particularly noticeable on the Winnipeg river.

(2) The Government is best able to thoroughly study a complete river system, since it alone is in a position to impartially analyse the conflicting interests which are affected.

(3) The relative importance and merits of various power possibilities and storage projects can best be determined by an impartial authority, based upon independent and thoroughly tested information, rather than by interested individuals, companies, or municipalities.

(4) The Crown, from first-hand information, is in a position to ensure that each individual power site is developed to its maximum efficiency and, by the supervision it maintains over the plans and designs

of the plant and power dam and over the actual construction operations, to ensure that thoroughly stable structures are built.

(5) The Winnipeg river is classed as a navigable waterway, and, as such, consideration must be given to its possible future canalization. Private enterprise in hydro-electric undertakings is [illegible]lly concerned with this phase, and whatever provision is made for future water transportation by unguided private initiative is at best [illegible]factory. On the other hand, a complete power system, pre-deter[illegible]d supervised throughout by the Crown, can fully consider th[illegible] fixing, as in the case of the Winnipeg river, the pond levels, a[illegible], for the future inclusion of locks in the power layouts, should the necessity for constructing the same ever arise.

(6) A pre-determined hydro-electric power scheme covering the entire river, and deciding the points of concentration, and also the head- and tailwater elevations throughout the whole system, enables the State to fix the location and elevations of railroad and traffic bridges, of railways and roads, and to guide the development of municipalities so as not to interfere with the future utilization of the undeveloped portions of the river.

(7) The present and future diversion of water supplies for domestic, irrigation, and other purposes, can be properly protected and arranged for, only through and by governmental supervision.

(8) Provision for the drainage and protection of those lands along the river which will be affected by raising the water level, can, in the public interests, be best arranged for by an authority giving full and impartial consideration of all issues involved.

(9) In patenting Dominion lands adjoining the river banks, the Crown is enabled to reserve for water-power purposes such sections as may be subsequently required, thus keeping down the future cost of actual development. For some time past the department has been following this course with all homestead entries along the Winnipeg river.

(10) The numerous, and at times conflicting, interests affected by storage in such natural reservoirs as the Lake of the Woods, Rainy lake, and other lakes in the upper Winnipeg basin, compel the intervention of some impartial authority, so that some equitable storage arrangement may be evolved satisfactory to all parties and interests concerned. Private investigation or control by any single interested party seldom secures a satisfactory settlement of questions of this nature.

(11) Since the tailwaters of each plant as designed herein, are dependent on, and controlled by, the headwater elevation of the plant below, and since certain sites along the river can be so developed and so operated as to entirely cut off the flow from plants lower down the river, a centralized control for the whole river in the interests of all the powers and parties concerned must form an essential feature of the completed scheme. As a result of the extensive studies just completed, such a system of control can now be readily instituted.

(12) Water-power is perpetual inasmuch as river discharge is continuous, and in this respect differs from power derived from coal and other sources. It is essential, therefore, that its utilization should be conserved to the utmost by efficient and complete development, in order that future as well as present power requirements of the public may be served to the maximum capacity of the river.

(13) Water-power is, from its nature, peculiarly susceptible to monopolistic control. The Winnipeg river forms the natural source of power for the city of Winnipeg and for southern Manitoba. Investigation by the Dominion Water Power Branch shows that water-power from other sources in this section is limited. With the supply thus limited, it becomes the duty of the Crown to see that the perpetual cheap power which nature has provided is kept available for the public use, at rates not dictated by "what the traffic will bear," but determined upon a reasonable competitive basis.

(14) Full conservation in all its phases, both of power and of capital, can only be secured through Crown control, dictated from the most reliable and independent data obtainable.

Situation Leading to Commencement of Survey.

At the time when the power and storage investigations along the Winnipeg river were begun by the Dominion Water Power Branch, the hydro-electric plant of the Winnipeg Electric Railway Company was in operation on the river, and the initial installation of the municipal plant of the City of Winnipeg was rapidly approaching completion.

The Winnipeg Electric Railway Company's plant is located on the Pinawa channel of the Winnipeg river, about 58 miles from Winnipeg. The construction of this plant was commenced in 1902, and was completed in 1906, with a total turbine capacity of 34,000 h.-p. A 22,000-horsepower steam turbine plant in the city, supplements the Pinawa plant.

In order to meet a growing market demand, construction operations on a municipally owned power plant were commenced by the city of Winnipeg in 1908, and the first installation of five 5,200-horsepower turbines was being placed in position when the departmental field studies were commenced. The power output of both the company's and the city's undertakings is transmitted to Winnipeg for traction, lighting, industrial, and domestic use.

With the power from these two sites either developed or in course of development, the department was in receipt of numerous applications covering other sites along the river. The majority of these were in the nature of blanket applications for particular falls, and were accompanied by no engineering data or plans of proposed development. Others were supported by exhaustive reports and estimates based on extensive field work from reliable engineering firms.

It was realized that further hydro-electric development on the river was a matter of the immediate future, and that if a comprehensive policy was to be mapped out into which new developments could be incorporated as component units, no delay should be permitted in commencing the departmental power investigations. Independent schemes before the department were based on the individual viewpoint, and contemplated development of certain sites without considering the effect of such concentrations on the power possibilities of the balance of the river.

Early in 1911 aggressive steps were taken to organize a field party for the thorough study of the Winnipeg river in Manitoba.

Scope of the Investigation.

The departmental purpose of guiding the development of the river along a definite system, complete in all details, necessitated securing full and reliable data covering all features of hydro-electric studies.

The plan of campaign laid down involved:—

(1) A preliminary reconnaissance of the power reach of the river, by engineers of recognized standing, with a view to mapping out a systematic method of attack by the field parties.

(2) A continuous profile of the power reach of the river, on which could be based all the detail surveys.

(3) Detailed contour surveys with soundings of all falls or rapids at which power concentration was possible.

(4) Contour survey of the river banks throughout the entire power reach of the river.

(5) Determination of the locations at which the drop of the river could best be centralized and developed.

(6) Design of layouts for such locations, in sufficient detail to permit fairly accurate estimating.

(7) Estimates of the capital cost of constructing the various plants proposed, in order to compare the economic feasibility of the different sites.

(8) Estimates of the annual cost of operation of the various plants proposed.

(9) Estimates of the cost of transmission from a typical site to Winnipeg.

(10) Establishment of metering stations for the purpose of obtaining accurate records of the river flow, and the thorough study of the same together with all pre-existing records.

(11) Establishment of evaporation stations.

(12) Study of existing rainfall and temperature records, with effect of same on run-off.

(13) Close investigation into the question of storage in the upper waters of the basin in all its aspects.

(14) Investigation into and study of prior water rights, and the relative value and effect of the same.

(15) Comprehensive provision for future navigation should the necessity for it ever arise.

(16) Close study of existing power plants, and of all existing interests on the river.

(17) Study of present and future power market conditions and prospects.

(18) Recommendations for the carrying out of an aggressive policy of hydro-electric and power development, and of ensuring government supervision over regulation, both in connection with individual power plants, and of the storage conditions as a whole.

In instituting an investigation with such far-reaching ends in view, it was essential that the department should be guided by expert engineering advice and opinion. This was particularly the case in considerat f the fact that the powers of the Winnipeg were of such magnitude as to require the services of engineers and engineering firms of outstanding reputation, in the actual design and layout of the various independent plants. If the conclusions of the department were to be made the basis of the development of the river, it was therefore necessary that such conclusions should be backed by recognized and reliable engineering authorities. To this end the services of Mr. J. R. Freeman, C.E., of Providence, Rhode Island, were secured in a consulting capacity, to assist in the commencement and organization of the field investigations. The services of Mr. J. B. McRae, C E., of Ottawa, were likewise secured in this connection, and he was further retained to act as consulting engineer throughout the full period of field and office investigations.

The suggestions and advice of these engineers were acted upon in full, and the results of the investigations as submitted in this report are considered as forming a reliable basis on which to administer the water powers of the Winnipeg river. The direct connection of Mr. Freeman and Mr. McRae with the work is referred to in more detail throughout the report.

It must be kept in view that the layouts designed herein are mainly for the purpose of securing a fair estimate of the cost of developing the various sites in order to demonstrate their economic feasibility. It is not intended that the designs will be followed without alteration by the parties doing the actual development work. It is intended, however, that the general head- and tail-water elevations shall be observed as now submitted, with such modifications as may be considered advisable from the further detailed investigations and the more complete run-off and surface level records now being secured.

ACKNOWLEDGMENTS.

It is desired to acknowledge here the hearty co-operation which the various interests affected by and interested in the general situation, have evinced in making available data pertinent to the question at issue. Particular mention in this connection is due to:—

The civic officials of the city of Winnipeg.

The civic officials of the town of Kenora.

The Winnipeg Electric Railway Company.

The Winnipeg River Power Company.

The Lake of the Woods Milling Company.

The Ontario and Minnesota Power Company.
The Keewatin Power Company.
The Director of the United States Geological Survey.
The Department of Public Works of the province of Ontario.
The Meteorological Service of Canada.
The Lake of the Woods Technical Board.
W. J. Stewart, Chief Hydrographer of the Naval Service Department.
H. G. Acres, Hydraulic Engineer of the Hydro-electric Power Commission of Ontario.
S. J. Chapleau, of the Dominion Department of Public Works.
Hon. H. A. Robson, Public Utilities Commissioner of Manitoba.
C. F. Roland, Industrial Commissioner of the city of Winnipeg.

REPORT

ON

THE WINNIPEG RIVER POWER AND STORAGE INVESTIGATIONS

CHAPTER II.

WINNIPEG WATERSHED AND FIELD INVESTIGATIONS

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WINNIPEG WATERSHED AND FIELD INVESTIGATIONS.

HISTORICAL.[1]

In this highly utilitarian age very little thought is given to romance, and the appropriation of any natural resource for the use of commerce is usually a matter of dollars and cents, interest charges and depreciation. The financier in his office studies the reports and plans of his engineers with no thought of the long process of development that brought this or that scheme within the realms of profitable investment.

The Winnipeg river formed the last link in the chain of waterways connecting the vast basin and tributaries of the Great Lakes with lake Winnipeg, in which was centralized a second great system of canoe routes. In early and pioneering days this gave to the Winnipeg river an exceptional importance as an avenue of travel, trade and commerce.

Without expending much time on this aspect of lake Winnipeg, it is interesting to note that by the Red and Mississippi rivers there was a way to the gulf of Mexico; by the Nelson to Hudson bay; by the Saskatchewan to the Rockies, and thence by the Columbia river to the Pacific; by way of Cumberland House and up the Churchill river to the Clearwater and Athabaska waterways, giving access on one hand to the Arctic ocean by way of the MacKenzie, and on the other, to the Fraser by way of the Peace and Parsnip rivers.

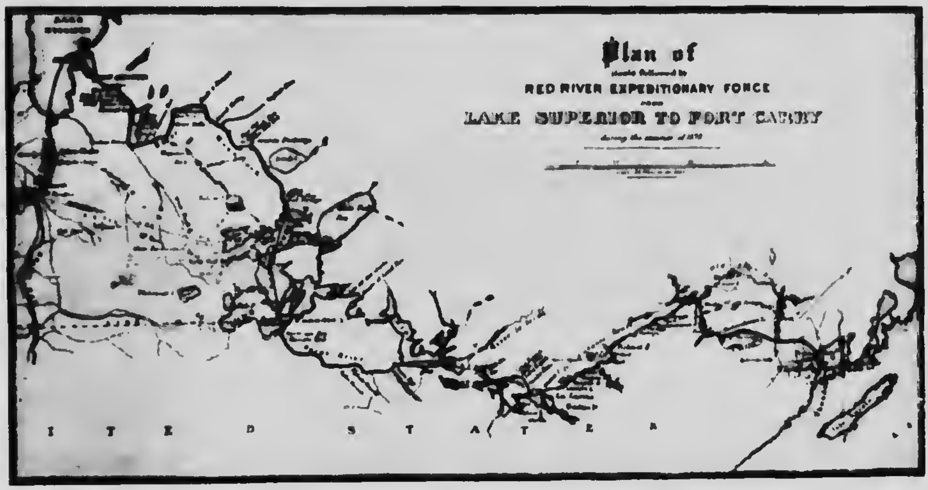
In the early days, the Hudson's Bay Company operated from Hudson bay; many of the routes in the Northwest were known to them, and their traders and trappers soon reached lake Winnipeg by way of the Nelson.

The Winnipeg river, on the other hand, was first discovered by the French penetrating from Montreal. We see Le Caron and Champlain in 1615, Etienne Brulé in 1622, Nicolet in 1634, and Joques in 1641 pushing westward from Montreal to lake Huron. Gradually the traders of New France (the French Company) and their legitimate successors, the Northwest Company, pushed around the north shore of lake Superior, Menard and Radisson in 1651, Allouez in 1665, and Du Lhut in 1678. Jacques de Noyon reached Rainy lake in 1688, and in 1689 descended to the Lake of the Woods and here heard fabulous stories from the Indians concerning a great sea, probably referring to lake Winnipeg.

There seems to have been a lull here, and we have no record of progress, until 1731, when the Sieur de la Verendrye was stationed at Kaministikwia and began his long series of western exploration, apparently rediscovering Rainy lake and the Lake of the Woods. He also led the way into lake Winnipeg by the river of the same name, which river became and remained the highway for the fur trade for upwards of 100 years.

[1] Lawrence J. Burpee's "The Search for the Western Sea" contains much interesting information concerning the routes of early explorers. Mr. Burpee has also contributed papers published in the Proceedings of the Royal Society of Canada, which contain interesting notes on early travel in the West.

Now and again we turn up old books of travel and read of some well-known explorer who journeyed by this route. Sir John Franklin, in May and June, 1825, passed down the Winnipeg river *en route* for the Arctic, his second overland journey; returning safely he passed up the river in July, 1827. Earlier than this, in Sir Alexander MacKenzie's account of his voyages in the years 1789 and 1793, we read a detailed description of the river.



Route of Red River Expedition.

Probably the most interesting historical incident in connection with the Winnipeg river was the passage in 1870 of "The Red River Expedition" under the late Lord Wolseley *en route* to the suppression of the ill-fated Riel rebellion. The problems connected with the transport of a completely equipped military expedition by canoe and boat over some five hundred miles of river and lake, with innumerable portages, can only be faintly realized even by those who have been fortunate enough to travel the same route under more advantageous conditions. The force under Colonel Wolseley, as he was then, consisted of detachments of the Royal Artillery, Royal Engineers, Army Service Corps, and Army Hospital Corps, together with 26 officers and 351 non-commissioned officers and men of the 60th Rifles, all of the British Regular Army. There were also 28 officers and 350 men each of the 1st or Ontario Battalion and 2nd or Quebec Battalion of the Canadian Militia, a total of 1,213 men of all ranks.

The force assembled for the boat journey at Prince Arthur Landing, in Thunder bay, lake Superior, where one company of the Quebec Battalion remained to protect the depot from possible Fenian attack. The remainder of the force, with 150 boats, 32 feet in length and 6-foot beam, a light gig and three large bark canoes pushed forward towards Fort Frances. Each boat carried about 3,300 pounds of stores, besides nine or ten soldiers and three Iroquois and voyageurs, with their camp equipment.

From Fort Frances a start was made on or about the 8th August, 1870, this part of the expeditionary force consisting of all the regulars, with fifty boats. The passage down the Rainy river, across the Lake of the Woods and down the Winnipeg was successfully made and with remarkable speed, the force arriving at Fort Alexander on August 20, and proceeding across lake Winnipeg on the 21st.

Riel having fled, the regulars started back by the same route on August 29, with the exception of one company of the 60th Rifles, which went across country to the Northwest Angle of the Lake of the Woods.

Lieutenant Riddell, of the 60th Rifles, and Captain Huyshe, of Wolseley's staff, have left interesting accounts of the campaign, referring at some length to the beauties, excitement, and dangers of the trip down the Winnipeg river, enabling one to picture to some extent the difficulties successfully overcome.

Since the advent of the railroad, the Winnipeg river has fallen from its former greatness as a route of travel, though pleasure boats from Kenora ply regularly during the summer past Minaki on the National Transcontinental railway to the head of White Dog falls. The river still forms the local medium of travel for the hunter and the fisherman, and for the Indian and the settler, while the hydro-electric activity which has developed in recent years has made it a highway for field parties and engineers. The old Indian legends are still told to the traveller—how Slave falls is named after the slave who, unable to further submit to the cruelty of her master, stepped into a canoe and floated gently over the cataract, and how in the days of Indian tribal warfare, the islands were by mutual agreement made sanctuaries where the squaws and non-combatants might remain unmolested.

General Description of Basin and River.

The basin of the Winnipeg river (Plate 3) forms a portion of the great Nelson River drainage system. The Winnipeg river from the east, the Red river from the south, and the Saskatchewan river from the west, unite their waters in a great central reservoir, lake Winnipeg, which in turn discharges the combined run-off into the Nelson river, and thence into Hudson Bay. The Winnipeg River basin, itself 53,500 square miles in area, lies largely in the westerly portion of New Ontario, while what is referred to in this report as the power reach of the river, i.e., the reach below the junction of the English river, lies almost entirely within the province of Manitoba. The basin is international as well as interprovincial; 11,000 square miles lying in the state of Minnesota; 4,600 square miles in Manitoba; and 37,900 square miles in Ontario. The upper waters are almost equally divided between two drainage systems, which together make up practically the entire basin outside of the province of Manitoba. The southern portion of the run-off is collected by the Rainy river, which in reality is the continuation of the Winnipeg above the Lake of the Woods, while the northern portion is carried by the English river. The two branches unite at a point about 4 miles east of the Manitoba-Ontario boundary.

The entire watershed is very sparsely populated, and a large proportion offers little opportunity for agricultural settlement. Those portions best adapted for such use are the sections lying in southern Manitoba, in Minnesota, and extending inland on the Canadian side from the Rainy river. The balance of the basin consists for the most part of a forest-covered Laurentian formation, with much granite outcropping, and is interspersed with lakes and muskegs and occasional stretches of agricultural land. The forest cover is composed largely of spruce, poplar, jack pine, and oak, a considerable portion of which is too small to possess any great timber value. In the sheltered valleys and gullies the timber is better developed and is of great commercial value. The smaller timber makes excellent pulpwood material.

The great extent of the forest cover exercises a most beneficial influence on the run-off from the basin. It is to the interests of the conservation not only of the timber resources, but also of the power resources as dependent on the regularity of the run-off, that efficient measures be taken towards the preservation of the forest cover from wanton and wasteful timber cutting, and towards the reforestation of denuded areas. Large sections of the basin are suited only to forest growth, and a consistent policy of reforestation will not only directly repay may times over the organization and administrative charges, but will also prove an invaluable and direct aid to the preservation of the water-power resources of the basin. It is to the best interests of the entire district that the watershed area should be created a forest reserve, and so administered.

Throughout the entire central, northern, and western portion of the basin the granite formation is almost continuously in evidence in the form of ridges, mounds, cliffs, and gullies, showing in all directions, traces of glacial striation.[1] As is characteristic of this formation, the entire region is seamed and dotted with lakes of every size, from mere ponds to the expansive spread of the Lake of the Woods. The lakes are likewise dotted with outcropping granite islands and islets, the Lake of the Woods being sometimes, for this reason, referred to as the Lake of Ten Thousand Islands, in contra-distinction to the Lake of a Thousand Islands on the St. Lawrence.

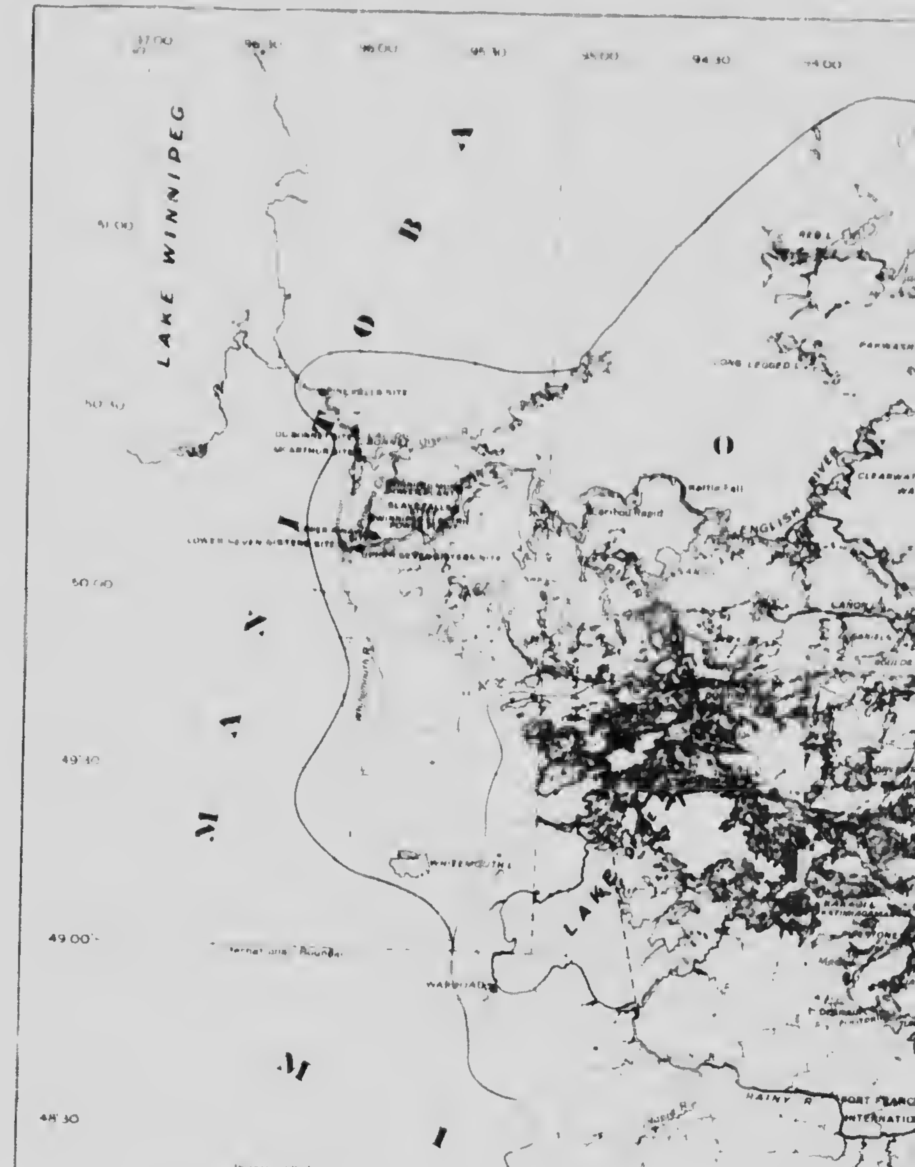
Joining the lakes are innumerable streams and rivers, of size depending on their respective catchment basins, and for the most part made up of deep ponds and lake-like expanses interspersed with rapids and falls tumbling over the natural granite. It is to these conditions both of lake and forest that the Winnipeg river owes its almost unequalled natural regulation, its normal yearly flood seldom exceeding three or four times its minimum.

In the more level sections along the Rainy river, and in Manitoba, and to the south and west of the Lake of the Woods, the existing alluvial conditions are not favourable to lake formation, and the innumerable reservoirs, so much in evidence elsewhere, are almost non-existent. The country is therefore more adapted for settlement.

The basin is now traversed by the three transcontinental lines of railway, the Canadian Pacific, the National Transcontinental, and the Canadian Northern. These routes, running through the heart of the region, are rapidly making its resources available, and are promoting its settlement wherever conditions are favourable. Among the more important towns are Kenora and Fort Frances, in Canada, and International Falls and Warroad in the United States.

The more important natural reservoirs in the southern portion of the basin are lakes Rainy and Namakan, of 330 and 100 square miles area, respec-

[1] For a detailed description of the geological characteristics of the basin, see Appendix III by Mr. Charles Camsell, B.Sc., Ph.D., of the Geological Survey of Canada.



LAKE WINNIPEG
MANITOBA
ONTARIO
MINNESOTA
WINNIPEG RIVER POWER SURVEY
WINNIPEG RIVER BASIN
ENGLISH RIVER
LAKE OF THE WOODS
RAINY R
WHITEMOUTH R
WHITEMOUTH L
WARROAD
LONG LEGGED L
LOWER SEVEN SISTERS SITE
Caribou Rapid
49 00
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93 30
Drawn in the Office of the Chief Draughtsman, Dominion Water Power Branch

PLATE No 3

A R I O
E S
STURGEON LAKE
LAC DES MILLE LACS
PORT FRANCES
INTERNATIONAL FALLS
International Boundary
VERMILION
WHITE OTTER L
TURTLE L
NORTHERN LIGHT L
50°00'
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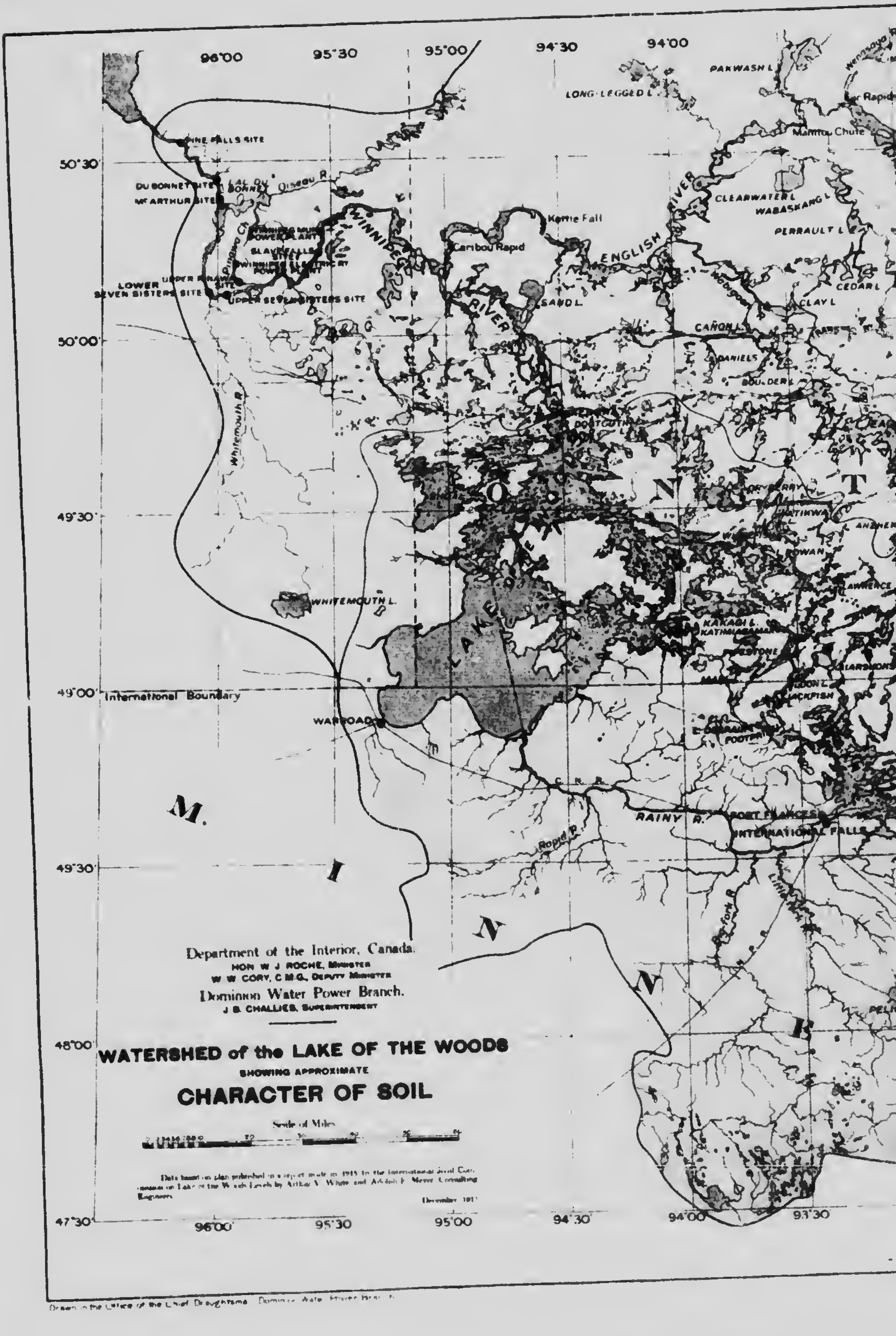

Drawn in the Office of the Chief Draughtsman, Dominion Water Power Branch.

PLATE No. 3A

NOTE
LEGEND
92°30′
92°00′
91°30′
BLUFFY L
Rapids
CEDAR L
VERMILION
GULL
SANDY L
KUKUKUS L
BASKET L
DINORWIC L
MAMEIGWESS L
PAGUCHI L
PINE L
DOG L
BOTSFORD L
Sturgeon
STURGEON LAKE
L of BAYS
PEMASSI L
BELL L
OTTER L
English R
River Divide
BENDING L
RICHARD L
PEKAGONING L
WHITE OTTER L
TURTLE L
CLEARWATER L
LAC DES MILLE LACS
Lit Turtle R.
Seine R.
SHOAL L
BEAVERHOUSE L
NAMAKAN L
STURGEON L
PICKEREL L
QUETICO
NORTHERN LIGHT L
SAGANAGA L
International Boundary
PELICAN L
VERMILION
WHITE IRON L
50°00′
49°30′
49°00′
48°30′
48°00′
47°30′
93°00′
92°00′
91°00′
90°30′
90°00′
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[1] For
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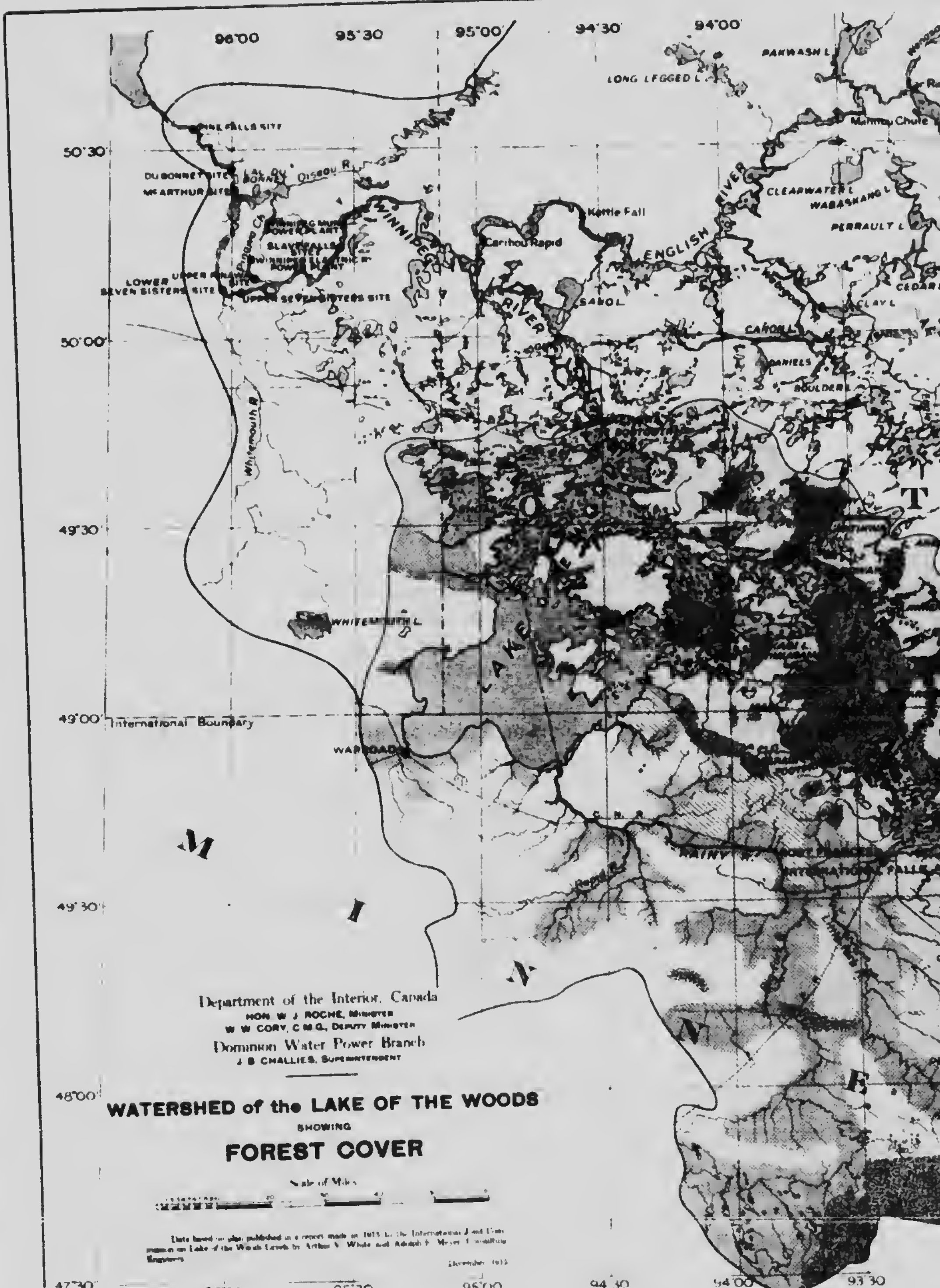
Department of the Interior, Canada
HON. W. J. ROCHE, MINISTER
W. W. CORY, C.M.G., DEPUTY MINISTER
Dominion Water Power Branch
J. B. CHALLIES, SUPERINTENDENT
WATERSHED of the LAKE OF THE WOODS
SHOWING
FOREST COVER
Scale of Miles
96°00
95°30
95°00
94°30
94°00
93°30
50°30
50°00
49°30
49°00
48°00
47°30
International Boundary
WARROAD
WHITEMOUTH L.
Whitemouth R.
LAKE
WINNIPEG
RIVER
ENGLISH RIVER
Kettle Fall
Caribou Rapid
SABOL
CLEARWATER L
WABASKANG L
PERRAULT L
PAKWASH L
LONG LEGGED L.
DANIELS
BOULDER L
CAROLL
CLAY L
M
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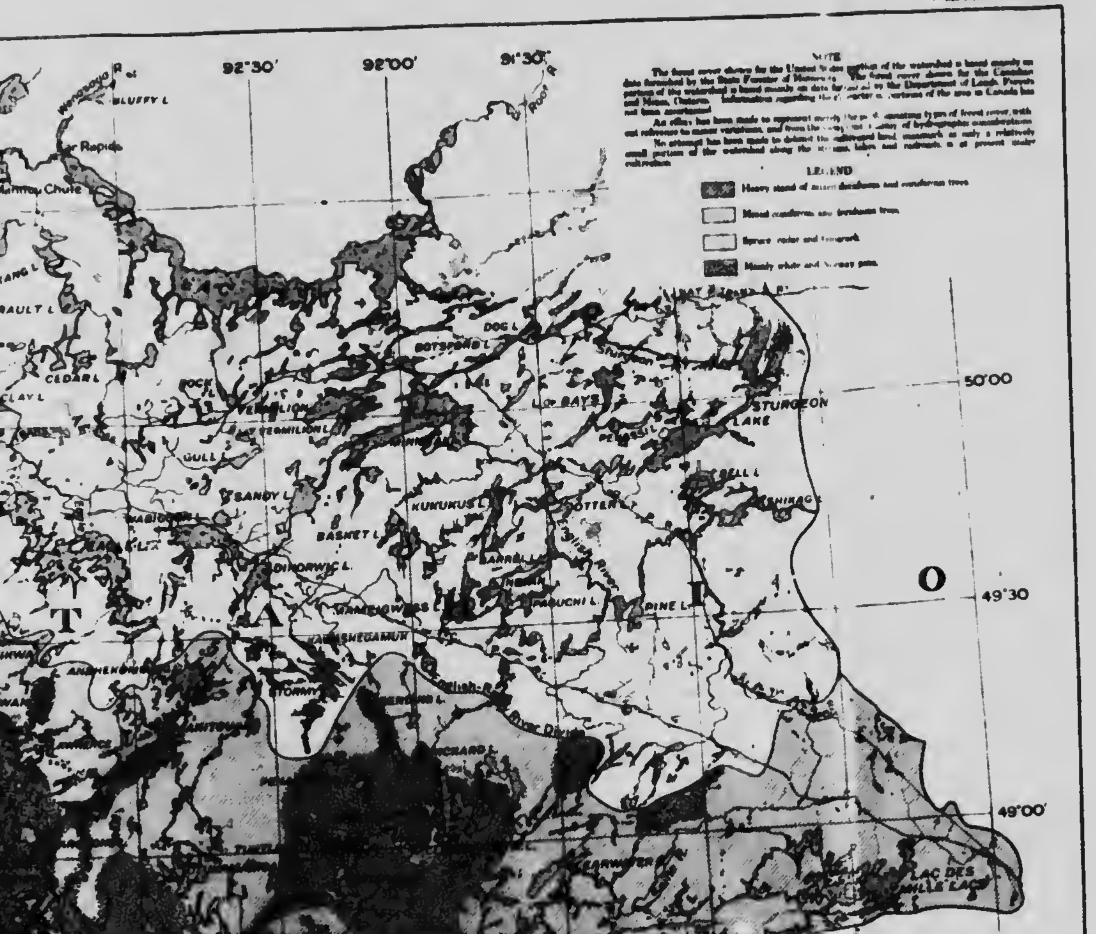
T

PLATE No. 38



92°30′
92°00′
91°30′
BLUFFY L
CEDAR L
DOG L
BOTSFORD L
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DINORWIC L
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91°00
90°30
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tively. These lakes together collect the run-off from 14,400 square miles of drainage basin.

Passing from the western end of the Rainy lake into the Rainy river, the discharge takes place over what were formerly the Koochiching falls, but which are now utilized in operating the hydro-electric and pulp-mill installations of the Ontario and Minnesota Power Company at the towns of Fort Frances and International Falls. A normal head of some 33 feet is developed here. The Rainy river flows in a westerly and slightly northerly direction to the Lake of the Woods, the largest body of water in the Winnipeg watershed. The river below Fort Frances is navigable, 6-foot draught being maintained. Plans have been developed by the Dominion Department of Public Works, for the installation of a lock with an 11-foot lift at Long Sault rapids to improve navigation, but no construction steps have as yet been taken.

The Lake of the Woods receives the discharge of numerous streams, other than the Rainy river, none of which are of outstanding importance. Its surface, as stated above, is dotted with innumerable islands, which form ideal sites for summer houses, a fact which is being fully recognized by the people of Winnipeg and the surrounding cities and towns. The lake discharges through two branches, the eastern and the western, the entrances to which lie within the limits of the town of Kenora. Here the Winnipeg river proper begins. The basin above Kenora is 26,400 square miles in extent, and the Lake of the Woods is 1,500 square miles in surface area, forming a unique combination in the interests of storage, more especially in view of the 347-foot drop between the lake level and lake Winnipeg 160 miles below.

The eastern outlet is closed by the Kenora municipal power station, developing a normal head of 20 feet. The western outlet is closed by the Norman dam, a rock-fill, stoplog controlled structure. Farther to the west, at the town of Keewatin, are two additional outlets which have been blasted for power purposes through the rock ridge separating the lake from the river below. The situation at the outlets of the lake is treated fully in chapter III.

Leaving the Lake of the Woods, the Winnipeg river flows first in a northerly direction, expanding into deep lake-like expanses with little or no current, and again narrowing into congested channels and forming rapids and falls of greater or less turbulence. This characteristic formation continues throughout the entire reach of the river to lake Winnipeg. The ponds are usually very deep, having, in fact, originally been the deeper gullies and valleys lying between the rocky ridges and hummocks covering the surface of the region, through which the drainage of the basin above found exit towards lake Winnipeg. As a rule, discharge from these basins takes place over granite ridges at points where the elevation drops below the general level, thus forming the falls and rapids which obtain throughout the length of the river. Evidence as to the existence of these submerged ridges can be readily noted, and is definitely shown at all rapids and falls where detailed soundings have been secured. Granite outcrop is invariably in evidence on both river banks at all such points and is, as a rule, indicated also in the intervening river-bed, by outcropping islands and ridges. In all cases, the rock is of the most massive character, showing small signs of wear or disintegration even where exposed to the most turbulent current or to the most severe ice action.

These submerged ridges at the critical points along the river, combined with the deep ponds which are already in existence immediately above, which ponds are deepened and bettered by the construction of power dams, supply unequalled sites for the development of power.

About 11 miles below Kenora the river enters a somewhat narrow channel of rather rapid current, known as the Dalles. Leaving this, open expanses with little or no current are the rule until the crossing of the National Transcontinental railway at Minaki is reached. From Kenora to this point the river is navigable by steamer. Minaki has become recognized as a summer resort by the people of Winnipeg, as it is the centre of a beautiful lake and island region, and has good rail connection with the city.

Fifteen miles below this, the river discharges through the White Dog rapids. In these rapids there is a total drop of 45 feet, occurring in several abrupt pitches, with quieter water intervening. These form an excellent power prospect but, as they lie within the province of Ontario, do not come within the jurisdiction of the Dominion Water Power Branch, and hence are not treated in the power studies covered in this report.

The English river joins the Winnipeg at a point 50 miles below Kenora. It is a river very similar to the Winnipeg at this point, draining 21,600 square miles of basin as against 27,500 square miles by the Winnipeg. The principal reservoir in the upper reaches of the English river is Lac Seul, 340 square miles in area. There are, however, innumerable other lakes of sizes up to 94 square miles, scattered over the region in all directions. The waters of these two great branches combine within 4 miles of the boundary between Ontario and Manitoba. Before reaching the interprovincial boundary, what is known as the First fall is passed. The drop here is 4 feet.

From the eastern boundary of Manitoba, the Winnipeg river flows in a generally northwesterly direction towards lake Winnipeg. Its general characteristics continue as already described, and since the individual falls and rapids are treated at length in connection with the power concentrations, it is unnecessary to do more than refer to them here. Only a few of the main features will be dealt with.

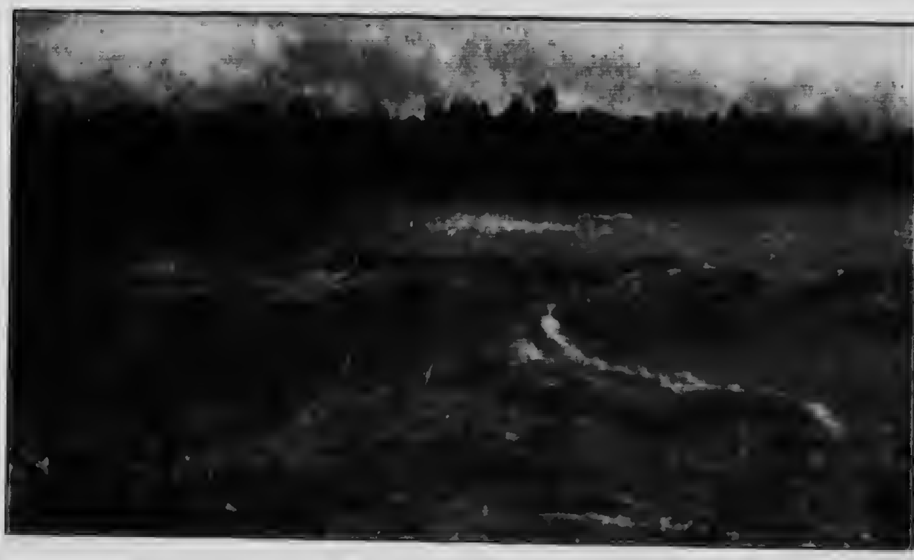
After crossing the interprovincial boundary there is but one distinct drop before the municipal plant of the city of Winnipeg is reached. This slight pitch of about one and a half feet is all that is left of Lamprey falls, the former 16-foot natural drop which has been flooded out by the construction of the city plant. This development incorporates Lamprey falls, together with the Point du Bois falls, making in all a 45-foot normal working head.

Below the city plant come the Eight Foot and Slave falls, of 7 and 19-foot drop respectively. At the latter of these, 4½ miles below Point du Bois, the first power concentration of 26-foot head is proposed.

Sixteen miles below Slave falls the river is broken into two channels, the left carrying the main flow through what is known as the Seven Sisters reach, and on which two of the proposed power sites are located; and the right or

Pinawa channel, carrying a sufficient flow to properly operate the hydro-electric plant of the Winnipeg Electric Railway Company. The latter channel, 21 miles in length, was formerly a high water by-pass of the main river. It has been very considerably straightened and deepened in the upper reaches, while diversion weirs have been placed across the main and secondary channels, with the result that a flow of from 7,000 to 12,000 second-feet is diverted for the operation of the power station. A power concentration is proposed on this channel above the present power station.

The main and Pinawa channels unite in Lac du Bonnet, a body of water 32 square miles in area. From Lac du Bonnet, the river discharges over the First McArthur falls, followed a short distance below by the second drop of the same name. At the latter point is placed the fifth concentration, with a proposed head of 18 feet, partially secured by raising the level of Lac du Bonnet. Below the McArthur falls the river's flow is quiet, with a just appreciable current in places, until the Grand du Bonnet falls are reached. Here a total drop of 35 feet takes place in four distinct pitches, and is followed a short distance below by the Little du Bonnet drop of 8 feet. At this point has been placed the sixth concentration, with an ultimate proposed head of 56 feet, to be partly secured by blasting away the ridge forming the Whitemud falls.



Pine Falls, Main Drop.

After leaving the Du Bonnet falls, the river resumes its characteristic course, abrupt drops taking place at Whitemud and Silver falls. The latter are the most spectacular falls on the Winnipeg river, owing to the comparative concentration of the 21-foot drop. Below the Silver falls the river flows without disturbance to the Masqua rapids, where there is a total drop of 5 feet. Passing the Masqua rapids, quiet water prevails until the Pine falls, forming the last pitch before reaching Lake Winnipeg level, are reached. At Pine falls the seventh

Silver Falls.

concentration is proposed with a head of 37 feet. Below Pine falls the river gradually broadens out and enters Traverse bay, an eastern arm of lake Winnipeg.

With the exception of that section of the river below Silver falls, settlement along the river banks is not as yet far advanced. Below Silver falls, the river banks have been cleared and cultivated. This comparative freedom from settlement is an outstanding advantage in mapping out a general scheme of hydro-electric development.

Preliminary Reconnaissance.

In June of 1911, initial steps were taken looking to the commencement of active field investigations. As already stated, the services of Mr. J. B. McRae, C.E., of Ottawa, were secured in the capacity of consulting engineer, to act throughout the investigation, while the services of Mr. J. R. Freeman, C.E., of Providence, R.I., were engaged to advise, in company with Mr. McRae, on the organization and scope of the survey. Mr. D. L. McLean, B.Sc., of Ottawa, was engaged as chief engineer in charge of the field investigations, and a preliminary field staff was organized.

The main survey work was preceded by a reconnaissance trip made by the consulting and departmental engineers down the Winnipeg river from Kenora to lake Winnipeg, with a view to securing a comprehensive grasp of the entire power reach, and of laying out the general plan of attack. In the meantime, Mr. McLean proceeded to the ground and placed a levelling party in the field for the purpose of establishing the essential base profile to which the further survey work could be tied in. The levelling party, under Mr. A. M. Beale, commenced operations on June 21, 1911, starting from a Canadian Pacific Railway bench-mark near the Winnipeg City bridge at Lac du Bonnet. This datum, based on mean sea-level, was used throughout.[1]

Leaving Lac du Bonnet, the levelling party carried the profile down to Fort Alexander at the mouth of the river, reaching the settlement on July 18. High-water marks, which are most distinctly preserved on the rock formation, were tied in at frequent intervals. The party returned to Lac du Bonnet on the 22nd, and continued the profile up the river by way of the Seven Sisters reach arriving at Kenora on September 20, after an uninterrupted trip. Here the levels were tied in to the Canadian Pacific Railway bench-marks, and a most satisfactory check obtained.

In running the line up the river, a diversion was made at the head of the Pinawa channel, and the levels were carried down the same to the Winnipeg Electric Railway Plant. From this point, a pre-existing line of levels was utilized to the exit of the channel into Lac du Bonnet, and by water transfer carried across the lake to the head of the First McArthur falls, a check on the closed circuit of 0.15 feet being obtained.

Due to the prevalence of exposed granite along the entire river, it was possible to establish bench-marks of the most permanent description. Standard bench-marks were located on suitably exposed granite knolls, these being as a

[1] 0.0 Water Power Survey Datum is equal to 1.31 mean sea tide at New York, i.e. the United States Coast and Geodetic Survey Datum.

rule in evidence at all vital points. The bench-marks were given succession numbers, which, together with the elevations, were painted on the rock surface. A complete list of the principal bench-marks established along the power reach, together with their location, is attached in Appendix V.

Typical Survey Bench Mark.

Towards the end of August, when the levelling party were in the midst of their operations, arrangements were completed for the desired power reconnaissance of the river. The reconnaissance party, consisting of Mr. Freeman, Mr. McRae, Mr. McLean, and the writer, assembled at Winnipeg on the morning of August 26, and immediately proceeded to Kenora, from whence the start was to be made. During the afternoon a detailed inspection was made of the various outlets of the Lake of the Woods, together with their control structures in the way of dams, power stations, and mills.

The following morning the party boarded the *Kathleen*, a small steamer making regular trips from Kenora to Minaki at the crossing of the National

Transcontinental railway, 19 miles down the river. From this point, the trip was continued by canoe and portage to the mouth of the river.

At each fall or rapid, a stop was made to permit of a thorough inspection of the site and surroundings, and the securing of such notes, sketches, and photographs as were desirable. Throughout the reaches between the falls, careful note was made of the banks, mainly from the canoe. Each site was studied from the viewpoint of concentrating thereat the greatest feasible head. It was impossible to do more than form general conclusions at this stage, and it was recognized that such temporary findings were merely useful as forming a preliminary guide on which to base the field work, and were to be revised in the

White Dog Rapids, Third Pitch.

light of the actual results secured by the field parties. With such information as could be obtained by observation on the ground, conferences were held at the various falls, in which the scope of the necessary surveys was discussed, and the best prospect of development at each site tentatively outlined. It might be said here, that while the conditions exposed by actual survey work called for several radical departures from these first outlined suggestions, and required different treatment from that tentatively discussed, the basic principles laid down served as a continuous and sufficient guide throughout the entire work.

While the scope of the actual power investigations was not to extend beyond the province of Manitoba, the reach of river between Kenora and the boundary was included in the reconnaissance examination. The White Dog rapids was passed on the morning of the 28th. There is here a total drop of 45 feet, with the apparent opportunity of developing the entire head, and of flooding back to the tailwater of the Kenora plants. Such a development would undoubtedly prove commercially attractive. Extensive detail contour surveys of the river banks above are necessary to determine the flooding which would be involved. A back channel, with upper entrance above the first drop, also requires investigation in connection with any development here.

The First falls, reached during the same day, are located about 16 miles below the White Dog rapids, and 1 mile below the junction with the English river. There is here a natural drop of 4 feet, and the fall forms an excellent power prospect, the full capacity of which can only be ascertained by a contour survey of the river banks above.

White Dog Rapids Fourth Pitch.

On the morning of August 29, the party left First falls, and about noon encountered the levelling party working up stream, a short distance above Lamprey falls. These falls have a drop of about $1\frac{1}{2}$ feet only, all that is now left of the original 16-foot pitch, which has been flooded out by the construction of the city of Winnipeg municipal plant.

The city plant was reached at 4 p.m., and a thorough inspection made. At this time, the initial installation was being rushed to completion. Leaving the city plant and passing the Eight Foot falls, Slave falls was reached the same evening.

On the morning of the 30th, the Slave site was inspected. This appeared to be the obvious point of concentration for the Slave and Eight Foot falls. Subsequent survey has confirmed this conclusion, as is covered in chapter VI. Immediately above Slave falls there occurs a fairly narrow river section, which appeared to offer better opportunities for the establishment of a metering station than were elsewhere obtainable along the river. This was confirmed in the subsequent detailed examination of the river, and a cable station was established here in October of the same year.

The diversion weirs of the Winnipeg Electric Railway plant were reached shortly after noon, and were briefly inspected. The canoes were then turned down the Pinawa channel. Time did not permit of a reconnaissance of the main or Seven Sisters channel, and as the problems to be investigated thereon were not of as pressing importance as were those on the Pinawa, the latter channel was selected for immediate attention. The principal features of the Pinawa channel are referred to in another section of this report, and need not be repeated here. The street railway plant was reached at 4 p.m. Leaving the power station, the party reached Lac du Bonnet about nightfall. Good progress was made throughout the Pinawa, due to the rapid current which prevails for a considerable portion of its length.

Pinawa Channel, Rock Cut.

On the morning of the 31st, the two McArthur falls were examined, followed by the Grand and Little du Bonnet falls. The outstanding advantages of combining the entire drop of this group of falls at the last named was recognized, and was made the basis of the subsequent field investigations. These, however, showed that the scheme was not practicable in its entirety, owing to the low-lying lands to the east, and it has been found necessary to break this section into two developments, as is discussed in chapter VI.

The Whitemud, Silver, and Pine falls were passed during the afternoon, and the general scope of the field investigations covering the same decided upon.

At 7 p.m. the party boarded the launch which was waiting at the foot of Pine falls, and proceeded across lake Winnipeg to Gimli, and thence by train the following morning to Winnipeg. The entire trip from Kenora to Pine falls occupied five full days, which, considering the time spent on the examination of the falls, rapids, and plants, en route, was considered exceptionally good travelling, and was only attained as a result of continuous effort and hard paddling by every member of the party.

Mr Freeman and Mr. McRae submitted to the department comprehensive reports covering the trip, the investigations, the field work recommended, and the general conclusions as to the scope of the work to be undertaken. The following final summing of Mr. Freeman's report is quoted:—

> "In brief, I recommend that you have surveys made in sufficient detail at each site so that the best plan for conserving all the power can be worked out, and that plans be prepared in outline, and the cost of each project carefully estimated, and the whole then published very fully, so as to attract attention and at the same time give opportunity for easily verifying the principal statements and estimates, and that this be prefaced by a statement of the generous policy of the Government regarding the granting of water-power rights."

This summary was supplemented by recommendations to thoroughly study the river discharge, and to establish the records of the same on a reliable basis, to collate all existing rainfall records and establish new stations where necessary, to establish a fully equipped evaporation station on the lake of the Woods, and to look into the storage prospects on Lake of the Woods, Rainy lake, Lac Seul, and other lakes of the watershed. All these questions had been the subject of conference and discussion throughout the reconnaissance, and the various aspects and details in connection with the same, had been thoroughly considered.

Field Survey.

In view of the pressing and conflicting character of the applications which were before the department covering the development of the Du Bonnet falls, the reach of the river below Lac du Bonnet called for first consideration in the field, and it was at the Du Bonnet falls that the actual detail survey work was commenced. In spite of the extreme temperature conditions which prevail in this latitude, it was determined that the field work should be prosecuted continuously throughout the winter season. The disadvantages and hardships incident to work during this season were largely counterbalanced by the added speed which could be attained in cross-section work, due to the bareness of the trees and shrubbery. The necessary soundings could also be obtained much more readily from the ice surface, than under open-water conditions.

Upon the completion of the profile work in the latter part of September, the levelling party was enlarged and transferred to the Du Bonnet falls, and there installed in a roomy log shanty which had formed the headquarters of previous power survey parties conducted by private enterprise. In the meantime, a cable metering station was established at Slave falls, and gauges were placed at all points where records of the water level would prove of value, and where gauge readers could be secured.

The survey work in the vicinity of the Du Bonnet falls was more extensive in scope than was necessary at other possible concentrations along the river.

This was due to the conflicting nature of the schemes of development proposed by private interests, and to the necessity of ascertaining, beyond doubt, the feasibility or otherwise of carrying the Lac du Bonnet level to the Du Bonnet falls for incorporation with the existing drop. This involved very extensive cross-section work back from the direct river bank, in a search for the highest land. Also, before any final decision could be reached as to the head- and tailwater elevations permissible at the Du Bonnet site, full detail data were necessary covering the entire reach of the river down to Pine falls, and up to and including the shores of Lac du Bonnet.

In addition to the extensive work which was required in the vicinity of the Du Bonnet falls, the balance of the field data secured along this reach consisted principally of a contour survey of the river banks between the various falls, and of detail cross-sectioning and sounding at the falls and wherever there was prospect of future construction. This detail included the two McArthur falls, the Du Bonnet group, the Whitemud, the Slave, and the Pine falls. During this season also, a reconnaissance survey was made along the shores of Lac du Bonnet. Some realization of the conditions under which this work was carried on is conveyed by the statement that during January and February there were thirty-four days during which the temperature never rose above zero, and eighteen days during which the temperature never rose above 10° below zero. Extreme temperatures of 20°, 25° and 30° below were common. The remainder of the winter was of similar severity, but, notwithstanding, there were no days in which outside work was not carried on.

As fast as the field work was completed, it was plotted in the camp, and traced on standard-sized sheets 30 by 37 inches, reproductions of which accompany this report. This immediate plotting on the ground was greatly aided by the loose-leaf system of field notes adopted throughout the work. Standard-size leather covers, with 5-inch by 8-inch fillers, suitably printed and ruled for transit, stadia, and level work, were provided. The great flexibility of the loose-leaf system proved of outstanding advantage to the rapid and efficient carrying on of the work, more especially as the results were being plotted into final shape as rapidly as the notes were available. The loose leaves also lent themselves most readily to a simple filing system, in which the records of the survey could be properly grouped, and be at all times available for instant reference.

The field work for this lower section of the river was practically completed by the middle of April, 1912, and the party was moved to the Point du Bois power plant, in order to commence the detailed work required from that point down the river. Pressing questions arising in the department in connection with this reach called for first-hand information, and made it the next section of the river requiring urgent attention. The survey work was similar to that on the lower reach, contours of the banks being secured, with detail work at the Eight Foot and the Slave falls. The work was at this stage continued down the river to Sturgeon falls, which point was reached early in July. The party worked from a movable tent camp headquarters, transport being secured by means of canoes.

Towards the end of July it became necessary, in the interests of departmental work, to transport the Winnipeg River party and outfit to the Grand

Rapids on the Saskatchewan river, for the purpose of there carrying out similar power investigations. This work was not completed until about the middle of October, and it was the 23rd of this month before the Winnipeg River survey was recommenced.

The Winnipeg field work was restarted from the McArthur falls, and continued up the western shore of Lac du Bonnet to the Winnipeg City bridge, after which it was continued from the falls around the shores of the lake and up the Pinawa channel. At all points, the bank contours were secured, and the low-lying sections and muskegs traced. Along the western shore of the lake, this involved rather extensive exploration work as the land is low-lying and adjoins an extensive muskeg, of which limits have never been definitely ascertained. Its mean elevation in the vicinity of the lake is 829. This forms a limiting feature in the power investigations, which is fully discussed herein in the section dealing with the McArthur power site.

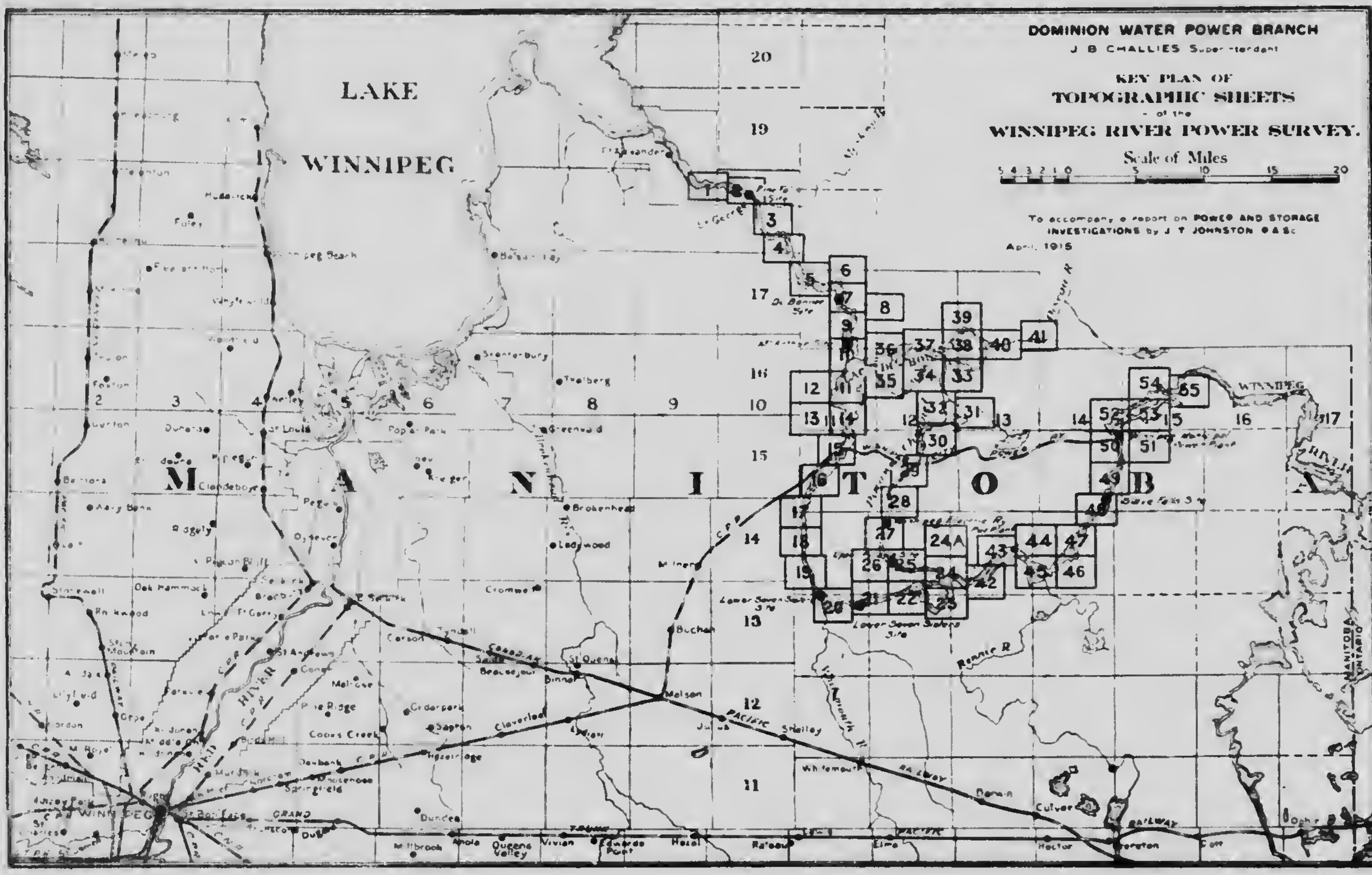
Further detail work along the Pinawa channel was stopped for the time being at the city bridge, which point was reached on February 3, 1913, work having been proceeded with throughout the winter season as in the previous year. From this point, a traverse line was run along the city tramway and tied in to the detail work on the main channel, completing the closure.

The field work was then continued up past the town of Lac du Bonnet, and along the Seven Sisters reach. The usual bank contours were secured, and detail soundings obtained at the falls and rapids. At the head of the reach, the three diversion weirs and the control dam of the Winnipeg Electric Railway Company were tied in. The numerous islands and structures in this vicinity necessitated a considerable amount of traverse work, and occupied the party until the middle of July.

From the head of the Pinawa channel, the survey was carried down to the street railway company's plant, and united to the work which had been carried up to this point in February. All the company's plant and buildings were carefully tied in to the power survey lines. This work was finished by the end of August and, for the time, completed the regular survey of the river.

At this stage, the entire river banks from Pine falls to the city of Winnipeg plant at Point du Bois, with the exception of one small gap, had been completely contoured, and the sites detailed. The unclosed gap consisted of about 6 miles of river extending from a short distance above the diversion weirs to the Sturgeon falls. The information along this reach was not immediately necessary, and was left to a more convenient season, the power party being more profitably used in securing additional sections and soundings, etc., at points where the office studies had shown the same to be necessary. The gap was closed the following year, in order to complete the series of topographic sheets, and at the same time further and more accurate data were secured respecting the higher contours along the Pinawa channel. The complete series of topographic sheets, Nos. 1 to 50 accompany this report, and depict the field data secured. Plate 4 is a key plan of these topographic sheets, and illustrates the reach of river covered. Sheets 51, and 55 were plotted in Ottawa, and are based on land survey field notes. They depict the flooding caused by the construction of the municipal power plant of the city of Winnipeg at Point du Bois.

PLATE No. 4


DOMINION WATER POWER BRANCH
J B CHALLIES Superintendent
KEY PLAN OF
TOPOGRAPHIC SHEETS
of the
WINNIPEG RIVER POWER SURVEY.
Scale of Miles
5 4 3 2 1 0 5 10 15 20
To accompany a report on POWER AND STORAGE INVESTIGATIONS by J. T. JOHNSTON B.A.Sc
April, 1915
LAKE
WINNIPEG
M A N I T O B A
MANITOBA
ONTARIO
Selkirk
Whitemouth R
Rennie R
Brokenhead
Beausejour
Culver
Dunrea

The completion of the survey work to the electric railway company's plant finished that portion which was essential to the preliminary power studies. The field work, as it was completed, was compiled and plotted as rapidly as possible, those portions which were most urgently required being given first consideration. This plotting was carried on under Mr. McLean's direction in the Winnipeg office after the removal of the headquarters to that city in April of 1912, at the time of the organization of the Manitoba Hydrographic Survey. The finished tracings, on standard sheets, were forwarded to Ottawa as completed, where immediate study was given to a scheme of comprehensive power development.

In this study, the writer collaborated constantly with Mr. J. B. McRae, and the results are incorporated in the plans and text following.

Preliminary studies for the determination of the points of power concentration indicated that these would be placed at the Second McArthur, the Little du Bonnet, and the Pine falls, while the natural drop below the Point du Bois plant could be concentrated at the Slave falls. Tentative layouts were designed for these sites, and general conclusions were drawn as to the feasibility and efficiency of the same.

Before final designs or estimates were proceeded with, the writer made a further inspection trip along the river, in order to examine the actual selected sites, and to determine whether the detail of the ground was wholly suited to the layouts proposed.

This inspection trip was made in September, 1913, and the Pine, Du Bonnet, and McArthur sites were visited, together with such other points on the reach as the office study of the field plans had indicated as requiring inspection. The information secured served to confirm the preliminary conclusions which had been reached. Further detail work was outlined on the ground to ensure additional accuracy in the estimates and to the location of the shoreline and rock outcrop in the immediate vicinity of the proposed plants.

This reconnaissance also included the Seven Sisters reach, in which two concentrations were necessary. The general location of these two sites was tentatively pre-determined from a study of the uncompleted field plans, and it was possible to study the ground forearmed with a fair idea of the final scheme of development, and of the particular features and localities which required close investigation in connection with the same.

The receipt of the further detailed data, secured as a result of this inspection of the proposed sites, permitted immediate and aggressive work on the final designs and layouts, the results of which are submitted herein. The points of power concentration are shown in profile on plates 5, 6, and 7.

While the power survey was being prosecuted, steps were taken towards securing and collating the further data pertinent to the investigation. Continuous meterings were secured at the cable station at Slave falls, and the results obtained were combined with prior records secured by the engineers of the city and of the electric railway company. A careful rating was made of the Pinawa channel, and a continuous record of its discharge secured. The importance of the Lake of the Woods to a storage system for the river was recognized from the commencement of the investigations, and particular care has been exercised to secure a reliable record of the run-off. Metering stations were

Department of the Interior, Canada

Water Power Branch

WINNIPEG RIVER POWER SURVEY.

PROFILE OF WINNIPEG RIVER

FORT ALEXANDER TO LAC DU BONNET

SHOWING PROPOSED POWER CONCENTRATIONS

Note: Water Levels were taken between the 13th and the 18th of May 1914, during which period the discharge at Slave Falls rose from 17,900 to [illegible] C. Ft per Sec.
Distances in feet are measured from the original plotted plane of the Winnipeg River, zero being at B.M. [illegible]
Elevations are referred to Mean Sea Level Datum, obtained from the C.P.R. at Lac du Bonnet.

SCALES

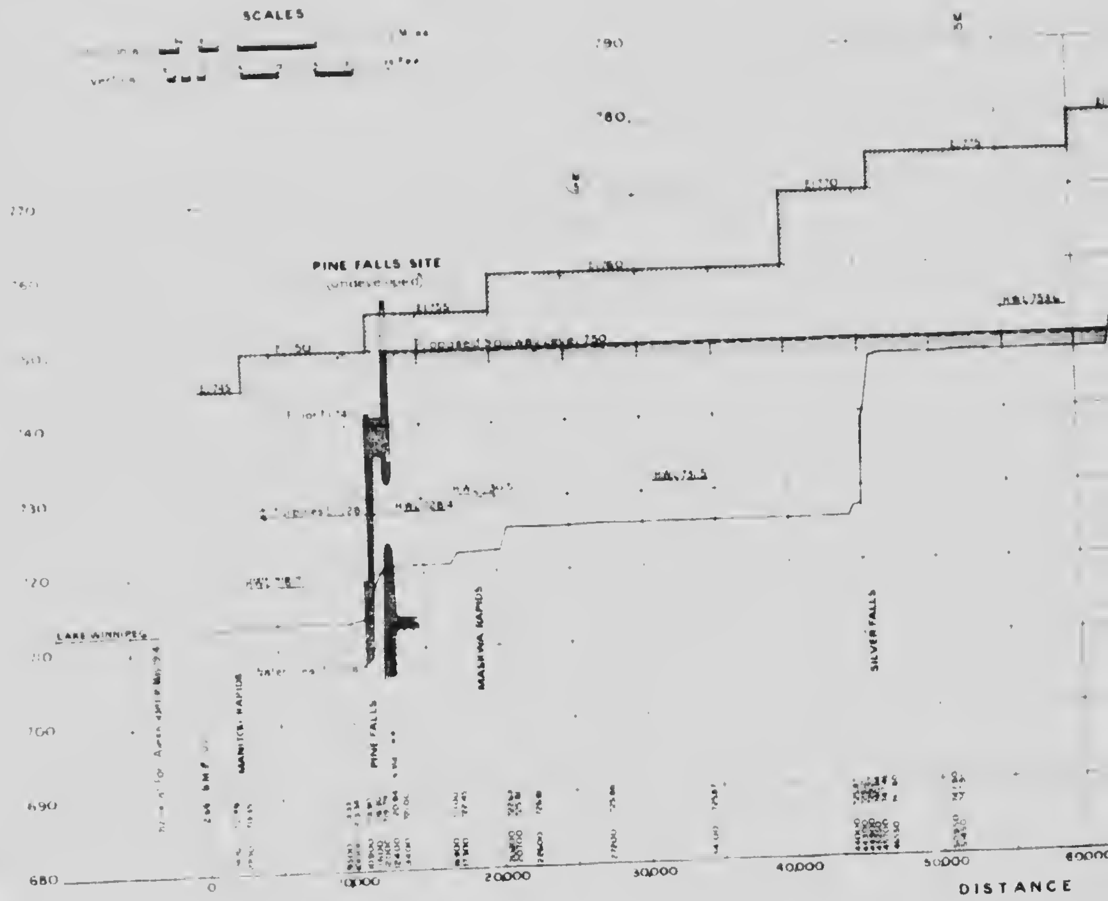
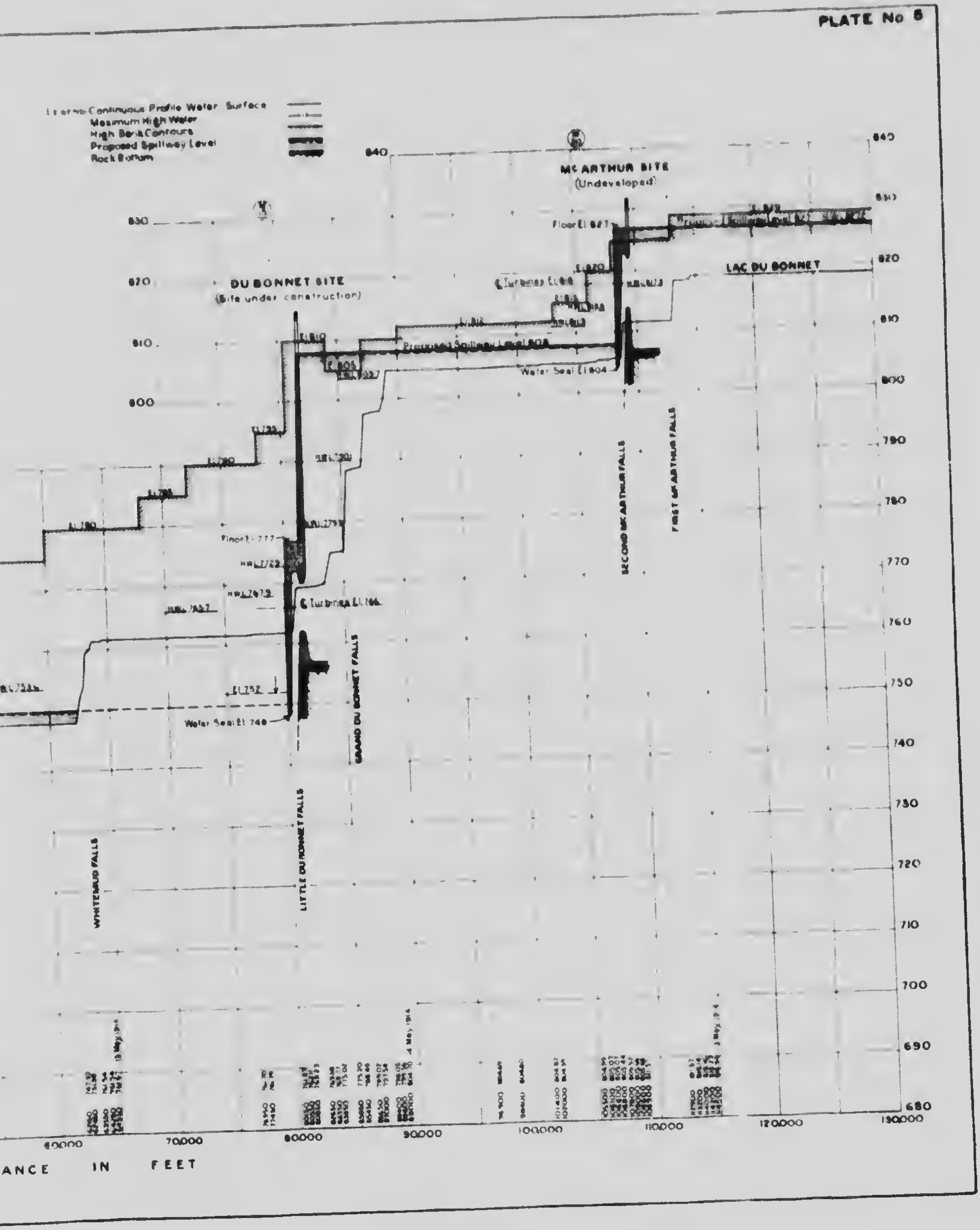
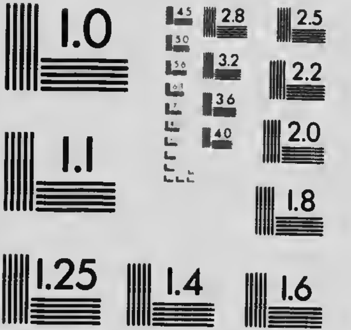


PLATE No 8


Legend: Continuous Profile Water Surface
Maximum High Water
High Bank Contours
Proposed Spillway Level
Rock Bottom
DU BONNET SITE
(Site under construction)
McARTHUR SITE
(Undeveloped)
LAC DU BONNET
Proposed Spillway Level 808
Water Seal El 804
Water Seal El 740
C Turbines El 766
C Turbines El 816
Floor El 827
Floor El 777
WHITEMUD FALLS
LITTLE DU BONNET FALLS
GRAND DU BONNET FALLS
SECOND McARTHUR FALLS
FIRST McARTHUR FALLS
ANCE IN FEET

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



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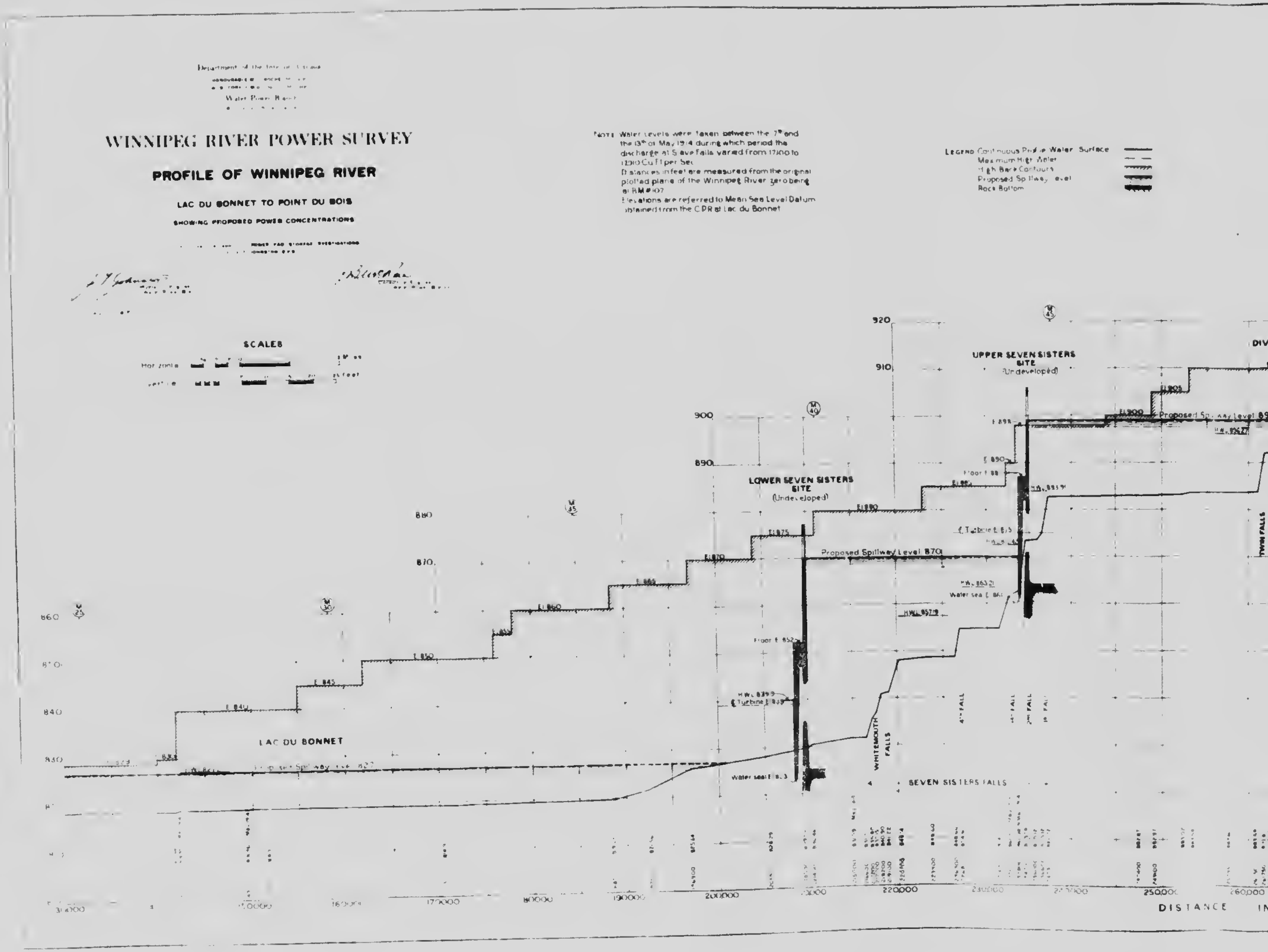
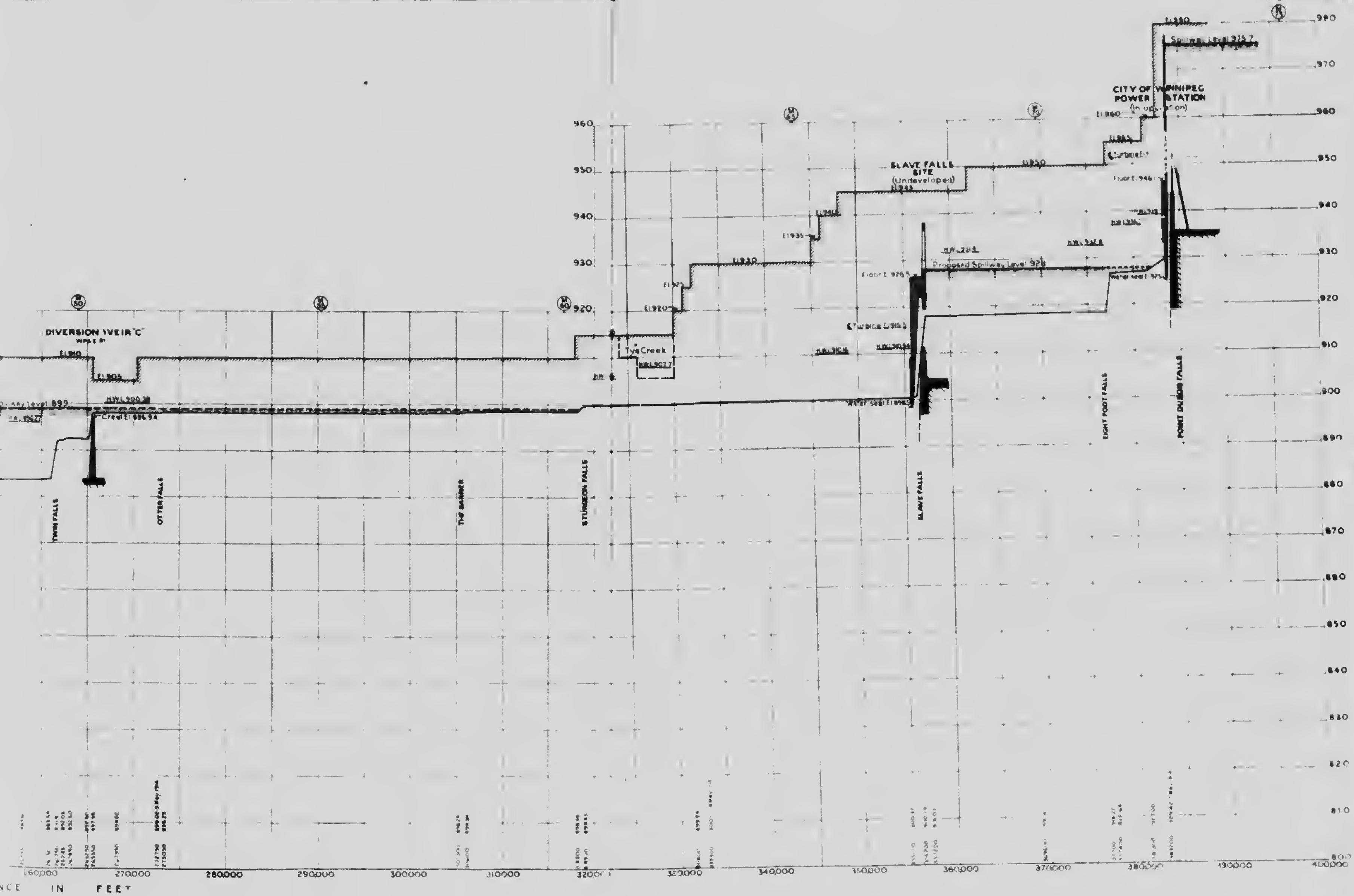

WINNIPEG RIVER POWER SURVEY
PROFILE OF WINNIPEG RIVER
LAC DU BONNET TO POINT DU BOIS
SHOWING PROPOSED POWER CONCENTRATIONS
SCALES
NOTE Water Levels were taken between the 7th and the 13th of May 1914 during which period the discharge at Slave Falls varied from 17100 to 12910 Cu.Ft per Sec.
Distances in feet are measured from the original plotted plane of the Winnipeg River zero being at B.M.#107
Elevations are referred to Mean Sea Level Datum obtained from the C.P.R. at Lac du Bonnet
LEGEND Continuous Profile Water Surface
Maximum High Water
High Bank Contours
Proposed Spillway Level
Rock Bottom
LAC DU BONNET
LOWER SEVEN SISTERS SITE (Undeveloped)
UPPER SEVEN SISTERS SITE (Undeveloped)
Proposed Spillway Level 870
Proposed Spillway Level 899
WHITEMOUTH FALLS
SEVEN SISTERS FALLS
TWIN FALLS
DIVER
920
910
900
890
880
870
860
840
830
200000
220000
250000
260000
DISTANCE IN

PLATE No. 6


DIVERSION WEIR "C"
TWIN FALLS
OTTER FALLS
THE BARRIER
STURGEON FALLS
Tye Creek
SLAVE FALLS SITE
(Undeveloped)
Proposed Spillway Level 928
SLAVE FALLS
EIGHT FOOT FALLS
CITY OF WINNIPEG POWER STATION
POINT DU BOIS FALLS
Spillway Level 975.7
Creat El. 896.94
960
950
940
930
920
980
970
910
900
890
880
870
860
850
840
830
820
810
800
270,000
280,000
290,000
300,000
310,000
320,000
330,000
340,000
350,000
360,000
370,000
380,000
390,000
400,000
IN
FEET

Department of the Interior Canada

Water Power Branch

WINNIPEG RIVER POWER SURVEY.

PROFILE OF PINAWA OHANNEL

NOTE Water levels between 0 and 50,000 were t
during the winter months of 91
Water levels from 10000 to 30000 were
during the open season when the
approximately uniform at about 10000Se
Distances in feet are measured from the
tracings of the topographic sheets
on the North Boundary of Sec 25
Elevations are referred to Mean Sea Level
obtained from the C.P.R. at Lac du Bonnet

SCALES

Horizontal

Vertical

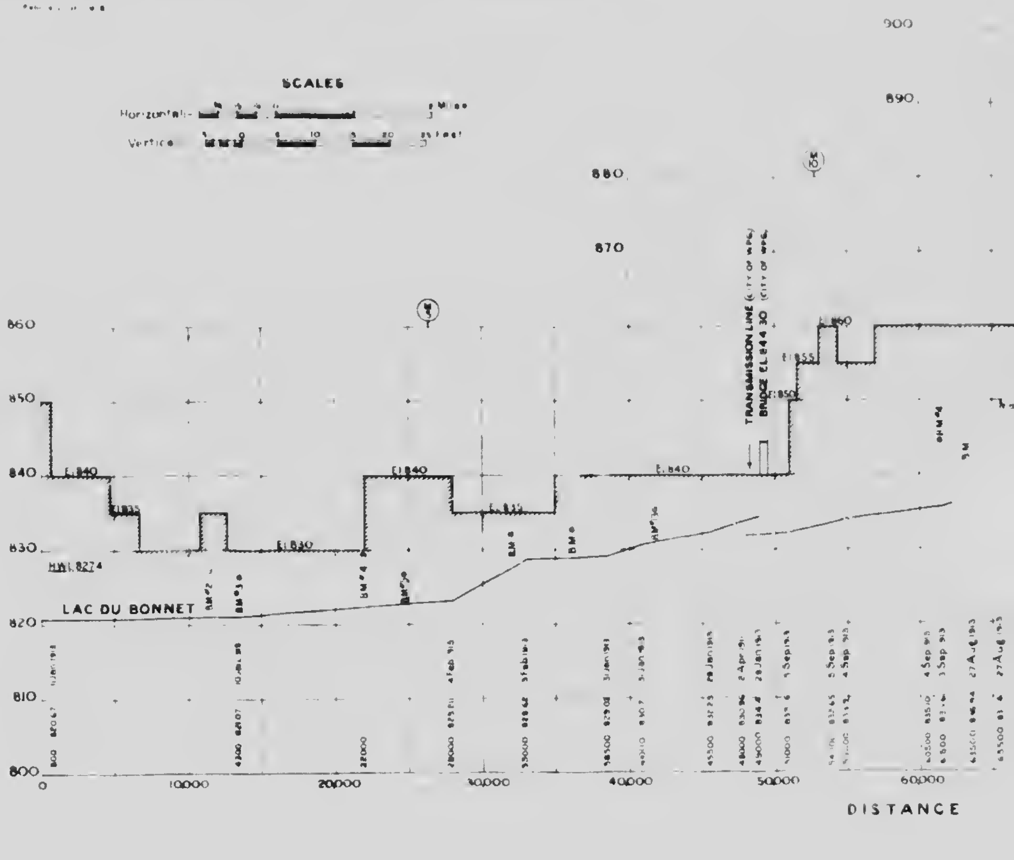
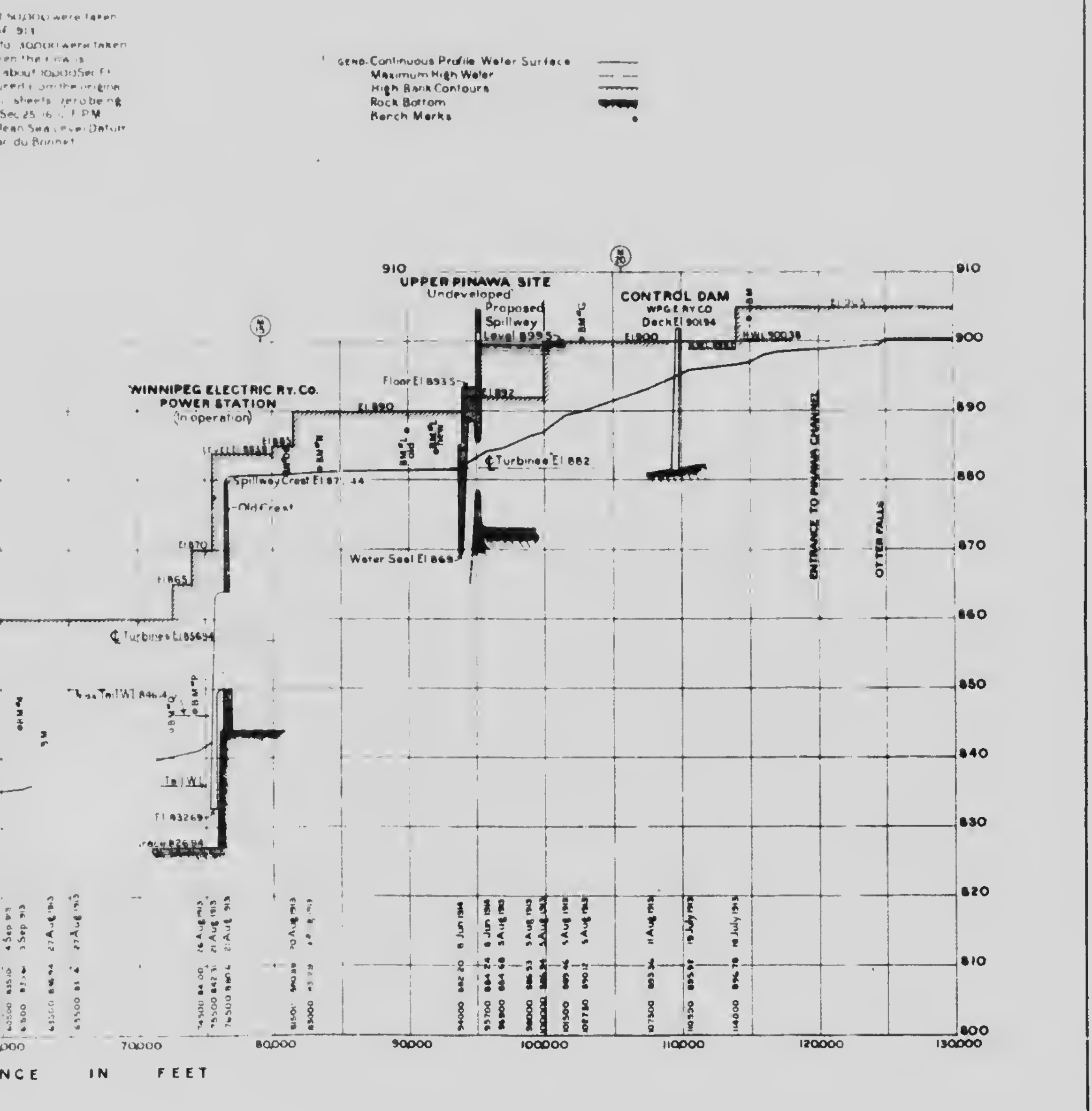


PLATE No. 7



Continuous Profile Water Surface
Maximum High Water
High Bank Contours
Rock Bottom
Bench Marks
UPPER PINAWA SITE
Undeveloped
Proposed Spillway Level 899.5
CONTROL DAM
WPG.E.RY.CO
Deck El 901.94
WINNIPEG ELECTRIC RY. Co.
POWER STATION
(In operation)
Floor El 893.5
El 890
El 900
Spillway Crest El 87 .44
Old Crest
Turbines El 882
Water Seal El 869
El 870
El 865
Turbines El 856.94
Tail W.L.
El 832.69
ENTRANCE TO PINAWA CHANNEL
OTTER FALLS
910
900
890
880
870
860
850
840
830
820
810
800
70000
80000
90000
100000
110000
120000
130000
...NCE IN FEET

established at the lake outlets in June of 1912, and a most complete series of measurements obtained. These have been co-related with pre-existing gauge records so as to secure a discharge record from 1907 to date.

Wherever possible, continuous records of the water level were secured at points where such information was of value to the power studies. The sparse settlement along the river banks made it difficult to secure gauge readers at all points desired, and this has, to a certain extent, delayed the gathering of certain data which are required to definitely calculate the working conditions in certain reaches. This deficiency is, however, being made good as rapidly as possible, and the information will be available long before it is urgently required in connection with plant operation.

A well-equipped evaporation station was established on the Lake of the Woods near the outlets, and valuable records of the meteorological conditions have been secured.

This summary of the field investigations should not be closed without due acknowledgment of the very efficient and hearty co-operation of the entire field staff of the Manitoba Hydrographic Survey who, under the direction of Mr. D. L. McLean as chief engineer during the early stages of the work, and of Mr. M. C. Hendry during the later stages, gave their services loyally and wholeheartedly to the sucess of the investigation. Special reference should be made to Mr. S. S. Scovil, assistant chief engineer throughout the greater portion of the investigation, and acting chief for a considerable period, under whose immediate supervision a large part of the field work, particularly in respect to the storage and run-off studies, was conducted. Mr. Scovil's energetic direction, aided by his personal knowledge of the entire district, due to his long residence therein, has been invaluable, not only to the success of the field survey but also to the compilation of this report.

Special mention should also be made of the services in the field of Messrs. E. B. Patterson, W. J. Ireland, S. C. O'Grady, and A. M. Beale; also of Mr. B. E. Norrish, chief draughtsman, in connection with the preparation in this office of the plates illustrating this report.

REPORT

ON

THE WINNIPEG RIVER POWER AND STORAGE INVESTIGATIONS

CHAPTER III.

METEOROLOGICAL PHENOMENA AND RUN-OFF

CHAPTER III.

METEORLOGICAL PHENOMENA AND RUN-OFF.

Temperature.

In a study of hydro-electric development possibilities, the question of temperature conditions must receive careful consideration, particularly in respect to the effect of the same on run-off and on plant operation. Throughout the Dominion of Canada, this phase of power investigation is exceptionally necessary, in view of the low temperatures to be counted on in certain localities during the winter months.

Plate 8 provides a convenient means for comparing the general temperature conditions obtaining in the Winnipeg River watershed, with temperature conditions in other parts of the country. On this plate are plotted the mean maximum monthly and the mean minimum monthly temperatures at Vancouver, Calgary, Winnipeg, Toronto, Montreal, Quebec, St. John, and Halifax. These cities are scattered from the Pacific to the Atlantic coasts, and provide representative points to which the Winnipeg temperatures can be readily compared. The Winnipeg records are sufficiently representative of the temperature conditions on the Winnipeg power reach (some 65 miles distant) for comparative purposes.

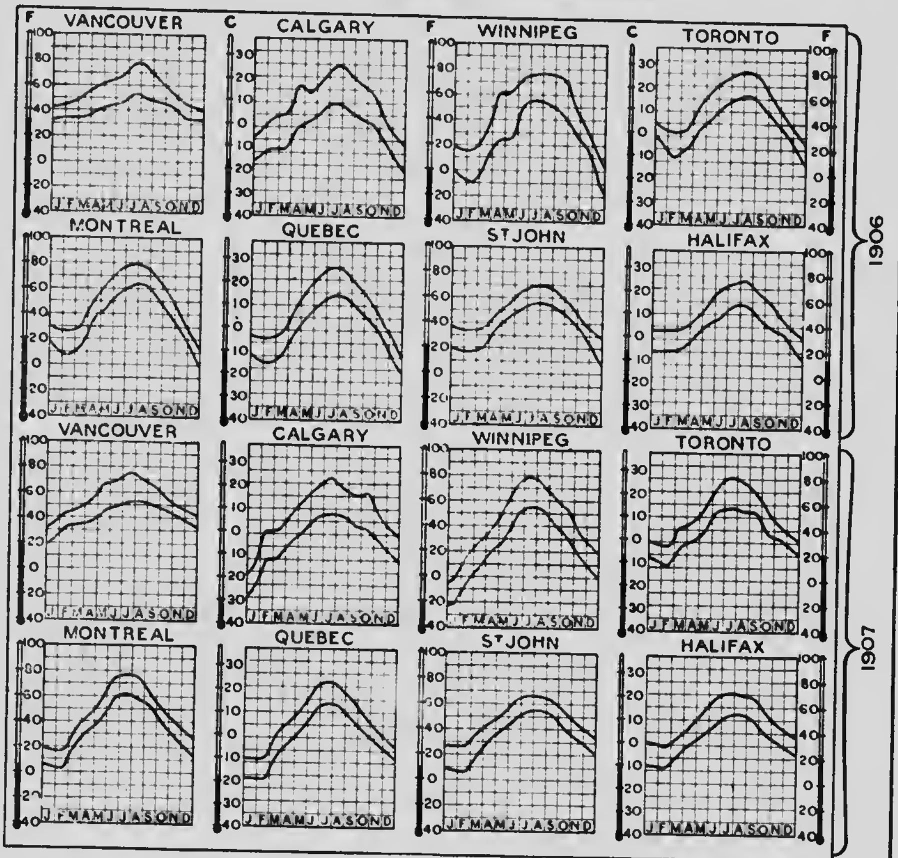
Temperatures for two years, 1906 and 1907, are shown, these two years representing, respectively, winters of the more severe and of the milder type in the West. It will be noted that Winnipeg and Calgary are subject to more extreme temperature conditions than are the other cities listed.

The Meteorological Service of Canada is obtaining temperature records throughout the Winnipeg watershed at Dryden, Ignace, Kenora, Rainy river Shoal lake, and Sioux lookout. Fifteen years' observations have been taken at Kenora, and one year at each of the other points. Forty years' records have been secured in Winnipeg. For convenient reference the daily temperature records at Winnipeg for the years 1912 and 1913, and the comparative monthly records at Winnipeg and Kenora for the years 1906 to 1914, inclusive, are attached as tables 48 and 49, respectively, in Appendix VI.

Reference to the tables indicates that the yearly temperature at Winnipeg averages a few degrees higher than at Kenora. The temperatures recorded on the Winnipeg River power reach should not vary to any great extent from the records at these two stations. Winter temperatures of 40 degrees below zero are to be expected in this region, while severe conditions may continue over considerable periods, as is instanced by the month of January, 1907, where the mean temperature for the month was 11·4 degrees below zero, and the average of the minimum daily readings was 21·6 degrees below zero.

PLATE No. 8

COMPARATIVE TEMPERATURE RECORDS



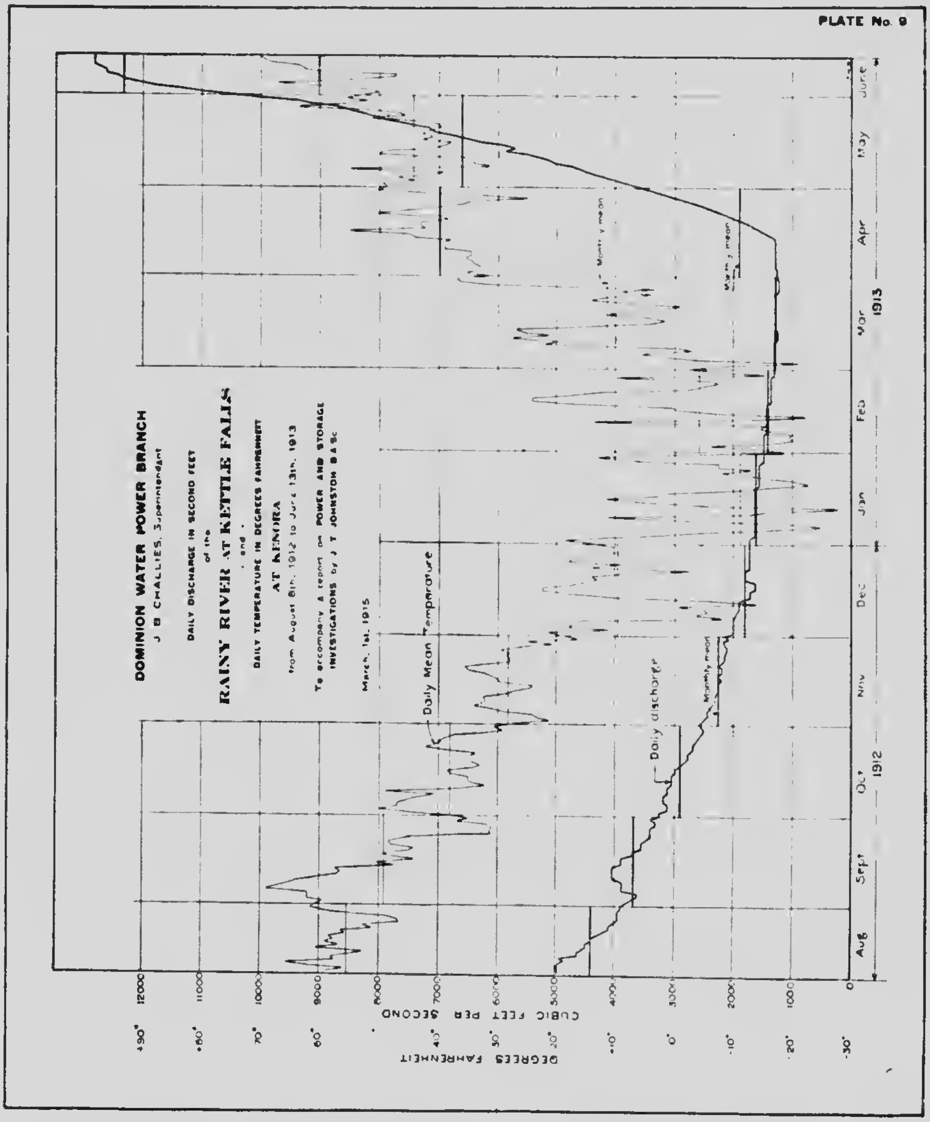
Relative temperature records at typical points throughout Canada.

Upper Curve:- Mean monthly maximum temperature.

Lower Curve:- Mean monthly minimum temperature.

INFLUENCE ON RUN-OFF.

The influence of temperature on the run-off of the Winnipeg during the winter season cannot be fully dealt with at the time of writing. The majority of the continuous discharge records available are more or less influenced by storage in the lake of the Woods and in Rainy lake, which, to a certain extent militates against securing records showing the direct relation between temperature range and river discharge. The installation of automatic gauges, ensuring continuous and accurate surface-level records at vital points, will probably remedy this, and render possible a determination of that direct influence which is so much in evidence in the prairie rivers. In comparison with these latter



rivers, the relation between temperature and run-off is largely modified on the Winnipeg, due to the character of the watershed and to the vast number of lakes with which it is supplied.

On plate 9 are plotted the discharge records at Chaudiere falls (Kettle falls) from August, 1912, to June, 1913. These records cover the run-off from an, at that time, unregulated portion of the basin. With them are plotted the mean daily temperature records at Kenora. It is evident, from a comparison of the curves, that there is no direct daily connection between the temperature and the run-off through the summer months. It is probable, however, that were automatic gauge and temperature records available for this period, a distinct relation would be noted during the winter season. It is apparent, that any such relation as may exist is not to any great extent detrimental to power plant operation on the main river, in so far as the run-off is influenced. The natural balancing reservoirs in the basin are of sufficient capacity and so well distributed as to modify immediate temperature influences.

Temperature has, however, its usual influence in this latitude, in that the periods of minimum flow are to be looked for during the winter season. Reference to the mean monthly temperatures and run-offs on plate 9 plainly shows this connection.

While the low winter temperatures have the effect of lowering the winter discharge, the excellent natural reservoir system provided by the innumerable lakes, effectually prevents the extreme low flows which are experienced in rivers in this region not provided with headwater lakes. The minimum low flow recorded to date is 11,700 cubic feet per second. While this is influenced by the artificial regulation in the Lake of the Woods and Rainy lake, the influence of the natural lakes is also very evident. The Whitemouth river, tributary to the Winnipeg just below the Seven Sisters falls, drains some 1,400 square miles of watershed, almost wholly deficient in lake area. The minimum flow recorded to date is 15 cubic feet per second. This is particularly illustrative both of the influence of the low winter temperature on the run-off, and also, by contrast, of the benefits which, under these conditions, accrue to a basin well supplied with natural reservoirs.

Apart from the influence of low temperature on the run-off is the question of ice troubles in plant operation. Where the winter run-off is as dependable as is that of the Winnipeg, this question becomes the more important of the two.

ICE CONDITIONS ON THE WINNIPEG RIVER.

In a country where the prevailing temperatures are as low during the winter season as in Canada, the most careful attention must be given to the proper protection of hydro-electric installations from ice troubles. This is particularly the case in the western provinces east of the Rocky mountains, throughout the section which is now being rapidly settled, and where hydro-electric development is being aggressively prosecuted.

The troubles, which have been experienced in the past in connection with the operation of power undertakings in northern latitudes, were for a long period considered a necessary evil and a prevailing condition beyond hope of permanent remedy, and only to be met by the yearly employment of local help in blasting and ice-cutting operations. The fact, however, that certain plants were comparatively free from ice troubles, while others were practically closed, under and following certain temperature conditions, proved an incentive to a closer study of the actual underlying causes and processes of ice formation. Many papers have been prepared and books compiled on this interesting subject, the most authoritative being probably that on "Ice Formation" by Prof. H. T. Barnes, Associate Professor of Physics, McGill University, Montreal.

Following this recent fuller appreciation of the underlying causes of ice troubles, the construction of hydro-electric undertakings, in climates where extreme winter conditions prevail, in such a manner that their successful operation throughout the cold season is assured, has largely become a matter of proper forethought and care in location, layout, and design. The successful and uninterrupted operation of the Point du Bois plant of the city of Winnipeg on the Winnipeg river, throughout the past three winter seasons, is sufficient assurance that no adverse ice troubles need be anticipated in connection with the development and operation of the projected sites on the river, providing proper foresight is displayed in their design and construction.

In this report it is not intended to give any detailed study to the origin of and protection against ice troubles in hydro-electric development. In view, however, of the conditions which must be encountered in power-plant construction and operation along the Winnipeg river, it is considered advisable that a general synopsis should be given of the troubles to be anticipated and of the measures which have been taken to eliminate the same.

It is intended to refer only briefly to the three varieties of ice which affect power plant construction and operation, i.e., sheet ice, frazil ice, and anchor ice, with particular attention to the conditions tending to and produced by their respective formation, and which are found and may be anticipated along the Winnipeg river. Reference to the preceding section dealing with the winter temperatures of the Winnipeg basin will disclose the extreme conditions which prevail and which must be combated.

Sheet Ice.—What is commonly known as sheet ice is the ordinary ice covering of ponds, quiet rivers, and protected waters of all descriptions. In its formation and continuance throughout the winter season it has no direct adverse influence on power-plant operation. On the contrary, a broad sheet of ice cover above a power station is directly beneficial to its successful operation, in that it forms a protective covering which prevents the local formation of frazil and anchor ice. The, at times, adverse influence of sheet ice in connection with hydro-electric development is of two natures; first, the pressure exerted on permanent structures; and, second, the combined effects of floods and ice jams during break-up in the spring.

Much has been written and many divergent views expressed regarding the nature and intensity of ice pressure as developed in the formation of sheet ice on lakes and reservoirs. Ice, after its format[illegible]s still subject to expansion and contraction accompanying a rise or fall i[illegible]nperature. The contraction due to lower temperatures results in cracks throughout the ice cover. These cracks at once fill with water from below which freezes and renews the continuous ice sheet. A rise in temperature causes the whole mass to expand with a resulting pressure which must find relief. The extreme limit of pressure would, of course, be found in the crushing strength of ice. Such a condition, however, need not usually be anticipated on a reservoir or pond surface. Relief may be found in several ways, according to the locality; sloping and shelving shore lines permit the ice sheet to slide or push its way beyond the limits of the water surface. The effects and, in fact, the actual operation of this action can be frequently observed along the borders of large ponds and lakes where long ridges of gravel, boulders, and masses of rock, frequently of surprising size, are formed by the ice push. Wide expanses of water surface, with abrupt shore lines preventing the above action, find relief from ice compression by the buckling or, at times, crushing of the ice sheet.

The general conditions which tend to endanger from ice thrust, permanent structures, such as dams, etc., are found in narrow waters, where the ice is confined between the structure on one side and an abruptly vertical shore line on the other. In such cases there is an undoubted and heavy thrust, acting horizontally against the face of the structure at water level. A heavy ice covering freezing solidly to the face of a dam, followed by a lowering of water in the reservoir also produces strains of magnitude and character dependent on local conditions. A rise in the water level in cold weather following the conditions produced by the above drop, undoubtedly results in a strong leverage thrusting against the dam.

Among other causes of ice pressure might be mentioned the action of winds on ice cover. Ice thrust and movement from this source is frequently very marked. Conditions seldom lend themselves, to the full concentration of such pressure on dams and permanent works; irregular shore line, islands, etc., usually mitigating the same.

An overflow dam, so long as it acts as such, does not experience the above adverse influences from ice cover, since, while there is sufficient overflow, the ice will not attach to the crest. Non-overflow dams, retaining walls, and embankments will, however, experience ice thrust under the climatic conditions of the Winnipeg river, where local measures of relief, whether natural or artificial, are not available or applied. Cutting the ice along the face of the dam is frequently resorted to in order to relieve pressure of this nature.

No hard and fast rule can be laid down fixing a definite ice thrust which must be anticipated and allowed for in the design of dams located in extreme climates. The Board of Experts commissioned in 1884 to design the proposed Quaker Bridge dam on the Croton river, in connection with the water supply of New York city, advised that an ice thrust of 43,000 pounds per lineal foot at the highest ice line should be provided for. This recommendation was not adopted in the actual construction of the dam, which was finally built at a site 3 miles farther up stream, under the name of the New Croton dam. The recommendation has, however, been frequently quoted in discussion on safeguarding against ice thrust. The Wachusett dam, built in Massachusetts in 1900 to 1906, was designed to withstand an ice pressure of 47,000 pounds per lineal foot at the highest ice line. Other ice thrusts which have been allowed in the design of dams actually built in recent years are: Croton Falls dam in the Croton watershed, 30,000 pounds; Cross River dam, also in the Croton watershed, 24,000 pounds; Olive Bridge dam, New York state, 47,000 pounds; Kensico dam, New York state, 47,000 pounds.

The above dams were all of the reservoir, non-overflow type, and the variation in ice pressure allowed was due to [illegible]ation in local conditions as affecting the use and operation of the reservoirs, and as resulting from the location.

The proposed dams along the Winnipeg river are of a combined free spillway and sluice control type. It is intended that the reaches shall be maintained by sluice control at regulated level throughout the year, and that the spillway shall come into use only as a safeguarding measure, in caring for sudden or extreme floods. Under these conditions, the ice cover will attach itself to the crest and face of the dam at pond level. A thickness of from 2 to 3 feet of ice may be counted on in the undisturbed reaches of the Winnipeg river, where the ice cover has not been protected by a snow covering. In general, the dams will not be subject to extreme adverse ice thrust conditions. No general rule can be laid down as establishing a uniform safety factor to be applied to the design of the structures. Local conditions, as affecting each site, can only be studied individually, and corresponding precautionary measures adopted. The general question of ice thrust must, however, be given careful consideration in the design of the proposed power stations, and contingent structures.[1]

The break-up of the sheet ice in the spring is frequently the cause of inconvenience and sometimes of disaster in power-plant operation. In a river where large blocks and masses of ice, together with other miscellaneous drift, are carried down stream in flood time, there is always a tendency towards the formation of ice jams, with a consequent backing up of water until the increasing pressure bursts the obstruction, and the whole mass is discharged down stream. Such conditions are the frequent cause of the destruction of bridges, dams, and other obstructions in the natural stream bed. Jams below a power station have the adverse affect of raising the tailwater and of possibly flooding out the plant.

The Winnipeg river does not, however, give rise to conditions favourable to the formation of ice jams. The river, as a whole, consists of large lake-like expanses, with deep water and practically no current, connected to each other by abrupt falls or short stretches of rapids. In the spring the ice on these reaches as a rule slowly melts and disappears. Where ice breaks away and discharges over the falls and rapids it is not generally in sufficient mass to form a jam. The slow rise of the spring flood also has a tendency to reduce the liability to ice-jam formation, and to assist in the quiet melting and disposal of the ice cover.

After the construction of the p[illegible]posed system of hydro-electric plants, the present excellent conditions in this respect will be greatly improved. Above each site there has been provided a large expanse of pondage, extending frequently many miles up stream. The finally completed system will transform the river into a series of ponds or lakes, with the falls and rapids totally flooded out. These pondages, both collectively and individually, will do away with any slight tendencies which may at present exist towards the formation of jams.

[1] An interesting discussion on the question of ice thrust in relation to the design of dams is to be found in the Transactions of the American Society of Civil Engineers, volume lxxv, 1912, wherein are submitted the opinions of several widely known engineers.

Frazil ice.—Frazil ice or, as it is sometimes called, slush ice has a much more direct bearing on water-power plant operation than has sheet ice. It is a surface-formed ice, its formation occurring in open channels where a too swiftly flowing current prevents the formation of an ice cover. While a smooth surface permits the formation of frazil ice in the form of thin plates, an agitated surface offers much more favourable conditions. This disturbance may be caused by wind action. It is always present to excess in rapids and falls. The ice itself under these conditions forms in fine needle-like crystals, which grow and accumulate with great rapidity when weather conditions are favourable.

The combination of long periods of intense cold with the disturbed water in the rapids and falls of the Winnipeg river, offers ideal conditions for frazil-ice formation. These conditions are, however, largely counterbalanced by the extensive ice-covered reaches.

Throughout the winter season, vast quantities of frazil are formed in the falls along the river, and are carried down stream and lodged beneath the ice sheets which are practically always found below. This condition was very evident in the soundings taken along the lower reach of the river by Mr. B. E. Norrish, an engineer of the department, during the winter of 1909-10, prior to the organization of the survey. Deposits of slush ice beneath the ice cover were found below all falls and disturbed stretches of open water. In places, these deposits were from 25 to 30 feet in depth, and there is every reason to suppose that greater depths were reached where conditions for formation and accumulation were favourable. The natural result of this condition was a blocking of the river channel, with a consequent rise in the water level above. This condition was particularly observed below the Little du Bonnet falls, where the accumulations of frazil ice resulted in a rise of several feet in the water level. This slow rise would continue until the rising head was sufficient to clear out the accumulations and to open an under-ice channel, and permit normal flow conditions to resume, after which the gradual choking up would again commence. Under-ice deposits of the above nature were met from a quarter to half a mile below the various falls.

That this frazil ice may prove extremely detrimental to satisfactory plant operation is illustrated in the Pinawa channel of the Winnipeg river, where, in certain reaches, a narrow and winding channel with rapid current prevents ice cover forming, and is particularly favourable to the production of frazil ice during periods of extreme cold. The deposition and accumulation of these frazil crystals on the under surface of the sheet ice in the quieter reaches at times assumes large proportions and frequently partially blocks the river channel, necessitating constant vigilance and frequent resort to blasting operations in order to clear both the approach to and the discharge from the power station. It might be repeated here, however, that the Pinawa channel differs in character from the main channel of the Winnipeg river.

Anchor ice.—Although the two terms, anchor ice and frazil ice, are frequently used indiscriminately, the two varieties are entirely distinctive in source, although in some respects they may, after formation, possess somewhat similar characteristics. Differing from frazil ice, which is surface formed, anchor ice has its origin and growth on the stream or river bed at depths seldom exceeding 30 or 40 feet. While turbulent water and low temperature always favours the formation of frazil crystals, irrespective of other conditions, a smooth water surface exposed to a clear sky, combined with low temperature, forms the ideal conditions for the formation of anchor ice. From Professor Barnes' comprehensive work on the subject, it is apparent that radiation is the prime cause of anchor-ice formation. A clear calm night, with little or no air currents, is particularly conducive to radiation, and on such nights the formation of anchor ice goes on rapidly. A cloudy night is never accompanied by anchor ice formation. A bridge cover will prevent the ice forming in the river bed beneath, whereas on the same night on the stream above and below, large masses accumulate. Sunshine and a clear sky counteracts radiation by day, and not only prevents new anchor ice forming, but loosens the masses previously formed, causing them to rise

Ice Conditions on Pinawa Channel.

to the surface, often carrying with them boulders of surprising size. In short, anything which is conducive to the radiation of heat from the river-bed to the colder air above will tend to the formation of anchor ice, while anything which interferes with or cuts off such radiation immediately stops or tends to stop its formation. Frazil ice, after depositing on submerged structures, or on masses of anchor ice, becomes for all practical purposes of the same nature as anchor ice, and it is this circumstance which leads to the common confusion of the terms. Anchor ice is, however, granular in structure, and readily distinguishable from frazil.

Effects of frazil and anchor ice on power plant operation.—Where conditions are favourable to the formation of frazil crystals, the question of power station operation must receive careful consideration. Frazil is a much greater menace to successful winter operation than is anchor ice. The crystals attach themselves most readily to heat-conducting structures. Among the most vulnerable parts of a station in this regard are the racks. Here the metal, more especially where it projects above the water surface into the cold outside air, forms a ready surface for the accumulation of ice crystals, with a consequent partial or complete closing off of the water from the turbines. This is, at times, accompanied by the collapse of the racks, due to the pressure of the headwater. The gates are also objects of attack, as are also the wheels themselves. The accumulation of ice masses in the wheel pit has frequently been the cause of the complete blocking of the turbines, and the consequent closing down of the plant.

Various remedies have been applied to combat conditions of the above nature. These remedies have, as their basis, the application of heat to the parts affected, i.e., to the racks, gates, and turbines. The success which has fol-

Ice Conditions below Du Bonnet Falls.

lowed such experiments is founded on the fact that the raising of the temperature of the racks and parts affected by even one-thousandth of a degree, will prevent the initial attaching of the ice crystals, and their consequent accumulation.

In the layout of new plants in localities where the winter conditions are such that frazil and anchor ice are to be anticipated, forethought in the design will largely mitigate, and frequently entirely prevent, ice troubles. In the layouts of the proposed plants along the Winnipeg river, care has been taken to provide conditions in all respects unfavourable to the formation of either frazil or anchor ice. The extensive ponds provided will form an ice sheet sufficiently extensive to not only prevent the formation of the ice in question, but also to arrest and accumulate on its under surface any frazil which may be formed in undeveloped rapids or falls above. In general, the wheels draw water direct and undisturbed from the pond without an intervening head-race, and where such has been necessary, easy curves and ample sections have been provided in order that a quiet and undisturbed current may reach the racks. The ice cover of the pond will in all cases reach to the protecting curtain along the face of the racks.

Under these conditions, no ice troubles need be anticipated. This is abundantly proved by the successful winter operation of the municipal plant of the city of Winnipeg at Point du Bois on the same river. No ice troubles of any description have been experienced here during the three winters in which the plant has been in operation.[1]

PRECIPITATION.

A study of the rainfall records of any watershed is at all times interesting, more particularly in regard to the relation between the precipitation and the run-off. Where actual discharge records are not available, precipitation records will often afford a basis upon which run-off may be deduced. Such calculations must, however, be approached with caution. While the relation between the precipitation and run-off is direct, the deduction of its exact ratio necessitates much more accurate and more comprehensive data than are generally available. Stream run-off is influenced by so many complex conditions apart from precipitation such as: nature of soil, slope of surface, area and configuration of catchment basin, geologic structure of basin, forests, winds, evaporation, etc., that an arbitrary deduction as to the run-off, based on some general and average ratio already established in more or less similar basins, is liable to result in considerable error. This is particularly the case in endeavouring to establish, from precipitation records alone, the extent and duration of minimum flow in connection with hydro-electric power studies.

In view of the numerous conflicting conditions which influence the run-off from any particular watershed, it may be assumed that until the ratio between the precipitation and run-off has been definitely established by careful and prolonged observation, backed by actual records and comprehensive data, any deductions which may be made as to the relation existing must be considered as more or less approximate. It is recognized that, in this relation, every stream is a law unto itself.

In the Winnipeg River basin there are sufficient continuous run-off records available to permit of a fairly satisfactory study of the discharge conditions, and dependence on the precipitation records is not therefore necessary.

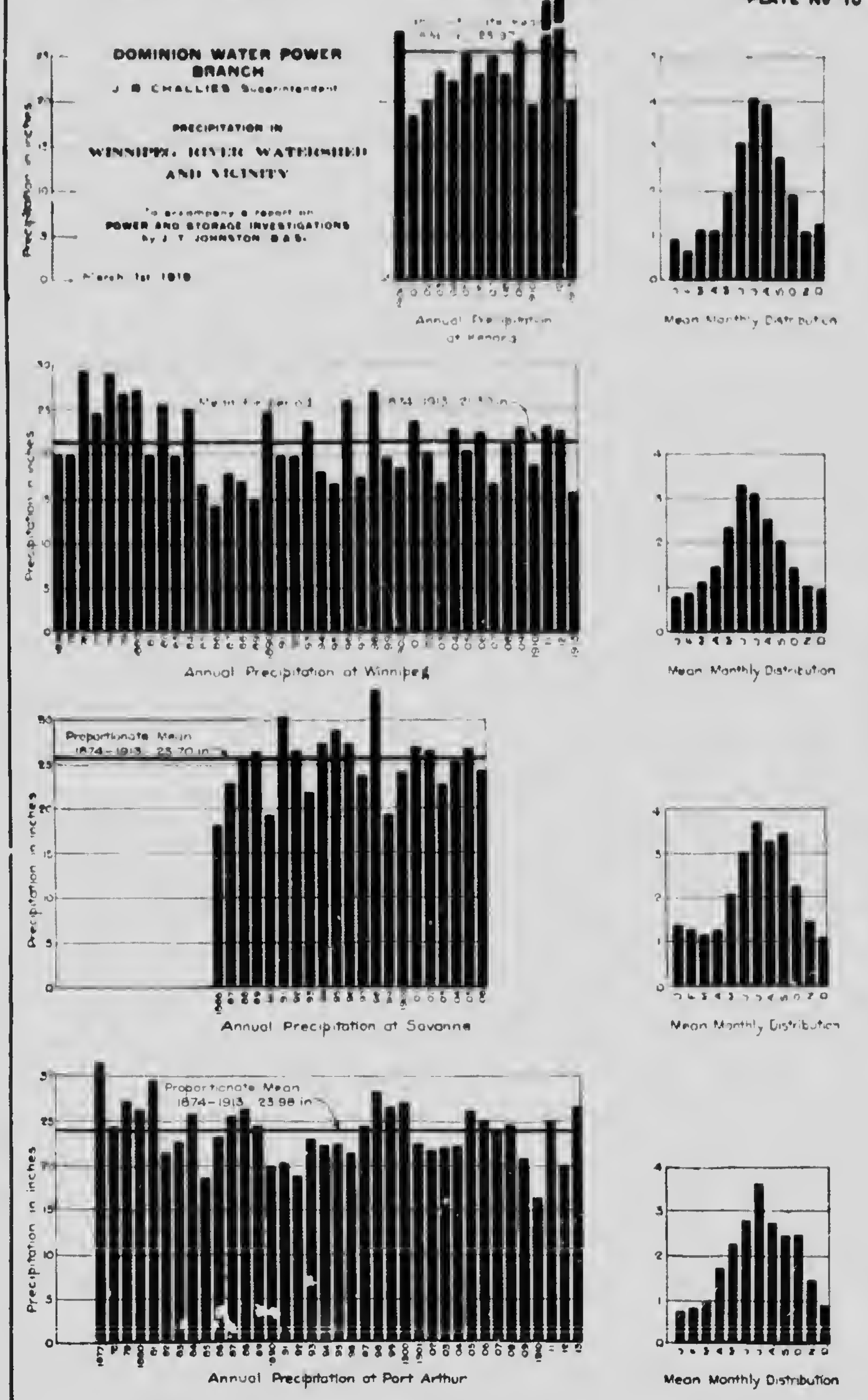
RECORDS AVAILABLE.

Within the Winnipeg River watershed, precipitation records have been secured by the Meteorological Service of Canada at Dryden, Fort Frances, Ignace, Kenora, Sioux Lookout, and Savanne. Of the above stations, two only, i.e., Kenora and Savanne, extend over a series of years. Kenora, located at the outlet of the Lake of the Woods, furnishes records from 1900 to date, and Savanne, located near the eastern limit of the watershed, from 1886 to 1906. These records are neither of sufficient extent nor sufficiently widespread to permit a study of precipitation and run-off phenomena.

More prolonged series of precipitation records are available at points a short distance outside the limits of the basin. At Winnipeg, records have

[1] For a full and complete study of the question of ice formation, the reader is referred to the book of "Ice Formation" by Howard T. Barnes, M.A.Sc., Associate Professor of Physics, McGill University, Montreal.

PLATE No 10



DOMINION WATER POWER BRANCH
J. B. CHALLIES Superintendent
PRECIPITATION IN
WINNIPEG RIVER WATERSHED AND VICINITY
To accompany a report on
POWER AND STORAGE INVESTIGATIONS
by J. T. JOHNSTON B.A.Sc.
Precipitation in inches
Annual Precipitation at Kenora
Mean Monthly Distribution
Annual Precipitation at Winnipeg
Mean Monthly Distribution
Proportionate Mean
1874 – 1913 23.70 in.
Annual Precipitation at Savanne
Mean Monthly Distribution
Proportionate Mean
1874 – 1913 23.98 in.
Annual Precipitation at Port Arthur
Mean Monthly Distribution

been secured since 1874. At Port Arthur, on lake Superior, records are available since 1877. For convenient reference, these records, together with the ... Kenora and Savanne, are represented on plate 10, and are tabulated in table 59, Appendix VI.

It is not intended in this report to attempt any analysis of the ratio existing between precipitation and run-off in the Winnipeg River basin. The precipitation data available are not sufficient to permit of other than the most general deductions being drawn, while the run-off data on hand have been largely influenced by artificial conditions of storage. The above records are, however, published as of general interest to the subject-matter covered in this report.

EVAPORATION.

Evaporation usually, but not always, forms the greatest source of loss to the run-off from any watershed. The rate of evaporation differs widely in

Evaporation Station on the Lake of the Woods.

different climates, and varies also with different classes of vegetation and with different classes of land surface. It is practically impossible to secure an accurate estimate of what precipitation loss is due to evaporation over a drainage basin as a whole, owing to the other losses by percolation and seepage. It is possible to secure a reasonably close estimate of the loss due to evaporation from open-water surfaces. This is particularly pertinent to the Winnipeg River watershed, where so large a proportion of the basin is lake area.

In order to secure definite data as to the rate of evaporation from water-surface area in the Winnipeg River watershed, an evaporation station was established on the Lake of the Woods in the vicinity of the town of Keewatin. This station is centrally located in the western portion of the Winnipeg basin, and in view of the lake being by far the largest and most important of the regulating reservoirs, it furnishes data which are of particular interest to the general storage question.

EVAPORATION STATION.

The evaporation station was established on May 1, 1913, the equipment consisting of one galvanized evaporation tank, with brass pointer and measuring cups; one Howard rain gauge; one thermometer for water temperatures; one recording thermometer; one recording barometer; one wind gauge of the Robertson type; and one hydrometer. This equipment is fitted to record all atmospheric phenomena which will affect the extent of evaporation, as well as to measure its actual rate.

The tank is of galvanized iron and is 35 inches by 31 inches by 18 inches deep, braced externally by diagonals of 1 inch by 1 inch galvanized angle iron riveted to the tank. The sides are turned over at the top to form a 3-inch lip in order to prevent the inflow of wave wash. In the centre of the tank, and soldered to the bottom, is a brass pointer 14 inches in height. The tank is supported on a raft consisting of four 4-inch by 4-inch by 16-foot timbers spiked together at the corners. The supports in the centre of this raft are 2-inch by 10-inch timbers placed parallel on either side of the tank, and capped by 2-inch by 4-inch timbers to catch its edge. The raft is fastened to the shore, but is free to move with the waves. The rain gauge is supported by a 2-inch by 10-inch plank spiked to the raft. Plate 11 illustrates the installation.

The recording thermometer and barometer are placed in a suitable shelter, close at hand. The wind gauge has been placed on the top of the Lake of the Woods Milling Company's Mill C, about one-half mile from the raft.

RECORDS AVAILABLE.

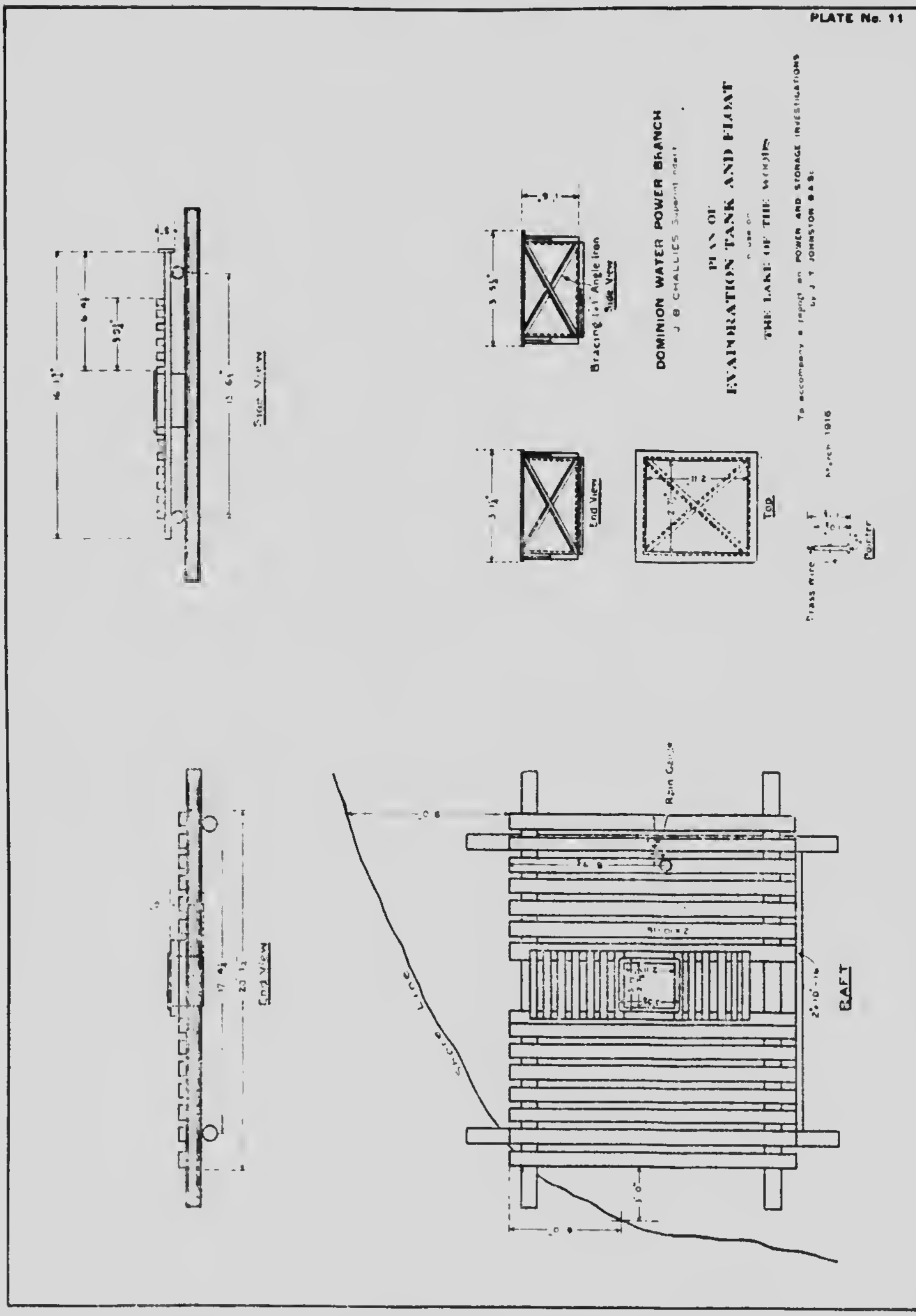
Continuous records of evaporation and of all pertinent meteorological data have been secured since the establishment of the station in May, 1913. The evaporation observations were, of course, discontinued through the winter season. The complete records available are attached in Appendix VI in table 51.

The comparative evaporation and rainfall in inches for the months May to November, 1913, and April to November, 1914, is appended in table 2.

Table 2.—Comparative rainfall and evaporation on the Lake of the Woods.

Month.	1913.		1914.	
	Rainfall in inches.	Evaporation in inches.	Rainfall in inches.	Evaporation in inches.
April	[1]	[1]	1·79	[3]0·51
May	1·29	1·36	1·87	0·62
June	2·09	2·25	4·67	2·46
July	3·84	3·39	3·80	2·78
August	4·58	3·42	2·07	3·67
September	1·01	4·08	4·07	3·01
October	3·34	2·15	3·11	2·66
November	1·35	[2]0·53	0·31	[4]1·04
Total	17·50	17·18	21·69	16·75

[1] No records secured in April, 1913.
[2] Ice formed on November 7, and evaporation records discontinued.
[3] Evaporation records commenced April 20.
[4] Evaporation records discontinued November 14.



It will be noted that during the seven months listed in 1913 the evaporation loss of 17·18 inches practically equalled the 17·5-inch rainfall. In the eight months listed in 1914, the rainfall exceeded the evaporation by 4·94 inches. The records do not as yet cover a sufficient period to permit of an analysis of the general evaporation phenomena. From the above, it is, however, apparent that evaporation loss from surface water during the open-water season is a very high percentage of the rainfall, and there is little doubt but that in certain seasons it is in excess of the same. An evaporation loss of 17 inches over the surface area of the Lake of the Woods is equivalent to a continuous discharge of 10,000 cubic feet per second for two and one-quarter months. Considering the extent of the lake area in the watershed, the evaporation losses are therefore high.

The high ratio of evaporation from water-surface area does not of course apply to the basin as a whole. The lack of widespread precipitation data with which to compare the run-off from the basin, prevents the setting out herein of any definite general ratio between the two. The precipitation at Kenora for the years beginning October, 1912, and October, 1913, respectively, was 18·96 inches and 25·01 inches. The run-off for the two calendar years of 1913 and 1914 was equivalent to 6·12, and 6·46 inches over the drainage basin. The balance was mainly lost through evaporation and percolation, the larger part undoubtedly being due to evaporation.

RUN-OFF.

Run-off in general is dependent on a variety of conditions of which the controlling features are: precipitation, topography, vegetation, and climate. These features have a paramount bearing on the seasons and limits of maximum and minimum discharge. The seasons of, and the ratio between, high and low water, and the facilities for partially or wholly equalizing the run-off in extreme cases, are phases of preliminary investigation which must receive thorough study and consideration in all water-power investigations. Accordingly, one of the earliest steps taken at the inception of the power and storage investigations in the Winnipeg basin was to secure and collate all existing records of temperature, rainfall, run-off, and water levels, etc., throughout the watershed, while an aggressive campaign was started to augment these by further first-hand records, secured by departmental field officers.

The Manitoba Hydrographic Survey was established in 1912 as a sub-organization of the Dominion Water Power Branch, and as a logical outgrowth of the Winnipeg River power survey work. An aggressive campaign of stream measurement work along the river and throughout the province was at once commenced. During the earlier stages, the power and stream measurement organizations were closely intermingled, and the respective staffs transferred from one survey to the other as the exigencies of the work demanded. As time passed, it was possible to organize a more permanent staff and to place the stream measurement work on a more satisfactory basis. The two surveys have at all times been carried on under the direction of one chief engineer.

The run-off records from the commencement of 1907, which are now available, indicate the exceptionally well-regulated character of the river basin. Under present conditions the highest flood flow in a normal year seldom exceeds four times the minimum, a condition which is vastly different from the rivers of the prairie farther west. Typical of the latter might be mentioned the North

Saskatchewan at Edmonton, where the maximum flow has at times exceeded 180 times the minimum. This favourable feature of the Winnipeg renders it peculiarly adapted to hydro-electric development, and is due to the extensive lake areas with which the larger portion of the watershed is supplied. These lakes form equalizing reservoirs, collecting the surplus waters in times of flood, and gradually discharging the same during the low-water season. Owing to these favourable conditions, the Winnipeg is not subject to sudden or extreme floods, and the question of regulating the various pond levels at the proposed plants presents no difficulties.

Table 3, herewith, illustrates concisely the highly uniform character of the river flow.

Table 3.—Percentage of variation of the flow of the Winnipeg river at Slave falls from the mean flow of the seven-year cycle.

Month.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	Mean.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
January	+ 4·27	+42·63	− 4·17	− 2·30	−42·67	−22·35	+ 8·28	− 2·33
February	−11·47	+41·73	− 6·48	− 6·09	−48·63	−34·87	+ 1·12	− 9·24
March	−33·00	+21·37	−27·20	− 7·84	−51·53	−46·55	−26·14	−24·41
April	−43·55	+10·23	−35·41	+54·33	−52·10	−47·53	−30·98	−20·71
May	−37·00	+26·10	−21·48	+104·30	−42·88	−11·81	+ 9·73	+ 3·85
June	+ 8·42	+61·05	− 5·01	+88·37	−29·06	+ 8·68	+26·60	+22·72
July	+23·85	+66·23	− 4·66	+42·92	−11·43	+ 2·03	+14·11	+19·01
August	+21·21	+53·02	− 5·12	− 4·47	+ 1·06	+ 7·18	+ 7·12	+11·43
September	+43·66	+38·87	−13·79	−24·09	− 4·04	+13·75	− 2·29	+ 7·44
October	+64·47	+27·80	−21·37	−34·24	+ 0·41	+27·91	−29·32	+ 5·09
November	+65·07	+ 9·85	−20·83	−44·78	−11·24	+26·15	−39·42	− 2·17
December	+52·80	− 9·73	−12·86	−50·03	−25·24	+13·71	−43·07	−10·63
Year Mean	+13·23	+32·43	−14·86	+ 9·67	−26·45	− 5·31	− 8·69	

This table is based upon discharges recorded at the Otter and Slave Falls metering stations for the years 1907 to 1913, inclusive, and shows the percentage of variation of the mean monthly discharges from the seven-year mean flow. The largest monthly variation was that for May in the year 1910, when a discharge 104·3 per cent above the average occurred. On the other hand, 52·1 per cent below the average occurring in April, 1911, forms the lowest monthly mean on record. The mean yearly flows show a variation of 32·43 per cent above for 1908, and 26·45 per cent below for 1911.

It is well to note here that the controlled regulation in the Lake of the Woods and Rainy lake has had considerable beneficial effect in equalizing the discharge of the river below Kenora, although such control to date has largely lacked that effectiveness which a careful investigation of the entire run-off conditions would render possible, and which it is hoped will be reached in the future.

AVAILABLE RECORDS IN BASIN.

Slave Falls Metering Station.

During the reconnaissance trip down the Winnipeg river from Kenora to the mouth, taken by the departmental and consulting engineers prior to the commencement of the detailed power survey work, one of the principal points kept in view was the selection of a metering station suitable for recording the complete run-off from the basin. Any station located along the main river in Manitoba would be satisfactory for this purpose. The site fixed upon as offering the most favourable conditions for metering is located just above Slave falls, about 6 miles below Point du Bois. The river at this point is sufficiently narrow, and the banks, which are of solid granite, sufficiently high to permit the establishment of a cable station. Below this point there is a drainage area of 3,860 square miles, of which the Whitemouth and Bird rivers drain the major portion. Records of the former are available from May 29, 1912, and are published herein. For the purpose of study in this report, the Whitemouth records are omitted from consideration, and the Otter-Slave Falls records are taken as representing the discharge available along the power reach for the entire hydro-electric scheme. Such an assumption simplifies the discussion and does not materially differ from the actual conditions.

At the time of the reconnaissance trip, metering stations had already been established along this reach, both by Messrs. Pratt and Ross, engineers of the Winnipeg Electric Railway Company, and by the engineers of the city of Winnipeg in connection with the municipal power undertaking. The company's engineers made their measurements at Otter falls, located about 1½ miles above the present diversion weirs. No cable station was established, the readings being secured by boat during the open season, and from ice cover throughout the winter. Measurements were taken at intervals throughout the years 1907 to 1911, inclusive, the gauge heights afterwards being referred to the lower gauge at Point du Bois. The city metering station was located about 10 miles below Point du Bois, several measurements being secured here during the winters of 1910, and 1911.

On the readings secured from these two stations, referred to the Point du Bois gauge, are based the records of the river in Manitoba, up to the date of the regular metering instituted by the Dominion Water Power Branch.

In October, 1911, the cable station at Slave falls was established by the field officers of the power survey. Continuous meterings have since been secured at this station, some 115 measurements being made to the end of 1914. As the river-bed at the station is of permanent rock formation, the gauge readings alone will, once a completely defined rating curve is determined, furnish continuous discharge records. The development of the Slave Falls site will necessitate the establishment of a new station.

The station is under the same disadvantage as were the two established by the city and the company, in that, due to the unsettled nature of the country, no gauge reader is available on the ground. The records have been referred to the city gauge a Point du Bois. This gauge is located in a bay just below the power station, readings having been taken since January 23, 1907, thus rendering available a run-off record from that date onward. The level recorded by the gauge is controlled by the Eight Foot falls, this being the only break between the gauge and the metering station. Until the winter of 1910-11 the Eight Foot falls discharged under natural conditions. During this season an endeavour was made on the part of the municipal engineers to provide for a better regulation of the tailwater level of the city plant during high-water conditions. To this end, a cut was made through the rock ridge over which the Eight Foot falls occurs. This cut is 120 feet in width and 180 feet in length, with the bottom elevation at 927.1 (Water Power Survey datum) at the upper end, and with a 2 per cent grade. The cut was made on the right river bank immediately adjacent to the channel. A second cut is also contemplated, but

Cable Station at Slave Falls.

as yet no active steps have been taken in this connection. Due to the cutting of this channel, the discharge curve for Otter falls cannot be used later than June, 1911.

The readings of the gauge have, to a certain extent, been influenced by the daily fluctuation of the power-station loads. The pond above is 6,500 acres in area, forming an ample basin for local storage. Sudden increase in the load involves a draw on the pondage, with a consequent higher record on the gauge than the actual river discharge would register. Similarly, lightening the load involves storage in the pond and lower gauge readings below until equilibrium is restored by the automatic discharge over the free spillways. There is also a slight back-water effect during prolonged periods of very extreme cold, due to ice formation at Eight Foot falls. This is not a frequent occurrence.

While the tailwater gauge readings have been influenced by these conditions since the plant was placed in operation in October, 1911, the errors have largely balanced, and the records secured closely represent actual conditions from month to month. As the turbine installation is increased, the fluctuations, with their adverse influence, will become more marked. An automatic gauge is now being installed at Slave falls to eliminate errors arising from this fluctuation.

Slave Falls Discharge Records.—The complete records of the run-off at Otter and Slave falls are to be found in Appendix VII, tables 52, 53, and 54, and in graphical form in plate 12. For convenience of reference the mean monthly flows are published herewith in table 4.

Table 4.—Mean Monthly Discharge of the Winnipeg River at Otter Falls, 1907-10, and at Slave Falls, 1911-14.

[Drainage area above Otter Falls, 50,550 square miles; above Slave Falls, 49,700 square miles.]

Month.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	Mean.
	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.
January	26,960	36,880	24,770	25,260	14,820	20,080	27,996	13,703	23,809
February	22,880	36,650	24,180	24,280	13,280	16,840	26,145	13,253	22,189
March	17,320	31,380	18,8[illegible]	23,830	12,540	13,820	19,095	13,845	18,831
April	14,590	28,500	16,700	39,900	12,390	13,570	17,847	14,589	19,761
May	16,290	32,600	20,300	52,820	14,770	22,800	28,370	18,745	25,837
June	28,030	41,670	24,560	48,690	18,340	28,100	32,733	31,480	31,700
July	32,020	42,980	24,650	36,950	22,900	26,380	29,503	34,735	31,265
August	31,340	39,560	24,530	24,700	26,130	27,710	27,695	31,550	29,152
September	37,140	35,900	22,290	19,630	24,810	29,410	25,263	26,170	27,577
October	42,520	33,040	20,330	17,000	25,960	33,070	18,276	24,805	26,875
November	42,680	28,400	20,470	14,280	22,950	32,610	15,662	21,230	24,785
December	39,500	23,340	22,530	12,920	19,330	29,400	14,722	19,840	22,698
The Year	29,272	34,242	22,011	28,355	19,018	24,483	23,609	21,995	25,373
Maximum	43,980	43,980	28,480	53,440	27,220	34,780	32,733	35,460	53,440
Minimum	14,400	21,660	16,100	12,400	11,700	12,300	14,722	11,700	11,700

NOTE.—The monthly mean for January, 1908, is the mean of the last nine days of the month only. The maximum and minimum discharges refer to daily flow.

Reference to the table indicates the uniform character of the discharges during the eight-year cycle.

A discharge of 25,373 second-feet represents the average flow for the eight-year period. The year 1908 with a mean of 34,242 second-feet, and 1911 with a mean of 19,018 second-feet are, respectively, the years of maximum and minimum flow. The highest monthly mean recorded is 52,820 second-feet in May, 1910, and the lowest, 12,390 second-feet in April, 1911. Slightly more extreme daily flows have occurred, as 53,440 second-feet on May 7, 1910, and 11,700 on several dates in 1911. This low discharge only held for a day at a time, and for all practical purposes, 12,000 second-feet may be taken as the dependable low discharge throughout the period. Undoubtedly had the

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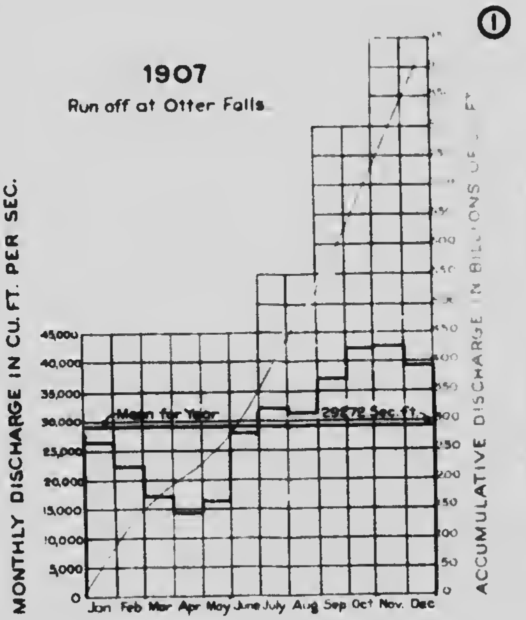
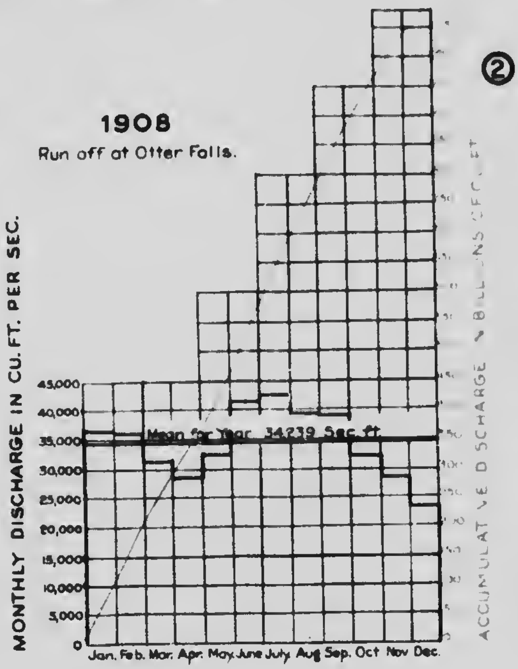
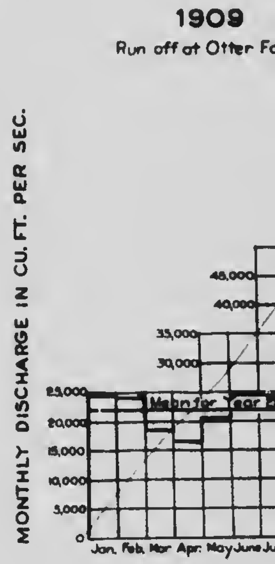
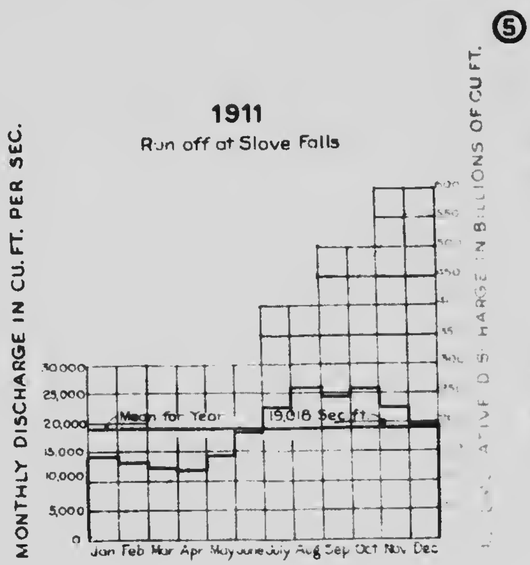
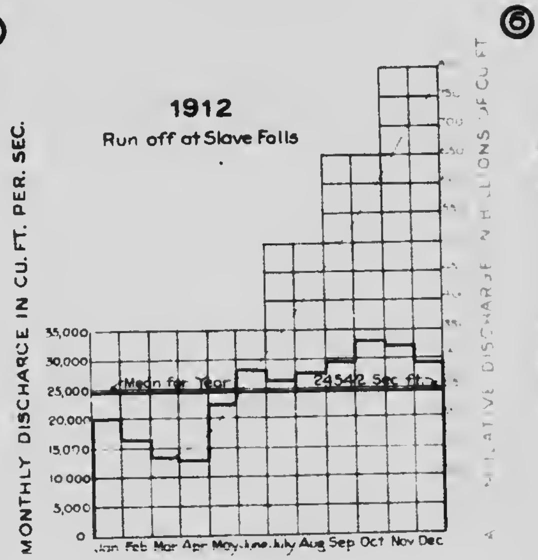

①
1907
Run off at Otter Falls
MONTHLY DISCHARGE IN CU. FT. PER SEC.
ACCUMULATIVE DISCHARGE IN BILLIONS OF CU. FT.
Mean for Year 29872 Sec. ft.
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Jan Feb Mar Apr May June July Aug Sep Oct Nov. Dec


②
1908
Run off at Otter Falls.
MONTHLY DISCHARGE IN CU. FT. PER SEC.
Mean for Year 34239 Sec. ft.
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Jan. Feb. Mar. Apr. May. June July Aug Sep. Oct Nov Dec.


1909
Run off at Otter Fa
MONTHLY DISCHARGE IN CU. FT. PER SEC.
Mean for Year
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Jan. Feb. Mar Apr. May June


⑤
1911
Run off at Slave Falls
MONTHLY DISCHARGE IN CU. FT. PER SEC.
Mean for Year 19,018 Sec. ft.
30,000
25,000
20,000
15,000
10,000
5,000
0
Jan Feb Mar Apr May June July Aug Sep Oct Nov Dec


⑥
1912
Run off at Slave Falls
MONTHLY DISCHARGE IN CU. FT. PER. SEC.
Mean for Year 24542 Sec. ft.
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Jan Feb Mar Apr May June July Aug Sep Oct Nov Dec

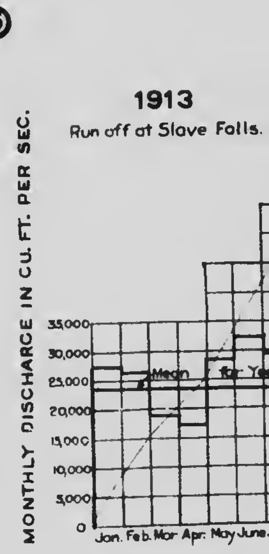
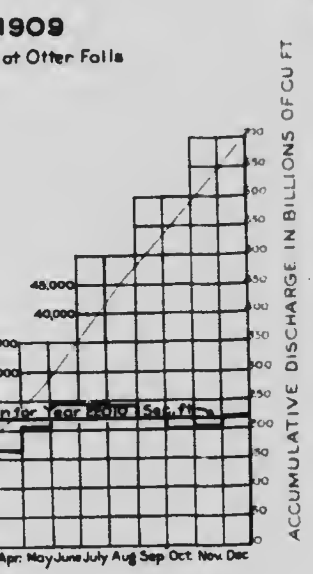
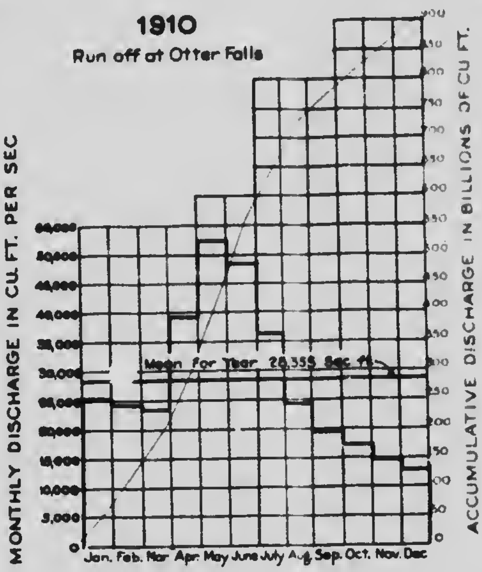

1913
Run off at Slave Falls.
MONTHLY DISCHARGE IN CU. FT. PER SEC.
Mean for Ye
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Jan. Feb. Mar Apr. May June

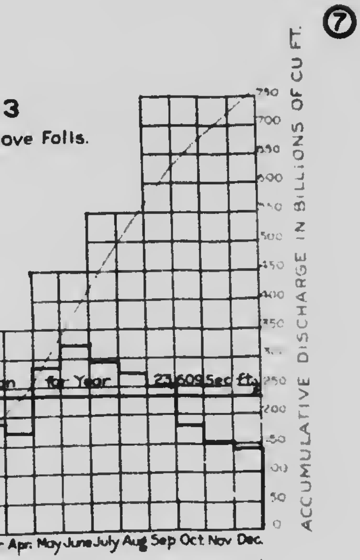
PLATE No. 12





— Note —

For the Years 1907 to 1910 inclusive the records in which the Curves are plotted were secured by utilizing the Gauge heights recorded at the Municipal Power Plant at Point du Bois, together with the discharge measurements taken by Pratt & Ross at Otter Falls. Corresponding drainage area. 30,550 Sq. Miles. For the Years 1911 to 1913 inclusive the Point du Bois gauge heights were combined with the discharge measurements taken by the Engineers of the Water Power Branch at Slave Falls Corresponding drainage area 48,700 Sq. Miles.-



For Uniform Flow in Sec. ft. of.	Necessary Storage in Billions of Cubic Feet.						
	1907	1908	1909	1910	1911	1912	1913
14,000	0	0	0	2.63	10.76	0.71	0
16,000	3.69	0	0	12.46	30.68	10.76	4.23
18,000	15.18	0	3.40	25.54	56.64	22.97	15.09
20,000	30.67	0	11.72	42.20	86.76	36.66	37.67
22,000	46.56	0	35.06	63.12	123.37	58.35	63.62
24,000	65.16	1.73	69.36	84.49	164.06	79.27	89.97
26,000	86.10	6.86	123.30	120.49	213.64	107.79	118.05

WATER POWER BRANCH

J. B. Challies, Superintendent.

WINNIPEG RIVER

MASS CURVES OF MEAN MONTHLY DISCHARGE & VOLUME OF RUN-OFF

- - - at - - -

SLAVE FALLS

To accompany report on POWER & STORAGE INVESTIGATIONS

by J. T. JOHNSTON, B. A. Sc.

influence of the Lake of the Woods regulation been removed, the high and low limits would have been much more extreme than has been the case.

High-water marks along the banks would indicate a much more serious flood than has taken place during the cycle under discussion, and 100,000 second-feet would more nearly represent the flood discharge which has taken place in the past. This figure, from a careful study of all evidence to hand, is considered the outside limit of flood to be expected under natural conditions in the basin.

Pinawa Channel Discharge.

Prior to the construction of the Winnipeg Electric Railway Company's power station, the discharge down the Pinawa channel was only a small

Metering Station on Pinawa Channel.

proportion of the river flow. However, the construction of the company's diversion weirs across the main river channel resulted in a very material change in these conditions, and at the present time a fairly uniform flow is maintained in the channel at all seasons. During periods of low river-run-off, this flow forms a high percentage of the total river discharge.

The discharge down the channel is dependent on the water level above the weirs, which level, owing to the fact that the weirs act as free spillways, is in turn directly dependent on the stage in the river. A control dam near the head of the channel permits the cutting off of the entire Pinawa flow if necessary.

Meterings were taken below the control dam by the engineers of the company during the years 1907 to 1911, inclusive, and by the field officers of the Manitoba Hydrographic Survey during the years following. These measurements have been referred to a gauge located immediately below the control dam, records of which, with the exception of the year 1913, are available since early in 1908. Due to the abnormal conditions arising from ice formation, the open-water discharge curve is not applicable during the winter season.

The available records are to be found in tables 55, 56, and 57 in Appendix VII. For the open seasons tabulated the discharge has varied from 4,100 to 11,225 cubic feet per second.

The entire flow is not, as a rule, fully utilized at the plant, there being an almost continuous wastage over the spillway dam. Throughout this report, a flow of 8,000 cubic feet per second has been assumed necessary to properly operate the power station, which figure is based upon a careful rating of the station by the field officers of this branch. It is considered ample to meet the station requirements.

Lake of the Woods Outlets.

Equally important as the run-off of the power reach of the river is an accurate record of the discharge from the Lake of the Woods. This lake forms the great natural regulating reservoir for the basin above. Its location in the watershed, with reference to both the power reach and to the drainage, rendered a thorough knowledge of its run-off essential to a proper power and storage study; hence early steps were taken to obtain the necessary data.

A very complicated situation exists at the outlets of the lake, as will be seen by reference to plate 13. Some description of the same is therefore necessary in order to convey a proper appreciation of the involved nature of the stream measurement work required.

The lake discharges through several outlets, both natural and artificial, all of which are now subject to artificial control. The two main and natural outlets called respectively the East and West Branches, are located within the town limits of Kenora. The East Branch is now closed by the municipal power station of the town of Kenora (plate 37), developing a drop of some 20 feet under normal conditions. The approach to the power-house is by a somewhat narrow channel, in which there is a slight current of strength depending on the load on the turbines and the surface level of the lake.

The power station completely closes the channel, with the exception of the log slide adjacent to the left bank. It contains bays for six main and two exciter units, four of the main units, together with the exciters, being now installed. The station is more fully described in chapter V. The present controlled East Branch discharge is carried through the turbines, with the exception of a small amount passed through the log slide.

The West Branch discharge leaves the lake about 2,500 feet west of the eastern outlet. Between the two branches lies what is known as Tunnel island. Leaving the lake in a north-easterly direction, the channel is spanned by a traffic bridge and by two bridges of the Canadian Pacific Railway. Turning through considerably more than a right angle it flows in a westerly direction to the end of Tunnel island, midway in which reach is located the Norman dam. Rounding Tunnel island the channel turns again to the northeast and joins the East Branch, the length of the total course being some 2¾ miles. The Norman dam (plate 38) is a solidly built masonry structure, designed on the principle of stoplog control, with discharging capacity sufficient to regulate the lake level as desired. It was originally constructed for power purposes, and power sluices have been left at either end. The central section of the dam consists of a rock-fill, backed on the upstream side by finer material. This section of the dam has never been impervious, due probably to the fact that no power construction has been proceeded with, and the necessity for making the structure water-tight has not been pressing. The leakage through the rock-fill is continuous, and reaches high proportions, varying with the lake level from about 2,000 to 4,500 second-feet at times of low and high water, respectively.

Both the power and the regulating sluices are closed by stoplogs, and up to date have been available for regulating purposes. Under normal conditions there is considerable leakage through the sluices, due to the use of old logs and the difficulty of properly placing the same. As, however, there has been at practically all times up to the present, a surplus of water over that required for power purposes at the outlets from the lake, this leakage has not been of importance, and has not merited attention by the power users. The only exception to this condition occurred in the year 1911, when, due to the extremely low water in the lake, combined with a period of low general run-off, it became necessary to conserve the available water. To this end the logs of the sluiceways were tightened, and straw was used to choke the remaining leaks. Mats were also sunk above the stone fill for the same purpose. The dam is referred to in greater detail in chapter V.

Farther west along the lake shore, is located Portage bay, on the shores of which is built the town of Keewatin. This bay is separated from the river below by a rock ridge, through which three outlets now discharge waters from the lake. Of these outlets, two are entirely artificial and have been constructed for power and industrial purposes. The third outlet probably discharged naturally during extreme high water in the lake.

The most easterly cut was made in 1881, the power being used for the operation of a saw-mill. Discharge through this cut has not been continuous, it being closed for long periods, at different times, due to lack of demand for the power, and to change of ownership. In 1905 the site was acquired by the Keewatin Flour Milling Company, and the flume was nearly doubled in size. The following year the Keewatin Flour Milling Company was purchased by the Lake of the Woods Milling Company, and in May, 1907, the present mill "C" was put in operation. From this date onward, the mill has been operated and the discharge through the cut continuous. The entire flow through this channel is utilized by the mill. The discharge from the turbines is conveyed to the river below by a tail-race excavated through the solid rock below the mill.

About 480 feet westerly along the shore from the above channel, a second intake has been cut, also in connection with the milling industry. This cut was made in 1887 by the Lake of the Woods Milling Company, in connection with mill "A." The discharge through the channel has been constant since that date. The entire flow through the channel is utilized by the mill. The discharge from the turbines takes place directly into the river below. These mills are more fully covered in chapter V.

The third outlet from Portage bay is known as the Keewatin Lumber and Manufacturing Company outlet, and leads from the extreme westerly end of the bay. This end was formerly blocked with muskeg and by a ridge of rock, which prevented outflow, excepting possibly during times of high water in the lake.

In 1879, a power-house, together with a head-race some 400 feet in length and 40 feet in width in its narrowest part, was constructed by the Keewatin Lumber and Manufacturing Company. The head-race was a timber structure partially in earth excavation, with the exception of a small rock cut immediately above the power-house. The mill was placed in operation in June, 1880, and the mill-race deepened in 1885. The tail-race discharges into Mink bay, and, at approximately 1 mile west of Keewatin, Mink bay discharges into Darlington bay, an inlet of the Winnipeg river, through a tunnel cut in solid rock through the Canadian Pacific Railway right of way.

The power developed was used in the operation of a saw-mill, together with a planing-mill. The saw-mill was destroyed by fire in the fall of 1905, and was never rebuilt. The planing-mill was operated in 1906, but since that date the outlet has been closed by stop logs.

Meterings at Outlets of the Lake of the Woods.—The above brief description of the outlets of the lake is sufficient to indicate that the work of securing satisfactory discharge measurements is somewhat involved. This is particularly the case in attempting to analyse the past flows through the various outlets. Difficulty was also experienced in locating a satisfactory station to record the combined discharge from the lake, due to the channel below being broken by islands, and widening into large lake-like areas.

Prior to the stream gaugings of the Dominion Water Power Branch, little discharge data had been secured around the lake outlets, and no attempt had been made to obtain continuous discharge records.

The first measurement secured on the Eastern Branch was taken on July 29, 1903, by Pringle & Sons, engineers in charge of the construction of the Kenora power station. The discharge recorded was 4,122 cubic feet per second, with lake at elevation 1,059·3, Water Power Survey datum.[1] Two meterings were made by the officers of the Hydro-Electric Power Commission of Ontario on October 14, 1905, and April 8, 1906, the discharges secured being 5,320 and 4,490 cubic feet per second, respectively, with the lake level approximately 1,060·1 and 1,059·4.

In order to secure a record of the past discharge through this outlet the power station has been rated. During the summer and fall of 1912, discharge measurements were made by the field engineers of the Water Power Branch, at a section below the power house and lying between Old Fort island and the main shore. This section was discontinued, due to the channel being altered by blasting and excavation on the part of the Dominion Public Works Department, and also due to the fact that the discharge, on account of a large bay intervening and tending to equalize the flow, did not respond rapidly to a change in the discharge at the power station.

In February, 1913, a station was established above the new power-house and at approximately the crest of the old Ka-ka-be-kitchewan falls, now flooded out by the power plant forebay. Up to December 31, 1914, some 125 discharge measurements have been taken at this section. Readings of forebay

[1] Zero of Water Power Survey datum is equal to [illegible] of the United States Coast and Geodetic Survey datum.

and tail race gauges, together with load and valve readings, were made while the meterings were in progress, and a rating of the power station secured. Included in the meterings was the discharge through a V-shaped spillway or log chute. This log chute has been kept partially open in order to maintain sufficient water in the tail-race. The discharge through this chute has been calculated, and the net discharge through the power-house obtained. The meterings on which the rating curve is based are published in Appendix VII, table 60.

The new power station commenced operation on February 9, 1907, the wheel installation at this date being three 40-inch Sampson twin horizontal turbines, connected to the generators, and two 30-inch Sampson twin turbines connected to the exciters. No further additions were made to the station until 1913. The discharge through the station has shown a fairly constant, if slow, growth. Commencing in August of 1907, the water required averaged about 550 second-feet, which during the following winter with the consequent heavier load increased to 780. During the following years, increases were recorded from time to time the flow reaching as high as 1,700 second-feet in February of 1912. This was an extreme condition, the average flow required at present being more in the neighbourhood of 1,300 second-feet.

On the western outlet, but few measurements were secured prior to the work of the Water Power Branch engineers. In connection with the construction of the Norman dam, Mr. William Kennedy secured two meterings of this outlet, the first on November 11, 1892, and recording 22,563 cubic feet per second, and the second on May 26, 1893, recording 15,937 cubic feet per second. On October 18, 1905, the officers of the Hydro-Electric Power Commission of Ontario secured a gauging of 22,000 second-feet at the Norman dam. In June, 1912, a station was established at the Norman traffic bridge, at the entrance to the channel. Twenty-eight meterings were secured here by officers of the survey staff, throughout 1912 and 1913.

This station was established in order to secure a record of the leakage through the Norman dam, under various conditions of lake level. Since the discharge through this channel is dependent on two controlling conditions, i.e., the lake level and the number of logs in place at the dam, both of which are constantly changing, the station was not suitable for securing permanent daily records of the run-off. It has been maintained to serve as a check on the station north of Tunnel island, at which station the flow through the Norman dam, as well as that through the three western outlets, is recorded.

Early steps were taken to secure records of the water used by the Keewatin mills. A station was established on the intake to mill "C" on July 17, 1912. To the end of 1914, some ninety-seven measurements have been secured by the hydrographic field officers, the discharge varying from 600 to 1,100 second-feet, with an average of about 700. Under ordinary conditions, the load on the mill is fairly constant, and the fluctuation is slight. There are no records from which the past discharges might be deduced.

In the intake to mill "A," a station was also established by Mr. Scovil, Assistant Chief Engineer of the Manitoba Hydrographic Survey, on December 23, 1912, and continuous meterings secured. Under usual conditions of load the discharge remains fairly constant at about 850 cubic feet per second. A low flow of 200 second-feet usually occurs on Sunday, when the generators only are being operated. A discharge measurement secured at this mill on October 16, 1906, by the officers of the Hydro-Electric Power Commission of Ontario showed a flow of 899 second-feet.

The old Keewatin Lumber and Milling Company outlet has also been carefully metered. The discharge at present consists of the leakage through the stoplogs closing the old intake. The metering station established in July, 1912, is located at the entrance to the tunnel under the Canadian Pacific Railway embankment, and records, in addition to the leakage, the drainage from a small area tributary to Mink bay. The records have shown a gradual increase in discharge from 95 to 130 cubic feet per second. A measurement obtained

Old Keewatin Lumber Co. Outlet from the Lake of the Woods.

here on October 16, 1905, by the officers of the Hydro-Electric Power Commission of Ontario while the plant was in operation, showed a flow of 400 second-feet.

The total discharge from the three Keewatin outlets, and from the West Branch, is carried to the north of Tunnel island, where the main metering station has been established. The gauge is bolted to the solid rock shore at the south end of the traffic bridge below Keewatin, while the metering section is located about 1 mile down stream. The station was established by Mr. Scovil on June 28, 1912, since which date continuous measurements have been and are being secured, upwards of 280 being obtained to the end of 1914.

In view of the importance of the records at this place, especial care has been exercised in the metering, and the results are considered to be satisfactory. The discharge records have been carried back to the beginning of 1907 by means of the gauge records of the Ontario Department of Public Works. Since the establishment of the regular station, independent gauge readings have been secured by the survey staff.

The flow is largely dependent on the operation of the Norman dam and of the Lake of the Woods Milling Company's mills at Keewatin.

Some 12 miles down stream from the station, the river enters a gorge and forms what are known as the Dalles rapids. These consist in reality of little more than swift-flowing water. In times of high water a back channel comes into play just above the Dalles, and a portion of the flow is discharged through the same, the entrance going under the name of the Throat rapids. Some 28 miles below the Dalles there is a series of rapids and falls known as the White Dog. The White Dog, Dalles, and Throat rapids form the control of the river reach extending back upstream to Kenora. This is a most important consideration, since the river expansion between the Dalles and Kenora is 20 square miles in area, and between White Dog and the Dalles, 65 square miles. These areas require considerable time to adjust the surface elevation to meet sudden changes in discharge, due to the operation of the Norman dam. Backwater effects are consequently experienced at the gauging station. The unsettled nature of the country prevented the early establishment of a permanent station farther down the river. Such a station will, however, be established in the near future.

The backwater effect is now being thoroughly investigated by Mr. S. S. Scovil of the Lake of the Woods Technical Board, with a view to making whatever corrections may be necessary on the present records, and on those which have been deduced back to 1907. Any such corrections as may be applied will not alter, to any marked extent, the totals published herein, and it is not considered advisable to delay the publication of this report until such time as the revision is complete. The corrected results will be published when prepared in a future Water Resources Paper.

The total discharge from the lake is secured by totalling the records of the North Tunnel Island station with those of the Kenora power-house station.

Lake of the Woods Discharge Records.—The complete records of the total run-off from the Lake of the Woods are to be found in Appendix VII, tables 58, and 59, and in graphical form on plate 14. For convenience of reference, the mean monthly flows are published herewith in table 5.

Table 5.—Mean Monthly Discharge of the Winnipeg River at the Outlet of the Lake of the Woods at Kenora.

[Drainage area 26,400 square miles.]

Month.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	Mean.
	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.
January	11,790	19,190	9,970	11,650	7,700	5,555	11,560	8,030	10,682
February	11,250	18,230	10,040	11,790	7,110	5,795	9,570	8,380	10,271
March	10,640	17,340	10,910	12,260	6,835	6,010	6,990	10,320	10,413
April	10,280	16,900	10,870	22,120	8,905	6,270	8,550	9,780	11,721
May	11,170	18,470	11,040	24,600	8,770	6,505	18,370	12,300	13,914
June	14,000	22,830	11,770	21,870	8,945	5,435	20,100	18,450	15,425
July	14,055	21,800	11,850	16,290	8,770	4,870	15,020	19,910	14,071
August	12,730	20,300	11,695	13,270	7,935	5,430	14,880	18,200	13,061
September	17,080	18,200	11,940	11,750	6,715	5,425	13,100	13,520	12,216
October	20,790	15,420	12,095	10,180	5,945	9,720	8,130	11,460	11,712
November	21,075	12,810	12,020	8,785	5,615	10,900	8,000	9,900	11,161
December	19,730	10,580	11,925	8,110	5,530	11,520	8,050	9,850	10,661
The Year	14,560	17,670	11,345	14,570	7,410	6,955	11,872	12,508	12,109
Maximum	21,672	23,944	12,450	25,238	9,387	12,010	20,806	20,476	25,238
Minimum	10,100	10,118	9,465	7,654	5,078	4,425	5,847	7,077	4,425

NOTE.—The maximum and minimum discharges refer to daily flow.

Reference to the table indicates a discharge which apparently has, in the majority of the years, been little influenced by the seasons. This has been due to the artificial control exercised at the Norman dam. The year 1907 shows the highest discharges in the months of October, November, and December; 1908 is more normal, although the winter months are high; 1909 has a practically uniform flow throughout; 1910 shows the usual influence of the seasons; 1911 is fairly uniform throughout; 1912 shows the highest flow during the months of October, November, and December; while 1913, and 1914 show the normal high-water period in its proper season. These discharges can be profitably studied in conjunction with the elevations of the lake surface throughout the period, as shown in table 20. This influence is discussed more fully in connection with the question of storage in the lake, and the results are tabulated in table 21. It is sufficient at this stage to make note of the very marked influence which the control of the lake has had on the recorded discharges. While the discharges during the individual years do not follow the seasonal periods of high and low water, the eight-year means of the various months, as may be seen graphically in figure 2, plate 16, show up more satisfactorily.

The average eight-year flow from the lake has been 12,109 second-feet. The years of highest and lowest discharge are 1908 and 1912, respectively, and the maximum daily discharge recorded was 25,238 on May 4 in 1910, with a minimum of 4,425 on July 21 in 1912. This maximum discharge coincides closely with the time of maximum at Slave falls.

Fort Frances Metering Station.

The third location at which has been secured a series of discharge measurements of prime value in studying the run-off of the basin, is at Fort Frances, at the outlet of Rainy lake. Past records are available here from March 1, 1907.

The metering station is located a short distance below the Ontario and Minnesota Power Company's dam at Fort Frances. It was established on March 1, 1907, by the Power Company, who furnished the gauge heights to the United States Geological Survey until the spring of 1910. The gauge was originally located on the United States side, but in the spring of 1910, was moved to the Canadian side and located in the tail-race of the power plant. The operation of the turbines at this point affects the water surface to such an extent that it is not always a true index of the flow, and accordingly the station was discontinued. Immediately following, on April 20, 1911, a new gauge was installed by the United States Geological Survey at the American steamboat dock below the falls.

The field officers of the Department of Public Works of the Dominion Government established a metering station at the same location as that used by the United States engineers. At the same time, the turbines in the power stations on both sides of the river were carefully rated. Records of the discharge past the dam and power stations have in this manner been daily recorded to date, and have been checked by monthly meterings at the station below the dam. Measurements have also been taken at this station by the field officers of the Dominion Water Power Branch during the years 1912, and 1913.

The Department of Public Works has under way a topographic survey of the entire Rainy river and banks, a considerable portion of which is now completed.

Fort Frances Discharge Records.—The records published herein from March 1, 1907, to November 30, 1912, have been secured from the records of the United States Geological Survey as published in Water Supply Paper 305, to which have been applied the percentage corrections submitted in Water Supply Paper 325 by Mr. Adolph Meyer, consulting engineer of the International Joint Commission. The previously published results were subsequently found to be inaccurate, primarily due to back-water effects from ice cover and flood discharge of the Little and Big Fork rivers. The records herein from December 1, 1912, to date have been supplied by the engineers of the Department of Public Works. The above records are appended in complete form in tables 61, and 62, in Appendix VII, and in graphical form in plate 15. For convenience of reference the mean monthly discharges are given herewith in table 6.

Table 6.—Mean Monthly Discharge of the Rainy River at Fort Frances.

[Drainage area 14,400 square miles.]

Month	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	Mean.
	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.
January	5,883	12,000	5,170	9,680	2,860	5,330	6,620	6,718	6,783
February	3,641	8,410	4,740	9,680	2,380	4,830	6,561	6,823	5,883
March	4,910	7,030	5,500	10,750	2,530	4,740	6,420	6,707	6,073
April	4,955	,020	3,250	10,600	3,020	4,850	6,405	6,694	5,721
May	6,070	7,910	4,220	10,600	4,600	6,090	6,620	6,866	6,626
June	10,200	...430	6,850	10,000	5,740	6,020	7,274	8,464	8,247
July	13,000	13,060	10,600	6,630	3,970	7,680	12,597	10,464	9,750
August	17,470	12,680	10,600	5,280	6,560	8,120	8,544	10,044	9,912
September	20,110	10,740	9,250	5,080	5,900	7,360	6,770	9,749	9,381
October	19,760	9,680	9,050	5,120	5,210	6,880	5,318	9,787	8,963
November	17,700	7,510	5,400	5,280	5,410	6,730	6,129	9,927	8,011
December	13,000	5,701	10,010	4,300	5,900	6,230	6,300	8,991	7,561
The Year	11,391	9,350	7,052	7,759	4,514	6,213	7,214	8,436	7,744
Maximum	20,110	13,060	10,600	10,750	6,560	8,120	12,597	10,464	110
Minimum	3,641	6,020	3,250	4,300	2,380	4,740	6,129	6,694	389

NOTE.—No records were available at Fort Frances for the months January and February in 1907, and the discharges used were deduced from Kenora records by proportional areas.
The maximum and minimum discharges refer to mean monthly flows.

Reference to the table and to plate 15 indicates that, as was the case in the Lake of the Woods, the use of the lake in conjunction with the hydro-electric and industrial undertakings at the outlet has largely interfered with the normal seasonal influences on the run-off. A reference to the eight-year monthly means in column 10 above, indicates that the average flow has followed the seasonal changes more closely than have the individual years.

The eight-year mean flow was 7,744 second-feet. The years of maximum and minimum flow were 1907 and 1911, with a mean of 11,390 and 4,514 second-feet, respectively, while the monthly maximum and minimum was 20,110 and 2,380 second-feet, respectively.

The theoretical inflow, as tabulated in table 25, discloses a much closer relation between the run-off and the seasons.

Chaudière Falls (Kettle Falls) Metering Station.

The metering station of next importance to the study of the run-off conditions in the basin is that at Chaudière or Kettle falls. These falls are located at the outlet of Namakan lake where the outflow drops direct into Rainy lake. At the falls the river is divided by an island into two channels, the Canadian and International, respectively. The normal drop was about 8 feet under natural conditions. The station was established by the field officers of the Dominion Water Power Branch in August, 1912. Owing to the shortness of the period over which the work has extended, there are insufficient records to permit a detailed study of the run-off.

Two metering sections were established, one on each channel. The combined flow gives the total discharge from Namakan lake, a body of water 100 square miles in area with a tributary drainage of 7,060 square miles. The gauge was placed on the Canadian main shore, 200 feet above the Canadian falls, and was not affected by backwater. The station was discontinued in June, 1913, and the subsequent construction of the storage dams referred to in chapter V has destroyed the natural run-off conditions previously existing. The combined records are attached in tables 63, 64, and 65, Appendix VII.

Miscellaneous stations and records.

Run-off measurements have been made by the officers of the Manitoba Hydrographic Survey on certain of the lesser tributary rivers, the Whitemouth river being the only one on which continuous records are available.

Whitemouth River.—The Whitemouth river rises near the international boundary and flows north, entering the Winnipeg from the south just below the lowest pitch of the Seven Sisters falls. It drains an area of 1,400 square miles, the great proportion of which is entirely unsupplied with lakes. A station was established on this river by the Manitoba Hydrographic Survey in May, 1912, and the records are attached in Appendix VII, tables 66, 67, and 68.

The maximum flow recorded since the establishment of the station has been 2,250 second-feet on June 4, 1914, while a minimum of 16 second-feet was metered on January 20 of the same year. Attention is called to the extreme low winter flow of the river. This flow is particularly striking in view of the extent of the drainage area, and is illustrative of the winter run-off conditions which must be anticipated from those portions of the watershed unsupplied with equalizing lakes. Low run-off may also be experienced in the summer season, as is instanced in the records for August, and September in the year 1914, when the average flow of only 136, and 174 second-feet, respectively, was maintained.

Numerous individual meterings have been secured from time to time on various streams throughout the basin. These have been collected and grouped and are attached in Appendix VII, table 69.

There is available no continuous record of the English River flow This river drains the entire northern portion of the basin, in all some 21,570 square miles. Isolated measurements have been secured, but owing to its inaccessibility, no attempt has been made until recently to record its continuous discharge. The Ontario Hydro-Electric Commission is taking steps to secure permanent records. At present the best that can be done in studying the run-off and storage conditions of the English river is to deduce a discharge by proportional areas.

Ontario Hydro-Electric Power Commission Discharge Records.

The Hydro-Electric Power Commission of Ontario has recently instituted energetic measures to secure adequate and reliable stream run-off records throughout that portion of the Winnipeg watershed lying within the province of Ontario. Permanent metering stations have been established on the Seine, Turtle, Manitou, Footprint, Wabigoon, Eagle, and English rivers. As has also been the case in other portions of the basin, considerable difficulty has been experienced in securing gauge readers in connection with this work. The inaccessible nature of the district, coupled with this lack of suitable recorders, has added largely to the difficulties attendant on the maintenance and enlargement of the sphere of operations. A comprehensive programme has, however, been mapped out and is being energetically prosecuted.

Through the courtesy of the commission, the Dominion Water Power Branch is enabled to publish the discharge records which have been secured throughout the watershed. These records are appended in tables 70 to 91, Appendix VII.

United States Geological Survey Discharge Records.

Throughout that section of the Winnipeg River basin lying in Minnesota, stream measurement work has been carried on for several years by the officers of the United States Geological Survey. Through the courtesy of the Director of the Survey, it has been possible to incorporate in this report the run-off data available.

Big Fork River.—The Big Fork river is located entirely in Minnesota, and is the second largest tributary of the Rainy river from the south. It rises in Jessie lake, in township 147 north, range 25 west, in Itaska county, at an elevation of about 1,320 feet above sea-level. It flows into Bowstring lake, thence north into Wabatawangang lake, and thence east and north into Rainy river near Laurel. The entire length is about 175 miles. Stream measurement work is carried on by the officers of the Water Resources Branch of the United States Geological Survey, and records are available from August 27, 1909, to November 12, 1910. On account of the interference by backwater from a log jam during the years 1911, and 1912, no daily or monthly records for these years are published. The published records are attached in Appendix VII, tables 92, 93, and 94.

Little Fork River.[1]—The Little Fork river, the largest tributary of the Rainy river from the Minnesota side, rises in the central part of St. Louis county, a few miles south of Vermilion lake, at an elevation of about 1,440 feet above sea-level, and flows westward and then northwestward to its junction with Rainy river, about 12 miles below International Falls. The total length of the river is about 160 miles. Records secured by the United States Geological Survey officers are available from June 23, 1909, to December 31, 1914, and are attached in Appendix VII, tables 95, [illegible], and 97.

Vermillion River.[1]—The Vermilion river, which rises in Vermilion lake, has its ultimate source in Pike river, which rises in the southern part of township 58 north, range 17 west. From Vermilion lake the general course of the Vermilion river is southwest and then northeast, emptying into Crane lake, which in turn empties into Sand Point lake, and then into Namakan lake. From Vermilion lake to Crane lake, the length of the river is 42·5 miles. Throughout its course, the river falls 245 feet, through a series of rapids interspersed with small lakes and level stretches. Records secured through the United States Geological Survey are available from May 17, 1911, to December 31, 1914, and are attached in Appendix VII, tables 98, 99, and 100.

Kawishiwi River.[1]—The Kawishiwi river rises in Syenite la[illegible] the eastern part of township 62 north, range 6 west, in Lake county, and [illegible] north and west through a chain of lakes., the chief ones being Polly, Boulder, Alice Wilder, and Crab lakes. In the southwest corner of township 63 north, range 10 west, the river divides, one fork known as the North Kawishiwi, continuing westward through Friday and Farm lakes into Garden (or Eve) lake. The other fork, known as the South Kawishiwi or Birch river, flows southwest through Copeland lake into Birch lake, where it runs northward and flows through White Iron lake into Garden lake, joining the North Kawishiwi. From Garden lake, the Kawishiwi flows northward through Fall and Newton lakes into Basswood lake, a tributary of Rainy river. The south Kawishiwi is the larger of the two forks. Records of the run-off of the Kawishiwi river are available from June 21, 1905, to June 30, 1907. These records were compiled by the Minnesota Canal and Power Company and published in the Report of Water Resources Investigation of Minnesota, 1909-12, by the State Drainage Commission. Records are also available from October 14, 1912, to December 31, 1914, secured through the International Joint Commission co-operating with the United States Geological Survey. The records are attached in appendix VII, tables 101, and 102.

GENERAL RUN-OFF.

For the purpose of general study of the run-off conditions of the Winnipeg river, reference may be made to plates 16, 17, and 18.

The curves on plate 16 are plotted from the average eight-year monthly discharges at Slave falls, Kenora, Fort Frances, and of the English river at its mouth and at the outlet from Lac Seul. It will be noted that in these average curves the discharge follows the seasonal variations much more closely than do

[1] For the above descriptive data on the Big Fork, Little Fork, Vermilion, and Kawishiwi rivers, the writer is indebted to the Report of Water Resources Investigations of Minnesota, 1909-12, by the State Drainage Commission

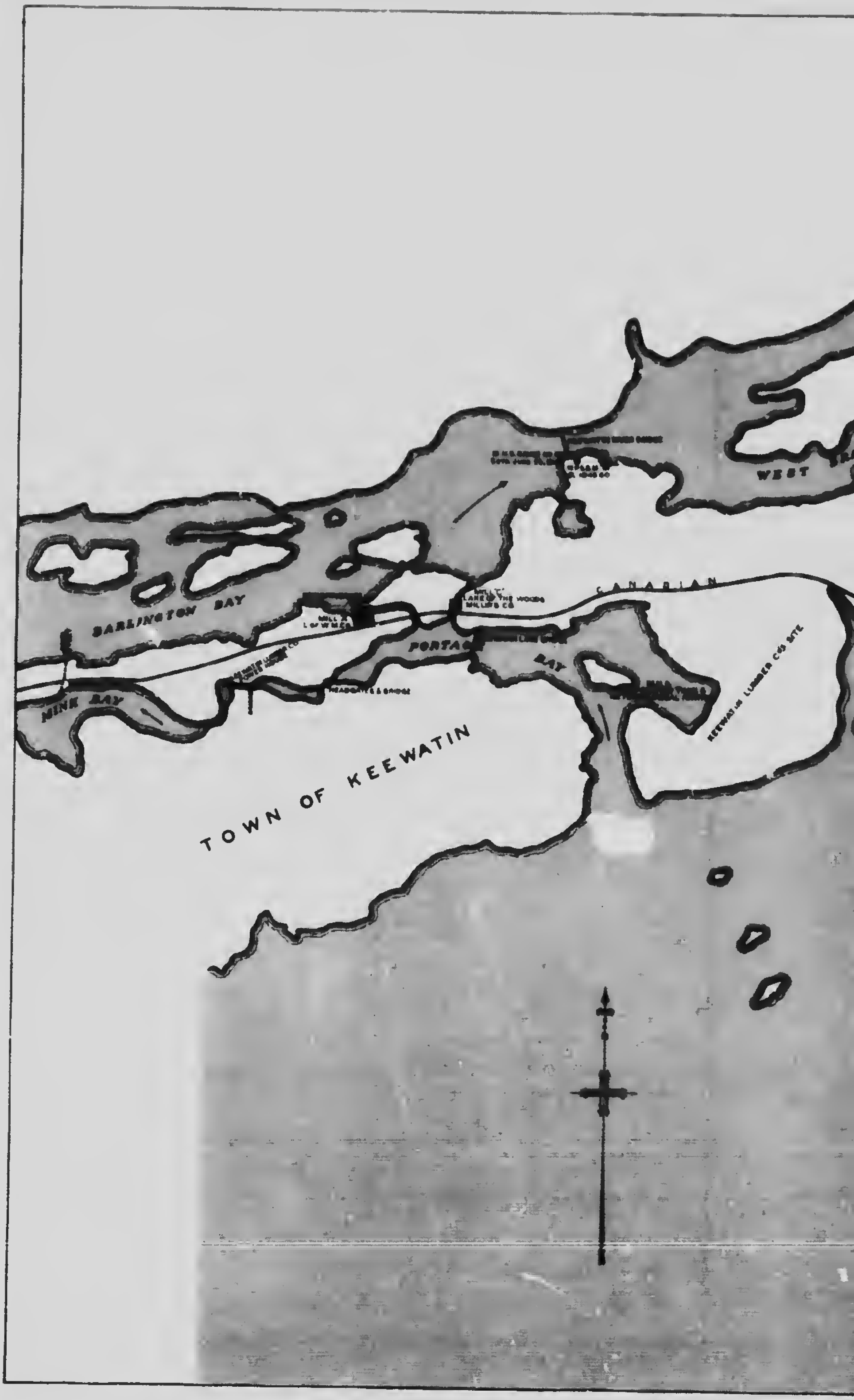

DARLINGTON BAY
MINK BAY
TOWN OF KEEWATIN
PORTAG
BAY
CANADIAN
WEST

PLATE No. 13
OLD FORT ISLAND
TUNNEL ISLAND
WEST BRANCH WINNIPEG RIVER
EAST BRANCH
RAILWAY
PACIFIC
NORMAN DAM
LAKE OF THE WOODS
CONEY ISLAND
TOWN OF KENORA
Department of the Interior, Canada.
Water Power Branch
WINNIPEG RIVER POWER SURVEY.
OUTLETS OF
THE LAKE OF THE WOODS

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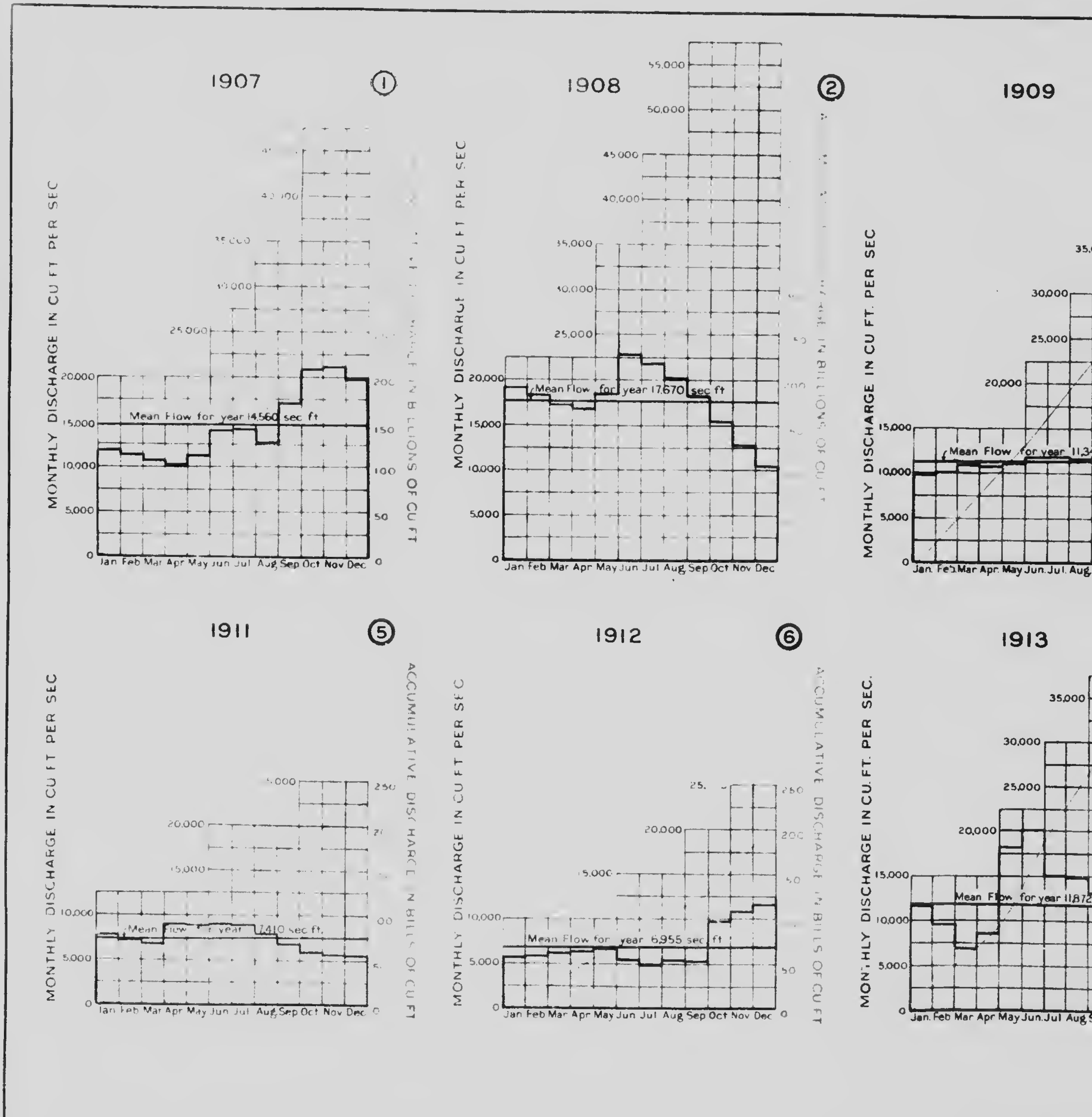
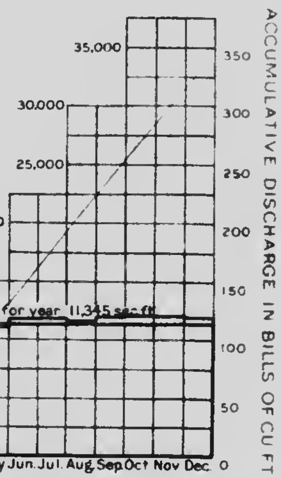
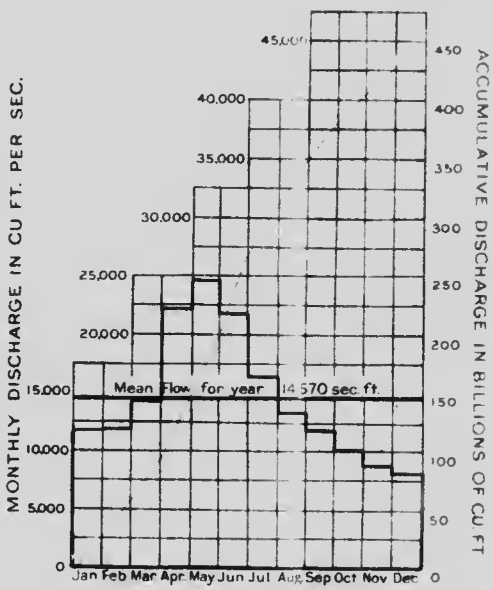


1907
①
MONTHLY DISCHARGE IN CU FT PER SEC
Mean Flow for year 14,560 sec ft
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
ACCUMULATIVE DISCHARGE IN BILLIONS OF CU FT
1908
②
MONTHLY DISCHARGE IN CU FT PER SEC
Mean Flow for year 17,670 sec ft
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
1909
MONTHLY DISCHARGE IN CU FT. PER SEC
Mean Flow for year 11,3
Jan. Feb Mar Apr. May Jun. Jul. Aug
1911
⑤
MONTHLY DISCHARGE IN CU FT PER SEC
Mean Flow for year 7,410 sec ft.
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
ACCUMULATIVE DISCHARGE IN BILLS OF CU FT
1912
⑥
MONTHLY DISCHARGE IN CU FT PER SEC
Mean Flow for year 6,955 sec ft
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
ACCUMULATIVE DISCHARGE IN BILLS OF CU FT
1913
MONTHLY DISCHARGE IN CU. FT. PER SEC.
Mean Flow for year 11,872
Jan. Feb Mar Apr May Jun. Jul Aug

909 ③



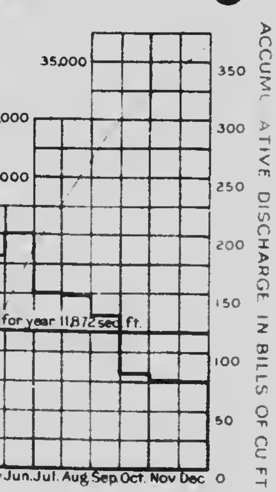
1910 ④



NOTE.

The discharge records from which these curves are plotted were secured by the Engineers of the Dominion Water Power Branch by totalling the Records from the East and West branches of the Winnipeg River at Kenora.
the East branch records were obtained by rating the Kenora Power Station. The West Branch Records were obtained by a metering station North of Tunnel Island referred to gauge records of the Ontario Department of Public Works.
Drainage area - 26,400 Square miles.

913 ⑦



For Uniform Flow in Sec Ft. of	Necessary Storage in Billions of Cubic Feet.						
	1907	1908	1909	1910	1911	1912	1913
6,000	0	0	0	0	2 38	9·14	0
7,000	0	0	0	0	11 42	30·64	·029
8,000	0	0	0	0	27 66	54 21	2 64
9,000	0	0	0	2 89	49 69	77 78	13 46
10,000	0	0	78	8 13	81·24	102 08	27 68
11,000	2 82	1·10	5 79	15 51	112·73	128 53	43 41
12,000	12 74	3·72	20·93	25 45	144 05	158 31	59 11

WATER POWER BRANCH

J. B. Challies, Superintendent

WINNIPEG RIVER

MASS CURVES OF MEAN MONTHLY DISCHARGE & VOLUME OF RUN-OFF

- - at - - -

KENORA

To accompany report on POWER & STORAGE INVESTIGATIONS

by J. T. JOHNSTON, B. A. Sc.

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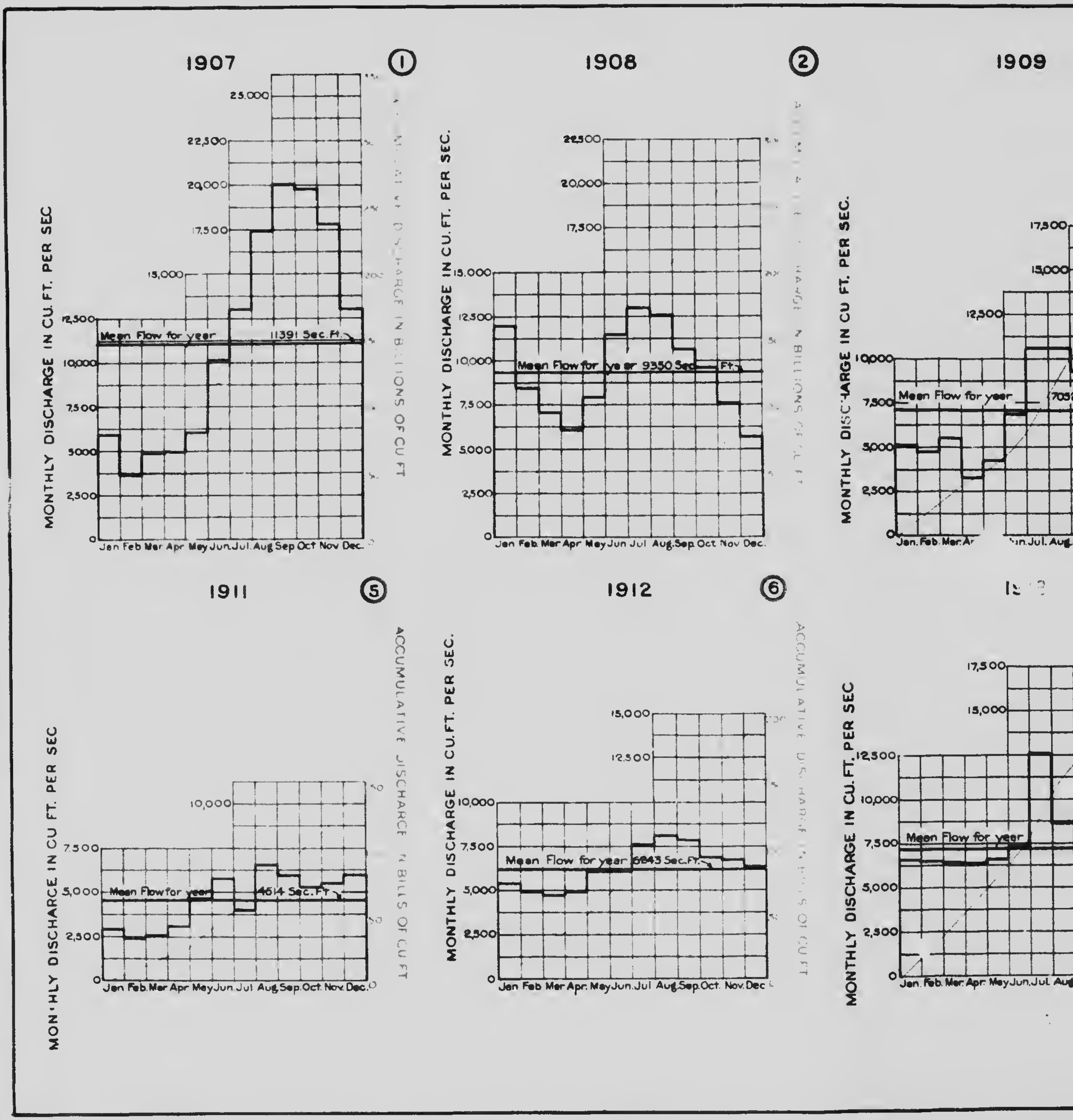
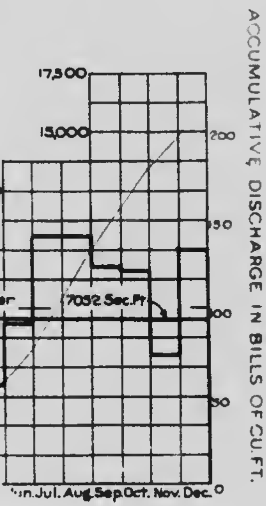
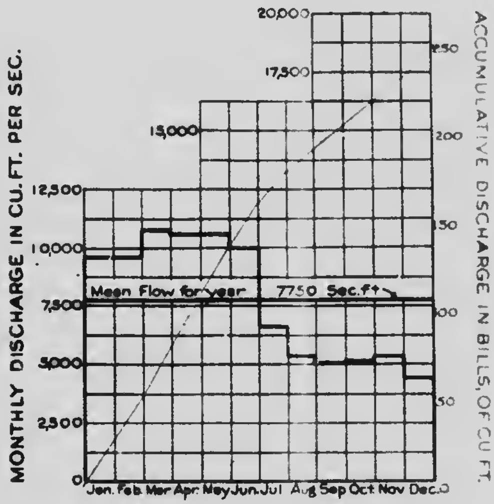

1907
①
MONTHLY DISCHARGE IN CU. FT. PER SEC
Mean Flow for year 11391 Sec. Ft.
Jan Feb Mar Apr May Jun. Jul. Aug Sep Oct Nov Dec.
1908
②
MONTHLY DISCHARGE IN CU. FT. PER SEC.
Mean Flow for year 9350 Sec. Ft.
Jan Feb. Mar Apr May Jun Jul Aug. Sep Oct Nov Dec.
1909
MONTHLY DISCHARGE IN CU. FT. PER SEC.
Mean Flow for year
1911
⑤
MONTHLY DISCHARCE IN CU FT. PER SEC
Mean Flow for year 4614 Sec. Ft.
Jan Feb. Mar Apr May Jun Jul Aug Sep. Oct. Nov. Dec.
ACCUMULATIVE DISCHARCE IN BILLS OF CU FT
1912
⑥
MONTHLY DISCHARGE IN CU.FT. PER SEC.
Mean Flow for year 6843 Sec. Ft.
Jan Feb Mar Apr. May Jun. Jul Aug. Sep. Oct. Nov. Dec
MONTHLY DISCHARGE IN CU. FT. PER SEC
Mean Flow for year
Jan. Feb. Mar. Apr. May Jun. Jul. Aug

PLATE No. 15

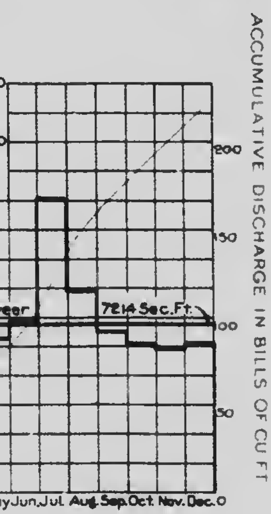
909 ③



1910 ④



19..3 ⑦



NOTE

From March 1907 to November 1912 inclusive the records on which these curves are plotted are taken from the published records of the Water Resource Branch of the U.S. Geo. Survey. The records from November 30. 1912, have been supplied by the field officers of the Department of Public Works of the Dominion Government.

Drainage Area – 14,400 sq. miles.

For Uniform Flow in Sec Ft	Necessary Storage in Billions of Cubic Feet						
	1907	1908	1909	1910	1911	1912	1913
4,000	·87	0	1·95	0	13·78	0	0
5,000	3·65	0	7·27	1·65	27·98	1·50	0
6,000	11·64	·97	20·11	13·09	48·35	10·96	0
7,000	24·50	6·02	36·12	27·32	78·41	29·27	12·68
8,000	37·54	15·34	54·35	43·22	109·95	55·37	38·18

DOMINION WATER POWER BRANCH

J. B. CHALLIES, Superintendent

RAINY RIVER

MASS CURVES OF MEAN MONTHLY DISCHARGE AND VOLUME OF RUNOFF

– at –

FORT FRANCES

To accompany a report on POWER AND STORAGE INVESTIGATIONS by J. T. JOHNSTON, B.A.Sc.

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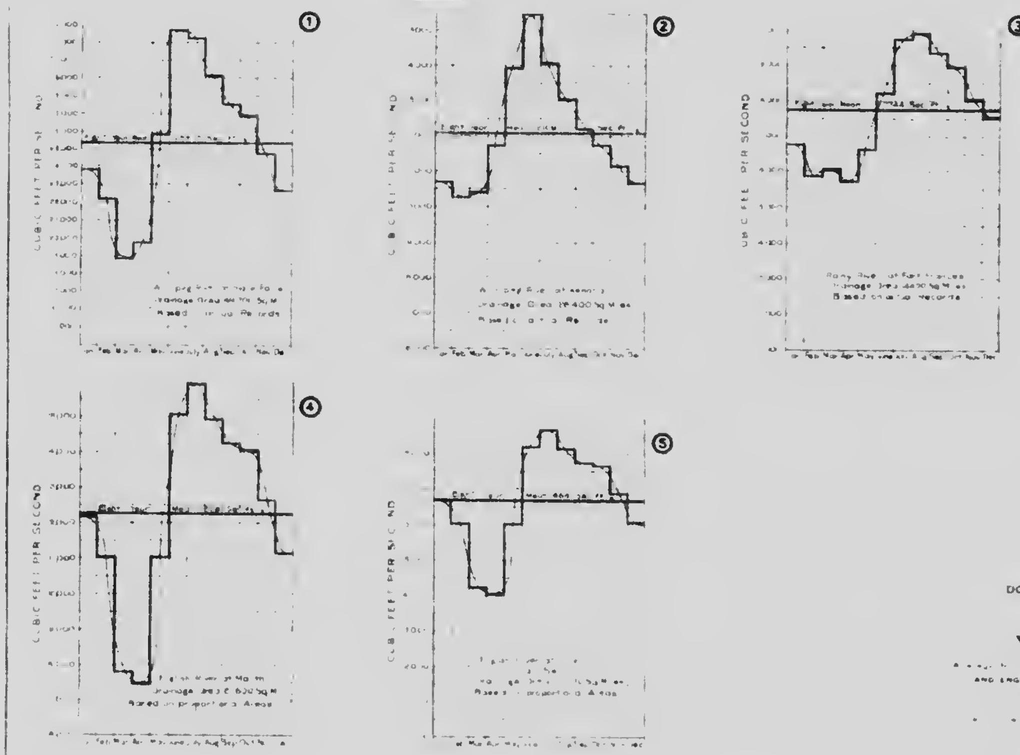


DOMINION WATER POWER BRANCH

WINNIPEG RIVER BASIN

PLATE No. 18

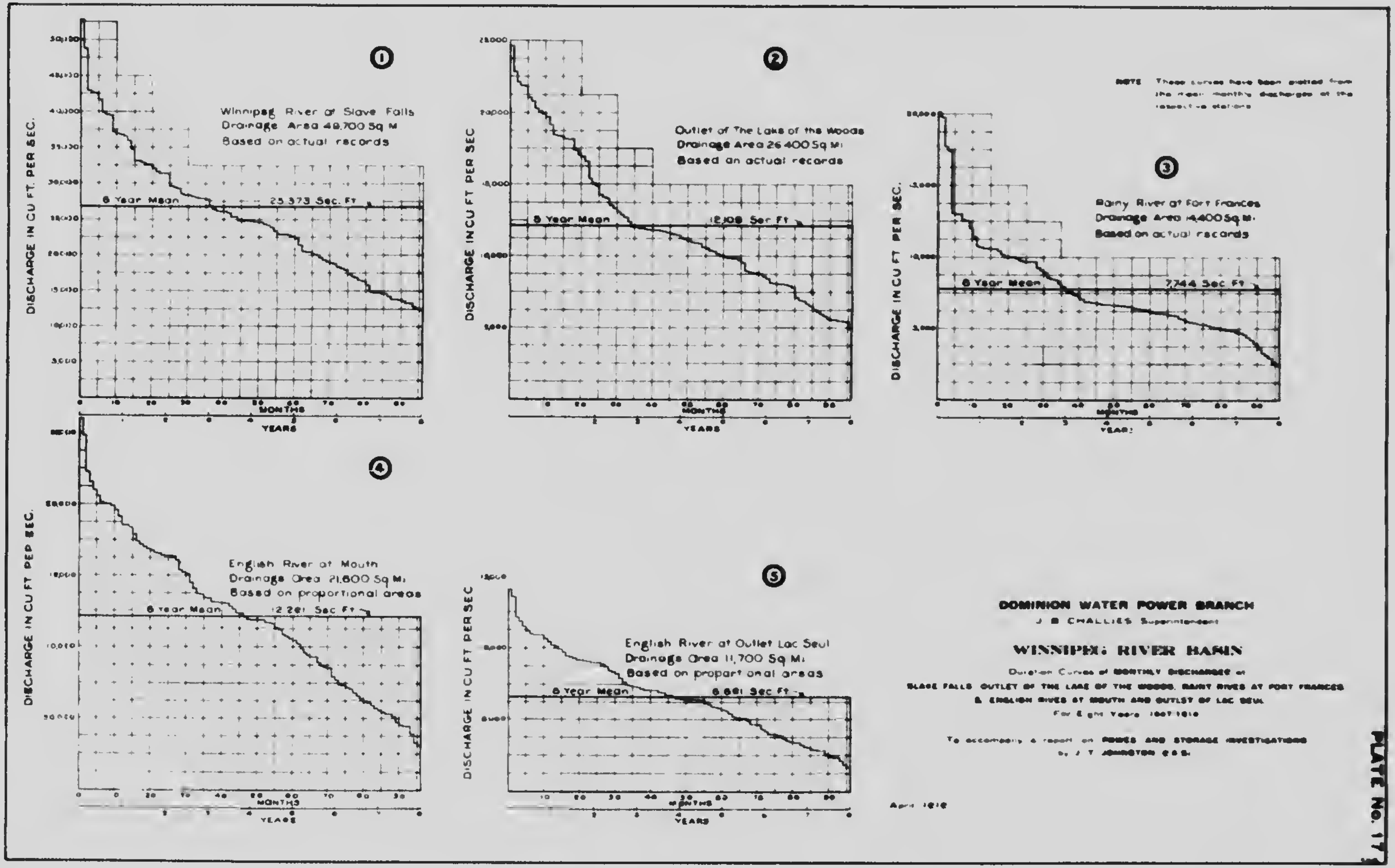


PLATE No. 17
NOTE These curves have been plotted from the mean monthly discharges of the respective stations
1
Winnipeg River at Slave Falls
Drainage Area 49,700 Sq M
Based on actual records
6 Year Mean
25,373 Sec. Ft.
DISCHARGE IN CU. FT. PER SEC.
MONTHS
YEARS
2
Outlet of The Lake of the Woods
Drainage Area 26,400 Sq Mi
Based on actual records
6 Year Mean
12,108 Sec Ft
DISCHARGE IN CU FT PER SEC
MONTHS
YEARS
3
Rainy River at Fort Frances
Drainage Area 14,400 Sq Mi
Based on actual records
6 Year Mean
7,744 Sec Ft
DISCHARGE IN CU FT PER SEC.
MONTHS
YEARS
4
English River at Mouth
Drainage Area 21,600 Sq Mi
Based on proportional areas
6 Year Mean
12,261 Sec Ft
DISCHARGE IN CU FT PER SEC.
MONTHS
YEARS
5
English River at Outlet Lac Seul
Drainage Area 11,700 Sq Mi
Based on proportional areas
6 Year Mean
6,661 Sec Ft
DISCHARGE IN CU FT PER SEC
MONTHS
YEARS
DOMINION WATER POWER BRANCH
J B CHALLIES Superintendent
WINNIPEG RIVER BASIN
Duration Curves of MONTHLY DISCHARGES at
SLAVE FALLS, OUTLET OF THE LAKE OF THE WOODS, RAINY RIVER AT FORT FRANCES
& ENGLISH RIVER AT MOUTH AND OUTLET OF LAC SEUL
For Eight Years 1907-1916
To accompany a report on POWER AND STORAGE INVESTIGATIONS
by J. T. JOHNSTON C.E.S.
April 1916

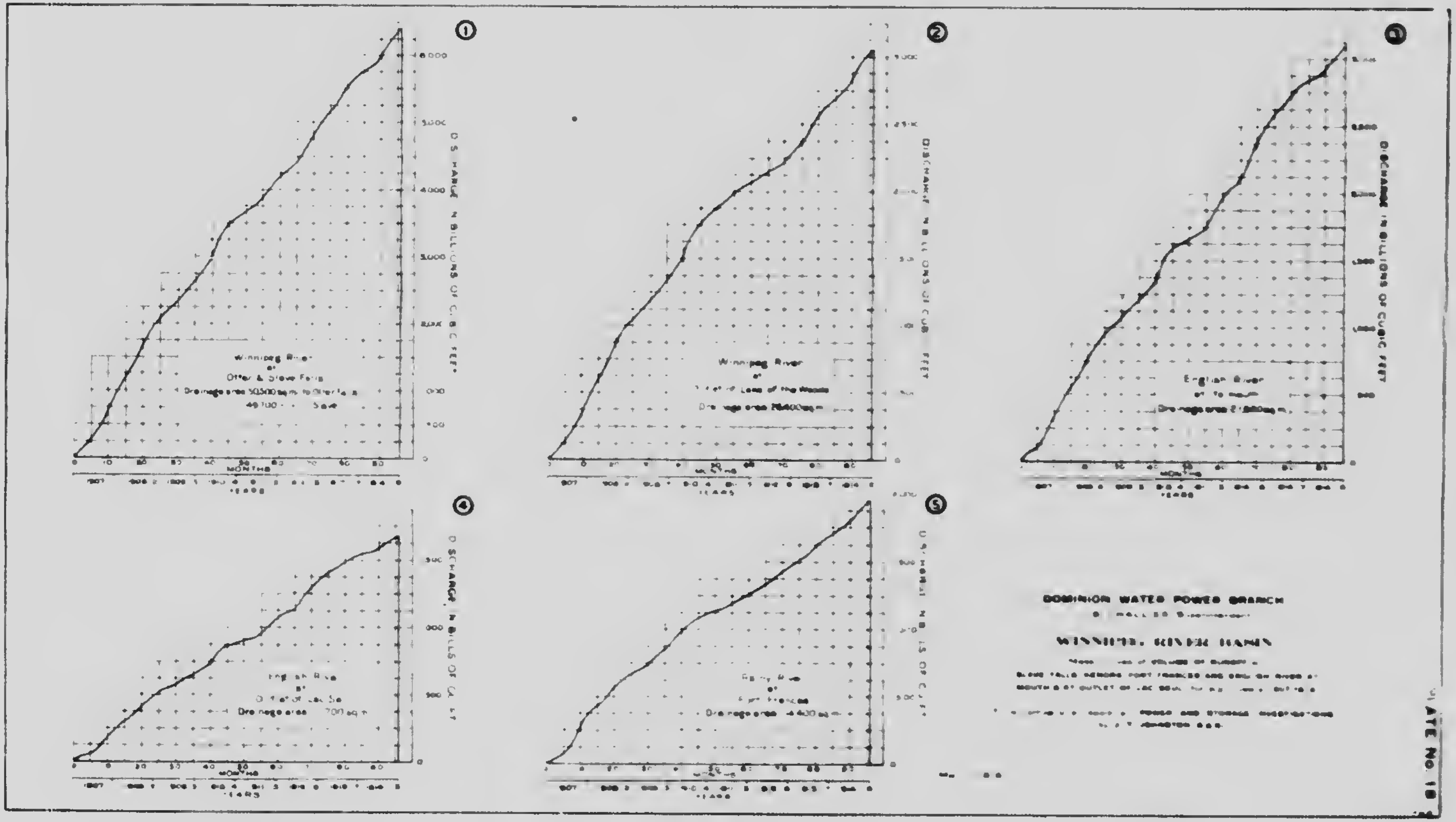


PLATE No. 18
DISCHARGE IN BILLIONS OF CUBIC FEET
MONTHS
YEARS
Winnipeg River
Otter & Slave Falls
Winnipeg River
English River
Drainage area
DOMINION WATER POWER BRANCH
WINNIPEG RIVER BASIN

the individual yearly records, the inequalities due to the regulation which has been maintained being more or less modified.

The curves on plate 17 are plotted from the mean monthly discharges at the above points, and illustrate the proportionate volume of run-off to be anticipated from eight years' records. The mass curves on plate 18 are of interest as depicting the total volume of discharge at the five principal points studied along the river.

Tables 7, 8, and 9, listing the estimated monthly discharges in cubic feet per second per square mile at Slave falls, Kenora, and Fort Frances, respectively; together with tables 10, 11, and 12, listing the equivalent depth in inches on the drainage areas of the monthly discharge at Slave falls, Kenora, and Fort Frances, are appended for reference purposes.

Table 7. Estimated Monthly Discharge of the Winnipeg River at Otter Falls from 1907-10 and at Slave Falls 1911-14, in cubic feet per second per square mile of the Drainage Area.

(Drainage area above Otter Falls 50,550 square miles; above Slave Falls 49,700 square miles.)

Month	1907	1908	1909	1910.	1911.	1912.	1913	1914	Mean
January	0·533	0·729	0·490	0·499	0·298	0·404	0·563	0·276	0·474
February	0·453	0·725	0·478	0·480	0·267	0·339	0·526	0·267	0·442
March	0·343	0·621	0·472	0·472	0·253	0·278	[illegible]	0·279	0·375
April	0·289	0·564	0·340	0·789	0·249	0·273	[illegible]	0·294	0·403
May	0·322	0·615	0·403	1·045	0·297	0·459	[illegible]	0·377	0·515
June	0·555	0·824	0·486	0·964	0·369	0·566	[illegible]	0·634	0·642
July	0·634	0·850	0·488	0·731	0·461	0·531	[illegible]	0·698	0·624
August	0·620	0·783	0·485	0·489	0·526	0·558	[illegible]	0·635	0·581
September	0·735	0·710	0·441	0·388	0·499	0·592	[illegible]	0·526	0·550
October	0·841	0·651	0·402	0·416	0·517	0·665	0·368	0·499	0·545
November	0·844	0·562	0·405	0·283	0·462	0·656	0·315	0·428	0·494
December	0·782	0·362	0·415	0·256	0·389	0·592	0·296	[illegible]	0·452
The Year	0·578	0·677	0·445	0·561	0·381	0·493	0·475	0·443	0·505
Maximum	0·844	0·850	0·490	1·045	0·526	0·665	0·658	0·698	1·045
Minimum	0·289	0·462	0·340	0·256	0·249	0·273	0·296	0·267	0·249

Note.—The maximum and minimum discharges refer to mean monthly flows.

Table 8. Estimated Monthly Discharge of the Winnipeg River at Kenora in cubic feet per second per square mile of Drainage Area.

(Drainage area, 26,400 square miles.)

Month	1907	1908	1909	1910	1911	1912	1913	1914	Mean.
January	0·447	0·727	[illegible]	0·313	0·292	0·211	0·438	0·304	0·405
February	0·426	0·690	0·381	0·347	0·269	0·220	0·363	0·317	0·389
March	0·403	0·657	[illegible]	0·510	0·250	0·228	0·265	0·394	[illegible]
April	[illegible]	0·640	[illegible]	0·838	0·341	0·241	0·324	[illegible]	0·444
May	0·423	0·700	0·418	0·935	0·332	0·247	0·606	0·466	0·527
June	0·530	0·865	[illegible]	0·828	[illegible]	0·206	0·761	0·698	0·584
July	0·532	[illegible]	[illegible]	0·617	0·331	0·185	0·569	0·754	[illegible]
August	[illegible]	0·768	0·443	0·505	0·303	0·206	[illegible]	0·689	[illegible]
September	0·647	0·689	0·452	0·415	0·254	0·205	[illegible]	0·512	[illegible]
October	0·787	0·584	0·454	[illegible]	0·325	0·368	[illegible]	0·434	[illegible]
November	0·798	0·488	0·455	0·333	0·215	0·416	[illegible]	[illegible]	[illegible]
December	0·748	[illegible]	[illegible]	[illegible]	[illegible]	0·436	[illegible]	[illegible]	[illegible]
The Year	0·551	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Maximum	[illegible]	[illegible]	0·455	[illegible]	0·341	[illegible]	[illegible]	[illegible]	
Minimum	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

Note.—[illegible]

Table 9.—Estimated Monthly Discharge of the Rainy River at Fort Frances in cubic feet per second per square mile of the Drainage Area.

[*Drainage area, 14,400 square miles.*]

Month.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	Mean.
January	0·409	0·831	0·359	0·672	0·199	0·370	0·460	0·467	0·471
February	0·253	0·584	0·329	0·672	0·165	0·336	0·456	0·474	0·409
March	0·341	0·489	0·382	0·748	0·176	0·329	0·446	0·466	0·422
April	0·341	0·418	0·226	0·736	0·210	0·337	0·445	0·465	0·398
May	0·422	0·552	0·293	0·736	0·320	0·423	0·463	0·477	0·460
June	0·709	0·794	0·476	0·695	0·399	0·448	0·506	0·588	0·573
July	0·904	0·908	0·736	0·461	0·276	0·531	0·876	0·727	0·678
August	1·214	0·882	0·736	0·367	0·456	0·564	0·591	0·698	0·689
September	1·398	0·747	0·643	0·353	0·416	0·542	0·470	0·677	0·652
October	1·373	0·672	0·628	0·356	0·362	0·478	0·439	0·680	0·623
November	1·230	0·522	0·375	0·367	0·376	0·468	0·426	0·690	0·557
December	0·904	0·396	0·695	0·299	0·410	0·436	0·438	0·625	0·525
The Year	0·792	0·650	0·490	0·539	0·314	0·434	0·501	0·586	0·538
Maximum	1·398	0·908	0·736	0·748	0·456	0·564	0·876	0·727	1·398
Minimum	0·253	0·396	0·226	0·299	0·165	0·329	0·426	0·465	0·165

NOTE.—The maximum and minimum discharges refer to mean monthly flows.

Table 10.—Estimated Equivalent Depth in Inches on the Drainage area, of the Monthly Discharge of the Winnipeg River at Otter Falls 1907-10 and at Slave Falls, 1911-14.

[*Drainage area above Otter Falls, 50,550 square miles; above Slave Falls, 49,700 square miles.*]

Month.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	Mean.
January	0·615	0·841	0·565	0·576	0·344	0·466	0·649	0·318	0·547
February	0·471	0·755	0·498	0·500	0·278	0·353	0·548	0·278	0·460
March	0·395	0·716	0·429	0·544	0·291	0·321	0·443	0·321	0·433
April	0·322	0·630	0·369	0·882	0·279	0·305	0·404	0·328	0·439
May	0·372	0·744	0·463	1·205	0·343	0·529	0·658	0·435	0·594
June	0·619	0·921	0·542	1·075	0·442	0·632	0·736	0·708	0·707
July	0·731	0·980	0·562	0·843	0·531	0·612	0·684	0·806	0·719
August	0·745	0·902	0·560	0·564	0·606	0·646	0·642	0·732	0·671
September	0·820	0·793	0·492	0·431	0·558	0·655	0·568	0·588	0·614
October	0·970	0·754	0·464	0·388	0·602	0·767	0·424	0·575	0·618
November	0·913	0·627	0·452	0·315	0·516	0·732	0·352	0·477	0·552
December	0·901	0·532	0·511	0·295	0·448	0·682	0·342	0·460	0·522
The Year	7·87	9·20	5·91	7·62	5·21	6·70	6·45	6·03	6·88
Maximum	0·970	0·980	0·565	1·205	0·606	0·767	0·736	0·806	1·205
Minimum	0·322	0·532	0·369	0·295	0·278	0·305	0·312	0·278	0·278

NOTE.—The maximum and minimum depths refer to the mean monthly flows.

Table 11.—Estimated Equivalent Depth in Inches on the Drainage Area, of the Monthly Discharge of the Winnipeg River at Kenora.

[Drainage area, 26,400 square miles.]

Month.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	Mean.
January	0·515	0·839	0·436	0·540	0·33[illegible]	0·243	0·505	0·354	0·467
February	0·444	0·720	0·397	0·466	0·281	0·229	0·378	0·334	0·406
March	0·465	0·758	0·477	0·623	0·299	0·263	0·335	0·451	0·455
April	0·435	0·715	0·469	0·936	0·389	0·265	0·363	0·411	0·496
May	0·488	0·807	0·482	1·078	0·383	0·234	0·803	0·538	0·608
June	0·592	0·966	0·498	0·925	0·378	0·230	0·850	0·789	0·652
July	0·641	0·953	0·518	0·712	0·383	0·213	0·65[illegible]	0·870	0·615
August	0·556	0·887	0·541	0·589	0·349	0·237	0·658	0·796	0·571
September	0·723	0·770	0·505	0·497	0·284	0·229	0·551	0·572	0·517
October	0·908	0·671	0·524	0·445	0·260	0·425	0·357	0·504	0·512
November	0·892	0·512	0·508	0·371	0·237	0·465	0·342	0·419	0·472
December	0·862	0·462	0·521	0·354	0·242	0·503	0·352	0·430	0·466
The Year	7·49	9·09	5·84	7·50	3·81	3·59	6·12	6·45	6·24
Maximum	0·908	0·966	0·524	1·078	0·383	0·503	0·850	0·870	1·078
Minimum	0·435	0·462	0·397	0·354	0·237	0·213	0·335	0·331	0·213

Note.—The maximum and minimum depths refer to mean monthly flows.

Table 12.—Estimated Equivalent Depth in Inches on the Drainage Area, of the Monthly Discharge of the Rainy River at Fort Frances.

[Drainage area, 14,400 square miles.]

Month.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	Mean.
January	0·472	0·962	0·411	0·776	0·229	0·427	0·539	0·538	0·514
February	0·263	0·608	0·313	0·700	0·172	0·349	0·474	0·493	0·425
March	0·391	0·561	0·411	[illegible]	0·203	0·380	0·514	0·538	0·487
April	[illegible]	0·46[illegible]	0·252	0·8[illegible]2	0·234	[illegible]	0·497	0·519	0·441
May	0·487	0·636	0·338	0·850	0·30[illegible]	0·43[illegible]	0·531	0·531	[illegible]
June	0·591	0·886	[illegible]	[illegible]	0·445	0·46[illegible]	0·554	0·656	[illegible]
July	1·019	1·04[illegible]	[illegible]	0·53[illegible]	0·318	0·616	1·011	0·839	[illegible]
August	[illegible]	[illegible]	0·850	0·423	0·526	0·651	[illegible]	0·805	[illegible]
September	[illegible]	0·842	[illegible]	0·491	0·464	[illegible]	0·825	0·75[illegible]	[illegible]
October	1·581	0·776	[illegible]	0·410	0·448	0·572	[illegible]	0·784	[illegible]
November	[illegible]	0·582	0·419	[illegible]	0·419	[illegible]	[illegible]	[illegible]	0·621
December	1·032	0·457	0·80[illegible]	0·345	[illegible]	0·504	0·59[illegible]	0·721	0·606
The Year	10·79	8·83	6·68	7·30	4·27	5·91	6·82	7·9[illegible]	7·32
Maximum	1·581	1·047	0·850	0·862	0·526	0·651	1·011	0·839	1·581
Minimum	0·263	0·457	0·252	0·345	0·172	0·349	0·474	0·493	0·472

Note.—The maximum and minimum depths refer to mean monthly flows.

REPORT

ON

THE WINNIPEG RIVER POWER AND STORAGE INVESTIGATIONS

CHAPTER IV.

STORAGE

CHAPTER IV.

STORAGE.

An accurate analysis of the storage situation in the Winnipeg River basin, covering both the conditions which have held during past years and the conditions which theoretically might have been maintained under a properly supervised control is, in view of the character and scarcity of the data on which the study must be based, a matter of some difficulty.

The discharge data which are available for the study of the run-off consist principally of records at Slave falls, Kenora, and Fort Frances, continuous since the beginning of 1907.

These discharge records do not represent the run-off under natural conditions in the basin. The stations record measurements which are influenced to a greater or less extent by the storage in, and draw from, the Lake of the Woods and Rainy lake. They will, however, furnish a fairly satisfactory basis on which to found a storage policy. Continuous gauge records of the surface level on both these lakes are available for reference throughout the period. While run-off records are published in Appendix VII for the years 1907-14, inclusive, the seven-year period from 1907-13 is considered in connection with certain analyses herein. The records for 1914 were not available in time to permit a revision of these calculations. The deductions drawn in such cases are not, however, to any appreciable degree, affected by the omission of the 1914 records.

Natural reservoirs available throughout the basin largely simplify the question of regulating the river in a satisfactory manner. The distribution of these possible sources of storage is on the whole favourable to a fairly complete measure of river control, although certain areas, more especially in the western portion, are unprovided with suitable lake area.

It is possible to deal fairly definitely with the Lake of the Woods, Rainy lake, Lake Namakan, and certain of the smaller lakes, in so far as their capacities for storage are concerned, since definite information as to the banks, outlet facilities and possible flooding is to hand, or is now being secured. With regard to the majority of the lesser lakes it is only possible to treat the same in general terms since, as yet, no systematic study of their capacities has been made.

Throughout the following study of the storage question, it will be necessary to refer continuously to the lesser lakes and to the general drainage and reservoir areas. The storage discussion is therefore prefaced by a summary of these lakes, together with their surface and tributary drainage areas.

Lake and Drainage Areas of the Winnipeg Watershed.

In consequence of the Winnipeg River basin lying in the two provinces of Manitoba and Ontario, and also of the southern portion lying in the United States, it was difficult to secure a uniform plan covering the entire watershed. Various large-scale maps were available covering different sections, but co-ordination was necessary before a suitable working plan for the whole was available.

The topographic maps of the Rainy and English River districts published by the Dominion Government were taken as the basic foundation of a new plan, since they contained the best and most complete information extant covering the major part of the basin, and were, in addition, published to a convenient scale. Such sections of the watershed as were not included on these two sheets were taken by pantograph from the best obtainable published maps of Manitoba and Minnesota, the pantograph work being carefully checked by means of the lines of latitude and longitude. The completed plan is published herein as plate 3. In order to simplify the study of the natural reservoirs and their relation to the drainage system, plate 19, a diagrammatic representation of the watershed, has been prepared.

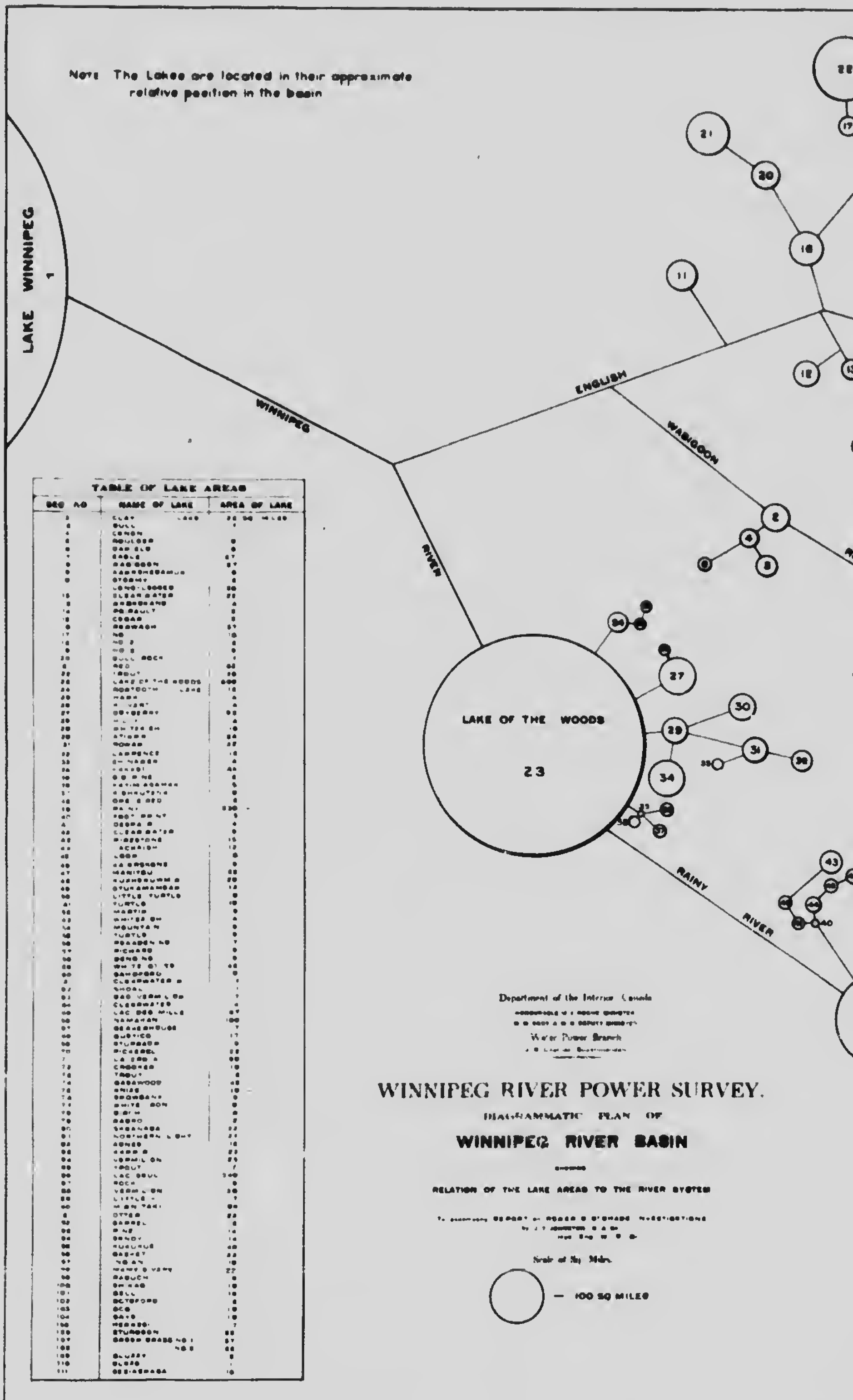
The lake areas have been taken off the best available published maps by planimeter. In view of the usually irregular character of the shore lines, and of the almost innumerable islands and islets, as well as of the incomplete character of the surveys of a number of these lakes, the areas published herein cannot be considered as entirely accurate. The areas are, however, sufficiently close to permit a general discussion of the use of the lakes as storage basins. Whenever larger scale plans of the lesser lakes were available, they were used for securing areas in preference to the smaller scale topographic plans. The larger lake areas can be considered as fairly accurate.

The above remarks apply equally to the drainage area as a whole and to the lesser basins adjacent to the lesser lakes. The boundaries of these latter sub-basins can be only approximated from the general direction of the run-off as shown on the plans. The areas are therefore used only for drawing general conclusions. All areas have been carefully checked, and the sub-areas adjusted.

The areas used throughout the report are given hereunder in tables 13, 14, 15, 16, 17, and 18. Table 13 lists the more important drainage areas useful for reference and use in considering the run-off of the watershed.

Table 13.—Principal Areas of the Winnipeg River Watershed.

River.	Limits.	Area in square miles.	Remarks.
1	2	3	4
Winnipeg river	Above mouth	53,536	
" "	Above Otter falls	50,548	Otter falls was the original metering station.
" "	Above Slave falls	49,677	Slave falls is the present metering station.
" basin	Above English river	49,096	Including English river.
" river	Above English river	27,522	Omitting English river.
" "	Above Kenora	26,393	Lake of the Woods basin.
Rainy river	Above Fort Frances	14,387	Rainy Lake basin.
" "	Above Kettle falls	7,056	Namakan Lake basin.
English river	Above mouth	21,573	
" "	Above Lac Seul	11,728	Lac Seul basin.



Note The Lakes are located in their approximate relative position in the basin
LAKE WINNIPEG
1
WINNIPEG
RIVER
ENGLISH
WABIGOON
RAINY
RIVER
LAKE OF THE WOODS
23
TABLE OF LAKE AREAS
REG. NO. | NAME OF LAKE | AREA OF LAKE
Department of the Interior, Canada
Water Power Branch
WINNIPEG RIVER POWER SURVEY.
DIAGRAMMATIC PLAN OF
WINNIPEG RIVER BASIN
SHOWING
RELATION OF THE LAKE AREAS TO THE RIVER SYSTEM
Scale of Sq. Miles.
— 100 SQ MILES

PLATE No. 19

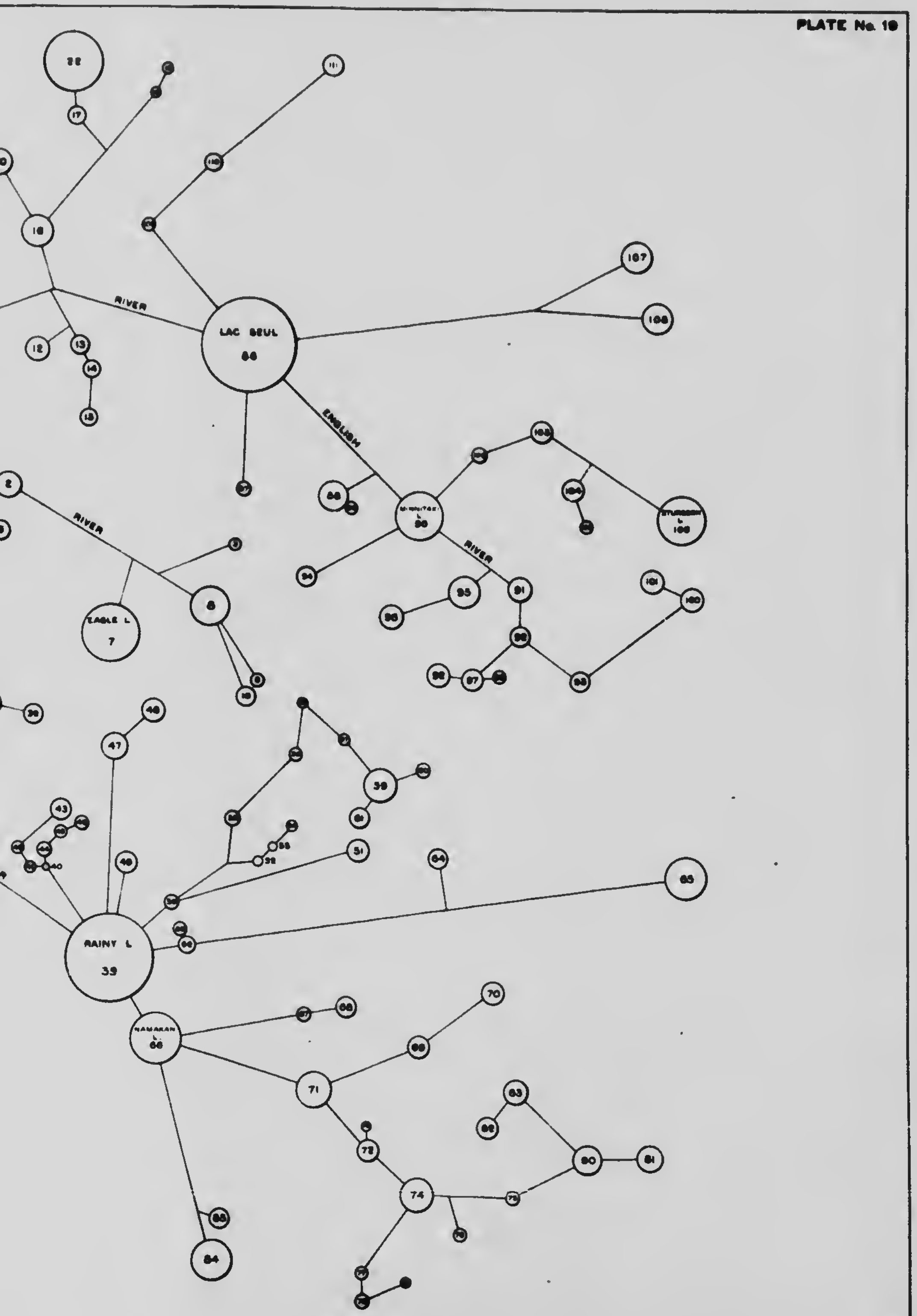

LAC SEUL
RIVER
ENGLISH
RIVER
RIVER
EAGLE L
7
RAINY L
39
NAMAKAN L
66

Table 11. Storage Possibilities of the Wisconsin River

Table 14 — Storage Possibilities of the Winnipeg River Watershed in the Lakes tributary to the Lake of the Woods and below Rainy Lake.

	BASIN.						RESERVOIR.					
No.	Lake or River.	Area in Square Miles. To Outlet of	Area in Square Miles. Adjacent Area.	Area in Square Miles. Total.	Run-off in Average Year. Sec.-ft.	Run-off in Average Year. Bills. of Cu. ft.	Name.	Area in Square Miles.	Area in Square Miles. Total.	Depth of Storage in feet to hold one average year's run-off.	Billions of cubic feet in Lake assuming 5 ft. Storage	Remarks.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13
6·0	Winnipeg River.	Lake of the Woods		[4]26,393	13,600	429·00	Lake of the Woods		1,500	15·25	200·20	[4]Total area above Kenora
6·1	Dogtooth Lake.	Dogtooth Lake..		134	69	2·18	Dogtooth Lake	15				
							[2]Hawk Lake	4				
							[2]Kilvert Lake	4	21	3·72	[3]2·18	[3]3·72 feet storage.
6·2	Dryberry Lake	Dryberry Lake .		246	127	4·00	Dryberry Lake	43				
							Hills Lake	4	47	3·05	[3]4·00	[3]3·05 feet storage.
6·3	Whitefish Lake		[1]144		74	2·34	Whitefish Lake		19	4·42	[3]2·34	[3]4·42 feet storage.
6·31	Atikwa Lake.	Atikwa Lake..	[1]192		99	3·12	Atikwa Lake .		24	4·66	[3]3·12	[3]4·66 feet storage.
6·32	Rowan Lake	Rowan Lake	[1]351		181	5·71	[2]Rowan Lake	22				
							[2]Lawrence Lake.	13				
							Shunawak Lake	4	40	5·24	5·44	
6·33	Kakagi Lake..	Kakagi Lake .	[1]112		58	1·82	[2]Kakagi Lake.		44	1·48	[3]1·82	[3]1·48 foot storage.
6·3	(Total).....			799	412	12·99						
6·4	Big Pine Lake	Big Pine Lake		145	75	2·36	[2]Big Pine Lake	2				
							[2]Kattimagamak Lake.	5				
							[2]Kishkutena Lake.	6				
							[2]One Sided Lake	3	16	5·28	2·33	

[1]Drainage areas immediately adjacent to lakes listed in column 3.
[2]These lake areas are taken from large scale maps.
[3]Average year's run-off equivalent to less than 5 feet on the reservoir area.
The results in column 11 are based on an average annual run-off of 7 inches.

Table 15.—Storage Possibilities of the Winnipeg River Watershed in the Lakes tributary to Rainy Lake and below Lake Namakan.

	BASIN						RESERVOIR					
No.	Lake or River.	Area in Square Miles. To Outlet of	Area in Square Miles. Adjacent Area.	Area in Square Miles. Total.	Run-off in Average Year. Sec.-ft.	Run-off in Average Year. Bills. of cu. ft.	Name.	Area in Square Miles.	Area in Square Miles. Total.	Depth of Storage in feet to hold one average year's run-off.	Billions of cubic feet in Lake, assuming 5 ft. Storage.	Remarks.
1.	2.	3.	4	5.	6.	7.	8	9	10	11	12	13
7·0	Rainy River	Rainy Lake		[1]14,487	7,420	233·80	Rainy Lake		330	25·40	46·01	[1]Total area above Rainy Lake.
7·1	Footprint Lake	Footprint Lake		378	195	6·14	[2]Footprint Lake	3				
							[2]Despair Lake	4				
							[2]Clearwater Lake	6				
							[2]Pipestone Lake	13				
							[2]Jackfish Lake	12				
							[2]Loon Lake	8				
							[2]Katarskons Lake	9	57	3·87	36·14	[illegible] feet storage.
7·2	Manitou Lake	Manitou Lake		361	188	5·92	[2, 3]Manitou Lake	28				10 feet storage permissible.
							[2]Auxbekummun Lake	20	48	4·42	35·92	4·42 feet storage.
7·3	Otukamamoan Lake.	Otukamamoan Lake.		438	226	7·12	[3]Otukamamoan Lake	17	17	15·02	2·37	40 ft. storage permissible
7·4	Turtle River	Little Turtle Lake	[1]669		345	10·87	[2]Little Turtle Lake	9				
							[2]Turtle Lake	19	28	13·94	3·91	
7·41	Turtle River	Martin Lake	[1]138		71	2·24	[2]Martin Lake	5				
							[2]Whitefish Lake	4				
							[2]Mountain Lake	5	14	8·75	1·95	
7·42	Turtle River	Turtle Lake	[1]559		288	9·09	[2]Turtle Lake	8				
							[2]Pekagoning Lake.	7				
							Richard Lake	5				
							Bending Lake	5	[illegible]	13·03	3·49	
7·43	Turtle River	White Otter Lake.	[1]303		157	4·93	[2, 3]White Otter Lake.	12				7 ft. storage permissible.
							[2]Sandford Lake	10	52	[illegible]	1·93	3·49 feet storage
7·44	Turtle River	Clearwater West Lake.	[1]107		85	1·74	[2]Clearwater West Lake		17	3·68	1·74	[3]68 feet storage
7·4	(Total)			1,776	916	28·87						
7·5	Seine River	Shoal Lake	[1]1,611		831	26·22	[2]Shoal Lake	11				
							[2]Red Vermilion Lake.	7	18	52·20	3·51	
7·51	Seine River.	Clearwater Lake	[1]110		57	1·79	[2]Clearwater Lake		14	4·8	1·79	5·8 feet storage.
7·52	Seine River	Lac des Milles Lacs	[1]682		351	11·09	[2]Lac des Milles Lacs		67	5·94	9·35	4 ft. storage permissible
7·5	(Total)			2,403	1,239	39·10						

[1]Drainage areas immediately adjacent to lakes in column 3.
[2]These lake areas are taken from large scale maps.
[3]Average year's run-off equivalent to less than 5 feet on the reservoir.
The results in column 11 are based on an average annual run-off of 7 inches.

Table 16.—Storage Possibilities of the Winnipeg River Watershed in the Lakes tributary to Lake Namakan.

BASIN							RESERVOIR					
No.	Lake or River.	Area in Square Miles. To Outlet of	Adjacent Area.	Total.	Run-off in Average Year Sec.-ft.	Run-off in Average Year Bills. of Cu.-ft.	Name.	Area in Square Miles.	Area in Square Miles. Total.	Depth of Storage in feet to hold one average year's run-off.	Billions of cubic feet in Lake, assuming 5 ft. Storage.	Remarks.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
8·0	Rainy River	Namakan Lake		[5]7,050	3,638	114·75	Namakan Lake		[2]100	41·10	13·94	[5]Total area above Lake Namakan
8·1	Beaverhouse Lake	Beaverhouse Lake		[illegible]	184	5·80	Beaverhouse Lake	7				
8·2	Maligne River	Sturgeon Lake					[2]Quetico Lake	17	24	8·67	4·35	
8·21	Maligne River	Pickerel Lake			195	3·32	[2]Sturgeon Lake		19	6·26	2·65	
8·2	(Total)				22?	7·01	[2]Pickerel Lake		23	10·92	3·21	
8·3	Rainy River	La Croix L.		6??	327	10·33						
8·31	Rainy River	Crooked L.			256	8·08	La Croix Lake		50	5·80	6·98	
					1?8	5·53	Crooked Lake	19				
8·32	Rainy River	Basswood L.					Trout Lake	3	22	9·01	3·07	
					332	10·45	Basswood Lake	13				
							Knife Lake	10				
8·33		White Iron Lake					Snowbank Lake	6	59	6·36	8·22	
					600	18·94	White Iron Lake	6				
							Birch Lake	10				
8·34							Gabbro Lake	5	21	42·45	2·93	
		Saganaga Lake	[1]5,[illegible]		767	24·20	Saganaga Lake	32				
							Northern Light Lake	27				
							Agnes Lake	18				
							[2]Kawnipi Lake	34	97	8·94	13	
8·3	(Total)			4,133	2,130	67·20						
8·4		Vermilion Lake		6?1	328	10·26	Vermilion Lake	63				
							Trout Lake	12	75	4·91	[4]10·26	[4]4·91 feet storage

[1]Drainage areas immediately adjacent to lakes listed in column 3.
[2]These lake areas are taken from large scale maps.
[3]This area includes lakes Namakan, Sand Point, Kabetogama, Crane and Little Vermilion.
[4]Average year's run-off equivalent to less than 5 feet on the reservoir area.
The results in column 11 are based on an average annual run-off of 7 inches.

Table 17.—Storage Possibilities of the Winnipeg River Watershed in the Lakes tributary to the English River below Lac Seul.

Basin: No.	Basin: Lake or River.	Basin: Area in Square Miles: To Outlet of	Basin: Area in Square Miles: Adjacent Area.	Basin: Area in Square Miles: Total.	Basin: Run-off in Average Year: Sec.-ft.	Basin: Run-off in Average Year: Bills. of Cu. ft.	Reservoir: Name.	Reservoir: Area in Square Miles: —	Reservoir: Area in Square Miles: Total.	Reservoir: Depth of Storage in feet to hold one average year's run-off.	Reservoir: Billions of cubic feet in Lake, assuming 5 ft. Storage.	Remarks.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
4·0	English River	Mouth		[4]21,574	11,120	351·00						[4]Total area above mouth.
4·1	Wabigoon River	Clay Lake	[1]893		460	14·52	Clay Lake	23				
							Gull Lake	7	30	17·35	4·18	
4·11	Canon River	Canon Lake	[1]343		177	5·58	Canon Lake	11				
							[3]Boulder Lake	15				[3]Includes lesser lakes.
							Daniels Lake	6	32	6·25	4·40	
4·12	Eagle River	Eagle Lake	[1]949		489	15·43	[2]Eagle Lake		127	4·36	[3]15·43	[3]4·36 feet storage.
4·13	Wabigoon River	Wabigoon Lake	[1]1,019		525	16·58	[2, 3]Wabigoon Lake	57				[1]With Dinorwic Lake.
							[2]Kawashegamuk Lake	6				
							[2]Stormy Lake	12	77	7·72	10·73	
4·1	(Total)			3,204	1,651	52·11						
4·2	Long-legged River	Long-legged Lake		235	121	3·82	Long-legged Lake		30	4·57	[3]3·82	[3]4·57 feet storage.
4·3	Cedar River	Clearwater Lake		156	80	2·54	Clearwater Lake		22	4·13	[3]2·54	[3]4·13 feet storage.
4·4	Cedar River	Wabaskang Lake		581	299	9·45	Wabaskang Lake	14				
							Peirault Lake	12				
							Cedar Lake	12	38	8·91	5·30	
4·5	Red Lake River	Pakwash Lake	[1]822		424	13·36	Pakwash Lake	37				
							Lake No. 1	10				
							Lake No. 2	3				
							Lake No. 3	5	55	8·71	7·67	
4·51	Red Lake River	Gull Rock Lake	[1]269		139	4·37	Gull Rock Lake		27	5·81	3·77	
4·52	Red Lake River	Red Lake	[1]1,052		542	17·10	Red Lake		62	9·90	8·65	
4·53	Trout Lake River	Trout Lake	[1]418		215	6·80	Trout Lake		135	1·81	[3]6·80	[3]1·81 foot storage.
4·5	(Total)			2,561	1,320	41·63						

Drainage areas immediately adjacent to lakes listed in column 3.
[2]These lake areas are taken from large scale maps.
[3]Average year's run-off equivalent to less than 5 feet on the reservoir area.
The results in column 11 are based on an average run-off of 7 inches.

Table 18.—Storage Possibilities of the Winnipeg River Watershed in the Lakes tributary to the English River above Lac Seul.

BASIN.							RESERVOIR.					
No.	Lake or River	Area in Square Miles. To Outlet of	Adjacent Area.	Total.	Run-off in Average Year. Sec.-ft.	Bills. of Cu.-ft.	Name.	Area in Square Miles. —	Total.	Depth of Storage in feet to hold one average year's run-off.	Billions of cubic feet in Lake, assuming 5 ft. Storage.	Remarks.
1.	2.	3.	4	5.	6.	7.	8.	9.	10.	11.	12.	13.
9·0	English River	Lac Seul		[4]11,728	6,048	190·70	Lac Seul		340	20·10	47·42	[4]Total area above Lac Seul.
9·1	Rock Lake	Rock Lake		128	66	2·08	[2]Rock Lake		9	8·30	1·25	
9·2	Vermilion Lake	Vermilion Lake		179	92	2·91	[2]Vermilion Lake	30				
							[2]Little Vermilion Lake	7	37	2·82	[3]2·91	[3]2·82 feet storage.
9·3	English River	Minnitaki Lake	[1]2,434		1,255	39·61	[2]Minnitaki Lake	94				
							[2]Otter Lake	22				
							Barrel Lake	13				
							Pine Lake	14	143	9·93	[3]19·95	
9·31	Sandy Lake	Sandy Lake	[1]101		52	1·63	[2]Sandy Lake		14	4·21	1·63	[3]4·21 feet storage.
9·32	Kukukus Lake	Kukukus Lake	[1]240		124	3·90	[2]Kukukus Lake	40				
							[2]Basket Lake	23	63	2·22	[3]3·90	[3]2·22 feet storage.
9·33	Indian Lake	Indian Lake	[1]349		180	5·67	Indian Lake	18				
							Maneigivers Lake	22				
							Paguchi Lake	8	48	4·24	[3]5·67	[3]4·24 feet storage.
9·34	English River	Shikag Lake	[1]299	. .	154	4·86	Shikag Lake	19				
							Bell Lake	19	38	4·59	[3]4·86	[3]1·59 feet storage.
9·3	(Total)			3,423	1,765	55·67						
9·4	Sturgeon River	Botsford Lake	[1]957		493	15·55	[2]Botsford Lake	8				
							Dog Lake	19	27	20·63	3·77	
9·41	Lake of Bays	Lake of Bays	[1]205		106	3·33	[2]Lake of Bays	18				
							Penassi Lake	7	25	4·78	[3]3·33	[3]4·78 feet storage.
9·42	Sturgeon River	Sturgeon Lake	[1]477		246	7·76	Sturgeon Lake		92	3·02	[3]7·76	[3]3·02 feet storage.
9·4	(Total)			1,639	845	26·64						
9·5	Green Grass Lake	Green Grass Lake		572	295	9·30	Green Grass Lake No. 1	37				
							Green Grass Lake No. 2	33	70	4·76	[3]9·30	[3]4·76 feet storage.
9·6	Wenasaga River	Bluffy Lake	[1]251		129	4·08	Bluffy Lake		6	24·38	0·84	
9·61		Slate Lake	[1]161		238	7·50	Slate Lake		11	24·43	1·53	
9·62		Seskenaga Lake	[1]236		122	3·84	Seskenaga Lake		16	8·60	2·23	
9·6	Total			948	489	15·42						

[1]Drainage areas immediately adjacent to lakes listed in column 3.
[2]These lake areas are taken from large scale maps.
[3]Average year's run-off equivalent to less than 5 feet on the reservoir.
The results in column 11 are based on an average annual run-off of 7 inches.

Table 14 groups the lakes and drainages tributary to the Lake of the Woods and below Rainy lake; table 15 those tributary to Rainy lake and below lake Namakan; 16 those tributary to lake Namakan; 17 those tributary to the English river below Lac Seul; and 18 those tributary to Lac Seul.

In these tables, columns 2 to 7 refer to drainage basins. Column 1 lists the number which has been used to designate the drainage basin; the decimal system has been used to permit future expansion without interfering with the series. Column 2 designates the drainage basin, while column 3 gives the limits considered in each case; column 4 lists the area immediately adjacent to the basin designated and defined in columns 2 and 3; column 5, the total drainage area of the basin designated and defined in columns 2 and 3; column 6, the run-off in cubic feet per second for an average year, from the areas of columns 4 and 5; column 7, the same run-off in billions of cubic feet. Columns 8 to 12 refer to the reservoirs available to store the run-off from the basins defined in columns 2 and 3; column 8 lists the name of the reservoir. It will be noted that at times several lakes are taken in the one basin. Column 9 lists the individual lake area, and column 10 the totals of the areas where more than one are taken in the same basin. Column 11 lists the depth in feet to which an average year's total run-off (equivalent to 7 inches) from the drainage areas of columns 4 and 5 would fill the lakes, assuming no run-off at the outlet during the period. It will be noted that where more than one lake has been considered in one basin, the depth is given in terms of the total lake area. This is not strictly in accordance with what would be experienced in actual practice, as the lakes are not, as a rule, distributed in such a way as to collect the run-off uniformly. It, however, serves the purpose for general discussion. Column 12 lists the volume of storage in billions of cubic feet which would be provided by 5 feet of storage on the lakes, or by such depth as would store an average year's run-off.

It should be noted that a large number of smaller lakes are not included in the tabulation.

The entire watershed is well supplied with lakes, the use of which for storage purposes will well repay investigation. These lakes naturally and with good effect play their part in regulating the yearly run-off. Comparatively little expenditure is necessary to convert many of them into reservoirs of greater or less capacity. At the outlets of many lakes, lumber dams have been constructed in the past, of which some are yet in operation, and others have been allowed to fall into decay. It was beyond the scope of the general storage investigation carried on by the Dominion Water Power Branch to make any detail study of these lesser lakes. A certain amount of information has, however, been collected by the Hydro-electric Power Commission of the province of Ontario with regard to some of the more important lakes. The following quotations have been taken direct from the Sixth Annual Report of this commission, covering the year ending October 31, 1913:

[1]ONTARIO HYDRO-ELECTRIC POWER COMMISSION REPORT 1913.

"*Manitou lakes.* The drainage area of these lakes is about 446 square miles, and the area of the lakes themselves is about 66 square miles.

"A storage draft of 7 feet off these lakes would provide approximately 13,000 million cubic feet of storage, which would probably be more than sufficient to control the entire mean annual run-off of the tributary watershed.

"At present there is a government dam at the foot of the lower lake that would hold a storage head of 9·9 feet if it were in good condition.

"The shores of the lake are for the most part rock, with large patches of good jack pine here and there, but this is all well up from the lake. The present dam did practically no damage to timber, and the damage caused by a dam that would raise the water 3 feet higher than at present would be very small.

"The sill of the log chute of the present dam is sufficiently low to let the water run as low as the controlling ledge at Cedar rapids, which is above the dam. The present dam had the stoplogs in when the dam was inspected, but it was leaking about 150 second-feet, partly through and partly underneath. A cross-section parallel and similar to the one taken exists 50 feet below the present dam.

"No building sand was observed on this lake. The buildings around the lake are high enough to permit of a rise of 3 feet above high-water mark. These are only log shacks, not used at present.

"The present dam is not built on solid rock, but the banks of the river are solid rock, with large boulders and gravel bottom in the river-bed.

"The lumbermen who remembered this dam from its installation had never known the lake to be filled to the top of the dam.

"*Otukamamawan lake.* The drainage area of the lake above a possible dam site is about 500 square miles and the area of lake surface above this site is about 18 square miles.

"A dam at this point holding 30 feet of water on the sills would impound a run-off of 12 inches from the tributary watershed. This figure is probably greater than the actual mean annual run-off.

"There is evidence at the outlet of the lake to show that there existed at one time a small dam probably holding a 2- or 3-foot head of water, but no impounding action is caused by the fragments which now remain.

"The foundations at this point are all solid rock. There is a controlling rock ledge at the outlet which is only 1·5 feet below present water level, and which would necessitate keeping all the storage head above this level unless the ledge was blown out.

"There is sand of good quality on the shores of the lake at various points; and also gravel, but the surface gravel is not free from dirt.

"The shores of the lake have, as a general rule, steep slopes and

[1]The data in connection with the Manitou, Otukamamawan, Lac des Mille Lacs, Wabigoon and [illegible] water lakes have been quoted directly from the Sixth Annual Report of the Hydro-Electric Power Commission of the Province of Ontario.

in many places are precipitous, but there is nevertheless some good pine of tie size and larger that would suffer damage by flooding. This is confined, however, to a very narrow strip parallel to the water line.

"The map used of this lake shows all the islands, as far as could be judged, except the very small ones. This lake is sometimes called Trout lake. A 30-foot rise in level on this lake would add very little to its area.

"*Lac des Milles Lacs.* The drainage area of this lake is about 620 square miles, and the area of the lake surface is 90 square miles.

"Assuming 4 feet of storage draught available through raising the level and deepening the outlet, this lake would have an impounding capacity of about 10,000 million cubic feet. This volume of storage would be provided by a mean annual run-off of 7 inches from the tributary watershed.

"The raising of the level of this lake to any great extent will drown large tracts of muskeg, but without serious damage to timber, most of the low-lying timber being tamarack, which is still alive but not liable to damage by flooding. The valuable timber on the lake stands sufficiently high to be outside of any possible flooded area.

"The lumber camps on the lake are of no value.

"Damage to property by raising the level of this lake would occur at two places:

"(1) *Hogans' Mill.* Hogan Brothers, of Savanne, are the owners of most of the timber limits on the lake, and are the proprietors of a large saw-mill on the lake shore 2 miles west of Savanne station, on the Canadian Pacific railway. The saw-mill is fully equipped with a complete outfit for lumber, lath, and shingles, and is connected by a mile spur line to the Canadian Pacific railway, besides having more than half a mile of track through the piling yard. There is a bush road from Hogans' mills to Savanne.

"An increase of 3·5 feet over the present level of the lake would not damage the mill. Any higher level than this would affect the boiler room of the mill and also the piling yard track, and a 500-foot wharf and storehouse.

"The other buildings, residences, storehouses, offices, etc., belonging to the mill are all between 10 and 12 feet above the level of the lake.

"(2) *At Savanne.*—Taking the level of the lake as 100, the elevations of buildings and railway at Savanne are given below:—

Canadian Pacific Railway, bridge over creek	Base of rail	110·9
	Bottom of girder	107·7
F. Edward's store and post office	Floor elevation	105·0
	Cellar floor elevation	101·0
	Floor of warehouse elevation	103·0
	Two barns	103·0
Ice-house	Elevation of floor	102·5
Station lavatories	Elevation of floor	103·0
Other Canadian Pacific Railway buildings, station, tool houses, section house, etc.	Elevation of floors	108–110
Road bridge 150 feet long	Elevation of floor	103·8
Canadian Pacific Railway track, 1 mile each side of the river to rising grade	Base of rail	110·9
Six frame and log houses	Elevation of floors	104–105
One log house south of Canadian Pacific Railway track	Elevation of floor	104·5

"The above list includes all the habitable or used buildings at

Savanne. The buildings on the Indian reserve are all above any possible flood level. The residents at Savanne state that the river level varies a foot in elevation with changes in the wind. Some of the above-mentioned houses have cellars which are at present below the ordinary spring flood level.

"The muskeg surrounding that branch of the river passing under the Canadian Pacific Railway bridge extends $2\frac{1}{2}$ miles north of the Canadian Pacific railway, at an elevation of 2 feet to 3 feet above the present level of the lake.

"*White Otter or Big Clearwater Lake.*—The drainage area of this lake above the present dam is about 320 square miles, and the area of the lake above the dam is about 50 square miles. With 7 feet of storage draught on this lake there would probably be more than sufficient capacity to impound the mean annual run-off of the tributary watershed.

"Within the last two years a dam has been erected at the outlet of this lake capable of holding at least 7 feet of water on the sills, but a controlling ledge of rock in the outlet just above the dam makes it doubtful if the lake could be drained as low as the sill.

"The timber on this lake is practically all above any damage from flood water. There are a few old lumber camps on the lake, but these are also above any possible storage level. There is a gully not far from the present dam that would permit the water to flow out before the water would rise to the crest of the present dam. There are several low places above the present dam without timber which would be flooded, but high ground is close in every case.

"*East Clearwater Lake.* The drainage area of the lake is about 75 square miles, and the area of the lake surface above the outlet is about 12·4 square miles.

"There is a storage dam at present at the lake which was built at the time of the installation of the power plant of the Hammond Reef Mine, some thousand feet below the dam.

"The dam is in good condition, though the sluice-gate screw-block is damaged and the gate has to be levered up and down. The dam is built of stone-filled cribs and well backed with dry masonry, all on rock foundations. The sluice-gate is a single steel plate, braced with angle steel, and was operated by a screw-block above the gate.

"The extreme high-water mark is below the level of the top of the dam, which has more than sufficient capacity to hold all the water delivered to the lake.

"The shores of the lake are steep sloping rock, with no good timber at all near the water-line."

The Outer Slave Falls Discharge Records.

The station at Slave falls measures the discharge from 49,700 square miles of drainage basin, and for all practical purposes can be taken as representing the flow which is available throughout the power reach of the river in Manitoba.

While the discharges from month to month are affected by the storage already in operation, and do not therefore represent natural conditions or furnish a correct estimate of the actual run-off from the basin for any one month, they nevertheless balance up satisfactorily in the seven-year cycle.

MAINTENANCE OF THE SEVEN YEAR MEAN FLOW.

The mean monthly flow for the seven-year period from 1907 to 1913, inclusive, was 25,855 second-feet. It will be illuminative of the general conditions of run-off to look into what would have been involved in the maintenance of this mean flow throughout the cycle, had the means for storage been available. To this end, plate 20 has been prepared.

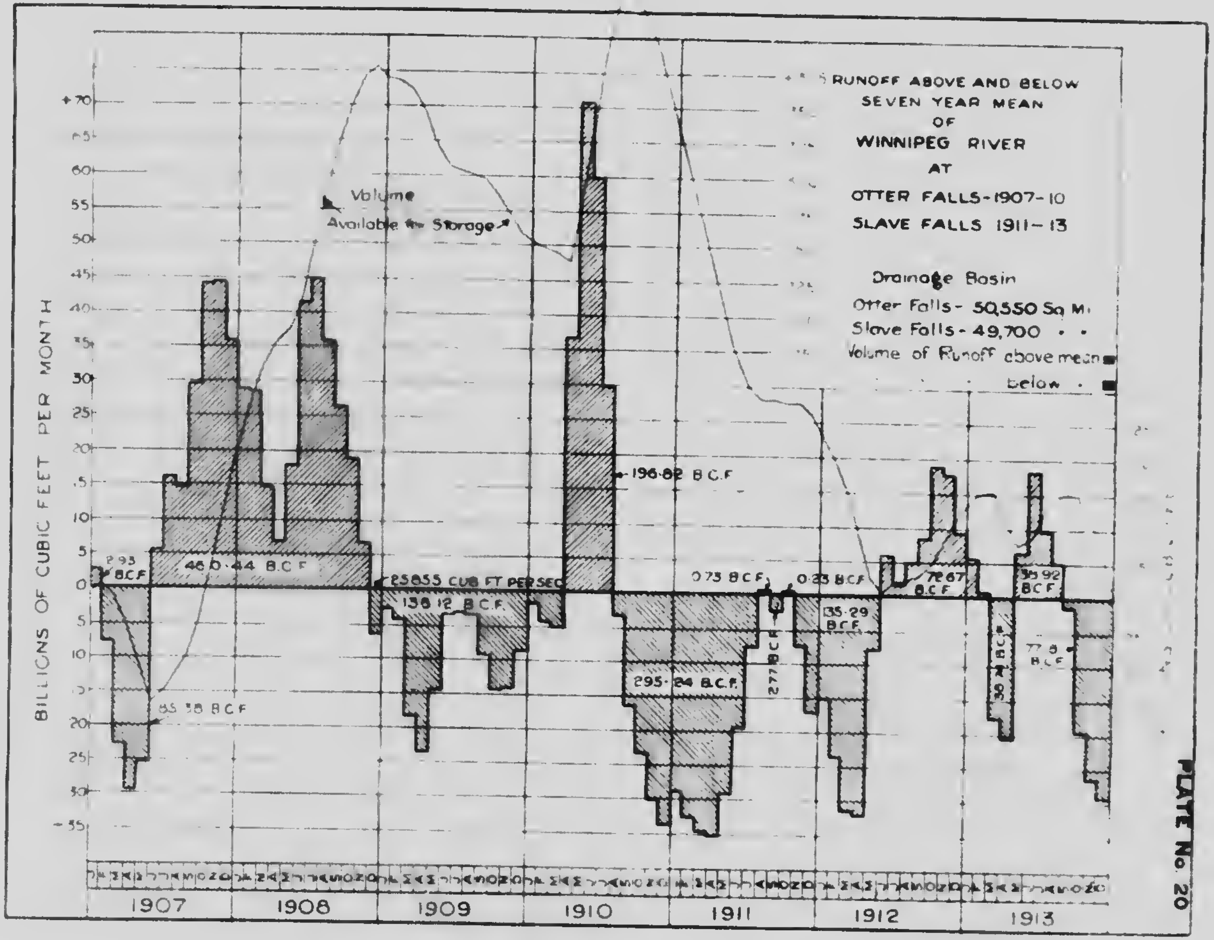
Little explanation of plate 20 is required. The monthly volumes of discharge in billions of cubic feet are plotted above and below the mean 25,855 second-foot line. The continuous volume available from month to month from the beginning of the period is plotted as a curve referred to the scale to the right of the diagram.

During the earlier portion of the year 1907, as might naturally be anticipated, a deficit of some 85 billions of cubic feet occurs between January 31 and May 31. To make this good would have necessitated drawing storage from the preceding year. Following May 31 comes a prolonged period of high run-off in the river, the discharge in no place falling below the mean until November 30, 1908. At this date the volume available for storage purposes from the commencement of the period amounted to 378 billions of cubic feet over and above the mean flow, or 460 billions of cubic feet, assuming that the first deficit was made good from the previous year. Following November 30 is a period of low water lasting until March 31 of 1910, involving a draw of 138 billions of cubic feet from the available storage. The months of April, May, June, and July, 1910, show another period of surplus discharge, adding 197 billions to the preceding volume, and bringing the net total for storage to date up to 437 billions. Following July 31, there is a practically continuous draw until May 31, 1912, at which date the surplus from the beginning of the period is reduced to 4 billions of cubic feet. From this date until the end of 1913, there is an alternate rise and fall in the volume available, the same dropping to zero at the end of the cycle.

It is worthy of note that after the initial deficit is made good, there is at all times throughout the cycle a sufficient volume of water to maintain the uniform mean flow of 25,855 second-feet. The curve of available volume approaches close to the mean line in 1912, but falls below at only one point during the period, i.e., during the initial deficit. That there should have been throughout the entire period, with the single exception noted, sufficient water to maintain the uniform seven-year mean flow is due to the exceptionally heavy run-offs during the first years of the cycle. These full years are followed in 1911 by an exceptionally slack year, the riding over of which places a severe strain on the entire storage system.

The above analysis shows that storage reservoirs to the capacity of 437 billions of cubic feet would have been required to ensure a complete uniform flow during the seven years. Upon examining the basin, however, it will be

PLATE No. 20


RUNOFF ABOVE AND BELOW
SEVEN YEAR MEAN
OF
WINNIPEG RIVER
AT
OTTER FALLS-1907-10
SLAVE FALLS 1911-13
Drainage Basin
Otter Falls - 50,550 Sq. Mi.
Slave Falls - 49,700
Volume of Runoff above mean
below
BILLIONS OF CUBIC FEET PER MONTH
Volume Available for Storage
2.93 B.C.F.
460.44 B.C.F.
85.38 B.C.F.
25855 CUB FT PER SEC
138.12 B.C.F.
196.82 B.C.F.
0.73 B.C.F.
295.24 B.C.F.
2.77 B.C.F.
0.33 B.C.F.
135.29 B.C.F.
72.67 B.C.F.
30.4 B.C.F.
35.92 B.C.F.
77.8 B.C.F.
1907
1908
1909
1910
1911
1912
1913

noted that there are practically no reservoirs available in an area of about 3,800 square miles above Slave falls. This area in an average year would have a run-off of nearly 1950 cubic feet per second. Imperfect distribution of reservoirs to meet the full requirements of the run-off, together with the extensive area of the basin and the inaccessible nature of portions of it, also tend to prevent such regulation being attained

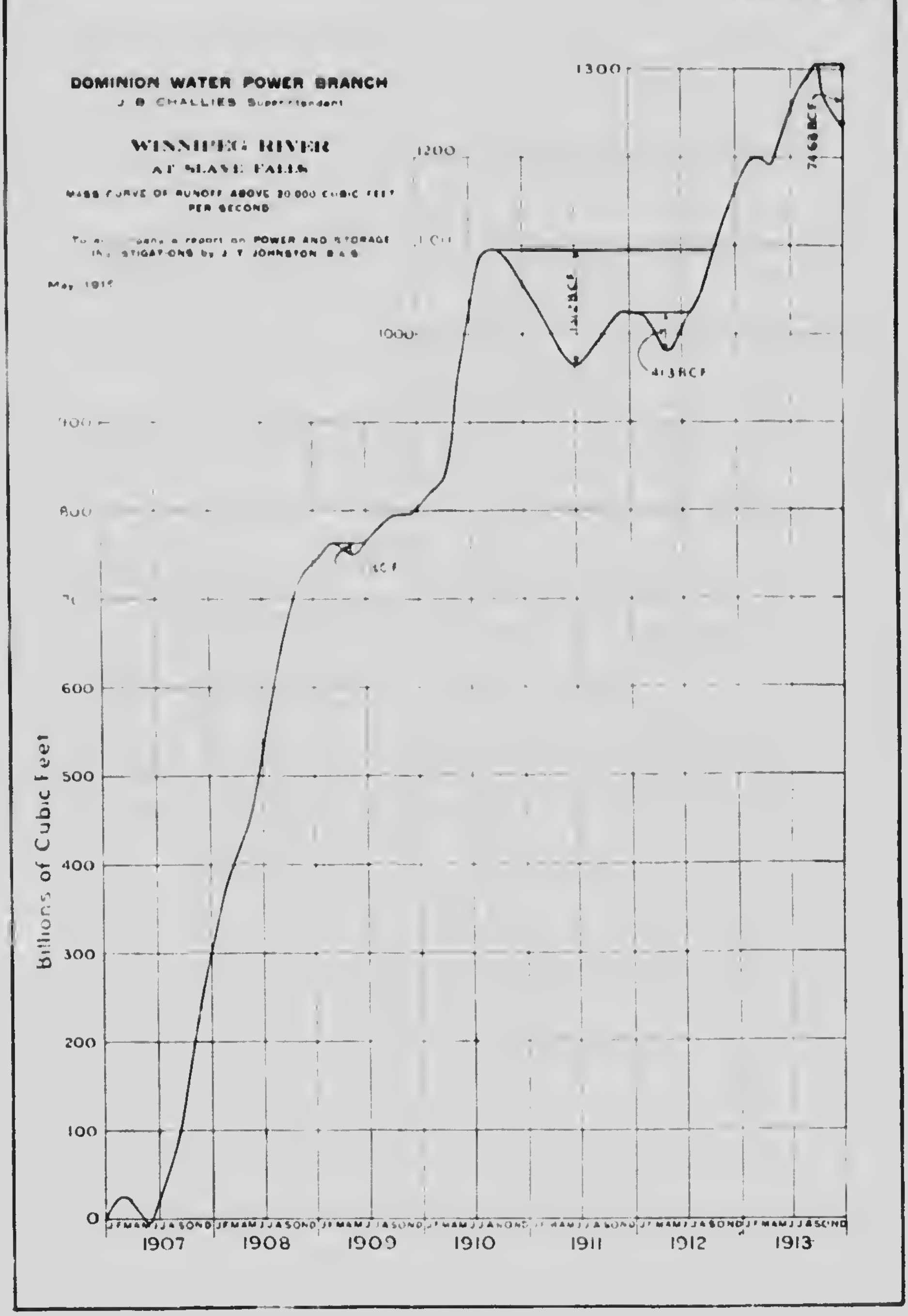
MAINTENANCE OF A 20,000 SECOND-FOOT MINIMUM FLOW.

The series of designs and estimates of the projected power plants along the river considered in this report, has been developed for an initial installation, based on a minimum flow of 12,000 cubic feet per second, such as is at present available on the river, and for a final installation based on a flow regulated to a minimum of 20,000 cubic feet per second. A full investigation into the questions involved in maintaining this latter flow is therefore desirable. The mass curve shown on plate 21 analyses this question.

Plate 21 is plotted by taking as abscissæ the time in months, and as ordinates the volume available for storage from month to month. The curve furnishes the following information as to discharge and storage conditions. The crests and hollows indicate the instants of time when the supply is exactly equal to the 20,000 second-foot demand. The rising portions of the curve indicate a surplus of supply over demand, while a falling portion indicates the reverse, the volume of such surplus or deficit between any two dates being secured by scaling off the ordinate between the same. A tangent drawn horizontally from any of the high points on the curve until it intersects the rising curve, measures the period during which the reservoir would be drawn below the high-water line, and the maximum ordinate drawn from such tangent to the curve indicates the necessary capacity of the reservoir to maintain the demand during the period. To ensure a full reservoir it is necessary that a parallel tangent drawn backwards from the low points shall intersect the supply curve at some point below.

At only one point throughout the seven-year period is there any insufficiency of water to maintain a 20,000 second-foot flow. A slight slack period occurs in May, 1907, and is due to the low winter flow during the earlier part of the year. Following this discrepancy is a continuous series of months to February, 1909, during which there is a surplus flow in the river, totalling 768 billions of cubic feet, all of which is available for storage. Two months slack water are again followed by ample discharge lasting until the end of August, 1910, and rendering available another 313 billions of cubic feet. Following this date comes the period of low water which calls for the most extensive storage provision in the seven-year cycle. By the end of June, 1911, the curve indicates that a continuous flow of 20,000 second-feet would require a draw on storage to the extent of 131 billions of cubic feet, while the water in the reservoirs would be drawn below highwater mark from August, 1910, until November, 1912, at which date the surplus flow available from April 1 of the latter year would be sufficient to make good the draw. For the balance of the period the run-off conditions are more uniform and the draws from storage less extensive. If the Lake of the Woods were immediately available for the

PLATE No. 21


DOMINION WATER POWER BRANCH
J. B. CHALLIES Superintendent
WINNIPEG RIVER
AT SLAVE FALLS
MASS CURVE OF RUNOFF ABOVE 30,000 CUBIC FEET PER SECOND
POWER AND STORAGE
JOHNSTON
Billions of Cubic Feet
0
100
200
300
400
500
600
800
1000
1200
1300
1907
1908
1909
1910
1911
1912
1913

disposal of the surplus run-off, sufficient storage for bridging the above critical period would be a simple matter, since 3·1 feet on the lake would supply the maximum draw, and would bridge the entire low-water period. The lake, however, can deal only with the waters from the basin above its outlets, and must, in addition, provide for power plants operating at its outlets.

Table 19 appended is of interest as showing to what extent storage would have been necessary to maintain various limiting minimum flows throughout the cycle. For the sake also of illustrating the capacity of the Lake of the Woods as a storage reservoir, the corresponding depths on the lake necessary to accommodate this storage for the different stages are also tabulated. As already stated, it is not possible to utilize the lake as advantageously as the table would indicate.

Table 19. Storage Conditions which would have been necessary to maintain various Minimum Flows on the Winnipeg River at Slave Falls from 1907 to 1913.

To ensure minimum flows in Sec. ft. of	Volume of Storage required in Billions of Cubic Feet	Depth in Feet on the Lake of the Woods to store Volumes in col. 2.	To ensure minimum flows in Sec. ft. of	Volume of Storage required in Billions of Cubic Feet.	Depth in Feet on the Lake of the Woods to store Volumes in col. 2.
1	2	3	1	2	3
13,000	4	0.07	20,000	128	3.06
14,000	16	0.34	21,000	168	4.02
15,000	32	0.77	22,000	222	5.31
16,000	48	1.15	23,000	272	6.50
17,000	65	1.55	24,000	325	7.78
18,000	80	1.91	25,000	420	10.04
19,000	107	2.56	26,000	540	12.92

To sum up, it may be said that the general run-off conditions in the power reach of the river would warrant the assumption that a fairly complete regulation of the river can be attained.

The Lake of the Woods.

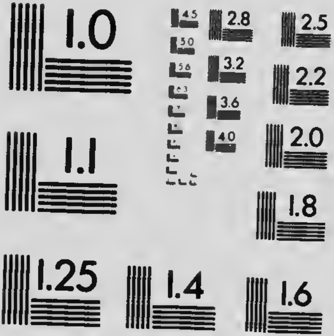
A glance at the drainage basin of the Winnipeg river (plate 3) immediately calls attention to the outstanding position of the Lake of the Woods. A study of the physical features of the basin emphasizes even more strongly the commanding position of the lake in relation to storage and power. This relation is somewhat complex and, in view of the conditions of regulation and control which have existed during the cycle over which records are available, its discussion requires careful analysis.

In the eight-year cycle over which records are available, there is a period of ample flow preceding a period of unusually low flow, thus forming a combination which readily lends itself to an effective study.

The manifest advantages of the lake as a reservoir have long been recognized by the power undertakings at the outlets. Since, however, the water utilized

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



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for power has at all times to the date of writing been considerably below the run-off available, careful conservation has hitherto been unnecessary. This condition is rapidly becoming a thing of the past. The development of hydro-electric plants on the lower river in Manitoba has already resulted in an urgent demand for auxiliary flow during the low months. Through the agency of the Dominion Water Power Branch a special arrangement was reached with the Ontario Government and the power users at the lake outlets, whereby the lake was drawn upon during the winter of 1913-14, and a critical power situation on the lower river thereby relieved. Similar conditions prevailed during the winter of 1914-15 necessitating a similar draw on the lake storage. Such demands for raising the minimum flow on the lower river will become more pressing in the immediate future. The Lake of the Woods is the logical first source of such storage supply, in that it is already existent as a storage basin, and is of adequate capacity to meet all demands for a considerable time to come.

As the use of the Lake of the Woods for storage purposes has become international owing to a reference regarding the levels of the lake having been submitted to the International Joint Commission, the importance and necessity to the power interests of the Winnipeg river in Manitoba, of the use of the Lake of the Woods for reservoir purposes, is treated in more detail in chapter IX of this report.

GENERAL RELATION OF THE LAKE TO THE BASIN.

The Lake of the Woods has a surface area of some 1,500 square miles. The accurate determination of its area is a matter of considerable difficulty as it is dotted with the innumerable islets and islands characteristic of lakes in territory of similar geological formation. On the entire northern and eastern shores of the lake, the exposed granite forms in general, abruptly sloping b nks, with here and there short intervening stretches of shore and muskeg land. Along the southern and western shores the natural features are entirely different. The general country is of a flat alluvial description, with low-lying and swampy areas, especially along the Minnesota shore. Throughout the southwestern section of the lake, the island formation disappears, and open water prevails.

Four outstanding features combine to render the Lake of the Woods a reservoir which is invaluable to the power interests on the river below. These features may be summarized as: the great surface area of the lake, its large tributary watershed area, the great dependable power opportunities below, and the existing controlling works at the outlets. The surface area has already been referred to. Twenty-six thousand four hundred square miles of drainage area above the lake forms a supply basin in keeping with the great capacity of the reservoir. Below the lake, there is a drop of 77 feet to the boundary of Manitoba, practically all of which can be developed. Within the latter province is a total drop of 270 feet, of which 250 feet is now being, or can be developed. The outlets of the lake have been very fully referred to in chapter III, and a reference to plate 13 will render the situation there clear.

OUTLETS FROM THE LAKE OF THE WOODS.

All the outlets are now artificially controlled, three for power purposes, one by means of an old intake structure at present kept permanently closed by stop-logs, and the fifth by the Norman dam.

The Norman dam, more fully described in chapter V, spans the western outlet and was originally built as a combined control and power dam, incorporating eight 21-foot power sluices with sills at elevation 1,040·6 (Water Power Survey datum), four being adjacent to either bank, and twelve 15·5-foot regulating sluices with sills at elevation 1,038·7. All control is by means of stoplogs. Up to the present no power development construction has been undertaken in connection with the dam, and the entire twenty sluices have been available for regulation purposes.

This dam is the crucial feature, not only in the regulation of the Lake of the Woods as a unit, but in its proper and permanent control in the interests of hydro-electric development along the entire river below.

Under an agreement dated June 22, 1898, between the Ontario Government and the Keewatin Power Company, the regulation of the lake in the interests of navigation is placed under the control of the Minister of Public Works of the province of Ontario. Should the company proceed with the contemplated power development in conjunction with the dam, it may, if it sees fit, terminate the above agreement, guaranteeing, however, to maintain the water in the lake at ordinary summer level for navigation purposes at all proper times.

Since the completion of the Norman dam the regulation of the lake level has been at times unsatisfactory to practically all the interests concerned. This has been due almost entirely to an insufficient grasp of the magnitude and diversity of the interests affected, and to the lack of run-off data upon which the capacity and resources of the lake and watershed could be established and properly conserved. It is hoped that the information compiled and presented in this report and which is being continually augmented by further field study, will supply this deficiency.

The importance of, and necessity for placing the control of the regulation of the Norman dam in the hands of an impartial central authority will become more apparent as the relation of the lake to the basin as a whole is analysed.

SURFACE LEVELS OF THE LAKE OF THE WOODS.

It is not the purpose here to go into a detailed study of the past surface levels of the Lake of the Woods. An exhaustive investigation into this question is now being carried on by Mr. S. S. Scovil of the Lake of the Woods Technical Board, and a comprehensive report will soon be possible. It is necessary, however, to discuss the general conditions which have existed during the past few years, in order to properly appreciate what will be involved by a regulation of the lake in the interests of the power plants and projects on the river below. To this end, table 20 of mean monthly elevations is appended.

Table 20.—Mean Monthly Elevations of the Surface of the Lake of the Woods.

Month.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.
January	1,059·0	1,059·2	1,060·1	1,058·0	1,059·1	1,057·9	1,057·5	1,060·3
February	1,058·9	1,058·9	1,059·8	1,057·8	1,059·2	1,057·7	1,057·1	1,060·2
March	1,058·6	1,058·2	1,059·0	1,057·7	1,058·9	1,057·5	1,056·9	1,059·5
April	1,058·4	1,058·0	1,059·0	1,057·5	1,059·0	1,057·3	1,056·9	1,059·3
May	1,059·2	1,058·1	1,059·6	1,058·6	1,059·8	1,058·2	1,057·8	1,059·9
June	1,060·0	1,058·1	1,059·7	1,059·1	1,060·0	1,058·8	1,058·7	1,059·8
July	1,060·8	1,057·9	1,060·0	1,059·2	1,059·5	1,059·3	1,060·1	1,059·9
August	1,060·6	1,057·6	1,059·5	1,059·3	1,059·1	1,059·2	1,060·7	1,059·6
September	1,060·0	1,058·9	1,059·3	1,059·0	1,058·7	1,058·7	1,060·6	1,059·1
October	1,059·5	1,060·4	1,058·8	1,059·1	1,058·6	1,058·3	1,060·2	1,058·5
November	1,059·8	1,060·7	1,058·2	1,059·0	1,058·3	1,058·0	1,060·1	1,058·1
December	1,059·6	1,060·4	1,058·0	1,058·9	1,058·1	1,057·7	1,060·3	1,058·0
Yearly Mean	1,059·5	1,058·9	1,059·3	1,058·6	1,059·0	1,058·2	1,058·9	1,059·4
Maximum	1,060·8	1,060·7	1,060·1	1,059·3	1,060·0	1,059·3	1,060·7	1,060·3
Minimum	1,058·4	1,057·6	1,058·[illegible]	1,057·5	1,058·1	1,057·3	1,056·9	1,058·0

Month.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	Mean.
January	1,057·9	1,060·4	1,058·4	1,059·3	1,056·5	1,055·4	1,059·2	1,058·8	1,058·6
February	1,057·7	1,060·2	1,058·2	1,059·4	1,056·3	1,055·7	1,059·1	1,058·8	1,058·4
March	1,057·5	1,059·9	1,057·9	1,059·5	1,056·0	1,056·0	1,059·1	1,058·7	1,058·1
April	1,057·2	1,059·6	1,057·7	1,060·1	1,055·8	1,056·2	1,059·4	1,058·7	1,058·1
May	1,057·6	1,059·9	1,057·8	1,060·0	1,055·9	1,056·9	1,059·7	1,059·3	1,058·6
June	1,058·4	1,060·1	1,058·2	1,059·4	1,056·2	1,057·5	1,059·6	1,060·0	1,059·0
July	1,058·7	1,059·9	1,058·5	1,058·8	1,056·0	1,057·8	1,059·5	1,059·9	1,059·1
August	1,059·3	1,059·5	1,058·6	1,058·1	1,055·7	1,058·2	1,059·4	1,059·3	1,059·0
September	1,060·0	1,059·2	1,058·6	1,057·6	1,055·6	1,058·7	1,058·9	1,059·1	1,058·9
October	1,060·8	1,058·9	1,058·7	1,057·1	1,055·6	1,059·4	1,058·7	1,059·3	1,058·8
November	1,060·7	1,058·6	1,058·9	1,056·9	1,055·6	1,059·5	1,058·8	1,059·4	1,058·8
December	1,060·6	1,058·5	1,059·1	1,056·8	1,055·5	1,059·3	1,058·8	1,059·5	1,058·6
Yearly Mean	1,058·4	1,059·6	1,058·4	1,058·6	1,055·9	1,057·6	1,059·2	1,059·2	1,058·7
Maximum	1,060·8	1,060·4	1,059·1	1,060·1	1,056·5	1,059·5	1,059·7	1,060·0	1,060·8
Minimum	1,057·2	1,058·5	1,057·7	1,056·8	1,055·5	1,055·4	1,058·7	1,058·6	1,055·4

Note.—The above elevations are based on the gauge records of the Ontario Department of Public Works taken at the Keewatin traffic bridge, to which have been applied certain corrections based upon a comparison of the gauge records around the lake.

Elevations are given to W.P.S. datum. Zero Water Power Survey Datum is equal to 1·31 United States Coast and Geodetic Survey Datum.

The above figures from 1899 (given to Water Power S datum) show a considerable and a decidedly irregular range. In following the surface levels from year to year there is ample evidence that no continuous and systematic policy dictated the operation of the control, other than efforts to better immediate and local conditions at times when the same became unsatisfactory to the power and navigation interests. This irregular control was the result of a lack of run-off data with which to measure the actual discharging capacity of the river, and also of the fact that in general there was ample water available for local needs at the outlets of the lake. The year 1911, during which the mean elevation was 1055·9, was the period of most adverse conditions for both power and navigation. On the other hand, lake levels above elevation 1060 are common, twenty-one months showing mean records above this limit. These levels represent average monthly elevations. Daily records show more extreme conditions.

THEORETICAL INFLOW AVAILABLE AT OUTLET FOR POWER AND STORAGE.

From a consideration of the lake levels, it is readily possible, by making allowance for the rise and fall in the lake from month to month, to deduce the conditions of storage and draw which have maintained during the past seven years. In undertaking a calculation of this nature, it was not deemed advisable to base the same on single readings at the beginning and end of each month, nor was it advisable to depend only on a single series of gauge readings, where others were available. The lake level is subject to influence by sudden storms and by prevailing winds. In order to eliminate so far as possible all such influences affecting the surface level, a mean of eight days' records, four at the end and four at the commencement of each month, was taken of the Keewatin gauge readings, and combined with a similar mean of the records secured at the forebay of the Kenora power-house, and at Warroad, on the southwest shore of the lake, whenever such records were available or considered reliable. Thus the average of the gauge records each month end was utilized, and the result is considered to indicate fairly accurately the actual lake level from which the past storage conditions can be deduced from month to month. Based upon these monthly changes of level, the theoretical inflow into the lake has been calculated. While the resulting figures indicate the monthly inflow into the lake which would have taken place had its surface been maintained at a uniform level, they do not indicate the theoretical outflow which would have taken place from the lake had there been no artificial regulation at the outlets, since the lake would under such conditions have varied in surface elevation according to various stages of flow. However, the deduced theoretical inflow gives the water which would have been available for use at the outlet.

Again, during the period under discussion, Rainy lake, in the basin above, was artificially regulated, and the flow therefrom consequently affected the monthly inflow into the Lake of the Woods. As a result, the deduced theoretical inflow does not represent wholly natural conditions on the basin. It is considered, however, that the two sets of figures in table 21 hereunder, representing as they do, the actual monthly outflow from the lake, and the theoretical monthly inflow into the lake, will serve as a fair basis on which to discuss its general storage possibilities.

Table 21.—Comparison of the Actual Outflow from the Lake of the Woods and the Theoretical Inflow deduced by taking into account the rise and fall of the lake from month to month.

Month.	1907.		1908.		1909.		1910.		1911.		1912.		1913.		Mean.	
	Outflow	Inflow.	Outflow.	Inflow.	Outflow.	Inflow.	Outflow.	Inflow.	Outflow.	Inflow.	Outflow.	Inflow.	Outflow.	Inflow.	Outflow.	Inflow.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.
January	11,790	10,073	19,190	16,770	9,970	7,238	11,660	14,860	7,700	3,407	5,555	3,214	11,560	9,219	11,061	9,254
February	11,?50	6,235	18,230	13,993	10,040	5,718	11,790	13,692	7,110	5,468	5,795	6,054	9,570	9,311	10,541	8,639
March	10,640	6,269	17,340	12,344	10,910	6,617	14,260	19,960	6,835	2,153	6,010	6,010	6,990	21,040	10,426	10,628
April	10,280	8,344	16,900	17,787	10,870	4,820	22,120	28,008	8,995	9,560	6,270	16,680	8,550	17,670	11,998	14,695
May	11,170	22,410	18,470	23,700	11,040	23,060	24,690	16,490	8,770	10,721	6,505	21,490	18,370	12,125	14,145	18,571
June	14,000	23,760	22,830	24,847	11,770	16,045	21,870	16,870	8,945	13,544	5,435	9,307	20,100	15,986	14,993	17,194
July	14,055	17,645	21,800	15,866	11,850	13,958	16,290	2,790	8,770	4,087	4,870	7,446	15,020	17,830	13,236	11,375
August	12,730	24,830	20,300	12,339	11,695	12,087	13,270	7,729	7,985	5,722	5,430	11,209	14,880	9,180	12,327	11,871
September	17,080	31,120	18,200	15,780	11,940	13,150	11,750	5,052	6,715	5,183	5,425	18,735	13,100	.740	12,030	13,251
October	20,790	25,319	15,420	10,190	12,005	15,925	10,180	3,938	5,945	7,819	9,720	13,936	8,180	9,039	11,749	12,309
November	21,075	18,977	12,810	8,777	12,020	12,262	8,785	9,833	5,615	5,615	16,990	10,425	8,090	9,058	11,341	10,707
December	19,730	17,700	10,580	10,424	11,915	16,208	8,110	5,690	5,530	6,467	11,520	9,490	8,050	7,269	10,776	10,464
The Year	14,560	17,724	17,670	15,235	11,345	12,257	14,570	12,076	7,410	6,646	6,955	11,166	11,872	11,789	12,052	12,413
Maximum	21,672	31,120	23,944	24,847	12,450	23,060	25,238	28,008	9,387	13,544	12,010	21,490	20,806	21,040	25,238	31,120
Minimum	10,100	6,235	10,118	8,777	9,465	4,820	7,654	2,790	5,078	2,153	4,425	3,214	5,847	3,740	4,425	2,153

A comparison of the mean monthly seven-year outflow and inflow as recorded in columns 16 and 17 illustrates at once the more natural conditions which are apparent in the inflow. The low-flow period, as is to be expected, occurs during the late fall and winter months, and is followed by the rise to flood flow in April, May, and June. That the two columns do not altogether balance is apparent from the mean flows for the cycle, i.e., 12,052 second-feet outflow and 12,413 second-feet inflow. A portion of this difference is accounted for by the fact that at the end of the period the lake stood at 0·7 foot higher elevation than on January 1, 1907, and the volume equivalent to this depth was not available as outflow. This volume would supply a continuous run-off of 132 second-feet for seven years, which practically makes the two mean flows, 12,184 and 12,413 second-feet outflow and inflow respectively. The remaining balance of 229 second-feet, amounting to less than 2 per cent of the seven-year mean, must be put down to inaccurate gauge records, since tl. actual discharge on which the whole is based remains the same throughout.

Evaporation losses do not enter into the calculation, since, whether a rising or a falling stage is in question, the net result of considering the rise or fall recorded by the gauge as the equivalent of actual inflow or outflow, is that the evaporation loss is eliminated.

A glance through the table indicates that full natural conditions are not shown by the deduced inflow. Abnormal figures may be the result of incorrect run-off data, poor gauge records, storage operations in Rainy lake above, or of a combination of these conditions. The general results, however, balance up well for the cycle as a whole. It is therefore on the theoretical inflow, rather than on the actual measured discharge, that the following discussion has been based.

In a lake of the area of the Lake of the Woods, a few inches storage or draw has a very marked effect on the outflow, and the changes of level which have occurred during the past seven years have exercised a very modifying influence on the discharge. A reference to the records year by year in table 21, and to mean monthly flows of the cycle as recorded in columns 16 and 17 illustrates this concisely.

STORAGE POSSIBILITIES OF THE LAKE OF THE WOODS.

The total drainage area above the Lake of the Woods is 26,400 square miles, of which about 10,400 square miles immediately adjacent to the lake and lying principally to the south, can be served by no reservoir other than the Lake of the Woods. The maximum storage requirement as deduced from the Rainy lake run-off data, is 0·174 billions of cubic feet per square mile. The Rainy lake run-off, as less influenced by storage in the upper reaches, is more nearly representative of natural run-off conditions than is that of the Lake of the Woods. On this basin it is essential, if a uniform mean flow is to be maintained from the outlets, that the Lake of the Woods provide storage capacity for 181 billions of cubic feet, calling for a storage depth of 4·32 feet. This assumes that the capacity and distribution of the lakes serving the balance of the watershed is such that they can fully and satisfactorily regulate the run-off of the same.

A study of the watershed will show that this assumption is not warranted.

The analysis of the Rainy Lake watershed shows the exhaustive nature of the regulation necessary to ensure a uniform mean discharge past Fort Frances. To ensure satisfactory regulation, it is therefore necessary to consider a greater storage depth than 4·32 feet on the Lake of the Woods. To this end, 5 feet has been made the basis of the following analysis.

The past conditions of discharge from and inflow into the lake, form a logical basis from which to draw conclusions as to the measure of its effectiveness as a reservoir. This is covered hereunder; first, year by year, and afterwards for the seven-year cycle as a whole. Water years are considered as giving better conditions of flow from a regulation standpoint.

Yearly regulation, 1907-13.—Table 22 hereunder deduced from yearly mass curves, presents the various minimum flows which might have maintained during the different years, together with the storage and depths on the lake necessary to secure the same. The theoretical inflow into the lake forms the basis of the table. It is recognized that for any one year, it would be impossible to foretell the maximum regulated flow which the year's run-off would permit. A consideration of the possibilities is, however, serviceable as indicating the exceptional storage facilities of the lake.

Table 22.—Storage Conditions which would have been necessary on the Lake of the Woods in order to maintain various Minimum Flows from year to year.

Water Year.	Mean Yearly Flow in Sec.-ft.	Minimum to be maintained in Sec.-ft.	Storage in Billions of Cub. Ft.			Depth in Feet.	
			Required at the beginning of the year.	Maximum supplied from the year's flow at any one time.	Total Volume Required.	Required at the beginning of the year	Maximum Required at any one time.
1.	2.	3.	4.	5.	6.		8.
1907-'08	19,434	19,434	30·0	48·0	78·0		1·91
		18,000	26·0	27·5	53·5		0·65
		16,000	21·0	15·0	36·0		0·50
		14,000	16·0	5·0	21·0		0·38
		[1]12,442	12·5	0·0	12·5		0·29
		12,000	11·0	0·0	11·0	0·26	0·26
		10,000	6·0	0·0	6·0	0·14	0·14
1908-'09	13,274	13,274	0·0	80·0	83·0	0·0	1·92
		[1]12,442	0·0	67·5	67·5	0·0	1·62
		12,000	0·0	62·5	62·5	0·0	1·50
		10,000	0·0	29·0	32·0	0·0	0·69
		8,000	0·0	13·0	13·0	0·0	0·30
		6,000	0·0	2·5	2·5	0·0	0·06
1909-'10	14,669	14,669	26·0	25·0	60·5	0·62	0·62
		14,000	24·0	12·5	49·5	0·57	0·57
		[1]12,442	20·0	5·0	25·0	0·48	0·48
		12,000	17·5	3·0	20·5	0·41	0·41
		10,000	13·0	0·0	13·0	0·31	0·31
		8,000	8·0	0·0	8·0	0·19	0·19
		6,000	3·5	0·0	3·5	0·08	0·08
1910-'11	8,952	[1]12,442	112·0	62·5	174·5	2·68	4·17
		12,000	95·0	67·5	162·5	2·28	3·90
		10,000	32·5	82·5	115·0	0·76	2·76
		8,952	0·0	89·0	92·0	0·0	2·14
		8,000	0·0	67·0	72·5	0·0	1·61
		6,000	0·0	19·0	35·0	0·0	0·45
		4,000	0·0	5·0	11·0	0·0	0·12

[1]Mean of seven water years.

Table 22.—Storage Conditions which would have been necessary, etc.—Con.

Water Year.	Mean Yearly Flow in Sec.-ft.	Minimum to be maintained in Sec. ft.	Storage in Billions of Cub. Ft.			Depth in Feet.	
			Required at the beginning of the year.	Maximum supplied from the year's flow at any one time.	Total Volume Required.	Required at the beginning of the year.	Maximum Required at any one time.
1.	2.	3.	4.	5.	6.	7.	8.
1911-'12	7,061	[1]12,112	175·0	2·0	177·0	4·48	4·18
		12,000	151·0	4·0	158·0	3·65	3·65
		10,000	93·5	11·5	107·0	2·21	2·51
		8,000	31·0	27·5	58·5	0·71	1·40
		7,000	0·0	33·0	35·0	0·00	0·78
		6,000	0·0	11·5	17·5	0·00	0·27
		4,000	0·0	2·5	2·5	0·00	0·06
1912-'13	13,191	13,191	20·0	36·0	68·0	0·48	1·29
		[1]12,442	6·0	28·5	52·5	0·14	0·68
		12,000	0·0	25·0	47·0	0·00	0·59
		10,000	0·0	0	14·0	0·00	0·21
		8,000	0·0	1·5	1·5	0·00	0·03
1913-'14	10,579	[1]12,412	58·0	36·0	91·0	1·39	2·26
		12,000	42·5	42·0	84·5	1·02	2·03
		10,579	0·0	55·0	55·0	0·00	1·33
		10,000	0·0	42·5	42·5	0·00	1·20
		8,000	0·0	12·5	12·5	0·00	0·29
		6,000	0·0	7·5	7·5	0·00	0·18

[1]Mean of seven water years.

The water year covering the period from April 1, 1907, to April 1, 1908, was the year of most ample flow in the cycle. A mean flow of 19,434 second-feet was recorded. Little trouble would have been experienced in maintaining this throughout the year. The month of April was slack, there being only 8,344 second-feet available, involving a storage requirement of 30·0 billions of cubic feet, or a depth of 0·71 foot on the lake on the first of the month. Assuming this to have been available, the lake surface would have been reduced to zero level by May 1. Following came a period of ample flow, continuing till the end of October, during which time a surplus volume to the extent of 78 billions of cubic feet was available for storage, calling for a rise of 1·91 in the surface level. This would have been the greatest storage depth necessary throughout the year. From October 31 to the end of the water year on April 1, 1908, there was a constant slackness in run-off, requiring a steady draw on the storage until the lake level was reduced to 0·71 on the latter date. In short, starting with 0·71 foot on the lake on April 1, 1907, the lake level, reduced to zero by April 30, would have risen to 1·91 foot on October 31, and fallen gradually to 0·71 at the end of the year, maintaining throughout the period a uniform discharge of 19,434 second-feet.

In the year 1908-9 a sufficient water supply was again available to permit a substantial discharge being maintained and with but little variation of the lake levels. The mean flow of the year, 13,274 second-feet, involved no initial slack period at the commencement of the year, such as was required in the previous year. With the exception of a slight shortage in the month of August, there was a continuous surplus flow available until September 30, by which date it would have amounted to 80 billions of cubic feet and have raised the lake level (assuming zero at beginning) 1·92 foot. The slack discharge which followed would have lowered the lake to zero by the end of the water year.

The year of 1909-10 was also a year of high run-off, a mean of 14,669 second-feet being recorded. The month of April was below the mean, recording 4,820 second-feet, and necessitating an initial storage of 0·62 foot on the lake. Throughout the year, the flow was slightly more irregular than in the two years discussed above. In order to maintain the 14,669 second-feet, regulation of the lake surface would have been necessary only between every narrow limits. The maximum storage depth required would have been the 0·62 foot at the beginning of the year.

The year 1910-11 was a year of reduced run-off, the mean flow being 8,952 second-feet. To maintain this discharge from the lake would have called for a storage depth of 2·14 feet, this maximum occurring on June 30. After this date came a period of continuous low flow, calling for a steady draw on the lake until the end of the year. In all, 92 billions of cubic feet storage would have been required.

Assuming that surplus water was available from previous years, it will serve a purpose to look into the question of maintaining the seven-year mean uniform flow of 12,442 second-feet. With the existing run-off conditions, a maximum storage requirement of 174·5 billions of cubic feet would have been necessary in order to supply the deficiencies throughout the year, and would have involved a maximum depth of 4·17 feet on the lake, of which 2·68 feet should have been available at the commencement of the year. The date of highest water would have been June 30, and of low water, the winter months of January, February, and March.

The year 1911-12 supplied a mean run-off of 7000 cubic feet per second. The maintenance of this flow would have involved a maximum storage of 33 billions of cubic feet, and a storage depth of 0·78 foot on the lake. To have ensured 12,442 second-feet throughout the year would have required an initial storage of 175 billions of cubic feet or a depth of 4·18 feet, which would, with the exception of the month of June, have been continuously drawn upon throughout the year and reduced to zero by the end of the following March.

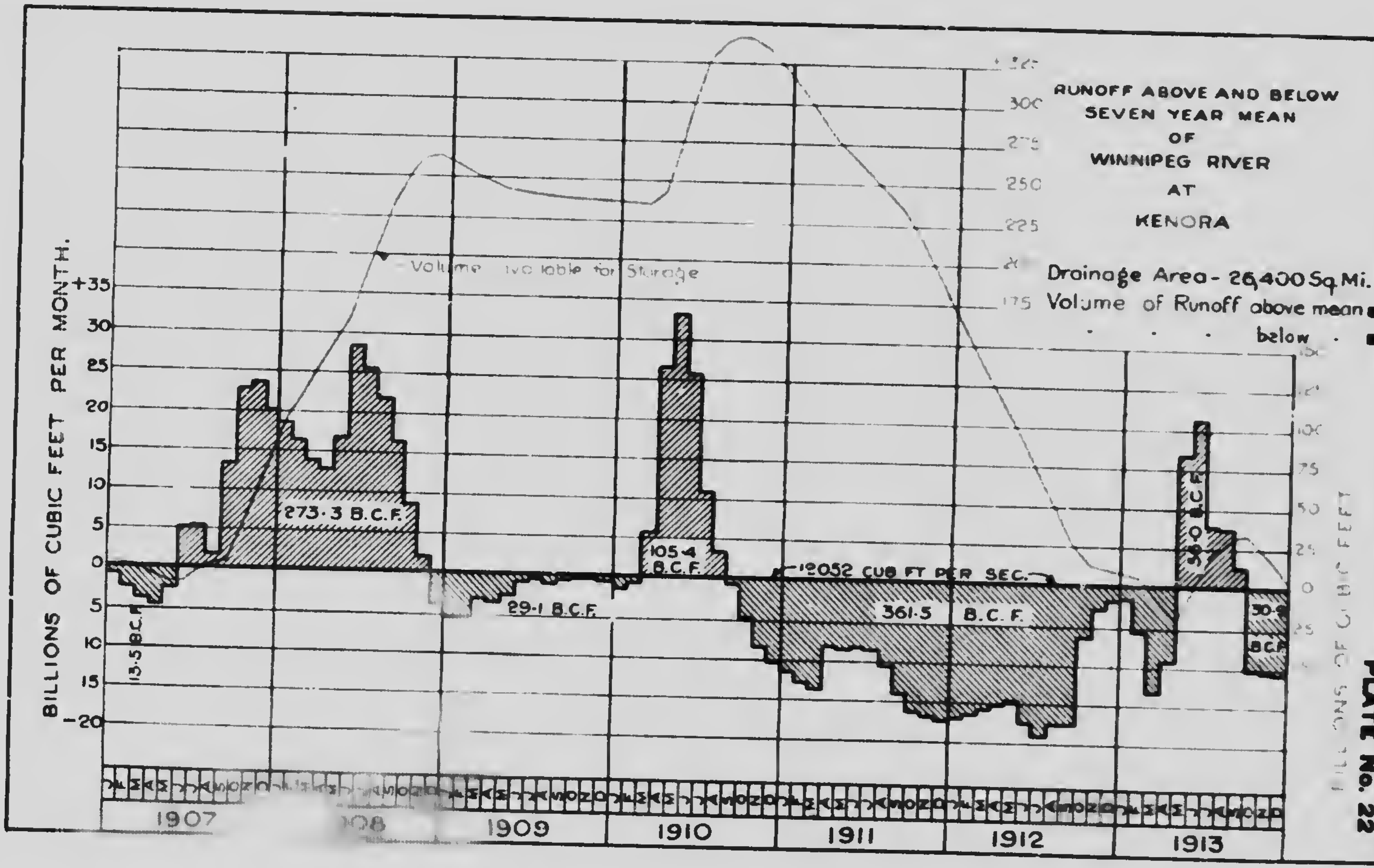
The year 1912-13 supplied a mean flow of 13,191 second-feet, somewhat above the seven-year average. To have rendered this flow available at the outlets during the entire year required a storage depth of 1·29 foot on the lake. An initial storage depth of 0·48 foot would have been necessary.

The year 1913-14 was below the mean discharge, 10,579 second-feet being available. To secure this uniformly, required a storage volume of 55 billions of cubic feet and a depth of 1·33 foot. No initial storage would have been necessary. To maintain the seven-year mean, i.e., 12,442 second-feet, called for a storage volume of 94 billions of cubic feet, and a maximum depth of 2·26 feet, 1·39 foot of which was necessary at the beginning of the year. Highest water would have occurred on July 31.

This review definitely emphasizes the value of the lake for reservoir purposes, and when paralleled with the conditions of run-off which actually maintained, forms a direct argument for the necessity of control.

Regulation over the seven-year cycle.—Turning to the seven-year cycle, it is of interest to look into the run-off from the standpoint of maintaining fixed uniform discharges from the lake throughout the entire period. Plate 22

PLATE No. 22


RUNOFF ABOVE AND BELOW
SEVEN YEAR MEAN
OF
WINNIPEG RIVER
AT
KENORA
Drainage Area - 26,400 Sq. Mi.
Volume of Runoff above mean
below
BILLIONS OF CUBIC FEET PER MONTH.
+35
30
25
20
15
10
5
0
5
10
15
-20
300
250
225
175
75
50
25
0
25
273·3 B.C.F.
13·5 B.C.F.
29·1 B.C.F.
105·4 B.C.F.
12052 CUB FT PER SEC.
361·5 B.C.F.
30·0 B.C.F.
Volume available for Storage
1907
1909
1910
1911
1912
1913

depicts the discharge conditions above and below the seven-year average. Table 23 herewith lists the storage conditions in the Lake of the Woods incident to maintaining continuously average discharges of varying limits, considering the lake as the only reservoir available.

Table 23.—Storage Conditions which would have been necessary on the Lake of the Woods in order to maintain various Minimum Outflows from April 1, 1907 to March 31, 1914.

Flow in Sec. ft.	Period of Maximum Draw — Dates.	Volume required in Billions of Cu. ft.	Equivalent depth on Lake in Ft.	Total Volume of storage used, in Billions of Cu. ft.
1.	2.	3.	4.	5.
[1]12,442	July 1, 1910, to Mar. 31, 1911	380	9·08	625
12,000	" "	323	7·73	569
11,000	" "	265	6·34	419
10,000	" "	210	5·04	318
9,000	July 1, 1910, to Aug. 24, 1914	155	3·71	251
8,000	July 1, 1910, to Sept. 20, 1912	94	2·25	169
7,000	July 1, 1910, to May 8, 1912	40	0·96	101
6,000	Jan. 1, 1911, to May 21, 1911	21	0·50	57

[1]Mean of seven water years.

Table 23 is compiled from a mass curve study; column 3 lists the maximum volume of storage capacity necessary to meet the most adverse conditions in the cycle; column 5 lists the total volume of water withdrawn from the reservoir throughout the period.

Analysing the maintenance of 12,442 second-feet more fully from the mass curve (plate 23) shows that, with three insignificant exceptions, there is a large surplus of water continuously available until October 1, 1908, at which date a slack period sets in, lasting until the following May. Ninety billions of cubic feet from storage, reducing the lake level by 2·16 feet only, would maintain the required flow over this gap, while the surplus flow commencing May 1, 1909, would refill the lake by the end of March, 1910, and supply a further 65 billions of cubic feet to the upper storage reservoirs by the end of June.

At this date, there has been a surplus flow totalling 380 billions of cubic feet, which, providing suitable reservoirs are in reserve, should be available to augment the prolonged period of slack and variable flow which follows.

Commencing July 1, 1910, a period of more or less continuous low flow follows, lasting until March 31, 1912. Assuming 5 feet storage available on the Lake of the Woods leaves the lake at its lowest limit by about the middle of August, 1911, immediately after which date a further draw of 139 billions is required. This must be furnished from other reservoirs.

March 31 is followed by a series of alternating surplus- and low-flow months, until the end of the cycle on March 31, 1914, by which date a further draw of 32 billions has been necessary from the upper reservoirs. The end of the cycle should find the entire reservoir system empty.

The above analysis indicates that a storage capacity of 380 billions of cubic feet is required if a flow of 12,442 second-feet is to be maintained throughout the seven-year cycle. Considering the entire basin above the Lake of the

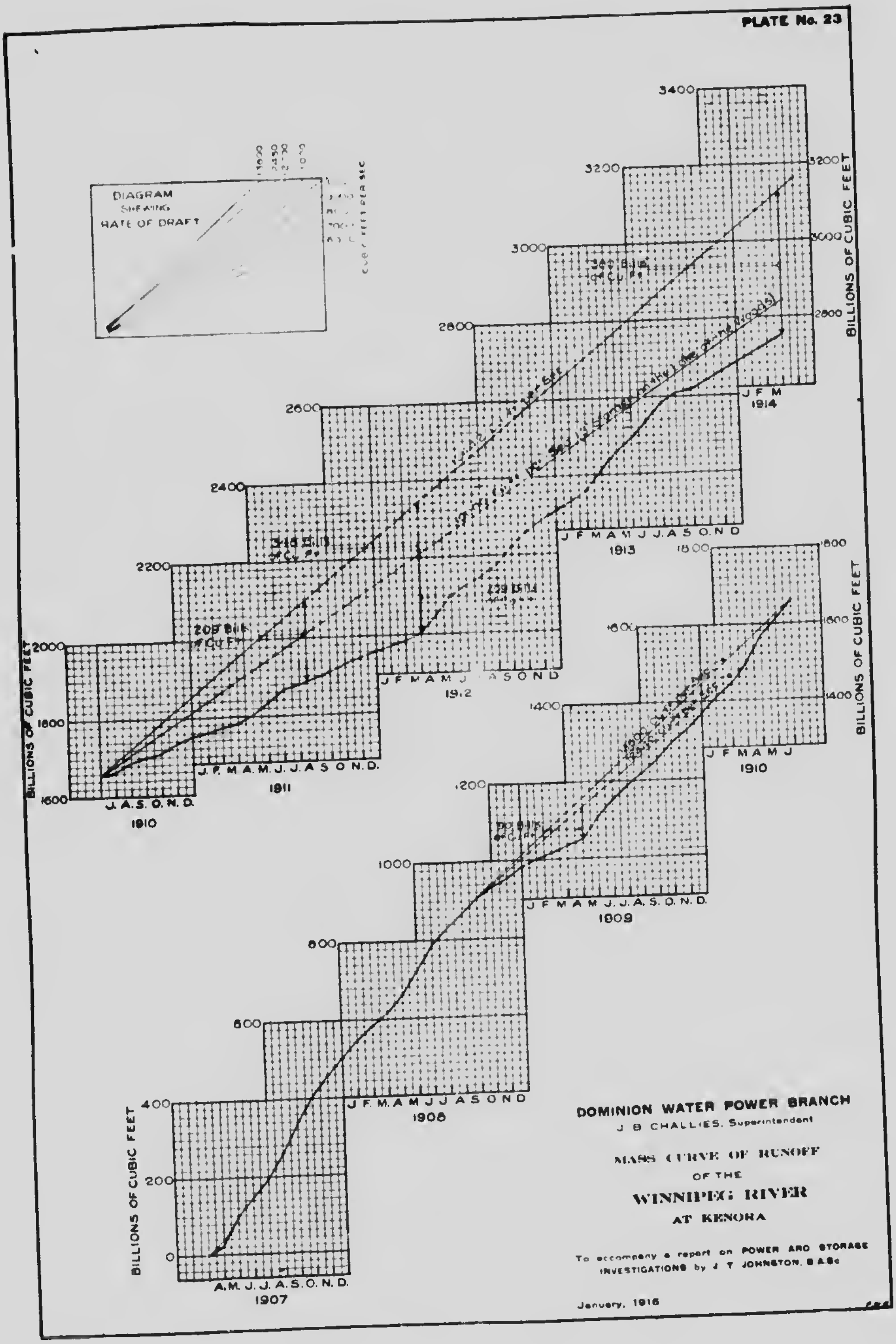


PLATE No. 23
DIAGRAM
SHEWING
RATE OF DRAFT
BILLIONS OF CUBIC FEET
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
A. M. J. J. A. S. O. N. D.
1907
J. F. M. A. M. J. J. A. S. O. N. D.
1908
1909
1910
1911
1912
1913
J F M
1914
205 Bill. of Cu. Ft.
DOMINION WATER POWER BRANCH
J. B. CHALLIES, Superintendent
MASS CURVE OF RUNOFF
OF THE
WINNIPEG RIVER
AT KENORA
To accompany a report on POWER AND STORAGE INVESTIGATIONS by J. T. JOHNSTON, B.A.Sc.
January, 1916

Woods available for the location of suitable reservoirs, indicates how this storage might be obtained. Five feet on Lake of the Woods will supply 209 billions of cubic feet; 5 feet on Rainy lake, 46 billions; 12 feet on lake Namakan 33 billions, leaving 92 billions of cubic feet to be supplied from the lesser reservoirs. Referring to tables 14, 15, and 16, wherein are listed the principal lesser lakes of the basin, shows a storage capacity of 120 billions, assuming 5 feet storage permissable on each lake, or sufficient depth to carry an entire average year's run-off where the same amounts to less than an equivalent of 5 feet. Storage in these lakes would necessitate the construction of some 60 dams.

However, it is not possible, to assume that the storage reservoirs of Rainy and Namakan lakes and of the lesser lakes in the basin above Fort Frances can be used unreservedly for the maintenance of a uniform discharge at the outlet of the Lake of the Woods. In view of the industrial and power developments at the outlet of Rainy lake, and of their present urgent demand for increased minimum flow, the storage available in Rainy, Namakan, and the upper lakes must be primarily used in bettering the discharge past Fort Frances. Regulation at this point will, of course, have its immediate and direct effect on the Lake of the Woods regulation.

The principal lesser lakes below Fort Frances and directly available to the Lake of the Woods are tabulated in table 14. The storage capacity of these lakes under the conditions listed in columns 12 and 13, is 21 billions of cubic feet, which could be used to directly supplement the lake storage. It should be again noted, however, that existing lumbering, fishing, milling, and other interests may prevent the full utilization of these smaller lakes for a general regulation scheme, and that the construction of some 15 dams is involved.

From the above it is clear that in order to maintain the full mean flow from the Lake of the Woods, supplementary storage is necessary in the upper lakes even assuming 5 feet storage in the lake itself. It is doubtful whether such complete regulation is economically valuable or practically feasible on account of the low efficiency in a general storage sense, of a large number of comparatively small and scattered reservoirs. The maintenance of a minimum flow of 10,500 second feet should be readily feasible under a properly systemized control.

Assuming that no reservoirs were available other than the Lake of the Woods, would necessitate a storage depth of over 10 feet on the lake in order to maintain a uniform flow from the outlets.

Five-foot Storage on the Lake of the Woods.—Considering for a moment that 5 feet storage or 209 billions of cubic feet is available on the Lake of the Woods, with no auxiliary storage, the actual inflow into the lake would have been sufficient to maintain a uniform outflow of at least 13,600 second-feet from May 1, 1907, to June 30, 1910. During this period a maximum draw of 111 billions of cubic feet would be required, or 2·67 feet on the lake. Ample water was available to supply the storage necessary, and to leave the lake surface at its upper limit on the latter date. Following June 30 came the prolonged period of low discharge previously referred to. Five-foot draw on the lake would permit the maintenance of a uniform discharge of practically 10,000 second-feet from the above date to the end of the cycle, the lake reaching its lowest point on March 31, 1912, and being replenished to the extent of 120 billions of cubic feet or to a depth of 2·87 feet by the end of the period.

It should be pointed out that there is no method by which it could be foretold that 10,000 second-feet would be the limit of regulated run-off for that portion of the cycle following June 30, 1910. The discussion is therefore only of interest as a theoretical analysis of past possibilities in as far as can be judged from records now available.

Regulation on the Lake of the Woods in the interests of the Manitoba Power Reach.—The foregoing discussion has dealt with the maintenance of various limiting minimum flows from the outlets of the Lake of the Woods. The direct utilization of the lake as a storage reservoir for bettering the run-off conditions on the power reach in Manitoba and, at the same time, maintaining sufficient run-off to properly operate the power plants and mills at the outlets is of particular interest to the subject of this report, i.e., power resources of the Winnipeg river in Manitoba.

While the run-off records available are influenced by past control, and the deductions are consequently thereby affected, the general beneficial influence which could have been exerted by the lake under a systematic and properly operated regulation can be gathered from the following.

Plate 24 represents the run-off, storage and draw, and the surface-level conditions which would have maintained had the Lake of the Woods been utilized as a direct regulating reservoir for the maintenance of a minimum flow of 20,000 cubic feet per second in the Manitoba power reach, and at the same time provided sufficient discharge to properly operate the industrial and power undertakings at the outlets.

For the purposes of the analysis, elevation 1,061·0 (Water Power Survey datum) was assumed to be the upper limit of permissible storage, and on reaching this level it was assumed that the surplus water was discharged down the river. The lower surface level curve represents the actual mean monthly lake level during the period. The upper surface level curve represents the lake level which could have been maintained under a systematically controlled regulation, which ensured, at the same time, sufficient water to properly operate the plants at the outlets of the lake, and a flow of 20,000 cubic feet per second in the Manitoba power reach.

An analysis of the curve shows that the two initial months of 1907 would supply a surplus of 25 billions of cubic feet for storage; the three following months would draw to the extent of 31 billions, after which a period of ample flow lasting until the end of February, 1909, would supply a total of 715 billions available for storage. Of this total 130 billions are stored, and the balance wasted, the lake reaching elevation 1,061 on October 7, 1907. The curve shows the period of greatest draw extending from September, 1910, to the end of June, 1911, requiring 131 billions of cubic feet. The lake reaches its lowest level in June, 1911, i.e., elevation 1,057·9. A series of storage and draw periods following leaves the lake full on December 31, 1914.

The two surface-level curves indicate the more uniform and regular conditions which would have been maintained on the lake throughout the cycle had systematic regulation been carried on. In place of an actual difference in lake level of 5·4 feet (or somewhat in excess of this if daily elevations are considered) there need only have been a difference of 3·1 feet. At the same time, in place of the actual low flow of 11,700 second-feet on the power reach, a flow of 20,000 second-feet would have been ensured.

The analysis on plate 25 is along the same lines as the above with the exception that a minimum discharge of 22,000 second-feet is maintained in the power reach in Manitoba. Under these conditions, the lowest lake level is elevation 1,056, occurring in April, 1912, that is to say, a maximum variation of 5 feet occurs during the eight years considered. The lake rises to elevation 1,059·2 at the end of 1914.

It is apparent that under the present conditions of power utilization at the outlets of the lake, it would be possible to secure a very high degree of regulation in the Manitoba power reach by the direct and properly controlled use of the lake of the Woods alone as a reservoir, and at the same time to greatly better past surface-level conditions. Upon the increased development of power at the lake outlets, necessitating the use of more water than has been required to date, the use of the lake in this manner will become more limited, and it must be devoted more exclusively to the maintenance of higher minimum outflows at all seasons. Its influence on the Manitoba reach under these conditions will be entirely beneficial, but not as direct as that shown in the analysis on plates 24 and 25. As hydro-electric development progresses in Kenora and Keewatin, it will become necessary to secure supplementary storage along the English river, in order to ensure 20,000 cubic feet per second in Manitoba at all seasons.

To sum it may be said that in whatever manner regulation of the run-off may be desired, a substantial measure of regulation in the lake of the Woods is essential. The records now available show that this measure of regulation should not be less than 5 feet, in order to ensure from year to year the desired run-off conditions from the lake and on the lower river. It is desirable to emphasize here that the necessity for lowering the lake to its low limit would arise only at intervals of a number of years.

Rainy Lake Watershed.

The watershed draining into Rainy lake has an area of 14,400 square miles, and is plentifully interspersed with lakes of areas varying from a few square miles up to 100 square miles. The discharge records at Fort Frances at the outlet of the lake form the only consecutive series in this region extending back to the beginning of 1907. Such records as are available in the upper basin are not sufficiently complete to warrant more than passing reference. In consequence of this, the basin above Fort Frances is treated as a unit in considering the regulation of its outflow. The large industrial undertakings at the outlet of the lake, dependent for power on the run-off, already demand that the minimum flow be raised to the highest feasible limit.

RAINY LAKE.

Rainy lake, lying centrally in the lake of the Woods drainage basin, is a body of water some 330 square miles in area, plentifully dotted with islands, and is inclosed on all sides by a rockbound shore. The tributary drainage basin is of the same general geological character and is, in consequence, plentifully interspersed with lakes.

Rainy lake forms a most valuable storage reservoir, both locally and in relation to the basin as a whole. The hydro-electric and pulp-mill installation of the Ontario and Minnesota Power Company, which harnesses the original Koochiching falls, about 2½ miles below the outlet of the lake, demands as complete a regulation as possible of the entire run-off from the basin above. The low-water conditions which have been experienced since these works were first projected have forced the company to pursue an aggressive storage policy. To this end, storage rights are stated to have been acquired on lakes Namakan, Lower Manitou, and Big Turtle in the basin above, in addition to the storage which is locally available in Rainy lake, which lake forms the direct headwater pond of the plant.

The dam which is more fully referred to in chapter V, consists of a masonry spillway section flanked on the Canadian side by ten gate-controlled sluices. The spillway crest is at elevation 497, based on an arbitrary datum[1] established by the Dominion Department of Public Works, to which the governing levels in the vicinity have been referred, and which is fixed by permanent bench-marks in the locality. The normal level in the lake prior to the construction of the works at the outlet has been placed at 488·6, although no gauge records are available.

Numerous complaints have been made at different times as to the manner in which the company have operated the regulation of the lake. These complaints have been in the main of two natures: first, that at certain seasons water has been conserved to such an extent that the flow from the river below has been cut off, and navigation and power interests adversely affected; and second, that the same conservation has resulted in abnormally high-water conditions on the lake, with consequent damage to various interests. The only restriction which has been placed upon the company with regard to the regulation of the lake is that by the Department of Public Works, which requires that at no time during the navigation season shall the flow past the dam fall below 5,000 cubic feet per second.

This measure of control is not sufficient to protect all the interests which are affected to a greater or less extent by the storage of water in the lake. Throughout the following discussion it has been assumed that 5 feet storage is available on the lake.

NAMAKAN LAKE.

Lake Namakan lies immediately above Rainy lake, and is possessed of similar characteristics. The Namakan level may be said to discharge directly into the Rainy Lake level over a rock ridge crossing the river-bed and forming Chaudière falls (Kettle falls), a natural and fairly abrupt drop of about 8 feet under normal conditions. At the falls the river is divided by an island into two channels. Namakan lake has been taken at 100 square miles in area. This area includes the lakes Namakan, Sand Point, Kapetogamuk, Crane, and Little

[1] 610·30 Water Power Survey datum = 0·0 Department of Public Works datum.

DOMINION WATER POWER BRANCH

J. B. CHALLIES, Superintendent

MASS CURVE STUDY OF THE USE

- of the -

LAKE OF THE WOODS AS A REGULATING RESERVOIR

AND THE EFFECT OF SUCH REGULATION

ON THE SURFACE LEVELS

To accompany a report on POWER AND STORAGE INVESTIGATIONS
by J. T. JOHNSTON, B.A.Sc.

March 1916

LEGEND

- Surplus water available for storage
- Water drawn from Storage
- Required from the Lake of the Woods to maintain 20,000 second feet flow and actually discharged
- Discharge necessary to operate the Power installations at the Outlets of the Lake

NOTE

In this analysis it has been assumed that a minimum flow of 20,000 second feet is maintained throughout the power reach of the Winnipeg River in Manitoba, by means of regulations in the Lake of the Woods reservoir alone. At the same time sufficient water has been discharged at all times to properly operate the power installations at the lake outlets.

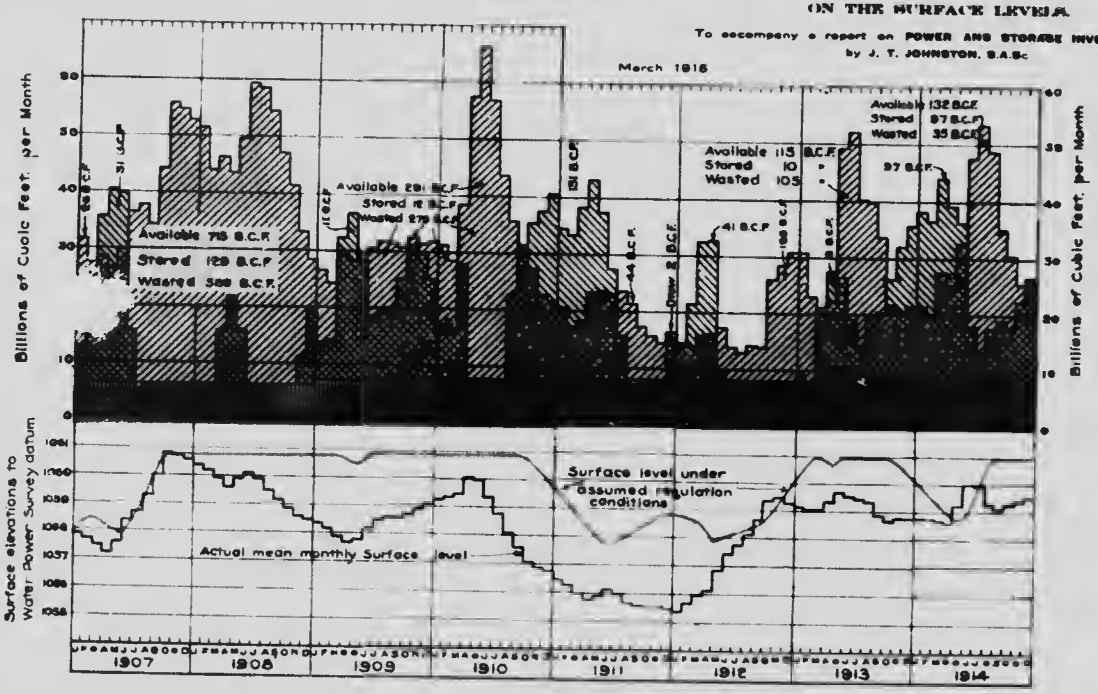


PLATE No. 24

Vermilion, all of which are closely connected and at practically the same level. The tributary drainage basin is 7,056 square miles in area, practically one-half of the entire Rainy Lake watershed. Namakan lake, like Rainy lake, forms a most important storage reservoir both locally and in relation to the entire basin.

The lowest level recorded by the gauge readings of the Dominion Water Power Branch, covering the period from August, 1912, to June, 1913, was 497·9, occurring on March 31, 1913. This series of records was taken before any work was done on the storage dam. The maximum high-water level, as shown by water marks, is placed at elevation 508·5.

In the grant made by the Ontario Government to the company, authority was given to raise the water in the lake "to a point no higher than the high-water mark." Before commencing construction operations, it was necessary that the Department of Public Works approve the plans, since the lake and river affected came under the classification of navigable waterways.

One of the conditions of the departmental approval of the plans was:—

> "That the company agree that the control of the flow past that section shall be regulated solely by such officers or persons as may be hereafter appointed for the purpose by the Minister of Public Works, and that, in case of any difference of opinion, the ruling of the Minister of Public Works for Canada shall prevail."

In accordance with this clause, Mr. S. J. Chapleau, District Engineer of the Department of Public Works, was authorized to arrange for the control of the flow and, after consultation with the United States engineers and other parties if necessary, to fix the extreme high-water level. Following this, an arrangement was made and agreed to, between Mr. Chapleau as representing the Dominion Department of Public Works, and Col. C. L. Potter, of the Corps of Engineers, representing the United States interests, whereby the high limit of lake regulation was fixed at elevation 508·5, subject to reconsideration by either Government or by the International Joint Commission.

This secures a regulation between 508·5 and the 497, or lower, should Rainy lake be drawn down.

The sluice-ways of the dam (plate 40) as constructed, are stoplog controlled, and of the following openings:—

Canadian channel—

- 1-14 foot sluice, sill elevation 498·15.
- 1-14 foot sluice, sill elevation 496·15.
- 2-14 foot sluices, sills at elevation 495·15.

International channel—

- 4-14 foot sluices, sills at elevation 490·15.

Throughout the cycle under discussion, lake Namakan was not subject to artificial control at the outlet, and except for the operation of lumber storage dams in the upper basin, it discharged the natural run-off under natural conditions. Systematic meterings at Chaudière falls were commenced in August, 1912, and are attached in tables 63, 64, and 65, Appendix VII. No gauge records of any description are available from which the run-off of previous years might be deduced.

REGULATION OF THE RAINY LAKE BASIN RUN OFF.

Surface levels of Rainy lake.—As was the case in studying the past condition maintained on the lake of the Woods, it is here necessary to look into the pas surface levels on Rainy lake. Since the completion of the hydro-electric an pulp and paper undertakings at Fort Frances, the lake has been maintained at artificial levels in an effort to equalize the annual flow. A continuous record of the forebay levels of the plant has been kept since early in 1907 by the engineers of the Ontario and Minnesota Power Company. This has been supplemented since August, 1911, by lake-level readings secured by the field officers of the Department of Public Works. The forebay readings do not represent true lake level as there is an hydraulic gradient between the lake and the dam, varying with the lake stage and the draught through the power plant. However the rise and fall in the forebay due to storage in the lake approximates the corresponding rise and fall in the lake itself. Table 24 has been compounded from the various sources available, and can be taken as representing the mean monthly elevations of the lake during the period covered.

Table 24.—Mean Monthly Elevation of the Surface Level of Rainy Lake.

Month.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	Mean.
January	......	490·2	486·9	495·7	488·3	491·7	494·4	495·2	......
February	......	488·9	486·4	494·8	488·2	491·0	493·5	494·6	......
March	486·7	488·0	485·5	493·5	487·9	490·3	492·4	493·5	489·7
April	486·5	487·6	486·4	494·1	488·2	489·9	491·8	493·9	489·8
May	487·2	488·4	489·4	494·6	489·2	491·5	493·0	493·4	490·8
June	489·6	489·9	492·7	494·0	490·9	494·2	496·0	495·4	492·8
July	491·8	492·1	493·8	493·2	492·6	496·0	497·2	497·1	494·2
August	493·1	492·1	494·1	492·6	493·5	496·2	497·3	496·9	494·5
September	494·5	490·9	494·5	491·8	493·3	496·2	497·2	496·5	494·4
October	494·4	489·4	494·3	490·7	493·1	496·1	496·9	......	......
November	493·3	488·2	495·1	489·1	492·7	495·7	496·6	......	......
December	491·6	487·3	495·9	488·4	492·3	495·1	496·1	......	......
The Year	......	489·4	491·2	492·7	490·9	493·7	495·2	......	......

NOTE.—The elevations from March, 1907, to July, 1911, inclusive, record the water level above the dam at Fort Frances.

The elevations from August, 1911, to September, 1914, inclusive, record the water level of Rainy lake at Ranier.

The readings at the dam record lower than those at Ranier, the drop depending on the flow in the river, and the draught through the power plant. The elevation for September, 1914, is the mean of the first eleven days of the month only.

The elevations are recorded to Department of Public Works datum.

Theoretical inflow available at outlet for power and storage.—A consideration of the above levels renders possible a close estimate of the theoretical inflow into the lake for the period. In dealing similarly with the lake of the Woods, more numerous gauge readings were available, and a more accurate determination of the mean lake level from day to day was possible. The records which are here available, and which form the basis of table 25 are, however, sufficiently representative of actual conditions to enable a fair estimate being made.

During the period under discussion, no storage operations were carried on in the upper portion of the basin, with the exception of those necessary in connection with logging operations. The theoretical inflow which is deduced by assuming a uniform level throughout the period, will therefore represent closely the natural run-off from the basin. Table 25, hereunder, records side by side the actual outflow from the lake, and the actual inflow into the lake, or rather the water available at the outlets, as deduced from a consideration of the outflow combined with the lake levels. The monthly outflow discharges from the lake are tabulated in full in tables 61 and 62, Appendix VII.

Table 25.—Comparison of the Actual Outflow from Rainy Lake and the Theoretical Inflow deduced by taking into account the rise and fall of the lake surface from month to month.

Month.	1907.		1908.		1909		1910.		1911.		1912.		1913.		Mean.	
	Outflow.	Inflow.	Outflow.	Inflow.	Outflow.	Inflow.	Outflow.	Inflow.	Outflow.	Inflow.	Outflow.	Inflow.	Outflow.	Inflow.	Outflow.	Inflow.
1	2.	3	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.
January	5,883	5,883	12,000	6,676	5,170	4,311	9,680	7,963	2,860	1,830	5,330	2,720	6,620	3,838	6,792	4,746
February	3,641	3,641	8,410	4,607	4,740	2,269	9,680	3,975	2,380	1,429	4,830	2,549	6,561	2,873	5,719	3,049
March	4,910	4,051	7,030	4,969	5,500	690	10,750	8,175	2,530	985	4,740	1,820	6,420	2,125	5,984	3,259
April	4,955	4,955	6,020	7,617	3,250	12,835	10,600	15,391	3,020	7,930	4,850	6,554	6,405	7,754	5,586	9,014
May	6,070	12,083	7,940	11,891	4,220	18,303	10,600	10,257	4,600	6,317	6,090	14,600	6,620	14,180	6,591	12,520
June	10,200	19,668	11,430	19,063	6,850	14,128	10,000	6,097	5,749	13,260	6,020	14,963	7,274	17,036	8,216	14,879
July	13,000	17,293	13,060	16,151	10,600	12,145	6,630	5,256	3,970	6,202	7,680	11,011	12,597	12,975	9,648	11,576
August	17,470	23,823	12,680	9,932	10,600	13,604	5,280	2,876	6,550	7,590	8,120	8,017	8,544	8,887	9,893	10,590
September	20,110	21,884	10,740	6,126	9,250	8,185	5,080	2,249	5,990	4,677	7,360	7,005	6,770	5,670	9,329	7,970
October	19,760	17,012	9,680	5,214	9,050	9,050	5,120	311	5,210	4,111	6,880	6,193	6,318	5,837	8,860	6,818
November	17,700	12,553	7,510	3,607	5,490	10,725	5,280	489	5,410	4,416	6,730	4,672	6,129	5,100	7,737	5,937
December	13,000	7,332	5,701	3,640	10,09[illegible]	10,343	4,300	4,128	5,900	4,251	6,280	4,048	6,300	4,420	7,356	5,452
The Year	11,391	12,510	9,350	8,291	7,052	9,666	7,750	5,596	4,514	5,255	6,243	7,013	7,214	7,558	7,645	7,984
Maximum	20,110	23,823	13,060	19,063	10,600	18,303	10,750	15,390	6,560	13,260	8,120	14,963	12,597	17,036	20,110	23,823
Minimum	3,641	3,641	6,020	3,607	3,250	690	4,300	[1]311	2,380	985	4,740	1,820	6,129	2,125	2,380	[1]311

[1] Probably attributable to poor gauge records.

A glance through the table shows that in spite of obviously incorrect figures for certain months (due to poor gauge records) the general character of the theoretical inflow conforms more closely to what is to be expected under natural conditions, than do the actual outflow records. This is brought out more definitely in the columns of averages, 16 and 17.

It will be noted that the mean seven-year outflow of 7,645 cubic feet per second does not balance with the 7,984 cubic feet per second inflow. The greater portion of this difference is occasioned by the fact that the water level at the end of the period was 9·27 feet higher than at the commencement, this being equivalent to a seven-year average flow of 386 second-feet. Adding this to the mean outflow gives an equivalent total of 8,031 second-feet, or 47 above the mean inflow. This balance is probably due to inaccurate gauge reading. The difference is less than 0·6 per cent.

In discussing the storage possibilities of the past seven years, the theoretical inflow is utilized, rather than the measured discharges from the lake.

The Ontario and Minnesota Power Company has, in recent years, exercised control over the run-off from Rainy lake for the purpose of increasing the minimum flow. While a considerable degree of success has been attained, there is still much to be done before a complete conservation of the run-off is attained. The company is fully aware of this, as is evidenced by the extent of the storage works which it now has under construction and in prospect. In so far as the minimum dependable flow is being increased through the construction and operation of these storage reservoirs, the best interests of the powers of the lower river are being served.

Regulation over the seven-year cycle.—The general storage conditions necessary to maintain uniform discharges of various limits from the outlet of Rainy lake throughtout the seven year cycle are concisely set out in table 26 hereunder.

This table is compiled from a mass curve study (plate 26). Column 3 lists the maximum volume of storage capacity necessary to meet the conditions; column 5 lists the total volume of water withdrawn from reservoirs throughout the period.

Table 26.—Storage Conditions which would have been necessary in order to maintain various Minimum Flows from Rainy Lake from April 1, 1907 to March 31, 1914.

Flow in Sec.-ft.	Period of Maximum Draw.			Total Volume of storage used, in Billions of Cu.-ft.
	Dates.	Volume required in Billions of Cu.-ft.	Equivalent depth on Rainy lake in feet.	
1.	2.	3.	4.	5.
[1]7,962	May 31, 1910, to Mar. 31, 1914	250	27·18	493
7,000	May 31, 1910, to Mar. 31, 1914	168	18·26	363
6,000	June 30, 1910, to Jan. 20, 1913	106	11·52	255
5,000	July 31, 1910, to June 24, 1912	68	7·39	159
4,000	July 31, 1910, to July 31, 1911	47	5·11	89

[1]Mean of seven water years.

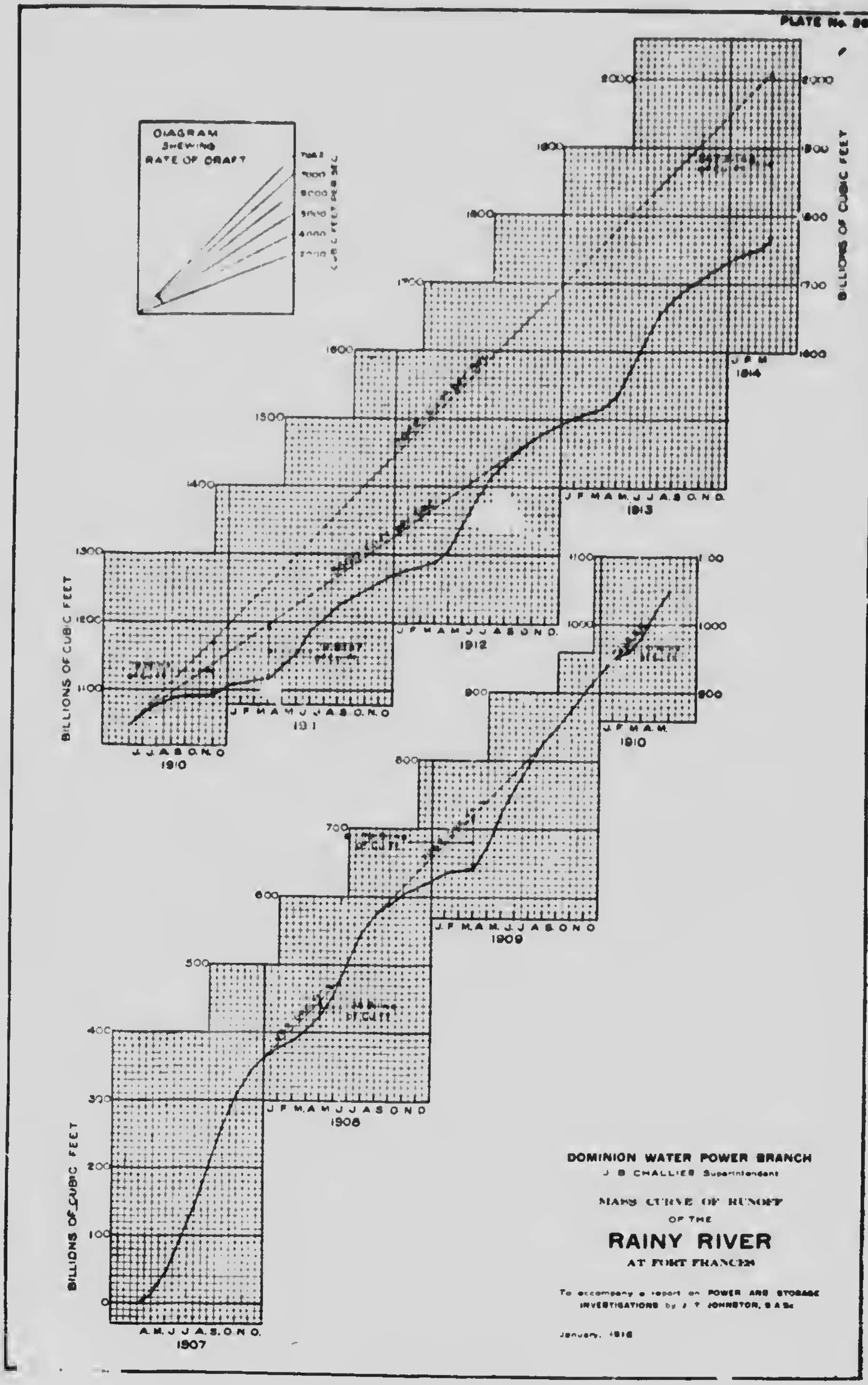


PLATE No. 26
DIAGRAM SHEWING RATE OF DRAFT
BILLIONS OF CUBIC FEET
J F M A M J J A S O N D
1908
1909
1910
1911
1912
1913
1914
A. M. J J A S O N D.
1907
DOMINION WATER POWER BRANCH
J. B. CHALLIES Superintendent
MASS CURVE OF RUNOFF
OF THE
RAINY RIVER
AT FORT FRANCES
To accompany a report on POWER AND STORAGE INVESTIGATIONS by J. T. JOHNSTON, B.A.Sc.
January, 1916

Regulation of the watershed above the outlet of Rainy lake to ensure a continuous average flow of 7,962 cubic feet per second throughout the seven-year cycle would have required a maximum storage capacity of 247 billions of cubic feet, which total should have been in storage and ready for use on May 31, 1910.

Analysing the storage and discharge data on the basis of maintaining the above average flow shows the following, the results being based on a mass curve study, and being therefore somewhat approximate.

The flow for April, 1907, i.e., the first month of the cycle, is slightly below the mean, requiring a draw on storage of about 7 billions of cubic feet. This storage must be provided from previous years' surplus, and would be made good by the end of May. Assuming, then, that 7 billions of cubic feet only are available at the beginning of April, the end of the month shows all reservoirs empty. Following this date there is a continuous surplus flow till November 30, amounting to, in all, 182 billions of cubic feet. Of this amount, 46 billions can be stored in Rainy lake, assuming 5 foot storage, and 33 billions in lake Namakan, assuming 12 foot storage. These lakes would be filled early in August, and the balance must be cared for in the upper lakes. November is followed by a slack period lasting until April 30, 1908, by which date 25 billions of cubic feet would be drawn from storage, preferably from lakes Rainy and Namakan, thus leaving them prepared to store surplus water from any part of the basin at whatever time the same should be available. Following April 30 is a surplus-flow period, replenishing the reservoirs towards the middle of June, 1908, and continuing until August 31 adding a further 43 billions of cubic feet to the reserve storage.

August 31 is followed by a slack period lasting until March 31, 1909, by which date 79 billions of cubic feet will have been withdrawn from storage. The two lakes, Rainy and Namakan, could have supplied this volume. A period of ample flow follows, replenishing the storage reservoirs by the end of August, and continuing until January 31, 1910, adds an additional 17 billions of cubic feet to the volume of available storage. February is slack and draws 10 billions from the reservoirs, which, however, are filled again about the middle of April, and a further 12 billions added by May 31.

By May 31, 1910, surplus flow totalling 254 billions of cubic feet has occurred and, providing reservoirs are available, should be on hand to supply the prolonged period of slack and variable flow which follows.

Assuming that the Rainy and Namakan reservoirs are first utilized to replenish this draw, shows them empty, or 79 billions of cubic feet utilized by November 30, immediately following which comes a further draw of 67 billions of cubic feet from the upper lakes, lasting until May 31, 1911. This continuous and rapid draw would have the effect of emptying a large number of the reservoirs, and leaving them ready for the storage of any surplus in the months following. June is a month of surplus flow, adding 12 billions to storage. This is, however, withdrawn by the end of September, following which is a continuous draw until April 30, 1912, by which time a further 77 billions of cubic feet has been withdrawn.

Four months' surplus flow follows, adding 46 billions of cubic feet to storage by August 31. This is required by the middle of February, 1913, and an additional 24 billions by the end of April. Following April are three months' surplus flow adding 55 billions of cubic feet to the reservoir by the end of July. From this date, there is a continuous draw totalling 55 billions, until the end of the cycle, at which date 7 billions of cubic feet are in the reservoirs, the equivalent of the initial supply.

Briefly, the above analysis indicates that a storage capacity of 247 billions of cubic feet is necessary in order to maintain a flow of 7,962 second-feet throughout the seven-year cycle. Of this total, 79 billions are supplied by 5 feet on Rainy lake and 12 feet on lake Namakan, leaving 168 billions to be provided from other sources. Referring to tables 14 and 15, which list a number of the more important lesser lakes in the Rainy lake watershed, it will be noted that column 12 lists the volume of storage which could be secured, assuming a permissible depth of 5 feet available in each lake where the annual run-off is sufficient to supply the necessary volume, and full storage where such is not the case. Storage to the extent of 98 billions of cubic feet could be secured in this way on these assumptions, by the construction of some 47 dams, leaving 70 billions to be elsewhere provided.

It might be noted that the sills of the Chandière falls dam are at 490·15 and will in times of emergency allow Namakan lake to be drawn several feet below the low limit considered above, and hence add further storage to the volume available. There are undoubtedly numerous lakes not listed in the tables, which might be suitable for reservoir purposes. Also, there is little doubt that the 5-foot limit on many lakes could be exceeded, as, for instance, 10 feet is permissible on Maniton lake, 30 feet on Otukanamawan lake, 7 feet on White Otter lake, according to the Sixth Annual Report of the Ontario Hydro-Electric Commission. Against this, must be placed in some cases the lack of sufficient catchment area to supply the run-off necessary to fill the reservoir, also the necessity of providing run-off for logging purposes, for the possible future operation of small water-powers, and for the maintenance of fishing interests. The 70 billions additional storage would undoubtedly strain the reservoir capacities of the watershed to the limit, leaving out of consideration the question of the economic feasibility of a storage system involving an excessive number of lesser reservoirs.

Referring again to the mass curve, it is noted that 79 billions of cubic feet storage would practically maintain the mean flow from the beginning of the cycle to the end of November, 1910: also, that 115 billions of cubic feet would maintain the same flow from the middle of March, 1911, to March 31, 1914, storage capacity for which quantity could very readily be found. The prolonged period of low flow commencing in the spring of 1910 is responsible for the excessive storage requirements noted above. To bridge this gap necessitates carrying water over from the year 1907 and the succeeding two years.

It is of interest to note briefly what general conditions of run-off might have been maintained throughout the cycle, assuming that the 79 billions of cubic feet storage capacity which is now available for power storage purposes in Rainy and Namakan lakes had been available at all times, with no auxiliary storage in the upper lakes. No difficulty would have been experienced in maintaining the mean 7,962 second-feet flow to the end of May, 1910. Throughout the prolonged slack period which followed, the 79 billions of storage would, however, only be sufficient to maintain a flow of about 5,500 second-feet. Under this condition of run-off the basins would be empty by March 31, 1911, and filled again by the middle of September, 1912, after which date no difficulty would be experienced in maintaining 7,962 second-feet to the end of the cycle.

It would seem from the foregoing that in normal years the maintenance of the mean flow, 7,962 second-feet, does not require excessive storage provision, but that in order to ensure its continuance over exceptional and prolonged periods of low flow, a very complete system of storage is required throughout the basin. It is recognized that the period over which discharge data are available does not cover a sufficient number of years to permit positive statements being made as to what absolute extremes are to be anticipated. More extreme conditions than are covered herein may undoubtedly occur. The long period of low flow which has been experienced forms, however, an excellent example, of the abnormal conditions which may be expected, and which must be ensured against.

To sum up it may be said that to maintain an average flow of 7,900 cubic feet per second at all seasons will require a most exhaustive system of storage reservoirs among the lesser lakes. Economic considerations will militate against the development of the lesser reservoirs beyond reasonable limits and a complete regulation of the run-off from this section of the watershed is not considered feasible. The measure of its practicability can only be finally ascertained by a detailed study of the lakes and basin. A dependable flow of 6,000 second feet can be readily ensured.

This phase of the Rainy river regulation is particularly important in relation to the question of diverting a portion of the tributary drainage into the St. Louis river and utilizing it for the development of power in the neighbourhood of Duluth, under what is known as the Birch Lake Diversion Project. This matter is covered in detail in chapter IX.

English River Watershed.

The English river drains an area of 21,600 square miles, comprising the entire northern portion of the Winnipeg watershed, which portion is very similar in general characteristics to the southern section. It is plentifully supplied with lakes of all sizes up to Lac Seul of 340 square miles area.

For purposes of storage and regulation study, the English River basin can be most readily considered from two standpoints; first, the regulation of the entire basin as a unit so as to secure the best run-off conditions at the mouth of the river; and second, the regulation of the basin above Lac Seul with the object of securing the best run-off conditions at the lake outlet. The first method of regulation has more direct bearing on the bettering of run-off conditions along the power reach of Manitoba, while the second would be more beneficial to a future hydro-electric scheme along the English river, and at the same time equally as desirable from a standpoint of bettering the Manitoba conditions.

Lac Seul is the largest lake in the basin. While little information has as yet been collected by the engineers of the Dominion Water Power Branch with respect to its adaptability to use as a storage reservoir, and the extent of flooding which would be involved in various storage depths, it is at least certain that limited storage is available. Throughout the following, 10 feet has been considered as the limit permissible. While a theoretical discussion of the lesser lakes would indicate that less than 10 feet on Lac Seul would probably still permit of a satisfactory regulation of the run-off, it is important that its reservoir capacity be as great as possible, in order that it may serve as a balancing reservoir for the lakes above. As was previously noted, the distance of the upper lakes from the reach at which regulation is desired, places practical difficulties in the way of efficient control.

Run-off conditions.—No continuous records of discharge have been secured to date along the English river, due to difficulty of access. Steps are being taken at present by the Hydro-Electric Power Commission of Ontario to secure such a record in the immediate future. Miscellaneous measurements taken in the past will be found in Appendix VII, tables 86 to 91.

In the meantime, the only run-off data available on which to base a study of the regulation of the river, are the continuous records taken by the engineers of the Dominion Water Power Branch at Otter-Slave falls station on the Winnipeg, and at the outlets from the Lake of the Woods at Kenora. The difference between these records, reduced in proportion to the area of the drainage basins, has been used in the analysis hereunder.

The mean monthly discharges deduced as above are listed in table 27.

Table 27. Mean Monthly Discharge of the English River at its junction with the Winnipeg.

[Drainage area, 21,600 square miles.]

Month.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	Mean.
	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.
January	11,056	16,392	13,711	12,602	6,597	13,459	15,230	5,257	12,163
February	10,776	17,068	13,102	11,573	5,717	10,231	15,358	1,515	11,043
March	6,190	13,009	7,329	8,857	5,286	7,237	11,216	3,260	7,800
April	3,994	10,719	5,102	16,175	3,146	6,761	8,615	1,456	7,480
May	4,711	13,093	8,580	26,065	5,560	15,099	9,260	5,942	11,047
June	13,000	17,457	11,851	24,851	8,705	21,001	11,706	12,074	15,081
July	16,616	19,625	11,860	19,113	13,093	19,931	13,120	13,737	15,932
August	17,211	17,816	11,893	10,591	16,813	20,611	11,874	12,370	14,909
September	18,587	16,401	9,500	7,302	16,767	22,225	11,270	11,421	14,233
October	20,135	16,327	7,711	6,319	18,516	21,636	9,355	12,365	14,050
November	20,019	11,416	7,830	5,092	16,063	20,033	7,016	10,198	12,625
December	18,319	11,823	9,836	4,457	12,787	16,568	6,182	9,257	11,151
The Year	13,612	15,353	9,892	12,778	10,757	16,236	10,875	8,791	12,291
Maximum	20,135	19,625	13,714	26,065	18,546	22,225	15,358	13,737	26,065
Minimum	3,994	10,749	5,402	4,157	3,146	6,761	6,182	3,260	3,146

NOTE.—Discharges are deduced by taking the difference between the Otter—Slave Falls and the Kenora records, and reducing the same in proportion to the areas of the drainage basins.
The maximum and minimum flows refer to the mean monthly flows.

The mean flow for the eight-year cycle, according to the above table, is 12,291 cubic feet per second. This average must represent very closely the actual discharge from the basin over the period in question.

For the purpose of analysing the run-off conditions as shown by table 27, a mass curve has been plotted, see plate 27. In this curve, water years have been used in keeping with the previously considered curves of the Lake of the Woods and the Rainy lake discharge. The mean run-off over the seven water years is 12,576 cubic feet per second.

Regulation over the seven-year cycle.—In the English river basin there is, so far as can be judged from existing maps, an area of some 3,000 square miles immediately adjacent to the river, which is either poorly or entirely unsupplied with lake area suitable for storage reservoir purposes. While exploration may result in the discovery of lesser lakes in portions of this section, it is necessary to consider such at this stage as non-existent. No control is therefore counted on over the run-off from this portion of the watershed. This run-off would, in a normal year, average 1,750 cubic feet per second. Omitting this flow from the seven-year mean, leaves 10,826 cubic feet per second to be maintained by regulation.

The general storage conditions which would be necessary in order to maintain uniform discharges of various limits at the mouth of English river throughout the cycle are concisely set out in table 28 hereunder.

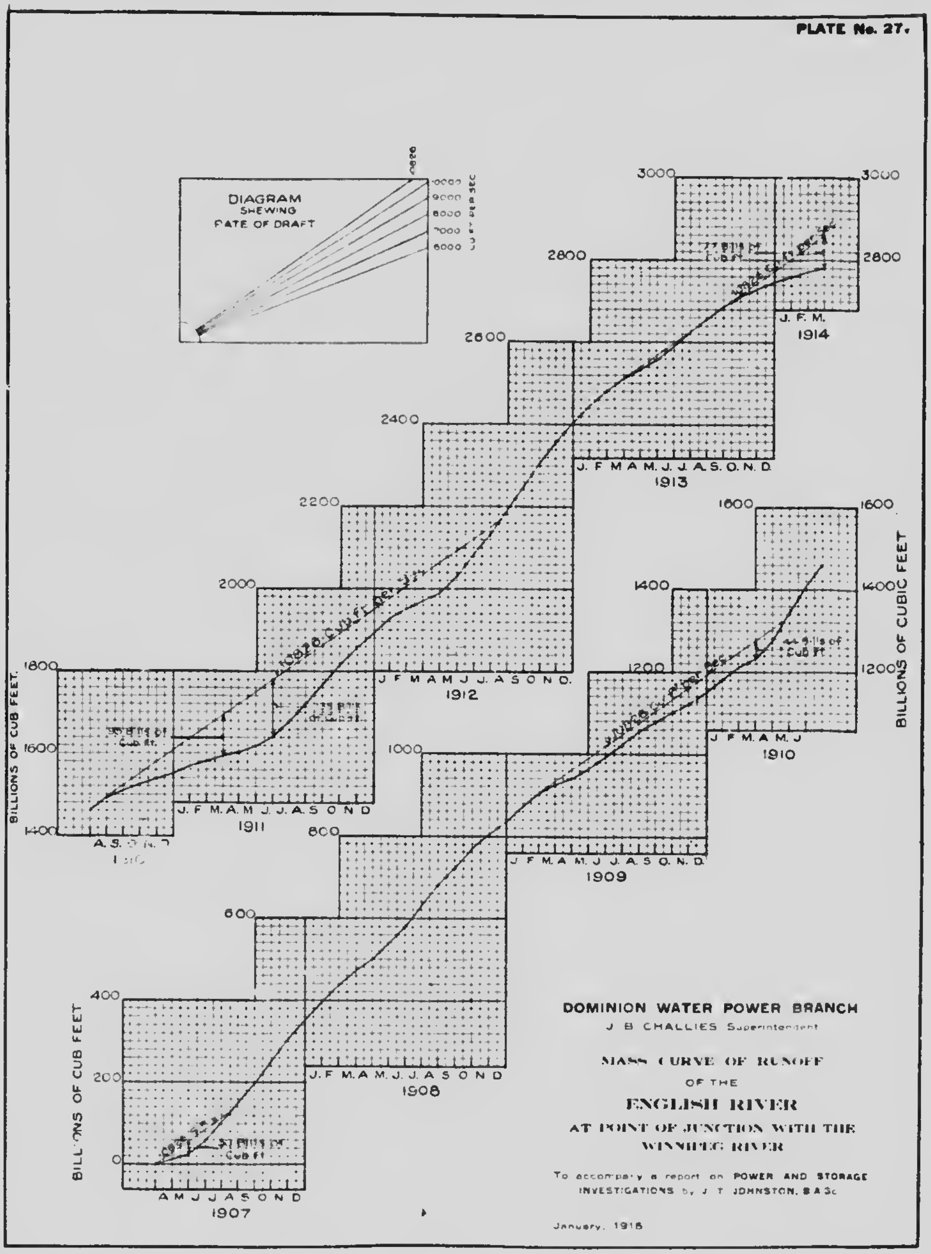
This table is compiled from a mass curve study. Column 3 lists the maximum volume of storage capacity necessary to meet the conditions; column 5 lists the total volume of water withdrawn from reservoirs throughout the period.

Table 28.—Storage Conditions which would have been necessary in order to maintain various Minimum Flows on the English River from April 1, 1907, to March 31, 1914.

Flow in Sec.-ft.	Period of Maximum Draw.			Total volume of storage used, in billions cu.-ft.
	Dates.	Volume required in billions cu.-ft.	Equivalent depth on Lac Seul in feet.	
1.	2.	3.	4.	5.
12,576	August 1, 1910 to end of period.	183	19·32	483
10,826	Aug. 1, 1910 to Aug. 15, 1912	134	14·14	331
10,000	Sept. 1, 1910 to June 10, 1912	109	11·51	256
9,000	Sept. 1, 1910 to Nov. 8, 1911	82	8·66	187
8,000	Sept. 1, 1910 to Sept. 20, 1911	59	6·23	129
7,000	Nov. 1, 1910 to Aug. 15, 1911	34	3·59	73

Analysing the discharge records from the mass curve (plate 27) on the basis of maintaining a mean flow of 10,826 second-feet shows the following.

The months of April and May, 1907, are slack and require an initial storage of 30 billions of cubic feet, which it is assumed are available from the previous year, and which 3·17 feet on Lac Seul would have provided. A period of surplus flow commences on June 1, restoring the 30 billions of cubic feet by about the middle of August, and continuing with only one slack month (April, 1908) until the end of February, 1909, by which date a further 245, or 275 billions of cubic feet in all, has been available for storage. Of this amount, 10 feet on Lac Seul can accommodate 95 billions. Following February is a period of alternate



slack and surplus flow lasting until March 31, 1910. The greatest draw during this period is 44 billions of cubic feet, which could be readily supplied from Lac Seul with a draw of 4·66 feet, the lowest stage occurring on March 31, 1910.

The surplus-flow period immediately following replenishes the lake towards the middle of the following May, and continues until the end of July, by which date a further 74 billions is available for storage.

Commencing with August 1, 1910, is the longest period of low flow encountered during the cycle. This slack period lasts until the end of June, 1911, and requires a draw from storage to the extent of 135 billions of cubic feet to maintain the required discharge. Lac Seul is emptied by March 31, leaving 40 billions to be supplied from the lesser lakes.

From the end of June, 1911, there is a long period of surplus flow, with but two minor slack periods, lasting until the end of September, 1913. This surplus flow would replenish Lac Seul towards the end of June, 1912, and the 40 billions from the lesser lakes by the middle of August of the same year, and would supply an additional 140 billions for storage purposes. September, 1913, is followed by a slack period which requires 77 billions of cubic feet from storage by March 31, 1914, the end of the seven-year cycle. This can be drawn from Lac Seul, leaving 18 billions in the lake, or a depth of 1·9 foot.

In reviewing the above it is noted that, assuming 30 billions available from previous years to bridge the initial slack period, there is a surplus of 489 billions of cubic feet available for storage purposes after providing for a discharge of 10,826 second-feet. The greatest draw during this period is 135 billions, of which it has been assumed that 95 billions are supplied by 10 feet on Lac Seul, the remaining 40 billions to be supplied by the lesser lakes.

Referring to tables 17 and 18, listing respectively the lesser lakes throughout the English River watershed below and above Lac Seul, it will be noted that the basin is well supplied with possible reservoirs. The total lake area tabulated in table 17 is 635 square miles. These lakes, 21 in number, would, under the conditions defined in columns 11 and 12 provide storage to the extent of 73 billions of cubic feet. Similarly, 25 lesser lakes above Lac Seul 599 square miles in total area, would provide for an additional 69 billions of storage. As has been noted previously, however, other interests may prevent these lakes being used for the sole purpose of maintaining satisfactory regulation for power purposes, and too great reliance must not be placed on a theoretical discussion, also there is a limit to the number of lesser reservoirs which can be economically constructed and maintained in a practical system of river regulation.

It would nevertheless appear from the above that, assuming 10 foot storage on Lac Seul, there is sufficient reservoir capacity in the English river watershed to maintain, if properly controlled, a mean run-off at the mouth of the river of 10,826 second-feet. A low limit of 10,000 second-feet should at least be feasible. To secure this end would necessitate holding a portion of the storage for a period of two years.

In the above analysis, 3,000 square miles of the watershed have been omitted from consideration on account of lack of reservoirs. Should a series of hydro-electric plants be in future installed along the English river, the local pondage basins of the same will partially rectify this condition. Under present conditions, 0·14 cubic foot per second per square mile can probably be depended on from this section as a minimum flow, i.e., a run-off of 420 cubic feet [illegible]ond.

This would increase the minimum at the mouth of the river and render more dependable the 10,000 cubic feet per second referred to above.

REGULATION OF THE WATERSHED ABOVE LAC SEUL.

Lac Seul bears much the same relation to the English river as does the Lake of the Woods to the Winnipeg river. From the lake to its junction with the Winnipeg the English river drops through a series of more or less abrupt falls and rapids. That these rapids and falls are capable of concentration after the manner of those on the Winnipeg, there is no room for doubt. Hydro-electric development along this river will take place just as soon as the market conditions are favourable. When this takes place, the question of regulation in Lac Seul and the upper waters will become more acute. The extent to which this regulation can be attained is briefly outlined hereunder, in so far as the basin run-off data available will permit.

Run-off conditions.—As was the case in considering the English river as a whole, the run-off data on which the following analysis must be made is deduced from the continuous records secured at the Otter-Slave Falls station on the Winnipeg, and at the outlets of the Lake of the Woods at Kenora. The difference between these records, reduced in proportion to the drainage areas, forms the basis of the theoretical discussion hereunder, and the deductions therefrom can serve as an indication of what is to be expected under natural run-off conditions.

The mean monthly discharges deduce [illegible] ve are listed in table 29.

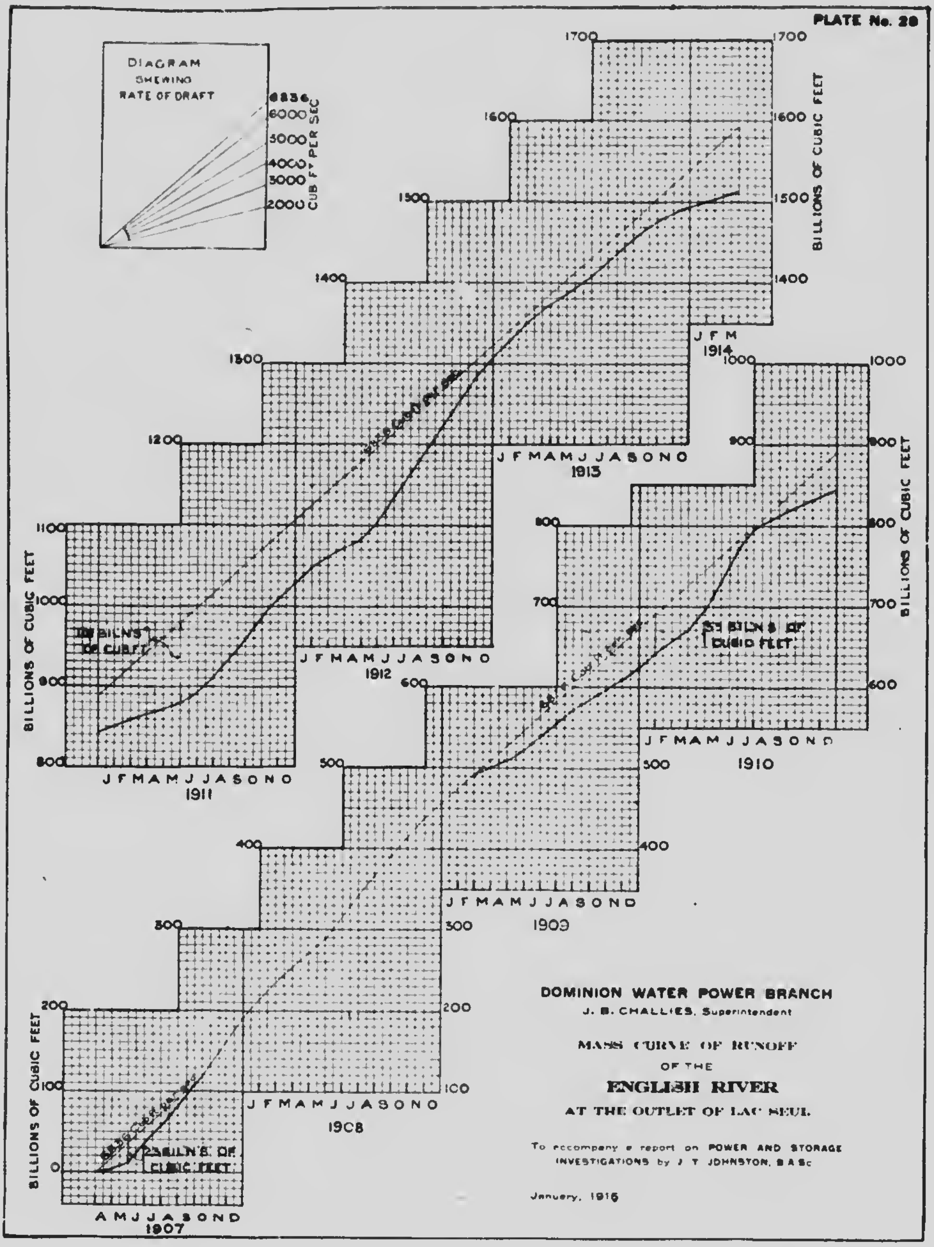
Table 29.—Mean Monthly Discharge of the English River at the outlet of Lac Seul.

[Drainage area, 11,700 square miles.]

Month.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	Mean.
	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.
January	7,641	8,910	7,455	6,850	3,586	7,316	8,279	2,857	6,612
February	5,858	9,278	7,122	6,291	3,108	5,563	8,319	2,155	6,003
March	3,365	7,074	3,981	4,820	2,871	3,934	6,097	1,776	4,241
April	2,171	5,843	2,937	8,956	1,710	3,677	4,683	2,422	4,019
May	2,579	7,117	4,664	14,169	3,022	8,208	5,037	3,216	6,005
June	7,067	9,490	6,442	13,509	4,732	11,416	6,363	6,563	8,198
July	9,049	10,668	6,447	10,406	7,117	10,835	7,295	7,467	8,661
August	9,374	9,701	6,465	5,757	9,140	11,222	6,455	6,724	8,105
September	10,104	8,915	5,213	3,969	9,111	12,081	6,125	6,372	7,737
October	10,945	8,875	4,193	3,435	10,082	11,761	5,085	6,722	7,637
November	10,882	7,853	4,256	2,768	8,732	10,899	3,811	5,707	6,863
December	9,958	6,427	5,347	2,423	6,951	9,036	3,351	5,032	6,063
The Year	7,416	8,346	5,377	6,946	5,847	8,826	5,912	4,779	6,681
Maximum	10,945	10,668	7,455	14,169	10,082	12,081	8,319	7,467	14,169
Minimum	2,171	5,843	2,937	2,423	1,710	3,677	3,351	1,776	1,710

NOTE.—Discharges are deduced by taking the difference between the Otter-Slave Falls and the Kenora records and reducing the same in proportion to the areas of the drainage basins.
The maximum and minimum flows refer to the mean monthly flows.

The mean flow for the eight-year cycle, according to the above table, is 6,681 cubic feet per second. This figure must closely represent the actual discharge from the lake over the period in question.



The mass curve, plate 28, is based on the above table. In plotting this curve, water years have been utilized in keeping with the practice adopted in other portions of the basin. The mean flow for the seven-year cycle of water years is 6,836 cubic feet per second.

Regulation over the seven-year cycle.—The general storage conditions which would be necessary in order to maintain uniform discharges of various limits at the outlet of Lac Seul are concisely set out in table 30 hereunder.

This table is compiled from a mass curve study. Column 3 lists the maximum volume of storage capacity necessary to meet the conditions; column 5 lists the total volume of water withdrawn from reservoirs throughout the period.

Table 30.—Storage Conditions which would have been necessary in order to maintain various Minimum Flows on the English River at the outlet of Lac Seul from April 1, 1907 to March 31, 1914.

Flow in sec.-ft.	Period of Maximum Draw.			Total volume of storage used, in billions cu.-ft.
	Dates.	Volume required in billions cu.-ft.	Equivalent depth on Lac Seul in ft.	
1.	2.	3.	4.	5.
6,836	Mar. 1, 1910 to end of period	104	[illegible]	267
6,000	Aug. 1, 1910 to Aug. 15, 1912	71	[illegible]	188
5,000	Sept. 1, 1910 to Nov. 15, 1911	48	5·06	112
4,000	Sept. 1, 1910 to Sept. 1, 1911	24	2·53	56
3,000	Nov. 1, 1913 to end of period	6	0·63	19
2,000	April 1, 1907 to May 15, 1907	1	0·11	2

Analysing the discharge records from the mass curve, plate 28, on the basis of maintaining a mean flow of 6,836 cubic feet per second shows the following.

The months of April and May, 1907, are below the mean flow, and require an initial storage of 23 billions of cubic feet, which volume is assumed to be available from previous years, and which 2·43 feet on Lac Seul would provide. The lake would be refilled early in October of the same year, while the continued high flow would provide an additional 77 billions of cubic feet by the end of February, 1909. Ten-foot storage on Lac Seul would accommodate 95 billions of this volume, leaving 5 billions to be stored in the lesser lakes.

Following February, 1909, is a continuous low-flow period until the end of March, 1910, by which date 55 billions of cubic feet are withdrawn from the reservoir. March is followed by ample flow until the end of July, by which date the storage basins are replenished by 53 billions of cubic feet.

With August 1, 1910, commences the greatest slack period in the cycle, lasting until the end of June, 1911, and requiring a withdrawal of 101 billions of cubic feet from storage to bridge the gap with the required mean flow. The net storage available from the commencement of the cycle to meet this draw is 98 billions, hence necessitating an additional three billions available and carried over from previous years.

Following June 30 is a period of alternate surplus and deficit, with the former predominating, lasting until the end of February, 1913. By this date a net total of 95 billions is available for storage. By the end of the cycle, i.e., March 31, 1914, this storage has been reduced by 69 billions, leaving 26 billions available.

In reviewing the above, it is noted that a total of 26 billions of cubic feet is required at the commencement of the cycle, and that the maximum storage required at any one time is 101 billions. This storage could probably be provided. Ten feet on Lac Seul will supply 95 billions of cubic feet. The lesser lakes listed in table 18 will accommodate, under the limitations of columns 11 and 12, a total of 69 billions.

There is therefore, under the above conditions of flow, and assuming 10 foot storage on Lac Seul, sufficient reservoir area for the storage capacity required. It must be repeated, that the discussion is theoretical and is not based on actual run-off measurements on the English river but on deduced records from the Winnipeg river. However, after making allowance for these considerations there is good ground for believing that if the upper lakes provide reasonable reservoir facilities, the discharge from Lac Seul can be uniformly regulated under a properly operated system of control, and a discharge of 6,800 cubic feet per second maintained.

Effect of Regulation of the Lac Seul Watershed on the Powers of the English River.—It is advisable to here briefly outline the influence which a controlled flow on the English river would have on the river's power possibilities. In dealing with this, no attempt is made to combine or concentrate the various rapids and falls. Each is considered as a separate power prospect. Undoubtedly an investigation of the river would indicate concentrations such as are possible on the Winnipeg river. The falls and rapids with their respective drops used hereunder, are taken from the Fifth Report of the Hydro-Electric Power Commission of Ontario, issued in 1907, covering Algoma, Thunder Bay, and Rainy River districts.

The minimum flow to be anticipated under natural conditions along the English river varies considerably from the outlet of Lac Seul to the mouth of the river, there being 9,846 square miles of tributary drainage basin added in this distance. From table 27 the minimum mean monthly run-off on record is 3,146 cubic feet per second, occurring in April, 1911. This figure is checked by means of the deduced minimum inflow into the lake of the Woods during the seven-year cycle. At the rate of 0·14 cubic foot per square mile, the minimum monthly run-off of the English river at the mouth would be 3,045 cubic feet per second. The general characteristics of the Lake of the Woods and the English River basins are very similar, and the minimum run-off conditions should not vary greatly. It would not therefore be advisable under present conditions to depend on a higher minimum flow than 3,100 cubic feet per second at the mouth of the English river. At the outlet of Lac Seul this would be reduced to 1,685, or, in view of the natural balancing effect of Lac Seul, say 2,000 cubic feet per second. With a minimum of 2,000 second feet at Lac Seul and 3,100 second feet at the mouth of the river, the minimum dependable flow at the rapids and falls has been assumed to increase with their respective distances from Lac Seul. This assumption is sufficiently close to actual conditions to permit a reasonable comparison being made between power conditions under regulated and non-regulated run-off.

The analysis of the flow of the English river shows a mean flow of 6,836 cubic feet per second, from a regulation of the Lac Seul basin. A consideration of the whole basin shows a mean flow of 12,576 second-feet. In reviewing the conditions rendering this latter flow possible, it will be noted that the storage required can probably all be obtained above the Lac Seul outlet. Considering this, and the presence of the possible storage reservoirs tributary to the river just below the lake, it will be conservative to assume for comparative purposes a minimum flow of 8,000 second-feet throughout the English river under a properly controlled system of storage.

On this basis, table 31 hereunder has been deduced, i.e., an unregulated minimum flow varying from 2,000 second-feet to 3,100 second-feet from Lac Seul to the mouth of the river, and a regulated minimum of 8,000 second-feet throughout the reach.

Table 31.—Effect of Properly Controlled Regulation in the English River Watershed on the undeveloped powers of the English river below Lac Seul.

Site.	Head in feet.	Power in Terms of 24-hour H.-P. 75% Efficiency.	
		At estimated minimum flow under natural conditions.	At estimated regulated flow.
1.	2.	3.	4.
Ear Rapids	29	4,910	19,800
Manitou chute	28	5,100	19,100
" fall	15	2,730	10,200
" rapids	6	1,270	4,090
" fall	10	2,120	6,800
" rapids	6	1,270	4,090
" rapids	6	1,270	4,090
Kettle falls	19	4,670	13,000
" rapids	15	3,670	10,200
Caribou rapids	6	1,590	4,090
Total	140	28,630	95,460

From the above table the total power available, under estimated minimum conditions of flow, is 28,630 horse-power, while under a regulated flow this would be increased to 95,460 horse-power or by 233 per cent. It is apparent, therefore, that so soon as hydro-electric development becomes commercially feasible on the English river, the question of controlling the flow will likewise become active, so that, omitting all consideration of the power reach in Manitoba, the local needs of the English river will demand as complete regulation in the upper waters as the reservoir capacity will permit. Such regulation will be entirely beneficial to the Manitoba reach.

In reviewing the question of regulating the English River flow, it appears feasible by properly exercised control to ensure a minimum flow of 6,800 cubic feet per second at the outlet of Lac Seul, and 10,000 at the mouth of the river.

It is essential that the control and regulation when instituted shall be in independent and impartial hands.

Summary of the Results to be Obtained from Storage.

A review of the storage discussion can best be summarized under the natural run-off divisions of the watershed.

LAKE OF THE WOODS AND TRIBUTARY DRAINAGE.

The maintenance of the seven-year mean flow from Rainy lake (7,962 cubic feet per second) can only be ensured at all seasons by a most exhaustive and complete system of storage reservoirs among the lesser lakes, and is not considered to be practically feasible. A flow of 6,000 cubic feet can be readily ensured with the reservoirs now in operation.

The seven-year mean flow from the lake of the Woods (12,442 cubic feet per second) can theoretically be maintained at all seasons, but only if the lake of the Woods storage is supplemented by a very full measure of regulation in the upper basin. A discharge of 12,000 second-feet under a complete system of storage reservoirs and careful control may be ultimately practicable. A minimum of over 10,500 second-feet can be ensured with 5-foot regulation on the lake, and with the reser voirs now in operation in the upper basin. The full 5-foot limit on the lake of the Woods need only be drawn upon at intervals of years.

ENGLISH RIVER AND TRIBUTARY DRAINAGE.

The seven-year mean flow from Lac Seul (6,836 cubic feet per second) may possibly be maintained at all seasons. It is probable that little difficulty would be experienced in ensuring from 6,000 to 6,500 second-feet discharge in practical operation.

The seven-year mean flow of the English river at its mouth (12,576 cubic feet per second) cannot apparently be fully maintained, due to lack of suitable reservoirs in portions of the watershed. A discharge of 10,000 second-feet should be ensured by a full measure of practical control.

POWER REACH IN MANITOBA.

From the foregoing it would appear that the maintenance of a flow of 20,000 cubic feet per second in the power reach in Manitoba should be quite practicable. At the same time it would be well to emphasize here that the foregoing calculations should be revised from time to time, as later and more exact data become available both as to the storage capacities of the upper lakes and as to the general run-off of the basin. This is particularly true in respect to the English river, since it has been necessary in the foregoing to base its run-off on deductions from existing records on the Winnipeg. The systematic gauging operations now maintained on the English river by the Hydro-Electric Power Commission of Ontario will provide reliable data for checking and, if necessary, revising the conclusions now submitted covering the northern portion of the watershed.

Under present conditions of hydro-electric development in the upper watershed, 20,000 second-feet in the power reach can be secured from a proper control of the Lake of the Woods reservoir alone. With the increase in power utilized at Kenora and Keewatin, storage works must be installed in the English River basin, in order to ensure 20,000 second-feet in Manitoba at all seasons.

The increased use of power at the outlets of the lake of the Woods will necessarily involve a more regular outflow from the lake or, in other words, a raising of the present permissible minimum discharge. While this will be directly beneficial to the power reach, it will not meet the requirements of 20,000 cubic feet per second throughout the winter season.

Assuming that under conditions of greater power development at the lake outlets, 12,000 cubic feet per second were ensured from the lake of the Woods, it would not be possible to depend on a natural supplementary flow from the English river of more than 3,000 [illegible] 4,000 cubic feet per second, or say 16,000 cubic feet per second on the power reach. Lac Seul is the obvious source from which the extra 4,000 cubic feet per second to make up the required 20,000 must be secured.

It is altogether probable that the next considerable storage reservoir established in the watershed will be Lac Seul. Its waters can be used for the direct benefit of the Winnipeg reach until such time as power development takes place on the English river.

GENERAL PRINCIPLES OF REGULATION.

It is not possible to do more than theorize about the future course of development throughout the basin, and hence it is impracticable to lay down final principles which should control future regulation. It is possible, however, to enunciate a few general principles which should be kept in mind.

The Fort Frances power undertakings require the fullest measure of regulation attainable in the Rainy Lake watershed. All efforts must therefore be made to secure the highest feasible minimum flow, and to conserve to the greatest degree possible the entire run-off. It is scarcely probable that it will be feasible or desirable to establish sufficient reservoirs in the upper lakes to fully regulate the run-off from all portions of the basin. Rainy lake, as receiving the entire upper drainage, is the natural balancing reservoir for the power works. At such times and under such conditions as it is necessary to conserve the run-off to the utmost, it will therefore be necessary to maintain the lake level below the spillway crest of the control dam, in order to provide storage capacity for unexpected run-offs from uncontrolled sections of the basin, and to prevent possible waste.

Namakan lake likewise acts as a balancing reservoir for the lakes in the basin above, and should be utilized to regulate, so far as possible, the flow from the uncontrolled portions of the tributary drainage. The filling and emptying of such reservoirs as may be established in the upper basin is altogether a matter dependent on their location, capacities, and most advantageous use. In any event, Rainy lake will be utilized as the final balancing reservoir for the power works.

The present power used at the outlets of the lake of the Woods does not normally require more than 3,000 cubic feet per second for satisfactory operation. This flow can be readily secured, and at the same time the lake be utilized as a balancing reservoir for the Manitoba reach. As shown on plates 29 and 24, 20,000 cubic feet per second in Manitoba can thereby be readily maintained.

So long as there is ample flow available, it will not be necessary to exercise control over the discharge other than to keep the lake as nearly full as possible at all seasons, and draw from it only at such times as the power interests on the lower river demand. In other words, the lake storage must be kept at all times available as an insurance against low run-off conditions. These may practically always be counted on during the winter season. In normal years, the lake should be full throughout the summer and navigation season, and drawn down throughout the winter.

When the power demand at the lake outlets becomes more pressing and requires a flow approaching the average run-off from the lake, the control of the regulation will require a much greater degree of care, and will aim at a minimum of waste. Under these conditions, the lake must be maintained at an elevation sufficiently below the upper limit to permit the storing of the surplus run-off from the south and west, where no reservoir capacity other than the lake is available, and to make provision for extreme floods. At the same time, the lake must be filled to upper level before the commencement of the low-water season. Proper control, with these ends successfully attained, can only be insured by a thorough and intelligent study of past run-off conditions, and by the careful recording and analysis of similar data from year to year. The control of the lake must be supplemented by regulation of the watershed above Fort Frances.

CONTROL OF REGULATION.

A review of the magnitude and diversity of the power interests of the Winnipeg River watershed, emphasizes the outstanding importance of the control of its run-off through the operation of storage reservoirs. It is immediately apparent that if these reservoirs are in private hands and are operated solely to meet local needs, the general power interests of the basin and the particular interests of competing undertakings are certain to suffer. For example, assume that the regulation of the lake of the Woods is wholly in the hands of a private firm developing power at the outlets. Closing the regulating sluices at the lake outlets would completely shut off the flow from the lake, possibly for weeks at a time, and thereby reduce the flow in the Winnipeg power reach by at least one-half. Even under ordinary operating conditions at the lake outlets, it would at all times be possible to so control the lake as to adversely affect power developments on the lower river.

Other examples could be given. The above is sufficient to illustrate the impossibility of private control over storage reservoirs on a river such as the Winnipeg, where a large number of independent power establishments are in operation, all of which are equally dependent on the run-off.

This question of control is again dealt with in chapter VI in connection with the interdependence of the projected power concentrations and the existing

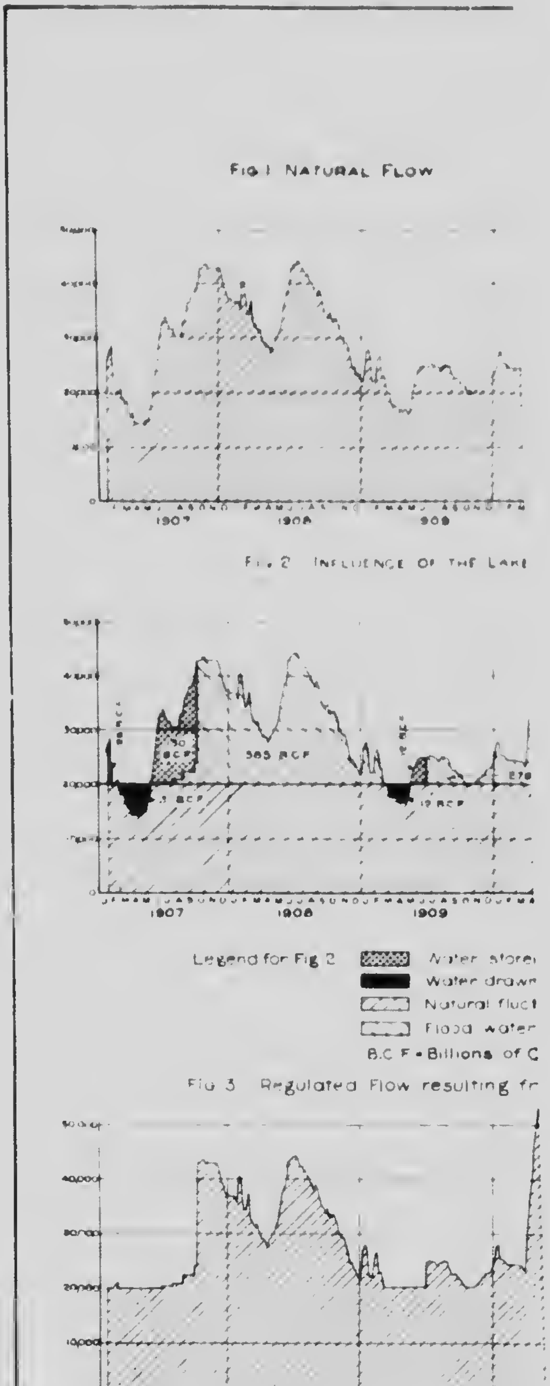


Fig 1 Natural Flow

Fig 2 Influence of the Lake

Fig 3 Regulated Flow resulting fr

PLATE No. 29

DOMINION WATER POWER BRANCH

HYDROGRAPHS SHOWING THE POSSIBLE REGULATING EFFECT OF THE LAKE OF THE WOODS

WINNIPEG RIVER FLOW AT SLAVE FALLS WITH PROPERLY CONTROLLED REGULATION

POWER AND STORAGE INVESTIGATIONS

Fig I. Natural Flow

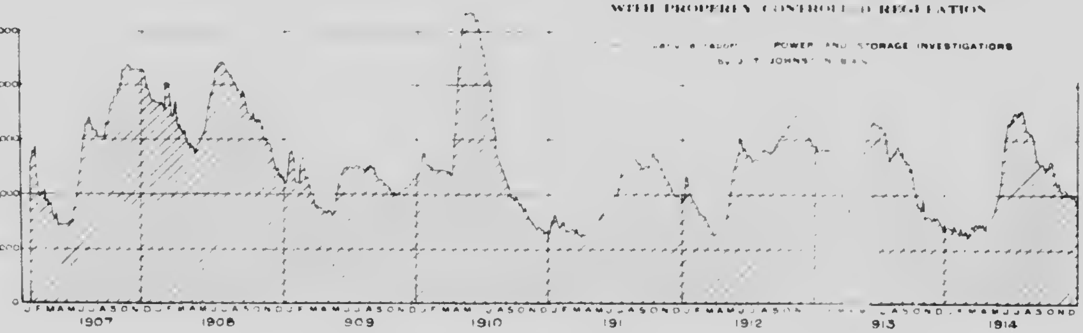
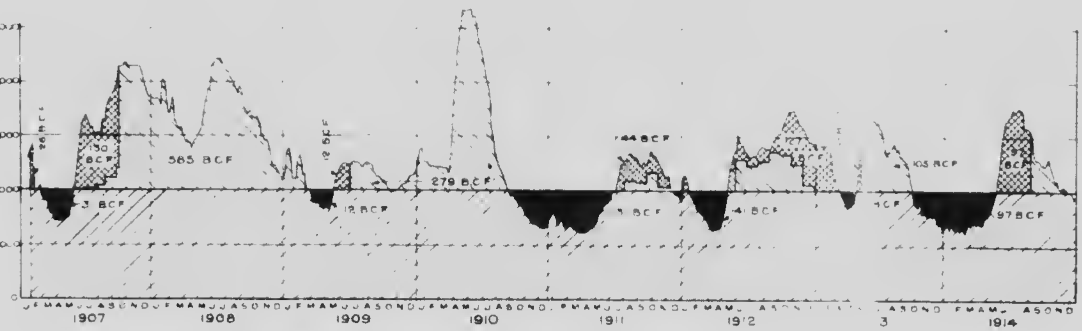


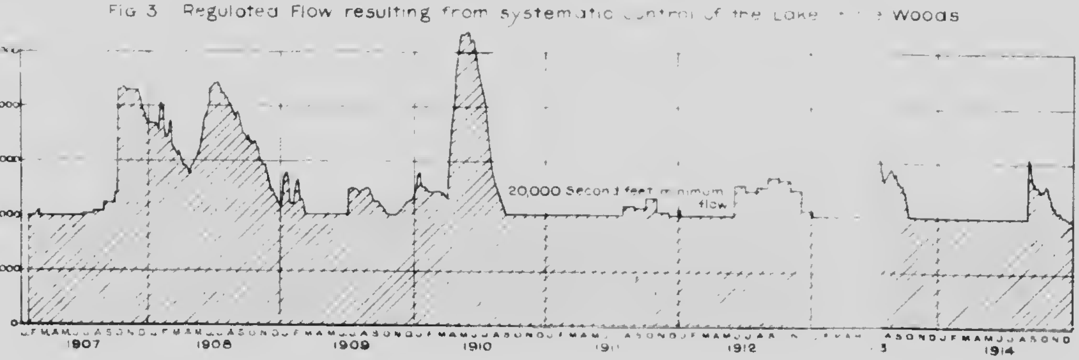
Fig 2 Influence of the Lake of the Woods Storage on the Natural Flow



Legend for Fig 2.
- Water stored from Natural flow
- Water drawn from Storage
- Natural fluctuation of flow exclusive of flood water
- Flood water wasted

B.C.F = Billions of Cubic Feet

Fig 3 Regulated Flow resulting from systematic control of the Lake of the Woods



plants on the Manitoba power reach, and the impracticability and unfeasibility of private regulation for purely local needs at each site is again clearly in evidence.

In addition to the power questions affected, the lumbering, fishing, navigation, and other interests must also receive their proper consideration in the general question of river regulation.

GOVERNMENT CONSTRUCTION OF RESERVOIRS.

If all interests dependent on and affected by the run-off are to be ensured satisfactory operating conditions, it is clearly apparent that there must be some central supervising control of the entire regulation of the river. The regulation of the basin must be in the interests of all concerned, as well as in the interests of each undertaking.

This being the case, it is evident that the establishment of storage reservoirs should be undertaken by the Government. The expense of their construction, maintenance, and operation should be shared among the various power users benefiting from their installation, and shared in proportion to the benefit received. Under these conditions, the proportionate charge on each power undertaking would be small. On the other hand, the private establishment of a reservoir throws the entire capital and operating costs on the particular company constructing the same, while the benefits derived from its moderating effect on the river flow are equally shared by all plants below. In view of this aspect, it should not be difficult for the Government and the power users to reach a mutually satisfactory basis of agreement with regard to the construction of necessary reservoirs, and to arrange for a proper sharing of the cost, maintenance, and operating expenses, among all parties benefited.

REGULATING AUTHORITY.

The operation of the regulation to the satisfaction of all can only be ensured by its being placed in charge of a responsible central control, to whom all questions pertaining to river regulation can be referred. It is considered that this central control could be best exercised through the joint action of the Dominion Water Power Branch and the Hydro-Electric Power Commission of the province of Ontario, or failing this, through some central governmental board or commission. To ensure satisfactory operation of the regulation, the controlling organization must possess the following primary qualifications:—

(1) It must possess the confidence of the various power and other interests affected by any phase of the regulation.

(2) It must be so constituted as to enable instant action being taken upon complaint or demand being made, that is to say, it must be represented on the ground, and immediately and at all times accessible to all parties interested in, or affected by the run-off regulation.

(3) It must at all times be in full possession of all data necessary to adjudge any question of regulation which may arise.

(4) It must have entire authority and direct charge over the operation of all storage reservoirs, and supervising control over the local regulation maintained by each hydro-electric and industrial undertaking utilizing the river run-off as a source of power.

METHOD OF CONTROL.

In order to fulfil the actual requirements of operation, it will be necessary for the controlling body to appoint and maintain a permanent and responsible regulating engineer in sole and direct charge of the regulation of the entire run-off. This officer, established in a central office, should be in daily receipt of full information as to the discharge of the river at all vital points, and as to the loads carried and water wasted at all hydro-electric and industrial plants along the river.

The satisfactory carrying out of the regulation will necessitate the careful rating of all power plants and dams throughout the basin, as well as full investigation into the time taken by the discharge from the various storage reservoirs to reach the different centres of development. Fairly complete data of this nature have already been gathered by the engineers of the Dominion Water Power Branch, and further investigations are being proceeded with. It is only by a thorough and continuous study of all run-off, storage, and load requirement data, that a control can be inaugurated which will, from its commencement, be satisfactory to all interests affected. Steps have already been taken by the Water Power Branch to carry out such a study.

In reviewing the entire situation as it now stands in the Winnipeg basin, and considering the conflicting interests which are at present affected by the question of regulation, as well as the importance of the future industrial development which must take place and is dependent on the river power, it is apparent that some such system of control as that outlined above must be instituted if the full benefit of the river flow is to be ensured to all. That this central control will be satisfactory to the interests affected and to the public at large, and will be vastly more efficient than haphazard regulation to meet immediate local needs, without regard to other interests and future requirements, is obvious to all who give the question serious consideration.

REPORT

ON

THE WINNIPEG RIVER POWER AND STORAGE INVESTIGATIONS

CHAPTER V.

EXISTING POWER AND INDUSTRIAL PLANTS.

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EXISTING POWER AND INDUSTRIAL PLANTS.

Before entering into a detailed study of the various units which go to make up the proposed scheme of hydro-electric development along the Winnipeg river in Manitoba, it will be advisable to deal briefly with the existing power plants and storage dams now constructed in the basin. Two large power stations are now in operation on the river in Manitoba, the Winnipeg Electric Railway plant on the Pinawa channel, and the city of Winnipeg municipal plant at Point du Bois. These plants and their safeguarding, formed controlling features which required first consideration in laying down a general scheme of development for the river. The entire reach of the river in Manitoba above Lac du Bonnet was more or less affected by the head- and tailwaters of, and the diversion conditions resulting from, the two existing undertakings. The river reach below Lac du Bonnet was undisturbed by existing structures, and offered full scope to development along maximum advantageous lines.

Pine Falls, Old Headrace.

First Development on the Winnipeg River in Manitoba.

What was probably the first power installation on the Manitoba reach of the Winnipeg river was undertaken some forty years ago at Pine falls. The river as a whole does not lend itself to small developments, and it is only by taking advantage of particular local opportunities that such developments are even feasible.

At Pine falls, advantage was taken of the rock and shore formation on the left river bank to blast a power raceway for the purpose of carrying the headwater level to a lumber and shingle mill located some 900 feet below. A head of about 9 feet was available. No diversion dam was constructed in connection with the head-race, the natural shore line providing of itself all the facilities which were necessary in this direction.

The mill was in continuous operation about thirteen years, was then shut down, and some five or six years afterwards destroyed by fire. The old turbine runner is still on the site, and is an interesting reminder of early industrial days on the river.

Winnipeg Electric Railway Company's Plant.

HISTORICAL.

The first large hydro-electric development constructed in Manitoba was that undertaken by the Winnipeg General Power Company on the Winnipeg river. This company was organized in 1901 for the purpose of developing power for distribution in Winnipeg. The Winnipeg Electric Railway Company was incorporated in 1904, and amalgamated the interests of the Winnipeg General Power Company with those of the Winnipeg Electric Street Railway Company. This latter company operated the street railway system of Winnipeg, and also distributed power for domestic and industrial use, supplying the same from a steam station located in the city.

The site selected for the construction of the plant is located on the Pinawa channel, in section 32, township 14, range 12, east Principal meridian, about 58 miles in a direct line from the city of Winnipeg. The general scheme proposed called for the diversion into the Pinawa channel of a portion of the Winnipeg River flow, by means of diversion weirs across the main channel, and the concentration and development of a 40-foot head.

CONSTRUCTION.

The site of the power station (plate 2) is 7 miles distant from the village of Lac du Bonnet, which at the time of construction gave the nearest railway connection. The city of Winnipeg tramway line now runs within 4 miles of the station. The construction of the plant required the installation of a ferry at Lac du Bonnet, where the river is somewhat less than a mile in width, and the construction of a traffic road. The heavier portion of the transport was carried during the winter season.

Operations on the excavation of the dam and tail-race began in the spring of 1902, the previous winter having been devoted to transporting the necessary plant to the ground, and the construction of the plant was practically completed by June, 1906.

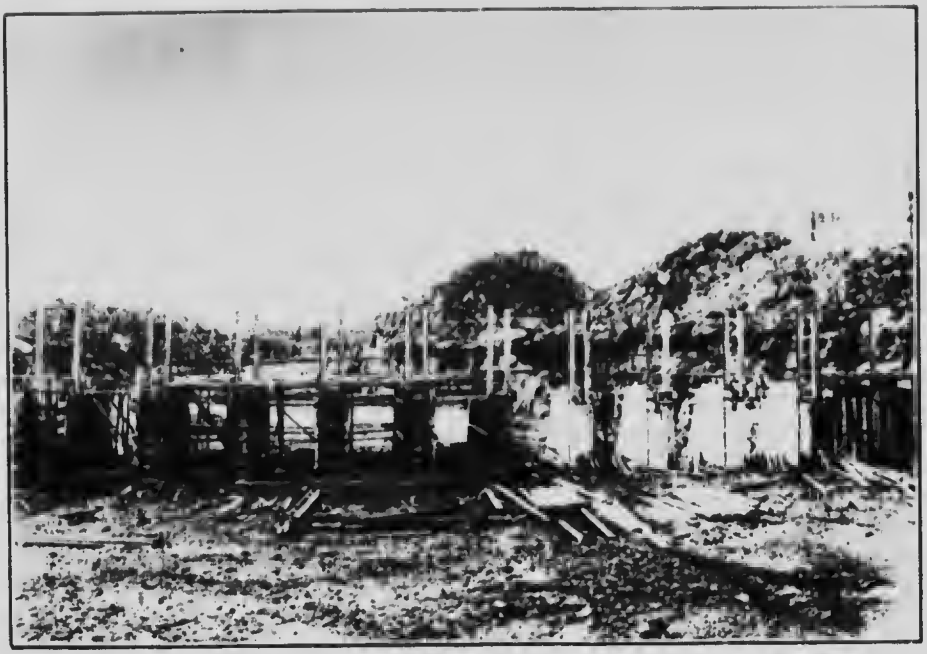
The late Dr. F. S. Pearson, consulting engineer of New York, with Mr. L. J. Hirt, C.E., had charge of the design and construction of the entire work.

Winnipeg Electric Railway Company, Main Weir.

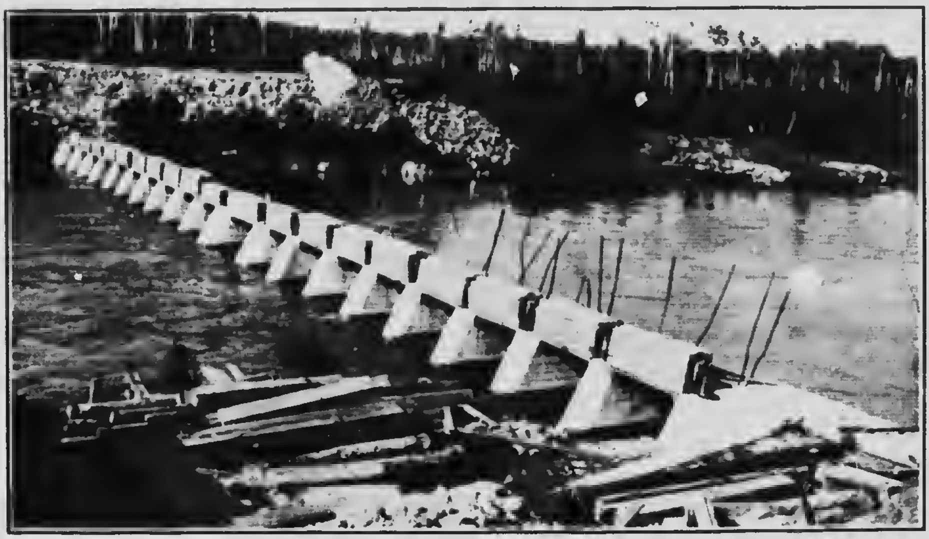
Fishway and Log Slide at Main Weir.

Winnipeg Electric Railway Company, Secondary Weir.

Winnipeg Electric Railway Company, Spillway on Loon River.



Winnipeg Electric Railway Company, Construction of Control Dam.



Winnipeg Electric Railway Company Control Dam.

DIVERSION WEIRS AND CONTROL DAM.

Three diversion weirs cross the main and secondary channels of the Winnipeg river at the head of the Pinawa channel (plate 30). The main weir consists of a 1,379-foot concrete capped, rock-fill structure, with crest at elevation 105·5, company's datum, or 897·44 Water Power Survey datum,[1] connected with the river banks on either side by concrete spillways with crests at 897·44, bringing the total length of the main weir up to 1,652 feet. This rock-fill section is not entirely water-tight, but fulfils the purpose for which it was constructed, i.e., raising the water level above to a sufficient elevation to divert the necessary flow down the Pinawa. A fish ladder and log slide are located at the west abutment of this weir. Two secondary weirs, one of timber, length 120 feet, crest at 896·94, and the other of concrete, length 535, crest at 895·94, spanning two secondary channels, complete the diversion system.

The discharge down the Pinawa to the plant is governed by a control dam, consisting of eighteen 9-foot and one 13½-foot stoplog sluice-ways, with sills at elevation 881·94. Above the control dam and the diversion weirs there is a pondage area of approximately 5,800 acres, extending up stream to the foot of Slave falls.

HEAD-RACE.

From the control dam to the power station pond some 2½ miles below, the head-race follows a somewhat winding route, which in places has been extensively improved, widened and straightened by excavation. The current is rapid, and the water surface, which above the weirs varies from elevation 898 to 901, drops to elevation 881 in the pond above the power dam. The tail-race presents conditions largely similar to those in the head-race, and the water finally rejoins the main river in Lac du Bonnet, about 13 miles below the station.

POWER STATION.

In the general layout of the plant (plate 31), the power station is placed on the west bank of the channel. The power-house building is 330 feet in length, 32 feet in width and 29 feet 9 inches from generator floor to top of roof truss. The generator floor is at elevation 851·44, with the bottom of the tail-race at 826·94. The intake dam is placed 95 feet upstream from the upstream side of the power station, the water being led to the turbines through 14-foot steel penstocks housed for protection against frost, and with their entrances guarded by the customary gates and racks. The transformer house lies to the north, and is an extension of the power-house. Its dimensions are; length 176 feet, width 53 feet, height 36 feet 9 inches. The entire building is of fireproof construction, being built of brick and structural steel throughout.

[1] 791·94 Water Power Survey datum = 0·0 Winnipeg Electric Railway Company datum.

Winnipeg River. Winnipeg Electric Railway Power House. Pinawa Channel.

INSTALLATON.

The hydraulic installation consists of nine main units, four of 2,595 h.-p. and five of 4,788 h.-p. (manufacturers' rating at 39-foot head). Each unit consists of four horizontal inward-flow runners mounted in pairs and located longitudinally in the penstocks. The draught tubes drop vertically into the tail-race, with the water seal at elevation 832·69. The turbines are direct connected to the generators, and are equipped with Lombard governors. The electrical installation consists of four 1,000-k.w. and five 2,000-k.w. revolving field, 60-cycle, 2,300 -volt, three-phase generators. The smallest machines run at 200 and the larger at 180 revolutions per minute. The generators are guaranteed to operate at full load at 95·5 per cent efficiency. Excitation is provided by two 100-k.w., 125-volt direct-current machines coupled to two 200-horsepower McCormick turbines, and operating at 600 revolutions per minute; and by two 175-k.w. 125-volt exciters coupled to three-phase 2,300-volt induction motors, operating at 514 revolutions per minute.

Table 32 lists the station equipment.

Table 32.—Machine Installation of Winnipeg Electric Railway Company in Pinawa Channel Plant.

Number of Units.	Turbine.	Generator.	Speed.	Voltage.
	H.-p.	K.w.	r.p.m.	
4	2,595[1]	1,000	200	2,300
5	4,788[1]	2,000	180	2,300
2	200	100	600	125
2	Motor driven.	175	514	125

[1] Manufacturers' rating at 39-foot head.

Fifteen transformers raise the voltage to 60,000 for transmission to Winnipeg.

A summary of the machine installation of the Winnipeg Electric Railway would not be complete without reference to the steam and storage battery plants operating in conjunction with the Pinawa station.

Prior to the year 1906, when hydro-electric power was first used in Winnipeg, all electric light and power was supplied from a steam plant on Assiniboine avenue in Winnipeg, owned by the Winnipeg Electric Street Railway Company. This plant had a capacity of about 5,000 brake horse-power. In the year 1910 the capacity of the Assiniboine Avenue power-house was increased by 1,000 horse-power. In the year 1911 an auxiliary steam plant of 12,000 horse-power capacity was constructed at Mill street adjoining the company's main substation. During the year 1913 the company built a storage battery house adjoining the Mill street substation, and installed a 5,000 ampere hour storage battery. At the present time (March, 1915) the Mill street station is capable of producing 16,000 horse-power, and the Assiniboine Avenue plant approximately 6,000 horse-power. At certain seasons of the year all of the company's steam power and the storage battery plant is in use and operated to capacity.

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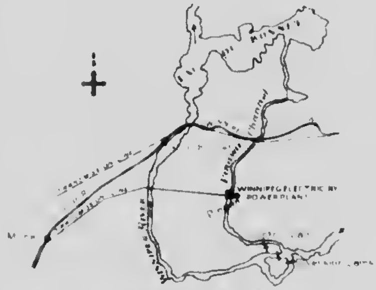
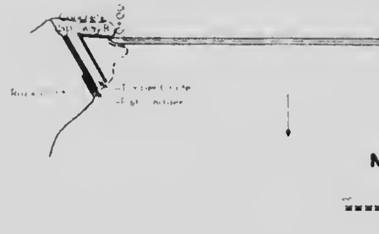
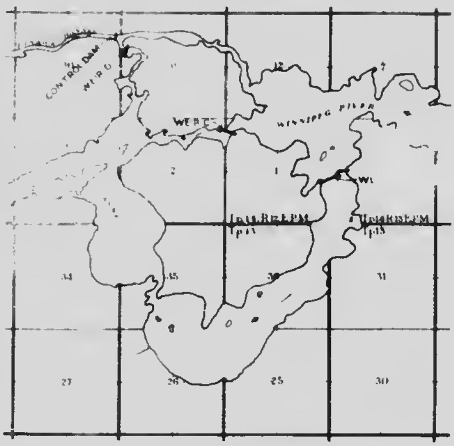


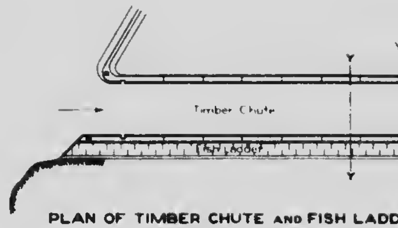
GENERAL KEY PLAN

Scale in Miles



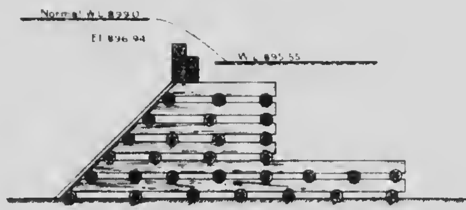


KEY PLAN OF WEIRS



PLAN OF TIMBER CHUTE AND FISH LADD

Scale of feet



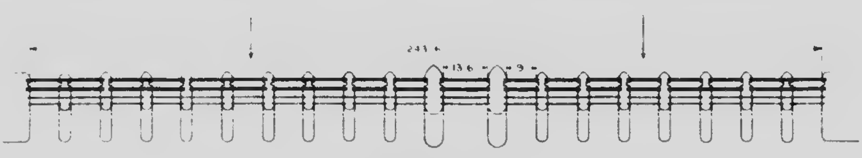
SECTION X.X. WEIR "C"

WEIR "C"

Scale of feet

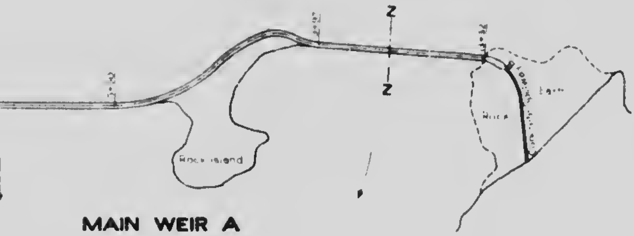
NOTE

PLAN BASED ON BLUE PRINTS FILED BY THE WINNIPEG ELECTRIC RAILWAY COMPANY



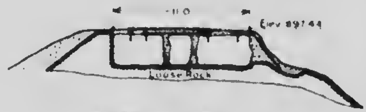
CONTROL DAM

PLATE No. 30



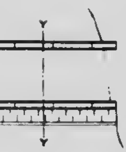
MAIN WEIR A

Scale of feet

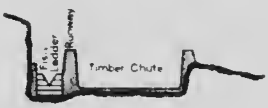


CONCRETE CAP OF Z. Z.

Scale of feet



FISH LADDER

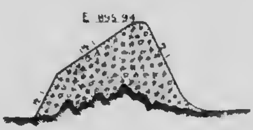


Y. Y.

Scale of feet

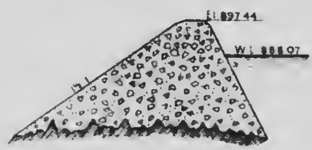
Z.Z.

Scale of feet



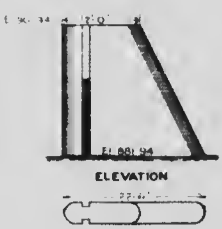
SECTION OF WEIRS "C" AND "D"

Scale of feet



SECTION OF SPILLWAY "B"

Scale of feet



ELEVATION

PLAN

PIER OF CONTROL DAM

Scale of feet

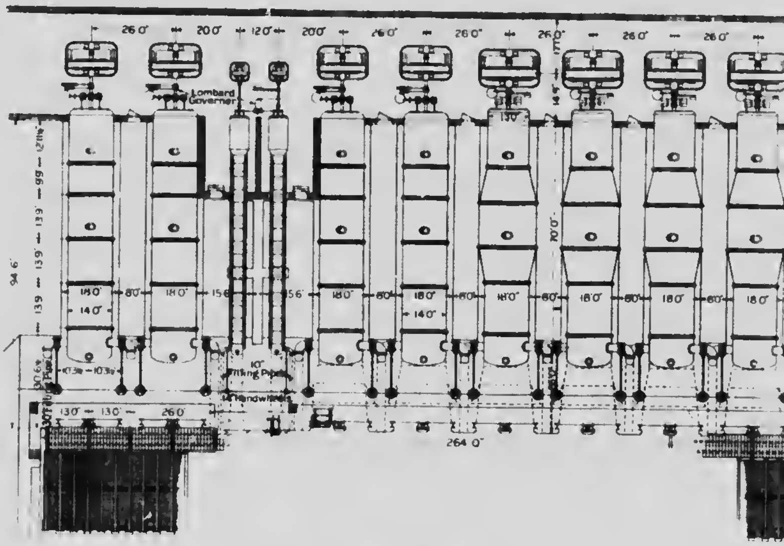
November 1914

Department of the Interior, Canada
Water Power Branch

WINNIPEG RIVER POWER SURVEY.

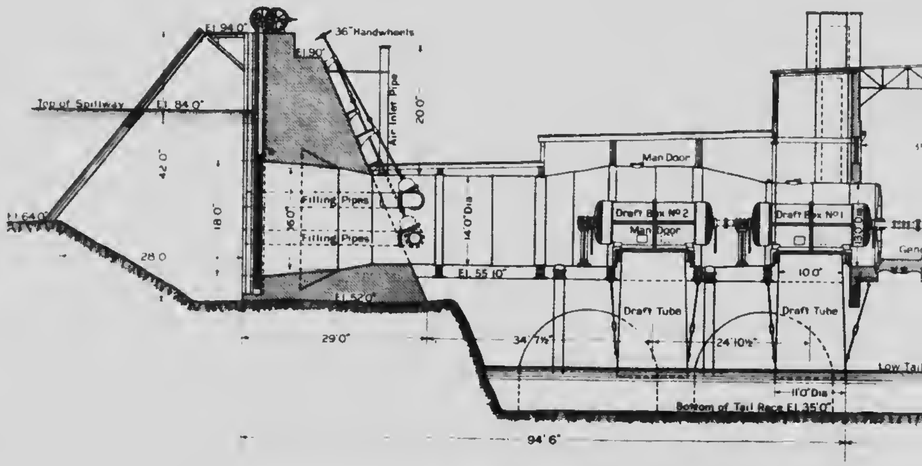
DIVERSION WEIRS and OONTROL DAM

CONSTRUCTED BY THE WINNIPEG ELECTRIC RAILWAY COMPANY
AT THE HEAD OF THE PINAWA CHANNEL



SECTIONAL PLAN

Scale of feet



TYPICAL SECTION OF INTAKE DAM, PENSTOCK & POWER H

Scale of feet

El. 791.94 W.P. Station – 0.0 Winnipeg Electric Ry Co datum

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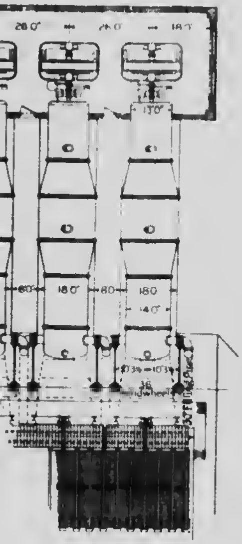
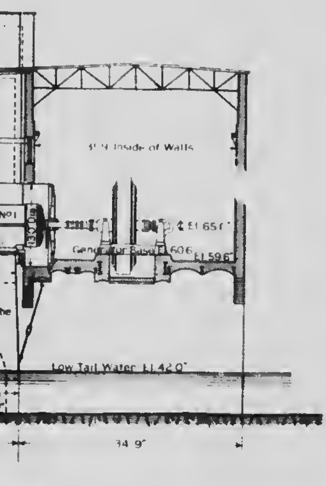
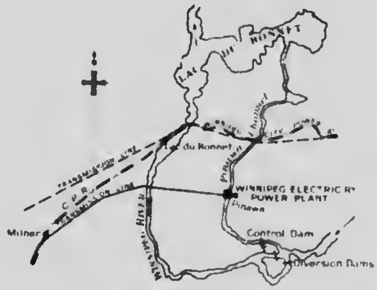
PLATE No. 31





...OWER HOUSE

NOTE
PLAN BASED ON BLUE PRINTS FILED BY THE WINNIPEG ELECTRIC RAILWAY COMPANY



GENERAL KEY PLAN

Scale of miles

GENERAL LAYOUT

Scale of feet

Department of the Interior Canada
HONOURABLE W. J. ROCHE Minister
W. W. CORY C.M.G. Deputy Minister
Water Power Branch
J. B. Challies Superintendent

WINNIPEG RIVER POWER SURVEY.

WINNIPEG ELECTRIC RAILWAY POWER STATION

CONSTRUCTED BY THE WINNIPEG ELECTRIC RAILWAY COMPANY ON THE PINAWA CHANNEL.

To accompany a report on power and storage investigations by J. T. Johnston B.A.S.

November 1916

Winnipeg Electric Railway Company, Model of Plant.

Winnipeg Electric Railway Company, Interior of Power Station.

The total power available for distribution in the city is in the neighbourhood of 45,000 horse-power.

POWER DAM.

A free spillway, curved in plan, and 429 feet in length, with crest at elevation 879·44, crosses the old river-bed along what was previously the crest of a natural

Winnipeg Electric Railway Company, Power Dam.

fall, and connects with the left bank. Low earth embankments with top at elevation 883 are located on either bank. All headworks are constructed to withstand a pond level of 882.

HEAD AVAILABLE.

The head available for power purposes varies considerably, depending on the season and the flow in the channel.

The original crest of the spillway was at elevation 875·67. This was raised in 1907 and again in 1910 to its present elevation, 879·51, by the placing of tiers of timbers along the crest. The average head available at the plant is 39 feet.

TRANSMISSION.

The entire output of the station is transmitted to Winnipeg at 60,000 volts, over a 65-mile duplicate transmission line. The line is supported on standard steel towers, 40 feet high and spaced at 500-foot intervals. It crosses the main Winnipeg river with a span of 760 feet, on 72-foot towers, and the Red river with a span of 1,100 feet on 105-foot towers.

The power is delivered to substations and distributed in the cities of Winnipeg and St. Boniface, the towns of Transcona, Stony Mountain, and Stonewall, the rural municipalities of Fort Garry, Assiniboia, East Kildonan, West Kildonan, St. Andrews, St. Vital, St. Pauls and Rockwood, and is supplied in bulk to the West Selkirk municipal plant.

Winter Conditions at Power Dam.

OPERATION.

Due to the long winding head-race, with its rapid and in places disturbed current, ice conditions have given considerable trouble. In the severe temperatures which prevail during the winter season, accumulations of frazil ice at times partially chokes the head-race, with a consequent reduction of the flow, and the use of explosives is sometimes necessary. Similar conditions are sometimes met with in the tail-race, and the choking of the channel results in backing up the tail-water with a consequent reduction of head. While these conditions result in considerable inconvenience, and require attention on the part of the company, they have not seriously interfered with the operation of the plant, and past experience enables the management to take prompt and efficient measures to combat adverse conditions as they arise.

FLOW REQUIRED.

In view of the fact that with a properly controlled run-off the surplus flow passing over the diversion weirs and down the main channel can be profitably developed on the Seven Sisters reach, a study of the flow in the Pinawa necessary to properly operate the company's plant, and also of the actual flow conditions since the plant was placed in operation, is of considerable importance.

As a result of the adverse ice conditions which occur during the winter season, and which produce sudden and considerable changes in the flow, and also from the fact that, until recently, no continuous systematic effort was made to secure a full record of the discharge, a determination of past conditions of flow at all seasons is a matter of considerable difficulty. A metering station was established by the field staff of the Dominion Water Power Branch in May, 1912, immediately below the control dam, and continuous records have been secured. This, combined with the existing gauge records provides a fairly accurate rating for summer conditions, but gives no data from which previous winter flows can be correctly determined. In order to secure this information it was necessary to rate the plant and to carefully study and utilize the load records.

While the final collation and reduction of the results secured is not yet completed, sufficient has been accomplished to indicate that the 8,000 cubic feet per second which has been utilized throughout this report as the flow necessary to properly operate the plant is amply sufficient for the requirements of the present installation.

The open-season discharge records of the channel are appended in tables 55, 56, and 57, Appendix VII. It will be noted that the discharge frequently exceeds 8,000 cubic feet per second. However, there is generally a considerable automatic discharge over the free spillway of the plant.

CITY OF WINNIPEG'S MUNICIPAL PLANT.[1]

HISTORICAL.

In order to meet the power demands of a rapidly growing population, and also for the purpose of creating, competitive conditions in the power market, the citizens of Winnipeg, after a prolonged consideration of the various phases of the matter, finally determined upon the construction of a municipally owned and operated power station on the Winnipeg river. In the year 1905, engineers were asked to examine the river with a view to selecting the best site available for the location of the proposed plant. A careful examination was made of

[1] In preparing the subject-matter for this section on the city plant, the writer is indebted to a paper read by Mr. W. G. Chace before the Canadian Society of Civil Engineers, and also to an article published in *Engineering*, July 26, and August 2, 1912, by the Vickers, Ltd., descriptive of the installation.

City of Winnipeg Municipal Plant, Power Station under construction.

City of Winnipeg Municipal Plant, Power Station under Con the hydraulic resources of the river, and the report presented justified the city authorities in having contour surveys made of the three most promising power sites. These surveys were carried out during the following winter, and the site finally selected was that at Point du Bois falls, at which point there was a natural fall of from 28 to 33 feet.

The final report, including the estimated cost of development, was submitted in April 1906, and in June the citizens voted $3,250,000 towards the construction of the plant. Designs and plans were begun in October of the same year, and it was then intended to complete the works within two and one-half years. Delay was occasioned, chiefly by the financial stringency of 1907, but tenders were finally called in August of that year for the construction of the plant. No contract was let at that date, but in the following spring work was commenced on the spur railway connection to Lac du Bonnet. In January 1909, contracts were let for the construction of the plant and the transmission line, and later in the year for other necessary construction and equipment. The plant was completed and the initial installation placed in operation in October, 1911.

The design and superintendence of the development was entrusted to Mr. C. B. Smith in the autumn of 1906, and was by him personally conducted until November, 1908, at which date the duties were assumed by Mr. W. G. Chace, as partner of the engineering firm of Smith, Kerry and Chace, resident in Winnipeg. There were engaged as a Board of Consulting Engineers, Col. H. N. Ruttan, City Engineer of Winnipeg; Professor Herdt, of McGill University, and William Kennedy, jr., of Montreal.

SCHEME OF DEVELOPMENT.

The Point du Bois falls are located 75 miles in a direct line from Winnipeg, in section 36, township 15, range 14, east principal meridian, and 22 miles from the nearest railway connection. This is at the village of Lac du Bonnet, referred to above. The spur line, or city tramway as it has since been called, is of standard-gauge construction, and crosses the main river by means of a wooden truss bridge at a point 2 miles below Lac du Bonnet station. A steel bridge carries the line across the Pinawa channel, 4½ miles below the plant of the Winnipeg Electric Railway Company.

At the Point du Bois falls the river pitches rather abruptly over two natural rock barriers, which, together with the smaller drops, rapids, and disturbed water, gave under natural conditions, a normal 30-foot drop in a distance of about 1,400 feet. The narrowest point of the river channel is at the crest of the falls. This location was selected as the site of the dam.

The layout is shown on plate 32. The dam spanning the main channel of the river is a rock-fill structure with crest at elevation 214, city datum, or 983·1 Water Power Survey datum.[1] This section is 700 feet long, and at present is not water-tight; it can be made so without much difficulty when occasion demands. At present the load carried has not reached the point at which the full minimum flow of the river is required.

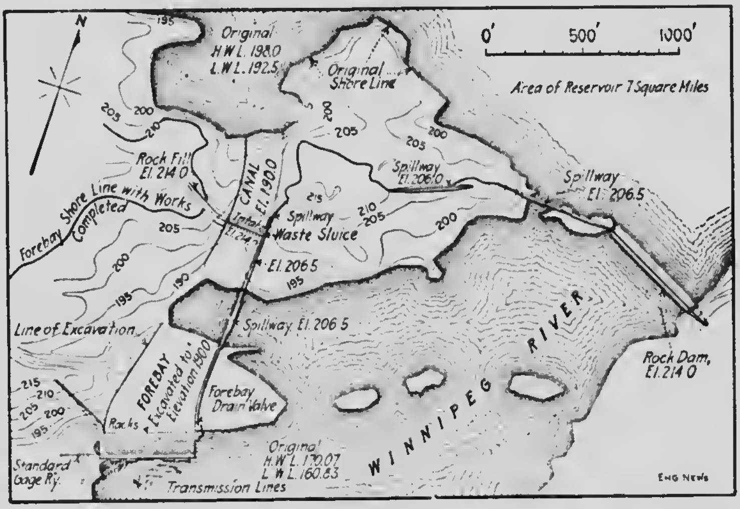
[1] 769·1 Water Power datum = 0·0 city datum.

Winnipeg River. Point du Bois Falls. Showing Dam of City of Winnipeg Power Plant in distance.

City of Winnipeg Municipal Plant, Model of Plant.

At the western end of the rock-fill section, the fishway and log slide have been located. To the west of this again, and crossing a bedrock island, is 550 feet of free concrete spillway with crest at elevation 975·7, connecting with the main shore.

PLATE 32.



Plan of Layout of City of Winnipeg Plant, Point du Bois, Winnipeg River. Elevations given to City Datum. Zero of City Datum = 769·1 Water Power Survey Datum.

A second section of spillway, 480 feet in length with crest at 975·7, spans a slight depression a short distance to the west of the main dam, while a third section, 245 feet in length, forms part of the canal wall immediately above the intake. The pond created is about 6,500 acres in extent, and floods the river back as far as Lamprey falls, about 7 miles above.

FOREBAY.

A forebay canal on the western side of the river, 1,600 feet in length, conveys the water from the pond to the power station. This canal is formed partially by excavation and partially by means of a retaining river wall (plate 33) with top at elevation 981·1. Two hundred and twenty-five feet of this wall acts as a free spillway, with crest at 975·7. The forebay has been excavated to 959·1, wherever necessary to provide sufficient section.

The entrance to the forebay canal is guarded by a control dam, regulated by twelve 17-foot stoplog sluices, sills at 959·1.

POWER STATION.

The completed power station (see plates 34 and 35) will be 442 feet in length, and will provide for seventeen bays. At present the nine bays adjacent to the river have been completely constructed, together with the headworks, rack supports, and the upstream half of the wheel pits for the remaining eight. The insertion of stoplogs above the wheel-pit entrance makes this section of the power station a provisional dam until such time as the market conditions demand the completion of the plant. The finished section of the building is 105 feet in width from the nose of the entrance piers to the exit from the draught tubes. The highest point of the roof is at elevation 1,013·3, or about 62 feet above the centre line of the turbines.

The building is constructed of concrete and steel, and is founded directly on the natural granite which is found practically on the surface over the entire

City of Winnipeg Municipal Plant, Power Station.

site. The wheel pits, galleries, and roofs are of reinforced concrete, while the main walls are of plain concrete.

The gate room, 34 feet in width, running along the upstream side of the power-house, has its floor at elevation 783·1, and provides protection for the handling of the screens, and the operation of the stoplogs and the emergency gates with which each unit is provided. Such protection is very necessary during the severe winter conditions prevalent in this latitude. The gate room is supported on concrete piers, 14 feet centre to centre, which piers also support the stoplogs and gates.

An upward sloping, strongly supported, reinforced concrete apron floors the bays between the piers, and forms the foundation for the screens, with their supporting struts, and for the gate and stoplog sills. This apron is designed to gradually increase the velocity of the water and to prevent the abrupt change which would otherwise take place at the entrance to the wheel pit. This entrance is 16 feet by 20 feet clear. The head gates are lifted by means of vertical screw shafts, 40 feet long, which rise through motor-driven nuts placed in the gate motor room. Each lifting motor operates any one of four gates. Stoplog gains are placed upstream from the gates.

Above the wheel pit is the turbine room, with floor at elevation 983·1. This is fitted with a 20-ton electric travelling crane of 29 feet span, with which the turbine parts can be readily handled. The wheel pits are elliptical

City of Winnipeg Municipal Plant, Headgate Room.

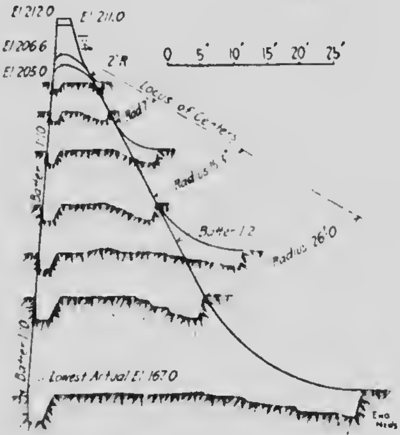
in plan, with floor at elevation 943·6. The double-runner horizontal turbine unit is placed with centre line at elevation 951·5. the discharge from the runners taking place axially into a common draught chest, and thence through a concrete moulded draught tube into the tail-race below the generator room, all changes of direction of flow being gradual and smooth. The water seal of the draught tube is at elevation 925·1.

The generator room is 36½ feet in width, and 51 feet in height, with floor at elevation 946·1. It is fitted with a 40-ton electric travelling crane. The transformer room is immediately downstream from the generator room, with floor at the same elevation.

INSTALLATION.

The original installation, completed in April, 1913, consisted of five units. Each of these original hydraulic units consists of a double-runner turbine of 5,200 horse-power, which, operating under a 45-foot head, passes 1,250 cubic feet of water per second. The turbines operate at 164 revolutions per minute,

PLATE 33



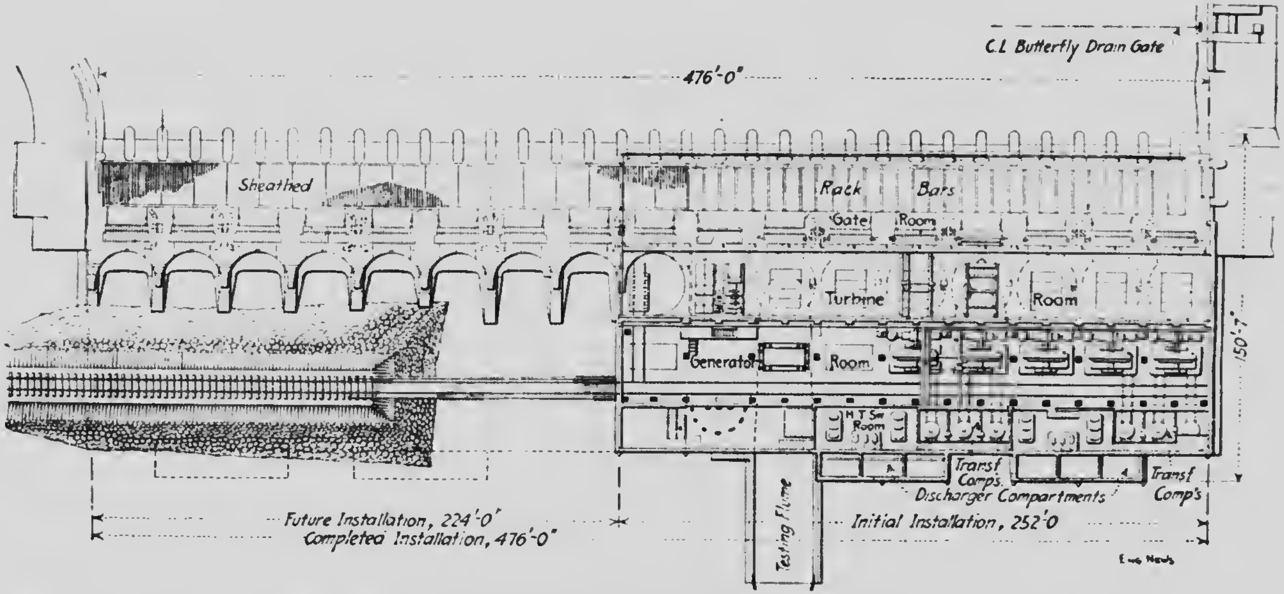
Section of Retaining Dam, City of Winnipeg Plant, Point du Bois, Winnipeg river.
Elevations given to City Datum. Zero of City Datum = 769·1 Water Power Survey Datum.

and have a guaranteed efficiency of 84 per cent at full load. They were supplied by Messrs. Jens, Orten-Boving & Company, London. The turbines have at times developed 5,900 horse-power per unit, but this is above their effective rating.

The turbine units are direct connected to 3,000-kilowatt generators, which generate three-phase current at 60 cycles and 6,600 volts, and which are of standard horizontal shaft, rotating field type. The machines were supplied by Messrs. Vickers, Limited, of River Don works, Sheffield.

The original machine installation was completed by two exciter units, each of 250-kilowatt capacity, and driven by water turbines running at 500 revolutions per minute. The transformers are of oil-immersed water-cooled type, and are situated in independent concrete compartments, delivering the power at 66,000 volts for transmission to Winnipeg.

In the year 1914, three additional main turbine units of different design to the original units were installed. These units are of the double-runner, horizontal-shaft type, but are of larger capacity than the inital units. Official tests give an output of 7,220 brake horse-power at 80 per cent gate opening and 46-foot head, or say 7,000 horse-power at 45 feet. The new turbines are direct connected to 5,000-k.v.a. Westinghouse generators, three-phase, 6,600 volts, 60 cycles, revolving fields.

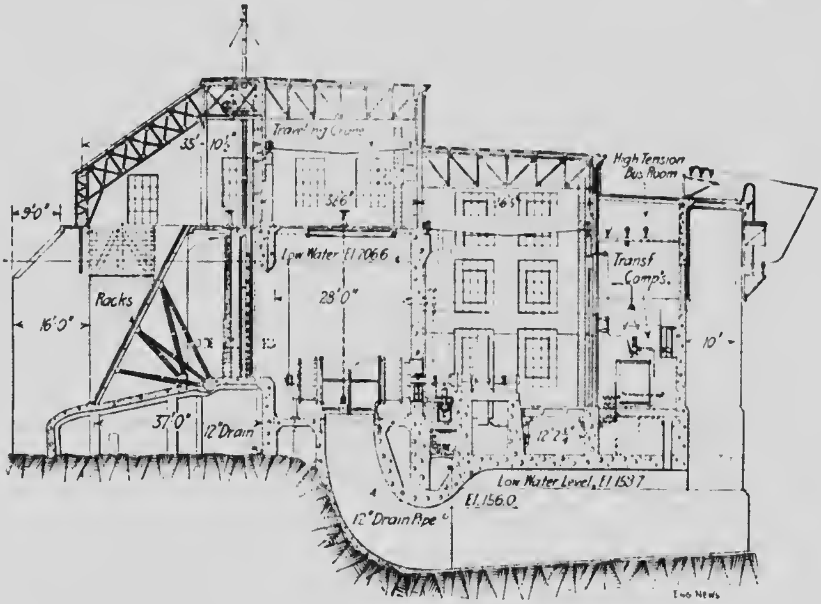


Plan of Power Station, City of Winnipeg Plant, Point du Bois, Winnipeg River. Elevations given to City Datum. Zero of City Datum = 769·1 Water Power Survey Datum.

The effective turbine installation to date of writing consists of the five initial units of 5,200 horse-power each, and three additional units of 7,000 horse-power each, or a total of 47,000 horse-power.

Assuming that the eight bays in the uncompleted section of the power station are equipped with units of similar output to these last installed, will give to the station a total water-wheel capacity of 103,000 horse-power, with some considerable additional overload capacity.

PLATE 35



Section of Power Station, City of Winnipeg Plant, Point du Bois, Winnipeg River.
Elevations given to City Datum.
Zero of City Datum = 769·1 Water Power Survey Datum.

HEAD AVAILABLE.

While the headwater elevation of the city plant can to a certain extent be regulated by the control dam at the head of the canal, at least to the end of keeping the level down in times of extreme flood should the same be desirable or necessary, the river walls and dams have been designed as free spillways which results in an automatic change in the pond level corresponding to the changes in the river stage. Under present conditions, the tailwater of the plant is subject to similar changes from the natural control at Eight Foot falls. The net result is that the head varies at different seasons. The normal head is 45 feet.

TRANSMISSION AND DISTRIBUTION.

The transmission line is built over a municipally owned right of way, 100 feet wide. It is 77 miles in length, and traverses a varied country, the eastern section being typically Laurentian rock, muskeg, and scattered areas of arable soil, the western section crossing a prairie and farming country, several miles of which are closely wooded. Two lines of double-circuit towers and a separate telephone line are to occupy this right of way. Up to the present one line only has been built. The first transmission circuit was placed in operation in October, 1911; the second circuit was erected on the existing line in 1914, bringing up the transmission capacity to 35,000 horse-power.

Winnipeg River. City of Winnipeg Development. Generator Room.

Steps are being taken towards the construction of the second line, the necessary funds having already been voted by the ratepayers. A 12-foot patrol road also occupies the right of way.

The line is supported by steel towers set on concrete foundations, bearing two three-phase aluminum circuits, the wires of which are at 6-foot centres. The towers are of two general types, braced and flexible, 42 feet high, and spaced generally 1,200 feet apart.

The three-phase, 60-cycle, 6,600-volt current delivered by the generators is transformed up to 66,000 volts, and delivered to the terminal station located on the river front on Point Douglas. The pressure is here stepped down to 12,000 volts for distribution to sub-stations in lead covered cables laid in conduits. Three sub-stations are now in use in the city, and one in Transcona, a town of 2,500 population, 7 miles east of Winnipeg.

Distribution to consumers from the sub-stations is by underground conduits in the principal down-town streets, and by overhead lines on wood poles in all other localities.

Direct current power is distributed in the business portion of the city mainly for operating elevators. Alternating current for both power and lighting is available at all parts of the distribution system.

OPERATION.

A pond area of some 6,500 acres which has been created above the plant has had the beneficial effect of protecting the station from ice troubles. The water is drawn from this pond into a head-race of such dimensions as to maintain a quiet and undisturbed current to the power-house, and it finally passes into the turbines with a minimum of disturbance. A free discharge from, and open water below the station prevents any choking of the tail-race, and no ice troubles have been experienced in the operation of the plant since its completion in 1911.

FLOW REQUIRED.

The station, with its present eight units in full operation, requires a flow of some 11,000 cubic feet per second, or practically the minimum flow of the river under present conditions. The eight additional units in the uncompleted section of the station will, if of the same capacity as the three units just installed, require some 13,000 cubic feet per second, or 24,000 cubic feet per second for the entire plant.

POWER.

The Point du Bois plant can draw on the entire flow of the Winnipeg river, and a discussion covering its power capacities must keep this constantly in view. At the time the plant was projected the lowest recorded flow of the Winnipeg river was 16,000 second-feet. The design of the plant was based upon this flow combined with local pondage and load considerations. At 75 per cent efficiency, and with a 45-foot head, the 24-hour power available on this basis was 61,400 horse-power. The actual capacity for which the plant was designed is 48,000 k.w. in generators, driven by turbines of maximum capacity of 83,200 horse-power, an output well within reason for the site and conditions.

Since the plant has been constructed, river measurements have recorded discharges as low as 11,700 second-feet. Throughout this report the minimum flow is taken at 12,000 second-feet, or just three-quarters of the previously

Winnipeg River. Panoramic View, City of Winnipeg Development at Point du Bois Falls.

considered low flow. Were this condition without remedy, it would appear that the city plant, when completed, would be overdeveloped, since 12,000 second-feet will only supply 46,100 24-hour power, in place of the 61,400 horse-power previously assumed.

Regulation of the river flow provides a ready and feasible remedy for this condition. A certain measure of regulation is at present maintained in the Lake of the Woods, and this has very materially benefited the river flow past the Point du Bois plant. A more systematic regulation based on the run-off data now available, and carried on in the interests of all the powers on the Winnipeg river below the lake, including those at the outlets of the lake, would vastly better the low winter flows now to be expected.

The rapid growth of the power market, as is evidenced by the three additional units just installed, following the placing in operation of the first units barely three years ago, emphasizes the fact that the question of regulation is of immediate concern.

Plate 36 illustrates in a power-percentage of time curve, the continuous 24-hour power available on a 75 per cent efficiency basis.

BENEFICIAL EFFECT OF REGULATION.

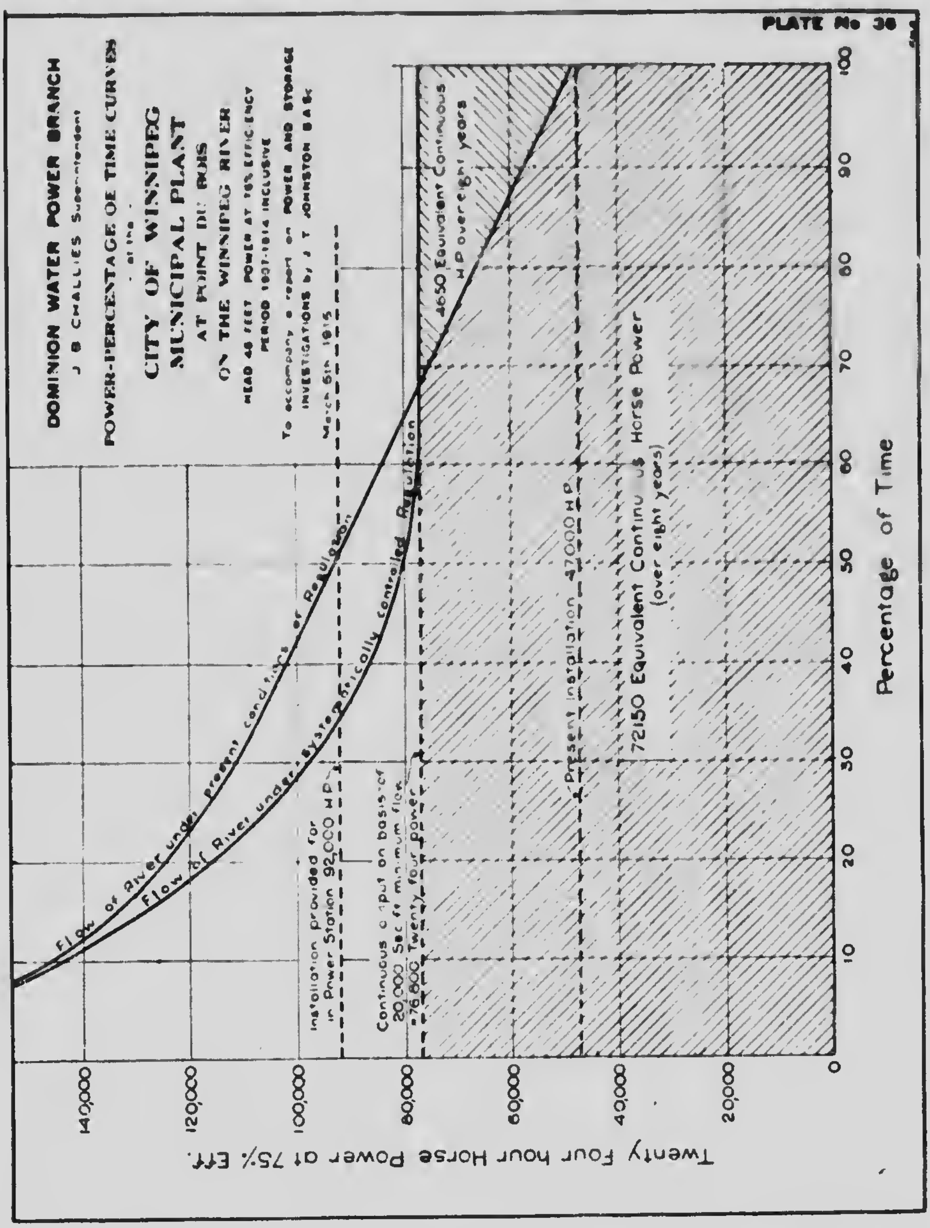
Throughout this report, the calculations for the power available at the located sites have been based on an initial installation capable of utilizing fully the minimum flow of 12,000 second-feet, and a final installation which will utilize a regulated flow of 20,000 second-feet. In chapter IV the question of regulating the river with a view to increasing the minimum flow is discussed. The mean flow for the eight years from 1907 to 1914, inclusive, has been 25,373 second-feet. It is entirely feasible to so control the run-off that the low flow will never fall below 20,000 second-feet, providing supervised control of the entire basin is maintained by some properly constituted authority. While 20,000 is taken as the low regulated flow, there is at certain seasons a very great surplus available over and above this.

With 20,000 second-feet under a 45-foot head and at 75 per cent efficiency, 76,800 24-hour power is available. With the advantages of a 6,500-acre pond for the peak load use, the actual power available for distribution and sale in a market such as is served by this plant is greatly in excess of this. The pondage facilities would readily permit a peak load development of 125,000 horse-power. A four-hour peak of 125,000 horse-power would draw on the local pondage to the extent of 0·6 foot only.

A regulation of the river to a 20,000 second-foot minimum, will therefore give to this site a considerably larger measure of dependable power than was contemplated in the design of the present power station, and will vastly better the power capacity as dependent on the present known minimum of 12,000 second-feet.

The general results of the above two limiting low flows are summarized as follows.

Under present conditions of river flow, with a known minimum of 12,000 second-feet, the dependable power available is 46,100 24-hour power. The development of this power will require only nine of the sixteen units provided for in the power station. The development of the sixteen units



will, under present conditions of river discharge, necessitate a steam auxiliary plant in the city to ensure dependable power during the low-water season.

With a minimum flow of 20,000 second-feet, the power available will be 76,800 24-hour power, with a peak load capacity of 125,000 horse-power

The development of this power will require the full utilization of the Point du Bois power station.

It is apparent from the above that the question of river regulation is of vital interest to the future of the municipal power undertaking.

OTHER DEVELOPMENTS IN THE BASIN.

While the two developments of the Winnipeg Street Railway and the city of Winnipeg, respectively, constitute the only hydro-electric plants in operation on the Winnipeg river in Manitoba, other undertakings in the upper portion of the basin must be referred to in order to properly understand and study the general run-off conditions and their relation to storage. To this end a brief description of the more important plants, power-using industries, and control structures is appended.

MUNICIPAL POWER PLANT OF KENORA.

In the year 1892 certain citizens of Kenora, after considerable investigation, undertook the construction of a small hydro-electric plant on the eastern outlet from the Lake of the Woods. Natural conditions at the outlets from the lake could not be bettered for the construction of economic low-head plants. There is an abrupt drop of from 18 to 20 feet between the lake level and the river below, which drop can be readily developed at several different locations. Added to this are the almost unequalled pondage and storage facilities afforded by the lake which forms the direct head-water reservoir. The eastern outlet offered particularly inviting conditions for power-development. The waters discharged through a narrow and somewhat winding channel, with an abrupt and concentrated drop at the narrowest point formerly known as the Ka-ka-be-kitchewan falls.

The station, constructed an[illegible] in operation in 1892 from designs by Col. H. N. Ruttan, afterwar[illegible]er of Winnipeg, was not intended to utilize the entire flow th[illegible]. A head-race partly in excavation and partly consisting o[illegible] about 10 feet by 10 feet in section, carried the water from a[illegible] on the right bank to the frame power station located below the p[illegible] charge from the turbines was protected by a wing dam from the effe[illegible] the rapid water below the falls. The first installation consisted of one 66-inch special Sampson vertical turbine, rated on a 17-foot head at 279 horse-power, 85 revolutions per minute, and 170 cubic feet per second.

In the following year a new penstock was constructed, and in 1894 a second turbine was installed. This wheel was a Standard Vertical Sampson, rated on a 17-foot head at 245 horse-power, 85 revolutions per minute, and 151 cubic feet per second. The head-race was enlarged to 20 feet total width. In 1896 or 1897 a third turbine was installed, being a 62-inch vertical turbine of the "Boss" type, and built by the William Hamilton Manufacturing Company.

In the year 1902, the municipal authorities considered the question of further enlarging the capacity of the plant to utilize the entire flow through the channel,

Kenora Power Station.

Kenora Power Station, Interior.

and engaged the engineering firm of T. Pringle & Sons to report on the proposed development, the power to be secured, and the cost of the works. Legal entanglements in connection with the land required on the left shore for this new construction delayed operations until 1906. In April of this year actual construction work was commenced, based on plans furnished by Pringle & Sons, under whose supervision the development work was carried on. The old power station and flume was removed, and on February 9 of the following year the new plant was placed in operation (plate 37). The installation at the opening was as follows:—

Three 40-inch Sampson twin horizontal turbines direct connected to generators, and supplied by the William Hamilton Manufacturing Company. Units 900 horse-power each (manufacturers' rating).

Two 30-inch Sampson twin horizontal turbines connected to exciter units, and supplied by the William Hamilton Manufacturing Company.

Three 625-k.w. generators, three-phase, 2,400 volts, 60 cycle, 150 revolutions per minute.

Two exciters, 120 volts, 175 revolutions per minute.

In the year 1913 a fourth 900 horse-power unit was installed, consisting of one 40-inch Sampson twin horizontal turbine supplied by the William Hamilton Company, direct connected to a 625-k.w. generator, three-phase, 60 cycle, 150 revolutions per minute, 2,400 volts. The governor installation consists of three hydraulic Lombard type N, and one hydraulic Allis Chalmers type C, governors, with two mechanical Woodward Compensating governors on the exciter turbines.

The power-house, which combines in itself the dam, is designed for six main units, and spans the entire channel, with the exception of a small space left for a log slide immediately adjacent to the left bank. The substructure is of mass concrete, and consists of a series of six arched bays forming the tail-races of the respective main units, and two lesser arched bays in the centre providing for the exciter units. The tail-water in these bays is maintained above elevation 76·0,[1] the water seal of the draught tubes, by a submerged weir constructed across the tail-race. The generator and turbine floor is at elevation 80·50, with the centre line of the machinery shaft at 88·83. The generator room is 35 feet by 158 feet, allowing 22 feet, centre to centre, for the main units. It is of brick construction and is covered with a peaked truss roof. The turbine chambers are covered with a 5-inch concrete roof which acts as a floor or platform giving ready access to the head gates.

The inflow to the turbines is controlled by hand-operated gates, with stoplog auxiliary apparatus for use if necessary. The racks, consisting of the regulation bar iron supported on 15-inch I-beams, rest on solid concrete sills, built up from the bedrock, immediately above the head gates.

Records of the load carried by the plant have been kept since August 21, 1907, at which time the total load was about 115 k.w. This increased to a peak of nearly 600 k.w. during the following winter. Since commencing operations the load has shown a steady growth reaching as high as 1,700 k.w. The

[1] An arbitrary datum of 100·0 has been used in the construction of the power house, and the establishment of the gauges. Zero of the Kenora power house datum is 961·32 Water Power Survey datum.

average load carried is in the neighbourhood of 1,300 k.w. The power is used in Kenora, Norman, and Keewatin for both lighting and industrial purposes.

No difficulty is experienced from ice troubles in the operation of this plant. The only condition which might lead to trouble in this connection would be abnormally low water in the lake during the winter season, under which circumstances the disturbed water and rapid current in the head-race might have a tendency to form frazil ice. During the summer of 1911, very low water in the lake reacted adversely on the operation of the plant. Elevation 93·7 was recorded in the head-race, due largely to the fact that the low lake level had reduced the section of the head-race, with the result that a very rapid current developed with a consequent drop in the surface level. These conditions resulted from imperfect regulation, and were not due to lack of run-off, since during the entire period some 2,000 second-feet were being wasted at the Norman dam on the western outlet. The condition could also have been remedied by deepening the head-race.

LAKE OF THE WOODS MILLING COMPANY'S MILLS AT KEEWATIN.

At the town of Keewatin, 1½ mile west of Kenora, excellent natural facilities exist for economic development. At this place the waters of Portage bay, an arm of Lake of the Woods, lie within 500 feet of, and some 20 feet above, a quiet reach of the Winnipeg river, and are separated therefrom by a rock ridge. The head- and tailwater conditions are similar to those existing at the Kenora power-house.

The first cut through the rock ridge was made in 1881 by a man named McAulay, the power developed being used for the operation of a saw-mill. In the following year, this power site became the property of Dick and Banning, and was used for saw-mill purposes until the year 1893. From this date, the flume was closed until 1899, when it was operated for two years by the Ottawa Gold Mining and Reduction Company, which acquired rights to the same in 1898. In 1900 the flume was again closed. In 1905 the site was acquired by the Keewatin Flour Milling Company, and the flume is stated to have been nearly doubled in size. The Keewatin Flour Milling Company was purchased by the Lake of the Woods Milling Company in 1906, and in May, 1907, the present mill, named mill "C," was put in operation. From 1907 to the present the mill has been in continuous operation.

The installation of mill "C" consists of two 56-inch twin horizontal turbines at 900 horse-power (manufacturers' rating), each at 20-foot head, and supplied by the William Hamilton Company. These two wheels are direct connected to the mill by rope drive. There is also a 45-inch twin horizontal turbine rated at 600 horse-power at 20-foot head, supplied by the William Hamilton Company, and direct connected to a 275-k.w. Allis Chalmers generator. This generator is an auxiliary, and is only used in case of a breakdown at the electric power-house, mill "A." The gate openings for the 56-inch wheels are operated by hand, while the generator-connected turbine is regulated by an automatic Lombard type B hydraulic governor. The electric power is used

Lake of the Woods Milling Company's Mills.

for elevators, hoists, etc. The working load of the mill is uniform in character and of 24-hour duration, and very suitable for direct application of power.

The average power developed is 1,100 horse-power, all of which is used by the company. No difficulty has been experienced in operating the mill, either from ice troubles or from lack of water.

The second cut was made through the ridge in 1887 by the Lake of the Woods Milling Company, for the development of power for use in flour milling. Mill "A" was constructed in connection with this intake, about twenty years before mill "C" was placed in operation.

The power installation consists of two pairs of 60-inch horizontal turbines on one shaft, at 2,400 horse-power, (manufacturers' rating), and supplied by the J. M. Voith Company, and one 22-inch vertical turbine rated at 95 horse-power supplied by the Dayton Globe Iron Works. The above wheels are direct connected to the mill machinery by square rope drive. There are in addition two 33-inch duplex horizontal turbines, each rated at 360 horse-power, and supplied by William Kennedy & Son, direct connected to 240-k.w., 600-volt, three-phase generators, running at 200 revolutions per minute, supplied by the Canadian General Electric Company. A further 33-inch single horizontal turbine rated at 180 horse-power, and supplied by Willian Kennedy & Son, is direct connected to a fire pump, and completes the installation. All ratings are given for a 20-foot head. The 22-inch wheel is used to drive the machine shop in case the flour mill is closed down, while the generator is used to supply power for elevators, hoists, lighting, etc., in both mills. Two hydraulic Brevette governors regulate the 33-inch wheels while the 60-inch wheels are regulated by hand.

The average power developed is 1,200 horse-power, all of which is used by the company. No difficulty from ice or low-water troubles has been experienced except during low water of 1911.

THE NORMAN DAM.

While no power has as yet been developed in conjunction with the Norman dam on the western outlet, its relation to the storage question in the Lake of the Woods is of primary importance.

Prior to the construction of the Norman dam, a timber dam had been built by the Dominion Government for regulation purposes, at the entrance to the western channel. This dam was removed by blasting by the Ontario Department of Public Works, in the year 1899. In the year 1891, the Keewatin Lumber and Manufacturing Company entered into an agreement with the Crown covering the construction of a regulating dam combined with a power-development project on the western outlet, and the following year a preliminary survey was made of the site and a report of the proposed development secured from William Kennedy, of Montreal. In 1893 the Keewatin Power Company took over the rights and obligations of the former company, and construction of the dam was commenced according to plans and designs by William Kennedy. Mr. James C. Kennedy acted as resident engineer during construction.

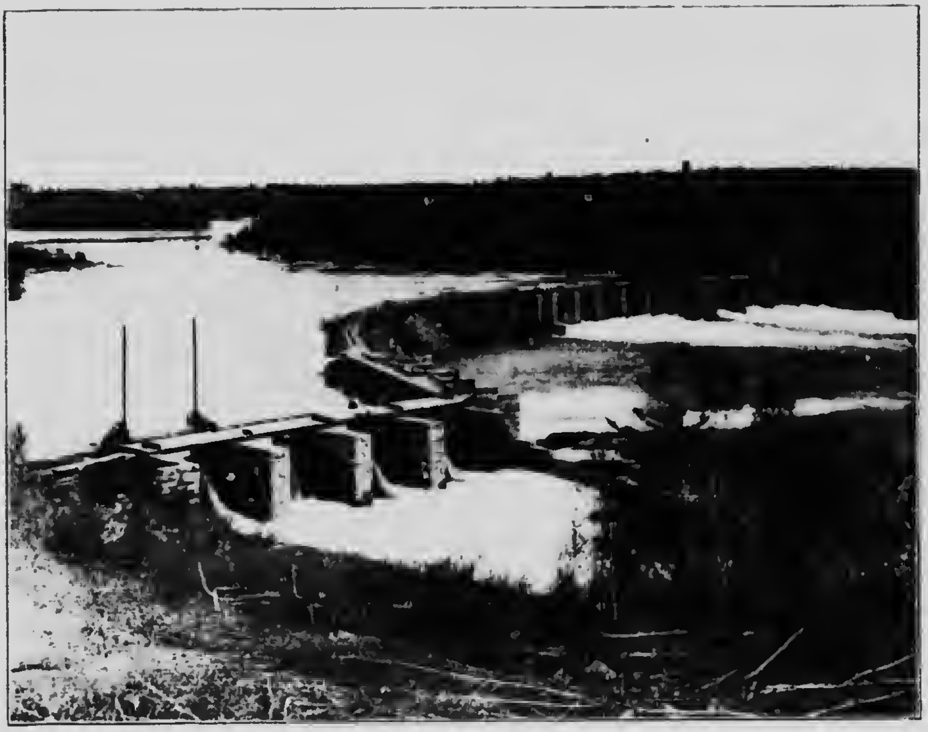
The general design of the dam (plate 38) called for a central portion composed of a rock-fill, made impervious by depositing graded stone, gravel, and finer materials along the upstream side, abutted on either end by stoplog controlled regulating sluices with piers and sills of granite masonry, and joined to either bank by power sluices, also stoplog controlled. In all, there are eight 21-foot power sluices, four adjacent to either bank with sills at elevation 1,040·6, and twelve 15·5-foot regulating sluices with sills at 1,038·7 (Water Power Survey datum). In plan the regulating sluices and rock-fill section are arched with

Norman Dam, under Construction.

the convex side upstream. A fishway has been constructed at the south end of the rock-fill.

Ideal foundation conditions existed in the form of solid granite, practically on the surface and readily unwatered.

The construction of the dam was commenced in November, 1893, a cofferdam being first built from centre island to the south shore. Masonry construction on the south flume and regulating sluices commenced the following March. During May, the north flume site was coffered, and construction on the northern sluices commenced. By October both power and regulating sluices had been completed. In December the cofferdams were removed and work was commenced on the rock-fill. This was completed in March, 1895. The timber platform on the piers, and the installation of the track and winches for operating the stoplogs, was delayed until 1898, although a few logs had been placed in all the sluices in 1895. In November, 1898, additional stoplogs were placed in the dam, and control of the regulation and gauge readings was taken over by the Ontario Department of Public Works. Due to the fact that no power development has as yet been undertaken in conjunction with the dam, no definite steps have been taken towards making the rock-fill section impervious, and considerable leakage takes place at all seasons.



Norman Dam.

The Norman dam is the controlling structure in connection with the regulation of the Lake of the Woods, discussed in detail in chapter IV.

FORT FRANCES DAM AND POWER PLANTS.

What were formerly known as the Koochiching falls are located on the Rainy river, about 2½ miles below Rainy lake. There was here a normal natural drop of about 22 feet, and the site offered an excellent opportunity for successful hydro-electric development. Its attributes in this respect were early recognized by the settlers residing in the vicinity on both sides of the river, but no steps were taken towards active construction until early in 1904. In this year an agreement was entered into between the Ontario and Minnesota

Ontario and Minnesota Power Company's Pulp, Paper and Power Plants at Fort Frances.

Ontario and Minnesota Power Company's Pulp, Paper and Power Plants at Fort Frances from below.

Power Company, represented by W. E. Backus, of Minneapolis, and the Department of Crown Lands of the province of Ontario, looking to the full development of the site. Since the Rainy river is an international waterway, and thereby comes equally under the jurisdiction of Canada and the United States, its resources belonging equally to both countries, specific clauses were inserted stipulating that one-half of the total power capable of development should be at all times retained and reserved for use on the Canadian side.

The particular matter of interest to the subject herein discussed is the relation which the operation of the power plants and the control of the dam bears to the regulation of the basin. The plant was ready for operation in 1910.

The general plan of development called for the construction of two power stations identical in size and capacity, one on either side of the river, connected by a dam of granite masonry which in plan resembled a letter V with the apex pointing upstream (plate 39). Each power-house allowed for the installation of nine units. The apex and left wing of the dam consisted of a concrete-capped free spillway section some 450 feet in length, crest at elevation 497, Department of Public Works datum,[1] and decked to allow ready access from one side of the river to the other.

In the right wing, and adjacent to the Canadian power station, were placed ten 10-foot gate-controlled arched sluiceways, with sills at elevation 477·50, and crown of arch at elevation 490·0. Through these sluiceways the river discharge is controlled, the spillway acting as a safety factor to combat extreme run-offs. Between the Canadian power station and the main river bank is an old excavated canal channel. This is not used for navigation purposes, its upper entrance being closed by head-gates. The American power station is connected to the river bank by a temporary crib dam, it being the intention to here add three additional units to the six now constructed.

The installation of the Canadian power-house at present consists of four 4-runner turbines of 1,700 wheel horse-power, supplied by the Holyoke Machine Company, connected to four 3-phase, 60-cycle, 6,600-volt, 1,250-k.v.a. generators. The greater proportion of the electrical power is transmitted to the United States side of the river. Adjacent to the generator room, and in the same power building, is the pulp-grinding machinery. This consists of five sets of grinders, three to a set, direct connected to horizontal turbines. A head of some 33 feet is developed, the tailwater averaging about elevation 463.

In the American power-house there are at present installed six 4-runner turbines of 2,200 wheel horse-power, supplied by the Morgan-Smith Company, each set connected to four wood-pulp grinders. Space is provided for three additional units. The power output of the entire development is utilized in pulp and paper manufacture, mills being in operation on both sides of the river. The Canadian mill is of recent construction and has about one-half the capacity of the American mill. A small block of power is used for lighting the towns of Fort Frances and International Falls.

The scheme of development as first laid down called for 18,000 horse-power installed turbine capacity in each power-house, or 36,000 horse-power

[1] 610·30 Water Power Survey datum = Zero, Department of Public Works datum.

in all. This would call for a much greater flow in the river than subsequent gaugings have found. The mean run-off past Fort Frances for the past eight years has been in the neighbourhood of 7,700 second-feet.

No difficulty has been experienced from ice troubles in the operation of the plant, but shortage of water at different seasons has, in an unmistakable manner, indicated the necessity for regulation in the upper waters. To this end, the company has investigated the storage possibilities of, and has taken active steps to secure storage rights on, several of the upper lakes.

CHAUDIÈRE FALLS DAM.

At Chaudière falls (Kettle falls), the Namakan lake level discharges into Rainy lake, with a normal drop of 8 feet under natural conditions. The

Chaudière (Kettle) Falls, Canadian Channel.

drop takes place in two channels, through the northern of which passes the international boundary, thus placing the dividing island and the south channel in Canadian territory. In February, 1912, plans were submitted to the Dominion Department of Public Works by the Rainy River Improvement Company (an allied interest of the Ontario and Minnesota Power Company) looking to the construction of storage dams across the two channels at Chaudière falls. It was hoped by this construction to secure 12 feet of storage on lake Namakan which, with its connected lakes, is 100 square miles in area. The first proposal called for dams of timber crib construction. Upon the recommendation of the engineers of the Department of Public Works the design was changed to a concrete and masonry structure, and additional discharging capacity was provided. Work on the construction of the dams proceeded throughout the year of 1914, and they are now completed (plate 40).

The International dam across the northern channel consists of four 14-foot stoplog controlled sluices with sills at elevation 490·15 (Department of Public Works datum), one of which is fitted with a timber log slide, with sill at 495·15. The piers rising to elevation 510·15 are of masonry construction with concrete sills. A fishway has been provided adjacent to the United States shore.

The Canadian dam across the southern channel consists of four 14-foot stoplog controlled sluices and a 6-foot fishway abutted on either side by an embanked masonry-face wall with top elevation at 510·15, connecting with the higher ground. The sill elevation of the most southerly sluice is 498·15, of the adjacent sluice, 496·15, and of the remaining two, 495·15. The northerly sluice is fitted with a timber log slide with sill at 500·15. The fishway is adjacent to the island. The general construction is similar to that of the international dam.

Chaudière (Kettle) Falls, International Channel.

It will be noted from the above that it is possible to lower lake Namakan by means of the international dam to a point much below its previous low level.

In conjunction with the above two dams it was necessary to close two gaps which would otherwise provide escape channels when the lake level approached its upper limits. These gaps were closed by the Bear creek and the Gold Portage dams, respectively.

The Bear Creek dam is a small timber-crib stone-filled structure spanning a 60-foot gap, with crest at 510·15, and some 6 feet high at the highest point.

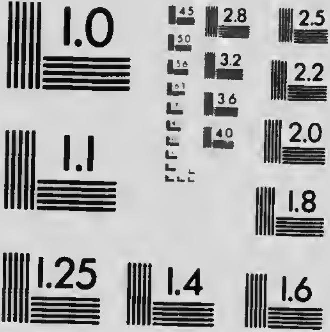
The Gold Portage dam is a longer structure, but of about the same maximum height. It consists of about 200 feet of crib dam and 225 feet of earth-fill. All structures are built to stand regulated high-water level of 508·5.

The storage questions involved are dealt with in chapter IV.

Various timber dams in a greater or less degree of repair are scattered throughout the basin. These dams have been constructed at the outlets of several of the lesser lakes by the lumbering interests, their purpose being to store water for a rapid flushing down of the timber during the log-driving season. Among the lakes so controlled are White Otter, Whitefish, Turtle, Martin, Beaverhouse, and Long.

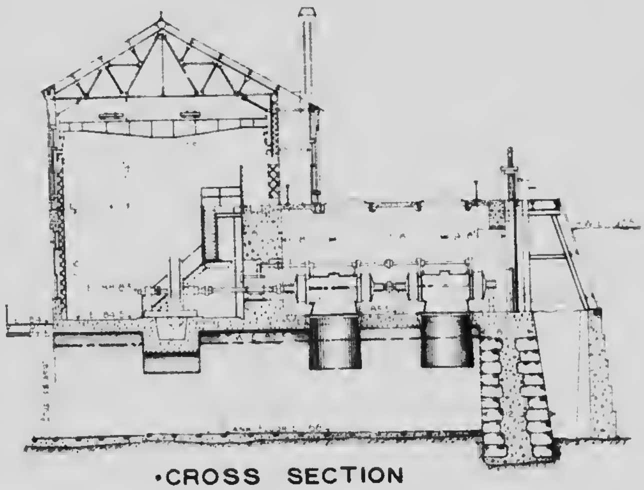
MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)

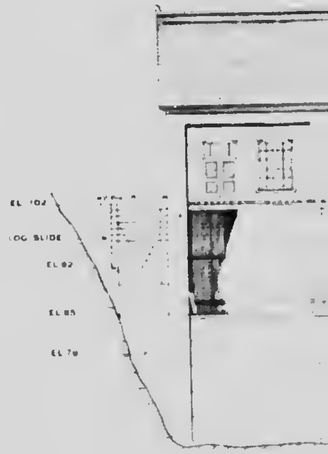


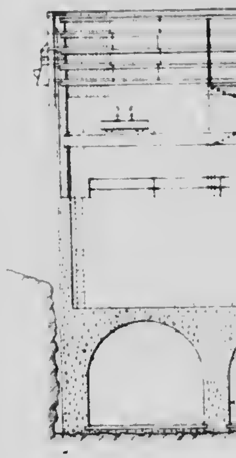
KEY PLAN

NORTH EAST ELEVATION



•CROSS SECTION





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DATUM
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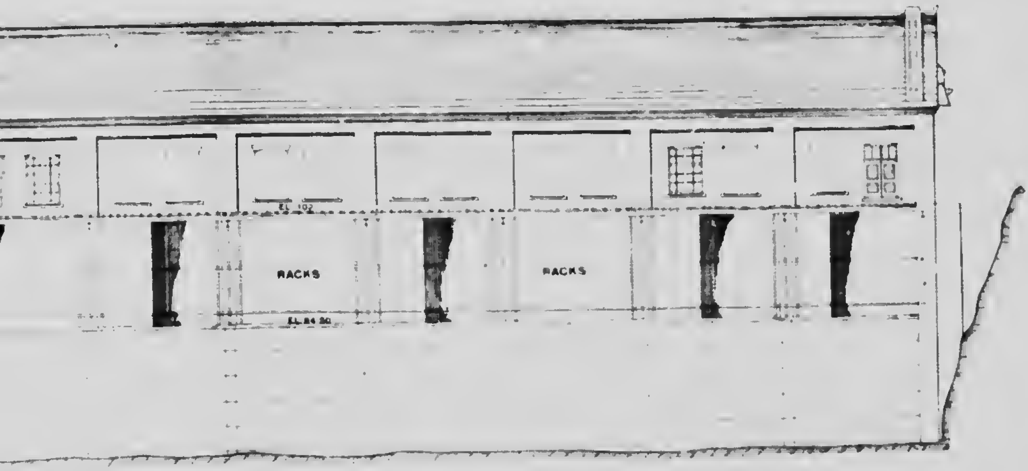
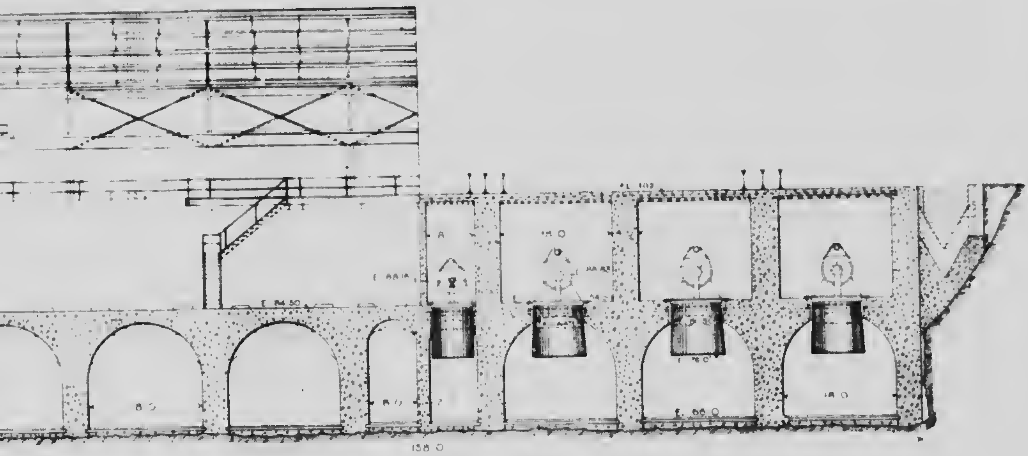
PLATE No 37



UP STREAM ELEVATION



LONGITUDINAL SECTION

NOTE
PLAN BASED ON PLANS SUPPLIED BY THE TOWN OF KENORA

961·32 WATER POWER SURVEYS DATUM = ZERO OF KENORA POWER HOUSE DATUM

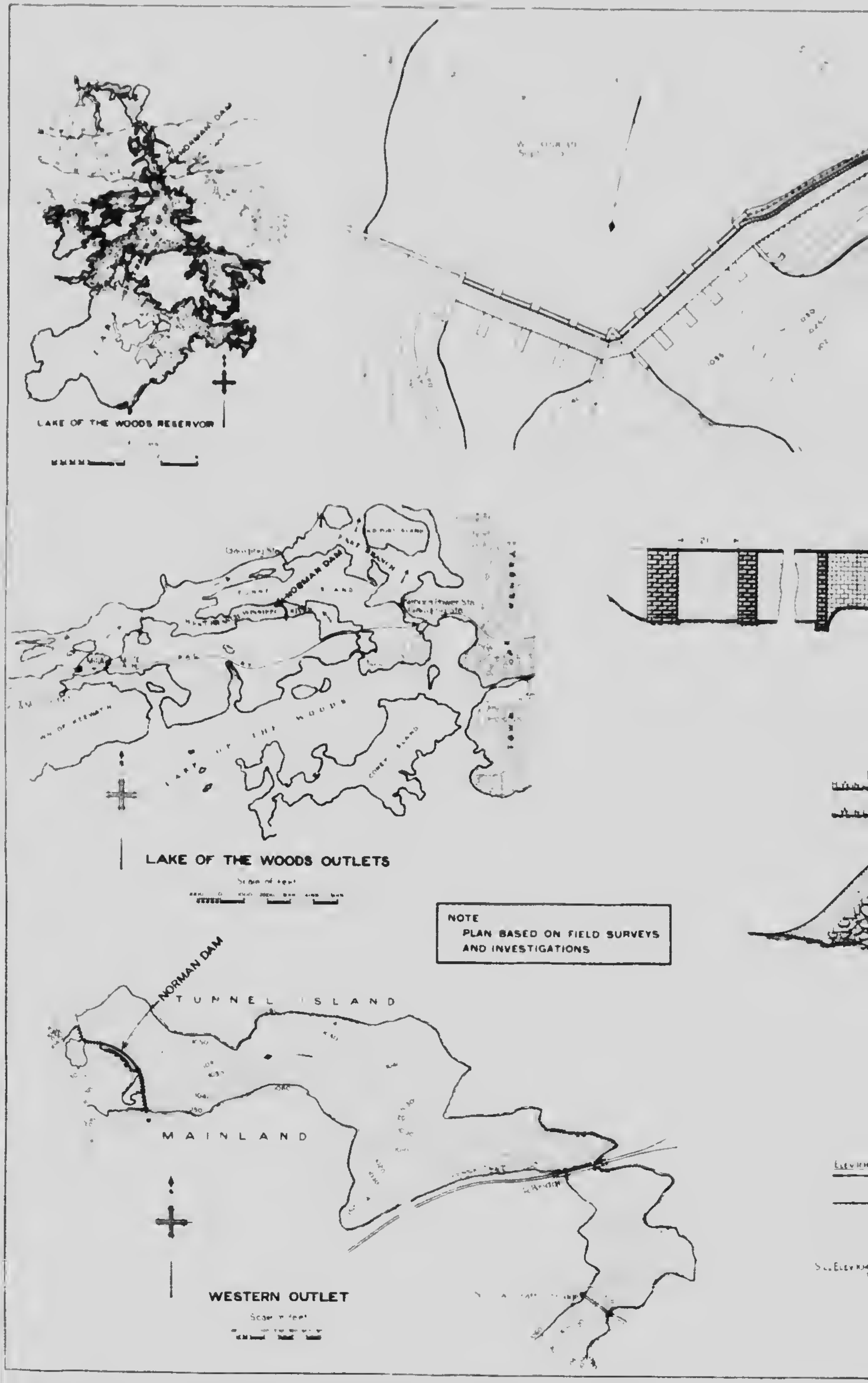
Department of the Interior Canada

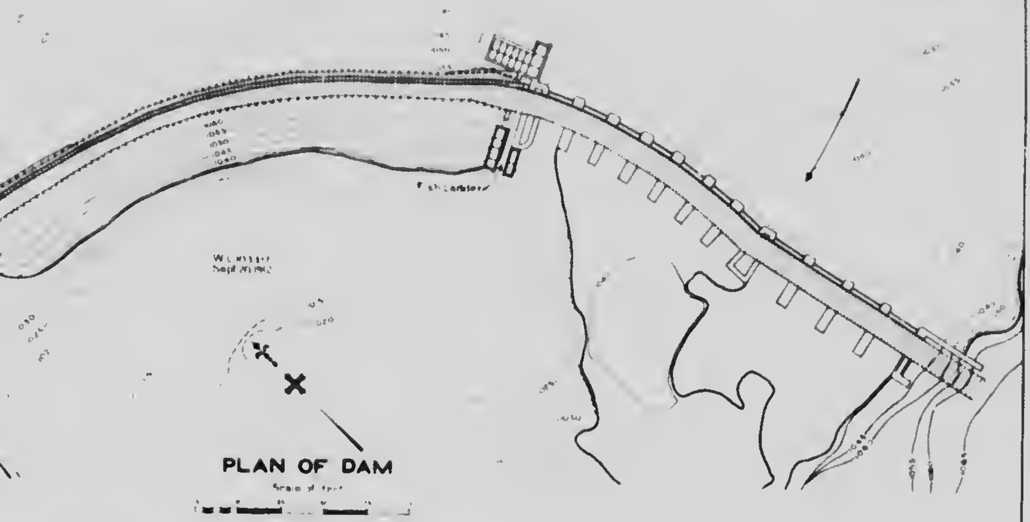
Water Power Branch

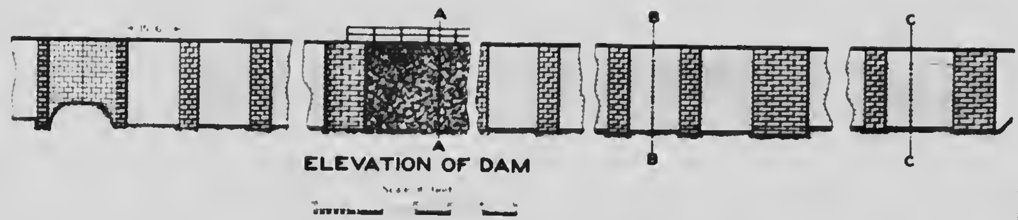
WINNIPEG RIVER POWER SURVEY

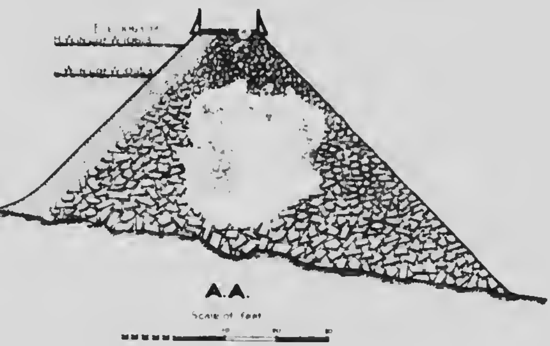
KENORA POWER STATION

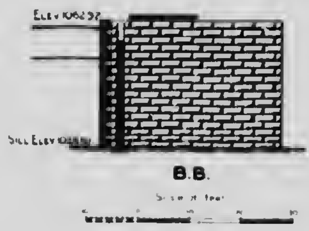
CONSTRUCTED BY THE TOWN OF KENORA ON THE EASTERN OUTLET OF THE LAKE OF THE WOODS

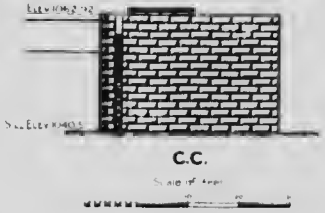

NORMAN DAM
LAKE OF THE WOODS RESERVOIR
NORMAN DAM
LAKE OF THE WOODS OUTLETS
NOTE
PLAN BASED ON FIELD SURVEYS
AND INVESTIGATIONS
NORMAN DAM
TUNNEL ISLAND
MAINLAND
WESTERN OUTLET











Department of the Interior, Canada

Water Power Branch

WINNIPEG RIVER POWER SURVEY.

NORMAN DAM

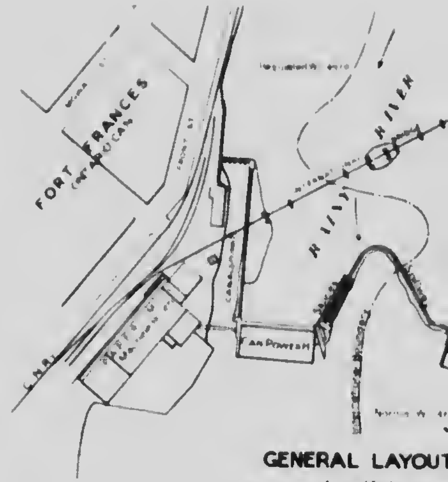
CONSTRUCTED BY THE KEEWATIN POWER COMPANY

SHOWING

GENERAL CONSTRUCTION FEATURES & DISCHARGING FACILITIES

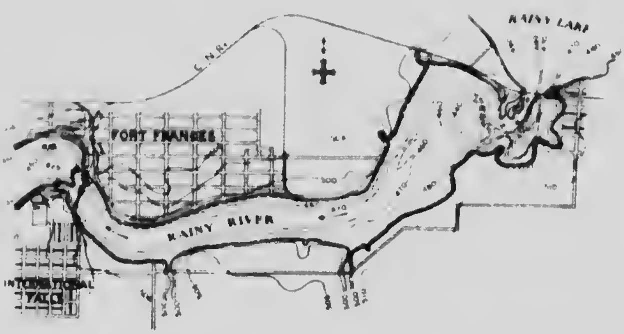
KEY PLAN

Scale in Miles



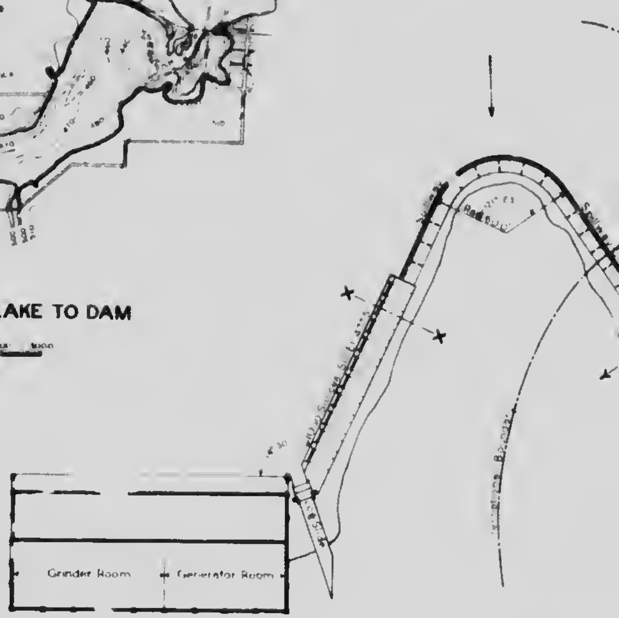
GENERAL LAYOUT

Scale of Feet



REACH FROM RAINY LAKE TO DAM

Scale of Feet

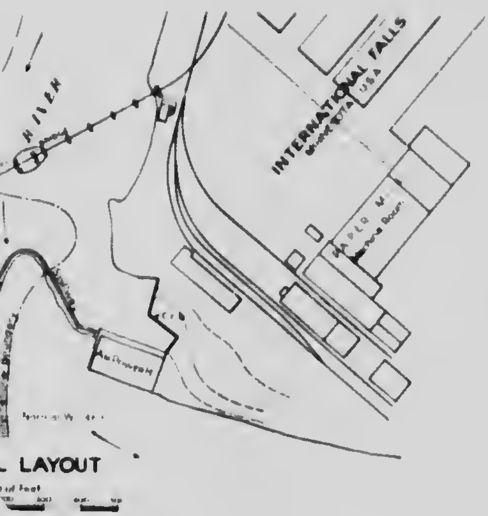


PLAN OF DAM

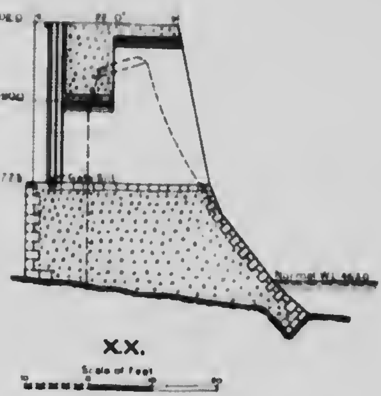
Scale of Feet

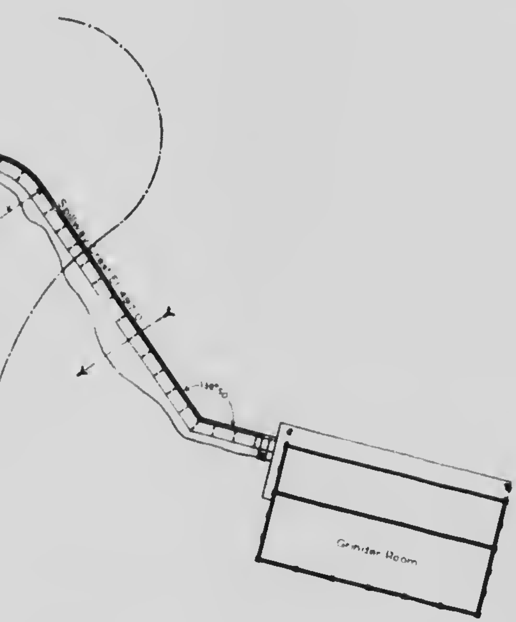
Note: This plan was compiled from Departmental Maps, [illegible] Surveys and Plans furnished by the [illegible] Minnesota Power Company

PLATE No 39



L LAYOUT





T DAM

Department of the Interior, Canada

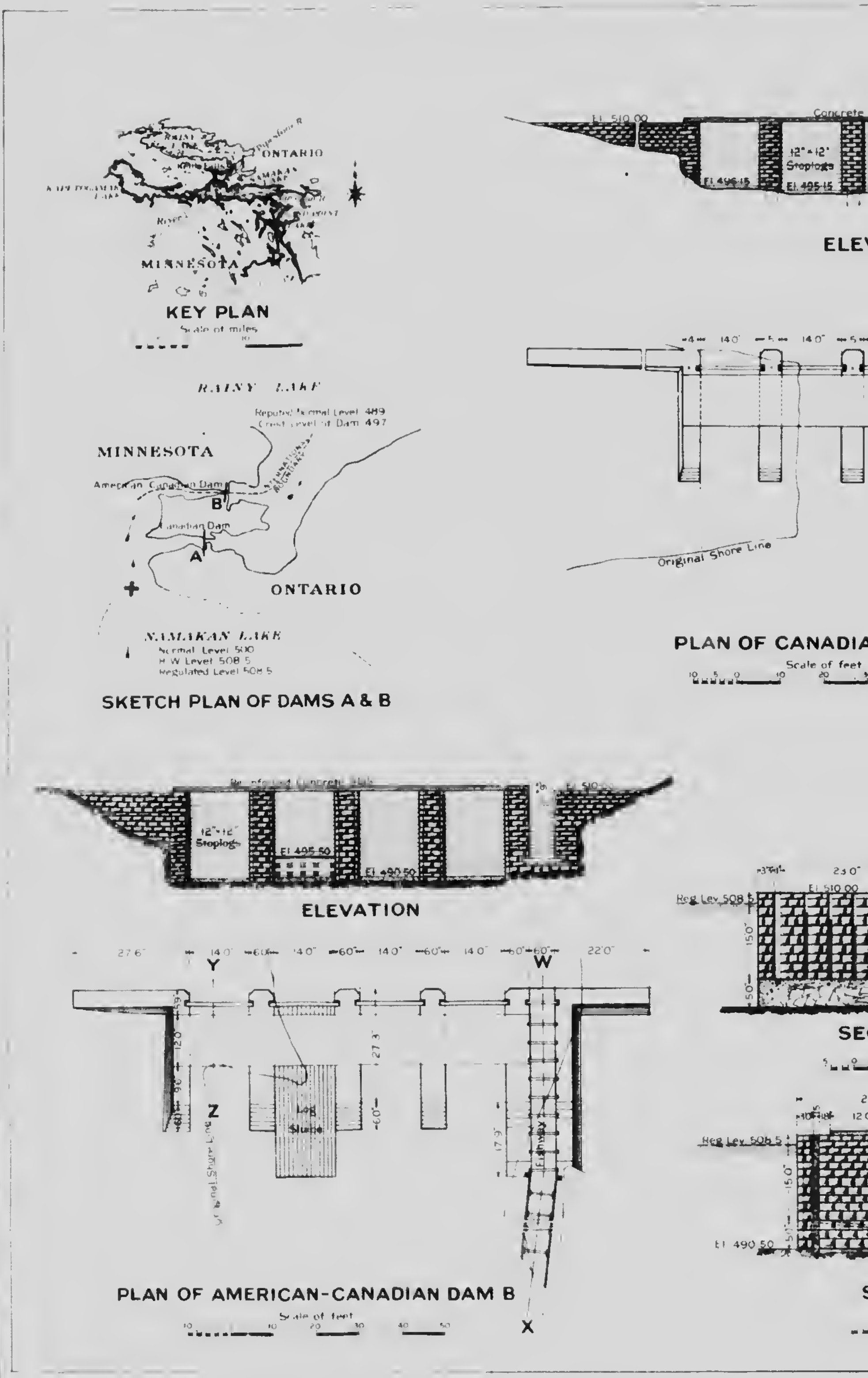
Water Power Branch

WINNIPEG RIVER POWER SURVEY.

FORT FRANCES DAM

CONSTRUCTED BY THE ONTARIO & MINNESOTA POWER COMPANY

GENERAL CONSTRUCTION FEATURES & DISCHARGING FACILITIES


ONTARIO
MINNESOTA
KEY PLAN
Scale of miles
RAINY LAKE
Crest Level of Dam 497
MINNESOTA
American Canadian Dam
B
Canadian Dam
A
ONTARIO
NAMAKAN LAKE
Normal Level 500
H.W. Level 508.5
Regulated Level 508.5
SKETCH PLAN OF DAMS A & B
Reinforced Concrete Slab
12"×12" Stoplogs
El. 495.50
El. 490.50
ELEVATION
Y
W
Z
Log Slide
Fishway
Original Shore Line
PLAN OF AMERICAN-CANADIAN DAM B
Scale of feet
X
El. 510.00
Concrete S
12"×12" Stoplogs
El. 496.15
El. 495.15
ELEV
Original Shore Line
PLAN OF CANADIAN
Scale of feet
El. 510.00
Reg. Lev. 508.5
SEC
Reg. Lev. 508.5
El. 490.50
S

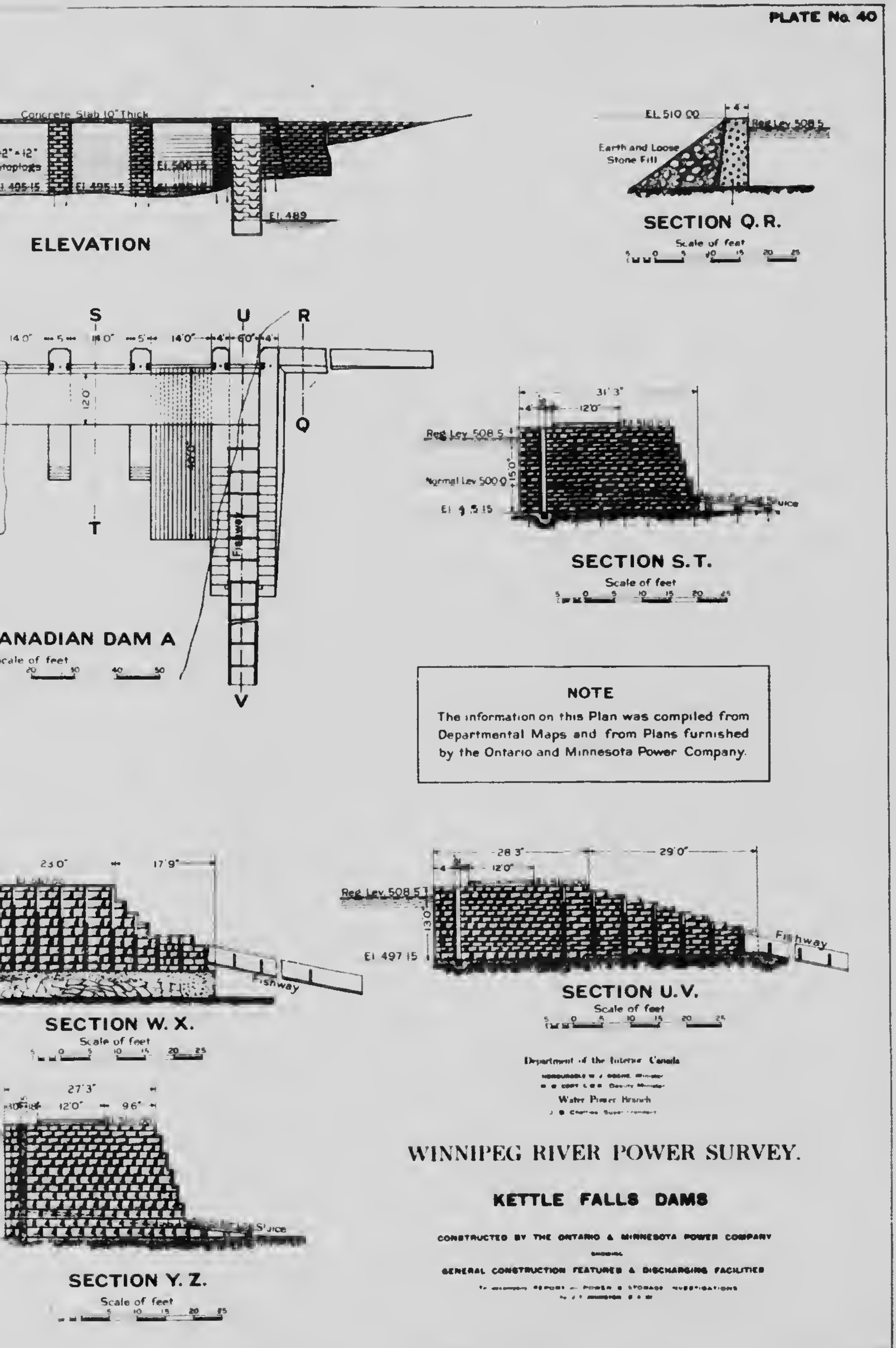


PLATE No. 40
Concrete Slab 10" Thick
EL 500.15
El. 495.15
EL 489
ELEVATION
EL 510.00
Reg Lev 508.5
Earth and Loose Stone Fill
SECTION Q.R.
Scale of feet
S
U
R
Q
T
V
14'0"
12'0"
Fishway
CANADIAN DAM A
Scale of feet
31'3"
Reg Lev 508.5
Normal Lev 500.0
15'0"
Sluice
SECTION S.T.
Scale of feet
NOTE
The information on this Plan was compiled from Departmental Maps and from Plans furnished by the Ontario and Minnesota Power Company.
23'0"
17'9"
Fishway
SECTION W.X.
Scale of feet
28'3"
29'0"
12'0"
Reg Lev 508.5
13'0"
El 497.15
Fishway
SECTION U.V.
Scale of feet
27'3"
12'0"
9'6"
Sluice
SECTION Y.Z.
Scale of feet
Department of the Interior Canada
Water Power Branch
WINNIPEG RIVER POWER SURVEY.
KETTLE FALLS DAMS
CONSTRUCTED BY THE ONTARIO & MINNESOTA POWER COMPANY
SHOWING
GENERAL CONSTRUCTION FEATURES & DISCHARGING FACILITIES

REPORT

ON

THE WINNIPEG RIVER POWER AND STORAGE INVESTIGATIONS

CHAPTER VI.

POSSIBLE POWER CONCENTRATIONS.

CHAPTER VI.

POSSIBLE POWER CONCENTRATIONS.

REACH OF THE RIVER DEVELOPED.

The reach of river covered in the power studies extends from lake Winnipeg to the headwaters of the city of Winnipeg municipal plant at Point du Bois, and comprises practically the entire drop of the river in Manitoba. The channel of the Winnipeg river follows the general trend of rivers flowing through this district where the Laurentian granite lies practically on the surface. The river is, to a large extent, composed of deep broad basins with but little current, broken by abrupt changes in level at the various falls and rapids. These pitches take place at, and are occasioned by, granite outcrops, which are invariably in evidence on both river banks and in the stream bed. At such points the bedrock as a rule forms a distinct ridge at a higher elevation than the bed of the river in the pond above, and is in fact the controlling feature governing the level of the lake-like expanses. As a result, the drops are generally well concentrated, and the hydraulic gradient between the various falls and rapids is usually negligible, a combination of circumstances which renders possible the utilization for power purposes of practically the entire fall of the river. The reach below the lower Seven Sisters, together with the Pinawa channel, are the only sections of the river where it has been necessary to sacrifice any considerable portion of the drop.

Table 33.—Profile of the Winnipeg River under natural conditions, and under proposed system of hydro-electric development.

NATURAL CONDITIONS.

Falls.	Tail Water Elev.	Head Water Elev.	Head in feet.
1.	2.	3.	4.
Pine	713	722	9
Masqua	722	727	5
Silver	728	749	21
Whitemud	750	762	12
Little du Bonnet	762	770	8
Grand du Bonnet	770	805	35
2nd McArthur	806	812	6
1st McArthur	812	818	6
Lower Seven Sisters	834	850	16
4th Seven Sisters	851	859	8
3rd Seven Sisters	859	867	8
2nd Seven Sisters	867	876	9
1st Seven Sisters	876	886	10
Diversion Weir	888	899	11
Slave	902	921	19
Eight Ft	921	928	7
Point du Bois	931	962	31
Lamprey	962	978	16

PROPOSED CONDITIONS.

Power Site.	Tail Water Elev.	Head Water Elev.	Head in feet.
5.	6.	7.	8
Pine	713	750	37
Du Bonnet	752	808	56
McArthur	809	727	18
Lower Seven Sisters	833	870	37
Upper Seven Sisters	870	899	29
Slave Falls	902	928	26
Winnipeg Power Plant	931	976	45

NOTE.—The plant of the Winnipeg Electric Railway Company on the Pinawa channel is not included in the above table since it is not a link in the main river channel. Its head- and tailwater elevations are 880 and 841, respectively.

86376—12½

Table 33 illustrates concisely the natural conditions on the river prior to power-plant construction, and the altered conditions which will result from the development of the available sites. It is proposed to concentrate the at present undeveloped portion of the power reach at seven sites, i.e., Slave falls, Upper Pinawa, Upper Seven Sisters, Lower Seven Sisters, McArthur, Du Bonnet, and Pine falls. Plate 41 graphically illustrates the co-relation of the governing elevations of the various proposed plants.

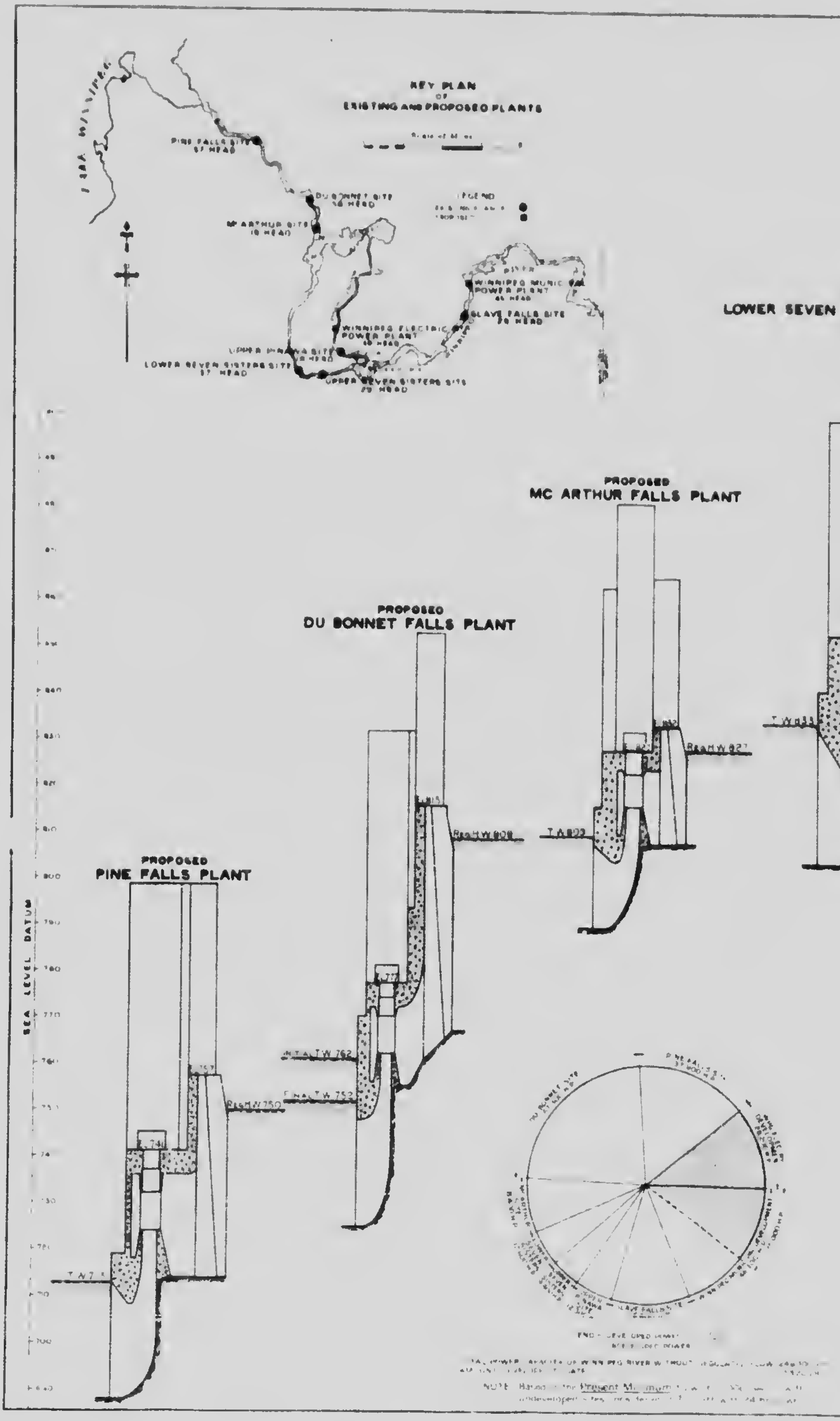
Discharge of the River.

A reference to chapter III, covering the run-off, will demonstrate the exceptionally well-regulated character of the Winnipeg River flow under present conditions. Actual meterings since January, 1907, have shown a minimum record of 11,700 cubic feet per second, and a maximum of 53,440, with an average of 25,373 for the past eight years. In a normal year the flood flow seldom exceeds four times the minimum. This favourable condition is of special importance to hydro-electric development in the lower reaches. In view of the excellent storage facilities in the upper watershed it is readily possible to so control the flow as to maintain a minimum of 20,000 cubic feet per second the year round. While regulation to a somewhat higher minimum is feasible, 20,000 second-feet is considered throughout the power discussions in this report, since it can, with supervised control, be secured in the immediate future, with the storage facilities already provided in the upper basin. Another characteristic of the discharge which is favourable to hydro-electric development is the comparatively slow rise of floods, due to the balancing effect of the upper lakes.

Flooding and Pondage.

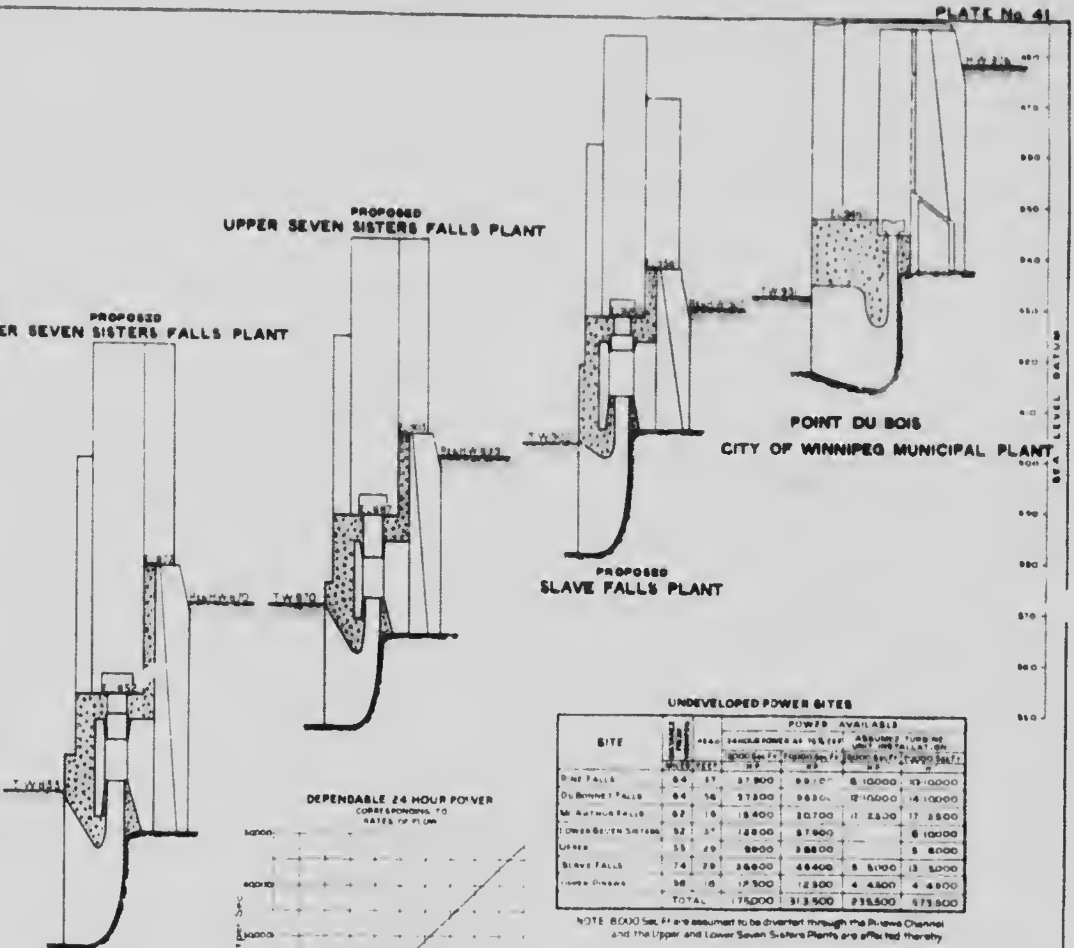
Since the selection of the sites has been largely governed by the contours of the banks, little flooding is involved along the river. At certain points where special aspects called for consideration and where existing interests introduced special conditions, it has been necessary to provide embankments in order to take full advantage of the fall available. The smallness of the proposed flooded area is largely due to the fact that the banks, as a rule, rise fairly abruptly from the water's edge. A large proportion of the river banks is still Dominion land, and reservation is being made of all such lands affected by the proposed power scheme.

The proposed plants are well provided with local pondage. The pond areas vary from 1,175 acres at the Lower Seven Sisters site to 38 square miles at the McArthur site. At certain sites where the pondage area is comparatively limited, conditions can be bettered by a supervised regulation of larger ponds farther up stream. This is particularly the case in Lac du Bonnet, which will form 38 square miles of pondage for the McArthur plant. This local storage is out of all proportion to the requirements of the McArthur development, and a sympathetic regulation will render the storage benefits immediately available to the Du Bonnet plant located immediately below. Similar conditions, though not so marked, occur at other points along the river.



KEY PLAN
OF
EXISTING AND PROPOSED PLANTS
LEGEND
LOWER SEVEN
PROPOSED
MC ARTHUR FALLS PLANT
PROPOSED
DU BONNET FALLS PLANT
PROPOSED
PINE FALLS PLANT
SEA LEVEL DATUM

PLATE No. 41



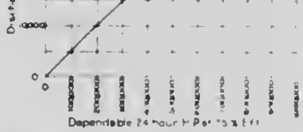
UNDEVELOPED POWER SITES

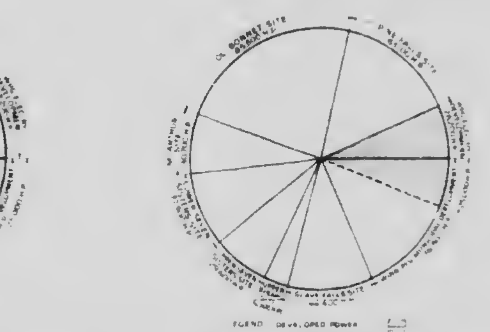
SITE	Miles	Head Feet	Power Available: 24 Hour Power at 75% Eff. 8000 Sec. Ft. H.P.	24 Hour Power at 75% Eff. 20000 Sec. Ft. H.P.	Assumed Turbine Unit Installation 8000 Sec. Ft. H.P.	Assumed Turbine Unit Installation 20000 Sec. Ft. H.P.
Pine Falls	64	37	37800	99100	6 10000	10 10000
Du Bonnet Falls	64	56	37300	98300	12 10000	14 10000
McArthur Falls	62	16	15400	30700	11 2600	17 3500
Lower Seven Sisters	52	37	18800	37900		6 10000
Upper	55	29	9000	38800		5 6000
Slave Falls	74	29	36600	46400	5 5000	13 5000
Upper Pinawa	98	16	17300	12300	4 4800	4 4800
	TOTAL		175000	313500	235500	373500

NOTE 8,000 Sec. Ft. are assumed to be diverted through the Pinawa Channel and the Upper and Lower Seven Sisters Plants are affected thereby.

TOTAL POWER AVAILABLE

	Unregulated Flow 8000 Sec. Ft. H.P.	Regulated Flow 20000 Sec. Ft. H.P.
Undeveloped at Proposed Sites	175000	316500
Undeveloped at Point du Bois	21100	61800
Developed on River to date	53200	53200
TOTAL	249300	418500





NOTE Based on a Regulated Minimum flow of 20,000 Sec. Ft. with undeveloped sites considered at 75% eff. with 24 hr. power

Department of the Interior Canada

Water Power Branch

WINNIPEG RIVER POWER SURVEY.

DIAGRAM OF

PROPOSED DEVELOPMENT IN MANITOBA

SHOWING RELATION BETWEEN GOVERNING ELEVATIONS OF EXISTING AND PROPOSED PLANTS ON THE MAIN WINNIPEG RIVER

To accompany a report on power and storage investigations by J. T. Johnston

J. T. Johnston

Table 34 hereunder illustrates concisely the flooding involved at the proposed developments, together with the pondage available at the same. The areas have been scaled off by planimeter from the topographic sheets, and represent the conditions with fair accuracy.

Table 34.—Pondage and flooding area of the proposed power concentrations.

Sites.	Pondage in acres.	Flooding in acres.
Pine	6,642	675
Du Bonnet	1,700	460
McArthur	24,420	2,444
Lower Seven Sisters	1,175	70
Upper Seven Sisters	8,470	404
Slave Falls	1,300	100

Ice Conditions.

The question of ice conditions as found on the Winnipeg river has already been discussed at length in chapter III. It is only necessary to repeat here that the northerly latitude in which the Winnipeg river is located necessitates a most careful consideration of possible ice troubles in the design of the hydro-electric plants along the river.

While in past years trouble has been experienced in the operation of power stations under extreme low-temperature conditions, the better understanding of the origin and nature of frazil and anchor ice which has been reached during recent years has resulted in these troubles being largely minimized, and frequently entirely overcome in the more recently designed stations.

The municipal plant of the city of Winnipeg on the Winnipeg river is an excellent example of modern design in this respect. A broad deep pond, some 6,500 acres in area, forms the headwater of the plant and acts as a settling basin for the disturbed water above. The head-race leading from this pond is of sufficient cross-section to maintain a quiet and undisturbed flow to the station. Here particular care has been taken to secure the undisturbed entrance of the water into the wheel pit. The result is an entire freedom from ice troubles.

In the layouts which are herein considered, especial attention has been given to this question, and in no case are ice troubles anticipated. In all designs the power stations draw undisturbed water into the turbines from deep, quiet ponds. The falls and rapids which in a natural state favour the formation of frazil ice will, in the general scheme proposed, be flooded out, and the entire drop in the river will practically take place from one pond to another, over and through the dams at the points of concentration.

Ample provision has beeen made at each site for drawing off all floating ice and drift. Wherever possible, ice sluices have been so placed that their discharge will produce a cross current along the face of the power station and automatically draw off floating material. The racks and entrance to the water passages of the turbines are protected by a sloping concrete curtain across the face of the entrance piers, the bottom elevation of which is placed from 2 to 3 feet below regulated pond level.

Foundation Conditions.

Unexcelled foundation conditions are assured at all the proposed plants. The natural granite formation which underlies the entire country is exposed on the surface at all locations selected for hydro-electric development. At several of the sites the rock outcrops throughout the entire layout. In other places it has been necessary to make assumptions as to the rock elevation in the stream-bed, since the nature of the field investigations did not warrant the expense of actual sounding at the crests of falls. This is deemed a proper expenditure for the interests doing actual development work. For the purpose of the present discussion, it is sufficient to ascertain the existence of the bedrock, and its probable elevation. Such assumptions as have been made are based on personal inspection of the site on the ground, and on a consideration of the actual conditions which exist at points along the river where definite data have been secured. The conclusions as to bedrock elevation, as set out in detail at each site, are considered to be conservative.

General Basis of Design and Layout.

The submitted designs and layouts have been worked out in this office on the general basis set out in the following, and have on this basis been approved by Mr. J. B. McRae, consulting engineer to the Dominion Water Power Branch. The designs of the power-houses, dams, and contingent structures, and the proposed hydraulic and electrical equipment, have been developed only in sufficient detail to permit making fairly accurate estimates of the quantities and costs involved. It is not intended that the designs and layout proposed, and the equipment suggested, should be adhered to in all respects by any parties developing the power at these sites. It is intended, however, that the basic elements of the design be maintained as proposed, in the interests of the complete river development scheme. These basic elements are: head- and tailwater elevations, discharging capacity and stability of dams, and stability and sufficiency of power-houses and contingent structures.

The layouts are designed for an initial and for a final installation. At points where the whole flow of the river is available for development, the preliminary installation is designed to utilize 12,000 second-feet (the present minimum flow of the river), with provision for the subsequent addition of sufficient units to properly care for a regulated flow of 20,000 second-feet. The latter is spoken of throughout the report as the final installation.

One feature which should be emphasized in connection with these future additions is that it is inadvisable to carry the construction of unfinished units further than is absolutely necessary to withstand the headwaters. The rapid advances which are being made in the development and settings of hydraulic machinery are such that the interval of even a year or so between the completion of the initial installation and the subsequent addition of the remaining units, may be sufficient to produce important alterations and improvements in design. It is essential that the unfinished portion of the power station should be left in such shape that the new units can, when installed, incorporate all later improvements in hydraulic installation. The neglect of this feature has proved costly to many plants now in operation throughout the country.

The details of the designs, such as sections and plans of the power-houses, dams, ice sluices, and embankments, etc., have been standardized throughout all the plants, varying of course according to the head and to the equipment at each site. In all cases, single-runner vertical turbines have been adopted. The purpose of this standardization of design is the desirability of having the cost of development at each site reduced to the same basis or measure in order that the comparative merits of the different projects can be ascertained.

It is recognized that nature has particularly favoured the Winnipeg river in supplying an extensive lake area in the upper waters, and that rapid rises and sudden floods such as are experienced in watersheds not so supplied do not take place. In the future, however, when the river is fully regulated, it is reasonable to anticipate a combination of circumstances which will result in more sudden rises and perhaps greater floods than have been so far experienced. Such a combination of circumstances might be a prolonged and widespread period of heavy rain, at a time when the reservoirs in the upper watershed are all filled to high level. The surplus waters would then be discharged at once. For this reason, and in view of the complete system of river development which is contemplated, a larger degree of discharging capacity has been provided at the various plants along the river than past floods in the river would apparently require.

Head- and Tailwater Elevation.

It is not intended in this report to unchangeably fix the exact head- and tailwater levels of all the proposed concentrations. These final elevations are dependent on full and complete surface level records under all conditions of discharge. Owing to the comparatively unsettled nature of a large portion of the river banks, it has been very difficult to secure satisfactory and regular gauge readers. As a result, on some reaches of the river the surface level records under different stages are not as complete as is desired. This information is being secured as rapidly as possible, and will be available in sufficient time to deal with any questions of administration which may arise in connection with the development of the reach along the lines set out herein.

The head- and tailwater levels as set out herein are considered to very closely represent the final levels, and any variation which later information may necessitate should not change the present conclusions to any great extent.

Navigation.

The Winnipeg river is classed as a navigable stream, and hence any power development thereon must conform to the provisions of the Navigable Waters Protection Act. This phase of the situation was kept constantly in view throughout the entire power study discussed herein, and reference to profiles on Plates 5 and 6, and to the layouts on Plates 43, 48, 53, 57, 61 and 68 will indicate the comprehensive provision which has been made to meet navigation needs, should the canalization of the river ever become an active issue. After the completion of the power developments, the construction of lockage facilities at the diffierent layouts, together with some necessary dredging and channel improvements, will render the river readily navigable throughout the power reach.

The plans of the completed power scheme were referred to the Dominion Department of Public Works for approval in so far as the navigation features were concerned. This approval has been given for the complete scheme as now submitted, with the necessary reservation that actual construction plans for the development of any particular site must be resubmitted for detail consideration and approval, before active construction is commenced.

Estimates of Cost.

The question of the advisibility of publishing detail capital and operating cost estimates was at first debated, as it was felt that they might be open to criticism and that conditions changing with the passage of time would possibly very materially alter the published figures. It was thought, however, that the advisibility of supplying prospective users of power with some conservative and authoritative measure whereby the economic as well as the engineering merits of the various sites could be readily compared, and with which competing sources of power could be analysed, more than outweighed other considerations. To neutralize possible future criticism of the published estimates, care has been taken to supply such plans and data covering each site as will enable independent estimates being made by any parties interested in its development.

In view of the fact that it is not possible at this stage to foretell which plants along the Winnipeg river will be utilized for the purpose of transmitting power to the industrial centres of Manitoba, and which ones will develop power for local use, the cost estimates place the power on the low tension switchboard in the power station. With the exception of Pine Falls site no allowance has been made for transformation and transmission. The purpose of the estimates has been primarily to arrive at the capital cost of the actual development of the independent sites, and by standardization, both as to design and as to unit prices, to compare the sites with each other from the view point of their economic feasibility. Since the basis of estimates is standardized throughout, a study of the results submitted herewith will be found of interest.

The general costs quoted are based on a 24 -hour output, at 75 per cent over-all efficiency, as this forms a uniform and, considering the more than 90 per cent efficiencies claimed for modern turbine runners, conservative measure for comparison. The figures on this basis, scarcely do the developments justice, since in them no account is taken of peak loads and of the re-sale of power such as is always possible in plants projected for the supply of power for general industrial and lighting consumption. In all designs ample machine capacity has been allowed to care for all peak loads which can be reasonably expected, and to supply spare units for emergencies. This over-development has added largely to the estimated cost of the plants and hence to the unit cost when the latter is based on 24-hour power. On the other hand, costs per horse-power, based on the installation, frequently convey erroneous ideas as to economic efficiencies, since local conditions or an auxiliary steam plant frequently permit the excessive over-development of a particular power site in proportion to the dependable power available from the river. However, in the designs and estimates considered herein, the machinery installed bears, in all cases, a definite ratio to the power in the river, and this ratio cannot be considered too high in plants handling normal industrial and lighting loads. The unit costs based on installation can therefore be profitably studied in conjunction with the unit costs on a 24-hour basis.

In all cases provision has been made for access to the site by rail, or in the case of the Pine Falls plant, by water. In each case 10 per cent has been allowed for contingencies, 5 per cent on this total for engineering and inspection, and 5½ per cent on the whole for one year for interest during construction.

The actual cost of the construction of the two existing plants on the river has been carefully studied and compared with the estimated costs of the various proposed developments. Independent estimates by private engineering firms have also been found to check closely with the capital costs herein submitted. The estimates may therefore be taken as setting out conservatively and closely the capital construction cost of the proposed sites.

As in the case of the capital costs, the annual operation costs have been estimated to a uniform standard, and hence form a measure whereby the commercial prospects of the different projects can be readily compared.

The operation costs include capital charges and are published in terms of cost per horse power year 24-hour power; cost per horse-power year machinery installed; cost per kilowatt hour at 100 per cent load factor, and cost per kilowatt hour at 50 per cent load factor. These costs represent the operating charges at the power station, and do not include transforming and transmission.

In order to secure a proper understanding of the cost of power in Winnipeg, the estimated cost of transmitting power from the Pine Falls site to Winnipeg has been included.

In view of the involved nature of the storage situation in the upper watershed, the proportionate cost of storage reservoir construction has not been included in the estimates of the various sites. The necessary steps to insure 20,000 second-feet minimum flow are dependent largely upon the course of power development.

Aesthetic Treatment.

Considerable attention has recently been given to the aesthetic treatment of public buildings, and with such desirable results that it has been felt that the Dominion Government should encourage in every reasonable way the architectural embellishment of power-houses constructed under Dominion authority, and especially where the location is, or is likely to be, accessible to the general public. While it is not proposed to compel power companies to adopt a scheme of architectural treatment of power-house design which would entail an unnecessary or unreasonable extra expense, it is proposed to insist upon the design of important structures being given such consideration from an aesthetic standpoint as will conform to modern conceptions of architectural treatment.

As the water-powers of the Winnipeg river are so close to the city of Winnipeg, and as this river offers many attractions to the traveller and the pleasure seeker, it is certain that the river will receive an increasing number of visitors. Looking to the future, it will not be long before power-houses will succeed one another from lake Winnipeg to the eastern boundary of the province of Manitoba, and with proper foresight and with advantage taken of the opportunities for architectural treatment of these power-house structures, and also of the landscape treatment of the surroundings, this river will in future generations form one of the most interesting features of the district, both from an engineering and from an aesthetic standpoint.

Consistent with this policy, arrangements have been made for the special architectural study of the various power-house structures which have been worked out in connection with the investigations described herein from an engineering standpoint. The students of the Architectural Department of Toronto University were invited to compete for a small prize in connection with a suitable design of a typical power-house. The results of this competition are indicated in the accompanying illustrations, and while it is not the purpose of the branch to insist upon any of the designs submitted being accepted by a company contemplating the construction of one of the power developments worked out along the Winnipeg river, still it is proposed to insist that the suggestions offered by these designs be given serious consideration, and that the architectural treatment of the power-house structures shall receive due attention.

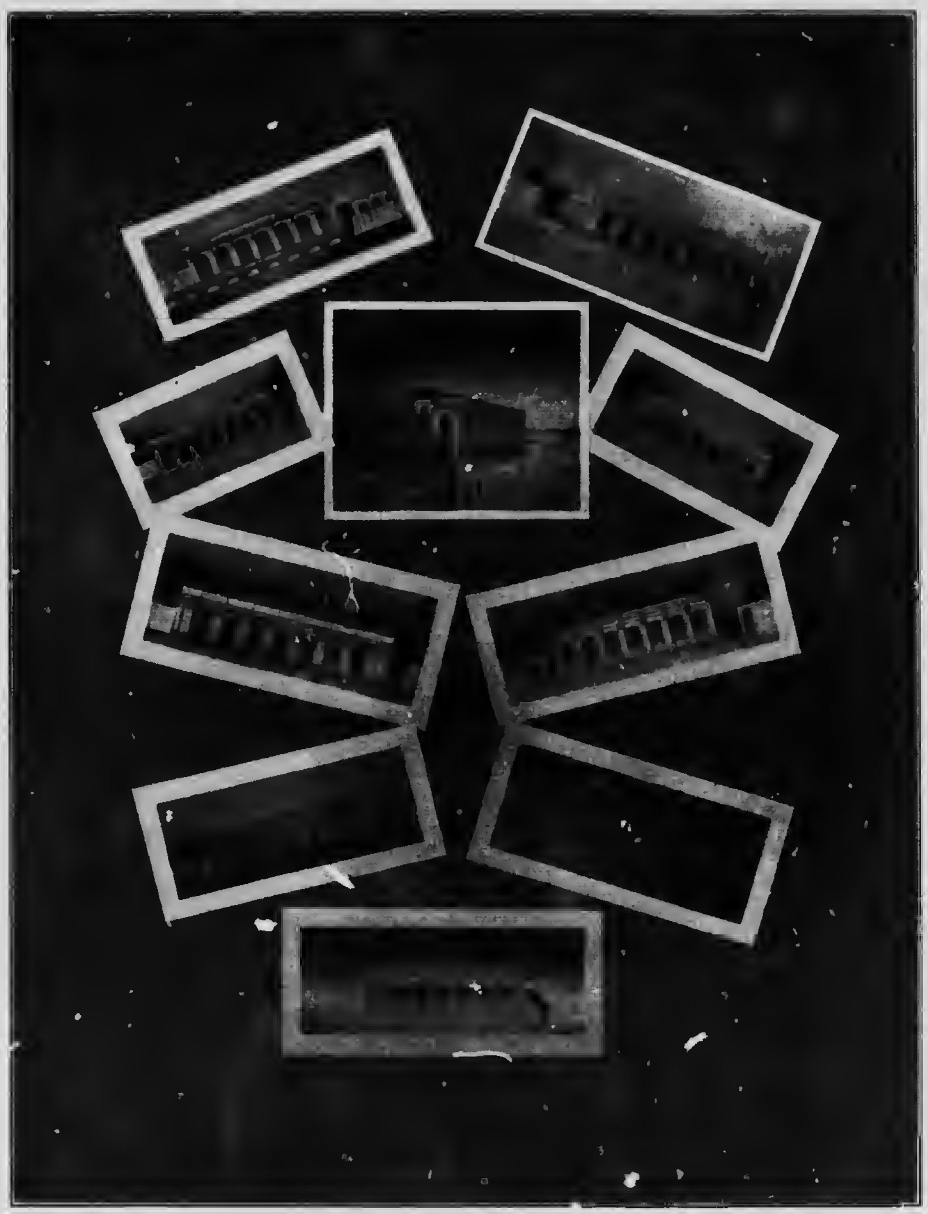
Lake Winnipeg to Lac du Bonnet Reach.

Upon the completion of the topographic field plans, Nos. 1 to 10, covering that section of the river from Lake Winnipeg to Lac du Bonnet, a careful study of the whole reach and of various aspects requiring consideration made it apparent that three concentrations were necessary to fully utilize the fall available. The governing elevation at the lower end of this reach was the surface level of Lake Winnipeg, and that at the upper end was the maximum high water limit of Lac du Bonnet.

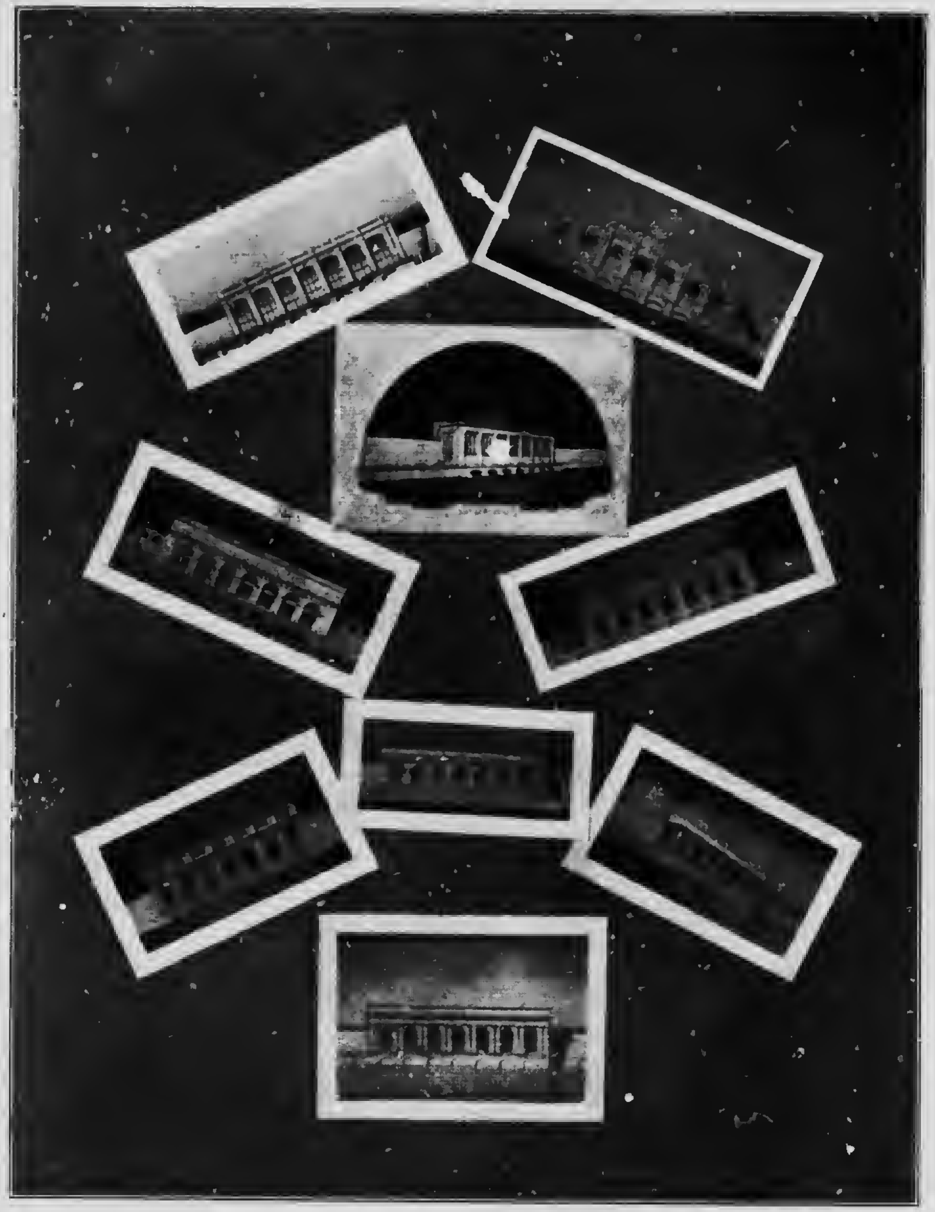
Tentative layouts, covering the three concentrations were prepared, and the proposed sites at Pine, du Bonnet and McArthur falls, were again visited by the writer in September, 1913, and were examined in detail with a view to determining the general fitness of the contemplated layouts and designs to the selected locations. Following this, the final plans and estimates have been prepared, and are submitted herewith.

Pine Falls Site.

A study of the reach showed that in order to secure the full drop available in three heads, it was necessary to concentrate at the Pine falls the highest head feasible. Reference to Plates 43, 44 and 45 will illustrate the following discussion.



Competiti e Power Station Designs.



Competitive Power Station Designs.

SPECIAL CONSIDERATIONS AT PINE FALLS.

The disposal of Whitemud falls required careful consideration. The more profitable course, had physical conditions permitted, would have been to flood out the drop at these falls and combine the head with the Pine Falls development. The contours of the river banks above Pine and below Silver falls, do not, however, allow the raising of the headwater level above that proposed hereunder, except at the cost of excessive flooding or embanking. Since the land along this section of the river has been taken up and is under cultivation, it is not desirable to incur any more flooding than is necessary. The headwaters of the proposed plant have been raised to what is considered the highest permissible limit in view of the interests which will be affected. The disposal of Whitemud falls is covered in the discussion on the Du Bonnet site.

REACH OF RIVER DEVELOPED.

The reach of the river developed by the Pine Falls concentration extends from Pine falls to the foot of Whitemud falls, drowning out the Masqua rapids

Winnipeg River below Masqua Rapids.

and Silver falls, and raising the normal water level above the latter by some 2½ feet. The river banks throughout the reach rise fairly abruptly from the water, and the flooding will be confined to the natural river channel.

Masqua rapids.—The Masqua rapids are situated about 1¾ mile above Pine falls, just above the mouth of the Masqua river. There is a normal drop here of slightly over 2 feet, broken by granite outcrops which are more or less submerged during the high-water season. About three-quarters of a mile below the Masqua rapids another slight drop of about 1½ foot takes place over a second granite ridge. This ridge forms a fairly large island in the centre of the channel, and in several other places rises above the water surface.

Silver falls.—The Silver falls are located about 5½ miles above Pine Falls. There is here a drop of some 22 feet in three well-defined pitches, taking place in a total distance of about 1,500 feet. The banks are high and abrupt, and the Silver falls would of itself form an economic development. It can, however, be more profitably combined with the Pine Falls site.

Silver Falls.

HEAD- AND TAILWATER ELEVATION.

It is proposed to regulate the headwater to elevation 750 (Water Power Survey datum). This elevation is about 2½ feet above the normal water level at the head of Silver falls, and backs up to about the same extent on the Whitemud falls. When the river is fully developed as proposed, the headwater level of the Pine Falls development will be carried to the foot of the Little du Bonnet falls, and will, allowing for the necessary hydraulic gradient, form the tailwater of the Du Bonnet plant. Contour 750 is wholly confined within the natural river banks, with the exception of about 2,300 feet on the left bank of the river just above the power station. Here embankment will be required. The general river banks will permit a rise of at least 5 feet above this level without any considerable flooding.

The tailwater of the Pine Falls concentration is practically Lake Winnipeg level and will be affected by the fluctuation of the lake. A maximum high-water elevation of 719 is in evidence on the rocks in the river channel below. This would probably indicate the extreme conditions which may be anticipated. The lake level varies from year to year; it also varies from day to day, depending on the direction and force of the wind. A normal water level of 713 can be counted upon for the greater part of the time. This has been utilized as the tailwater level throughout the present discussion, and gives a head of 37 feet available at the Pine Falls site.

FLOODING.

Flooding is entirely confined by the immediate banks to the river channel. Between Pine and Silver falls the land bordering the river has been settled and is under cultivation. As the banks rise rather abruptly from the water's edge, little of this land will be flooded by the proposed development. Above Silver falls the banks are steep and rise to a higher elevation, while the land is unsettled, the whole being covered with a thick growth of poplar, spruce, and birch. In all about 375 acres of steeply sloping land will be submerged by the raising of the water level. An item covering this is inserted in the estimates.

The Pine Falls site offers fair pondage facilities, there being an area of 2,598 acres of water surface from the plant to the foot of the Whitemud falls. This will be increased by an additional 1,044 acres after the Whitemud head has been added to the Du Bonnet site, and will provide satisfactory facilities for handling peak loads. The value of this pondage to the plant can best be illustrated by stating that 1 foot draw will, in conjunction with 20,000 second feet regular flow, carry a four-hour peak load equivalent to the full extent of the proposed ultimate installation, i.e., 100,000 horse-power. In this connection it is advisable to emphasize the necessity of some degree of Crown supervision over any dam or power development controlling the outlet of Lac du Bonnet, 19 miles above Pine falls, since an abrupt storage of water in this lake will most adversely affect the powers on the river below. On the other hand, properly supervised regulation will result in material aid to these powers.

ICE CONDITIONS.

The proposed Pine Falls plant will draw water from a deep quiet pond direct into the turbines, with a minimum disturbance. This pond, ice covered in winter, and varying from $\frac{1}{8}$ to $\frac{3}{4}$ of a mile in width and from 55 to 60 feet in depth for the first 6 miles, extends up the river to the foot of Whitemud falls, drowning out all intermediate falls and rapids, and hence doing away with the present tendency to form frazil ice at these points. Any such ice which may be formed at the Whitemud falls, either before or after the construction of the proposed channel, cannot affect the Pine Falls plant, 9 miles below. The discharge from the power station takes place directly downstream, and the unobstructed channel should prevent any choking of the current by the formation of ice jams or barriers.

The layout proposed will tend to naturally discharge all floating ice and drift through the four ice sluices provided on the left bank, and the sloping concrete curtain with bottom elevation 2 feet below regulated pond level, will amply protect the racks from all such floating material.

It is considered that the operation of the Pine Falls plant will prove to be entirely free from ice troubles.

FOUNDATION CONDITIONS.

Granite formation is in evidence on both river banks and in the bed of the channel throughout the entire length covered by the layout. On the right bank, rock has been assumed at elevation 740 beneath the section of the spillway extending over the high ground. The outcrop along the shore warrants this assumption. In the river-bed the rock has been considered at elevation 695 to 715, and is on the surface or in evidence at different points along the route of the dam. The assumptions which have been made are the result of a careful inspection on the ground, and on unwatering should be found to represent closely

Pine Falls, Site of Proposed Power Station.

actual conditions. The granite is in direct evidence through the entire length of the power-house site. Plate 45 depicts the rock elevations which have been utilized in the estimates.

LAYOUT.

Various layouts were considered at this site, and the one finally decided upon as being the most economical as well as making the most advantageous use of the natural features of the location is shown on plate 43. The general layout of ice sluices, power-house, and dam forms a straight line running diagonally across the river, the power-house being located on an island close to the left bank and below the lowest pitch of the Pine falls. The sluiceway and spillway section of the dam extend in a direct line towards the high ground on the right bank. On the left bank a short embankment is provided to protect the land to the rear, should it be necessary to raise the pond above the regulated level.

This is not anticipated since ample discharging capacity is provided below the crest of the spillway. All structures have been designed in massive concrete.

Spillway section of dam.—In order that there may be sufficient spillway capacity to automatically care for such sudden floods as may occur at times when for any reason the sluices may be neglected, advantage has been taken of the gully on the right bank. The spillway, with crest at 750, has been prolonged over the high ground to a total length of 775 feet. The gully formed by the creek below the spillway provides a channel whereby all discharge which may occur over the same can be carried to the river below. Above the spillway the overlying material has been excavated down to 745, or 5 feet below water level. Below the spillway the larger part of the excavation necessary to provide an unobstructed discharge can be left to the action of the water. Over the high

Model of Proposed Pine Falls Layout.

ground the rock has been assumed at elevation 740, or from 10 to 15 feet below the natural surface. This assumption is fully warranted by the formation of the natural granite which outcrops on the surface about 100 feet upstream from and parallel to the spillway, and outcrops also in the gully below.

Fish ladder and Log slide.—A fish ladder and log slide are located at the junction between the spillways and the sluiceways, and are accessible by means of the platform over the latter. Suitable provision can readily be made for booming logs to this point on the dam.

Sluiceway section of dam.—The sluiceway section of the dam, consisting of twenty 20-foot sluices with sills at elevation 735 (plate 45), is located adjacent to the power station. A motor-driven winch for handling stoplogs is included in the estimates. The sluiceway deck has its bottom elevation at 755·5, allowing 5½ feet clear above the regulated pond level.

Rock has been assumed at elevation 715 to 695, the lowest section being adjacent to the power station. At this point the set of the current indicates considerable depth, and the assumptions made have taken note of the same.

Power station.—The power station (pl[illegible]) has been designed for single-runner vertical turbines of 10,000 hor[illegible] [illegible]wer capacity at full gate. The design has been developed only in sufficient detail to determine the size of the water passages necessary to carry the water to and from the turbines at permissible velocities. The electrical and regulating equipment have been assumed for estimating purposes only.

The racks and headworks have been housed, and a sloping concrete curtain around the face of the entrance piers forms a protection against floating ice and drift. The floor of the headworks house at elevation 757 is connected with the left bank by means of four decked ice sluices and a corewall embankment. The generator floor at elevation 741 is connected with the river bank by means of a steel bridge spanning the channel below the ice sluices. The first pier of these sluices has been extended down stream, and the generator floor has been produced out over the same, creating additional floor space in the power-house for the disposition of machinery, etc. The draught tube seal is at elevation 708, the discharge taking place directly down the river.

The estimates for the power station have been calculated for two stages of development:—

(*1*) *Initial development.*—This consists of the six outer units. The turbines considered have a capacity of 10,000 horse-power at full gate, and the electrical installation has been selected with the normal full load corresponding to $\frac{8}{10}$ gate opening on the turbines. The initial installation of six units supplies sufficient machine capacity to utilize 12,000 second-feet at 37-foot head with turbines at 85 per cent efficiency and $\frac{8}{10}$ gate, and leaves one unit as a spare for emergencies. The output available on the low tension switchboard on a 75 per cent over-all efficiency and a 24-hour basis is 37,000 horse-power. The estimates for the initial development include the construction of the headworks of the remaining four units to a sufficient degree to support the stoplogs, leaving the balance of the bays to be completed when required.

(*2*) *Final development.*—This will consist of ten 10,000 horse-power units, the four additional being added to the landward end of the first installation. The ten units will supply machine capacity for the utilization of 20,000 second-feet at 37-foot head, with turbines considered at $\frac{8}{10}$ gate. This installation will under these conditions provide a spare unit for emergencies. The output at the swichboard at 75 per cent efficiency and on a 24-hour basis is 63,100 horse power.

Ice sluices and roadway.—Connecting the power station with the left bank are four ice sluices, followed by a corewall embankment. The location of these sluices is such that their operation will produce a current along the face of the power station, tending to automatically clear the forebay of floating material. The main floor of the generator room is connected with the high ground by means of a steel bridge spanning the discharge channel below the sluices.

Embankment.—The contours of the left bank necessitate the construction of a low embankment upstream for a distance of about 2,300 feet, to connect with contour 755. While this embankment may not be necessary with the pond at regulated level, it is required to protect the land to the rear at times when the pond is above normal level. In the layout submitted it has been made to serve the purpose of a sailing bank, leading to the upper entrance of the lock.

A more accurate and detailed survey on the ground may show that this embankment is not required. Provision has been allowed for it in the estimates. Drainage of the land to the rear is a simple matter.

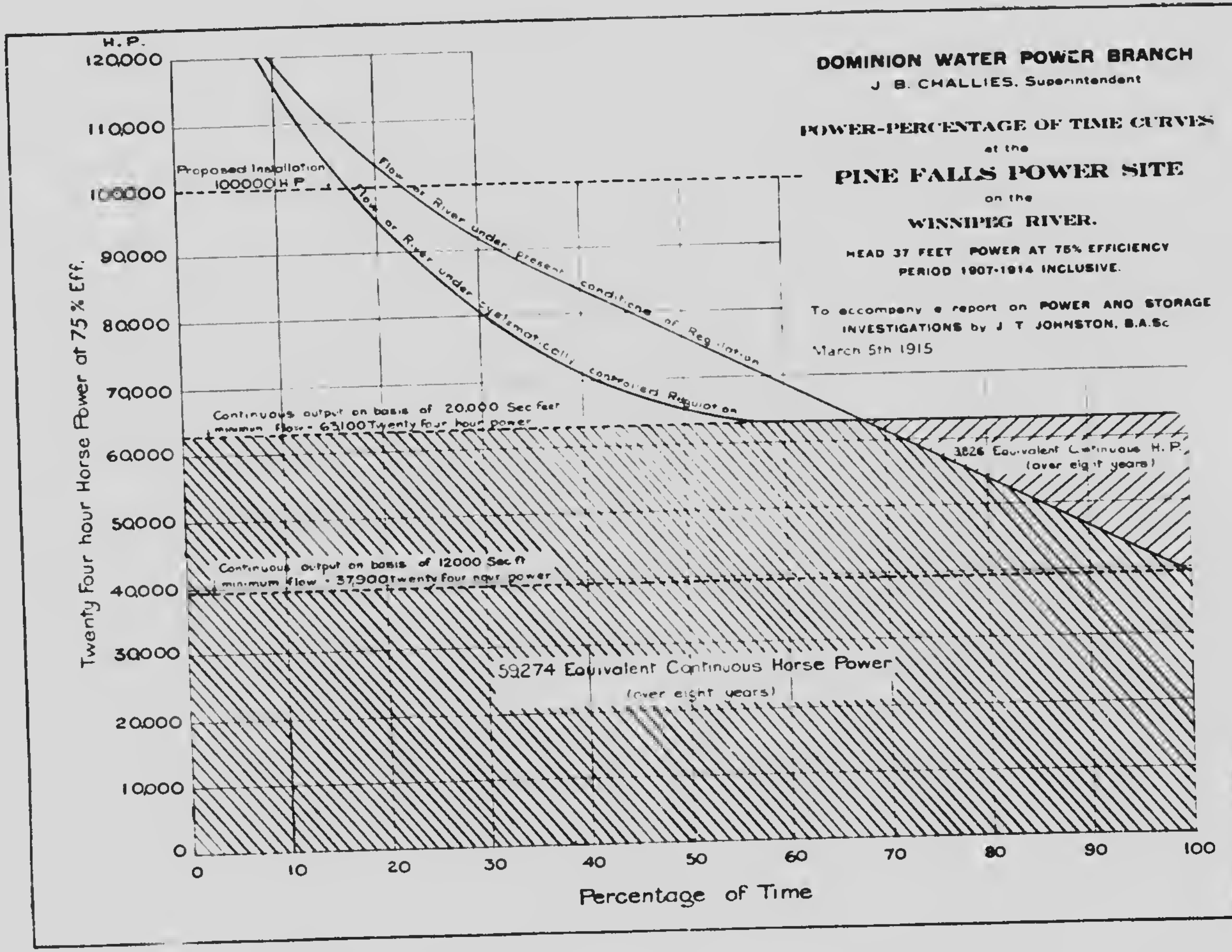
Pine Falls, Main Drop.

Pine Falls, Main Drop.

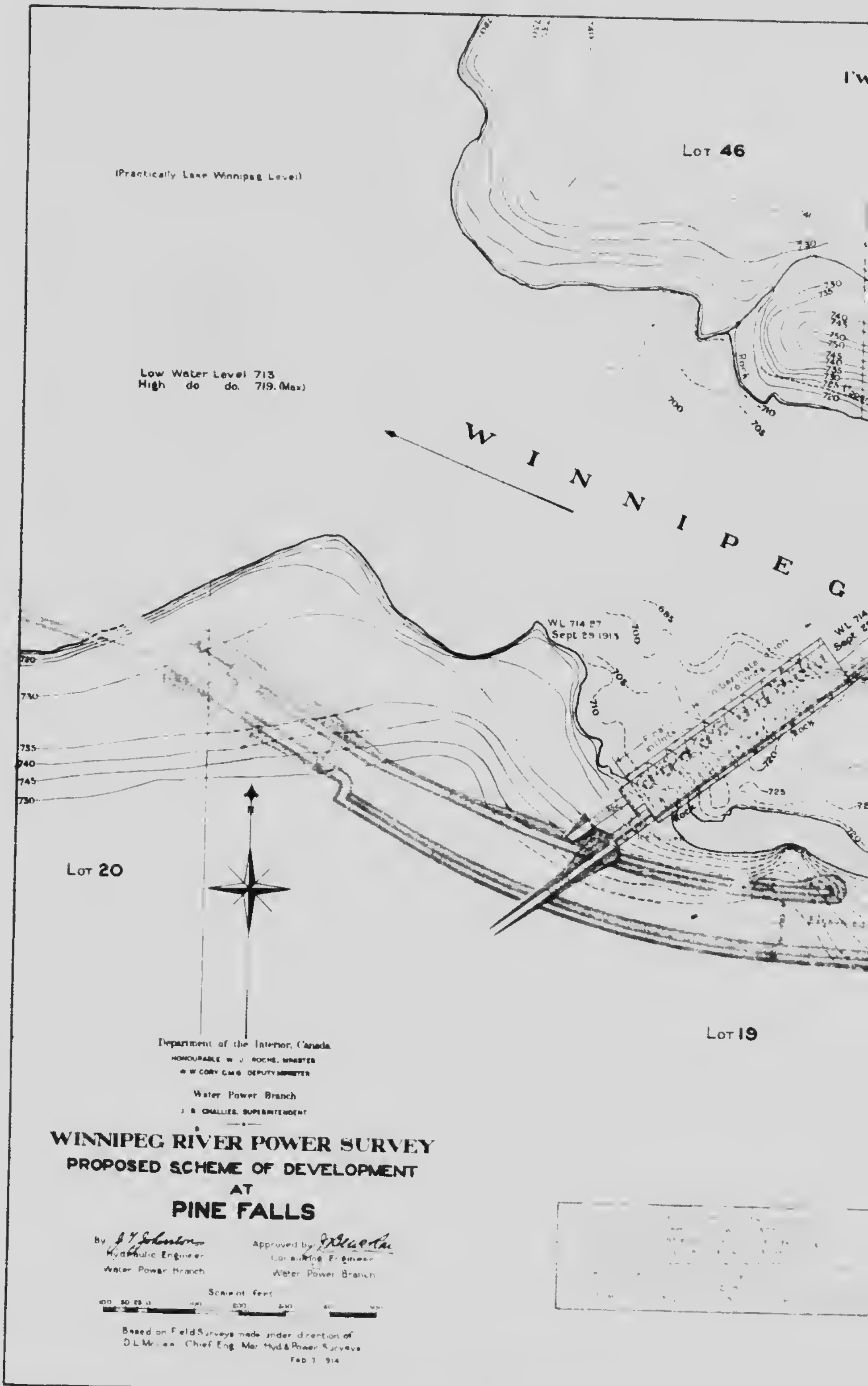
DISCHARGE CAPACITY.

At regulated pond level the sluiceways of the dam will discharge 92,000 second-feet. In addition to this the discharge through the power station amounts to 12,000 second-feet in the initial and 20,000 second-feet in the final installation.

PLATE No. 42



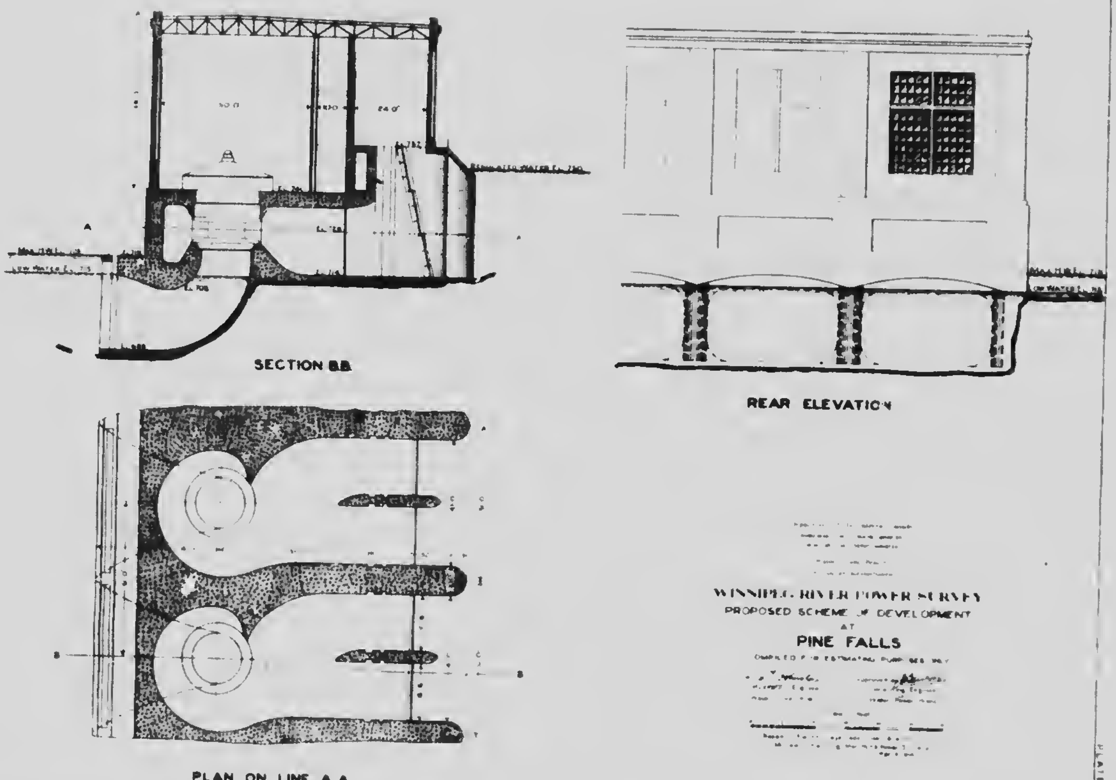
DOMINION WATER POWER BRANCH
J. B. CHALLIES, Superintendent
POWER-PERCENTAGE OF TIME CURVES
at the
PINE FALLS POWER SITE
on the
WINNIPEG RIVER.
HEAD 37 FEET POWER AT 75% EFFICIENCY
PERIOD 1907-1914 INCLUSIVE.
To accompany a report on POWER AND STORAGE INVESTIGATIONS by J. T. JOHNSTON, B.A.Sc
March 5th 1915
H.P.
Proposed Installation 100000 H.P.
Flow of River under present conditions of Regulation
Flow of River under systematically controlled Regulation
Continuous output on basis of 20,000 Sec feet minimum flow - 63100 Twenty four hour power
Continuous output on basis of 12000 Sec ft minimum flow - 37900 twenty four hour power
3826 Equivalent Continuous H.P. (over eight years)
59274 Equivalent Continuous Horse Power (over eight years)
Twenty Four hour Horse Power at 75% Eff.
Percentage of Time



Lot 46
(Practically Lake Winnipeg Level)
Low Water Level 713
High do do. 719. (Max)
W I N N I P E G
WL 714.87
Sept 29 1913
Rock
Lot 20
Lot 19
Department of the Interior, Canada
HONOURABLE W. J. ROCHE, MINISTER
W. W. CORY C.M.G. DEPUTY MINISTER
Water Power Branch
J. B. CHALLIES, SUPERINTENDENT
WINNIPEG RIVER POWER SURVEY
PROPOSED SCHEME OF DEVELOPMENT
AT
PINE FALLS
Hydraulic Engineer
Water Power Branch
Approved by
Consulting Engineer
Water Power Branch
Scale of Feet
Based on Field Surveys made under direction of
D.L. McLean, Chief Eng. Man. Hyd. & Power Surveys
Feb 7 1914

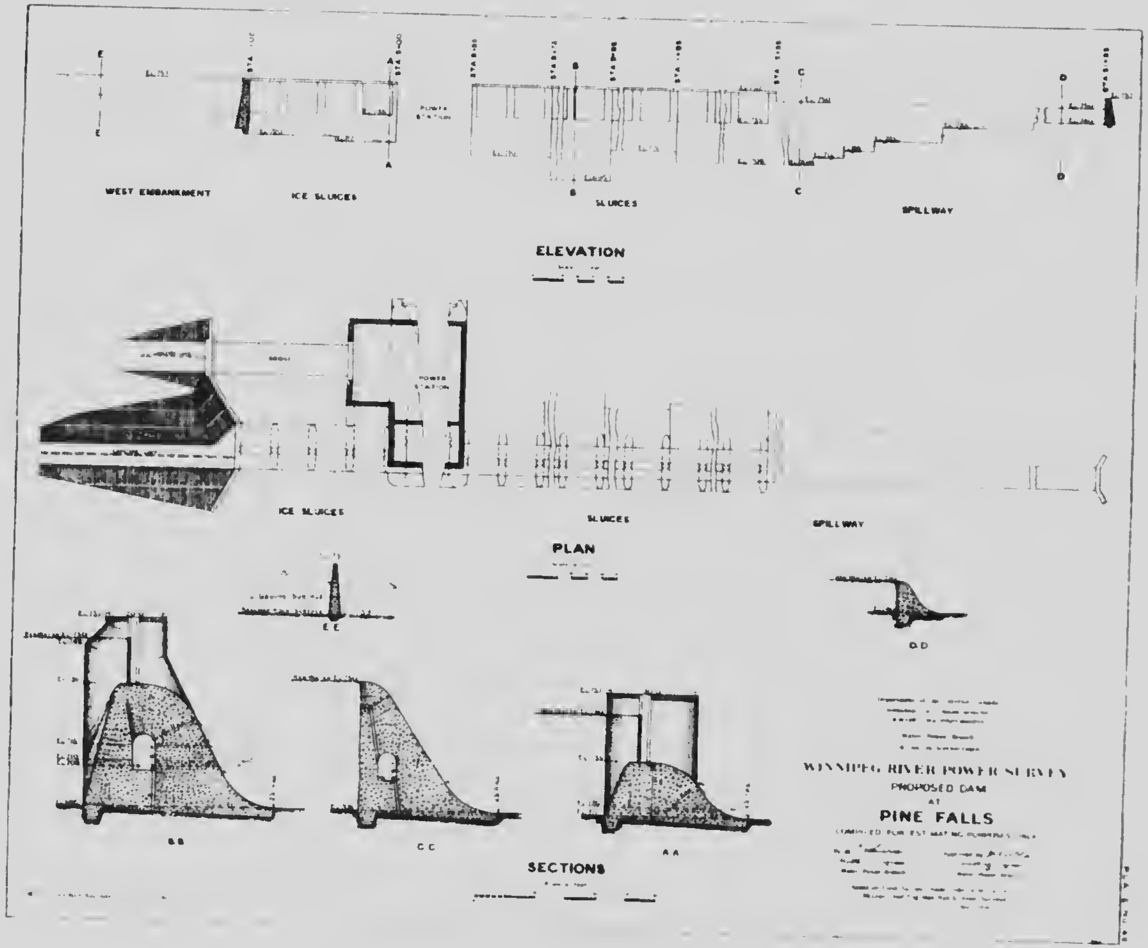

PLATE No. 43
Twp. 18, Rge. 10, E.P.M.
Lot 45
Lot 44
Present Shore Line
PINE FALLS
Fish Ladder
Log Slide
Rock
WL 714.42 Sept. 29, 1913
WL 720.56 Sept. 29, 1913
R I V E R
WL 720.44 Sept. 27, 1913
Normal Regulated Water Level 750
Old Headrace
Gauge
WL 721.78 Sept. 28, 1913
Lot 18

H.P



WINNIPEG RIVER POWER SURVEY
PROPOSED SCHEME OF DEVELOPMENT
AT
PINE FALLS

PLATE No. 44


WEST EMBANKMENT
ICE SLUICES
SLUICES
SPILLWAY
ELEVATION
POWER STATION
ICE SLUICES
SLUICES
SPILLWAY
PLAN
E E
D D
B B
C C
A A
SECTIONS
WINNIPEG RIVER POWER SURVEY
PROPOSED DAM
AT
PINE FALLS

While this latter is not considered to be a source of discharge available at all times, it nevertheless forms an additional factor of safety.

Although the above provides ample sluiceway discharge, it would not be wise to depend wholly on mechanical or manual operation to care for the fluctuations of the river flow. A 775-foot spillway, with crest at 750, gives the necessary automatic check on the pond level. Three feet over the crest will discharge 13,000 second-feet. The total discharging capacity at this latter elevation, with all sluices open and the power station in full operation, is 135,000 second-feet. The river is not subject to sudden floods.

UNWATERING.

Alternative schemes of unwatering may be adopted in the construction of this plant, the selection of the method depending largely upon the problems of construction which will arise when actual operations are started. Sufficient cofferdam yardage, together with ample provision for pumping, has been allowed in the estimates to cover this work. No special difficulties are anticipated in this connection.

NAVIGATION.

At the Pine Falls site no difficulty will be experienced in installing future lockage facilities on the left bank below the power-house, should the same ever become necessary. A sailing bank, built up from the material excavated from the approach to the lock, will protect the upper entrance from the effects of any draw towards the power station. The lock depicted is 300 feet by 40 feet, with 15 feet of water on the sills; a larger lock could as conveniently be constructed.

The lock, with approaches, can be constructed at any time in the future without in any way interfering with the operation of the power plant, nor will the provision for it incur any extra expenditure in the present construction of the plant. On the other hand, the present construction of the power installation will not place any obstacles in the way of the future construction or operation of the lock. No portion of the cost of the lock or approaches is included in the estimates for the power development.

ESTIMATES OF COST.

The following estimates of the cost of the initial and final installations place the power on the low tension switchboard in the power station. The estimates are considered to be amply conservative and all assumptions which have been necessary are fully warranted by the conditions on the ground. It is understood that a railway has been projected and partially located from Winnipeg to the vicinity of Pine falls. Should this railway be built before construction operations on the power plant are started, it will, of course, be utilized in connection with the same. Should, on the other hand, the railway not be built, a direct connection with Winnipeg is to be had by water transportation. It is understood that 10-foot navigation is available up the river to the tail-water of the plant. An item has been placed in the estimates for the construction of a dock, with the necessary apparatus for landing heavy material and for transporting the same to the site of construction operations.

Ten per cent has been allowed in the estimates for contingencies, 5 per cent of this total for engineering and inspection, and 5½ per cent of the whole for one year, for interest during construction.

The annual operation costs include capital charges, and represent the operating charges at the power station. They do not include transforming and transmission.

The cost of delivering power to Winnipeg from this site is covered towards the end of this chapter.

(1) Initial Development.—(six 10,000-horsepower units.)

(1) Capital Cost of Installation.

Dam and equipment	$381,000	
Ice slukes	61,000	
Power station and equipment	695,000	
Hydraulic installation	540,000	
Electrical installation	720,000	
Dockage facilities	50,000	
Permanent quarters	20,000	
Contingencies, 10 per cent	247,000	
Engineering and inspection, 5 per cent	136,000	
Interest during construction, 5½ per cent	157,000	
Flooding damages	50,000	
Total initial cost		$3,057,000

Twenty-four hour power available at 75 per cent over-all efficiency, 37,900 horsepower.

Capital cost per 24-hour horsepower	$80 66
Capital cost per installed horsepower	$50 95

(2) Annual Cost of Operation.

Interest, sinking fund, and depreciation charges—		
Interest, 5½ per cent on $3,057,000		$ 168,000
Sinking fund, 4 per cent (40-year bonds)		32,000.
Depreciation—		
1 per cent on permanent works	$ 10,000	
4 per cent on machinery, etc	56,000	
		66,000
Operation charges—		
Staff	$ 21,000	
Supplies	16,000	
		37,000
Total annual charge		$ 303,000

Annual cost per horsepower year, 24-hour power	$8·00
Annual cost per horsepower year, machinery installed	$5·05
Annual cost per Kilowatt hour	0·122 cent.
Annual cost per Kilowatt hour on basis of 50 per cent load factor	0·244 cent.

(2) Final Development.—(Ten 10,000-horsepower units.)

(1) Capital Cost of Installation.

Dam and equipment	$ 381,000	
Ice sluices	61,000	
Power station and equipment	958,000	
Hydraulic installation	900,000	
Electrical installation	1,200,000	
Dockage facilities	50 000	
Permanent quarters	25,000	
Contingencies, 10 per cent	358,000	
Engineering and inspection, 5 per cent	197,000	
Interest during construction, 5½ per cent	227,000	
Flooding damages	50,000	
Total final cost		$4,407,000

Twenty-four hour power available at 75 per cent over-all efficiency, 63,100 horsepower.

Capital cost per 24-hour horsepower	$ 69·84
Capital cost per installed horsepower	44·07

(2) Final Development.—(Ten 10,000-horsepower units)—*Con.*

(2) Annual Cost of Operation.

Interest, sinking fund, and depreciation charges—		
Interest, 5½ per cent on $4,107,000		
Sinking fund 4 per cent (40-year bonds)		$ 212,000
		46,000
Depreciation—		
1 per cent on permanent works	$ 12,000	
4 per cent on machinery, etc.	90,000	
		102,000
Operation charges—		
Staff	$ 29,000	
Supplies	28,000	
		57,000
Total annual charge		$ 417,000
Annual cost per horsepower year, 24-hour power		$7.08
Annual cost per horsepower year, machinery installed		4.47
Annual cost per Kilowatt hour		0.108 cent.
Annual cost per Kilowatt hour on basis of 50 per cent load factor		0.216 cent.

[1]Du Bonnet Falls Site.

Pressing power applications before the department called for a field survey of the Du Bonnet falls as the first step in the systematic study of the whole river. This work was carried on throughout the winter season of 1911-12. A comprehensive study of the best means of controlling and developing the Du Bonnet falls was not possible without including in the field work the entire reach from Lake Winnipeg level to Lac du Bonnet. It was necessary, in order to conserve the full power of the river, and to assure the most efficient development of the entire head available, that each concentration should be considered not only from the standpoint of its individual economic development, but also as forming a component part of a complete hydro-electric system. Hence the permissible head- and tailwater levels of the Du Bonnet site were largely dependent on the limiting water levels of possible concentrations of heads both above and below. This consideration was particularly pressing in view of the nature of the power applications before the department covering this reach of the river.

SPECIAL CONSIDERATIONS AT DU BONNET FALLS.

At the commencement of the field investigations, an application was before the department looking to the concentration at Du Bonnet falls of the entire drop of the river below. The method proposed was to blast away the rock ridges at Whitemud falls, Silver falls, Masqua rapids, and Pine falls, and thereby lower the Du Bonnet tailwater. The proposal was not based on field surveys, but was deemed feasible by the applicants because of the deep lake-like expanses which occur between each fall, and because of the distinct rock ridge which is in evidence at each drop. The preliminary inspection trip by the department engineers was sufficient to determine the impracticability of this proposal. The best disposal of Whitemud falls was a matter requiring more detailed consideration before being finally determined.

A second application before the department involved the raising of the headwater of the Du Bonnet falls (normally 804) to 815·5. Such a development would leave at the McArthur falls an unused head of 11·5 feet which could not be economically developed.

[1]This site is being developed by the Winnipeg River Power Company, see appendix II.

One of the principal ends kept in view by the field engineers was to ascertain the possibility of completely flooding out the two McArthur falls and of concentrating their drop at the Du Bonnet falls, thus securing a head of some 75 feet. The results of the surveys, as can be seen by reference to topographic sheets 7, 8, 9, and 10, Volume II of this report, definitely determined that this was impracticable, the elevation and nature of the ground on both river banks being entirely unsuited to the project, and necessitating the construction of a very extensive system of heavy embankments.

The raising of the headwater level to elevation 815·5, as proposed in the second application referred to above, was for similar reasons considered impracticable. A full study of all the conditions and interests involved resulted in the layout and governing elevations submitted herein.

Little du Bonnet Falls.

REACH OF THE RIVER DEVELOPED.

The reach of the river developed by the Du Bonnet falls concentration includes Whitemud falls, Little Du Bonnet falls, the four drops of the Grand du Bonnet falls, and the raising of the normal headwaters of the latter about 3 feet. The power station has been placed immediately below the Little du Bonnet falls, with the dam spanning the river along the crest of the pitch. The Whitemud Falls drop is added to the developed head by blasting out a channel through the rock ridge. The total drop of the upper falls is secured by flooding back from the dam.

Whitemud falls.—Whitemud falls are located about 3 miles above Silver falls. There is here a normal drop of 14 feet, practically all of which takes place in a distance of 900 feet. The banks rise abruptly from 20 to 25 feet above the water surface. The natural granite outcrop is continuously in evidence on both river banks, and also throughout the river-bed.

Little du Bonnet falls.—The Little du Bonnet falls occur about 3 miles above Whitemud falls, there being here a normal drop of 8 feet. The drop is abrupt, practically the whole taking place in one pitch. Rapid and broken water extends about 300 feet above the main drop. The usual granite formation is in evidence, with the banks rising to 35 feet above the water in the immediate vicinity of the river, and to 50 and 60 feet a short distance inland.

Grand du Bonnet falls.—The lowest pitch of the Grand du Bonnet falls takes place three-quarters of a mile above the Little du Bonnet falls. There is here a total drop of 35 feet, occurring in four distinct pitches of 5 feet, 13 feet, 8 feet, and 7 feet, respectively, with broken and rapid water between. The whole drop takes place in a distance of 4,000 feet, measured along the centre line of the river channel, and forms the most compact group of falls on the lower river. A few islands of varying size break up the falls.

Towards the lower portion of the falls the banks are steep and vary from 35 to 40 feet in height in the immediate vicinity of the river. Above the upper pitch the banks are from 8 to 10 feet above the water surface. The usual rock formation is in evidence on all sides.

DISPOSAL OF WHITEMUD FALLS.

The disposal of Whitemud falls has been briefly referred to in the discussion on the Pine Falls site. It was there pointed out that the contours immediately above Pine falls prevented the incorporation of the Whitemud drop with the head developed at the Pine Falls site.

The river banks above Silver falls would permit raising the water level to elevation 875, giving a head of about 48 feet. Such an elevation would flood out Whitemud falls, Little du Bonnet falls, and the lowest pitch of the Grand du Bonnet falls. This would undoubtedly form a very profitable development, considered as an individual project without reference to the balance of the river. It would, on the other hand, leave only some 12 feet to be developed at Pine falls. This of itself would not be commercially attractive in view of the competing sites in the river. At the same time there would be left some 52 feet between elevation 875 and the high level of Lac du Bonnet, which could only be developed in two heads of 33 and 18 feet, respectively. The net result on this reach of the river of concentrating development at Silver falls would therefore be four concentrations of 12 feet, 48 feet, 33 feet, and 18 feet, as opposed to the three concentrations of 37 feet, 56 feet, and 18 feet, which are recommended herein.

The 14-foot head available at Whitemud falls would render feasible the development of the falls as a unit should no other disposition of the drop be available, although on account of the low head such a utilization could only be made at a high unit cost. A careful study and detailed field survey of the falls show, however, that the drop can be practically eliminated by means of a channel (plate 46) cut through the ridge forming the river-bed through the falls. That this proposal is practical is due to the typical rock formation of the reach. The basin above the falls is in places 70 feet in depth, and except at one point referred to hereafter, will permit without any ill effects, the surface drop contemplated.

The soundings which have been secured above and throughout the falls clearly and definitely locate this rock ridge, and are sufficiently complete to permit of an estimate of the quantities involved, and to assure the feasibility of the construction of a channel of sufficient dimensions to lower the upper reach and add the drop to the Du Bonnet concentration.

The south side of the river appears to offer the better opportunities for the excavation of such a channel. Estimates have been made covering the cost of a cut 150 feet in width, and of sufficient depth to carry 25,000 second-feet at a velocity of about 4 feet per second. This channel will be 1,700 feet in length, and will involve the removal of 263,000 cubic yards of rock. Under conditions of normal flow it should carry the discharge with a drop of about 0·3 foot.

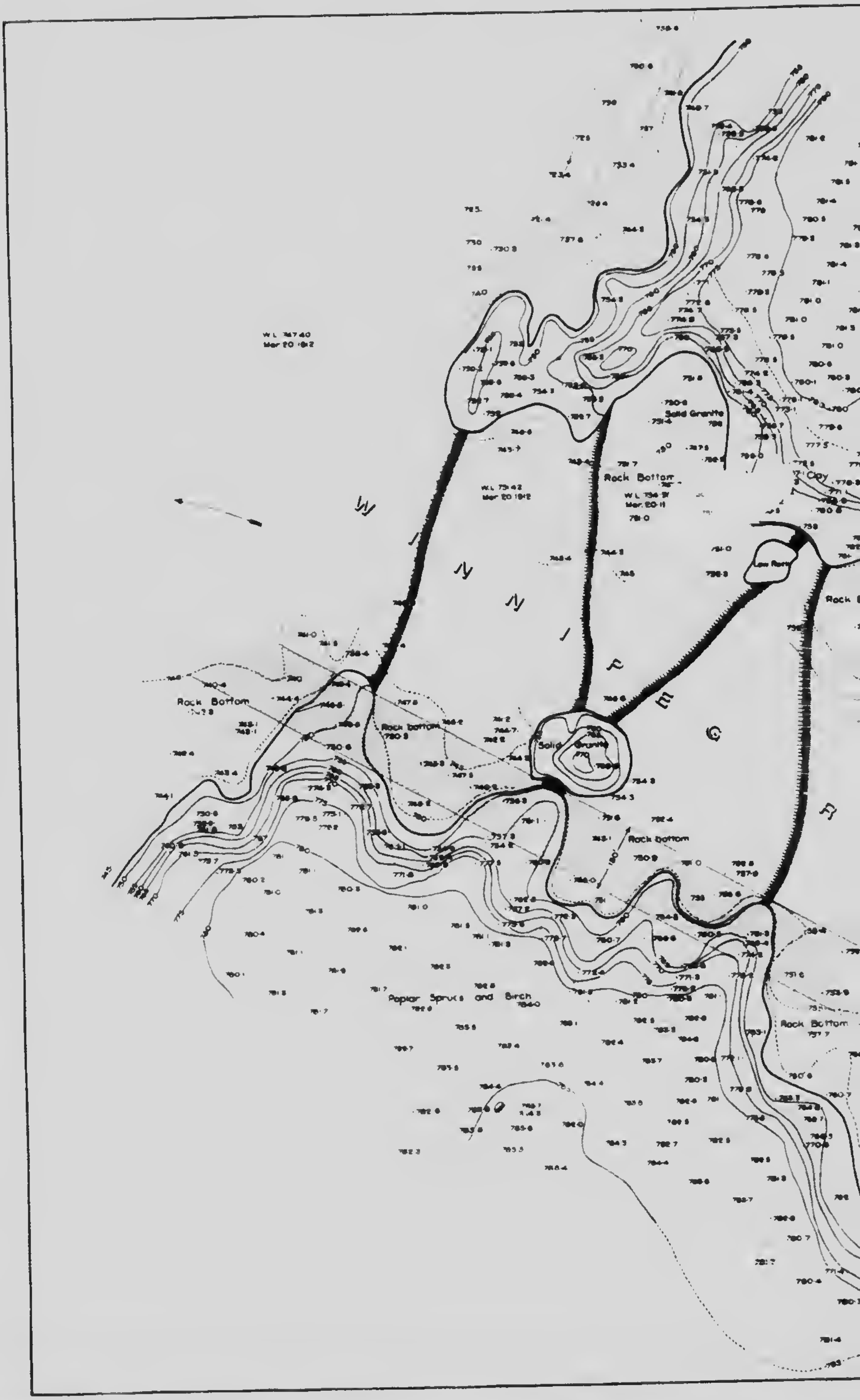
The removal of the Whitemud falls will result in a rapid current in the vicinity of island No. 2, a short distance below the Little du Bonnet falls. Under present conditions of river run-off, the river channel here becomes choked with accumulations of ice during the winter season. Lowering the reach 10 feet will accentuate the conditions favourable to the deposition of ice at this point. On the other hand the flooding out of the Du Bonnet falls, and the replacing of the same by a deep and extensive pond, will largely reduce the present tendency to produce frazil ice, and tend to better the conditions at island No. 2. Before the effects of lowering the reach 10 feet can be finally determined, a further investigation should be made in the vicinity of the island with a view of determining the nature of the river-bed. Should conditions warrant it, the question of concentrating the head at this point rather than at the Little du Bonnet falls might be advisable, although the capital cost of such a location would be considerably higher than that of the layout discussed herein. Such higher cost might be compensated for by the elimination of possible channel improvement work in the vicinity of island No. 2. The further field investigations into this alternative site should consist of soundings and borings in the river-bed, and are of a character such as can best be undertaken by the parties developing the site.

HEAD- AND TAILWATER ELEVATIONS.

The headwater at the proposed Du Bonnet plant has been placed at elevation 808. This will result in a 4-foot rise in the present normal water level at the head of the falls, and will flood back to the foot of the second McArthur falls. This rise in the normal headwater of the Du Bonnet falls will prove sufficient to pass the average flow over what is now the first pitch, at a velocity of from 3 to 4 feet per second. More detailed soundings than are now available are necessary to exactly determine the future conditions here.

According to well-defined water marks, the water level below the Little du Bonnet falls has risen to elevation 767 under extreme conditions. In an average year the level varies from 760 to 764. These conditions will recur in the future until such time as construction work is undertaken at the Whitemud falls. An average elevation of 762 has been assumed as the tailwater level under present conditions.

The regulated level of the Pine Falls site is 750. Upon the excavation of the proposed channel at Whitemud falls, this elevation will control the Du


W. L. 747.40
Mar 20 1912
W. L. 751.42
Mar 20 1912
Rock Bottom
Solid Granite
Clay
Rock Bottom
Rock bottom
Solid Granite
Rock bottom
Rock Bottom
Poplar Spruce and Birch
W I N N I P E G R

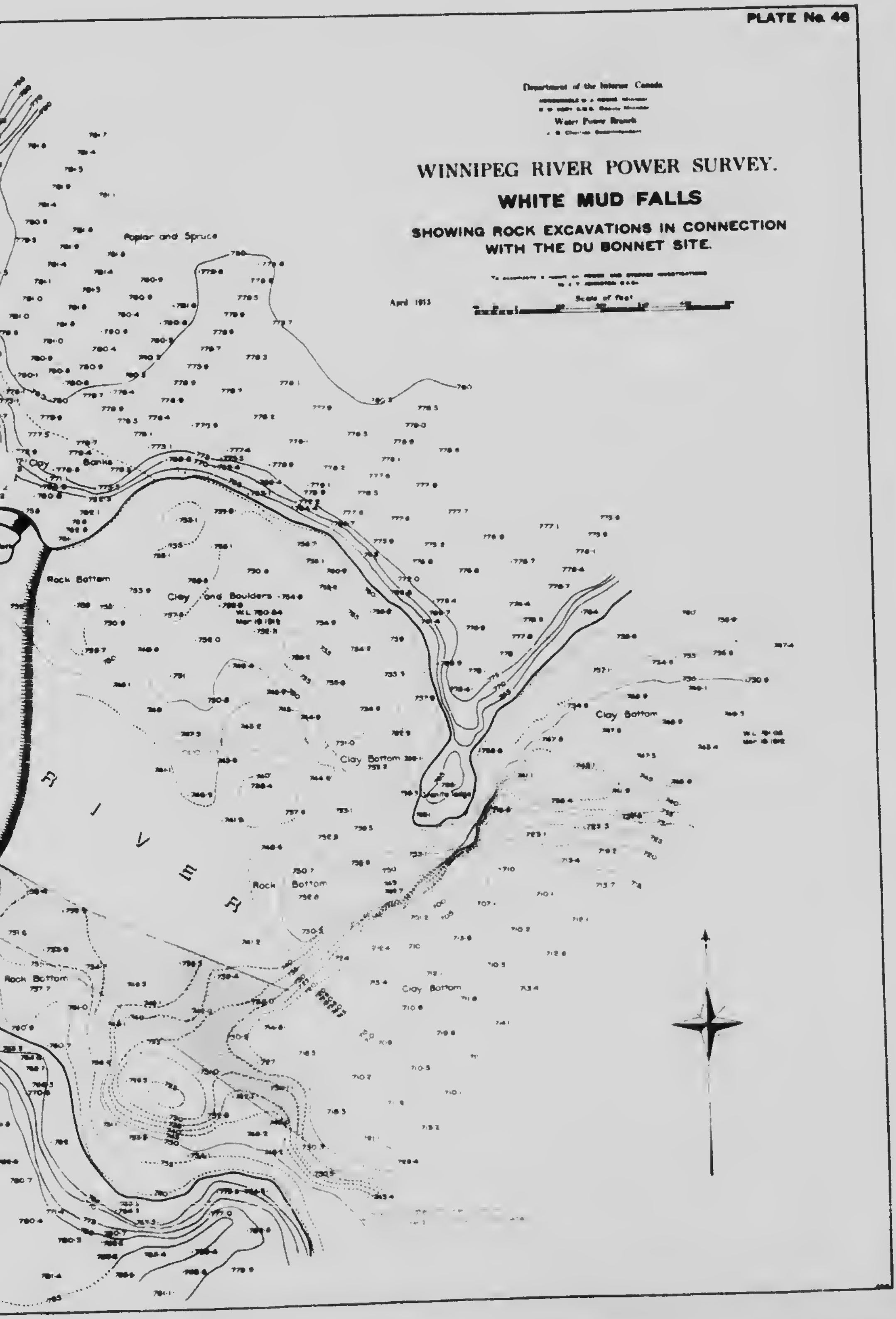


PLATE No. 46
Department of the Interior Canada
Water Power Branch
WINNIPEG RIVER POWER SURVEY.
WHITE MUD FALLS
SHOWING ROCK EXCAVATIONS IN CONNECTION
WITH THE DU BONNET SITE.
April 1913
Scale of Feet
Poplar and Spruce
Clay Banks
Rock Bottom
Clay and Boulders
Clay Bottom
Granite ledge
Rock Bottom
Clay Bottom
Rock Bottom
Clay Bottom
R I V E R

Bonnet tailwater. Throughout this discussion, 752 has been considered the elevation ultimately obtaining, although the estimates for the channel have considered a section which will pass 25,000 second-feet at a velocity of 4 feet per second with an hydraulic grade of 0·3 foot. Elevation 752 is considered a conservative assumption for the final tailwater level in view of the conditions already referred to as existing around island No. 2.

FLOODING.

Little flooding will result from raising the headwater to elevation 808. An embankment is necessary on the west side. This embankment is designed with a 10-foot top at elevation 815, and with 1½: 1 slopes. It is 800 feet in length, and at regulated level in the pond will withstand a head of from 5 to 7 feet at its heaviest sections. It can be constructed of the clay in the immediate vicinity. Apart from this section, the natural contours will retain the headwaters with the flooding of some 360 acres.

PONDAGE.

A regulated level of 808 will create 1,700 acres of pondage. A draw of 1·7 foot on this pond will supply a 4-hour peak load to the full installation considered, i.e., 140,000 horse-power, assuming a continuous flow of 20,000 second-feet in the river. While this provides very fair pondage facilities, these are not as favourable as the conditions at the majority of the sites proposed along the river.

The advisibility of a supervised control of the river regulation can be well illustrated here. The McArthur plant immediately above the Du Bonnet will have as its pond th[illegible]are miles water surface of Lac du Bonnet. This offers unexcelled faciliti[illegible]cal storage, which can, if properly controlled, be made as readily available to the Du Bonnet as to the McArthur plant. It is only by such control that the maximum power output of this section of the river can be secured.

ICE CONDITIONS.

During the winter season the channel in the vicinity of island No. 2, below the Little du Bonnet falls, becomes at times somewhat choked with a deposit of frazil and anchor ice. This is largely due to the long stretch of agitated water in the Grand and Little du Bonnet falls, presenting ideal conditions for the formation of frazil and slush ice. The contracted river channel in the vicinity of the island, together with this formation of frazil, forms a combination favourable to the formation of an ice barrier, and is at times the cause of more or less choking and consequent raising of the water level above.

The layout under consideration will entirely drown out all the falls above the plant, as far back as the lower McArthur drop, and will form an extensive pond, in places 70 feet deep. The water is drawn directly from this pond into the turbines, and no ice troubles in the operation of the plant itself need be anticipated. The flooding out of the falls will also largely do away with the production of the slush ice which leads to the choking of the channel below.

FOUNDATION CONDITIONS.

Solid red granite underlies the entire site, and is directly exposed over almost the entire layout. The river banks above the exposed rock line are

Grand du Bonnet Falls, Ice Conditions.

Little du Bonnet Falls, Site of Proposed Power Station.

composed of a fairly dense clay. In estimating on the corewall for the embankments, rock was assumed to be 10 feet below the natural surface, it being considered that the general configuration of the vicinity would warrant this assumption, and that in any event a trench of this depth in the material in question would permit of a tight foundation. Similar assumptions have been made at different points along the river. On the shore line the bare rock is in evidence at all points covered by the proposed structures. Along the line of the dam in the river-bed, the rock was assumed at elevations which were fixed after a careful observation on the ground. It is considered that these elevations are sufficiently close for estimating purposes.

LAYOUT.

The general layout (plate 48) connects with contour 815 on the right bank by means of a corewall embankment, ice sluices, and power station joined direct with a sluice and spillway dam of solid gravity section arched in plan

Model of Proposed du Bonnet Layout.

so as to follow the high rock above the falls, and finally closes with the high land on the opposite bank by means of a second embankment. The final location of the dam may be altered when detailed soundings are secured.

It was desirable to locate the power station on the west bank in order that direct rail connection could be secured. The shore-line formation does not, however, lend itself to this end, and such a location would involve extensive tail-race excavation, as well as a draught tube discharge poorly placed in relation to the pitch of the falls. The site selected for the power station provides ideal foundation conditions with a minimum of tail-race excavation, and secures a very favourable discharge.

East embankment.—The east embankment has been estimated with a 15-foot top at elevation 815, and 1½: 1 slopes, constructed from the material most readily available. Impermeability is secured by a concrete corewall with a 1-foot crest at elevation 814, and a batter of 1 : 12. This core will be bonded to the bedrock should the latter be within reasonable distance of the surface, and if not, a tight and safe bond can readily be obtained with the clay subsoil.

Ice sluices.—Between the east embankment and the power-house are located three 20-foot sluices with sills at elevation 793. These serve the double purpose of providing a suitable ice run and additional discharging capacity to the whole layout. The sluices are so placed as to clear the forebay of ice and drift by tending to produce a current parallel to the line of the power station. It has been assumed that rock will be available for the foundation at elevation 775 under the easternmost sluice, and at 770 under the remaining two. Rock is exposed on the river bank at the latter elevation.

Power station.—The power station (plate 49) has been designed for single-runner vertical turbines of 10,000 horse-power at full gate. The section has been developed only in sufficient detail to enable a fairly accurate estimate being made of the quantities involved. This was mainly a question of the size of the water passages to carry the requisite supply at permissible velocity to and from the turbines.

The racks and headworks have been housed in, and a sloping concrete curtain is provided as a protection against floating ice and drift. In conjunction with the ice sluices, this protection should be ample. The floor of the headworks house is at elevation 815, while the generator flood is at elevation 777. The centre line of the turbines is at elevation 766, and the draught tube seal at 748. This seal is placed at a sufficiently low elevation to permit of the projected lowering of the tailwater. The discharge from the draught tubes takes place directly into the river channel.

In view of the necessity of excavating a channel through the Whitemud falls in order to increase the available head from 46 to 56 feet, the estimates have been calculated for three stages of development: the initial, covering 12,000 second-feet at 46-foot head; the intermediate, covering 20,000 second-feet at 46-foot head; and the final, covering 20,000 second-feet at 56-foot head.

(1) *Initial development.*—This consists of the seven 10,000-horsepower units next the dam. It will provide for the utilization of 12,000 second-feet at 46-foot head, with the turbines running at eight-tenth gate and considered at 85 per cent efficiency. The above installation will practically leave one unit as a spare under the conditions stated. The output available at the switchboard on a 75 per cent over-all efficiency on a 24-hour basis is 47,000 horsepower. The headworks of the remaining units will be sufficiently constructed to support the stoplogs provided, leaving the balance of the units to be added when required.

(2) *Intermediate development.*—This consists of twelve 10,000-horsepower units, the additional five being adjacent to the initial installation. Twelve units will provide for the utilization of 20,000 second-feet at a 46-foot head, with the turbines running at eight-tenth gate.

This installation, under the conditions given, will provide a spare unit. The output available at the switchboard at 75 per cent efficiency on a 24-hour basis is 78,500 horsepower.

(3) *Final development.*—This consists of fourteen units which will provide for the utilization of 20,000 second-feet at 56-foot head with turbines at eight-tenth gate. This installation will practically provide a spare unit with the turbines running at eight-tenth gate. The power available at the switchboard at 75 per cent efficiency on a 24-hour basis is 95,500 horsepower.

An ideal sloping foundation of red granite is available at the proposed location of the station.

Sluiceway section of dam.—Fifteen 20-foot sluiceways (plate 50), with sills at elevation 793, are immediately adjacent to the power station. The sluiceway deck, with its underside elevation at 813·5, will permit of a 5½-foot rise in the regulated level. Solid rock underlies the sluiceway section. Its elevation has been assumed at 765.

Spillway section of dam.—The spillway section of the dam, 400 feet in length, has its crest at elevation 808, and is surmounted by a 10-foot platform supported by three-foot piers, spaced 23 feet, centre to centre. The platform will give ready access to the plant from the rail connection on the west bank. This free spillway section will discharge 14,000 second-feet with headwaters at elevation 813 and, together with the increased capacity of the sluices under these conditions, will automatically safeguard unexpected fluctuations in the river flow.

[1]Rock has been assumed at elevation 758 after a careful inspection on the ground. Its presence is unmistakably in evidence.

Fish ladder and log slide.—The fish ladder and log slide are placed adjacent to the west embankment, and away from the power station. Their operation in this location should be satisfactory.

West embankment.—The west embankment is of similar design to that on the east side already described. Rock foundation for the corewall should be obtainable throughout its length, or if it is not within economic reach at the higher elevations, a satisfactory foundation can be secured in the clay soil.

DISCHARGE CAPACITY.

At regulated level the fifteen sluiceways and three ice sluices will discharge 72,000 second-feet. In addition to this the completed power station will pass an additional 20,000 second-feet, which, although not a source to be relied upon at all seasons, may be considered as a safety factor.

A free spillway, 400 feet in length with crest at 808, provides for automatic regulation. Three feet over this crest, with all sluiceways open and the power station in operation, gives a total discharging capacity of 113,000 second-feet. Five and one-half feet above the spillway crest can be carried by all structures.

UNWATERING.

The estimated cost of unwatering has been made on the basis of first unwatering the spillway section of the dam and constructing the same, leaving

[1]Since completing the estimates herein, the Winnipeg River Power Company, now developing this site, has sounded the river-bed along the line of the dam as proposed herein, and rock has been located at elevation 755 to 760.

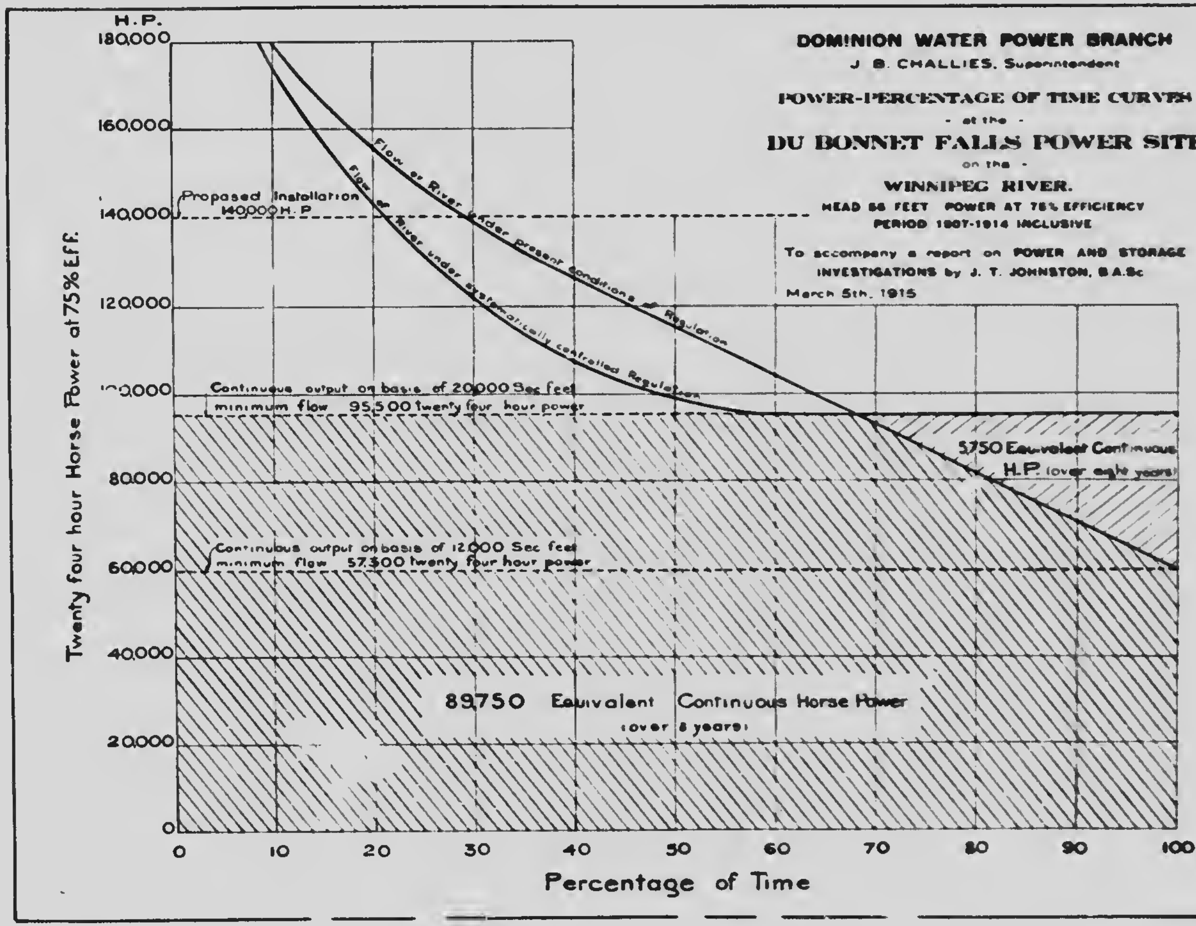

DOMINION WATER POWER BRANCH
J. B. CHALLIES, Superintendent
POWER-PERCENTAGE OF TIME CURVES
- at the -
DU BONNET FALLS POWER SITE
- on the -
WINNIPEG RIVER.
HEAD 56 FEET POWER AT 75% EFFICIENCY
PERIOD 1907-1914 INCLUSIVE
To accompany a report on POWER AND STORAGE INVESTIGATIONS by J. T. JOHNSTON, B.A.Sc
March 5th, 1915
H.P.
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
Twenty four hour Horse Power at 75% Eff.
0
10
20
30
40
50
60
70
80
90
100
Percentage of Time
Proposed Installation 140,000 H.P.
Flow of River under present conditions of Regulation
Flow of River under systematically controlled Regulation
Continuous output on basis of 20,000 Sec feet minimum flow 95,500 twenty four hour power
5750 Eauivalent Continuous H.P. (over eight years)
Continuous output on basis of 12,000 Sec feet minimum flow 57,300 twenty four hour power
89,750 Eauivalent Continuous Horse Power (over 8 years)

PLATE No. 47

Percentage of Time


Low Water Level 762
Max High W. L. 767.9
Proposed Future Reg W. L. 759
W I N N I P E G R I V E R
It is proposed to add Whitemud Falls
to the du Bonnet development lowering
the present tail water to 759
765
770
775
780
785
790
795
800
805
810

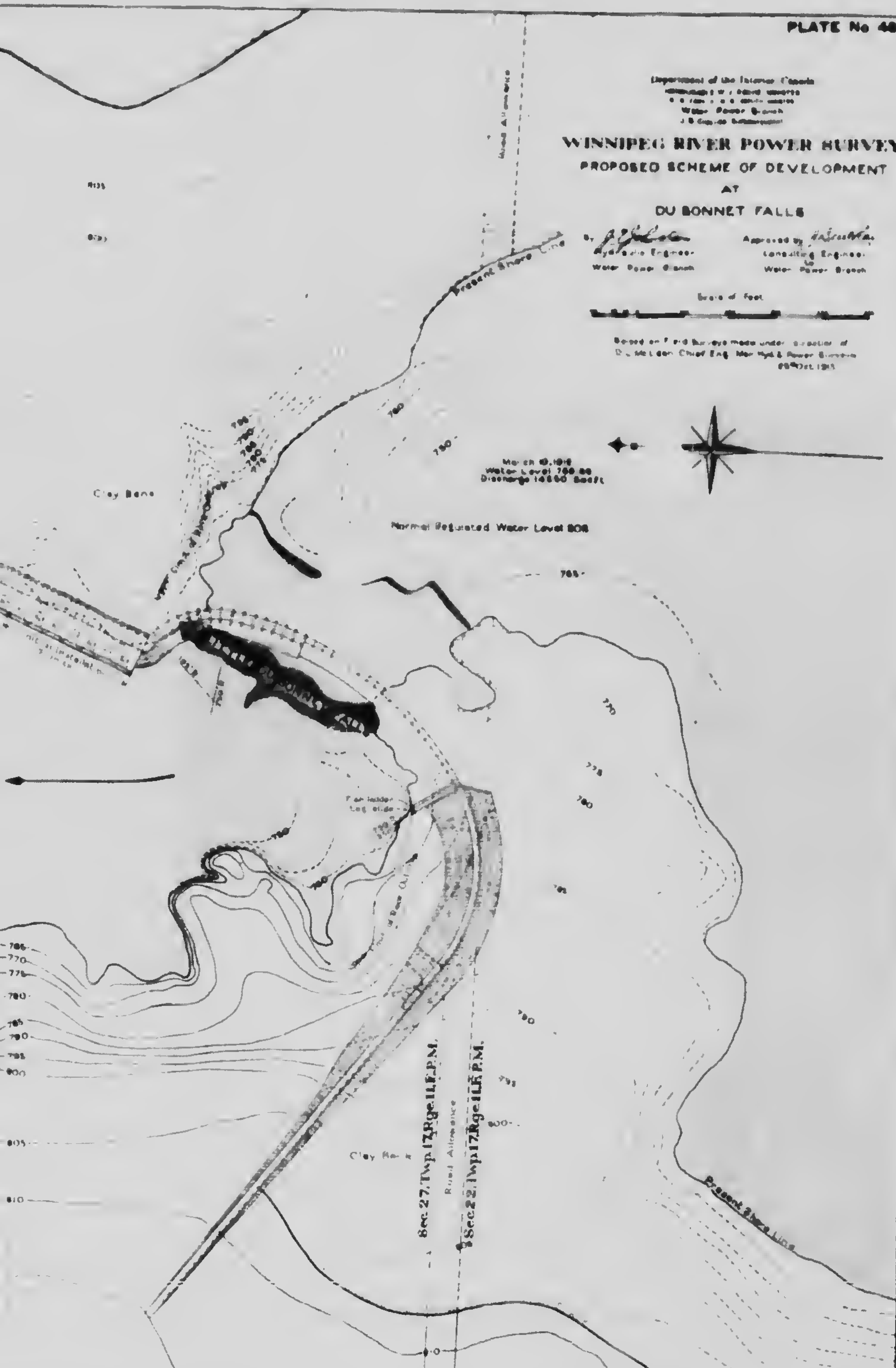


PLATE No 40
Department of the Interior Canada
Water Power Branch
WINNIPEG RIVER POWER SURVEY
PROPOSED SCHEME OF DEVELOPMENT
AT
DU BONNET FALLS
Hydraulic Engineer
Water Power Branch
Approved by
Consulting Engineer
Water Power Branch
Scale of Feet
Normal Regulated Water Level 808
Present Shore Line
Clay Bank
Road Allowance
Sec.27.Twp.17.Rge.11.E.P.M.
Sec.22.Twp.17.Rge.11.E.P.M.
Present Shore Line

PLATE No. 49

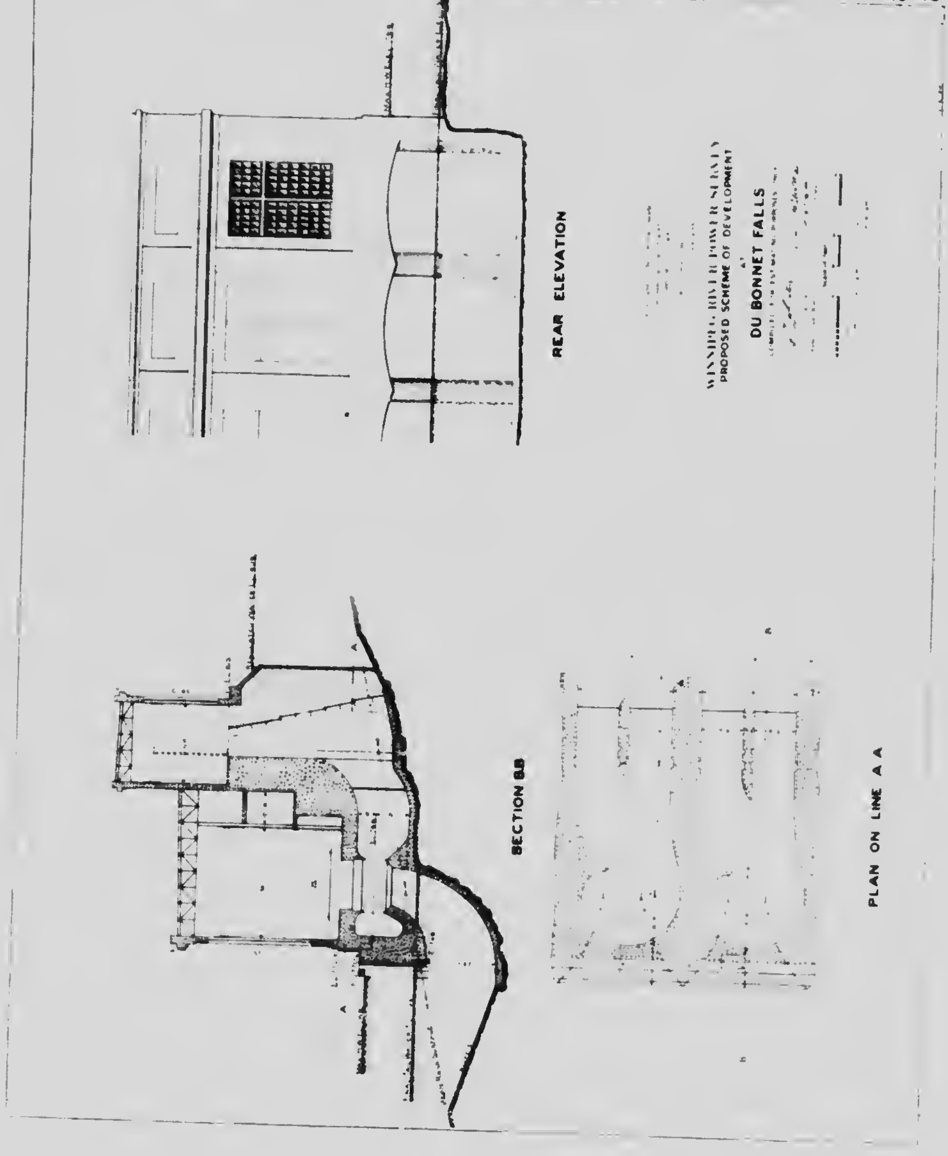
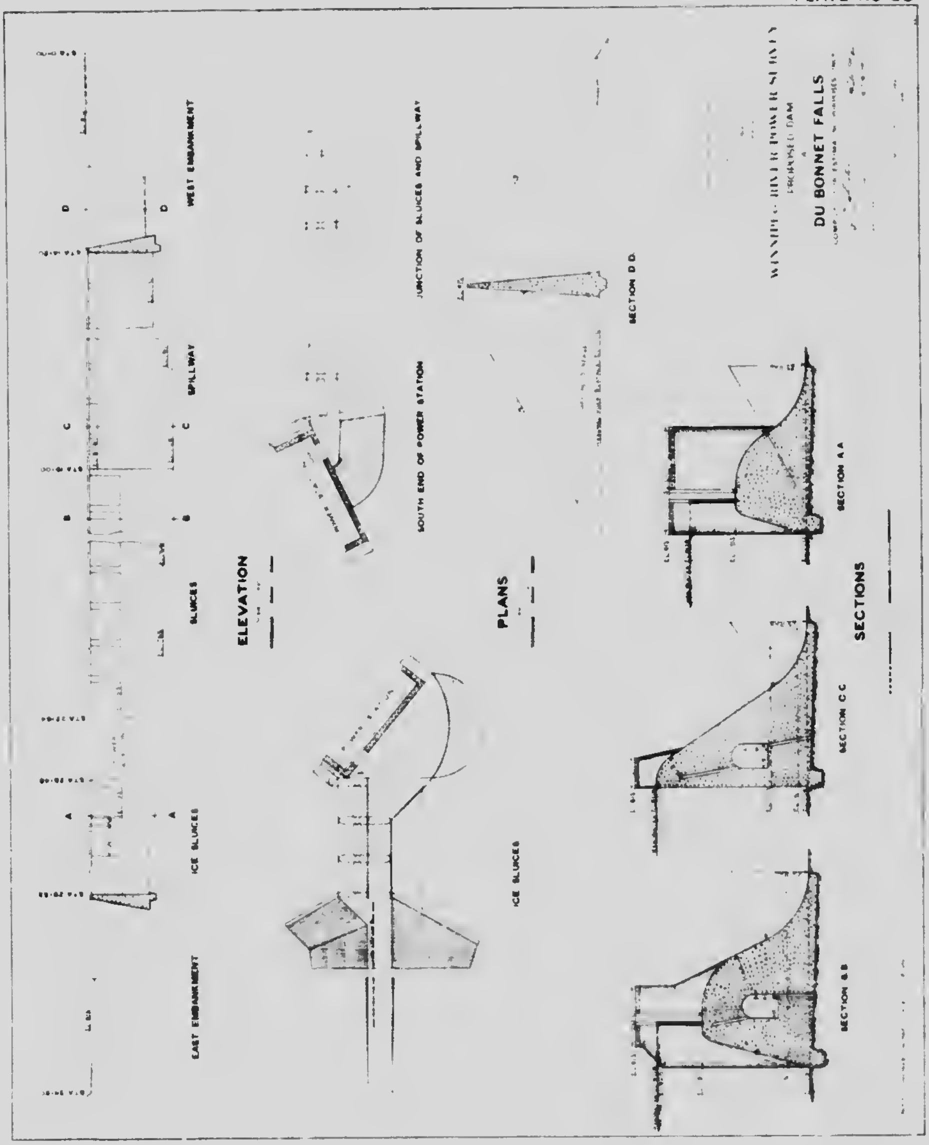

REAR ELEVATION
SECTION B.B
PLAN ON LINE A A
WINNIPEG RIVER POWER SURVEY
PROPOSED SCHEME OF DEVELOPMENT
AT
DU BONNET FALLS

PLATE No 50


WINNIPEG RIVER POWER SURVEY
PROPOSED DAM
AT
DU BONNET FALLS
ELEVATION
EAST EMBANKMENT
ICE SLUICES
SLUICES
SPILLWAY
WEST EMBANKMENT
PLANS
ICE SLUICES
SOUTH END OF POWER STATION
JUNCTION OF SLUICES AND SPILLWAY
SECTIONS
SECTION B B
SECTION C C
SECTION A A
SECTION D D

a sufficient number of temporary discharge sluices therein to discharge the river flow while the sluiceway section is unwatered and built. The temporary sluices can afterwards be closed off with stoplogs and built up to the regular crest level at 808. The power station can be unwatered by sections as built.

Alternative methods can be adopted to suit the method and order of construction. The estimates herein are considered to be amply sufficient to cover whatever method may be adopted.

NAVIGATION.

At this site the navigation lock has been located on the east bank below the power station (plate 48). A flight of two locks can be constructed, if desirable. Advantage has been taken of the upper entrance excavation to construct a sailing bank and at the same time protect the approach to the lock from the draw towards the power station. The lock depicted is 300 feet by 40 feet, with 15 feet of water on the sills. No trouble will be experienced in securing suitable foundations for all structures.

Should the installation of lockage facilities become desirable in the future, the construction of this lock, with approaches, and the utilization of the same, will in no way interfere with the operation of the power station. Nor will the present construction of the suggested power development place any obstacles in the way of the future construction or operation of the lock.

The estimates herein do not include any portion of the cost of the lock or approaches.

ESTIMATES OF COST.

The estimates place the power on the switchboard in the power station, and do not include transmission. It is considered that the assumptions which have been necessary are more than warranted. Actual construction will possibly lead to a considerable reduction in the totals submitted, as it has been considered advisable at all points where any reason for doubt exists, to make the most liberal provision for eventualities.

The estimates include a 13-mile spur line from the present terminal of the Canadian Pacific railway at Lac du Bonnet. This will bring rail connection to the west bank of the river. An item has been included for the construction of a ferry for the transport of loaded cars across the river to the power station site.

In addition to the above, 10 per cent has been added for contingencies, 5 per cent on this total for engineering and inspection, and $5\frac{1}{2}$ per cent on the whole for one year for interest during construction. The estimated cost of the Whitemud Falls excavation has been inserted as a unit.

The annual operation costs include capital charges, and represent the cost of operation at the power station. They do not include transforming and transmission.

(1) Initial development.—(Seven 10,000-horsepower units.)

(1) *Capital Cost of Installation.*

Dam and equipment	$542,000	
Embankment (flood protection)	5,000	
Ice sluices	72,000	
Power station and equipment		
Hydraulic installation	657,000	
Electrical installation	665,000	
Railroad	805,000	
Ferry	156,000	
Permanent quarters	50,000	
Contingencies, 10 per cent	25,000	
Engineering and inspection, 5 per cent	298,000	
Interest during construction, 5½ per cent	164,000	
	189,000	
Total initial cost		$3,628,000

Twenty-four hour power available at 75 per cent over-all efficiency, 47,000 horsepower.

Capital cost per 24-hour horsepower	$77.19
Capital cost per installed horsepower	51.83

(2) *Annual Cost of Operation.*

Interest, sinking fund, and depreciation charges—		
Interest, 5½ per cent on $3,628,000		$ 200,000
Sinking fund, 4 per cent (40-year bonds)		38,000
Depreciation—		
1 per cent on permanent works	$ 12,000	
4 per cent on machinery, etc	64,000	
		76,000
Operation charges—		
Staff	$21,000	
Supplies	20,000	
		41,000
Total annual charge		$ 355,000

Annual cost per horsepower year, 24-hour power	$7.55
Annual cost per horsepower year, machinery installed	5.07
Annual cost per kilowatt hour	0·115 cent.
Annual cost per kilowatt hour on basis of 50 per cent load factor	0·230 cent.

(2) Intermediate development.—(Twelve 10,000-horsepower units.)

(1) *Capital Cost of Installation.*

Dam and equipment	$ 542,000	
Embankment (flood protection)	5,000	
Ice sluices and roadway	72,000	
Power station and equipment		
Hydraulic installation	926,000	
Electrical Installation	1,140,000	
Railroad	1,380,000	
Ferry	156,000	
Permanent quarters	50,000	
Contingencies, 10 per cent	25,000	
Engineering and inspection, 5 per cent	430,000	
Interest during construction, 5½ per cent	236,000	
	273,000	
Total intermediate cost		$5,235,000

Twenty-four hour power available at 75 per cent over-all efficiency, 78,500 horsepower.

Capital cost per 24-hour horsepower	$66.69
Capital cost per installed horsepower	43.62

(2) *Annual Cost of Operation.*

Interest, sinking fund, and depreciation charges—		
Interest, 5½ per cent on $5,235,000		$ 288,000
Sinking fund, 4 per cent (40-year bonds)		55,000
Depreciation—		
1 per cent on permanent works	$ 14,000	
4 per cent on machinery, etc	106,000	
		120,000
Operation charges—		
Staff	$ 27,000	
Supplies	32,000	
		59,000
Total annual charge		$ 522,000

Annual cost per horsepower year, 24 hour power	$6.65
Annual cost per horsepower year, machinery installed	4.35
Annual cost per kilowatt hour	0·102 cent.
Annual cost per kilowatt hour on basis of 50 per cent load factor	0·204 cent

(3) Final development.—(Fourteen 10,000-horsepower units.)

(1) *Capital Cost of Installation.*

Dam and equipment	$ 542,000	
Embankment (flood protection)	5,000	
Ice sluices and roadway	72,000	
Power station and equipment	1,035,000	
Hydraulic installation	1,330,000	
Electrical installation	1,610,000	
Railroad	156,000	
Ferry	50,000	
Permanent quarters	25,000	
Contingencies, 10 per cent	483,000	
Engineering and inspection, 5 per cent	265,000	
Interest during construction, 5½ per cent	307,000	
Whitemud falls rockcut	671,000	
Total final cost		$6,551,000

Twenty-four hour power available at 75 per cent over all efficiency, 95,500 horsepower.

Capital cost per 24-hour horsepower	$68 60
Capital cost per installed horsepower	$46 79

(2) *Annual Cost of Operation.*

Interest, sinking fund, and depreciation charges—		
Interest, 5½ per cent on $6,551,000		$ 360,000
Sinking fund, 4 per cent (40-year bonds)		69,000
Depreciation—		
1 per cent on permanent works	$ 15,000	
4 per cent on machinery, etc	123,000	
		138,000
Operation charges—		
Staff	$ 30,000	
Supplies	38,000	
		68,000
Total annual charge		$ 635,000
Annual cost per horsepower year, 24-hour power		$6.65
Annual cost per horsepower year, machinery installed		4 54
Annual cost per kilowatt hour		0·102 cent.
Annual cost per kilowatt hour on basis of 50 per cent load factor		0·204 cent.

McArthur Falls Site.

The second pitch of the McArthur falls is located about 4½ miles above the Du Bonnet site, and about 26 miles from Winnipeg. The field investigations in the vicinity of this site were completed during the winter of 1911-12, and were supplemented by a reconnaissance of the shores of Lac du Bonnet, with a view to ascertaining its flooding limit. The actual detail survey of the shores of the lake was carried on during the fall of 1912.

A study of the complete field data submits the following general scheme of development as being at once commercially feasible, and as forming a component link in the complete power development scheme.

SPECIAL CONSIDERATIONS AT MCARTHUR FALLS.

The two outstanding features of the proposed hydro-electric development at the McArthur Falls site are the low head and the large local storage in Lac du Bonnet. The lowness of the head naturally has a tendency to increase the capital cost of construction. The natural configuration of the ground has lengthened the dam and necessary embankments, but the latter are low and can be cheaply constructed. The disadvantage of a low head is, to a certain extent, balanced by the unexcelled storage facilities in Lac du Bonnet. By raising this lake to elevation 827, a surface area of 38 square miles is available. This elevation encroaches on the low lands at the west end of the lake, and ample sluiceway and free spillway capacity is necessary in order to regulate the high water and prevent further flooding.

REACH OF THE RIVER DEVELOPED.

The reach of the river developed at this point extends from the lower or second McArthur falls, up to practically the foot of the Seven Sisters falls. In the development the upper or first McArthur falls are drowned out, and Lac du Bonnet is raised to high-water level, the drop of 18 feet being concentrated at the second fall.

Second McArthur falls.—The second or lower McArthur falls are located about 3 miles above the first pitch of the Du Bonnet falls. The river is here

Second McArthur Falls, Main Pitch.

divided into two channels by a large island, the major portion of the flow taking place through the right channel. The total normal drop is about 6½ feet. These falls form the site of the proposed concentration.

First McArthur falls.—The first McArthur falls occur about 1 mile above the lower falls. The river is again divided, this time into three channels, by a group of islands. The right channel carries the major portion of the flow. The total drop is about 7 feet. Granite outcrop is in evidence on all sides.

Lac du Bonnet.—Lac du Bonnet (plate 51) has a water surface normally some 33 square miles in area, which in times of maximum high water is increased to 38 square miles. The limiting feature preventing further raising without remedial works is a muskeg located to the west of the lake. Its mean surface level is about 829. This muskeg is understood to drain to the southwest into lake Winnipeg, but so far as is known no line of levels has been run to determine this question. It is not essential to the present discussion, since it is not proposed

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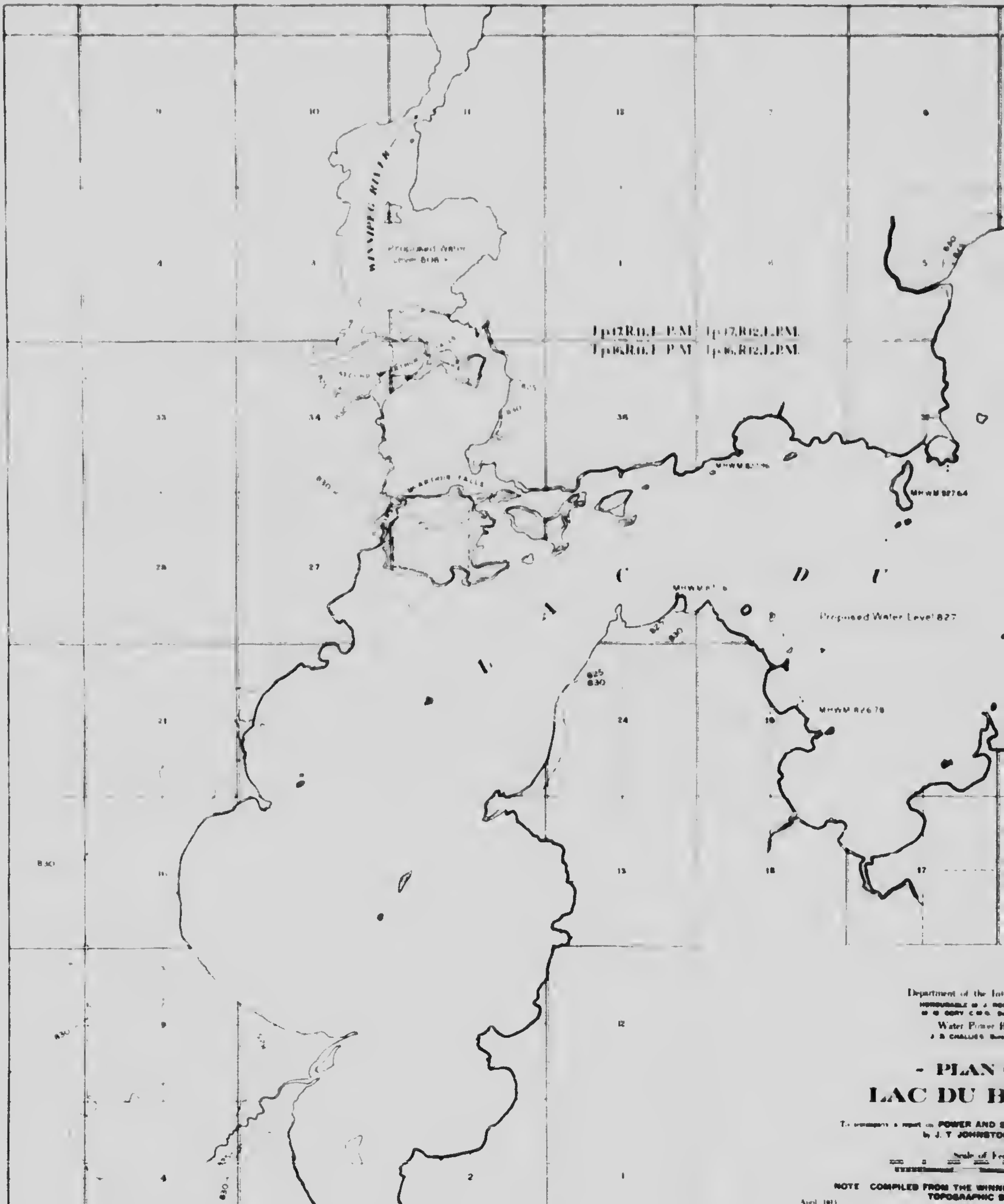
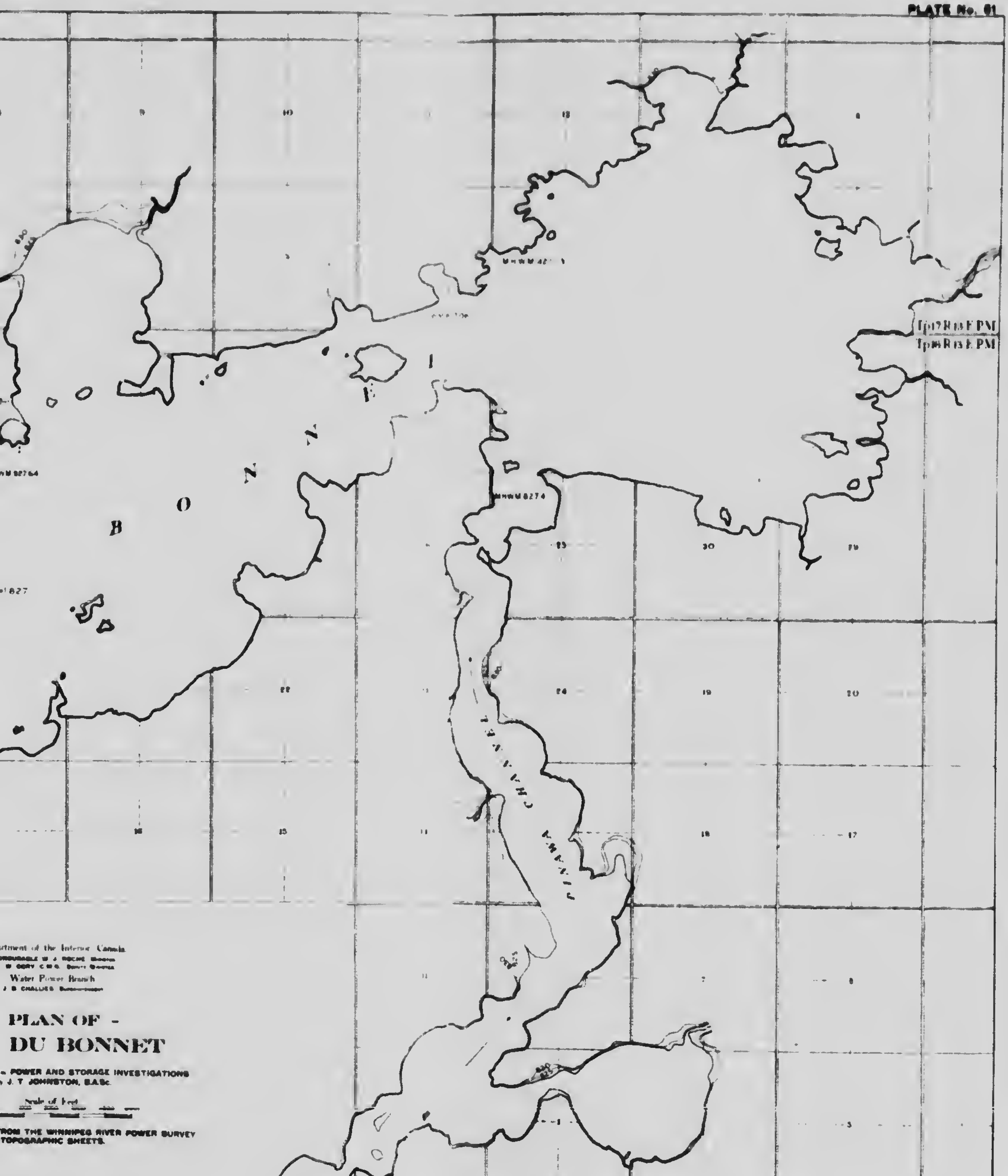


Drawn in the Office of the Chief Draughtsman Dominion Water Power Branch

PLATE No. 61



Tp17 R13 E PM
Tp16 R13 E PM
PINAWA CHANNEL
B O N N E T
Water Power Branch
PLAN OF -
DU BONNET
POWER AND STORAGE INVESTIGATIONS
J. T JOHNSTON, B.A.Sc.
Scale of Feet
FROM THE WINNIPEG RIVER POWER SURVEY
TOPOGRAPHIC SHEETS.

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to flood above elevation 827. In any event, should it be desired to raise the water above 829, the construction of a low dyke about 1 mile in length would protect the muskeg from the lake. Sufficient discharging capacity is provided in the dam to pass the largest floods which have occurred in the past, or may be anticipated in the future, without raising the surface above regulated level. In addition, 1,725 feet of free spillway will offer automatic protection from sudden floods.

HEAD- AND TAILWATER ELEVATIONS.

The headwater is regulated to elevation 827, Water Power Survey datum. This elevation will completely drown out the first McArthur falls, and will raise Lac du Bonnet to practically maximum high-water level. Above Lac

First McArthur Falls, Left Channel.

du Bonnet the river is divided into two channels, the main and the Pinawa. Holding the surface of the lake at elevation 827 will back up the water in the main channel, drown out the small rapid which now exists about 5 miles above the town of Lac du Bonnet, and allowing for the hydraulic gradient in the upper portion of the reach, will control the tail-water elevation of the proposed Lower Seven Sisters development.

The Pinawa channel, on which is located the present plant of the Winnipeg Electric Railway Company, will also be subject to backwater. Whether or not the tailwater of the company's plant will be in any way affected is questionable. Its present normal elevation is about 842, or 15 feet above the proposed level of Lac du Bonnet. The channel below is irregular and winding and obstructed in places by rock-ridges, at which considerable blasting has been carried on by the company to assist the discharge and improve the tailwater conditions at the plant.

It is doubtful whether the raising of Lac du Bonnet to elevation 827 would reduce the head at the power plant to any appreciable extent during the summer season, while, on the other hand, by quieting the flow in the lower reaches and lessening the tendency to accumulate anchor ice, with the consequent backing up of the tailwater, it should prove beneficial during the ice period. In this connection the following quotation from Mr. J. R. Freeman's report following the preliminary reconnaissance is pertinent:—

> "It would doubtless be claimed by the railway company that this raising of the lake would impede the discharge from their works on the Pinawa channel, but after having carefully reconnoitred the wasteful rapids near the outlet of the channel, particularly the two pitches, one of about 3 feet at the bridge for the railroad leading to the municipal power plant, and another of nearly 5 feet, where some blasting has been done, at the rocky reef about a mile, more or less, downstream from this railroad bridge; and, moreover, having had the opportunity to observe the effect of back-flowage under somewhat similar conditions, I believe it highly probable that true conservation and the greatest public good would result from this raising of the lake and of this Pinawa outlet level.
>
> "I consider it highly probable that the effect of raising Lac du Bonnet 5 feet would be practically inappreciable at the power-house some 5 miles or more upstream from these two abrupt falls, which, with neighbouring rapids, aggregate nearly 8 feet."

The tailwater of the McArthur concentration is fixed by the headwater elevation of the proposed plant at the Du Bonnet site. The present tailwater of the McArthur falls, with a flow of 20,000 second-feet in the river, is about elevation 806. The headwater level of the Du Bonnet development has been placed at 808 to allow for the drowning out of the first pitch of the falls. Allowing 1 foot for the hydraulic gradient from the Du Bonnet dam to the McArthur tailrace, places the latter at 809. This is a higher elevation than will occur during low and normal water, but it is being used throughout the present discussion as being conservative. Extreme floods will undoubtedly raise the tailwater above this level and reduce the working head. The increased water available for power purposes at such periods will, however, more than counterbalance any such loss.

FLOODING.

A reference to plate 51 will illustrate the extent of flooding involved by raising the water level to 827. Between the two McArthur falls a low embankment may be required on the west bank to protect the low land. This embankment will not be more than 5 to 8 feet high, and can be cheaply constructed. Further detailed surveys may show that it is not required. The larger proportion of the land flooded is located at the western end of Lac du Bonnet. It is questionable whether it would be more economical to protect this land by the low embankments necessary, or to buy the land outright. An item for flooding damages has been included in the estimates.

As the records along the shore of the lake show that the water has attained an elevation of 827 in extreme floods under natural conditions, the question of flooding cannot be considered as introducing entirely new conditions.

PONDAGE.

The McArthur site offers the best facilities for local pondage that exist on the full reach of the Winnipeg river in Manitoba. In the contemplated development, Lac du Bonnet forms the pond of the plant, and renders 38 square miles of water surface available for local regulation. This extensive area is a double advantage in that the necessary storage can be obtained without appreciable loss of head, a matter of importance in the McArthur plant. The capacity of the pond can best be illustrated by stating that 1 inch of storage on the lake will provide slightly over 1,000 second-feet continuous run-off for twenty-four hours, or 4,000 second-feet for six hours.

These exceptional facilities for local pondage can be placed equally at the disposal of the Du Bonnet site below, providing some supervising control is exercised by the Crown. *In any event it will not be permissible to give the control of the regulation of Lac du Bonnet to any single interest*, since local regulation could for considerable periods completely shut off the water from the plants below.

ICE CONDITIONS.

The prevention of the formation of anchor and frazil ice has been fully taken into account in the layout proposed at this site.

The McArthur plant draws its water from Lac du Bonnet, all the present falls and rapids being flooded out. The water passes directly from the pond to the turbines, and the discharge takes place directly down stream. No ice troubles are anticipated.

A sloping concrete curtain, with bottom elevation 2 feet below regulated pond level, protects the racks from floating ice and drift, and ice sluices at either end of the power station provide means of escape for all such material.

FOUNDATION CONDITIONS.

Granite formation is in evidence throughout almost the entire length of the layout. Where it does not lie on the surface, it has been located by means of an iron bar at a depth of a few feet. The only point at which there is any doubt as to its elevation is under the sluiceway section of the dam. This is taken up in more detail in discussing the layout.

Assumptions have been necessary as to the rock elevation along the site of the main spillway dam at the crest of the main pitch of the falls. The elevations assumed are based on actual observation on the ground, and are considered to be conservative. There is no question whatever as to the actual existence of rock formation at this point.

Actual soundings at the site of the power station give the rock elevation as shown on the plans.

LAYOUT.

The contours and general physical characteristics at the second McArthur falls permit various layouts, no one of which apparently offers any great outstanding advantages. Alternate designs and locations were considered, each offering feasible development opportunities. To determine the most economic

Second McArthur Falls, Site of Proposed Power Station.

of these layouts would require a very careful detailed estimate of each, assisted by further boring and sounding operations in the field. On the whole it is considered that, with the conditions which must be met, the layout suggested herein (plate 53) will form as economic a development as is possible at this site.

Model of Proposed McArthur Layout.

The power station as located spans the western channel, and provides a free discharge with no possibility of ice choking below. The dam consisting of embankment, sluiceways, and free spillway, runs diagonally across the large island, and by a second spillway spans the right channel.

Spillway section of dam.—The main spillway section of the dam, 925 feet n length, has been located along the crest of the main pitch of the second

McArthur falls, adjacent to the right bank of the river. The rock surface has been assumed at elevations 800 to 811, and the spillway crest placed at 827.

A second spillway, 750 feet in length, crest at 827, has been included in the dam on the large central island. The granite is here exposed on the surface, and at such elevation that a spillway section can be constructed at but small expense. The free spillway can be lengthened if necessary by replacing the earth embankment. No flashboards or bridge deck have been considered with the spillways, and the discharge above elevation 827 will be entirely automatic.

A fish ladder and log slide are provided at the island end of the main spillway.

Embankment on Island.—The greater portion of the dam on the island consists of a corewall embankment with top elevation at 832. This embankment is low over the greater portion of its length, and is based on the exposed granite everywhere in evidence along its route.

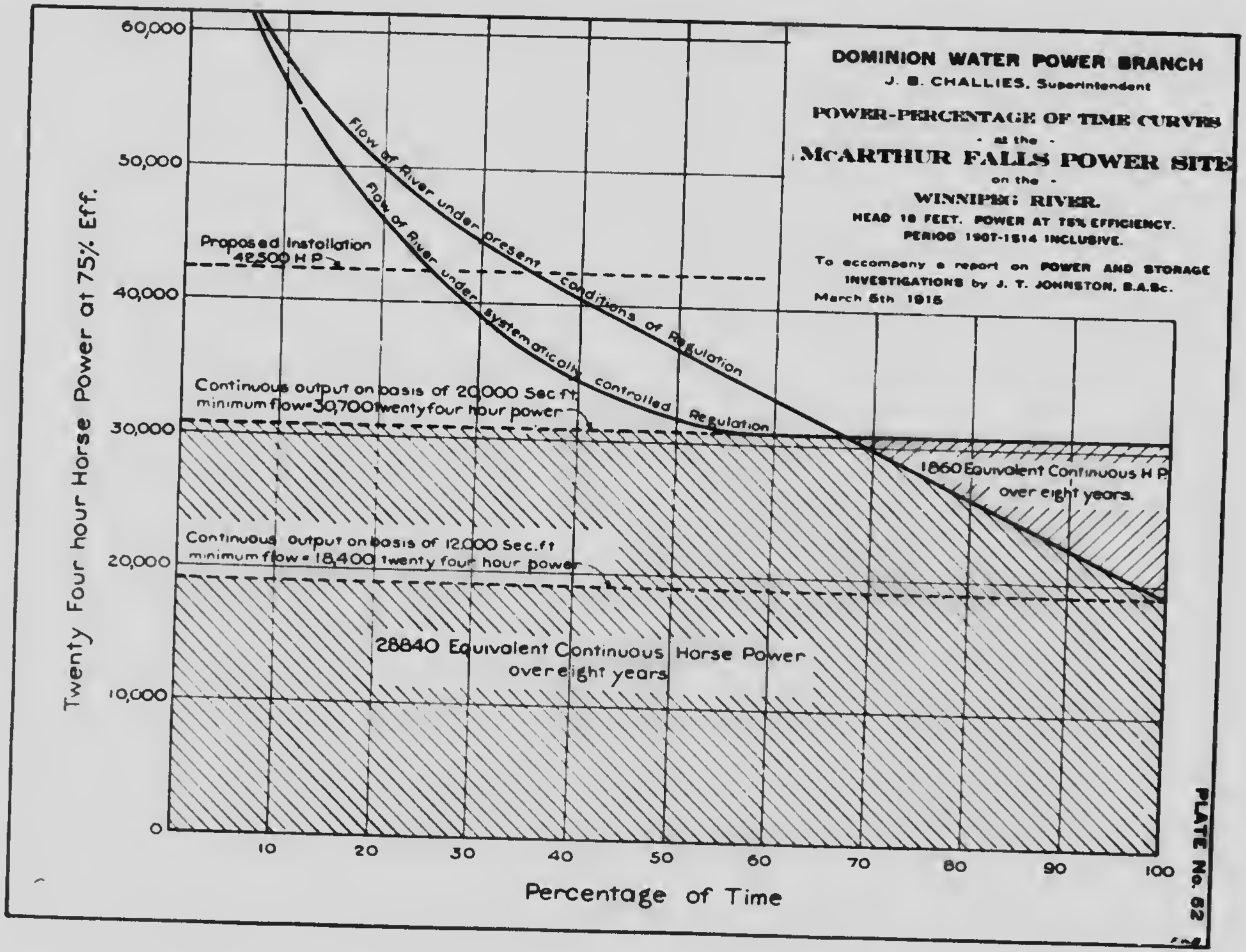
Sluiceway section of dam.—Fifteen 20-foot sluices, with sills at elevation 812 (plate 55), are located in the shallow gully on the island. The elevation of the rock surface has not been determined over this portion of the layout. It has been assumed at elevation 802. The general character of the formation and contours in the vicinity would warrant this assumption. Should borings show rock to be at too low an elevation to permit the economical construction of the sluiceways at this point, they can be located in the main spillway section, and their present location closed by a continuation of the corewall embankment. The locations of the power station and the sluiceways might also, under these conditions, be profitably interchanged.

The sluiceways have been placed in their present location so as to be within easy operating distance of the power station. As located they will discharge all the surplus water across the island, and away from the tail-race. This is a matter of considerable importance, since the narrow channel below the power station will not pass a discharge much over 20,000 second-feet, without backing up on the tailwater.

Ice sluices.—Six 20-foot ice sluices, three at either end of the power station, provide means of clearing the forebay from floating ice and detritus. If desirable the discharge through the easterly sluices can, by means of a rock-fill composed of the excavated material, be diverted across the gully on the island below the power station, and thus be kept free from the tailwater. Both sets of sluices are decked, the easterly to provide means of access to the main sluiceway section of the dam, as well as to operate the stoplogs, and the westerly to provide roadway access to the power station.

Power station.—The power station (plate 54) has been designed for single-runner vertical turbines of 2,500-horsepower capacity at full gate. The section has only been developed in sufficient detail to arrive at the size of the water passages necessary to carry the water to and from the turbines at permissible velocities. The electrical and regulating equipment have been assumed for estimating purposes only.

The racks and headworks have been housed in with floor at 832, and a sloping concrete curtain along the face of the entrance piers provides a protection against floating ice and drift. The generator floor is at elevation 827, and is



DOMINION WATER POWER BRANCH
J. B. CHALLIES, Superintendent
POWER-PERCENTAGE OF TIME CURVES
at the
McARTHUR FALLS POWER SITE
on the
WINNIPEG RIVER.
HEAD 18 FEET. POWER AT 75% EFFICIENCY.
PERIOD 1907-1914 INCLUSIVE.
To accompany a report on POWER AND STORAGE INVESTIGATIONS by J. T. JOHNSTON, B.A.Sc.
March 5th 1915
Proposed Installation 42,500 H.P.
Flow of River under present conditions of Regulation
Flow of River under systematically controlled Regulation
Continuous output on basis of 20,000 Sec.ft. minimum flow = 30,700 twenty four hour power
Continuous output on basis of 12,000 Sec.ft. minimum flow = 18,400 twenty four hour power
1860 Equivalent Continuous H.P. over eight years.
28840 Equivalent Continuous Horse Power over eight years
Twenty Four hour Horse Power at 75% Eff.
60,000
50,000
40,000
30,000
20,000
10,000
0
10
20
30
40
50
60
70
80
90
100
Percentage of Time

PLATE No. 52

Normal Regulated Water Level
Water Level
Initial Installation
11 Units
Final
17 Units
Water Level
Normal Regulated Water Level

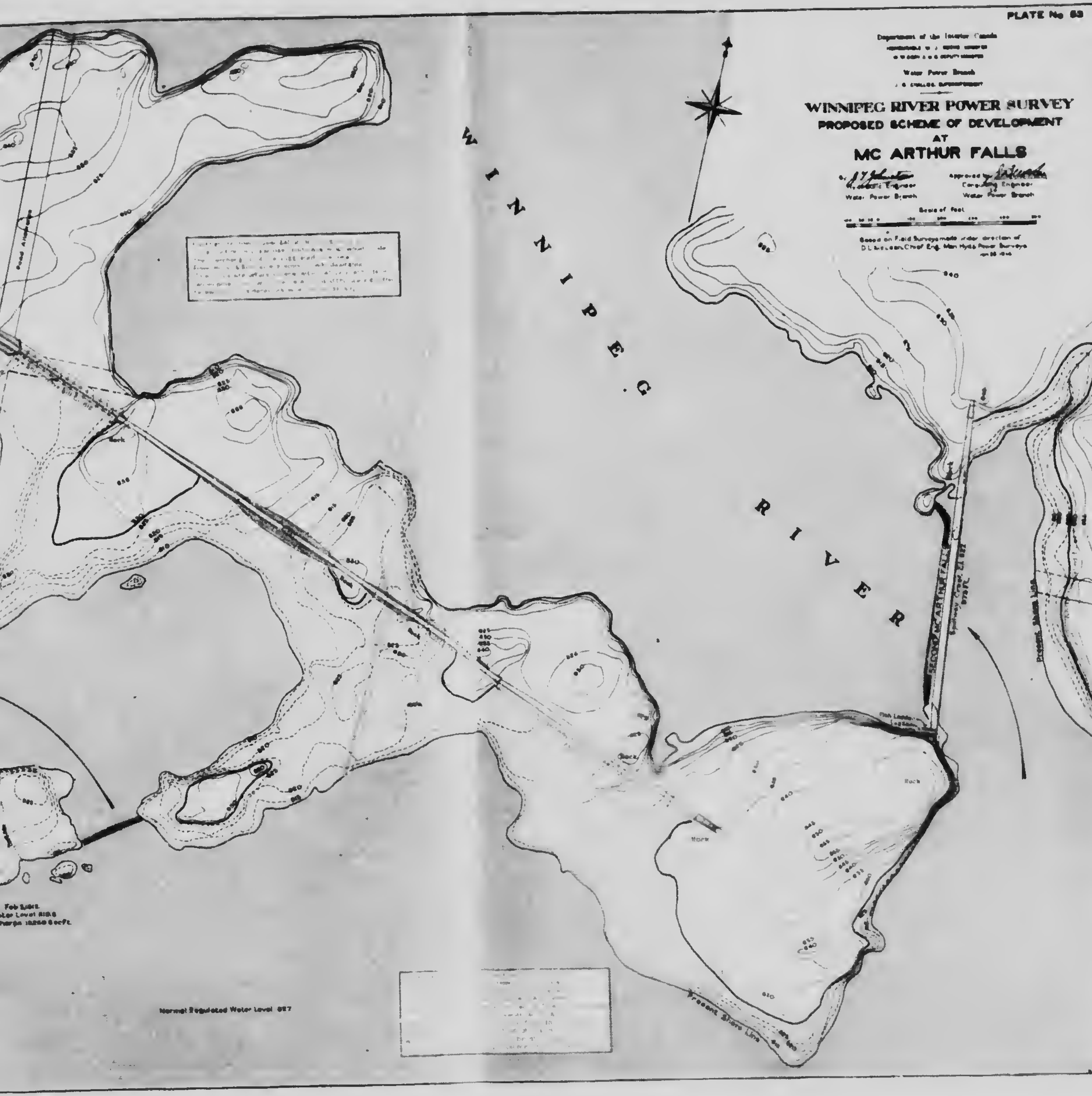
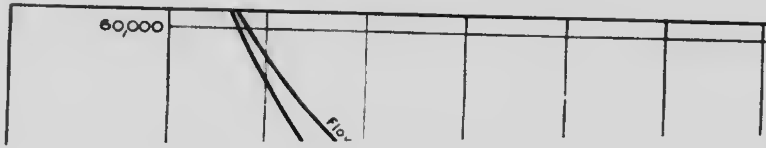


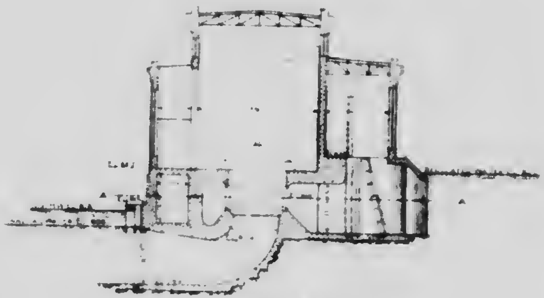
PLATE No 63
Department of the Interior Canada
Water Power Branch
WINNIPEG RIVER POWER SURVEY
PROPOSED SCHEME OF DEVELOPMENT
AT
MC ARTHUR FALLS
Hydraulic Engineer
Water Power Branch
Approved
Consulting Engineer
Water Power Branch
Scale of Feet
Based on Field Surveys made under direction of
WINNIPEG RIVER
Rock
Present Shore Line
Normal Regulated Water Level 827



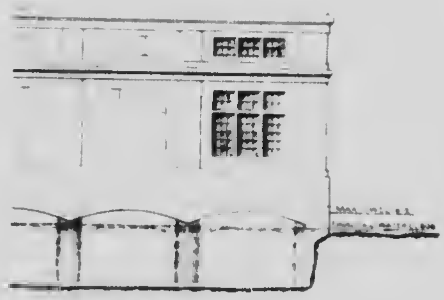
DOMINION WATER POWER BRANCH

J. B. CHALLIES, Superintendent

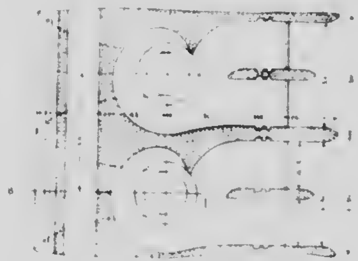
POWER-PERCENTAGE OF TIME CURVES



SECTION BB



REAR ELEVATION



PLAN ON LINE A A

WINNIPEG RIVER POWER SURVEY
PROPOSED SCHEME OF DEVELOPMENT
AT
MC ARTHUR FALLS

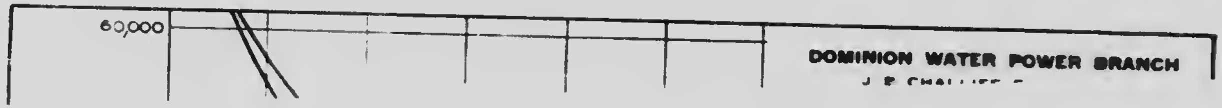
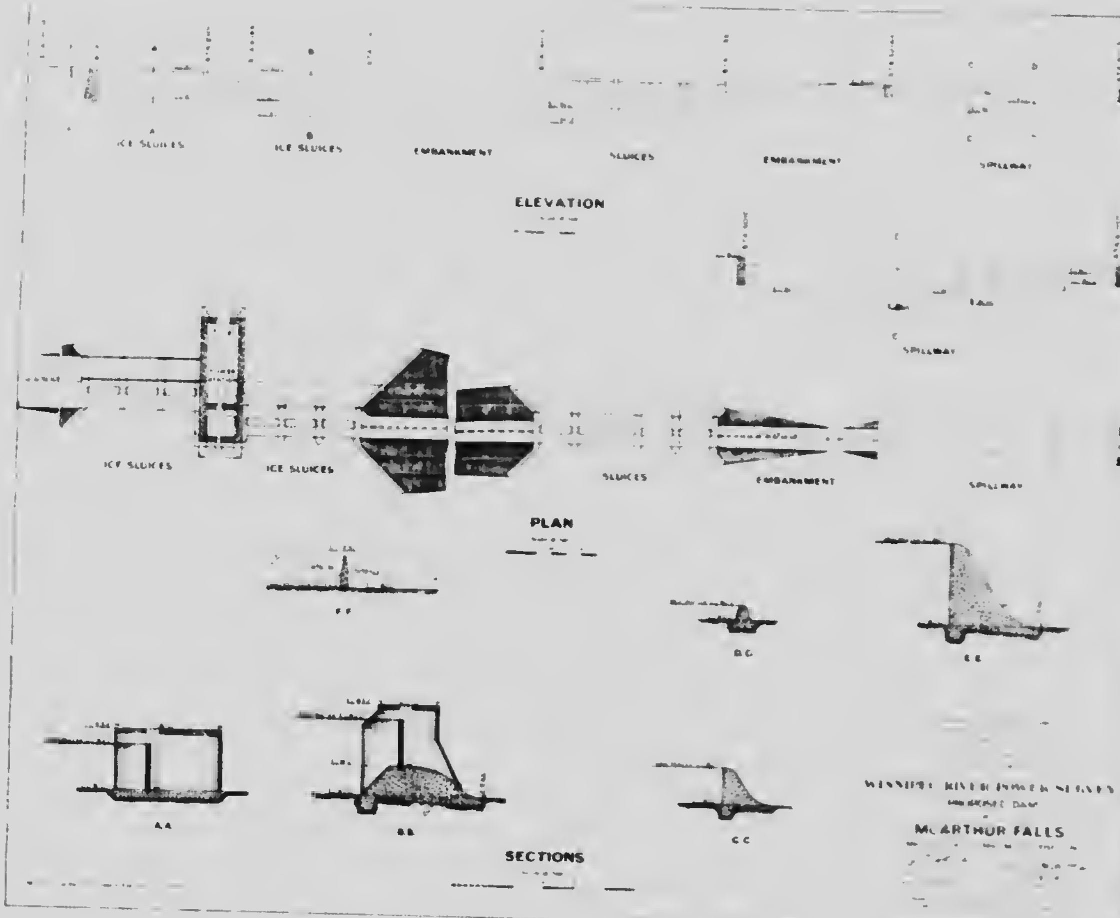

60,000
DOMINION WATER POWER BRANCH

PLATE No 55


ICE SLUICES
ICE SLUICES
EMBANKMENT
SLUICES
EMBANKMENT
SPILLWAY
ELEVATION
SPILLWAY
ICE SLUICES
ICE SLUICES
SLUICES
EMBANKMENT
SPILLWAY
PLAN
SECTIONS
McARTHUR FALLS

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)

1.0 2.8 2.5 3.2 2.2 3.6 2.0 4.0 1.1 1.8 1.25 1.4 1.6

4.5 5.0 5.6 6.3 7.1

WATER POWER BRANCH

directly connected to the left bank of the river by a roadway over the three westerly ice sluices, and along the embankment leading to the high ground. The draught tube seal is at elevation 804, the discharge taking place directly down the river. The narrow channel, a short distance below the power-house is of sufficient capacity to carry the full discharge of the final installation without adverse backwater effects.

The estimates for the power station have been calculated for two stages of development.

(1) *Initial development.*—This consists of the eleven easterly units. The turbine units considered have a capacity of 2,500 horsepower at full gate, and the electrical installation has been selected with the normal full load corresponding to eight-tenth gate opening on the turbines. The initial installation of eleven units gives a sufficient machine capacity to utilize 12,000 second-feet at 18-foot head, with turbines at 85 per cent efficiency and eight-tenth gate, and at the same time leaves one unit as a spare for emergencies.

The output available on the low tension switchboard on a 75 per cent over-all efficiency on a 24-hour basis, is 18,400 horsepower. The estimates for the initial development includes construction of the headworks of the remaining six bays to a sufficient degree to support the stoplogs, leaving the balance of the bays to be added when required.

(2) *Final development.*—This consists of seventeen 2,500-horsepower units, the six additional being added to the west of the first installation. The seventeen units will supply machine capacity for the utilization of 20,000 second-feet at 18-foot head, with the turbines considered at eight-tenth gate. This installation will, under these conditions, provide a spare unit for emergencies. The output at the switchboard at 75 per cent efficiency on a 24-hour basis is 30,700 horsepower.

DISCHARGE CAPACITY.

It is proposed to hold the pond level at elevation 827 at all seasons of the year. The limit of flooding (without embanking) on Lac du Bonnet is elevation 829, this being the level of the muskeg at the westerly end of the lake. It is essential therefore to assure sufficient discharging capacity to meet all possible requirements at regulated level. The twenty-one 20-foot sluices, sills at 812, will provide for the discharge of 81,000 second-feet at pond level of 827. No consideration is here given to the discharge through the power station, which, when in full operation, will be 20,000 second-feet.

In addition to ample sluiceway discharge, it is necessary that there should be an extensive automatic spillway discharge in order that any unexpected rise of the river will be automatically cared for should the sluiceways for any reason be neglected. Spillway to the length of 1,725 feet is provided in the suggested layout, which, with 2 feet over the crest, will discharge 16,000 second-feet. The total discharging capacity with pond at elevation 829, all sluices open and the power station in full operation is 134,000 second-feet.

Exceptional length of spillway is supplied in view of the narrow limits within which the headwaters are to be held. The construction of a dyke connecting the higher contours on the west shore of the lake would allow a further raising of the lake level, and might repay further investigation.

UNWATERING.

Several methods of unwatering might be adopted in the construction of this plant, the selection of which depends on further investigation on the ground, and the exigencies of construction. In the following estimates, ample yardage for cofferdams and provision for pumping has been allowed. No exceptional difficulties are to be anticipated in this connection.

NAVIGATION.

At the McArthur site, provision for lockage facilities, should they become necessary in the future, has been made on the central island (plate 53). There are other feasible locations. The lock depicted is 300 feet by 40 feet, with 15 feet of water on the sills. First-class foundation can be found for all structures.

This lock with approaches, can be constructed at any time in the future without in any way interfering with the operation of the power plant, nor will the provision for it incur any extra expenditure on the present construction of the plant. On the other hand, the present construction of the power installation will not place any obstacles in the way of the future construction or operation of the lock. No portion of the cost of the lock or approaches is included in the estimates for the power development.

ESTIMATES OF COST.

The following estimates of the cost of the initial and final installations place the power on the low tension switchboard in the power station. It is considered that the estimates are amply conservative, and that the assumptions which have been made are fully warranted. As it is wholly improbable that the McArthur development will be undertaken before the construction of the Du Bonnet plant, it has not been considered necessary to estimate on the capital cost of a spur line from the town of Lac du Bonnet to the site. It has been assumed that this spur line has already been constructed to the Du Bonnet plant, and the estimates herewith include only sufficient to construct the necessary connecting siding from this spur line.

Ten per cent has been allowed on the estimates for contingencies, 5 per cent on this total for engineering and inspection, and 5½ per cent on the whole for one year for interest during construction.

The annual operation costs include capital charges, and represent the cost of operation at the power station. They do not include transforming and transmission.

(1) Initial development.—(Eleven 2,500-horse power u

(1) *Capital Cost of Installation.*

Dam and equipment	$ 312,000	
Ice sluices	52,000	
Power station and equipment	581,000	
Hydraulic installation	248,000	
Electrical installation	385,000	
Railroad	12,000	
Permanent quarters	15,000	
Contingencies, 10 per cent	161,000	
Engineering and inspection, 5 per cent	88,000	
Interest during construction, 5½ per cent	102,000	
Allowance for flooding damages	75,000	
Total initial cost		$2,031,000

Twenty-four hour power available at 75 per cent over-all efficiency, 18,400 horse-power.

Capital cost per 24-hour horse-power	$110.38
Capital cost per installed horse-power	73.88

(2) *Annual Cost of Operation.*

Interest, sinking fund, and depreciation charges—		
Interest, 5½ per cent on $2,031,000		$ 112,000
Sinking fund, 4 per cent (40-year bonds)		21,000
Depreciation—		
1 per cent on permanent works	$ 7,000	
4 per cent on machinery, etc	30,000	
		37,000
Operation charges—		
Staff	$ 21,000	
Supplies	8,000	
		29,000
Total annual charge		$ 199,000

Annual cost per horse-power year, 24-hour power	$10.82
Annual cost per horse power year, machinery installed	7.24
Annual cost per kilowatt hour	0·166 cent.
Annual cost per kilowatt hour on basis of 50 per cent load factor	0·332 cent.

(2) Final development.—(Seventeen 2,500-horsepower units.)

(1) *Capital Cost of Installation.*

Dam and equipment	$ 312,000	
Ice sluices and west embankment	52,000	
Power station and equipment	793,000	
Hydraulic installation	393,000	
Electric installation	605,000	
Railroad	12,000	
Permanent quarters	20,000	
Contingencies, 10 per cent	219,000	
Engineering and inspection, 5 per cent	120,000	
Interest during construction, 5½ per cent	139,000	
Allowance for flooding damages	75,000	
Total final cost		$2,740,000

Twenty-four hour power available at 75 per cent over-all efficiency, 30,700 horse-power.

Capital cost per 24-hour horse-power	$89.25
Capital cost per installed horse-power	64.47

(2) *Annual Cost of Operation.*

Interest, sinking fund, and depreciation charges—		
Interest, 5½ per cent on $2,740,000		$ 151,000
Sinking fund, 4 per cent (40-year bonds)		29,000
Depreciation—		
1 per cent on permanent works	$ 9,000	
4 per cent on machinery, etc	44,000	
		53,000
Operation charges—		
Staff	$ 27,000	
Supplies	12,000	
		39,000
Total annual charge		$ 272,000

Annual cost per horse-power year, 24-hour power	$8.86
Annual cost per horse-power year, machinery installed	6.40
Annual cost per kilowatt hour	0·136 cent.
Annual cost per kilowatt hour on basis of 50 per cent load factor	0·272 cent.

SEVEN SISTERS REACH.

About 15 miles above Lac du Bonnet the Winnipeg river is broken into two channels. The western channel, in which are located the Seven Sisters falls, sometimes called the Seven Portages, carries the main portion of the river flow. The eastern or Pinawa channel, under natural conditions carried only a small part of the flow, more especially during the seasons of low water on the river. In connection with the construction of the Winnipeg Electric Railway Company's plant on this channel, diversion weirs were placed across the main and secondary channels for the purpose of diverting sufficient water to properly operate the power station at all seasons.

The discharge of the river over and above what is necessary to so operate the company's plant is available for development throughout the Seven Sisters reach.

Power development on this reach is subject to two governing considerations. The weirs at the head of the reach and the protection of the interests of the Winnipeg Electric Railway Company in respect to the diversion of water must be fully considered in fixing the headwater elevation. The proposed regulated level of Lac du Bonnet will control the tailwater.

The bank contours are not favourable to the development of the entire reach in one concentration. It has been necessary, therefore, to break the drop into two sites called, respectively, the Upper and Lower Seven Sisters.

Lower Seven Sisters Site.

Thirty-seven feet have been incorporated in the lower development, called the Lower Seven Sisters, since it includes the five lowest drops of the falls of that name. The proposed site is located about 1⅓ mile below the junction of the Whitemouth river with the Winnipeg, and is about 19 miles above the McArthur site and 50 miles from Winnipeg.

There are other feasible points along the reach at which this head might be concentrated. About 2½ miles below the site proposed there is a second shallow rapid at which rock outcrop is in evidence on both river banks and at various points in the river-bed, indicating the existence of favourable foundation conditions. The location of the plant here would secure a slightly greater head. On the other hand considerably more land will be flooded, and embankments would be required on the right bank to raise the pond to elevation 870.

The plant might also be placed at the foot of the Seven Sisters falls. Suitable foundation conditions are in evidence here, but a considerably longer dam would be required, and some loss of head would be experienced.

These alternative sites are referred to here, as it is recognized that detailed exploration with a view to construction may disclose more favourable foundation conditions at points other than the one which has been selected. The river-bed conditions, on which the layout discussed and estimated herein is based, have been determined solely by sounding through the ice cover, and while these soundings have given evidence of rock along the line of the layout at a suitable elevation, they cannot be taken as final.

River Bank above Lac du Bonnet.

First Rapid above Lac du Bonnet.

The rock outcrops which are in evidence at so many points both at and in the vicinity of the site selected and at the alternative sites referred to, indicate that conditions as favourable as those which have been assumed (where assumption is necessary) can be readily secured. It is considered therefore, that the estimates herein form a fair basis for studying the cost of developing this section of the river.

SPECIAL CONSIDERATION AT THE LOWER SEVEN SISTERS SITE.

In consequence of the division of the river into two channels *it will not be profitable to undertake the development of the Seven Sisters reach until such time as the river has been regulated,* since during times of low water the major portion of the flow is diverted down the Pinawa channel. For the purpose of present discussion it has been assumed that an average flow of 8,000 second-feet is diverted from the main river into the Pinawa channel. Under the present run-off conditions on the river, with a minimum flow of 12,000 second-feet, this diversion will leave a balance of only 4,000 second-feet for use on the Seven Sisters reach, while under a regulated condition of 20,000 second-feet, there will be left 12,000 available for use. In connection with plants utilizing the flow of the entire river, the estimates have been made for an initial and final development utilizing 12,000 and 20,000 second-feet respectively. On account of the altered conditions at this site, and the shortage of water as compared with the larger plants, it has been considered that estimates covering the complete development only will be sufficient for the purpose of demonstrating the possibilities of the site.

REACH OF THE RIVER DEVELOPED.

The reach of the river developed extends from the site $1\frac{1}{3}$ mile below the mouth of the Whitemouth river, upstream to the foot of the second drop of the Seven Sisters falls, drowning out the entire reach between these limits.

Fifth, sixth, and seventh drops of Seven Sisters [illegible] fifth, sixth, and seventh drops of the Seven Sisters falls take place im[illegible]bove the Whitemouth river, comprising a total drop of 16 feet in a [illegible] about 5,000 feet. The various pitches are irregular and much broken [illegible] of various sizes, these being formed by the projection above the water surface of the underlying granite formation. This formation is also in evidence along both shore lines. The three pitches are not clearly defined, but to a certain extent gradually merge into each other. The banks on either side of the river rise fairly abruptly from 45 to 55 feet above the water surface.

Fourth drop of the Seven Sisters reach.—The total drop at this point is some 9 feet, with a fairly abrupt pitch taking place over a well-defined ridge. A portion of this ridge rises above the water surface, forming a narrow granite island some 400 feet in length, along the line of the pitch. The river banks rise from 25 to 30 feet above the water surface, and the whole site offers exceptional facilities for the location of a hydro-electric development. The contours of the banks do not, however, fit in with the limiting features governing the development of the whole reach.

Whitemouth Falls.

Whitemouth Falls.

Seven Sisters Falls, Fourth Fall.

Seven Sisters Falls, Fourth Fall.

Third drop of the Seven Sisters reach.—This fall totals some 8 feet, and is not well defined. The pitch is broken by numerous and irregular islands formed of the usual outcropping granite. The granite formation is also in evidence on both shores, with the overlying soil rising to a height of about 25 feet above the water surface.

Seven Sisters Falls, Third Fall.

HEAD- AND TAILWATER ELEVATION.

The headwater elevation is governed by the tailwater of the Upper Seven Sisters plant, which has been fixed at elevation 870. A variation of a few feet from this elevation may be advisable when more complete information as to the river-bed is available. Any slight change which may be considered necessary in the final fixing of this elevation will not alter, to any great extent the estim[illegible] which follow hereunder. In times of ordinary low water in the riv[illegible] should be no appreciable hydraulic gradient between the Lower and the [illegible]per Seven Sisters plants. In times of high water the tailwater of the up[illegible] [illegible]nt will undoubtedly be slighlty interfered with. It is to mitigate this inter[illegible] that the regulated level is at present fixed at 870, this being about 3 fe[illegible] than the normal water level above the third pitch. Any such int[illegible] as may occur, during times of high water will not be excessive, [illegible] surplus water which is available for power purposes at such times wil[illegible] than make up the small loss in head.

The proposed tailwater level is governed by the regulated level of Lac [illegible] Bonnet, that is, elevation 827. There is at present, with Lac du Bonne[illegible] normal elevation of 820, an hydraulic gradient of some 11 feet between the lake and the power-house site. The river channel is fairly regular in section throughout this reach but is broken by a slight rapids about 2½ miles below the proposed site. When Lac du Bonnet is raised to its proposed regulated level there will still remain an hydraulic gradient in the reach but, under normal conditions of flow, the present drop will be greatly reduced. In view of this the tailwater of the proposed plant has been conservatively placed at 833, 6 feet above Lac du Bonnet regulated level. A normal head of 37 feet is therefore considered available for development under normal conditions of river flow.

FLOODING.

The banks in the immediate vicinity of the site rise to an elevation somewhat above 875, that is, from 6 to 8 feet above regulated level. As one goes upstream, both banks gradually rise, being at all points fairly abrupt. As a result, the flooding involved in the construction of the plant is unimportant and will be limited to the river channel, no embankments being necessary. The Whitemouth river will be flooded for a distance of 13 miles upstream, but the flooding will be confined by the natural river banks. In no place will raising the headwaters to 870 militate against a natural and satisfactory drainage of the adjoining lands. In all, some 70 acres will be flooded, consisting entirely of the steeply sloping banks in the immediate vicinity of the river.

PONDAGE.

A pond of 1,175 acres extending back to the tailrace of the Upper Seven Sisters plant will be created by the construction of the dam. This acreage will provide excellent pondage facilities for the operation of the plant. A four-hour peak to the full extent of the ultimate proposed installation, 60,000 horsepower will, assuming a continuous discharge of 12,000 second-feet in the reach, only draw 0·9 foot on the pond level. To supplement this there will be at the upper plant a pond area of 8,'70 acres, which, with supervised regulation, can if necessary be made equally available to the lower plant.

ICE CONDITIONS.

It is considered that full protection against all classes of frazil and anchor ice troubles is provided in the layout submitted herewith, and that ample provision is made for the passage of floating surface ice. The plant will draw its water direct from an expansive pond, of which a very large portion immediately above the site, is from 50 to 60 feet in depth. This pond, varying in width from 500 to 3,200 feet, extends from the lower plant to the upper site, drowning out the five lower pitches of the Seven Sisters falls. Under the proposed regulated conditions the present water surface of the lower three pitches will be submerged from 20 to 35 feet. This will entirely do away with the conditions favourable to the production of frazil ice, which now exist at these points. Any such ice as may be formed farther up the river will have ample opportunity for settling in the ice-covered pond before the power station is reached.

The sluices at the lower end of the power-house are well located to draw off all floating ice and drift lodging against the sloping concrete curtain which extends across the face of the entrance piers to the power house. The racks are considered to be amply protected by these measures.

FOUNDATION CONDITIONS

The whole site, so far as could be determined from inspection and sounding through the ice cover, is underlaid with granite formation. This formation is exposed on both river banks, and rises above the water surface in the channel close to the line of the dam. At points where solid rock was not indicated by sounding, the presence of boulders was in evidence. This feature has already been covered in the general introduction and the remarks as to the foundation conditions in this vicinity and at other available sites, should be again noted.

Model of Proposed Lower Seven Sisters Layout.

LAYOUT.

In the layout which has been adopted for the purpose of consideration (plate 57), the power-house has been placed adjacent to the right bank. Leaving the outer end of the power station, the dam curves 67 degrees through the arc of a circle, and is extended as a tangent to the left bank. The line of the dam and power station has been located along the route showing the best evidence of underlying granite.

Ice sluices and roadway.—The power station is connected to the right bank by means of three ice sluices in conjunction with a concrete corewall embankment. This gives access to the floor of the headwork's house. Access to the main generator floor of the power station is secured by means of a steel bridge spanning the channel below the ice sluices. The three 20-foot ice sluices with sills at elevation 855, are ideally located for clearing the forebay of the

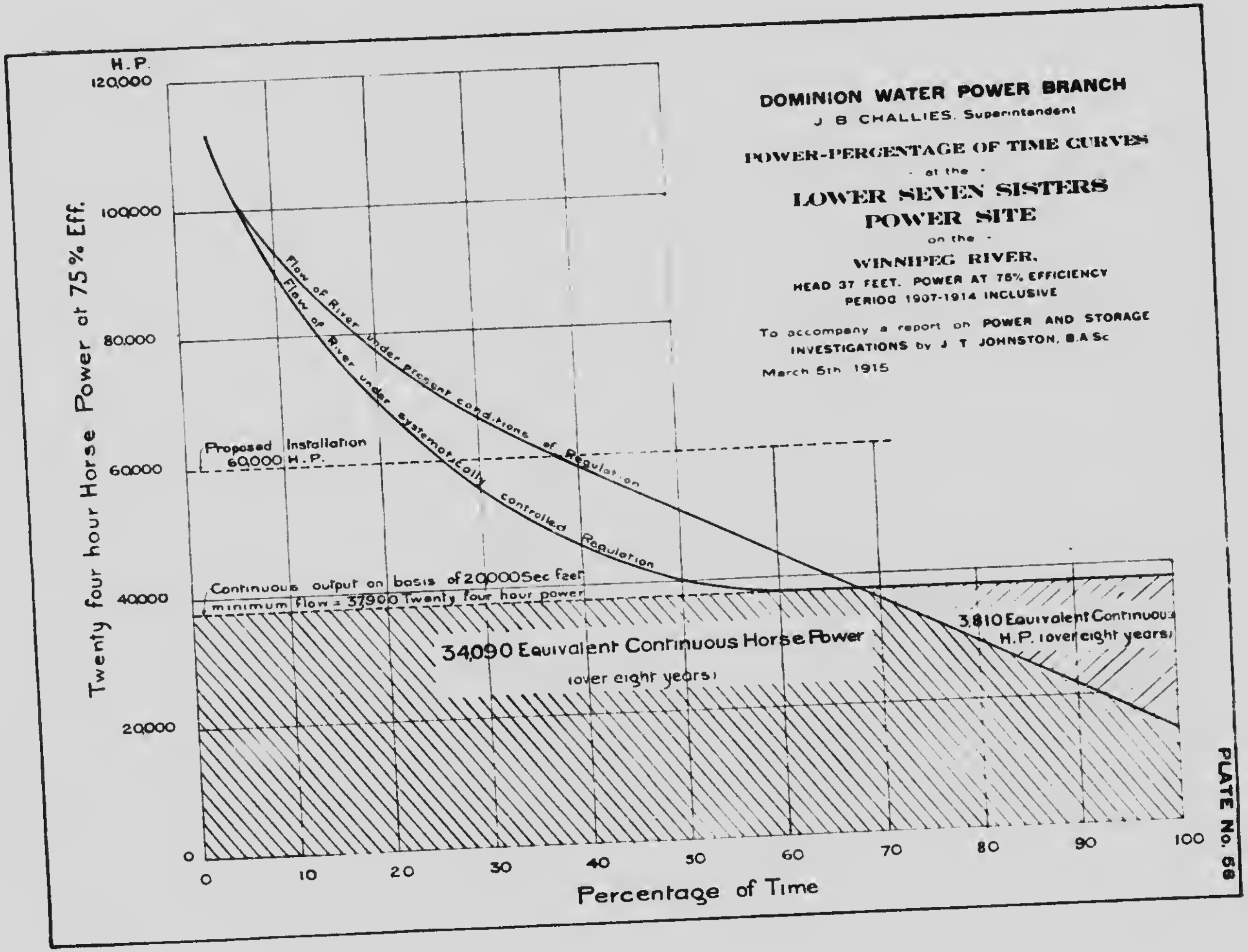


PLATE No. 58
DOMINION WATER POWER BRANCH
J B CHALLIES, Superintendent
POWER-PERCENTAGE OF TIME CURVES
at the
LOWER SEVEN SISTERS
POWER SITE
on the
WINNIPEG RIVER.
HEAD 37 FEET. POWER AT 75% EFFICIENCY
PERIOD 1907-1914 INCLUSIVE
To accompany a report on POWER AND STORAGE
INVESTIGATIONS by J T JOHNSTON, B.A.Sc
March 5th 1915
H.P.
120,000
100,000
80,000
60,000
40,000
20,000
0
Twenty four hour Horse Power at 75% Eff.
Flow of River under present conditions of Regulation
Flow of River under systematically controlled Regulation
Proposed Installation
60,000 H.P.
Continuous output on basis of 20,000 Sec feet
minimum flow = 37,900 Twenty four hour power
34,090 Equivalent Continuous Horse Power
(over eight years)
3,810 Equivalent Continuous
H.P. (over eight years)
0
10
20
30
40
50
60
70
80
90
100
Percentage of Time


W I N N I P
Normal Regulated Tail Water Level 833.
Normal Regulated Water Level 870
Sluiceways
Complete Installation 6 Units
Present Shore Line
Large Boulders
Rock

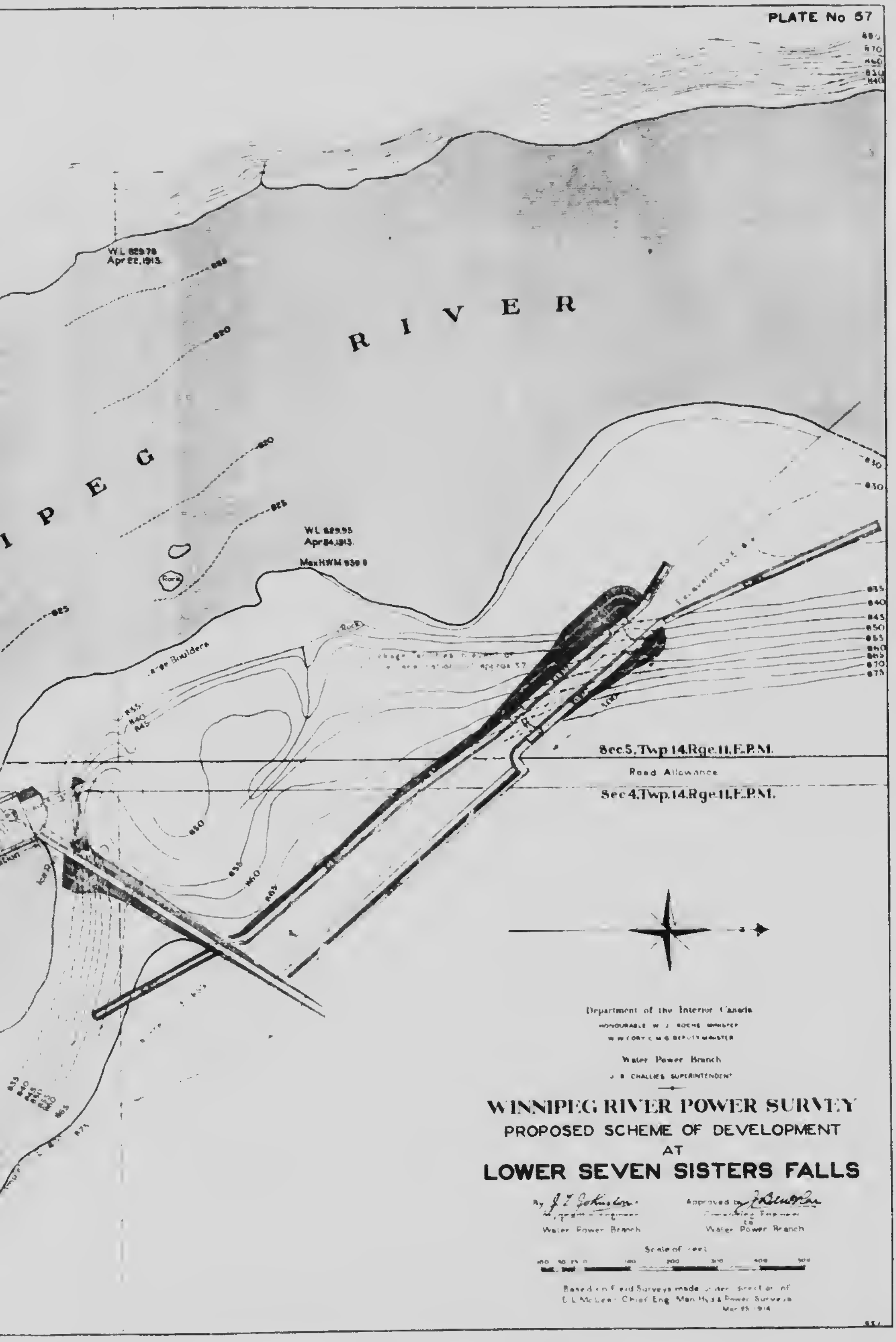


PLATE No 57
W.L. 829.78
Apr 22, 1913.
RIVER
PEG
W.L. 829.95
Apr 24, 1913.
Max H.W.M. 839.8
Rock
Large Boulders
Sec.5, Twp.14, Rge.11, E.P.M.
Road Allowance
Sec.4, Twp.14, Rge.11, E.P.M.
Department of the Interior Canada
Water Power Branch
WINNIPEG RIVER POWER SURVEY
PROPOSED SCHEME OF DEVELOPMENT
AT
LOWER SEVEN SISTERS FALLS
Water Power Branch
Approved by
Water Power Branch
Scale of Feet

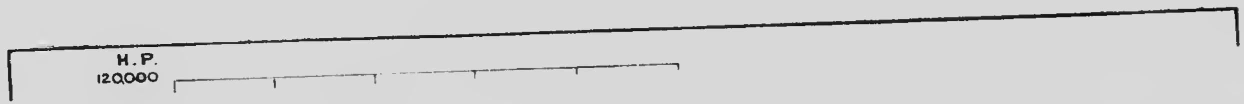

H.P.
120,000

PLATE No. 58

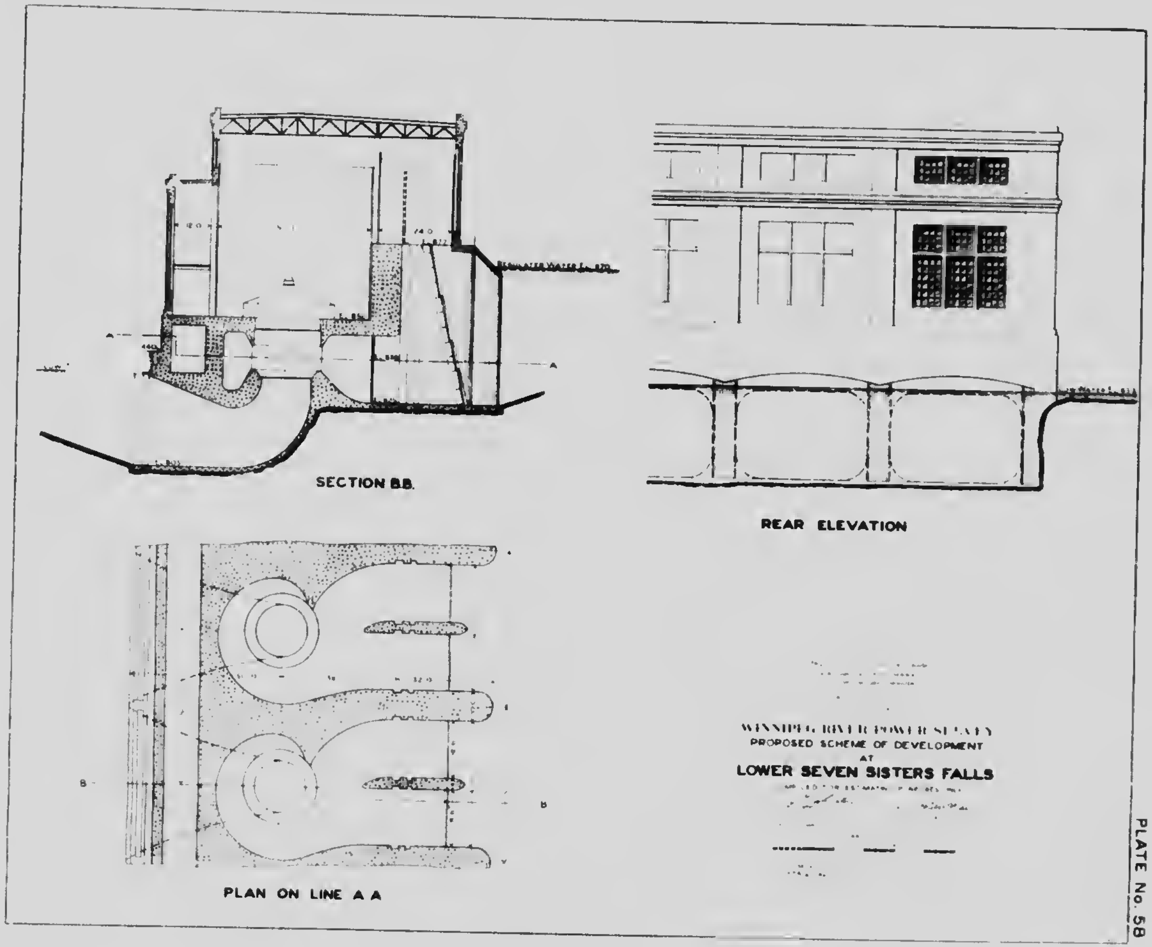
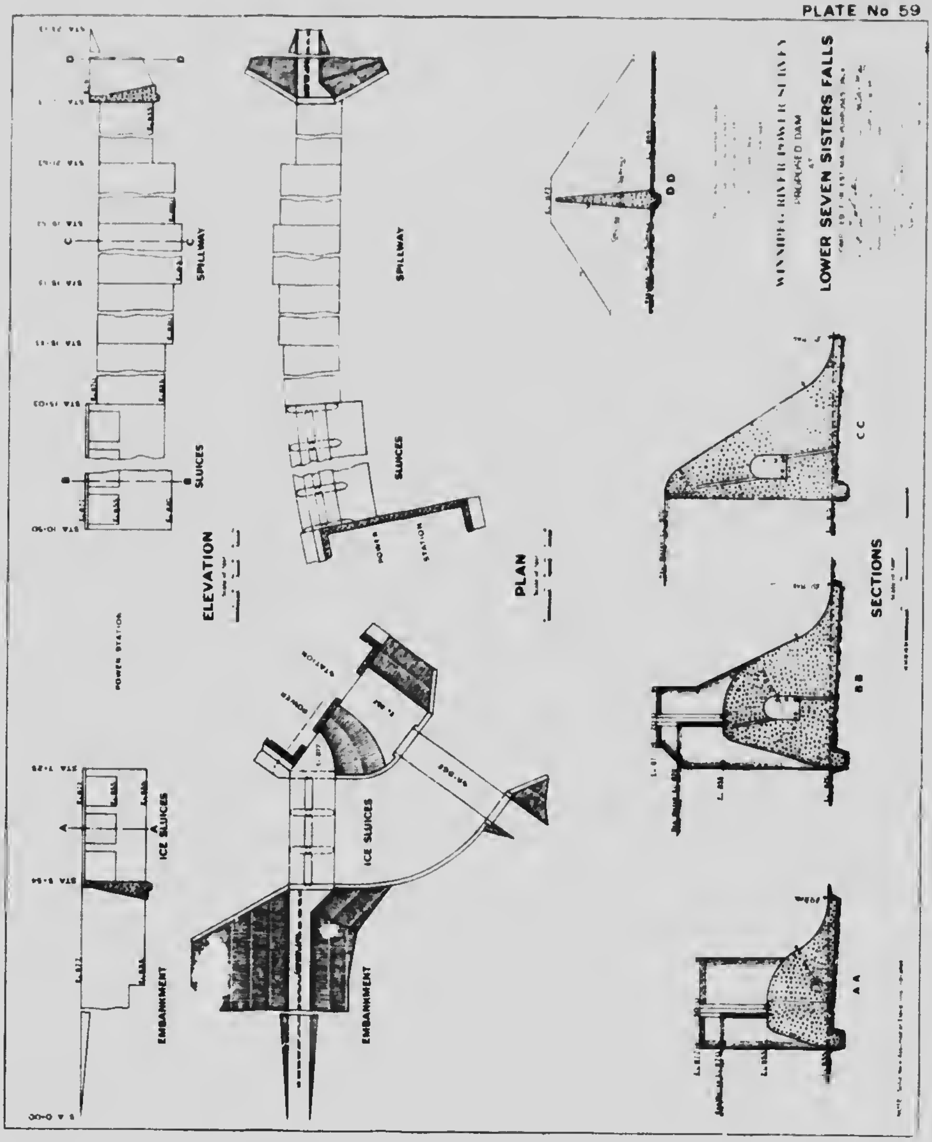

SECTION B.B.
REAR ELEVATION
PLAN ON LINE A A
WINNIPEG RIVER POWER SURVEY
PROPOSED SCHEME OF DEVELOPMENT
AT
LOWER SEVEN SISTERS FALLS

PLATE No 59


WINNIPEG RIVER POWER SURVEY
PROPOSED DAM
AT
LOWER SEVEN SISTERS FALLS
ELEVATION
PLAN
SECTIONS
SPILLWAY
SLUICES
ICE SLUICES
EMBANKMENT
POWER STATION
AA
BB
CC
DD

power station from all floating ice and drift. The discharge through the sluices finds its way into the river below without interfering with the tailwater.

Power station.—The power station (plate 58) is designed to contain six single-runner vertical turbines, each of 10,000 horse-power capacity at full gate. The plan and section have been developed only in sufficient detail to arrive at the size of the water passages necessary to carry the water to and from the turbines at permissible velocities. The electrical and regulating equipment have been assumed for estimating purposes only.

The racks and headworks have been housed, both for ease of operating the stoplogs and racks and for protection during the winter season. The racks are further protected by a sloping concrete curtain, with lower edge 2 feet below regulated level, across the face of the entrance piers. The floor of the headworks house is at elevation 877, or 7 feet above regulated level; the generator floor is at elevation 852. The seal of the draught tube has been placed at 822 and the discharge from the plant takes place across the river. As there is ample river section at this point, there should be no interference between the discharge through the power station and through the sluices of the dam. Should such interference take place, a crib protection for the tailrace could be economically constructed.

(1) Complete development.—This will consist of six 10,000 horse-power units supplying machine capacity for the utilization of 12,000 second-feet at a 37-foot head with turbines considered at eight-tenth gate opening and 85 per cent efficiency. Under these conditions the installation will provide a spare unit for emergencies. The output at the switchboard at 75 per cent efficiency on a 24-hour basis is 37,900 horse-power.

Sluiceway section of dam.—The sluiceways of the dam are, for convenience of manipulation, located on the arc section adjacent to the power station. The sluices are eighteen in number, 20 feet clear between piers, with sills at elevation 855 (plate 59). A motor-driven winch for handling the stoplogs is included in the estimates. The underside of the sluiceway deck has been placed at elevation 875, allowing 5 feet clear above the regulated pond level. Rock has been assumed at elevation 820 and 825 throughout the length of the sluiceway section.

Spillway section of the dam.—The spillway section of the dam connecting the sluiceway section with the left abutment is 700 feet in length with crest at elevation 870. This will provide for such automatic regulation over and above the sluiceway discharge as is necessary to care for sudden rises in the river. The discharge over the spillway will find its way unobstructedly into the river below. Rock has been assumed at elevation 815 and 820 beneath this section.

A fish ladder and log slide are located adjacent to the left abutment. Suitable provision can be made for booming logs to this point of the dam.

DISCHARGE CAPACITY.

The layout submitted will discharge 81,000 second-feet through the ice and sluiceway sections at regulated pond level. The power station itself is designed to utilize 12,000 second-feet at normal load, and although this should not be considered as a permanent source of discharge it forms an additional factor of safety which may be available in an emergency. The Pinawa channel is being considered as drawing an average of 8,000 second-feet from the main river although, in times of high water in the past, this has been increased to above 11,000 second-feet. From the above, the Lower Seven Sisters plant can accomodate a flood of 104,000 second-feet without exceeding the proposed regulated level. This provides for a more extreme flood than the highest recorded water marks along the shore would indicate as having occurred in the past.

Although the above provides for ample discharging capacity, it would not be wise to depend wholly on mechanical or manual operation to care for the fluctuations of the river flow. In order that sudden rises in the stage of the river may be automatically cared for, a 700-foot spillway with crest at elevation 870 is provided. Three feet over this crest, which all the headworks of the plant more than provide for, will discharge 12,000 second-feet. The total discharging capacity at this latter elevation, with all sluices open and the power station in full operation, is 130,000 second-feet, in addition to which there is the discharge down the Pinawa channel.

UNWATERING.

As at the other proposed plants along the river, alternative schemes of unwatering may be adopted in the construction of this plant, the selection of which will depend largely upon the general conditions which arise and which must be met when actual construction operations are commenced. Sufficient cofferdam yardage, together with ample provision for pumping, has been allowed in the estimates for this purpose and no special difficulties are anticipated.

NAVIGATION.

The winding course and swift current in the Pinawa channel in its present state wholly prevents continuous navigation. That being the case, provision is being made in the Seven Sisters reach for the future inclusion of lockage facilities.

At the Lower Seven Sisters site, future lockage facilities can if necessary be installed on the right bank below the power-house (plate 57). A sailing bank built up from the material excavated from the approach to the lock will protect the entrance from the effects of any draw towards the power station. The lock depicted is 300 feet by 40 feet, with 15 feet of water on the sills.

This lock with approaches can be constructed without in any way interfering with the operation of the power plant, nor will the provision for it incur any extra expenditure in the present construction of the plant. On the other hand, the present construction of the power installation will not place any obstacles in the way of the future construction or operation of the lock. No portion of the cost of the lock or approaches is included in the estimates for the power development.

ESTIMATES OF COST.

The following estimate of cost covers only the cost of a complete installation capable of developing 12,000 second-feet. An item for 7 miles of construction railway to connect the left bank of the river with the Canadian Pacific Railway Lac du Bonnet branch is included. A 10-mile spur line from the right bank adjacent to the power station would connect with the Winnipeg municipal tramway.

Ten per cent has been allowed in the estimates for contingencies, 5 per cent on this total for engineering and inspection, and 5½ per cent on the whole for one year for interest during construction.

The annual operation costs include capital charges and represent the cost of operation at the power station. They do not include transforming and transmission.

(1) Complete development.—(Six 10,000 horse-power units.)

(1) *Capital Cost of Installation.*

Dam and equipment	$ 668,000	
Ice sluices	86,000	
Power station and equipment	679,000	
Hydraulic installation	540,000	
Electrical installation	720,000	
Permanent quarters	20,000	
Railroad	84,000	
Contingencies, 10 per cent	280,000	
Engineering and inspection, 5 per cent	154,000	
Interest during construction, 5½ per cent	178,000	
Total cost		$3,409,000

Twenty-four hour power available at 75 per cent over-all efficiency, 37,900 horse-power.

Capital cost per 24-hour horse-power	$89.95
Capital cost per installed horse-power	56.82

(2) *Annual Cost of Operation.*

Interest, sinking fund, and depreciation charges—		
Interest, 5½ per cent on $3,409,000		$ 187,000
Sinking fund, 4 per cent (40-year bonds)		36,000
Depreciation—		
1 per cent on permanent works	$ 13,000	
4 per cent on machinery, etc	55,000	
		68,000
Operation charges—		
Staff	$ 21,000	
Supplies	16,000	
		37,000
Total annual charge		$ 328,000
Annual cost per horse-power year, 24-hour power		$8.65
Annual cost per horse-power year, machinery installed		5.47
Annual cost per kilowatt hour		0·132 cent.
Annual cost per kilowatt hour on basis of 50 per cent load factor		0·264 cent.

Upper Seven Sisters Site.

The upper portion of the Seven Sisters reach of the Winnipeg river has been concentrated at the second drop about 4½ miles above the lower site and about 55 miles from Winnipeg. It has been named the Upper Seven Sisters site. The general conditions governing the development here are the same as at the lower site, the same amount of water being available. The Winnipeg Electric Railway Company's diversion weirs and the tailwater of the Slave falls site about 21 miles upstream are directly affected by the headwaters of this site.

SPECIAL CONSIDERATIONS AT UPPER SEVEN SISTERS SITE.

As a result of the division of the river into two channels, ***it will not be profitable to undertake the development of this reach until such time as the flow of the river has been regulated.*** For the purpose of the present discussion it is assumed, as at the Lower site, that 8,000 second-feet are diverted to the Electric Railway Company's plant, leaving a balance of only 4,000 second-feet for the Seven Sisters reach under the present run-off conditions, and 12,000 second-feet available at such time as the river is regulated to 20,000 second-feet minimum flow. On this account, the estimates have been made only for a final development capable of utilizing 12,000 second-feet.

REACH OF THE RIVER DEVELOPED.

The reach of the river to be developed extends from the second drop of the Seven Sisters falls to the weirs of the Winnipeg Electric Railway Company at the head of the Pinawa channel.

Second drop of the Seven Sisters falls.—The layout discussed herein is located along the crest of the Second drop of the Seven Sisters falls. This drop totals some 9 feet under normal conditions. Bed rock is exposed on both banks and above the water surface towards the centre of the stream.

First drop of Seven Sisters falls.—The total fall at the first drop of the Seven Sisters falls is 9 feet under normal flow conditions and is, to a large extent, concentrated. The usual granite formation is in evidence on both banks and in the river bed.

Winnipeg Electric Railway Company's Weirs.—The necessary diversion of water down the Pinawa channel to the Winnipeg Electric Railway Company's plant is secured by three weirs. (Plate 30.) The main weir consists of 1,379 feet of concrete-capped rock-fill across the main river channel, with crest at elevation 105·5, company's datum, or 897·44 Water Power Survey datum, connected with the river banks on either side by concrete spillways, crest at 897·44. This brings the total length of the main weir up to 1,652 feet. Two secondary weirs, one of timber, length 120 feet, crest at 896·94, the other of concrete, length 535 feet, crest 895·94, complete the system. These weirs operate as free spillways, and the water level above varies with the stage of the river. After the construction of the Upper Seven Sisters plant, the weirs will be submerged.

HEAD- AND TAILWATER ELEVATION.

The headwater elevation of this site must be considered in the light of several important features which are here briefly outlined.

The discharge down the Pinawa channel varies with the elevation of the water above the weirs, but can be completely shut off by the control dam now in position across the head of the channel. The proposed development on the Pinawa channel, discussed hereunder, will call for the maintenance of the intake water level at a point above elevation 900. The headwater elevation of this reach will also directly affect the tailwater of the proposed Slave falls development.

Seven Sisters Falls, Second Fall.

Seven Sisters Falls, Second Fall.

Seven Sisters Falls, First Fall.

Seven Sisters Falls, First Fall.

At the present time the data on hand covering the various vital features outlined above is not sufficiently complete to permit a detailed analysis of the effects and results of the diverse conditions which must be considered. For the present the headwater elevation of the Upper Seven Sisters has been assumed at elevation 899. This forms a fair basis upon which the site can be investigated, and will result in a somewhat higher elevation above the weirs. The field data necessary to accurately determine the effect of various headwater levels on the conflicting interests affected, are being secured, and will be available before this reach is developed.

The tailwater is controlled by the regulated pond level of the Lower Seven Sisters reach, giving a normal head of 27 feet.

FLOODING.

The banks of the river in the vicinity of the site rise abruptly to elevation 898. At this elevation the ground surface becomes approximately level, rising slowly as one goes upstream until, at a point about 2¼ miles up the river, contour 905 is reached, and about 1 mile farther contour 910 is found on both banks of the river.

Regulated level 899, without embankment, will result in a certain amount of flooding immediately above the plant. At the same time, the possibility of excessive floods or abnormal conditions raising the water above regulated level must also be guarded against. For this reason, the estimates cover the cost of an embankment with top at elevation 906 extending from the plant upstream to the high ground on both banks of the river. The material necessary for the construction of these embankments can be excavated in such a manner as to form a ditch for the drainage of the low land to the rear. At regulated water level the embankment will only have to withstand a three foot head at its heaviest portion. As this levee will follow closely the river bank, little or no flooding will result.

PONDAGE.

A pond of 2,600 acres will be created between the dam and the Electric Railway Company's weirs, and an additional 5,870 acres will be indirectly available above the same. The latter pondage also supplies the Winnipeg Electric Railway Company's plant on the Pinawa channel.

The utilization of this pondage for peak loads requires careful oversight. As pointed out above, the headwater level will at times be subject to a variety of possibly conflicting influences.

It is essential, therefore, that the control of the headwaters of the Upper Seven Sisters be kept in the hands of some independent body, such as the Dominion Government, in order that all interests affected may be fully protected and that the river may be regulated for the benefit of all concerned.

REMOVAL OF THE WEIRS.

After the Upper Seven Sisters power plant is placed in operation, the diversion weirs will no longer be necessary. Their removal in whole or in part will then be beneficial to the power situation, as it will place the headwater of the site in direct control of the pond level above the Pinawa channel, and will prevent the loss of head which must be anticipated during the high stages of the river with the weirs in place as at present. The pondage area above the weirs will also be directly available and readily controllable for use, both at the Upper Seven Sisters and the Upper Pinawa site.

The removal of the entire weir would be expensive, but a portion sufficient to counteract the anticipated submerged action in times of normal water and to reduce it in times of flood, could be removed at comparatively small expense.

It would be a decided advantage to the Winnipeg Electric Railway Company to have the present non-regulating weir, replaced by a regulated and permanent concrete dam. Such a structure would control at all stages the water level above the present intake to the Pinawa channel and would do away with the expensive repairs and renewals which will probably be required in the future on the present weir. It will also make feasible the development of an additional power site on the upper portion of the Pinawa channel.

ICE CONDITIONS.

The Upper Seven Sisters power station draws its water direct from a pond varying from 500 feet to a mile in widt nd extending upstream to the diversion weirs of the Street Railway plant, covering a surface area of some 2,600 acres, and drowning out all intervening falls and rapids. All disturbed points in this stretch of the river which under natural conditions have a tendency to form frazil ice are thus completely submerged and the whole pond will act in winter as an ice covered settling basin for such frazil ice as may be formed.

The sluices at either end of the power-house will serve to draw off all floating ice and drift, while the sloping concrete curtain with bottom elevation 3 feet below regulated pond level, extending across the face of the entrance piers to the power-house, will prevent the drawing of such material against the racks.

FOUNDATION CONDITIONS.

The whole site is underlaid with granite formation, exposed on the surface on both banks of the river and projecting above the water in the form of islands at different points along the line of the dam. The general formation indicates the presence of this granite, probably without any overlying material, in all portions of the river bed covered by the line of the dam and power station.

LAYOUT.

In the layout (plate 61) which has been considered herein, the power station is placed adjacent to the right bank and forms, with the iceways and sluiceways, a straight line running approximately north and south. At the south end of the sluices, the line of the dam turns to the southeast through an angle of 40 degrees in order to follow the high rock, and forms the spillway section. Long earth embankments parallel both banks of the river up stream from the site, until high ground is reached.

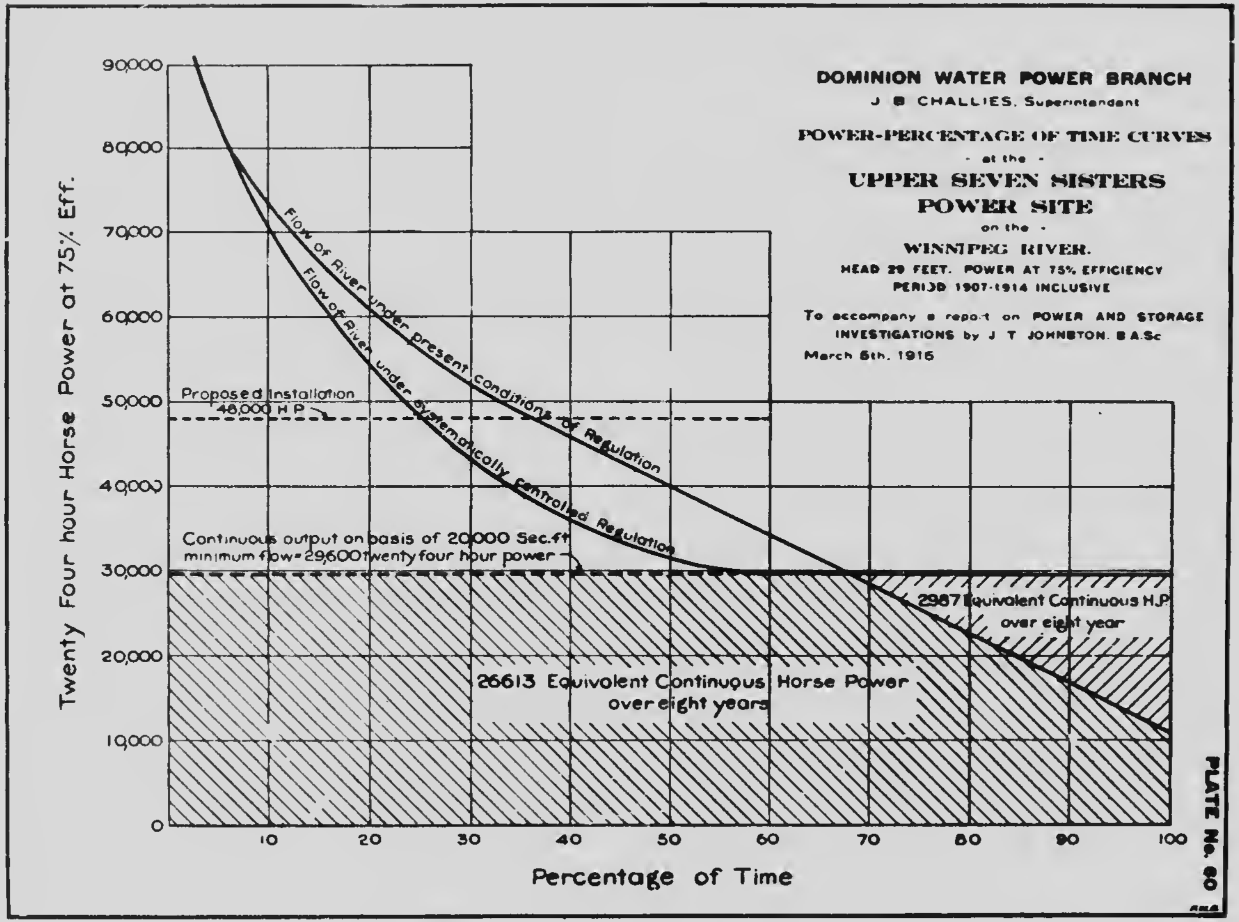
Spillway section of dam.—The spillway section of the dam has been extended out over the river bank giving a total length of 600 feet with crest at elevation 899 (plate 63). Rock has been assumed at elevation 885 throughout this extension, such assumption being fully warranted by the outcrop along the shore. The spillway could be further lengthened at comparatively small cost should it be considered desirable. The discharge will find its way into the river below without obstruction.

A fish ladder and log slide are located at the junction between the spillway and the sluiceways, and are accessible by means of the platform over the latter. Suitable provision can be made for booming logs to this point of the dam.

Model of Proposed Upper Seven Sisters Plant.

Sluiceway section of dam.—The sluiceway section of the dam consists of seventeen 20-foot sluices with sills at elevation 884, and is located adjacent to the power station for convenience in regulation. A motor-driven winch for handling the stoplogs is included in the estimates. The underside of the sluiceway deck has been placed at elevation 904·5, allowing 5·5 feet clear above the regulated pond level. Rock has been assumed at elevation 968 to 975 throughout the length of the sluiceway section.

Power station.—The power station (plate 62) is designed to contain eight single-runner vertical turbines of 6,000 horse-power capacity at full gate. The section has only been developed in sufficient detail to arrive at the size of the water passages necessary to carry the water to and from the turbines at permissible velocity. The electrical and regulating equipment have been assumed for estimating purposes only.



DOMINION WATER POWER BRANCH
J B CHALLIES, Superintendent
POWER-PERCENTAGE OF TIME CURVES
- at the -
UPPER SEVEN SISTERS
POWER SITE
- on the -
WINNIPEG RIVER.
HEAD 29 FEET. POWER AT 75% EFFICIENCY
PERIOD 1907-1914 INCLUSIVE
To accompany a report on POWER AND STORAGE INVESTIGATIONS by J T JOHNSTON, B.A.Sc
March 6th, 1916
Flow of River under present conditions of Regulation
Flow of River under systematically controlled Regulation
Proposed Installation 48,000 H.P.
Continuous output on basis of 20,000 Sec.ft minimum flow=29,600 twenty four hour power
2987 Equivalent Continuous H.P. over eight year
26613 Equivalent Continuous Horse Power over eight years
Twenty Four hour Horse Power at 75% Eff.
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
10
20
30
40
50
60
70
80
90
100
Percentage of Time
PLATE No. 60


Percentage of Time

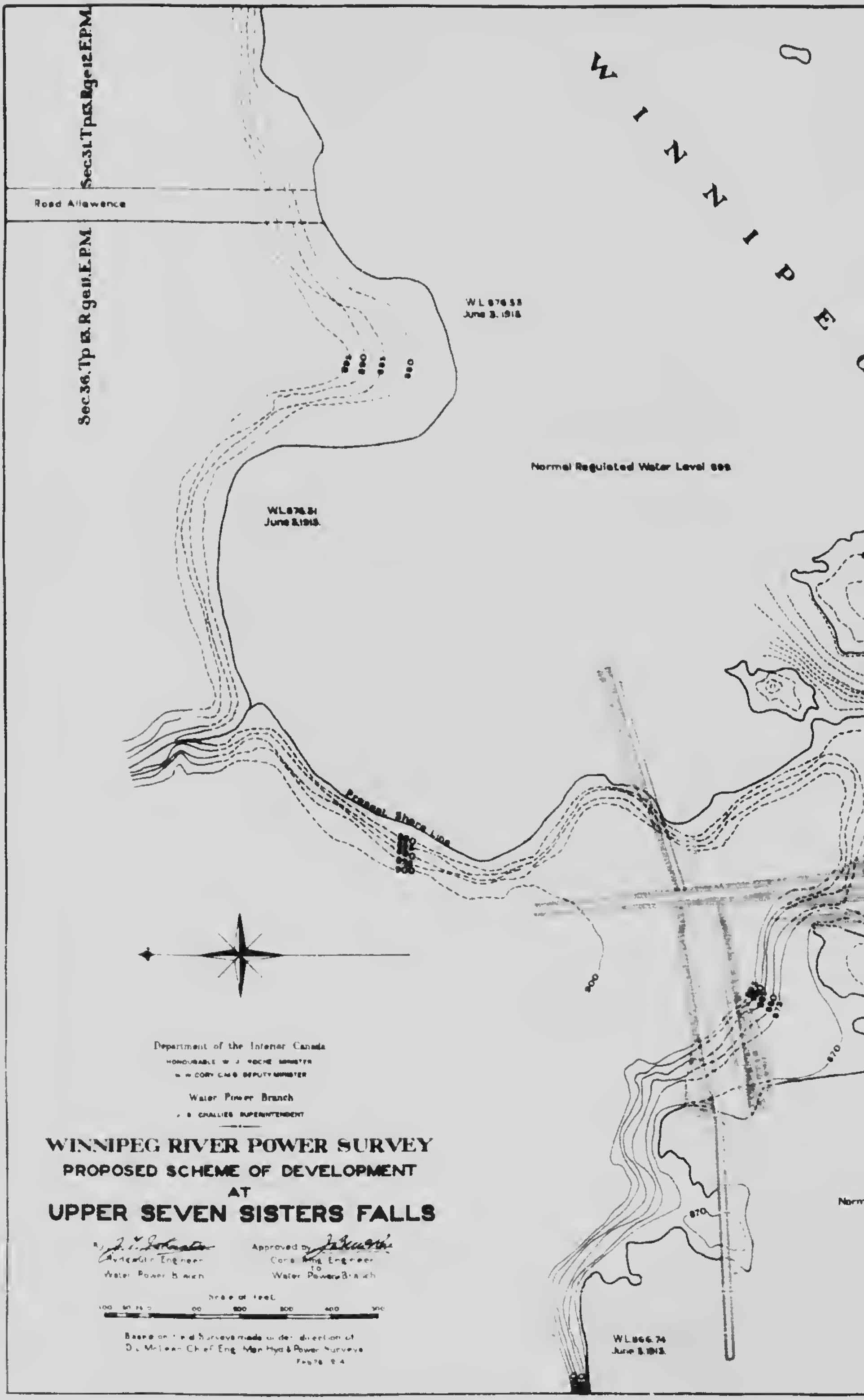
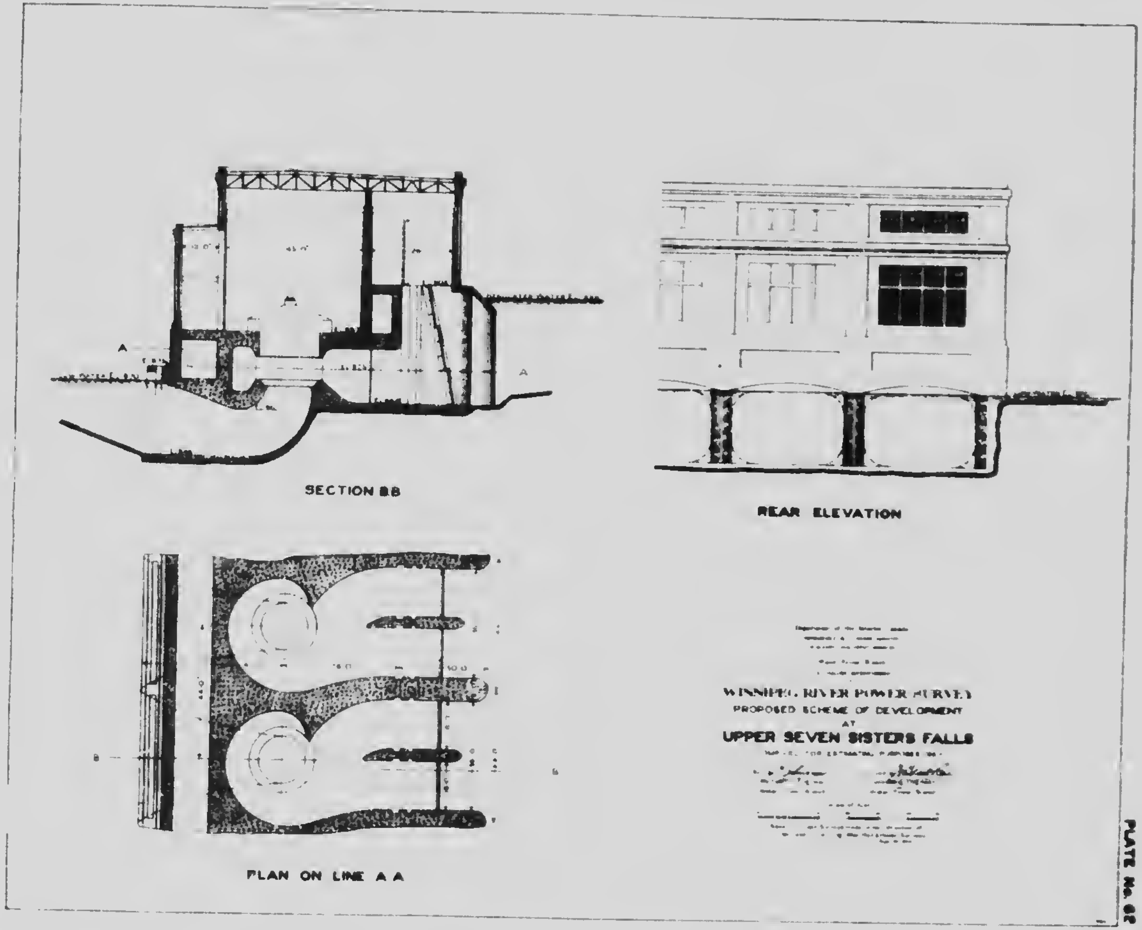
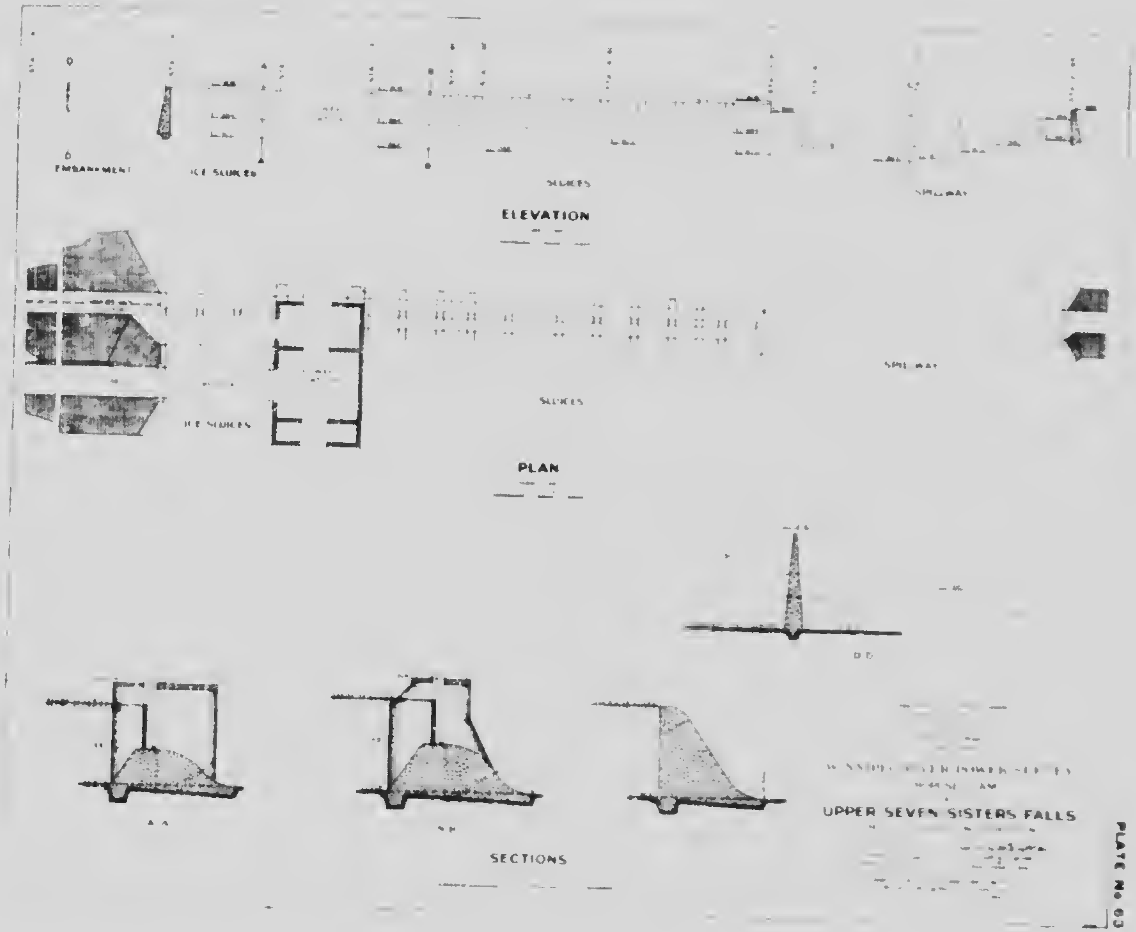

WINNIPEG
Sec.31.Tp13.Rge12.E.P.M.
Road Allowance
Sec.36.Tp13.Rge11.E.P.M.
Normal Regulated Water Level
Present Shore Line
Department of the Interior Canada
Water Power Branch
WINNIPEG RIVER POWER SURVEY
PROPOSED SCHEME OF DEVELOPMENT
AT
UPPER SEVEN SISTERS FALLS
Approved by
Scale of feet


PLATE No. 61
Road Allowance
P
E
G
R
I
V
E
R
W.L. 876.1
June 19, 1915.
Rock
Rock
Rock
Rock
Rock
Rock
Rock
Normal Regulated Tail Water Level 870

PLATE No. 62


SECTION B.B
REAR ELEVATION
PLAN ON LINE A A
WINNIPEG RIVER POWER SURVEY
PROPOSED SCHEME OF DEVELOPMENT
AT
UPPER SEVEN SISTERS FALLS


EMBANKMENT
ICE SLUICES
SLUICES
SPILLWAY
ELEVATION
ICE SLUICES
SLUICES
SPILLWAY
PLAN
SECTIONS
UPPER SEVEN SISTERS FALLS
PLATE No 63

The racks and headworks have been housed in. A sloping concrete curtain around the face of the entrance piers forms a protection against floating ice and drift. The floor of the headworks house is at elevation 903, 4 feet above regulated level, while the generator floor is at elevation 887. The seal of the draught tube has been placed at elevation 861, and the discharge from the plant takes place directly down the river.

(1) *Complete development.*—This consists of eight 6,000 horse-power units, supplying machine capacity for the utilization of 12,000 second-feet at a 29-foot head with turbines considered at eight-tenth gate opening and 85 per cent efficiency. Under these conditions, this installation will provide a spare unit for emergencies. The output at the switchboard at 75 per cent efficiency on a 24-hour basis is 29,600 horse-power.

Ice sluices and roadway.—The power station is connected with the right bank by means of the ice sluiceway deck from the headworks house, and by means of a steel bridge from the generator floor. The three 20-foot ice sluices, with sills at elevation 884, will assist in clearing the forebay of floating ice and drift, and the discharge through the same will be carried under the bridge to the river below. The bridge forms a continuation of the roadway whereby direct access may be had to the generator floor.

Embankments. The estimates include provision for the construction of two embankments, one on either side of the river. These have been referred to in the section on flooding.

DISCHARGE CAPACITY.

The layout submitted will discharge 77,000 second-feet through the ice- and sluiceway sections at regulated level. The power station itself is designed to utilize 12,000 second-feet at normal load, and although this should not be considered as a permanent source of discharge, it forms, nevertheless, an additional source of safety which may be available in an emergency. The Pinawa channel is being considered in this report as drawing an average of 8,000 second-feet from the main river, although in times of high water this has been increased to about 11,000 second-feet. The Upper Seven Sisters layout can accommodate a flood of 100,000 second-feet in the river, without exceeding the proposed regulated level.

Although the above provides for ample discharging capacity, it is not advisable to depend wholly on mechanical or manual operation to care for the fluctuation of the river flow. A 600-foot spillway with crest at elevation 899 is provided in order that sudden rises in the stage of the river may be automatically cared for at such times as, for any reason, the sluice control may be neglected. Three feet over this crest, which all the headworks of the plant more than provide for, will discharge 10,000 second-feet. The total discharging capacity at this elevation, with all sluices open and the power station in full operation, is 126,000 second-feet in addition to the discharge down the Pinawa channel.

UNWATERING.

As at other plants along the river, alternative schemes of unwatering may be adopted in the construction of this plant, the selection of which will depend largely upon the general conditions which arise and which must be met when actual construction operations are commenced. Sufficient cofferdam yardage, together with ample provision for pumping, has been allowed in the estimates for this purpose and no special difficulties are anticipated.

NAVIGATION.

The headwaters of this plant will be regulated to the highest permissible limit, keeping in view the effect of the same on the various interests involved. So long as the Winnipeg Electric Railway Company's weirs remain in place, it will be impossible to completely drown out the drop now taking place over the same except perhaps in times of extreme low water. The drop will vary with the stage of the river and with the consequent regulation necessary to protect the tailwater of the Slave falls plant and the discharge down the Pinawa channel. To secure navigation past this point will possibly necessitate the construction of a low-lift lock. On the other hand, the construction of the Upper Seven Sisters plant will render the diversion weirs of the Street Railway Company unnecessary, and the removal of a sufficient section to permit the passage of traffic will be less expensive than lock construction.

At the power site, lockage facilities can be provided on the north bank of the river at any time after the plant is constructed. The lock depicted on the accompanying plan (plate 61) is 300 feet by 40 feet, with 15 feet of water on the sills.

This lock with approaches can be constructed without in any way interfering with the operation of the power plant, nor will the provision for it incur any extra expenditure in the present construction of the plant, while the present construction of the power installation will not place any obstacles in the way of the future construction or operation of the lock. No portion of the cost of the lock or approaches is included in the estimates for the power development.

ESTIMATES OF COST.

The following estimate of cost covers the capital cost of a complete installation capable of developing a flow of 12,000 second-feet. An item for 12 miles of railway is included. This spur line may be run from the city of Winnipeg municipal tramway on the right bank, or from the main line of the Canadian Pacific railway to the south of the river, the distance being about the same in each case.

Ten per cent has been allowed in the estimates for contingencies, 5 per cent on this total for engineering and inspection, and 5½ per cent on the whole for one year for interest during construction.

The annual operation costs include capital charges and represent the cost of operation at the power station. They do not include transforming and transmission.

(1) Complete development.—(Eight 6,000 horse-power units.)

(1) Capital Cost of Installation.

Dam and equipment		$ 364,000
Ice sluices		66,000
Power station and equipment		585,000
Hydraulic installation		432,000
Electrical installation		624,000
Permanent quarters		20,000
Railroad		114,000
Contingencies, 10 per cent		224,000
Engineering and inspection, 5 per cent		123,000
Interest during construction, 5½ per cent		112,000
Total cost		$2,721,000

Twenty-four hour power available at 75 per cent over-all efficiency, 29,600 horse power.

Capital cost per 24 hour horse-power	92.03
Capital cost per installed horse-power	56.75

(2) Annual Cost of Operation.

Interest, sinking fund, and depreciation charges—		
Interest, 5½ per cent on $2,724,000		$ 150,000
Sinking fund, 4 per cent (40 year bonds)		29,000
Depreciation—		
1 per cent permanent works	$ 10,000	
4 per cent machinery, etc	46,000	
		56,000
Operation charges—		
Staff	$ 20,000	
Supplies	13,000	
		33,000
Total annual charge		$ 268,000
Annual cost per horse-power year, 24-hour power		$9.05
Annual cost per horse-power year, machinery installed		5.58
Annual cost per kilowatt hour		0.138 cent
Annual cost per kilowatt hour on basis of 50 per cent load factor		0·276 cent

Upper Pinawa Site.

The contemplated power scheme for the river will, through the replacement of the present non-regulating diversion weirs of the Winnipeg Electric Railway Company by a permanent and controlled dam at the Upper Seven Sisters site, render an additional power site available on the Pinawa channel (plate 54). This new site is located at what is known as the First Rock cut, about 3 miles above the existing power plant. The rock cut was excavated in the widening and deepening operations along the upper portion of the Pinawa channel in connection with the power station below. The physical features of the location lend themselves admirably to the construction of a very attractive power project.

SPECIAL CONSIDERATIONS AT UPPER PINAWA SITE.

The preceding discussion of the power possibilities of the Upper and Lower Seven Sisters sites, has considered an average discharge of 8,000 cubic feet per second down the Pinawa channel to the power station of the Winnipeg Electric Railway Company. This average flow is available also at the Upper Pinawa site under present discharge conditions on the river, and is not dependent on the further control of the river basin run-off.

In consequence of the necessity of maintaining the intake headwater above elevation 900, the development of the new site is scarcely feasible prior to the construction of the Upper Seven Sisters dam, or at least until the present diversion weirs have been either replaced or reconstructed.

First Rock Cut on Pinawa Channel, Site of Proposed Plant.

REACH OF THE RIVER DEVELOPED.

The reach of the Pinawa channel developed by this concentration extends from the first rock cut to the headwaters at the channel intake. The water level at the rock cut will be raised some 18 feet, and the entire lower section of the reach flooded. The control dam of the Electric Railway Company, about 2¾ miles above the site, and elsewhere described, will be flooded to deck level. Inexpensive alterations will permit its continued use as a complete control over the Pinawa flow.

Pinawa Channel, First Rock Cut.

HEAD- AND TAILWATER ELEVATIONS.

The tailwater elevation is controlled by the pond level of the plant below, the free spillway crest of which is at elevation 879·4. The normal tailwater elevation is 881·5.

The headwater elevation is dependent on the elevation to be maintained above the channel intake, and also to some extent on the volume of water taken down the channel.

The crest elevation considered in connection with the Upper Seven Sisters concentration is 899. This elevation is provisional and subject to slight revision upon the completion of river stage records now being secured. It will involve a somewhat higher water level above the diversion weirs, of extent dependent on the river discharge. No difficulty should be experienced in slightly raising this regulated level, should the same be desirable in the interests of the Upper Pinawa site.

The construction of the Upper Seven Sisters dam will convert Loon river into a feeder to the Pinawa, and the increased channel cross-section resulting will practically do away with the hydraulic gradient from the present intake to the control dam. From the control dam to the proposed power site, a discharge of 8,000 cubic feet per second can be secured with a grade drop of about 1 foot.

The crest level of the Upper Pinawa site has been provisionally placed at 899·5, giving a head of 18 feet. This can be considered as an average head available for development.

FLOODING.

The bank contours immediately above the site call for the construction of retaining embankments.

These will prevent any extensive flooding directly above the plant, while above the channel intake, flooding conditions will be practically the same as those now resulting from the diversion weirs. About 425 acres will be flooded between the site and the control dam.

PONDAGE.

The pondage above the Upper Seven Sisters site, inclusive of that above the diversion dam, is 8,470 acres. To this will be added 780 acres between the control dam and the proposed Upper Pinawa site, making a total of 9,250 acres. This pondage under a proper control can be made directly available to the proposed plants at the Upper Seven Sisters and the Upper Pinawa sites, and to the existing power station of the Winnipeg Electric Railway Company. Careful regulation is essential here, and can only be properly exercised through impartial central control.

ICE CONDITIONS.

The ice conditions which are encountered along this channel are elsewhere described. The development of the Upper Pinawa site will greatly better the present conditions during the winter season, although it is questionable whether ice troubles will be entirely done away with. Long stretches of disturbed water will be entirely flooded out, while the current in the balance of the reach will be quieted and reduced. Winter operating conditions for the Winnipeg Electric Railway Company's plant will be greatly improved.

FOUNDATION CONDITIONS.

The entire site of the power station and the dam shows exposed bedrock, providing foundation conditions which could not be bettered. Exploration is required along the route of the embankments but in view of the low heads to be withstood, no difficulty is anticipated in connection with their construction.

LAYOUT.

In the layout (plate 65) which has been considered herein, the power station has been placed at the foot of the rock cut. The station is connected with the high ground on the right by a combined sluice and free spillway concrete dam.

Power station.—The power station (plate 66) is designed to contain four single-runner vertical turbines of 4,500 horse-power capacity at full gate. The section has been developed for estimating purposes only. The power house floor is placed at elevation 893·5, the centre line of the turbines at 882·0, and the water seal of the draught tube at 874. The discharge takes place directly downstream. The station as a whole has been standardized along the lines of the other stations estimated on in this report. The output at 75 per cent efficiency on a 24-hour basis is 12,300 horse-power.

Dam.—Four 20-foot sluiceways with sills at elevation 884·5 have been placed to the east of and adjacent to the power station. The under side of the sluiceway deck is placed at elevation 904·5, allowing 5 feet free discharge above regulated level. The free spillway, 750 feet in length, spans the low-lying shore on the right bank. Bedrock is exposed on the surface throughout the length covered by the dam.

Upper Pinawa Power Site, Line of Proposed Dam.

Embankments.—Embankments are required on both river banks. They have been designed with a 15-foot top at elevation 906, and with 2 : 1 slopes. Detail exploration is required as to the most profitable route to be followed, but little difficulty should be encountered in finding a favourable location. About 8,000 feet of embankment is required, of which only about 1,000 feet will be called upon to withstand a greater head than 5 feet, while about 4,000 feet will merely act as a protection against flooding above regulated level. The greatest head to be withstood at regulated level is about 8 feet.

DISCHARGE CAPACITY.

At crest level the sluices will have a discharging capacity of 15,000 cubic feet per second, a much greater flow than has as yet been recorded down the

Pinawa channel. Seven hundred and fifty feet of free spillway will provide for automatic regulation. The headworks will withstand a five-foot rise above crest level.

UNWATERING.

The physical characteristics of the site simplify the unwatering problems. The estimates hereunder include sufficient cofferdam yardage and pumping allowance to cover the anticipated cost.

NAVIGATION.

Navigation interests have been provided for on the main river channel, *i.e.*, along the Seven Sisters reach. In both the Upper and Lower Seven Sisters layouts, lockage facilities can be included at any time in the future. In consequence of this there is no necessity for lockage provision along the Pinawa channel, and none is made at the site under discussion.

ESTIMATES OF COST.

The estimate of cost hereunder follows the standarized estimates of the other sites investigated. Eight miles of railway are included, covering a spur from the city tramway line.

Ten per cent has been allowed for contingencies, 5 per cent of this total for engineering and inspection, and 5½ per cent on the whole for one year for interest during construction.

The annual operation costs include capital charges and represent the cost of operation at the power station. They do not include transforming and transmission.

Complete Development—Four 4,500 horse-power units.

(1) *Capital Cost of Installation.*

Dam and equipment	$ 84,000	
Ice sluices	25,000	
Power station and equipment	385,000	
Hydraulic installation	180,000	
Electrical installation	270,000	
Railroad (8 miles)	96,000	
Permanent quarters	10,000	
Contingencies, 10 per cent	105,000	
Engineering and inspection, 5 per cent	58,000	
Interest during construction, 5½ per cent	67,000	
Total cost		$1,280,000

Twenty-four hour power available at 75 per cent over-all efficiency, 12,300 horse-power.

Capital cost per 24-hour horse-power	$104.07
Capital cost per installed horse-power	71.11

(2) *Annual cost of Operation.*

Interest, sinking fund, and depreciation charges—		
Interest 5½ per cent on $1,280,000		$70,000
Sinking fund, 4 per cent (40 year bonds)		13,000
Depreciation—		
1 per cent on permanent works	$ 4,000	
4 per cent on machinery, etc	20,000	
		24,000
Operating charges—		
Staff	$ 16,000	
Supplies	5,000	
		21,000
Total annual charge		$ 128,000
Annual cost per horse-power year, 24-hour power		$10.40
Annual cost per horse-power year, machinery installed		7.11
Annual cost per kilowatt hour		0·159 cent.
Annual cost per kilowatt hour, on basis of 50 per cent load factor		0·318 cent.


UPPER PINAWA SITE
PINAWA
W.L. 882.3
July 1,1914
Gauge A
CHANNEL
Proposed Water Level 899.5
Gauge C
W.L. 887.0
July 1,1914
CONTROL DAM
WEIR
W.L. 888.4
July 5,1913
Department of the Interior, Canada.
HONOURABLE W. J. ROCHE, Minister
W. W. CORY, C.M.G., Deputy Minister
Dominion Water Power Branch.
J. B. Challies, Superintendent
Winnipeg River Power Survey.
GENERAL LAYOUT AT
HEAD OF PINAWA CHANNEL
SHOWING EXISTING DAMS AND WEIRS
OF WINNIPEG ELECTRIC RAILWAY CO.
To accompany a report on POWER AND STORAGE INVESTIGATIONS
by J. T. JOHNSTON, B.A.Sc.
Scale of Feet.
1000 0 1000 2000 3000 4000 5000
May, 1915.
J. T. Johnston
Hyd Engineer W.P.B.
Consulting Engineer

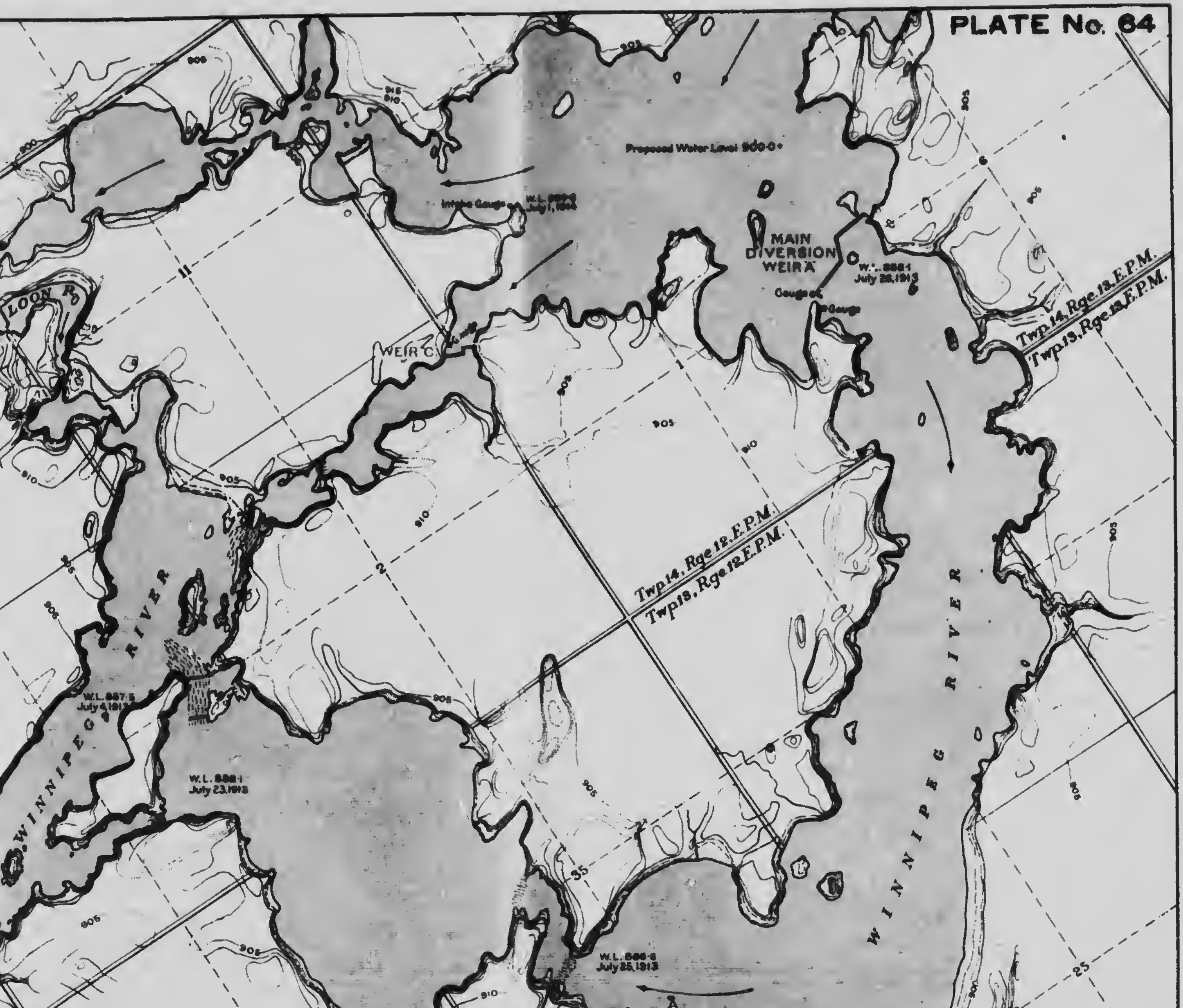


PLATE No. 64
Proposed Water Level 900·0+
Intake Gauge
MAIN
DIVERSION
WEIR A
July 28, 1913
Gauge
WEIR C
LOON
Twp.14, Rge.12, E.P.M.
Twp.13, Rge.12, E.P.M.
WINNIPEG RIVER
W.L. 887·5
July 4, 1913
W.L. 888·1
July 23, 1913
W.L. 888·6
July 25, 1913
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PLATE No 65
Sec.17. Tp14.Rg.12E.P.M.
Sec.16. Tp14.Rg.12E.P.M.
Present Shore Line
PINAWA
W.L. 884.96
Aug. 6. 1913
Present Shore Line
SECOND
ROCK
CUT
CHANNEL
W.L. 865.87
Aug. 5. 1913
Department of the Interior Canada
Water Power Branch
WINNIPEG RIVER POWER SURVEY.
PROPOSED SCHEME OF DEVELOPMENT
· AT ·
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Scale of Feet

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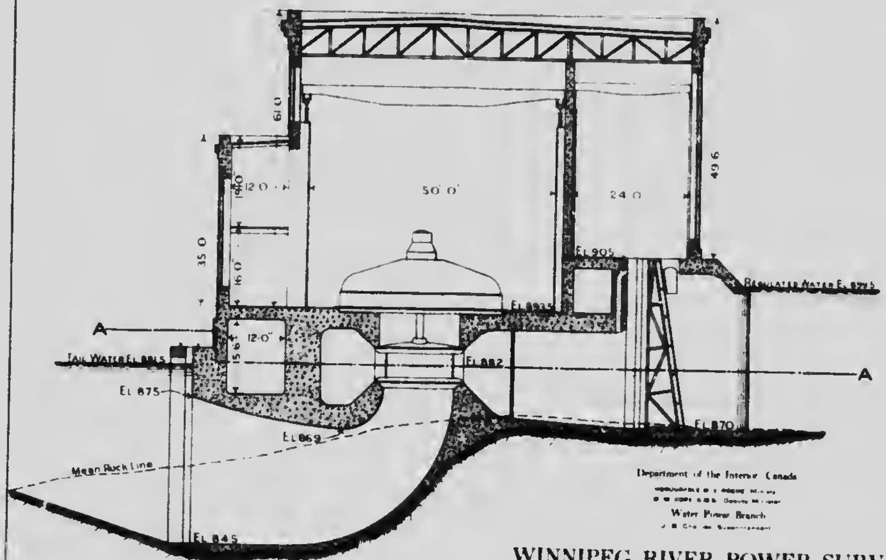
PLATE No. 66



SECTION B.B.

Department of the Interior Canada

Water Power Branch

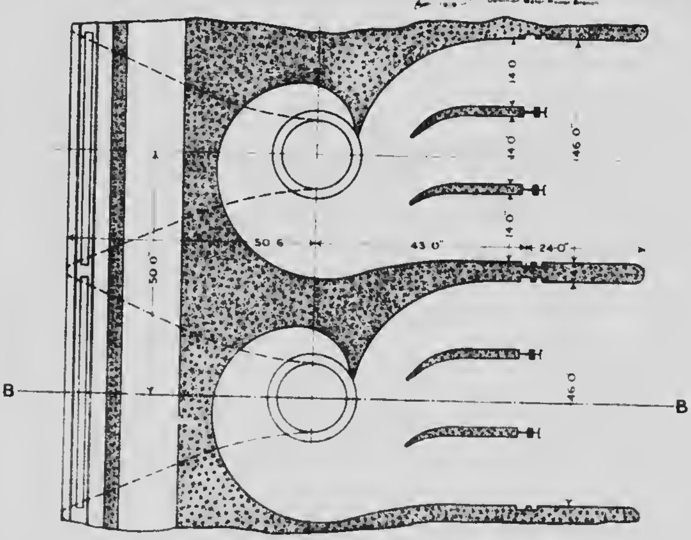
WINNIPEG RIVER POWER SURVEY.

PROPOSED SCHEME OF DEVELOPMENT AT

UPPER PINAWA.

NOTE COMPILED FOR ESTIMATING PURPOSES ONLY

Scale of Feet



PLAN ON LINE A.A.

Slave Falls Site.

The Slave falls site is located about 16 miles above the entrance to the Pinawa channel, and 74 miles from Winnipeg. The flow of the river is here confined to one channel, making the whole available for development. The contours of the river bank would permit holding the headwater level to 950, which would render available a head of some 50 feet. A development of this head would have been very attractive, but, due to the location of the municipal plant of the city of Winnipeg immediately above, cannot be considered.

SPECIAL CONSIDERATIONS AT SLAVE FALLS SITE.

At the Slave falls due consideration must be given to the effect of the proposed headwater on the present tailwater of the city of Winnipeg's municipal plant at Point du Bois. At the same time, the tailwater of the Slave falls site is directly affected by the Winnipeg Electric Railway Company's diversion weirs across the main river at the entrance to the Pinawa channel and by the contemplated layout developing the Upper Seven Sisters falls.

Water Marks on Rock below Eight Foot Fall.

REACH OF THE RIVER DEVELOPED.

The reach of river developed extends from Slave falls to the tailwater of the municiapl plant of the city of Winnipeg, and includes the drop at Slave and Eight Foot falls. It is proposed to combine the two at Slave falls.

Eight Foot Falls and its best disposal.—As indicated by the name, these falls have a drop of about eight feet. The drop is concentrated and takes place over a well-defined ridge of rock. The banks are high on either side.

The engineers of the city of Winnipeg have endeavoured to lessen ice troubles in connection with the Point du Bois plant by blasting away a portion of this ridge.

The water seal of the draught tubes of the power station is at elevation 925·1, while the normal water level below Eight Foot falls is about 921. The design of the power-house therefore places a distinct limit to blasting operations at these falls. Undoubtedly the high backwater effects which occur in the tailwater during flood period (high-water marks on the rocks hereabouts would indicate an elevation of about 938 or 939 at some time in the past) can, to a certain extent, be remedied by further blasting at the falls. However, unless means are provided for maintaining the tailwater during seasons of low water, at a higher elevation than the water seal above referred to, all such blasting operations must be limited. Such a measure of control will be available in the contemplated dam at the head of Slave falls. The construction of this dam will permit of considerable improvement in the city tailwater elevation during high water, and at the same time maintain the necessary level for the water seal during low water. It is doubtful, whether the advantage to be gained would warrant the expenditure necessary, since, during high-water conditions, the headwaters of the city plant rise and tend to compensate for the rise in the tailwater. Again, the extra water which is available for power purposes at such periods will provide a cheaper means of maintaining the power output than expensive blasting operations at the Eight Foot falls.

The results of the power survey have confirmed the opinion expressed on the ground by Messrs. Freeman and McRae, during the preliminary reconnaissance trip, i.e., that the natural and economic point at which to make use of the Eight Foot fall is at the Slave falls, about 4½ miles below.

Slave falls.—At Slave falls a fairly abrupt drop of about 18 fe[illegible]rs. The left bank is abrupt and high, while on the right bank below the ta[illegible] is a low fairly level strip of shore roughly sloping from elevation 915 down to the water's edge, and maintaining this slope, so far as present soundings would indicate, for some distance beyond the shore line. Landward from this low section, the bank rises abruptly to elevation 950. The whole forms a most suitable location for the contemplated power station and head-race.

HEAD- AND TAILWATER ELEVATIONS.

A detailed discussion of the effect of the headwater elevation of the Slave falls concentration on the city of Winnipeg plant, and of the effect of the Winnipeg Electric Railway Company's diversion weirs, and of the proposed Upper Seven Sisters development, on the tailwater elevation of the Slave falls plant, cannot be undertaken until the complete gauge records are available. For the present the head- and tailwater elevations are assumed at 928 and 902, respectively. The tailwater will vary in elevation with the stage of the river, due to the free spillway weirs below, and in order to maintain a mean head of 26 feet the headwater elevation must vary in proportion. This can be suitably arranged for, since the headwater of the city plant discharges over a free spillway dam, and hence also varies with the river stage. As a result, the tailwater which will be directly dependent on the headwater at Slave falls can also be permitted to vary in elevation in keeping with the headwater. Suitable regulation can be maintained at the proposed Slave falls development to ensure the required heads at both plants. This regulation must however be supervised by some independent authority.

FLOODING.

The flooding involved by raising the water level to 928 and allowing for a further rise of 5 feet if necessary during high water, will amount to about 100 acres. The banks are abrupt, and the land flooded consists practically entirely of a narrow strip along the immediate shore line of the river.

PONDAGE.

Holding the water to elevation 928 will create about 1,300 acres of pondage.

ICE CONDITIONS.

In considering a suitable layout for a hydro-electric development at this site, the question of ice conditions during the winter season was given special consideration, in view of the fact that the proposed layout involves a head-race. In the design decided upon (plate 68) it is anticipated that there will be no ice troubles experienced in the operation of the plant. The head-race has been laid out with easy curves, and has been excavated, where necessary, to a practically level bottom. It is designed to carry 12,000 second-feet to the initial development, and 20,000 second-feet to the final development at a rate of about 2·7 feet per second. This will provide an undisturbed approach, leading from a deep pond which extends upstream to the tailwater of the city plant, and which will be largely ice covered during the winter season. The principal conditions tending to the formation of frazil and anchor ice are thus eliminated and the water will be drawn into the plant with practically no disturbance. The discharge from the draught tubes takes place into the open river, which, although somewhat disturbed at this point, due to the discharge over the dam, can be readily protected if necessary by a rock-fill crib.

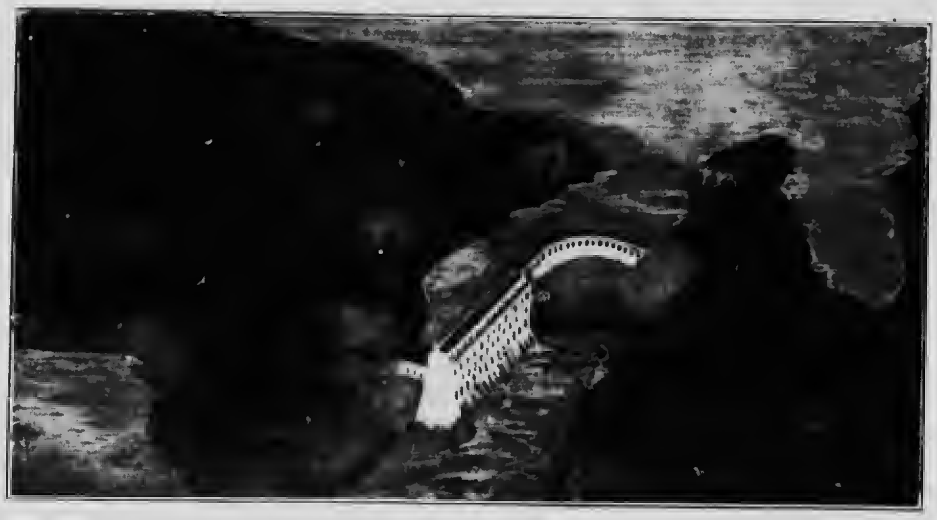
Floating ice and drift are efficiently cared for in the proposed layout by a log boom suitably placed at the entrance to the head-race, and by the sloping concrete curtain which protects the entrance to the racks in the power station. The three ice sluices at the south end of the power-house will provide both the current and the means of exit, by which all floating material passing the boom may be discharged automatically into the lower river.

FOUNDATION CONDITIONS.

Solid granite shows on the surface over practically the entire site, forming an unexcelled foundation for all structures. In carrying the dam across the river along the crest of the falls, it has been necessary to make assumptions as to the elevation of the submerged rock. The means at hand during the power survey did not permit detailed soundings being made along the crest of the falls for the purpose of determining the exact elevation and location of the highest rock. This was considered to be a matter which could be better determined by whatever interests might develop the power. Sufficient evidence is to hand to show that rock foundation is available, and the assumptions made as to the elevation of the same, after a careful study of the conditions and inspection on the ground, are considered to be sufficiently conservative for estimating purposes.

LAYOUT.

The contours in the vicinity of Slave falls lend themselves admirably to the layout adopted (plate 68). The abrupt rise in the rock on the right bank occurs just sufficiently far back from the water's edge to carry the waters of the head-race, at permissible rates of flow, without having to resort to excessive exca-



Model of Proposed Slave Falls Plant.

vation. This natural advantage is not continued to the entrance to the head-race, where a shoulder of rock juts out to the river bank.

In the general scheme of layout, contour 938 on the left bank, is connected with the power station by means of a solid concrete stoplog-controlled dam located along the crest of the falls, and curving in the arc of a circle through 90 degrees to a direction parallel to the river flow. The power station is connected with the right bank by means of a roadway over three ice sluices and a short embankment. In all structures only the most permanent class of construction has been considered.

Fish ladder and log slide.—A fish ladder and log slide are provided adjacent to the abutment on the left bank, hence preventing all interference with the operation of the power station from logging operations on the river.

Sluiceway section of dam.—Fifteen 20-foot sluiceways with sills at elevation 913 are provided for the control of the river in conjunction with five sluices adjacent to the power-house. The bridge deck over the dam (plate 70) is at elevation 938, with the underside at elevation 936·5. All headworks of the dam and power-house will stand the additional rise in headwaters. Regulation is secured by means of stoplogs, double gains being provided to simplify manipulation. A power-driven winch will handle the stoplogs. As the discharging length of the dam is limited, three foot piers have been considered. These will require heavy reinforcing.

For estimating purposes the foundation rock for this section has been considered at elevation 905 for a distance of 250 feet from the left bank dropping to elevation 890 below the crest of the falls.

Spillway section of the dam.—The spillway section has been designed with crest elevation 925, with provision for flashboards to raise the water to elevation 928 or regulated level. The crest has been placed at elevation 925, not only to provide additional discharging capacity during times of flood, but also to assist in forcing the discharge from the dam towards the left bank, and away from the tail-race. The fact that the main stoplog sluices are not adjacent to the power house, as well as the requirements of flashboard operation, necessitates a bridge over this section. A 10-foot platform is provided, supported by three-foot piers spaced 23 feet centre to centre.

Ice sluiceways above power station.—Two 20-foot ice sluices with sills at elevation 913 are provided immediately above the power station. These sluices serve the purpose of an additional safeguard against floating ice and drift, and assist in forcing the current away from the tail-race. An ice fender across the head-race, feeding into these sluices, can be installed if necessary.

Power station.—The power station (plate 69) has been designed for single-runner vertical turbines of 5,000 horse-power capacity at full gate. The section has only been developed in sufficient detail to arrive at the size of the water passages to carry the water to and from the turbines at permissible velocities. The electrical and regulating equipment have been assumed for estimating purposes only.

The racks and headworks have been housed in with floor at elevation 936. A sloping concrete curtain along the face of the entrance piers provides a protection against ice and drift. The floor of the generator room is at elevation 926·5, and is connected with the right bank of the river by a roadway over the lower ice sluices. The water seal of the draught tubes is at elevation 898, the discharge taking place directly across the river. The draft tubes can if necessary be protected from backwater effects of the discharge over the dam by a rock-filled crib in the river channel running from the north end of and parallel to the powerhouse.

The estimates for the power station have been calculated for two stages of development.

(1) *Initial development.*—This consists of the eight units adjacent to the dam. The turbines considered have each a capacity of 5,000 horse-power at full gate, and the electrical installation has been selected with the normal full load corresponding to eight-tenth gate opening of the turbines. This will provide sufficient elasticity to take care of peak loads and gives sufficient machine capacity to utilize 12,000 second-feet at 26-foot head, with turbines at 85 per cent efficiency and eight-tenth gate, at the same time leaving one unit as a spare.

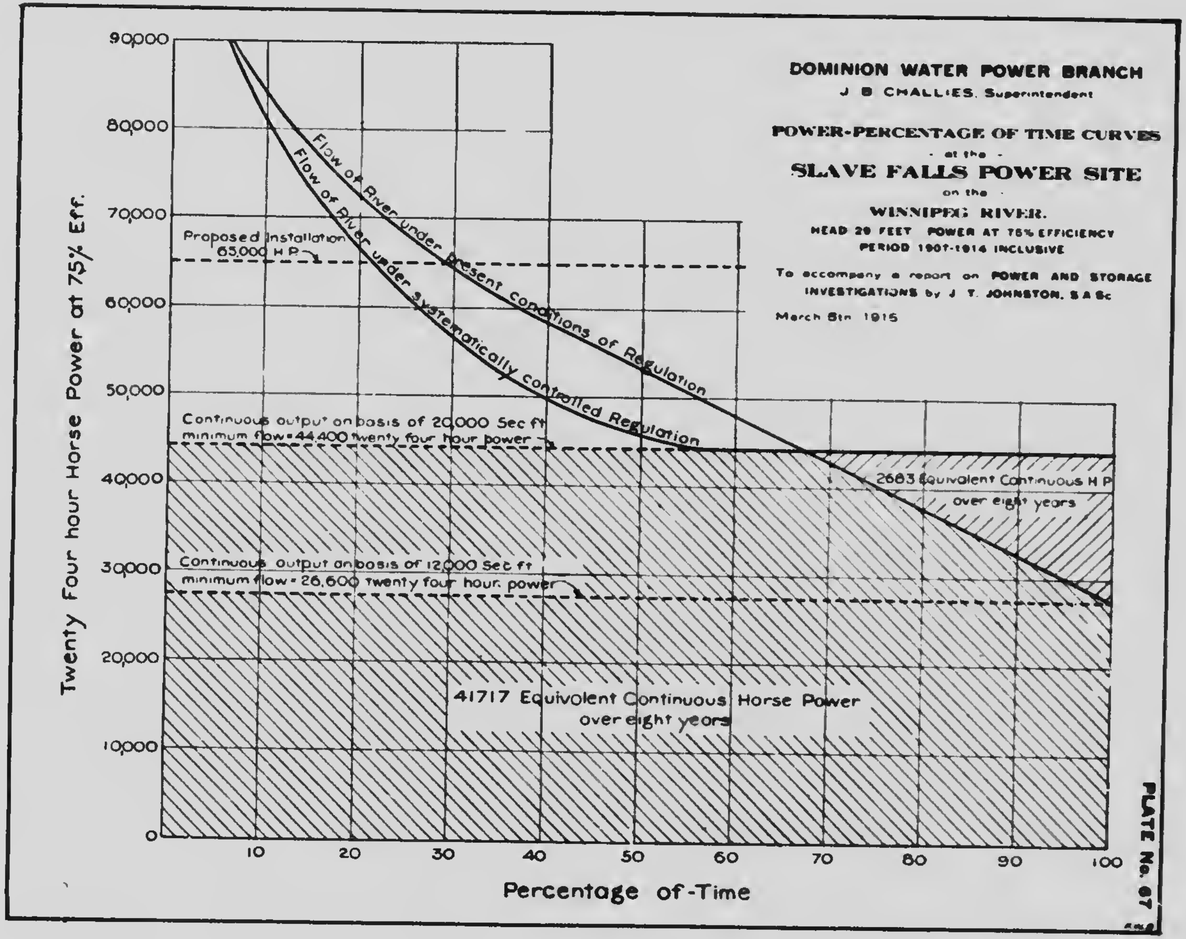
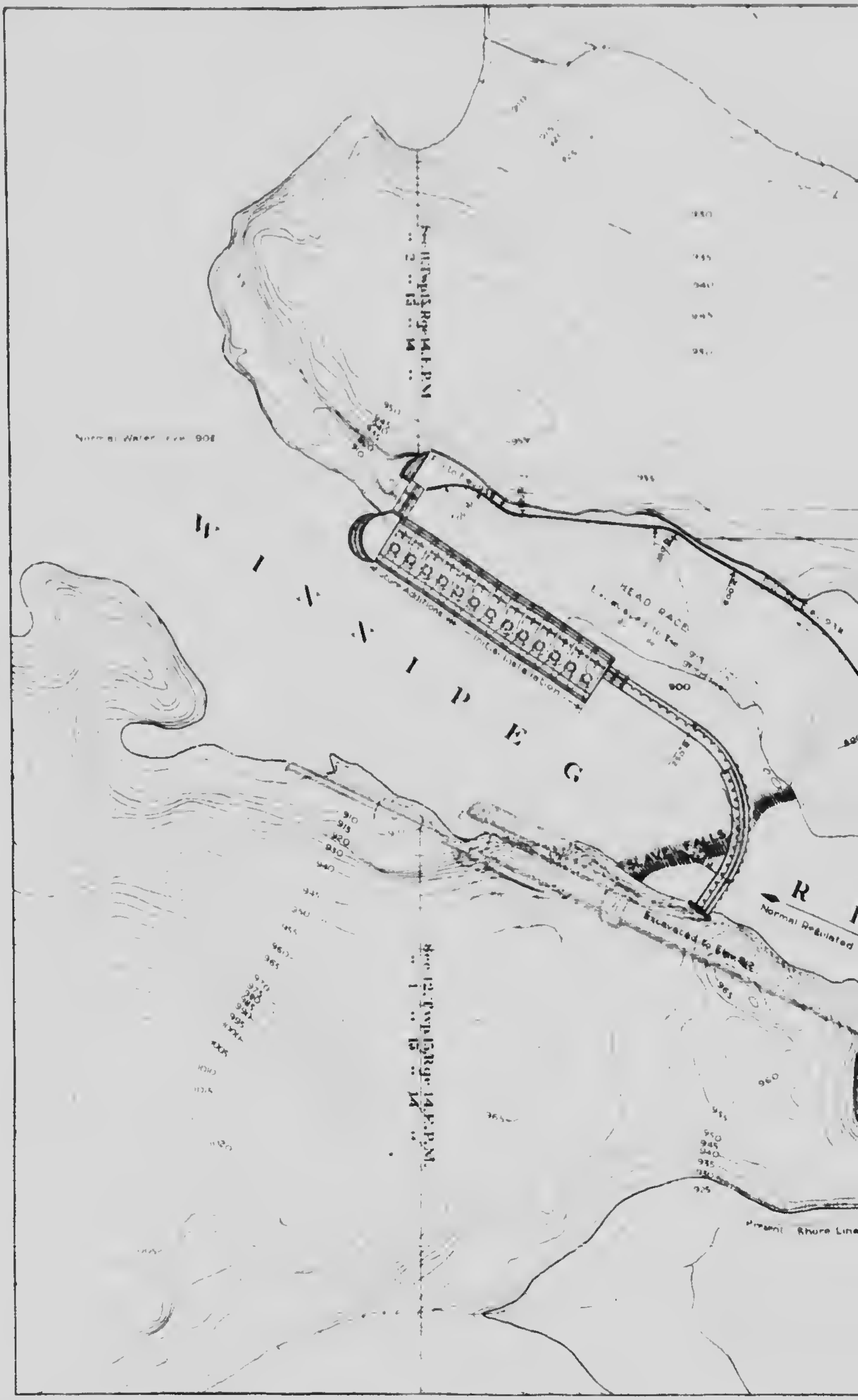

DOMINION WATER POWER BRANCH
J. B. CHALLIES, Superintendent
POWER-PERCENTAGE OF TIME CURVES
at the
SLAVE FALLS POWER SITE
on the
WINNIPEG RIVER.
HEAD 29 FEET POWER AT 75% EFFICIENCY
PERIOD 1907-1914 INCLUSIVE
To accompany a report on POWER AND STORAGE INVESTIGATIONS by J. T. JOHNSTON, S.A.Sc.
March 8th 1915
Flow of River under present conditions of Regulation
Flow of River under systematically controlled Regulation
Proposed Installation 65,000 H.P.
Continuous output on basis of 20,000 Sec ft minimum flow = 44,400 twenty four hour power
Continuous output on basis of 12,000 Sec ft minimum flow = 26,600 twenty four hour power
2683 Equivalent Continuous H.P. over eight years
41717 Equivalent Continuous Horse Power over eight years
Twenty Four hour Horse Power at 75% Eff.
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
10
20
30
40
50
60
70
80
90
100
Percentage of Time

PLATE No. 67


W I N N I P E G
HEAD RACE
900
960
R
Normal Regulated
Shore Line

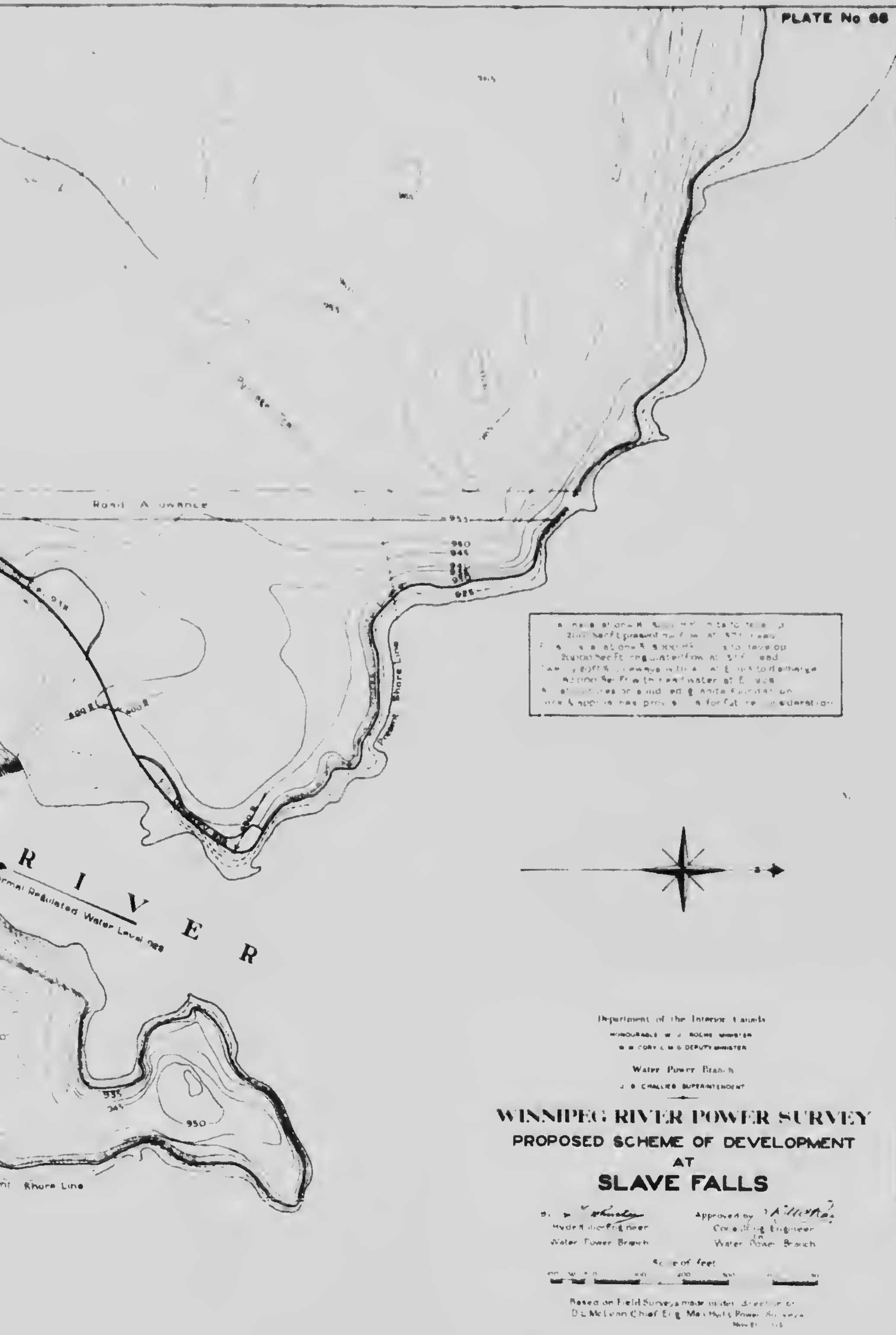
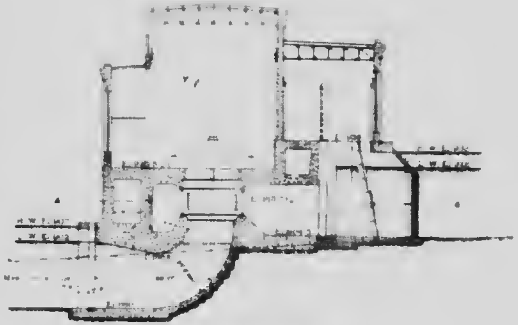


PLATE No 68
Road Allowance
Present Shore Line
R I V E R
Normal Regulated Water Level
Department of the Interior Canada
WATER POWER BRANCH
WINNIPEG RIVER POWER SURVEY
PROPOSED SCHEME OF DEVELOPMENT
AT
SLAVE FALLS
Approved by
Water Power Branch
Scale of Feet
Based on Field Surveys made under direction of

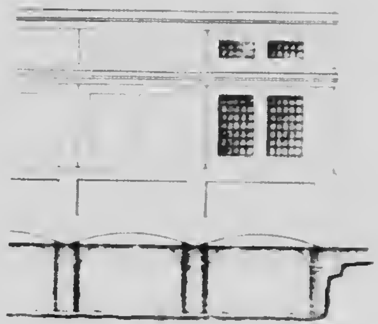
DOMINION WATER POWER BRANCH

J. B. CHALLIES

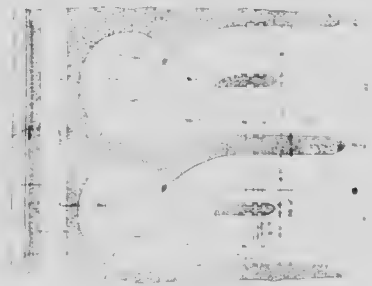
PLATE No 69



SECTION B B



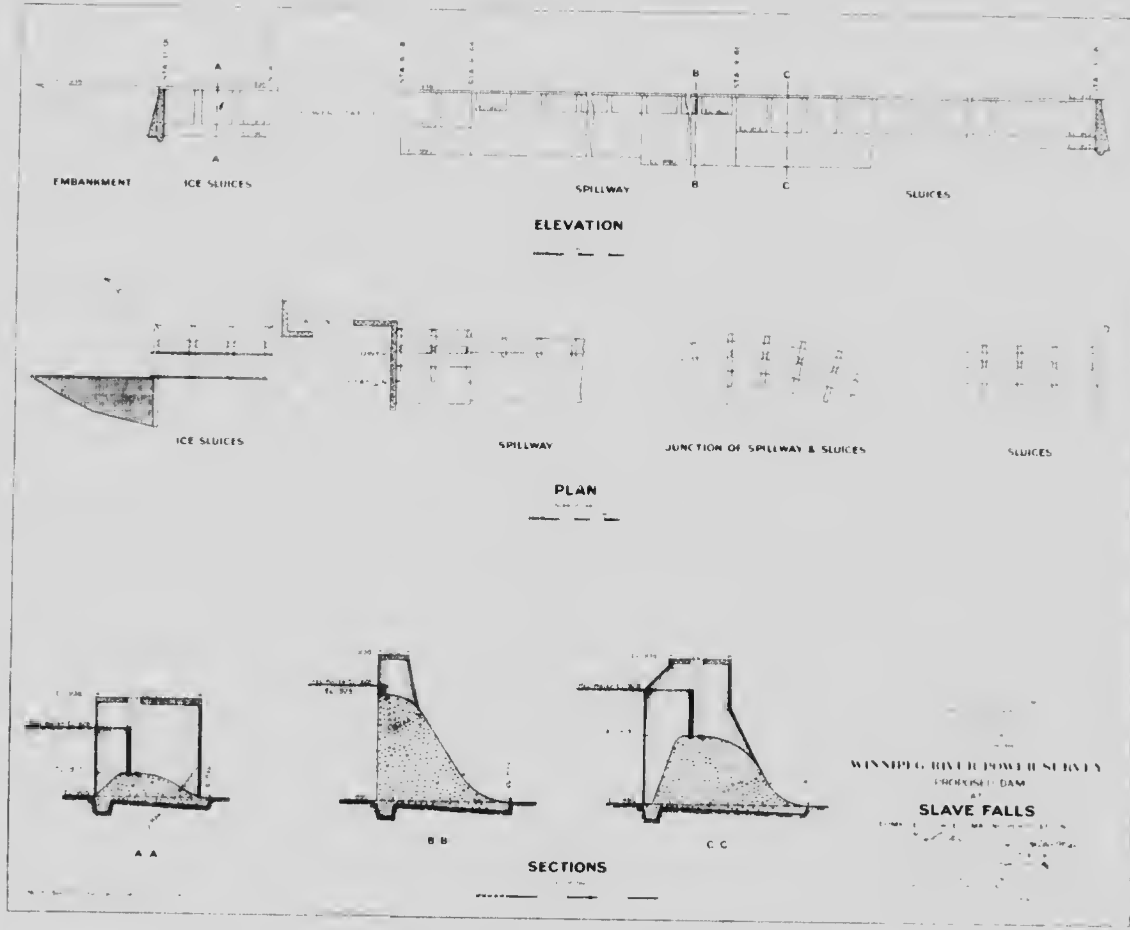
REAR ELEVATION



PLAN ON LINE A A

WINNIPEG RIVER POWER SURVEY
PROPOSED SCHEME OF DEVELOPMENT
AT
SLAVE FALLS

PLATE No 70


EMBANKMENT
ICE SLUICES
SPILLWAY
SLUICES
ELEVATION
ICE SLUICES
SPILLWAY
JUNCTION OF SPILLWAY & SLUICES
SLUICES
PLAN
A A
B B
C C
SECTIONS
WINNIPEG RIVER POWER SURVEY
PROPOSED DAM
AT
SLAVE FALLS

The output available on the low tension switchboard on a 75 per cent overall efficiency on a 24-hour basis is 26,600 horse-power. The initial development includes the construction of the headworks of the remaining five units to a sufficient degree to support the stoplogs, leaving the balance of the bays to be added when required.

(2) *Final development.*—This will consist of thirteen 5,000 horse-power units, five additional being added to the south of the first installation. The thirteen units will provide for the utilization of 20,000 second-feet at a 26-foot head, with turbines at eight-tenth gate. This installation will under these conditions provide a spare unit for emergencies. The output at the switchboard at 75 per cent efficiency on a 24-hour basis is 44,400 horse-power.

Ice sluices below the power station.—Three ice sluices at right angles to the head-race with sills at elevation 913, followed by a corewall embankment connect the power station with the high land on the right bank. These ice sluices are placed in such a way as to produce a current in the head-race parallel to the power-house, and in conjunction with the sloping concrete curtain in front of the racks, should thoroughly protect the machines from all floating ice and detritus. A 20-foot roadway is carried over these sluices, and provides access to the floor of the generator room.

Head-race.—In the head-race the natural contours of the site have been utilized to the fullest extent, and the forebay is in a large measure formed by a natural rock ridge on one side, and the dam and power station on the river side. Opposite the power station this ridge turns towards the river and narrows the channel, but not to such an extent as to augment the velocities. At the entrance to the head-race, a rock ridge approaches the natural river bank and its removal constitutes the major portion of the head-race excavation. Excavation to elevation 913 throughout the head-race will provide passageway for the 12,000 second-feet required for the initial installation at a maximum velocity of 2·8 feet per second, while deepening to elevation 900 will provide for 20,000 second-feet at a velocity of 2·7 feet per second. The land site of the head-race has, where excavation is necessary, been laid out in simple curves in such a manner as to provide for a smooth running and undisturbed flow.

DISCHARGE CAPACITY.

Owing to the peculiar conditions which must be met here in connection with the headwater elevation and the protection of the interests of the city of Winnipeg in the plant at Point du Bois, particular care has been given to the discharging features of the Slave falls plant.

The layout considered provides fifteen 20-foot sluices with sills at elevation 913 adjacent to the left bank. These are followed by a spillway with thirteen 20-foot sections with crest at elevation 925, and with flashboard provision to elevation 928. Adjacent to the upper end of the power station are two 20-foot sluices with sills at 913. Three similar sluices are located at the lower end of the head-race. In all, a discharging capacity of 82,000 second-feet is provided with the headwaters at elevation 928. In addition to this the power station, when working to its full capacity, will pass 20,000 second-feet. While this has not been considered as a dependable source of discharge, it may be considered as forming an additional factor of safety.

The maintenance of the 26-foot head at this plant in times of high water will necessitate the raising of the headwaters above 928. This will automatically increase the discharging capacity at the only time when such increased capacity will be required. Elevation 930 in the headwaters will discharge 103,000 second-feet, excluding the discharge through the power-house. The underside of the bridge decks over the sluices being at elevation 936·5 will provide a safety factor sufficient to pass such floods as are to be expected on the river.

The location of the main sluices adjacent to the left bank of the river permits the discharge of the unutilized water down the river, sending no more down the headrace than is required for the operation of the plant, and thereby keeping the velocities therein at a minimum.

Under natural conditions the main set of the current below the falls is away from the right bank of the river, leaving an eddy where the power-house has been located. This is of particular advantage to the draught tube discharge. The general curve of the dam and the location of the sluices is such that an efficient manipulation of the same will tend to force the main body of the current away from the tail-race to an even greater extent than occurs under present conditions.

UNWATERING.

Alternative schemes of unwatering, suitable to whatever method or order of construction may be adopted, should not exceed the estimates allowed herein.

NAVIGATION.

At the Slave falls site provision has been made for the future construction of lockage facilities on the left bank should the same ever become necessary (plate 68). The lock depicted is 300 feet by 40 feet, with 15 feet of water on the sills.

This lock with approaches can be constructed at any time in the future without interfering with the operation of the power plant, nor will the provision for it incur any extra expenditure in the present construction of the plant. On the other hand, the present construction of the power installation will not place any obstacles in the way of the future construction or operation of the lock. No portion of the cost of the lock or approaches is included in the estimates for the power development.

ESTIMATES OF COST.

The estimates of the cost of the initial and final installations place the power on the low tension switchboard in the power station. It is considered that the estimates are amply conservative and that the assumptions which have been made are fully warranted. Seven miles of railroad have been allowed to connect with the city of Winnipeg tramway line.

Ten per cent has been allowed on the estimates for contingencies, 5 per cent on this total for engineering and inspection, and 5½ per cent on the whole for one year for interest during construction.

The annual operation costs include capital charges, and represent the cost of operation at the power station. They do not include transforming and transmission.

(1.)—*Initial Development.*—(Eight 5,000 horse-power units.)

(1) *Capital Cost of Installation.*

Dam and equipment	$ 276,000	
Ice sluices and roadway	35,000	
Head-race	87,000	
Power station and equipment	533,000	
Hydraulic installation	360,000	
Electrical installation	520,000	
Railroad	84,000	
Permanent quarters	15,000	
Contingencies, 10 per cent	191,000	
Engineering and inspection, 5 per cent	105,000	
Interest during construction, 5½ per cent	121,000	
Total initial cost		$2,327,000

Twenty-four hour power available at 75 per cent over-all efficiency, 26,600 horse-power.

Capital cost per 24-hour horse-power	$87.50
Capital cost per installed horse-power	58.20

(2) *Annual Cost of Operation.*

Interest, sinking fund, and depreciation charges—		
Interest, 5½ per cent on $2,327,000		$ 128,000
Sinking fund, 4 per cent (40-year bonds)		24,000
Depreciation—		
1 per cent on permanent works	$ 7,000	
4 per cent on machinery, etc	40,000	
		47,000
Operation charges—		
Staff	$ 19,000	
Supplies	10,000	
		29,000
Total annual charge		$ 228,000

Annual cost per horse-power year, 24-hour power	$8.58
Annual cost per horse-power year, machinery installed	5.70
Annual cost per kilowatt hour	0·131 cent
Annual cost per kilowatt hour on basis of 50 per cent load factor	0·262 cent

(2.)—*Final Development.*—(Thirteen 5,000 horse-power units.)

(1) *Capital Cost of Installation.*

Dam and equipment	$ 276,000	
Ice sluices and roadway	35,000	
Head-race	204,000	
Power station and equipment	771,000	
Hydraulic installation	585,000	
Electrical installation	845,000	
Railroad	84,000	
Permanent quarters	20,000	
Contingencies, 10 per cent	282,000	
Engineering and inspection, 5 per cent	155,000	
Interest during construction, 5½ per cent	179,000	
Total final cost		$3,436,000

Twenty-four hour power available at 75 per cent over-all efficiency, 44,400 horse-power.

Capital cost per 24-hour horse-power	$77.39
Capital cost per installed horse-power	52.86

(2) *Annual Cost of Operation.*

Interest, sinking fund, and depreciation charges—		
Interest, 5½ per cent on $3,436,000		$ 189,000
Sinking fund, 4 per cent (40-year bonds)		36,000
Depreciation—		
1 per cent on permanent works	$ 9,000	
4 per cent on machinery, etc	61,000	
		70,000
Operation charges—		
Staff	$ 26,000	
Supplies	17,000	
		43,000
Total annual charge		$ 338,000

Annual cost per horse-power year, 24-hour power	$7.62
Annual cost per horse-power year, machinery installed	5.21
Annual cost per kilowatt hour	0·117 cent
Annual cost per kilowatt hour on basis of 50 per cent load factor	0·234 cent

Summary of Dependable Power.

A summary of the undeveloped power as outlined in the above power studies, together with the total dependable power on the river in Manitoba, including that developed to date, is appended in tables 35 and 36.

Table 35.—Undeveloped Power Sites on the Winnipeg River in Manitoba.

Site.	Distance from Winnipeg in Miles	Head in feet.	Power Available.			
			24 Hour Power at 75% Efficiency.		Turbine Installation (Units considered.)	
			12,000 Sec.-ft.	20,000 Sec.-ft.	12,000 Sec.-ft.	20,000 Sec.-ft.
1.	2.	3.	4.	5.	6.	7.
Pine Falls	64	37	37,900	63,100	6—10,000	10—10,000
Du Bonnet Falls	64	56	[1]57,300	95,500	[1]9—10,000	14—10,000
McArthur Falls	62	18	18,400	30,700	11— 2,500	17— 2,500
[2]Lower Seven Sisters	52	37	12,600	37,900	....	6—10,000
[2]Upper Seven Sisters	55	29	9,900	29,600	....	8— 6,000
[3]Upper Pinawa	58	18	12,300	12,300	4— 4,500	4— 4,500
Slave Falls	74	26	26,600	44,400	8— 5,000	13— 5 000
Total	.....	....	175,000	313,500	235,500	473,500

[1]This tabulation assumes an initial development of the Du Bonnet site utilizing 12,000 second-feet at 56-foot head.

[2]The Upper and Lower Seven Sisters sites are located in the main channel of the Winnipeg river paralleling the Pinawa through which 8,000 second-feet is assumed to be diverted for the operation of the Winnipeg Electric Railway plant.

[3]The Upper Pinawa site is located on the Pinawa channel.

Table 36.—Total Power Developed and Undeveloped on the Winnipeg River in Manitoba.

——	Unregulated Flow 12,000 Sec.-ft.	Regulated Flow 20,000 Sec.-ft.
Undeveloped at proposed sites	175,000	313,500
Undeveloped at Point Du Bois	21,100	51,800
Developed on River to date	53,200	53,200
Total	249,300	418,500

Note.—Power in terms of 24-hour horse-power at 75 per cent efficiency.

The above tables indicate that there is 53,200 horse-power developed to date, 196,100 horse-power undeveloped and available in times of present low water on the river, and 365,300 horse-power undeveloped and available when the river is regulated to a minimum flow of 20,000 second-feet. It must be borne in mind that these totals are given in terms of 24-hour power, and hence give a rather limited estimate of the river's resources. A translation of these totals into shorter range-power will therefore prove of interest.

Table 37.—Dependable Power on Winnipeg River in Manitoba.

—	Unregulated Flow 12,000 Sec.-ft.	Regulated Flow 20,000 Sec.-ft.
Twenty-four hour power	249,000	418,000
Twenty-hour power	299,000	502,000
Sixteen-hour power	373,000	627,000
Twelve-hour power	498,000	836,000

The above tabulation shows the greater scope of the power resources to meet varying demand, but must only be applied with discrimination. What might be called the dependable commercial power available can be placed at well above the half-million mark.

Plates 71 and 72 graphically indicate the relative power capacities of the different sites and plants under present run-off conditions and under systematically controlled regulation. The total power output of the entire reach in Manitoba is graphically depicted in the power percentage of time diagram, plate 73. This curve is based on eight years' records of run-off, and gives the power in terms of continuous 24-hour power.

SUMMARY OF CAPITAL AND OPERATING COSTS.

The data respecting the estimates of the various schemes have been condensed into tables 38 and 39 for the purpose of ready reference and comparison.

Table 38.—Estimated Capital Cost of developing the proposed power sites on the Winnipeg River in Manitoba. Power placed on the low-tension switchboard in the Power Stations.

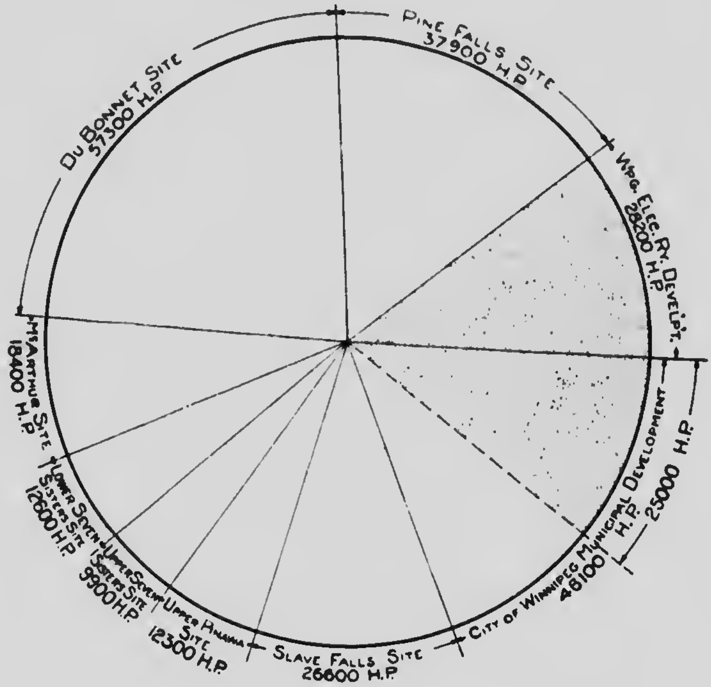
Site.	Capital Cost on Low Tension Switchboard in Power Station.					
	Total Cost.		Per H.P. on Basis of 75% Efficiency, 24-hour power.		Per H.P. on Basis of Installation.	
	12,000 Sec.-ft.	20,000 Sec.-ft.	12,000 Sec.-ft.	20,000 Sec.-ft.	12,000 Sec.-ft.	20,000 Sec.-ft.
1.	2.	3.	4.	5.	6.	7.
	$	$	$ cts.	$ cts.	$ cts.	$ cts.
Pine Falls	3,057,000	4,407,000	80 66	69 8[illegible]	50 95	44 07
Du Bonnet Falls	[1]4,624,000	6,551,000	80 70	[illegible]	53 80	46 79
McArthur Falls	2,031,000	2,740,000	110 38	89 25	73 88	64 47
[2]Lower Seven Sisters	....	3,409,000	....	89 95	...	56 82
[2]Upper Seven Sisters	....	2,724,000	....	92 03		56 75
Upper Pinawa	1,280,000	1,280,000	104 07	104 07	71 11	71 11
Slave Falls	2,327,000	3,436,000	87 50	77 [illegible]	58 20	52 86
Total	13,319,000	24,547,000				
Mean (based on power output)	....	....	87 30	78 30	56 60	42 80

[1]Proportional capital cost of development of 12,000 second-feet at 56-foot head.
[2]Upper and Lower Seven Sisters sites are not feasible of development until the river flow is more systematically regulated.

PLATE No. 7

DOMINION WATER POWER BRANCH

J. B. CHALLIES, Superintendent



LEGEND: Developed Power

Undeveloped Power

Total Power Capacity of Winnipeg River with Regulated Flow	249,300 H.P.
Amount Developed to Date	53,200 H.P.

NOTE: Based on a PRESENT MINIMUM flow of 12,000 Second Feet with undeveloped sites considered at 75% efficiency with 24 hour power.

DIAGRAM

SHOWING THE DEVELOPED AND UNDEVELOPED POWERS AT THE VARIOUS SITES ON THE

WINNIPEG RIVER IN MANITOBA.

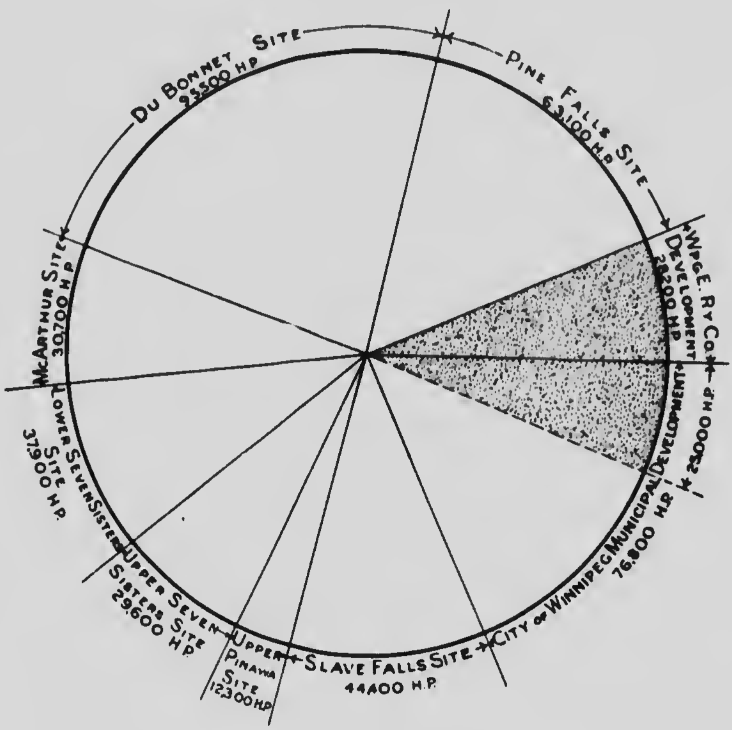
To accompany report on POWER AND STORAGE INVESTIGATIONS
by J. T. JOHNSTON, B.A.Sc.
Hydraulic Engineer,
Dominion Water Power Branch.

March, 1915.

PLATE No. 72

DOMINION WATER POWER BRANCH

J. B. CHALLIES, Superintendent



LEGEND: Developed Power

Undeveloped Power

Total Power Capacity of Winnipeg River with Regulated Flow	418,500 H.P.
Amount Developed to Date	53,200 H.P.

NOTE: Based on a REGULATED MINIMUM flow of 20,000 Second Feet with undeveloped sites considered at 75% efficiency with 24 hour power.

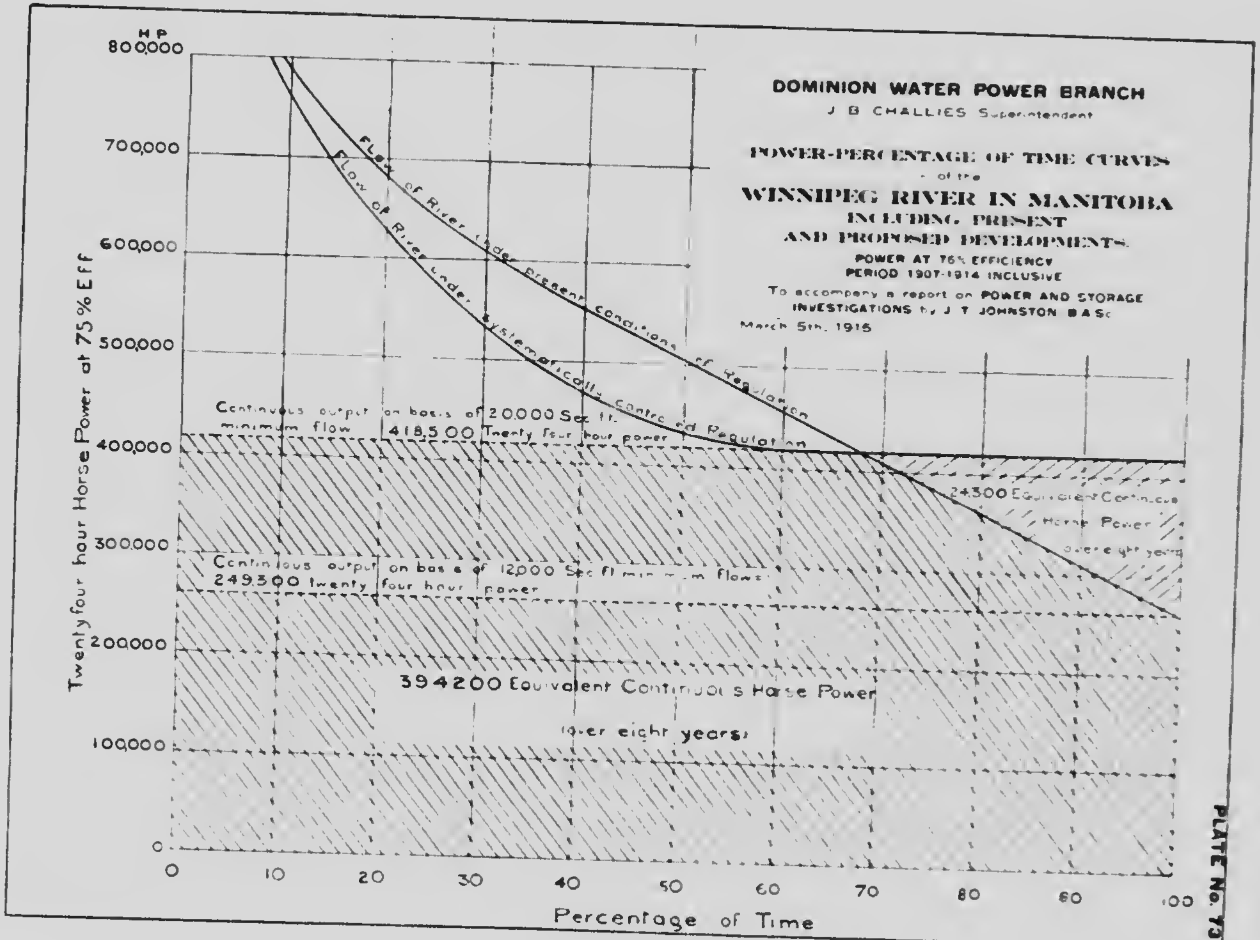
DIAGRAM

SHOWING THE DEVELOPED AND UNDEVELOPED POWERS AT THE VARIOUS SITES ON THE WINNIPEG RIVER IN MANITOBA.

To accompany a report on POWER AND STORAGE INVESTIGATIONS
by J. T. JOHNSTON, B.A.Sc.
Hydraulic Engineer,
Dominion Water Power Branch

March, 1915.

PLATE No. 73



DOMINION WATER POWER BRANCH
J B CHALLIES Superintendent
POWER-PERCENTAGE OF TIME CURVES
of the
WINNIPEG RIVER IN MANITOBA
INCLUDING PRESENT
AND PROPOSED DEVELOPMENTS
POWER AT 75% EFFICIENCY
PERIOD 1907-1914 INCLUSIVE
To accompany a report on POWER AND STORAGE
INVESTIGATIONS by J T JOHNSTON B A Sc
March 5th, 1915
Flow of River under present conditions of Regulation
Flow of River under Systematically Controlled Regulation
Continuous output on basis of 20,000 Sec ft. minimum flow
418,500 Twenty four hour power
Continuous output on basis of 12,000 Sec ft minimum flows
249,300 twenty four hour power
24300 Equivalent Continuous Horse Power over eight years
394200 Equivalent Continuous Horse Power
(over eight years)
HP
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Twentyfour hour Horse Power at 75% Eff
0
10
20
30
40
50
60
70
80
90
100
Percentage of Time

The Du Bonnet plant, in view of its high head, will prove the most economically efficient of the series, the capital cost per horse-power being $68.60, and the McArthur plant, in view of its low head and the long dam and headworks required, is actually the most costly as measured by the output, the cost being $89.25 per horse-power. The two Seven Sisters and the Upper Pinawa sites cannot be directly compared with the other four as each receives only a portion of the river flow, with a consequent comparative decrease in the power produced. However, under a regulated flow of 20,000 second-feet in the river their unit capital costs of $89.95, $92.03, and $104.07 respectively, will prove very attractive from a commercial view point.

In view of the uniform and conservative character of the over-development at each site, unit costs have been listed in terms of the horse-power installed, as well as in terms of 24-hour power, and as such can be profitably studied.

A consideration of the above total costs shows the following: The total final output of the seven proposed developments is 313,500 horse-power at a total capital cost of $24,547,000, i.e., an average cost of $78.30 per horse-power, or $42.80 per horse-power based on machinery installed.

The annual operating costs are probably of greater interest than the above capital costs, and are summarised in table 39.

The results tabulated herein bear out the general conclusions as to comparative economic efficiency that have been noted from a discussion of the capital costs. They are listed in terms of initial and final development, corresponding to present regulated run-off, respectively. The costs per kilowatt hour, considering a 50 per cent load factor, as shown in column 11, indicate in all cases highly desirable commercial undertakings.

Care has been taken to supply sufficient physical data in this report to enable independent estimates being made of the construction cost of any of the projects, by parties interested in their development.

While the annual operation costs quoted may appear low, a review of the estimates and of the general underlying principles upon which they are based will establish the conservativeness of the conclusions. The figures represent operating conditions which possibly would not be met upon the immediate completion of the undertakings, that is to say, the initial market would possibly not warrant the initial installation proposed. This would result in higher initial capital and operating costs than are submitted above. At the same time, it would be a simple matter to present the unit costs published herein in a much more favourable light than has been done. Considering the ample pondage facilities which exist, the general run-off conditions of the river, and the general opportunities of an industrial market, 24-hour power is a most conservative basis on which to establish final figures.

As illustrative of this, the Pine Falls site may be briefly considered. The continuous 24-hour power available here is 63,100, and the annual cost per horse-power on this basis is $7.08, or 0·216 cent per kilowatt hour on a 50 per cent load factor. The average load carried by the Pine Falls plant could, under a regulated river flow, be maintained at 63,000 horse-power and readily carry a peak load of 126,000 horse-power. The actual cost per kilowatt hour is therefore probably more truly represented by the figure 0·108 cent than by 0·216 cent.

Table 39.—Estimated Annual Cost of operation of the proposed power developments on the Winnipeg River in Manitoba. Power placed on the low-tension switchboard in the Power Stations.

Site.	Annual Operating Cost on Low-Tension Switchboard in Power Station									
	Total Annual Cost.		Per H.-P. on basis of 75% Efficiency 24-hour Power.		Per H.-P. on basis of Installation.		Per K.W. hour 100% Load Factor		Per K.W. hour 50% Load Factor.	
	12,000 Sec.-ft.	20,000 Sec.-ft.	12,000 Sec.-ft.	20,000 Sec.-ft.	12,000 Sec.-ft.	20,000 Sec.-ft.	12,000 Sec.-ft.	20,000 Sec.-ft.	12,000 Sec.-ft.	20,000 Sec.-ft.
1.	2.	3.	4.	5.	6.	7.	8.	9	10.	11
	$	$	$ cts	$ cts.	$ cts.	$ cts.	Cents.	Cents	Cents.	Cents
Pine Falls	303,006	447,000	8 00	7 08	5 05	4 47	0·122	0·108	0·244	0·216
[1]Du Bonnet Falls	[1]433,000	635,000	[1]7 56	6 65	[1]5 04	4 54	[1]0·116	0·102	[1]0·232	0·204
McArthur Falls	199,000	272,000	10 82	8 86	7 24	6 40	0·166	0·136	0·332	0·272
[2]Lower Seven Sisters Falls	....	328,000	...	8 65		5 47		0·132		0·264
[2]Upper Seven Sisters Falls		268,000		9 05		5 58		0·138		0·276
Upper Pinawa	128,000	128,000	10 40	10 40	7 11	7 11	0·159	0·159	0·318	0·318
Slave Falls	228,000	338,000	8 58	7 62	5 70	5 21	0·131	0·117	0·262	0·234
Total	1,291,000	2,416,000	...							
Mean (based on power output)	......	....	8 47	7 71	5 48	4 21	0·130	0·118	0·260	0·236

[1]Proportional annual cost of development of 12,000 second-feet at 56-foot head.
[2]Upper and Lower Seven Sisters sites are not feasible of development until the river flow is more systematically regulated

These remarks apply with equal force to the estimates of the other projects along the river.

While it is impossible in a work of this nature to go fully into the various conditions of load and market which may be experienced in the developments of the proposed concentrations, an endeavour has been made to supply sufficient data to permit an adjustment of the figures to meet individual requirements, and to enable the information and estimates herein being applied or compared, as may be desired.

Cost of Delivery of Power to Winnipeg.

No consideration has been given to the cost of transmitting the developed power to the present industrial market, the reason being the uncertainty as to the use to which the power developed at the various sites will be applied. Undoubtedly in some instances the power will be used industrially directly at the site, either for pulp grinding or in connection with one or more of the various electro-chemical processes which are now coming to the front. The foregoing estimates serve their general purpose, which is to indicate the relative commercial value of the sites as units.

An analysis of the power situation would, however, be incomplete unless some idea were given as to the cost of transmitting the power to the nearest industrial market, i.e., the city of Winnipeg. To this end, the following estimate of cost of transmission from the Pine falls site to the low-tension switchboard in the transformer house in Winnipeg is appended.

The estimates herewith are based on an initial and final development; the capital cost to the low-tension switchboard in the power station has been brought forward from the detailed estimates of the Pine falls development. The transmission distance is 60 miles.

The power station as designed does not include provision for step-up transformers, and hence a separate building has been provided at the site, together with a step-down station in Winnipeg. At the river station six 6,000 k.w., 6,600–66,000-volt transformers have been provided for the initial installation, and ten for the final. In the Winnipeg station corresponding provision has been made after allowing for transmission line drop. The resulting costs place the power ready for distribution in Winnipeg.

(1) *Initial development.*—(Six 10,000 horse-power units.)

(1) *Capital Cost of Installation*

Capital cost of installation to low-tension switchboard at falls, brought forward		$3,057,000
Transformer house at falls		
Transformers, switches, wiring, etc	$ 50,000	
Transmission line	216,000	
Transformer house in Winnipeg	360,000	
Transformers, switches, etc	45,000	
	194,000	
		865,000
Total initial cost		$3,922,000

Twenty-four hour power available in Winnipeg, considering 10 per cent loss, 34,110 horse-power.
Capital cost per horse-power $114.98

(2) *Annual Cost of Operation.*

Interest, sinking fund, and depreciation charges—		
Interest, 5½ per cent on $3,922,000		
Sinking fund, 4 per cent (40-year bonds)		$ 216,000
Depreciation—		41,000
1 per cent on permanent works		
4 per cent on machinery, etc	$ 11,000	
	87,000	
Operation charges—		98,000
Staff		
Supplies	$ 36,000	
	20,000	
		56,000
Total annual charge		$ 411,000
Annual cost per horse-power year 24-hour power		
„		$ 12.05
Annual cost per kilowatt hour		0·184 cent
Annual cost per kilowatt hour on basis of 50 per cent load factor		0·368 cent

(2) *Final development.*—(Ten 10,000 horse-power units.)

(1) *Capital Cost of Installation.*

Capital cost of installation to low-tension switchboard at falls, brought forward		$4,407,000
Transformer house at falls		
Transformers, switches, wiring, etc	$ 80,000	
Transmission line	360,000	
Transformer house in Winnipeg	420,000	
Transformers switches, wiring, etc	70,000	
	324,000	
		1,254,000
Total final cost		$5,661,000

Twenty-four hour power available in Winnipeg, considering 10 per cent loss, 56,790 horse-power.
Capital cost per horse-power $99.68

(2) *Annual Cost of Operation.*

Interest, sinking fund, and depreciation charges—		
Interest, 5½ per cent on $5,661,000		
Sinking fund, 4 per cent (40-year bonds)		$ 311,000
Depreciation		60,000
1 per cent on permanent works		
4 per cent on machinery, etc	$ 14,000	
	134,000	
Operation charges—		148,000
Staff		
Supplies	$ 45,000	
	25,000	
		70,000
Total annual charge		$ 589,000
Annual cost per horse-power year 24-hour power		
Annual cost per kilowatt hour		$10.37
Annual cost per kilowatt hour on basis of 50 per cent load factor		0·159 cent
		0·318 cent

As noted in connection with the operating costs at the power sites, 24-hour continuous power is a most conservative basis on which to base annual costs. The conditions under which the Pine Falls plant will operate are such that of the above two figures, 0·159 cent per kilowatt hour the more nearly represents the cost of power laid down in Winnipeg.

REPORT

ON

THE WINNIPEG RIVER POWER AND STORAGE INVESTIGATIONS

CHAPTER VII.

POWER FROM COAL, GAS, AND OIL.

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POWER FROM COAL, GAS AND OIL.

In order to complement the cost data relative to hydro-electric power in Winnipeg, it is considered desirable to include in this report a discussion on the comparative cost of power from other feasible sources. Cost data relative to auxiliary or reserve fuel plants are also as a rule a matter of import in connection with hydro-electric installation.

The following discussion has therefore been prepared by Mr. H. E. M. Kensit, an engineer of the Dominion Water Power Branch

Auxiliary or Reserve Fuel Plant.

In the foregoing estimates of the cost of development and operation of undeveloped powers on the Winnipeg river the cost of a stand-by fuel plant has not been included for the reasons that the requirements in this direction, if any, will depend entirely upon the conditions under which the water-powers are developed and the use to which the power is to be put.

In the first place, a distinction should be made between the terms "auxiliary plant" and "reserve plant."

"*Auxiliary plant*" is considered to mean the provision of such additional independent plant, operated by fuel, as would be necessary to provide against diminished output during periods of low water.

The result of the exhaustive investigations and surveys made by the Dominion Water Power Branch over a series of years has shown that ample storage of water is available to give the regulated flow on which all the foregoing estimates have been based.

It is therefore not considered necessary to allow for the provision of any auxiliary plant for the purpose of precaution against low water.

"*Reserve plant*" is considered to mean additional independent plant, operated by fuel, that might be considered necessary to provide for such contingencies as:

(1) Floods or troubles from ice

(2) Damage to the transmission line from wind, sleet, lightning, electric surges or other cause.

(3) Accident to the generating plant.

In regard to these contingencies it may be pointed out that:

(1) In respect to floods it is recognized that the natural regulation provided in the innumerable lakes, as above described, is an efficient safeguard against any such probability. In respect to troubles from ice it is believed that the natural and local conditions are such that with proper design and precautions the risk from this cause may be considered but slight.

(2) In respect to interruptions that may be caused by accidents to the transmission line, it is undoubtedly the fact that in the case of any transmission line such accidents are bound to occur sooner or later. If, however, either a double

circuit line, or preferably, two separate transmission lines are employed, each of capacity to carry the full output, then while accidents will still occur they should cause but momentary interruptions while the load is being switched from the damaged circuit to the spare circuit.

(3) In respect to accidents to the generating plant, all reasonable and usual precautions can be made by the provision of spare hydro-electric units.

Summing up the foregoing: Therefore, it is considered that separate fuel-operated plant will not be necessary for the purpose of providing against low water, but that it may possibly be advisable under some conditions as a reserve against accidents.

Desirability of reserve plant: It is generally conceded that in the case of a hydro-electric plant supplying light and power for general distribution in a city, an independently operated reserve plant should be provided and kept ready for immediate use at any time. This is especially the case if the power has to be transmitted any distance. The reason is that if a city is entirely dependent on the hydro-electric undertaking for light, power, and possibly for pumping the city water supply, no chances of interruption that can possibly be guarded against may be taken.

But it is not necessary or usual to provide steam or other reserve for a hydro-electric plant operated by a company for its own factory; or for supplying a limited number of individual factories.

In the case of the proposed developments that have been discussed in preceding chapters, it is doubtful if a company developing one or more of these powers for purposes other than general supply to a city, would consider steam reserve necessary, and especially would this be the case if the development was undertaken for the purpose of supplying power to industries locating near the power plant at the river, thus eliminating transmission risks.

A further possibility would be that of a company or group of interests acquiring two or more of the undeveloped powers for industrial purposes. In such case, a steam reserve plant, if considered necessary at all, might be considered to act as a reserve to more than one of the hydro-electric developments.

On account of the uncertainty caused by the above conditions, it was felt that any attempt to include the cost of stand-by plant would tend to obscure the estimates of the cost of the hydro-electric developments.

It is thought, however, that the inclusion of some separate estimates of cost of reserve plant operated by fuel may be of service to those interested, and who may not have cost data on hand.

ESTIMATES OF COST OF RESERVE PLANT.

As shown above, it is not considered that such plant would be required as an auxiliary in case of low water, but only as a reserve against possible accidents to the transmission line or power plant. In such case it is obvious that, with proper design and precaution in respect to the transmission line and hydro-electric plant, the reserve fuel-operated plant might be seldom required, possibly not for a year or more at a time.

It is therefore clear that the predominating factor in deciding on type of plant would be low capital cost rather than low operating costs.

The type of fuel plant that holds the field for low capital cost in large units is undoubtedly the steam turbine, and will therefore be the only one considered.

The undeveloped powers for which the possibility of steam reserve might arise are listed in table 35.

The size of reserve plant required would be a question for the individual judgment of the parties developing one or more of these powers, but it is obvious that the reserve plant would need to be large.

Whether required for use or not, it would be necessary to periodically run the engines under steam, and the generators on artificial load, in order to keep the plant in good condition and ready for service, and for this purpose it would be necessary to keep two men in continuous charge, with additional help when the plant was operated on artificial load to keep it in good condition.

In addition to interest and depreciation, repairs and maintenance would also be incurred, no matter how little the plant was used.

These and other charges may be figured as follows:

Capital charges: Interest, 6 per cent; depreciation, 4 per cent; total, 10 per cent.

Repairs and maintenance: 1·5 per cent.

Insurance: 1 per cent; taxes, 1 per cent; total, 2 per cent

Labour: Two men in constant service and additional help for periodic runs to keep the plant in proper order.

Coal: A supply must be kept in reserve whether the plant is used or not, and the cost must be added to capital expenditure, since it is capital lying idle. As to amount of fuel in reserve, allow say three days' supply at 75 per cent load factor at 5 pounds per kilowatt hour and $6.25 per ton.

In addition, at least twice the above amount would be required for periodic runs to keep the plant in order, and this would be an annual charge.

Oil and stores: The same remarks apply as to coal.

Heating and lighting are not allowed for, but would be but a small percentage addition to the total.

On this basis, the capital and annual costs *without operation* would be approximately as shown in table 40.

No estimate of any service can be made of operating costs where the operation depends on accidents only.

It is assumed that the plant will not be kept under steam continuously.

Table 40.—Approximate Cost of Steam Turbine Plants complete with steel and concrete buildings.

Size of Plant.		Cost per K.W.	Coal and Supplies in Stock	Total Cost.	Annual Cost without Operation					
Kilowatts.	Horse Power.				Capital Charges 10%.	Maintenance and Repairs 1·5%, Insurance and Taxes 2%.	Coal and Supplies Used.	Labor.	Total.	Per H.P. Installed
		$	$	$	$	$	$	$	$	$ cts
5,000	6,700	80	4,500	405,000	40,450	14,160	9,000	2,500	66,110	9 90
10,000	13,400	75	9,000	759,000	75,900	26,600	18,000	3,000	123,500	9 20
20,000	26,800	70	18,000	1,418,000	141,800	49,500	36,000	3,500	230,800	8 60

NOTE.—These plants would have an overload capacity of 50 per cent to meet peak loads. See text for details of charges given.

From the foregoing table it will be seen that the actual annual cost of keeping such a plant in reserve, without operation and without even keeping under steam continuously, would be from about $9 to $10 per horse-power year.

In the case of the Pine Falls site, the hydro-electric power per horse-power year is estimated to cost, delivered at Winnipeg and transformed down to 2,200 volts, $12.05 from the initial and $10.37 from the ultimate development.

The power generated by the steam plant during the periodic runs would be available to feed the circuits, but this would not really be a credit, for it would only replace hydro-electric power that would otherwise "run to waste." This power, on the basis above defined, would amount to about 540,000 horse-power hours, and at $12 per horse-power year, would be equivalent to about $2,700 per annum.

Cost of Fuel Power in Winnipeg compared with Hydro-Electric Power from Pine Falls.

An account of the water-power possibilities of the Winnipeg river and of the cost of hydro-electric power delivered at or near Winnipeg would hardly be a complete review of the resources of that river without a comparison of the cost of that power with fuel power produced at factories in the same neighbourhood.

It is assumed that the hydro-electric power to be developed would be transmitted to a terminal station near Winnipeg, and sold in blocks to factories that would be induced, by the low price of the power, to locate near the said terminal station.

Two specific cases will therefore be assumed, i.e., a supply of 250 horse-power and a supply of 500 horse-power.

Sources of fuel power available in Winnipeg. These consist of coal for steam plants, producer gas, and fuel oil.

The city fire department has four 500 horse-power and two 250 horse-power engines operated by producer gas for fire pressure purposes, and this plant is also used to pump water to the Canadian Pacific railroad shops.

Fuel oil at the present price of 7 cents per gallon is an economical source of power.

Manufactured gas, though it has been available for some years, is not used for power on account of the high cost.

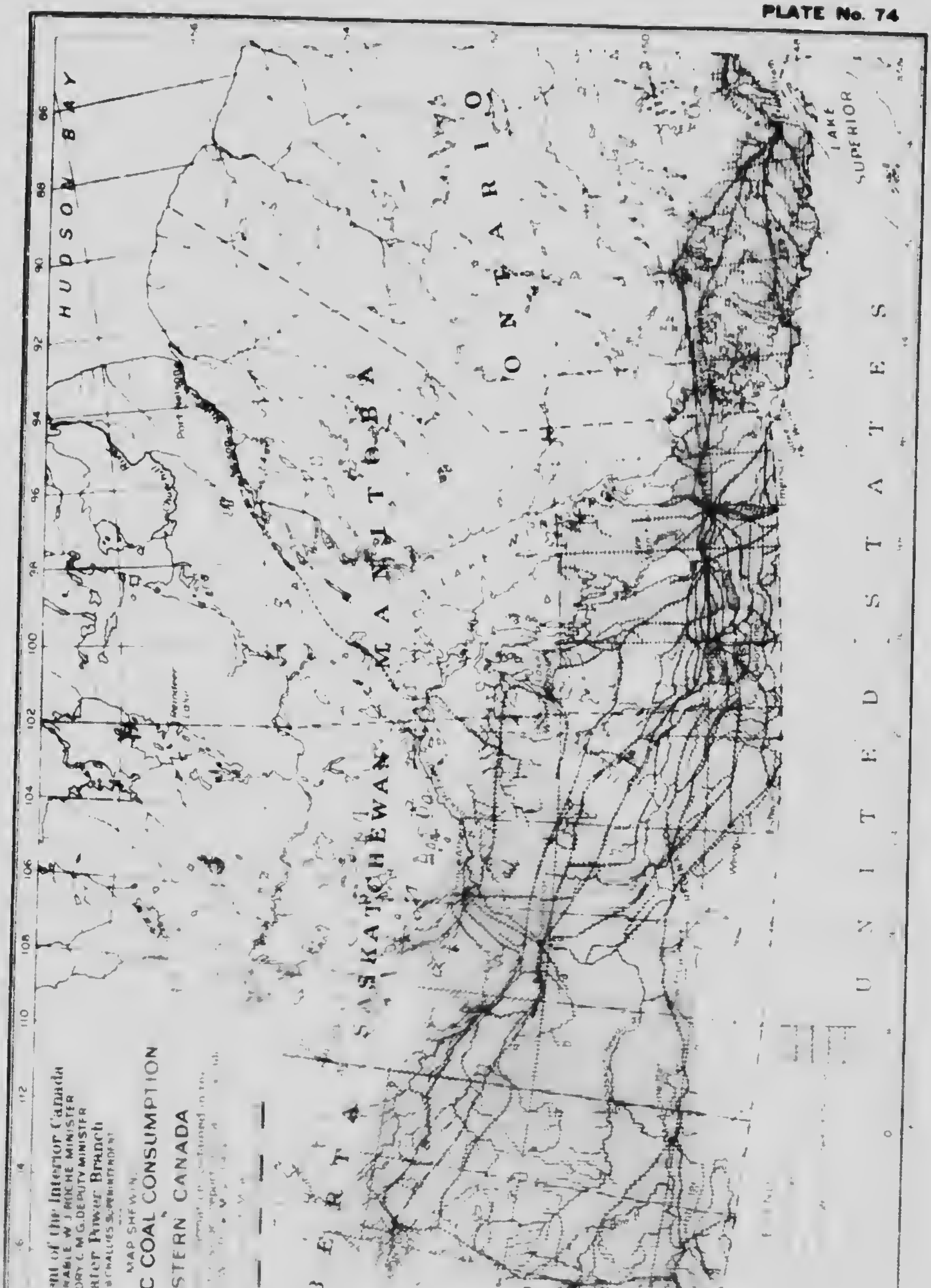
Natural gas is not available.

Steam, producer gas, and oil are therefore the only sources of fuel power to be considered.

Basis of Estimates.—The object herein is to make a fair comparison of the cost of fuel power in Winnipeg compared to low-priced hydro-electric power. Therefore, the estimates for fuel power have been put as *low* as could be reasonably done, both as to capital and operating costs.

The estimates represent the best conditions, and it is believed that few, if any, individual fuel-operated plants in the districts are obtaining or would obtain as good results in practice as those shown.

PLATE No. 74



Department of the Interior Canada
Water Power Branch
MAP SHEWING
DOMESTIC COAL CONSUMPTION
WESTERN CANADA
HUDSON BAY
ONTARIO
MANITOBA
SASKATCHEWAN
ALBERTA
UNITED STATES
LAKE SUPERIOR

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All estimates include brick buildings, single units, and no reserve plant, except a spare boiler for the steam plant, and no electric equipment. Heating and lighting is not included for either the fuel or hydro-electric plants.

Steam plants are figured on compound non-condensing engines, steam-driven auxiliaries, and feed water heaters, using Pittsburg run-of-the-mine bituminous coal at $6.25 per ton.

Oil plant is figured on Diesel engines. Fuel oil is now 7 cents per imperial gallon in Winnipeg, but is figured at 9 cents as an average price.

Producer gas is based on a pressure plant using run-of-the-mine Pittsburg bituminous coal at $6.25 per ton.

Cost of the Hydro-Electric Power. Any calculation of the cost of fuel power must include interest, depreciation, and maintenance of the plant that produces it. Similarly, to obtain the actual cost of hydro-electric power to the user, interest, depreciation, and maintenance on the electric motors and equipment must be added to the price paid for power.

The cost of fuel power is generally given per brake horse-power applied to the shaft in useful work.

Similarly, in giving the cost of hydro-electric power, it must be considered whether this is charged on the input to or output of the motor. The loss in an electric motor is from 10 to 20 per cent, depending on size and the percentage of full load at which it is worked. To compare with fuel power the cost of hydro-electric power must be stated in terms of the useful power delivered by the motor.

Some additions to the cost of hydro-electric power at the terminal station must, therefore be made in order to put it on the same basis as the fuel power.

For the purpose of this comparison we will take the Pine falls site and the prices at which it has been shown that power can be delivered at or near the city limits of Winnipeg from that source.

For ready reference these figures may be repeated here. The Pine falls power site is 64 miles from the city of Winnipeg.

Table 41.—Pine Falls Power Site on Winnipeg river.

	24 Hour Power at 75% Efficiency.		Cost at Winnipeg.	
	At the falls	At Winnipeg	Per H. P. year 24 hr power.	Per K.W. hr 50% load factor.
			$ cts.	Cents.
Initial plant	37,900	34,100	12.05	0.368
Ultimate plant	63,100	56,790	10.37	0.318

The above prices are for power delivered at a terminal station near Winnipeg and include transforming down to 2,200 volts pressure.

To these prices have been added allowances to cover the points above referred to, and the corrected prices are shown in Table 42 for comparison with fuel power.

Table 42.—Comparison of the Cost of Fuel Power in Winnipeg with power from Pine Falls. For details, see accompanying estimates.

	Capital Cost Installed Complete.	Per Horse-Power Year — Load Factor			Per Kilowatt Hour — Load Factor.		
		25%.	50%.	75%.	25%.	50%.	75%.
	$	$ cts.	$ cts.	$ cts.	Cents.	Cents.	Cents.
250 H.-P.—							
Steam	22,500	60 00	100 00	114 00	1 64	3·06	2·73
Diesel Oil ..	30,000	17 00	58 00	78 00	2 28	1·77	1·59
Producer Gas	27,500	47 00	77 50	108 00	2 88	2·37	2 20
Hydro-Electric—							
Initial	6,000	15 00	15 35	15 70	0 66	0·57	0·54
Complete..	6,000	13 30	13 70	14 10	0 60	0·51	0·48
500 H.P.—							
Steam	[illegible]2,500	52 50	87 50	115 00	3·22	2·63	2 32
Diesel Oil ..	55,000	35 50	55 50	75 50	2 18	1·50	1 54
Producer Gas..	50,000	42 50	70 00	97 00	2 60	2·13	1 97
Hydro-Electric—							
Initial.......	12,000	15 00	15 35	15 70	0 66	0·57	0 54
Complete ..	12,000	13 30	13 70	14 10	0 60	0 51	0·48

Commenting on this table, attention is drawn to the comparatively small expenditure required in connection with the use of hydro-electric power, this representing only electric motors and equipment, as against the cost of a complete fuel plant.

It will be noticed that Diesel oil plant will give power at a very reasonable rate with fuel oil at 9 cents per imperial gallon, but even then it is not comparable with the hydro-electric power.

The detailed estimates from which the table is constructed are attached hereto, and attention is again called to the remarks *re* " basis of estimates."

ESTIMATES OF COST OF STEAM, OIL, AND PRODUCER GAS POWER IN WINNIPEG.

250 B. H. P. Steam Plant.

Peak load, 250 horse-power   Average load, 75 per cent.

Capital Cost complete at $90 per b.h.p....... . . . $ 22,500

Interest, 6 per cent. Depreciation, 4 per cent.
Labour: 25 per cent load factor, one shift; 50 per cent, two shifts; 75 per cent, three shifts.
Repairs and maintenance: one shift, 2 per cent, two shifts, 3 per cent; three shifts, 4 per cent.

Production Cost.

	Load Factor — 25 per cent.	50 per cent.	75 per cent.
	$ cts.	$ cts.	$ cts.
Interest and depreciation, 10 per cent ..	2,250 00	2,250 00	2 250 00
Repairs and maintenance, as above..	450 00	675 00	900 00
Labour: 1 engineman, $90, 1 stoker, $75	1 980 00	3,960 00	5,940 00
Fuel: 1 shift, 5·5 lb.; 2 shifts, 5 lb.; 3 shifts, 4 5 lb. per b.h.p. hour at $6 25	9,400 00	17,100 00	23,000 00
Oil, waste, and supplies	350 00	600 00	900 00
Insurance, 1 per cent, taxes, 1 per cent ..	450 00	450 00	450 00
25 per cent of 8,760 hours × 250 horse-power = 547,500 b.h.p. hours per annum, 408,000 k. w. hours per annum.	14,880 00	25,035 00	33,440 00
	$ cts.	$ cts.	$ cts.
Per b.h.p. installed per annum	60 00	100 00	134 00
	Cents.	Cents.	Cents.
Per k. w. hour	3·64	3·06	2 73

ESTIMATES OF COST OF STEAM, OIL, AND PRODUCER GAS POWER IN WINNIPEG—*Continued.*

500 B. H. P. Steam Plant.

Peak load, 500 horse-power. Average load, 75 per cent.

Capital Cost complete at $85 per b.h.p. $ 42,500

Interest, 6 per cent. Depreciation, 4 per cent.
Labour: 25 per cent load factor, one shift; 50 per cent, two shifts; 75 per cent, three shifts.
Repairs and maintenance: one shift, 2 per cent; two shifts, 3 per cent; three shifts, 4 per cent.

Production Cost.

	Load Factor		
	25 per cent	50 per cent	75 per cent
	$ cts	$ cts	$ cts
Interest and depreciation, 10 per cent	4,250 00	4,250 00	4,250 00
Repairs and maintenance, as above	850 00	1,275 00	1,700 00
Labour: 1 engineman, $90; 2 stokers, $75	2,000 00	5,760 00	8,640 00
Fuel: 1 shift, 5 lb.; 2 shifts, 4·5 lb.; 3 shifts, 4 lb. per b.h.p. hour at $6.25	17,100 00	30,900 00	41,000 00
Oil, waste, and supplies	450 00	700 00	1,000 00
Insurance, 1 per cent. Taxes, 1 per cent	850 00	850 00	850 00
	26,300 00	44,735 00	57,440 00
25 per cent of 8,760 hours × 500 horse-power 1,095,000 b.h.p. hours per annum. 817,000 k.w. hours per annum.			
	$ cts	$ cts	$ cts.
Per b.h.p. installed per annum	52 50	87 50	115 00
	Cents.	Cents.	Cents.
Per k. w. hour	3·22	2·68	2·32

250 B. H. P. Diesel Oil Plant.

Peak load, 250 b.h.p. Average load, 75 per cent.

Capital Cost complete at $120 per horse-power $ 30,000

Interest, 6 per cent. Depreciation, 4 per cent.
Labour: 25 per cent load factor, one shift; 50 per cent, two shifts, 75 per cent, three shifts.
Repairs and maintenance: one shift, 2 per cent; two shifts, 3 per cent; three shifts, 4 per cent.

Production Cost.

	Load Factor		
	25 per cent.	50 per cent.	75 per cent.
	$ cts	$ cts	$ cts
Interest and depreciation at 10 per cent	3,000 00	3,000 00	3,000 00
Repairs and maintenance, as above	600 00	900 00	1,200 00
Labour: 1 man at $90; one-third time 1 man at $60	1,320 00	2,640 00	3,960 00
Fuel Oil: 0·56 lb. per b.h.p. hour at 9c. imp. gal.	3,150 00	6,300 00	9,450 00
Lubricating oil	180 00	360 00	540 00
Waste, supplies, etc.	100 00	175 00	250 00
Circulating water make up	70 00	140 00	210 00
Insurance, 2 per cent. Taxes, 1 per cent	900 00	900 00	900 00
	9,320 00	14,415 00	19,510 00
25 per cent of 8,760 hours × 250 horse-power 547,500 b.h.p. hours per annum. 408,000 k. w. hours per annum.			
	$ cts.	$ cts.	$ cts
Per b.h.p. installed per annum	37 00	58 00	80 00
	Cents.	Cents.	Cents.
Per k. w. hour	2·28	1·77	1·59

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)

1.0 1.1 1.25 1.4 1.6 1.8 2.0 2.2 2.5 2.8 3.2 3.6 4.0 4.5 5.0 5.6 6.3

ESTIMATES OF COST OF STEAM, OIL, AND PRODUCER GAS POWER IN WINNIPEG—*Continued.*

500 B.H.P. Diesel Oil Plant.

Peak load, 500 horse-power. Average load, 75 per cent.

Capital Cost complete at $110 per horse-power.................................... $ 55,000

Interest, 6 per cent. Depreciation, 4 per cent.
Labour: 25 per cent load factor, one shift; 50 per cent, two shifts; 75 per cent, three shifts.
Repairs and maintenance, one shift, 2 per cent; two shifts, 3 per cent; three shifts, 4 per cent.

Production Cost.

—	Load Factor.		
	25 per cent.	50 per cent.	75 per cent.
	$ cts.	$ cts.	$ cts.
Interest and depreciation, 10 per cent	5,500 00	5,500 00	5,500 00
Repairs and maintenance, as above	1,100 00	1,650 00	2,200 00
Labour: 1 man at $90; 1 at $70	1,920 00	3,840 00	5,760 00
Fuel Oil: 0·56 lb. per b.h.p. hour at 9c. imp. gal	6,950 00	13,900 00	20,850 00
Lubricating oil	360 00	720 00	1,080 00
Waste, supplies, etc	135 00	225 00	310 00
Circulating water make up	140 00	280 00	420 00
Insurance, 2 per cent. Taxes, 1 per cent	1,650 00	1,650 00	1,650 00
	17,755 00	27,765 00	37,[illegible]70 00
25 per cent of 8,760 hours × 500 horse-power = 1,095,000 b.h.p. hours per annum, 817,000 k. w. hours per annum.			
	$ cts.	$ cts.	$ cts.
Per b.h.p. installed per annum	35 50	55 50	75 50
	Cents.	Cents.	Cents.
Per k. w. hour	2·18	1·70	1·54

250 B.H.P. Producer Gas Plant.

Peak load, 250 horse-power. Average load, 75 per cent.

Capital Cost complete at $110 per horse-power.................................... $ 27,500

Interest, 6 per cent. Depreciation, 5 per cent
Labour: 25 per cent load factor, one shift; 50 per cent, two shifts; 75 per cent, three shifts.
Repairs and maintenance: one shift, 3 per cent; two shifts, 4 per cent; three shifts, 5 per cent.

Production Cost.

—	Load Factor.		
	25 per cent.	50 per cent.	75 per cent.
	$ cts.	$ cts.	$ cts.
Interest and depreciation, 11 per cent	3,025 00	3,025 00	3,025 00
Repairs and maintenance as above	825 00	1,100 00	1,375 00
Labour: 2 men per shift	1,980 00	3,960 00	5,940 00
Fuel: 3 lb. per b.h.p. hour at $6.25	5,150 00	10,300 00	15,450 00
Oil, waste and supplies	250 00	450 00	650 00
Insurance, 1 per cent. Taxes, 1 per cent	550 00	550 00	550 00
	11,780 00	19,385 00	26,990 00
25 per cent of 8,760 hours × 250 horse-power = 547,500 b.h.p. hours per annum, 408,000 k. w. hours per annum.			
	$ cts.	$ cts.	$ cts.
Per b.h.p. installed per annum	47 00	77 50	108 00
	Cents.	Cents.	Cents.
Per k. w. hour	2·88	2·37	2·20

ESTIMATES OF COST OF STEAM, OIL, AND PRODUCER GAS POWER IN WINNIPEG—*Continued.*

500 B.H.P. Producer Gas Plant.

Peak load, 500 horse-power. Average load, 75 per cent.

Capital Cost complete at $100 per horse-power . . $ 50,000

Interest, 6 per cent. Depreciation, 5 per cent.
Labour: 25 per cent load factor, one shift; 50 per cent, two shifts, 75 per cent, three shifts.
Repairs and maintenance: one shift, 3 per cent; two shifts, 4 per cent, three shifts, 5 per cent

Production Cost.

—	Load Factor. 25 per cent.	50 per cent.	75 per cent.
	$ cts.	$ cts.	$ cts.
Interest and depreciation, 11 per cent	5,500 00	5,500 00	5,500 00
Repairs and maintenance, as above	1,500 00	2,000 00	2,500 00
Labour: 2½ men per shift	2,500 00	5,000 00	7,500 00
Fuel: 3 lb. per b.h.p. hour at $6 25	10,300 00	20,600 00	30,900 00
Oil, waste, and supplies	450 00	750 00	1,050 00
Insurance, 1 per cent. Taxes, 1 per cent	1,000 00	1,000 00	1,000 00
	21,250 00	34,850 00	48,450 00
25 per cent of 8,760 hours × 500 horse-power 1,095,000 b.h.p. hours per annum. 817,000 k. w. hours per annum.			
	$ cts.	$ cts.	$ cts.
Per h.h.p. installed per annum	42 50	70 00	97 00
	Cents.	Cents.	Cents.
Per k. w. hour	2·60	2·13	1·97

COST OF HYDRO ELECTRIC POWER.

On account of the subdivision in applying the electric drive the connected horse-power is generally a good deal larger than the peak load taken.

For 250 horse-power load probably some 300 horse-power of motors would be installed ranging from 5 to 50 horse-power. These would cost, installed complete, about $15 per horse-power.

Power would be available at the terminal station at the price quoted at 2,200 volts. While motors are now frequently used at that voltage it is more usual to transform down to 220 or 440 volts. Transformers for this purpose, with housing and switching equipment, would cost about $8 per kilowatt or $6 per horse-power.

If the charge for power was based on the rated horse-power of motors connected, the question of the loss in the motors would not come in.

If, however, the charge was based on the metered kilowatt hours, this would be measured on the high-tension side of the transformers and to compare the charge with that for fuel power, expressed per brake horse-power hour, it would be necessary to allow say 17½ per cent for loss in transformers and motors at varying loads.

250 B.H.P. Hydro-Electric Power.

Costs to be added to Cost of Power at Terminal Station.

Peak load, 250 b.h.p. Average load, 75 per cent.

Capital cost—

300 b.h.p. of motors installed complete at $15	$ 4,500
250 h.p. of transformers and equipment at $6	1,500
	$ 6,000

Interest, 6 per cent. Depreciation, 4 per cent.
Repairs and maintenance: one shift, 1 per cent; two shifts, 2 per cent; three shifts, 3 per cent.

—	Load Factors.		
	25 per cent.	50 per cent.	75 per cent.
	$ cts.	$ cts.	$ cts.
Interest and depreciation, 10 per cent	600 00	600 00	600 00
Repairs and maintenance	60 00	120 00	180 00
Labour and oil	100 00	150 00	200 00
Insurance, 1 per cent. Taxes, 1 per cent	120 00	120 00	120 00
Totals	880 00	990 00	1,100 00
Per Horse-Power Year.			
If power is charged per rated horse-power of motors connected (300 horse-power) the extra cost per horse-power will therefore be	$ cts. 2 93	$ cts. 3 30	$ cts. 3 66
The cost at the terminal station is:— Initial plant, $12.05; Final 10.37.			
The total cost per horse-power year to the user will therefore be, under the—			
Initial development	14 98	15 35	15 73
Ultimate development	13 30	13 67	14 05
Per Kilowatt Hour.			
25 per cent of 8,760 hours × 250 horse-power = 547,500 b.h.p. hours on the shaft or tools. Loss in transformers and motors, average, say 17½ per cent. $547{,}500 \times \frac{100}{82\cdot5} = 663{,}500 \times \frac{746}{10000} = 495{,}000$ k.w. hours to be paid for, on 25 per cent load factor.			
Initial Development.	$ cts.	$ cts.	$ cts.
Metered k.w.h. at 0·368 cent	1,820 00	3,640 00	5,460 00
Additional costs as in preceding table	880 00	990 00	1,100 00
Totals	2,700 00	4,630 00	6,560 00
Ultimate Development.	$ cts.	$ cts.	$ cts.
Metered k.w.h. at 0·318 cent	1,580 00	3,160 00	4,740 00
Additional costs	880 00	990 00	1,100 00
Totals	2,460 00	4,150 00	5,840 00
495,000 k.w.h. is the amount paid for. 408,000 is the equivalent applied on shaft.			
Cost per k.w. hour. On latter basis as for fuel power—	Cents.	Cents.	Cents.
Under initial development	0·661	0·567	0·536
Under ultimate development	0·602	0·508	0·476

500 B.H.P. Hydro-Electric Power.

The rates would be increased in practically the same proportion in the case of 500 horse-power as for 250 horse-power, and may therefore be considered to be same as given for 250 horse-power.

REPORT

ON

THE WINNIPEG RIVER POWER AND STORAGE INVESTIGATIONS

CHAPTER VIII.

MARKET FOR POWER

CHAPTER VIII.

MARKET FOR POWER.

While it is not the intention in this report to go deeply into the power market situation in Manitoba, it is necessary, in order to secure a proper appreciation of the uses to which the power resources of the Winnipeg river may be applied, to briefly cover the main features. However excessive the latent power in the river may now appear, there is not the slightest doubt that profitable employment for the whole will be found, and that in the not distant future. In view of the almost unprecedented rapidity of the development of Western Canada, and of its undoubted continuance in the immediate future, the power resources of the Winnipeg possess added value, and the necessity for their conservation to meet this development is fully appreciated by water-power engineers of the department.

The advances which have been and are constantly being made in long-distance transmission have greatly extended the scope of power distribution. Markets which a few years ago were considered entirely beyond the reach of central hydro-electric stations are now within transmission distance and are being profitably developed. Transmission lines from 100 to 200 miles in length are now commonplace, while in California electric energy is being transmitted 240 miles. It is unlikely that the limit of long-distance transmission has been reached, but sufficient has been said to indicate the scope of the territory tributary to the Winnipeg river.

The constantly increasing industrial and domestic use of electrical energy, and the new uses which are constantly being discovered for its application, all tend to a future increase in the general power demand.

Ratio of Horse-power Installed to Population.

No general rule can be laid down establishing a fixed ratio between power requirements and population. The ratio is largely dependent upon the general living conditions, the distribution of industrial life, and the natural opportunities for successful economic power production. At the same time, in definite areas, the general relation of power generated to population serves at least as an indication of the power demand which may be anticipated in similar districts and territories.

The relation which the general occupation of the population bears to the power developed is marked, but cannot be applied indiscriminately to all sections, since it is largely combined with, and dependent on, existing physical opportunities for successful development. Water-power in any section is of course entirely based upon the physical features relating to and controlling the run-off, though its successful development where the opportunity exists, depends on market opportunities, and on the degree of competition from other power sources. In other words, while a water-power undertaking in one section of the country may prove an unsuccessful commercial venture, a similar and equally costly development may in different surroundings and und[illegible]ferent conditions of competition prove entirely efficient and successful.

Canada as Compared with Other Countries.

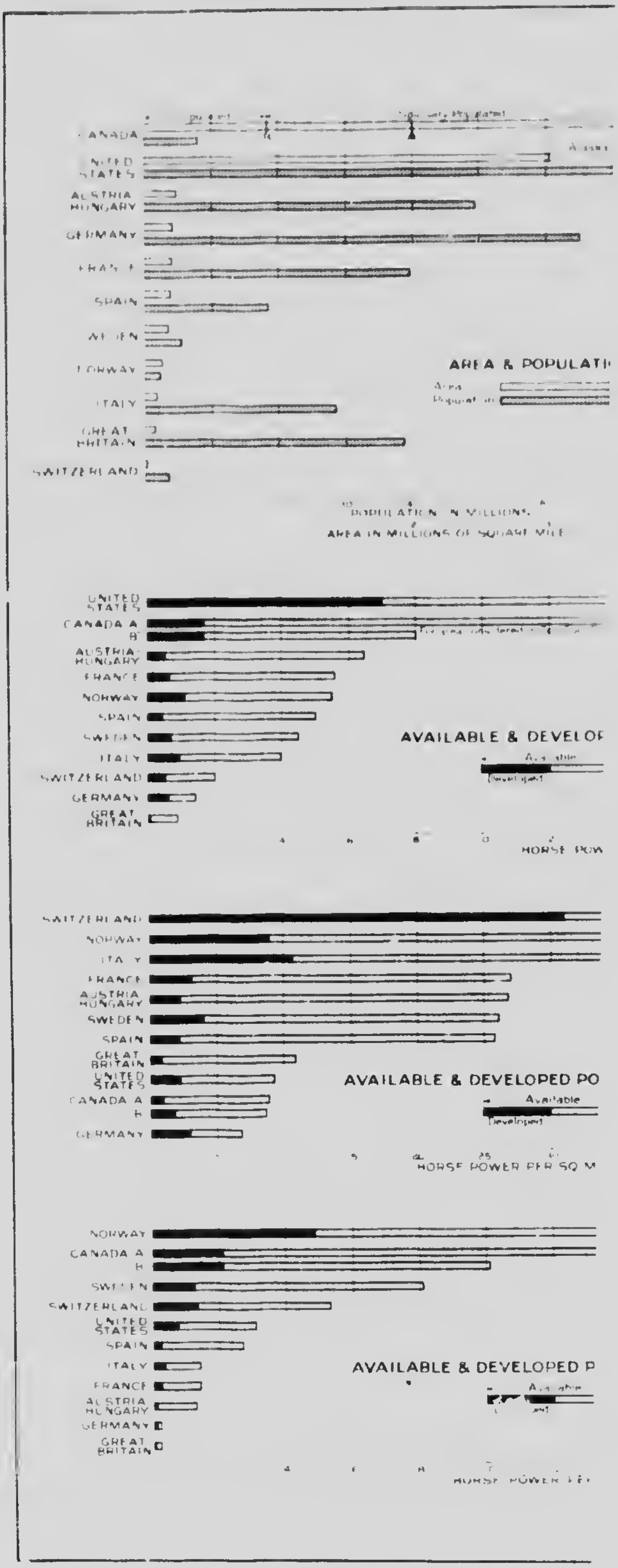
A general review of the present status of hydro-electric power development in the leading countries of the world is of interest in this connection, and to this end table 43 and plate 75 have been compiled and are appended.

In compiling data of this nature, considerable research was required and dependence had necessarily to be placed on data from various sources. The results are not given, therefore, as depicting accurately the exact status of hydro-electric development in the various countries listed, but are given merely as an indication of the comparative degree of progress which has been made along these lines. The figures for the United States are taken from the evidence given in December, 1914, before the Senate Committee on the Ferris Water-Power Bill. For the Dominion of Canada, the paucity of definite information concerning the rivers in the northern portions of the country prevents any accurate statement of the available undeveloped power. One estimate of 17,820,000 horse-power has been made in this connection, which, while probably based on meagre information with regard to the northern rivers, is the best figure available. It should, however, be used with reserve. The developed power in Canada is placed at 1,711,000 horse-power, and represents the compilation to date by the engineers of the Dominion Water Power Branch. For the purposes of comparison, Canada has been considered both in terms of its whole area and of the populated area. This has been considered advisable in view of the vast expanse of at present practically uninhabited area in the north.

A reference to the table and plate shows the Dominion as comparing well with other countries in the status of water-power development. While the ratio of power developed per square mile does not compare with Switzerland, Norway, Italy, Sweden, and other countries smaller in area or more advanced in settlement, the ratio of power developed to population places Canada second in positio[illegible] to Norway. The development per capita for the two countries [illegible]ely 0·210 and 0·487 or 210 horse-power and 487 horse-power per 1,000 [illegible].

Hydro-Electric Development in the United States.

In the United States the present total development of hydro-electric energy amounts to 7,000,000 horse-power, or at a ratio of 76 per 1,000 population. A report issued by the Commissioner of Corporations on water-power development in the United States dated March 4, 1912, lists data which are of general interest in viewing the growth of hydro-electric power in recent years. This report places the total prime moving stationary power installed in the United States in 1907 for manufacturing, mining, and quarrying, street and electric railways, and at central stations at practically 22,912,013 horse-power. This total is stated as being probably below the actual figure, as a considerable volume of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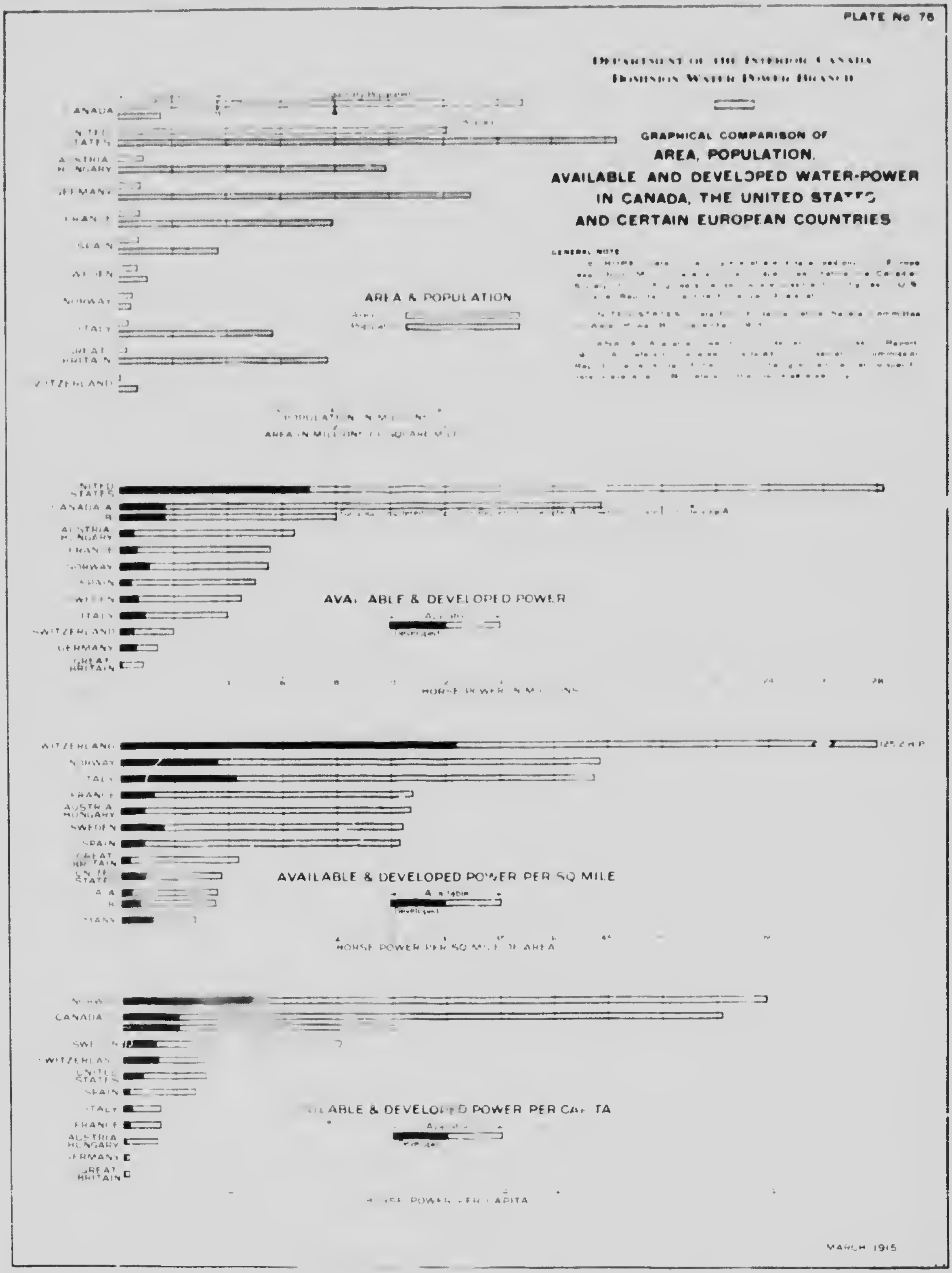
PLATE No 76
DEPARTMENT OF THE INTERIOR CANADA
DOMINION WATER POWER BRANCH
GRAPHICAL COMPARISON OF
AREA, POPULATION,
AVAILABLE AND DEVELOPED WATER-POWER
IN CANADA, THE UNITED STATES
AND CERTAIN EUROPEAN COUNTRIES
AREA & POPULATION
AVAILABLE & DEVELOPED POWER
AVAILABLE & DEVELOPED POWER PER SQ MILE
HORSE POWER PER SQ MILE OF AREA
CANADA
GERMANY
HORSE POWER PER CAPITA
MARCH 1915

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Table 43.—Comparative Status of Available Water-Power and of Developed Water-Power in Canada and other countr[illegible]

Country.	Area (Square Miles).	Population (latest available figures.)	H.P. Available Estimated to end of 1914.	H.P. Developed Estimated to end of 1914.	Percentage of Utilization.	H.P. per Square Mile of Area		H.P. per Capita	
						Available	Developed	Available.	Developed
1.	2	3.	4.	5.	6	7	8	9	10
Canada	3,729,700	[1]18,013,500	17,820,000	1,710,843	9.6	4.7	0.46	2.2	0.210
" Area populated	927,800	8,000,000	8,094,000	1,700,000	21.0	8.74	1.83	1.01	0.210
United States	[2]3,026,600	92,019,900	28,100,000	7,000,000	24.9	9.30	2.41	0.31	0.076
Austria-Hungary	241,330	49,418,600	6,460,000	566,000	8.8	26.80	2.33	0.13	0.013
France	207,100	39,601,500	5,587,000	650,000	11.6	27.00	3.14	0.14	0.016
Norway	124,130	2,402,700	5,500,000	1,120,000	20.4	44.30	9.02	2.39	0.487
Spain	194,700	18,618,100	5,000,000	440,000	8.8	25.70	2.27	0.27	0.024
Sweden	172,900	5,521,900	4,500,000	704,500	15.6	26.00	4.08	0.81	0.127
Italy	91,280	28,601,600	4,000,000	976,300	24.4	43.80	10.7	0.14	0.034
Switzerland	15,976	3,742,000	2,000,000	511,000	25.5	125.20	32.0	0.53	0.137
Germany	208,800	64,903,400	1,425,000	618,100	43.4	6.80	2.96	0.02	0.010
Great Britain	88,120	38,802,500	963,000	80,000	8.3	10.90	0.93	0.02	0.002

[1]Based on 12 per cent increase on official census of 1911.
[2]Does not include Alaska.

power in the aggregate was generated in small isolated plants, and was not covered in the tabulation. Also, the figures for the mines and quarries were complete only for 1902, and those of the manufactures were for 1905, while the balance were for 1907. Undoubtedly there was a marked addition during the omitted years, which would have considerably increased the total.

The three primary sources of the total power as listed were steam, water, and gas, supplying 18,858,000 horse-power, 3,423,000 horse-power, and 631,000 horse-power, or 82·3 per cent, 14·9 per cent, and 2·8 per cent, respectively. One of the most interesting features of the report is found in the data relative to the then recent development of central power installations distributing to more or less distant markets. The increase in the use of water-power in this connection during the period 1902 to 1907 was 208 per cent.

Returning to the listed total in table 43, the water-power now developed in the United States is 7,000,000 horse-power, or more than double the total for 1907. What proportion of this increase is due to the development of central stations for distribution to distant markets is not ascertainable from the data on hand. A review of the recent tendency in the construction of hydro-electric undertakings is sufficient, however, to indicate that the greater proportion has been so utilized. As covering the whole extent of the United States, the above is indicative of the rapid progress which has been made during recent years in the development of power projects distant from prospective markets, a progress that has been rendered possible by the advances in electrical transmission.

The results secured from a broad-based distribution of the above nature cannot, however, be applied indiscriminately to all sections of the country. A ratio of 76 horse-power per 1,000 population for the United States as a whole falls as low as 2 horse-power per 1,000 for Ohio, and rises to 650 horse-power per 1,000 in Montana.

It is apparent, therefore, that the distribution of water-power development is dependent not only on the natural facilities for cheap development, but also on the accessibility of a suitable market for the disposal of the energy. It is also evident that this market is not solely dependent on population.

Hydro-Electric Development in Canada.

Turning to the power situation in Canada, table 44 will be of interest. The developed power tabulated has been largely collected by engineers of the Dominion Water Power Branch, and is complete to the end of 1914. While the totals are not considered to be far astray, they cannot be taken as entirely accurate, since, due to lack of time, it has been necessary to place dependence on information from various unofficial sources. The population of the various provinces are based on a 12 per cent increase on the official census returns of 1911. The ratio of power developed to population as deduced from the above is a fair representation of the conditions maintaining in the Dominion to date.

The general ratio of water-power developed, taking the Dominion as a whole, is 214 horse-power per 1,000 population. A reference to the table will indicate that this distribution is by no means uniform throughout the provinces and the relation between the physical characteristics of the country, the occupa-

Table 44.—Ratio of Developed Power to Population in Canada.

Province.	Population.	Electrical Energy.		Pulp and Paper.		Other Industries.		Grand Total.	
		Total.	Per 1,000 Inhabitants.	Total.	Per 1,000 Inhabitants.	Total.	Per 1,000 Inhabitants.	For Province.	Per 1,000 Inhabitants.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
		H.-p.	H.-p.	H.-p.	H.-p.	H.-p.	H.-p.	H.-p.	H.-p.
Ontario	2,825,000	632,083	223·8	83,375	29·5	74,008	26·2	789,466	279·5
Quebec	2,230,000	370,000	165·9	100,000	44·9	50,000	22·4	520,000	233·2
Nova Scotia	551,000	3,062	5·6	12,650	23·0	5,700	10·3	21,412	38·9
New Brunswick	394,000	5,890	15·0	3,050	7·7	4,450	11·3	13,390	34·0
Prince Edward Island	105,000	50	0·5	...	...	450	4·3	500	4·8
Manitoba	510,000	56,730	111·2	...		50	0·1	56,780	111·4
Saskatchewan	551,000		...	...		100	0·2	100	0·2
Alberta	419,000	32,305	77·1					32,305	77·1
British Columbia	439,000	216,345	493·0	49,000	111·3	4,275	9·7	269,620	614·0
Yukon	9,500	12,000	126·4					12,000	126·4
Total	8,033,500	1,328,465	165·5	248,075	30·9	139,033	17·3	1,715,573	213·7

Note.—The population of the provinces is based upon a 12 per cent increase over the official census for 1911.

tion of the local population, and the power developed, is at once apparent. Ontario, Quebec, Manitoba, and British Columbia are all well supplied with the natural facilities for successful water-power development, as is indicated by the ratios of 279, 233, 111, and 614 horse-power per 1,000 population respectively. In the Yukon, where the population is small and largely engaged in mining, the proportionate power developed is high. In the mountainous province of British Columbia, where high heads and an abundant run-off supply exceptional facilities for successful power development, and where the population is comparatively small, the proportionate power developed per head is exceptionally high. The industrial and urban life in Ontario and Quebec is making large demands on the respective water-power resources of the two provinces, and development keeps pace with a rapidly growing market.

Different conditions exist in the central prairie provinces. The population is largely rural, and the physical characteristics of the Middle West do not supply the conditions of uniform run-off and natural river fall essential to the cheap and immediate development of power from water. The rivers throughout this section are irregular in flow, with high floods and low winter discharges, and with fairly uniform but slow fall. Storage reservoirs for the relief of the extreme low-water winter conditions must form a necessary adjunct to the successful development of large undertakings throughout the central portion of the West. This has had the effect up to the present of restricting development, especially in the province of Saskatchewan, in spite of rapidly growing towns and cities which provide a ready and suitable power market. The province of Alberta, with the eastern slope of the Rocky mountains lying along its western border, provides better facilities for the development of hydro-electric undertakings.

At the time of writing there is upwards of 30,000 -horse-power turbine capacity installed on the Bow river at the Horseshoe and Kananaskis falls, the greater part of which is transmitted to Calgary and, together with a smaller development within the city limits, renders available about 20,000 horse-power for the supply of the city, the population of which is in the neighbourhood of 74,000. The ratio in this instance becomes about 270 horse-power per 1,000.

In the province of Manitoba, with which this report is mainly interested, the Winnipeg river was early recognized as a source of cheap power, to the end that a ratio of 111 developed horse-power per 1,000 inhabitants is shown in the above table. This is a high average for a population mainly engaged in agricultural pursuits. On looking into the distribution of the power consumers, however, the situation in the province emphasizes more strongly the influence of an urban population.

Of the total tabulated above for Manitoba, 50,000 horse-power is developed on the Winnipeg river, about 45,000 horse-power of which is available on the Winnipeg terminals for use in and around the municipality for purposes of street railway operation, lighting, heating, industrial and domestic use.

The general electrical power load in Winnipeg is at present carried by the two hydro-electric plants on the Winnipeg river, and by the auxiliary steam plant of the Electric Railway Company in the city. A combined peak load of over 40,000 kilowatts or about 55,000 horse-power is frequently carried. On this basis, the general power requirements of the city are in the ratio of 260 horse-power per 1,000 population. In deducing the power requirements of the city of Winnipeg, this figure cannot be considered too high in view of the power which is in use throughout the city from other sources. It is probable that the ratio will rise rapidly in the future with the further development of industrial activity.

* * * * * * *

A summary of the above data respecting the relation of water-power development to the number of population would serve to emphasize that, granting the existence of a supply of power capable of profitable development in competition with power from other sources, the ratio of development is not dependent so much upon the mere extent of the population as to the grouping of the same in industrial centres within easy and convenient transmission distance of the power sources.

This conclusion is illustrated definitely and concretely in the discussion and estimates on hydro-electric distribution in Manitoba, dealt with at a later stage.

The Winnipeg Market.

The market which first presents itself for the disposal of the Winnipeg river power is that of the city of Winnipeg. The growth of this city has been one of the remarkable features of the general development of the Canadian West.

HISTORY AND GROWTH OF THE CITY.

As a trading post of the Hudson's Bay Company, Winnipeg had a long and varied history, with, however, little growth in population or industry. In the year 1812, Lord Selkirk established his colonists in the Red River valley, but lack of trade outlet prevented any real progress. With Confederation,the securing of the Hudson Bay territory from the Hudson's Bay Company, and the suppression of the Riel rebellion by Colonel, afterwards Lord Wolseley, a new order came into being, and the development of the western territory commenced, with Winnipeg as the portal to the new Empire.

In 1870, Winnipeg, then a Hudson's Bay trading post, had a population of 215. In 1874 a population of 1,869 had assembled, and Winnipeg was incorporated as a city. In 1878 the first steam railway reached the city, coming in from the United States to the south. This was followed in 1886 by the advent of the Canadian Pacific from Eastern Canada, and the era of rapid development had arrived. Railway extension proceeded with unexampled rapidity until to-day the city is the hub of five railroad systems, with a total of fifteen radiating lines. The tabulated increase in yearly population, realty values, etc., based on the assessment records, and appended herewith, illustrates concisely the growth of the city.

Table 45.—Increase in Population, Realty Values, Building Permits, and Factory Output of the City of Winnipeg.

Year.	Population.		Realty Value.	Building Permits.	Factory Output.
	City of Winnipeg.	Greater Winnipeg.			
1.	2.	3.	4.	5.	6.
			$	$	$
1870	215				
1874	1,869				
1885	19,574				
1898	39,384				
1900	42,500	50,500			8,606,248
1902	48,411		30,496,920	2,408,125	
1903	56,741		38,596,680	5,689,400	
1904	67,262		50,595,900	9,651,750	
1905	79,975	97,401	65,662,240	10,840,150	18,983,248
1906	101,057	119,837	84,752,580	12,625,950	
1907	111,729	136,953	112,413,900	6,309,950	
1908	118,252	139,869	124,523,160	5,513,700	
1909	122,390	157,383	131,402,840	9,226,325	
1910	132,720	172,865	185,870,140	15,116,450	39,400,608
1911	151,958	204,145	200,[illegible]88,600	17,550,400	
1912	166,553	227,339	247,601,580	20,563,750	
1913	184,730	260,436	299,698,980	18,357,150	
1914	210,000	276,177			[1]45,000,000

[1]Estimated by Winnipeg Industrial Bureau.
Column 2, from city assessment records.
Column 3, from Henderson's Directories, Limited.

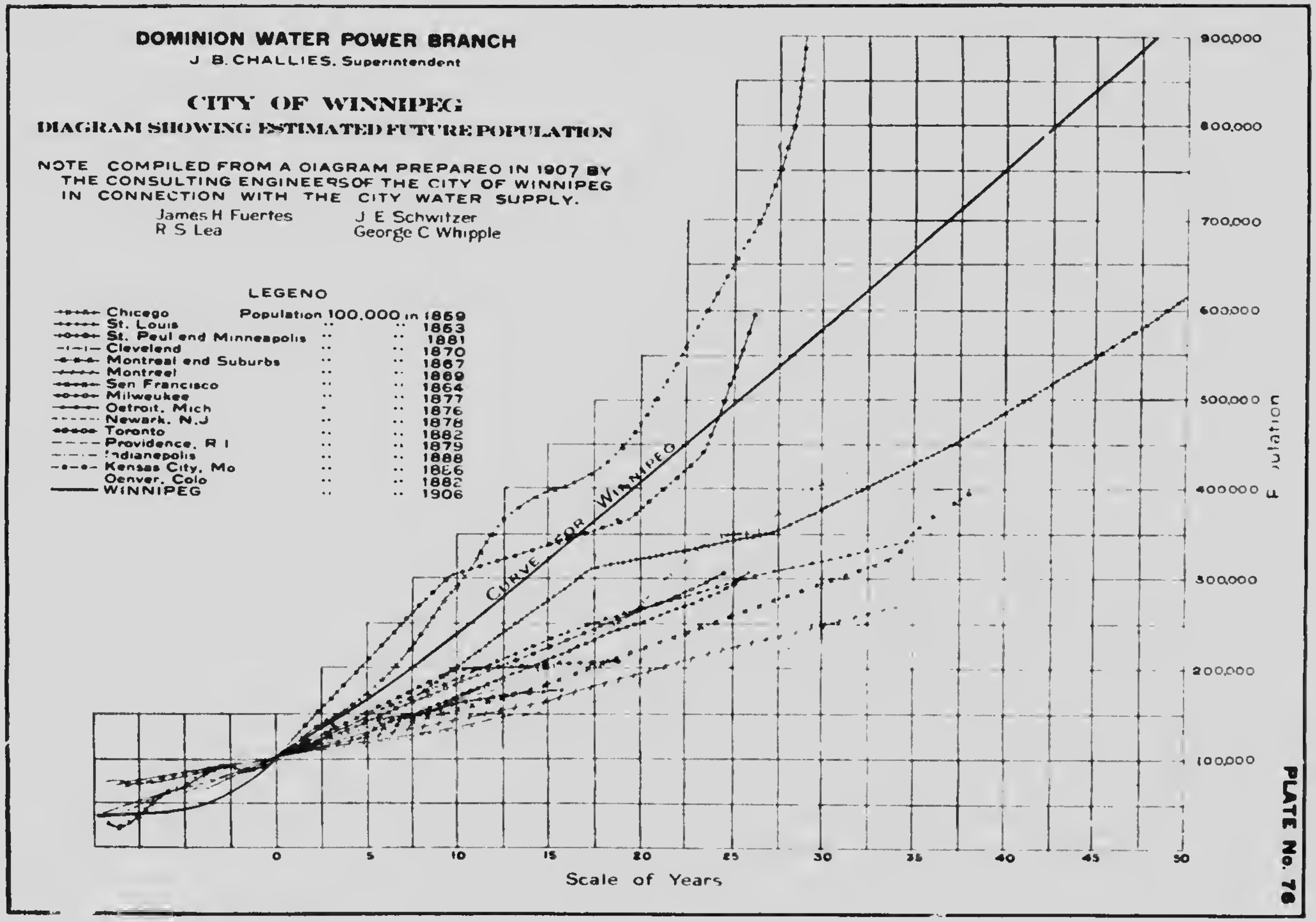
Twenty years from the date at which the population was only 215, the city had over 40,000 people. In the five years following 1902 the population was doubled. In 1914 the population is estimated, from assessment records, at 210,000. Including the surrounding municipalities which are comprised in the Greater Winnipeg Water district, i.e., St. Boniface, Transcona, Assiniboia, Fort Garry, St. Vital, and Kildonan, the total population is 237,000.([1])

In this connection, plate 76 is of interest. The curves thereon were compiled by the Board of Consulting Engineers, reporting to the Winnipeg Water Supply Commission in 1907, on the question of an adequate source of water supply for the future needs of the city. The curves show the relative rate of increase of the various cities of Canada and the United States after attaining a population of 100,000. According to the deduced curve of growth for Winnipeg, the population in 1914 should have been about 220,000. Reference to table 45 and to the population of the Greater Winnipeg Water District shows how closely the estimates of the engineers have been fulfilled.

The assumption that the rate of growth shown by the curve will continue in the future, will give to Winnipeg a population of 800,000 in the year 1948. Considering the past progress of the city and its unequalled situation and opportunities as the gateway of the West, and the abundant supply of cheap power within easy transmission distance this estimate does not seem unreasonable.

As was noted above, the present consumption of power in Winnipeg rises during peak loads to 260 horse-power per 1,000 population. The equivalent continuous power actually used is on the basis of 140 horse-power per 1,000.

[1]Henderson's directory for Winnipeg for the year 1915 gives the population of Greater Winnipeg as 273,047.


DOMINION WATER POWER BRANCH
J. B. CHALLIES, Superintendent
CITY OF WINNIPEG
DIAGRAM SHOWING ESTIMATED FUTURE POPULATION
NOTE COMPILED FROM A DIAGRAM PREPARED IN 1907 BY THE CONSULTING ENGINEERS OF THE CITY OF WINNIPEG IN CONNECTION WITH THE CITY WATER SUPPLY.
James H Fuertes
R S Lea
J E Schwitzer
George C Whipple
LEGEND
Chicago Population 100,000 in 1869
St. Louis 1863
St. Paul and Minneapolis 1881
Cleveland 1870
Montreal and Suburbs 1867
Montreal 1869
San Francisco 1864
Milwaukee 1877
Detroit, Mich 1876
Newark, N.J 1878
Toronto 1882
Providence, R I 1879
Indianapolis 1888
Kansas City, Mo 1886
Denver, Colo 1882
WINNIPEG 1906
CURVE FOR WINNIPEG
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
Population
0
5
10
15
20
25
30
35
40
45
50
Scale of Years
PLATE No. 76

A population of 800,000 in 1948 would, on this basis, require some 200,000 horse-power available for peak-load distribution. This would, conservatively speaking, mean a development of 225,000 peak load on the river, or say 140,000 continuous horse-power.

According to the totals compiled elsewhere in this report, 418,000 twenty-four hour horse-power can be developed on the regulated river. The above calculation indicates that, after reserving sufficient power *at the present rate of consumption* to supply the city's requirements till 1948, there would still be an ample balance of available power on the river to use for other purposes. However, reference to the proportionate power growth curve on plate 78 shows a rapidly increasing use of electrical energy per head of population, and assuming that this rate of increase continues, indicates that practically the entire output from the river would be required by the city in about forty years.

The curve on plate 77 indicates the growth of power consumption in the city. This curve represents in terms of kilowatt hours per month and in continuous horse-power, the total load used in and around Winnipeg, from the Winnipeg Electric Railway Company's hydro-electric and steam plants and from the municipal plant at Point du Bois. The load carried by the steam plant prior to the construction of the Pinawa station in 1906 is not plotted. From this date the curve shows a growth from zero to 15,000,000 kilowatt hours per month, or to some 28,000 continuous horse-power.

In this connection, table 46 is of interest as showing the growth of the ratio of power used to the population.

The curve on plate 78 is based on table 46. It is to be noted that the ratio of power consumption to the population has been growing continuously and regularly since hydro-electric power was first transmitted to the city. The regularity of this proportionate increase is remarkable. With the abundance of power seeking market, and the industrial growth of the city at present in its vigorous infancy, there is every reason to anticipate that this proportionate use of power will continue to increase.

Plates 79 and 80 are also of interest in this connection as showing the general conditions of daily load maintaining in the city under typical summer and early winter conditions.

INDUSTRIAL DEVELOPMENT.

In recent years an active campaign has been inaugurated looking to the establishment of Winnipeg as an industrial centre. The opportunities in this direction can be readily realized when the location of the city is noted, lying as it does at the threshold of the agricultural West, and in close touch with an abundance of cheap power to the east. The enormous influx of people to the new lands has created a heavy and constantly growing demand for manufactured goods which offers possibilities to the city in the manufacturing line that the municipal authorities have not been slow to realize.

It is difficult to determine the exact quantity of manufactured goods brought annually into the West, but the railroad receipts at Winnipeg, covering some of the heaviest lines of imports, give a fairly accurate idea of how great is the flow of industrial products through this city into Western Canada.

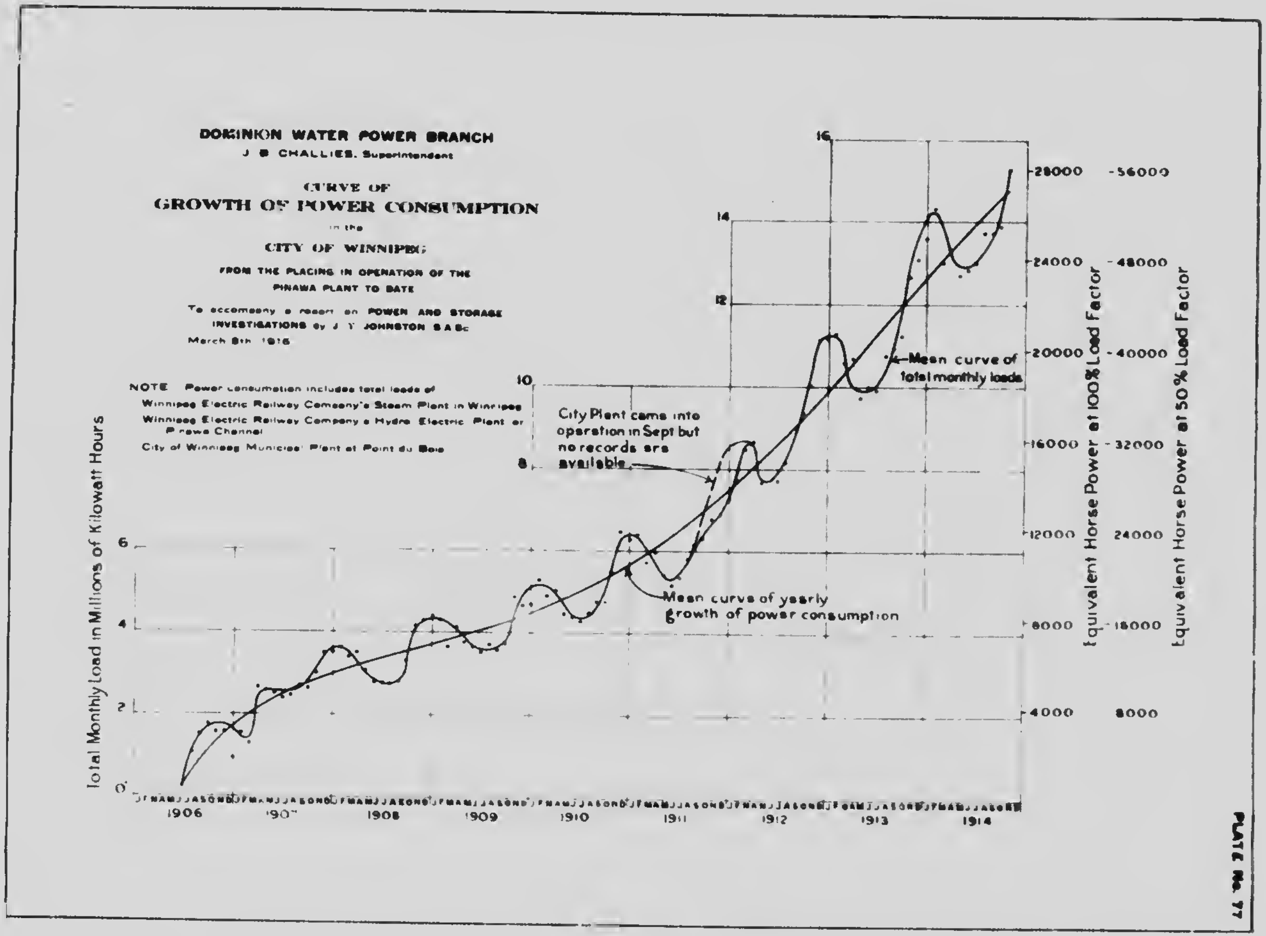

DOMINION WATER POWER BRANCH
J. B. CHALLIES, Superintendent
CURVE OF
GROWTH OF POWER CONSUMPTION
in the
CITY OF WINNIPEG
FROM THE PLACING IN OPERATION OF THE
PINAWA PLANT TO DATE
To accompany a report on POWER AND STORAGE
INVESTIGATIONS by J. T. JOHNSTON B.A.Sc.
March 8th 1916
NOTE Power consumption includes total loads of
Winnipeg Electric Railway Company's Steam Plant in Winnipeg
Winnipeg Electric Railway Company's Hydro Electric Plant on Pinawa Channel
City of Winnipeg Municipal Plant at Point du Bois
City Plant came into operation in Sept but no records are available
Mean curve of total monthly loads
Mean curve of yearly growth of power consumption
Total Monthly Load in Millions of Kilowatt Hours
Equivalent Horse Power at 100% Load Factor
Equivalent Horse Power at 50% Load Factor
1906
1907
1908
1909
1910
1911
1912
1913
1914

PLATE No. 77

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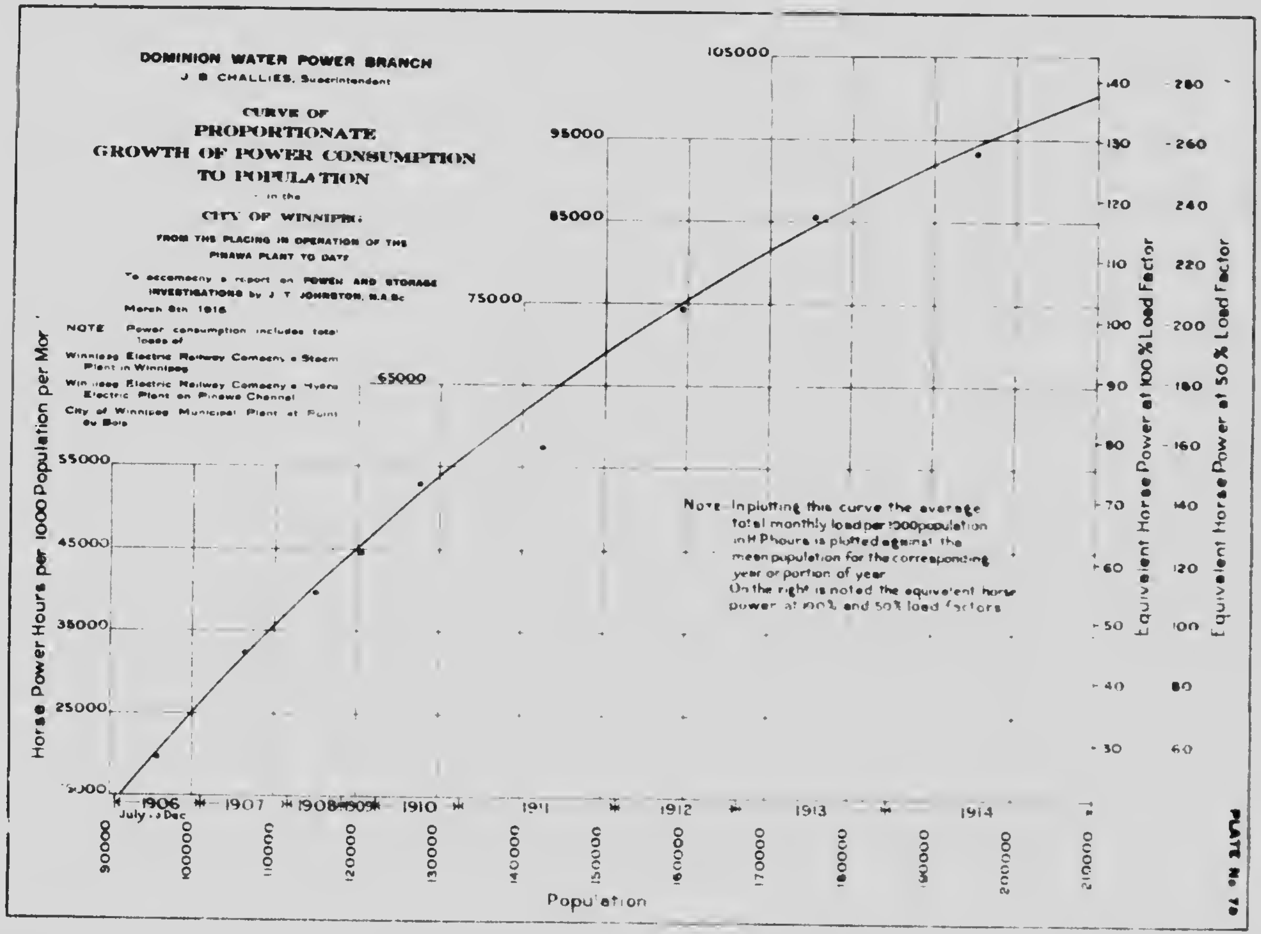

DOMINION WATER POWER BRANCH
J. B. CHALLIES, Superintendent
CURVE OF
PROPORTIONATE
GROWTH OF POWER CONSUMPTION
TO POPULATION
in the
CITY OF WINNIPEG
FROM THE PLACING IN OPERATION OF THE
PINAWA PLANT TO DATE
To accompany a report on POWER AND STORAGE
INVESTIGATIONS by J. T. JOHNSTON, B.A.Sc
March 8th 1916
NOTE Power consumption includes total loads of
Winnipeg Electric Railway Company's Steam Plant in Winnipeg
Winnipeg Electric Railway Company's Hydro Electric Plant on Pinawa Channel
City of Winnipeg Municipal Plant at Point du Bois
Note In plotting this curve the average total monthly load per 1000 population in H.P. hours is plotted against the mean population for the corresponding year or portion of year
On the right is noted the equivalent horse power at 100% and 50% load factors
Horse Power Hours per 1000 Population per Mo
Population
Equivalent Horse Power at 100% Load Factor
Equivalent Horse Power at 50% Load Factor
1906 July to Dec
1907
1908
1909
1910
1911
1912
1913
1914
PLATE No. 7

Table 46.—Ratio of the Growth of the Total Electrical energy used in Winnipeg to the Growth in Population. Power supplied by the Winnipeg Electric Railway company's steam and hydro-electrical plants and by the city municipal hydro-electrical plant.

Year.	Population.	Load in Kilowatt Hours.		Load in Horse-power Hours.		Monthly Power used per 1.000 Population.		
		Total.	Monthly Average.	Total[1]	Monthly Average.	Kilowatt Hours.	Horse-power Hours.	Continuous Horse-power.
[1]1906	101,057	8.500,000	1,417.000	11,390.000	1,898,780	14.030	18,800	25·8
1907	111.729	30,784.000	2,565.000	41,250.560	3.437,100	22.960	30.750	42·1
1908	118.252	40.734.000	3.395,000	54.583.560	4.549.300	28.700	38,450	52 6
1909	122.390	47.845.000	3.987.000	64,112.300	5.342.580	32,570	43.650	59·8
1910	132,720	60,441.000	5,037.000	80,990.900	6,749,580	37,970	50.900	69 7
1911	151,958	73.115.000	6,093.000	97,974.100	8.164.620	40.090	53,700	73·6
1912	166,553	105,769.000	8,814.000	141,730.460	11,816.760	52,900	70.900	97·1
1913	184.730	134.760.000	11,230.000	180,578 400	15,048 200	60,800	81.420	111·5
[2]1914	210.000	135,979,000	13.598.000	182.211 860	18.221.186	64,780	86.800	119·0

[1]1906 for six months only.
[2]1914 for ten months only.

PLATE No. 79

DOMINION WATER POWER BRANCH

J. B. CHALLIES, Superintendent

CURVES OF

TYPICAL DAILY POWER LOAD

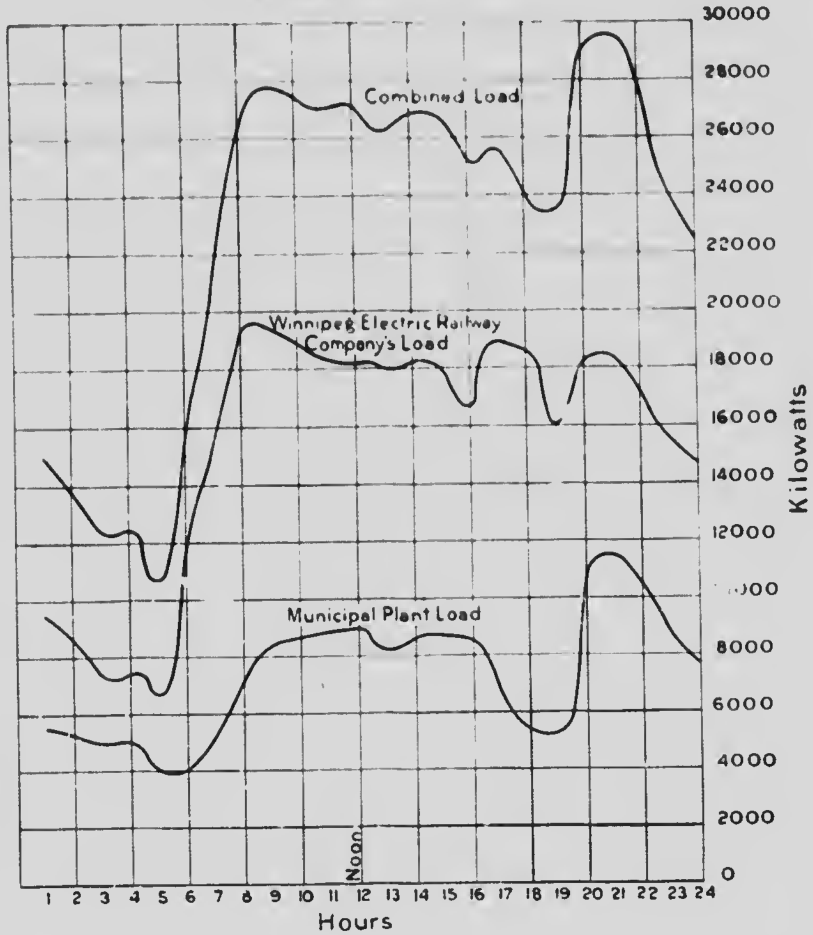
in the

CITY OF WINNIPEG

AUGUST 26, 1914

To accompany a report on POWER AND STORAGE INVESTIGATIONS by J. T. JOHNSTON B.A.Sc.

March 8th, 1915



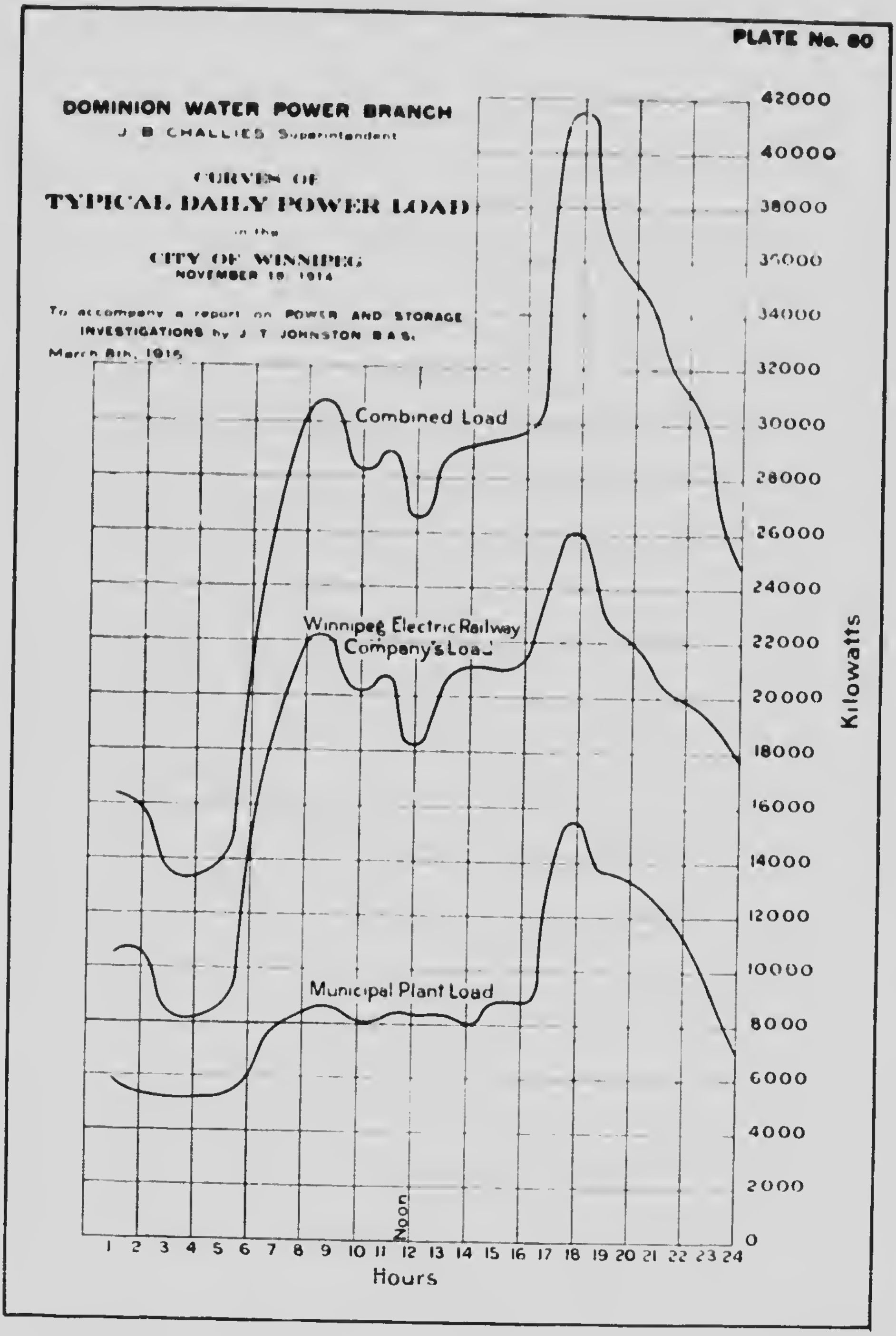


PLATE No. 80
DOMINION WATER POWER BRANCH
J. B. CHALLIES Superintendent
CURVES OF
TYPICAL DAILY POWER LOAD
in the
CITY OF WINNIPEG
NOVEMBER 19, 1914
To accompany a report on POWER AND STORAGE INVESTIGATIONS by J. T. JOHNSTON B.A.Sc.
March 8th, 1916
Combined Load
Winnipeg Electric Railway Company's Load
Municipal Plant Load
Kilowatts
Noon
Hours

Records show that 25,000 carloads of manufactured goods were received in 1910 with bills of lading reading Winnipeg, 75 per cent of which, it is estimated, could have been made in the country. A classification of the above total shows the following: 6,535 carloads of iron and the products of steel and iron, including structural steel, wire nails, hardware, machinery, iron pipe, stoves, furnaces, and tinware; 4,748 carloads of agricultural implements, automobiles, furniture, carriages, barrels, wagons, paints, organs and pianos. Paper, sugar, brick, sewer pipe, glass products, crockery, paints, canned goods all figure largely and range in quantities from 250 to 700 cars each.

The demand for manufactured goods is the normal sequel to the rapid development of the agricultural territory of the prairies. This development is proceeding continuously and rapidly, and is concurrently developing an increasing market for industrial products.

That Winnipeg is well able and ideally located to supply a large proportion of this demand for manufactured goods is well recognized, and that rapid progress in this direction is being made is evidenced by the fact that there are at present established in the city over 400 factories, employing in the neighbourhood of 20,000 hands, with an output in 1914 valued at $45,000,000. The percentage of increase in the manufactures in the past ten years was 351, and in twenty years was 608. While these figures are indicative of rapid and substantial development, it may be said without exaggeration that the possibilities in this direction are at present little more than broached upon, and that the future holds much greater opportunities than have been grasped to date. The outstanding advantages upon which the city may confidently rely as ensuring its future industrial development are: an abundant supply of cheap power, unexcelled distribution facilities in the shape of railway connections, and a practically unlimited market for manufactured products.

The General Manitoba Market.

Turning to the province as a whole, the question of market conditions becomes somewhat more complex. This is mainly due to the fact that the industry of the province as a whole largely pertains to agriculture, with a consequent dispersed population.

The mineral and timber resources of the Prairie Provinces are to a great extent undeveloped, and undoubtedly offer a very profitable field for investment. Among such resources, to the development of which the Winnipeg river will undoubtedly be in part applied, might be listed limestone with clay and shale for Portland cement, calcareous shales suitable for natural cement, gypsum, friable sandstone for glass, clay for brick and tile, timber for building and manufacturing, and wood-pulp for paper manufacture.

General Hydro-Electric Distribution in Manitoba.

While on the question of power market in Manitoba, it will be well to look into the prospects of a general scheme of hydro-electric distribution throughout the province. In this connection we are fortunate in having to hand recent and reliable data, the Provincial Government having, with the co-operation of the

Dominion Water Power Branch, recently completed a very thorough study of the problem.

The development of the hydro-electric system of the province of Ontario under the Hydro-Electric Power Commission has widely advertised public ownership of transmission systems for the distribution of electrical energy, as well as the opportunities for successful public ownership and operation of hydro-electric generating stations. For some time there existed throughout the province of Manitoba a feeling that with the great water-powers of the Winnipeg so readily available, a duplication of the Ontario hydro-electric system in Manitoba was not only feasible but was bound to prove a successful undertaking. The outstanding difference between the conditions existing in the two provinces, i.e., that Ontario was thickly dotted with manufacturing towns and cities offering a large existing and rapidly growing market for power, while Manitoba was essentially an agricultural province with more scattered and in general less populous municipalities, was to a large extent overlooked.

In order to test the feasibility of an hydro-electric system for Manitoba the Provincial Government determined to thoroughly investigate the whole question. To this end a resolution was passed in the legislature providing for an investigation into the question of the development of publicly-owned hydro-electric power within the province, with a view to securing for all sections of the province, rural as well as urban, the benefits and conveniences enjoyed by the citizens of Winnipeg as the result of the expenditure of public money for power development and distribution. Mr. H. A. Robson, K.C., Public Utilities Commissioner of the province, was placed in charge of the investigation.

The general results of this investigation are of great interest, not only from the standpoint of a state-owned hydro-electric system, but also from the standpoint of private ownership and operation of a similar project. The commissioner based his report upon very thorough personal research, backed by reliable engineering data and expert engineering opinion as to the power available, the market offering, and the cost of constructing and operating a suitable system. Full and definite information was supplied by the Dominion Water Power Branch as to the water-power available for supplying such a system as was under consideration. An exhaustive analysis of the capital and annual cost of distributing the power throughout the province was made by Mr. W. E. Skinner, C.E., of Winnipeg, based upon the market to be anticipated, this being determined after a careful canvass of the municipalities and rural districts to be served.

The definite project investigated involved a generating station at Pine falls, distant 64 miles from Winnipeg, 367 miles of 110,000-volt, 61 miles of 60,000-volt, and 525 miles of 30,000-volt transmission line, as well as local 6,600 volt transmission. The 110,000-volt line was projected from Pine falls direct to Winnipeg, thence westerly to Brandon, thence directly south some 33 miles, thence east to the vicinity of Morris, and thence northeasterly to Winnipeg. The 60,000 volt transmission involved two lines radiating from Brandon, one southwesterly to Hartney, and the other southeasterly to Wawanesa. The 30,000-volt transmission involved lines radiating from Winnipeg, Portage-la-Prairie, Brandon, Rapid City, Hartney, Pipestone, Wawanesa, Glenboro, Roland, and Plum Coulee. The 6,600-volt distribution was considered in a more general manner.

Mr. Skinner's estimates are based on first-class construction and standard equipment of permanent character, steel towers being considered for all 110,000-volt, 60,000-volt, and 30,000-volt lines. The proposed Pine falls—Winnipeg transmission comprised a single line of steel towers with two complete three-phase circuits. The balance of the high-tension line is estimated for one three-phase circuit, and provides for the stringing of a second. The distribution circuits are not included in the main estimates, as it was the intention of the report to cover only the outlay necessary to place the energy within reach of the different sections of the province.

The report assumes the development and placing on the low-tension switchboard of the Pine falls power plant 38,000 horse-power, i.e., the present minimum flow capacity of the river at that site. The transmission system is planned to deliver not less than 10,000 kilowatts over either branch of the loop.

The estimated capital cost of developing the necessary power at Pine falls was supplied by the Dominion Water Power Branch.

Summary of Capital Cost (excluding distribution).

Power-house, generating equipment, step-up transformers, etc.	$ 3,117,400
110,000-volt transmission	2,545,123
60,000-volt transmission	310,906
30,000-volt transmission	2,575,125
110,000-volt substations	600,511
60,000-volt substations	123,714
30,000-volt substations	569,330
Total	$ 9,902,109

Operation Costs (supplying towns and villages only).

Depreciation (on above capital cost)	$ 283,919
Interest, 5 per cent	495,105
Operation	177,580
Total Annual Cost	$ 956,604

With the information at hand, Mr. Skinner estimated that an hydro-electric system in the section of the province indicated would result in the use of energy totalling 8,308,320 kilowatt hours per annum, 2,400,000 kilowatt hours of this total being for lighting and power purposes in farming communities, leaving 5,908,320 kilowatt hours for the towns and villages. Upon the above basis the unit cost to the towns and villages would average at the rate of 16·2 cents per kilowatt hour.

Upon taking into consideration the cost of a comprehensive system of rural distribution, the capital cost rises to $18,633,909, with an annual charge of $1,926,669. Taking this on a basis of 10,000,000 kilowatt hours' output (considerably above the estimated market) it raises the average rate to 19·26 cents per kilowatt hour.

These figures are greatly in excess of the price for which power is now being developed and sold by local plants throughout the district.

It is clear, therefore, that the present industrial status of the province does not warrant the inauguration of an hydro-electric system of the nature described. The enormous overhead charges which must be borne render such a scheme entirely impractical, until such time as the local market conditions throughout the province will guarantee at least a fair return from the investment at rates reasonable to the consumer. That such a time will come, and that in the not distant future, can be confidently anticipated, if the present prosperity and rate of growth of the cities and towns of the province is continued.

While a comprehensive hydro-electric system of provincial scope for rural as well as urban supply is apparently out of the question at the present date, there is little doubt that the linking up of the major municipalities, especially those in the vicinity of Winnipeg, will offer attractive features and fair returns to the investor at rates reasonable to the consumer. An ample supply of cheap power to such centres will result in greatly accelerating their industrial development, enabling them to more fully grapple with the problem of supplying the West with manufactured products. Further investigation in this direction will probably show attractive features from a commercial standpoint.

Reference to plate 81, whereon are shown the municipalities of population over 100, located within a 400-mile radius of the power centre of the Winnipeg river in Manitoba, indicates the future promise of the district as well as the extent of the territory available for market. The Winnipeg river forms the only source of cheap hydro-electric power available in bulk for distribution in southern Manitoba. It will also be available for distribution in eastern Saskatchewan as soon as the market warrants its transmission.

Present Status of the Power Supply.

The present status of the power supply available in the city of Winnipeg has already been referred to, but can be briefly re-stated.

The Winnipeg Electric Railway Company's hydro-electric plant on the Pinawa channel (see chapter V) has an installed turbine capacity of 34,000 horse-power which allowing for transmission, is fully utilized for lighting, industrial, and traction purposes in Winnipeg. This plant is augmented by steam turbine plants in the city with an installed capacity of 22,000 horse-power.

The city of Winnipeg has constructed at Point du Bois on the Winnipeg river (see chapter V), a modern hydro-electric plant with a present turbine installation of 47,000 horse-power. This power is for use in the city, 77 miles distant, for lighting and industrial purposes. Future enlargement of this plant, combined with a system of regulation on the river, will permit of an ultimate development of 76,800 continuous 24-hour power.

The Winnipeg River Power Company has at present under construction at the Du Bonnet falls (see chapter VI and Appendix II) a plant capable of an ultimate development with a regulated river, of 95,500 twenty-four hour horse-power, destined for the Winnipeg market and vicinity.

A summary of the above shows that a total of 81,000 horse-power turbine capacity is now installed on the river, and that the new development now under construction, together with the possible expansion of the municipal plant, guarantees an additional supply of about 130,000 continuous horse-power (after allowing for line losses) which is rapidly being provided to meet the market demands.

This leaves a total of some 220,000 continuous horse-power suitable for commercial use still latent in the river in Manitoba.

Other Uses for Winnipeg River Power.

It is clear from a study of the market conditions that if the Winnipeg river is to be used solely to supply power for lighting, traction, and general industrial undertakings, a large reserve of power will be left unutilized for many years to come. The present hydro-electric plants on the river, with their reserve of power, together with the new undertaking now under construction, will supply ample power for the above purposes for many years, not only to the city of Winnipeg and vicinity but also to such hydro-electric distribution systems as are likely to be profitably established, even allowing for the anticipated industrial expansion. It is advisable, therefore, to look into the prospects offering for the immediate profitable utilization of the unused power, since available water-power unused is a definite although not generally appreciated waste of natural resources.

The power at present running to waste on the Winnipeg river in Manitoba is equivalent to an annual consumption of 3,500,000 tons of coal or, at $5 per ton, equivalent to an annual value of $17,500,000. In so far as this power is not put to profitable use in connection with industrial enterprise, it is a definite and distinct loss to the economic and commercial life of the province.

PULP AND PAPER MANUFACTURE.

The Pine falls site possesses certain attributes which appear to offer exceptional opportunities for its use as a pulp and paper manufacturing site. The entire river basin above is available as a source for pulpwood supplies. Water connection with lake Winnipeg assures the widening of this source to include pulpwood areas adjacent to lake Winnipeg and its tributaries. Rail connection with Winnipeg by way of the Canadian Northern is probably assured within a few years. At present there is direct water transportation to the city.

On the whole, it would seem that a study of the site with a view to its utilization in connection with pulp and paper manufacture would well repay investigation. Information with respect to the site itself, and to its development, is now complete. Definite data with respect to the sources from which pulpwood could be secured are a necessary complement.

ELECTRO-CHEMICAL, ETC., INDUSTRIES.

A further field for the profitable utilization of the Winnipeg river powers is to be found in the various electro-chemical processes which during recent years have come increasingly to the front. Mr. J. R. Freeman in his report to the department on the Winnipeg river powers touched on this phase. The following is a selection from his report.—

> "While water-power opportunities on the Winnipeg river may have a very few years ago appeared so far beyond possible use that ordinary economies were unnecessary, it is, I believe, plain to-day beyond serious question that all of the remaining opportunities for power should be

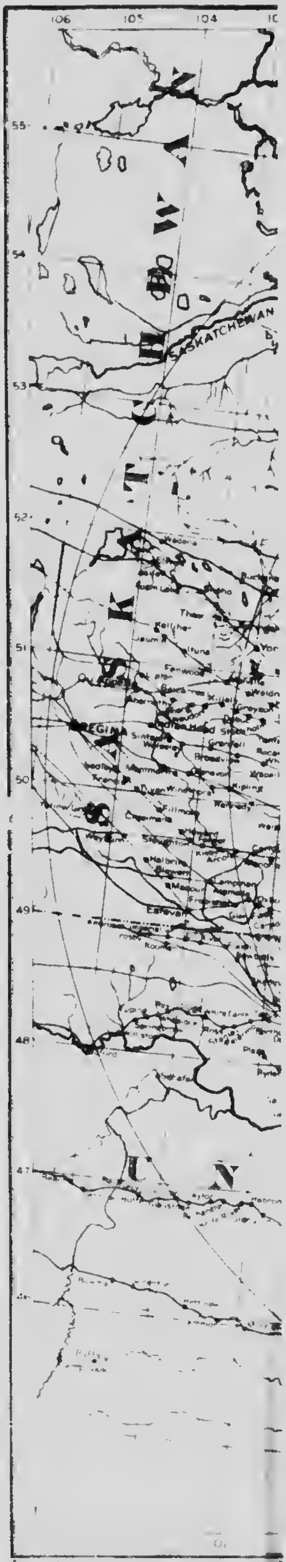
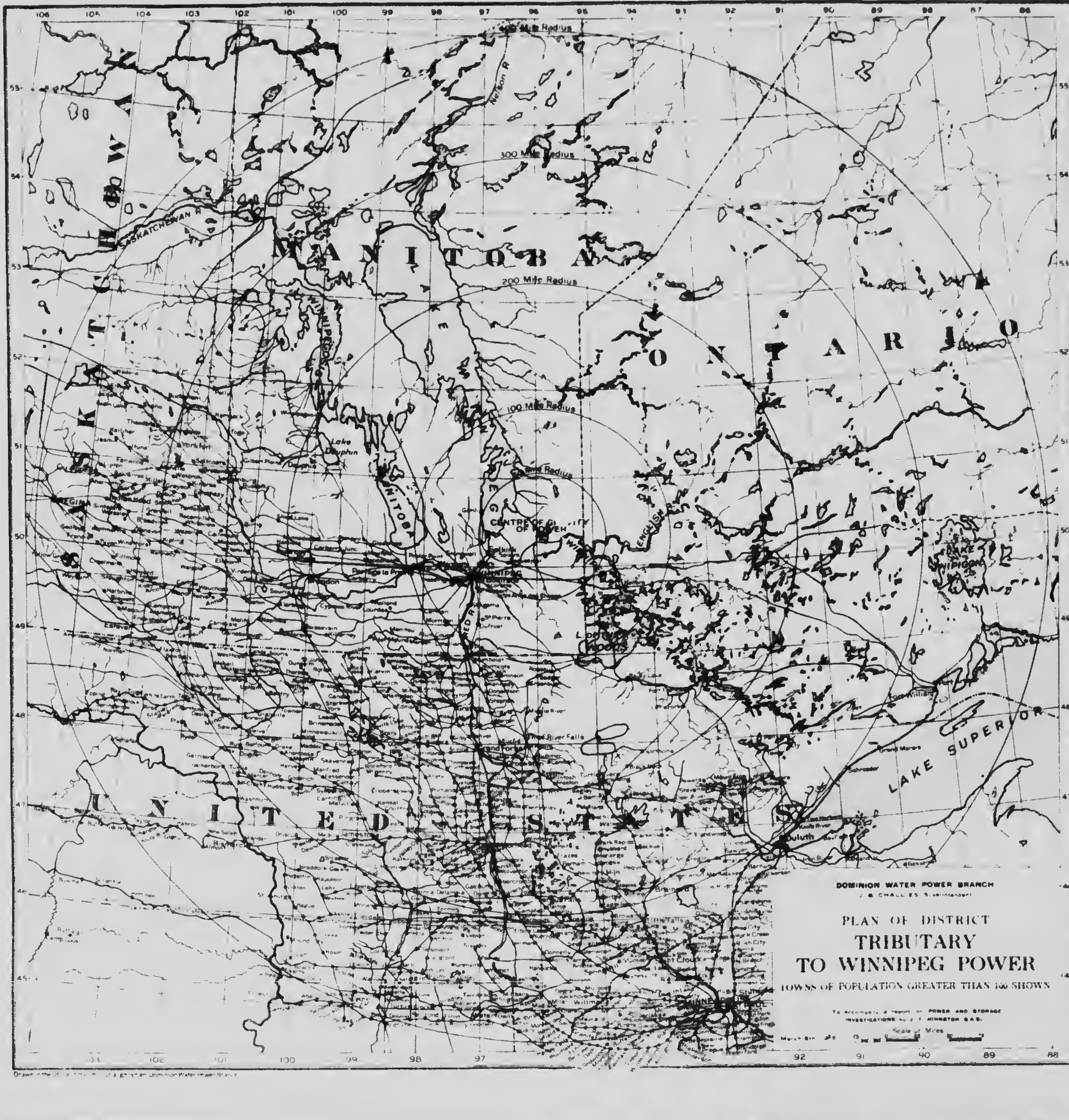

106
105
104
SASKATCHEWAN
REGINA
Estevan

PLATE No. 81


MANITOBA
ONTARIO
UNITED STATES
LAKE SUPERIOR
400 Mile Radius
300 Mile Radius
200 Mile Radius
100 Mile Radius
Nelson R
Saskatchewan R
Lake Dauphin
WINNIPEG
Duluth
English R
Thief River Falls
DOMINION WATER POWER BRANCH
PLAN OF DISTRICT
TRIBUTARY
TO WINNIPEG POWER
TOWNS OF POPULATION GREATER THAN 100 SHOWN
Scale of Miles

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carefully conserved and only developed under such conditions as will not necessitate any great waste or the impairment of remaining opportunities.

"Sundry remarkable electro-chemical processes have been very recently invented, which promise to be of great future benefit to agriculture and other arts. Fertilizer for farmers' use is now being successfully made by electricity from the nitrogen of the air, and great water-powers in Norway are now being developed for these purposes in addition to those already in use, and recent developments have also been made of similar processes not far from the southern boundary of Canada.

"The great uses of hydro-electric power at Niagara falls and at the Sault, for making aluminum, carbide for gas lighting, bleaching powders, and caustic soda and sundry other important products were unknown only a few years ago. Indeed it may be said that every one of the electro-chemical processes now located at Niagara falls has been invented since the first of the large hydro-electric power stations was built at that point. It is idle to say that the era of important electro-chemical invention is yet more than begun and, with the many able investigators now earnestly working on these lines in many parts of the world, great additional discoveries and commercial developments in the application of cheap electric power are almost sure to come, particularly in metallurgy or the reduction of ores.

"*The Winnipeg market now fully supplied.* The city of Winnipeg will soon have all the power that it needs for public service corporations and for any conceivable manufacturing purposes likely to locate in or near that city for perhaps a score of years to come.

"*A possible field for use.*—The best use that I can foresee for the vast water-powers now remaining untouched upon the Winnipeg river is as the basis for founding three or four new industrial cities based upon electro-chemical industry, very much as water power was the basis for creating years ago the cities of Lowell, Lawrence, Manchester, Holyoke, Bellows falls, and as in recent years it has brought together hundreds of new homes at Niagara falls, Shawenegan falls, and at the Sault.

"We cannot to-day say what the line of manufacture may be, for the electro-chemical arts are still in a state of ferment and creation. It has already been demonstrated that by electric smelting, steel for the manufacture of tools can be made having a quality and value difficult to obtain otherwise. Fertilizer in the form of artificial saltpetre is being produced commercially in large quantities under German processes, while carbide, carborundum, aluminum, and numerous other useful products are being made by electro-chemical means in great quantity at Niagara and elsewhere, and sooner or later the time will come when fertilizer will not be scorned by the farmers of the Canadian Northwest. There is pro... of new metallurgical processes for which cheap electricity is a necessity, and the price per pound of several of these products is such that they could stand a considerable cost of freighting to their markets, and such that a power capable of being developed in so vast quantity at one point and at so low a cost per horse-power as appears practicable at three of the sites along the Winnipeg river, will surely be very attractive.

"*These new industries must locate close to the water fall.* These electro-chemical processes when carried on in the large commercial way demand that the work be done close to the point where the power is generated, for two reasons: first, because although the air-saltpetre process used alternating current, most electro-chemical processes require the direct current at low voltage which cannot be transmitted to great distances with anything like the facility of alternating current; and second, because in order to attract these processes it is necessary that the cost per horse-power be the very lowest and not overloaded by the cost of long transmission lines or the percentage of power necessarily lost in such transmission.

"Wherever a new industrial centre with some hundred of homes can be established in the wilderness within a hundred miles of Winnipeg, it will add to Winnipeg's prosperity in a degree but little less than if located within its borders, and will add to the prosperity of the province by the new opportunities that it brings for employment, the diversity that it adds to its business interests and by the money that it will put into circulation."

With respect to the present status of electro-chemical, electro-metallurgical, and electro-siderurgical industries, and as showing the room for further progress in the development of the same in Canada, Mr. Arthur Surveyer, M. Can. Soc. C.E., in a recent paper on the subject contributed to the Proceedings of the Canadian Society of Civil Engineers, has compiled some very interesting data.

In the provinces of Ontario and Quebec only 7·8 and 14·1 per cent, respectively, of the developed water-power is used in electro-chemical and electro-metallurgical processes, the remainder being used for motive power, traction, and lighting. In Manitoba, Alberta, and Saskatchewan the entire developed output is utilized for the latter purposes. On the other hand, in France, Norway, and Sweden, the proportion of power used in these processes is, respectively, 49·1, 50·6, and 32·4 per cent of the whole.

This comparative disproportion between the European countries named and Canada in respect to the use of power for these purposes is due to the natural efforts of a young and rapidly developing country to first meet the most urgent requirements of growth. A stage has now been reached in the country's development where it is advisable to give more aggressive attention to the expansion of the present electro-chemical and similar undertakings, and to the inception of further development along these lines. There will undoubtedly be in the future a vast market for the use of fertilizers in the western provinces, and the application of the Winnipeg powers in this direction should receive close investigation.

Further development in this direction will add largely to the general prosperity of the Dominion as a whole. It is therefore of prime importance that the Government should co-operate with prospective investors, and endeavour to interest capital in the possibilities of our undeveloped rivers. One form of such assistance lies in placing before men of capital, such definite and exact information about our undeveloped water-powers as will enable them to accurately gauge the power procurable and the cost of developing the same. It is the object of this report to fully supply this information along the Winnipeg river.

In reviewing the general present market situation in Manitoba, with the prospects of future enlargement and of new industrial opportunity, the resources of the Winnipeg river do not appear greater than is necessary to ensure the continued progress of the province. Market for the whole power output of the river is assured when it can be produced as reasonably as is shown in the estimates in chapter VI.

It is therefore of the highest importance that the resources of the river be conserved to the utmost by careful oversight and by energetic control, based on definite knowledge of the situation. Such control, based on the extensive investigations which have been summarized herein, can now be exercised through the Dominion Water Power Branch.

REPORT

ON

THE WINNIPEG RIVER POWER AND STORAGE INVESTIGATIONS

CHAPTER IX.

INTERNATIONAL WATERWAYS REFERENCES

CHAPTER IX.

INTERNATIONAL WATERWAYS REFERENCES.

A considerable portion of the Winnipeg river watershed lies within the borders of the United States. The international boundary intersects the south-easterly limits of the basin, and has been established along a series of lesser lakes and connecting rivers and continued through lake Namakan, Kettle river, Rainy lake, Rainy river, and across Lake of the Woods to the western extremity of the Northwest arm, from whence it runs directly south to the intersection of the 49° parallel of latitude. In consequence of this international character, questions as to the handling of the water for power, storage, navigation, etc., are bound to arise and in many cases, to conflict with existing interests on both sides of the border.

Questions of this nature have arisen in the past and have been and are still being considered by international commissions appointed for this purpose.

In 1903, following correspondence between the representatives of Great Britain and the United States, the International Waterways Commission was provided for. Three commissioners from Canada and a similar number from the United States made up the commission and, among other questions, dealt with the Birch Lake diversion, a question of particular interest to the storage possibilities of the basin.

The International Waterways Commission, while continuing with a view to completing its investigations into international questions brought to its consideration, was superseded by the International Joint Commission. This commission was created by virtue of the provisions of the treaty between His Britannic Majesty and the United States, dated January 11, 1909. As in the case of the International Waterways Commission, the new Joint Commission consists of three commissioners from Canada and three from the United States. The commissioners were appointed in 1911, and two questions of particular moment to the Winnipeg river situation have been under consideration, i.e., the diversion of water from Shoal lake for the Greater Winnipeg Water District and the Lake of the Woods reference. These two questions, together with the Birch Lake diversion, are reviewed hereunder.

Birch Lake Diversion.

The Minnesota Canal and Power Company, a corporation organized under the laws of Minnesota, applied to the International Waterways Commission for permission to construct reservoirs in the Birch Lake basin in the southern portion of the Lake of the Woods drainage, in which water was to be stored and, as needed, conducted by artificial and natural channels southward to Duluth, there to be employed in generating power. This meant the withdrawal and diversion southward of the Birch Lake drainage from its natural outflow through the Winnipeg River system.

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The physical conditions in the locality are as follows: The Birch Lake drainage basin is situated in the counties of St. Louis and Lake, in the state of Minnesota, the border of the basin being only about 14 miles from lake Superior. The drainage basin contains a chain of small lakes, the largest of these known as Birch lake lying near the western border of the basin. A portion of the drainage of this basin flows westerly through the North Kawishiwi river and Farm lake to Garden lake, with a fall of about 56 feet in the distance of 9 miles; another portion flows southwesterly through the South Kawishiwi into Birch lake and thence northerly through the Birch river and White Iron lake to Garden lake, the distance traversed by the waters along this route being about 24 miles. Passing Kawishiwi falls, the waters, continually increasing in volume, flow through Fall lake over the Pipestone falls to Basswood lake, lying on the international boundary between Canada and the United States. The waters thence flow in a general northwesterly direction through Crooked and Iron lakes, Lac la Croix, Namakan river and lake to Rainy lake, and thence through Rainy river to the Lake of the Woods, and thence to the Winnipeg river.

Within 2 miles of the western end of Birch lake, and separated from it by a low divide, rises the Embarrass river, its waters flowing southwesterly through Sabin, Embarrass, and Esquagaman lakes into the St. Louis river, and thence into St. Louis bay and Lake Superior.

The general works proposed to carry out this diversion project involved a dam at the mouth of the Gabbro lake to impound the water in the lakes tributary thereto and form what was to be known as the Isabelle reservoir; a dam in the North Kawishiwi river to impound the waters in the lakes and streams tributary to Birch lake, naturally flowing westerly into White Iron and Garden lake; a dam in the South Kawishiwi river, which, in connection with the dam last mentioned, would form the Kawishiwi reservoir; and a dam in the Birch river at the outlet of Birch lake to impound its waters and form the Birch Lake reservoir. The reservoirs proposed were sufficient to store eight billion nineteen million cubic feet of water, and the claim was made that this capacity might be doubled by the extension of the works.

To convey the waters from the reservoirs to the site of development, the company proposed to cut a canal from the west end of Birch lake, a distance of about 6 miles, across the divide to the headwaters of the Embarrass river, and to erect controlling works at the entrance to this canal. From a point in the St. Louis river above Cloquet it was proposed to dig another canal about 24½ miles long, to a point in the city of Duluth where the bluff is about 600 feet above the level of lake Superior, and to lay pipes from the easterly end of the St. Louis river canal to the power house of the company to be erected on the shores of the St Louis bay.

The minimum discharge from the Birch Lake drainage basin has been estimated by the engineers of the company to be about 220 cubic feet per second, and the average discharge 975 cubic feet per second. The reservoir system was considered ample to permit of storing sufficient water through the flood period to maintain a minimum discharge of 600 cubic feet per second available for power purposes. It was proposed to withdraw at least 600 second-feet from the Birch Lake drainage basin and to utilize the same for the development of about 30,000 electrical horse-power in Duluth.

Many interests, both in the United States and Canada, were affected by this proposed withdrawal of the water from its natural channels. These interests were varied in character, the more important having to do with navigation, power, and lumbering. Several commercial corporations in both countries protested vigorously against the scheme. The Dominion Water Power Branch is particularly interested in the power and storage side of the question and the general effects of the diversion on the same. A short statement of these effects is appended.

After reaching the international boundary and Namakan lake, the water from the Birch Lake drainage basin, in its natural course, drops through 410 feet before reaching Lake Winnipeg, 348 feet of which are capable of successful commercial development. Of this total, 144 feet are already harnessed in hydro-electric and general commercial undertakings at Fort Frances, Kenora, Point du Bois, and in the Pinawa channel, while a further head of 56 feet is at present being harnessed at the Du Bonnet falls. The balance, 148 feet, can be sucessfully utilized as soon as the market demands. Of the full 348 feet of dependable drop, 30 feet are in international waters at the outlet of Rainy lake. 318 feet are wholly within Canadian territory, and 248 feet wholly within the provincial boundary of Manitoba. It will be readily understood, therefore, that the power interests affected by the withdrawal of 600 second-feet continuous flow from its natural channel of discharge are of very great magnitude. The argument might be carried a step further and the drop from Lake Winnipeg to Hudson bay by way of the Nelson river considered. This amounts to 710 feet in all, the greater part of which can be readily concentrated.

Considering the Winnipeg river system alone, 600 cubic feet per second with a concentrated drop of 348 feet means a permanent withdrawal of 19,000 horse-power.

It has been claimed that only the minimum or low-water discharge of the Birch Lake drainage should be considered in connection with the powers farther down the river, since during the balance of the year there is a great surplus of water in the remainder of the basin which would more than supply the amount withdrawn. With this viewpoint, considering the 220 feet minimum flow claimed by the company's engineers, the 348-foot head means a permanent loss of 7,000 horse-power to the Winnipeg river system.

The fallacy of this reasoning is evident when it is considered that unless storage or auxiliary power is secured, the low-flow period of the year is the measure of a power plant's capacity. When, as is the case of the plants of the Ontario and Minnesota Power Company at Fort Frances and International falls, the full minimum flow development has long been passed, and provision for extensive storage works to equalize the run-off is necessary, it becomes a matter of immediate concern, should any portion of the natural low-water run-off be by any means shut off or diverted. Even if it were practically feasible in the operation of the project after construction to discharge the natural low-flow run-off from the Birch Lake drainage down its natural channel, diverting the surplus only, a suggested solution, the general aspect of the question would remain as before. It would be, to say the least, a peculiar application of the principles of conservation, to create storage dams in one section of a drainage basin for the purpose of storing and diverting a portion of the run-off to an entirely different watershed, while, at the same time, other dams are being constructed and other reservoirs being created in the same watershed for the purpose of augmenting the low-flow run-off of the basin itself in the interests of undertakings already established and in urgent need of water. Any storage which is created in the Birch Lake district is required for, and should be applied to, the equalization of the Rainy Lake drainage.

A reference to the discussion on storage in Chapter IV of this report will emphasize the necessity of conserving to the fullest extent the natural run-off of the Rainy Lake basin. In whatever way the diversion question is faced the broad fact remains that the proposed diversion would result in the withdrawal from the run-off resources of the Winnipeg watershed of the equivalent of a uniform discharge of 600 cubic feet per second, all of which is required in the development of its water-power resources as contemplated.

As a result of the vigorous protests of the parties and municipalities interested in the question, among which might be mentioned the North Eastern Minnesota Power Company, the St. Croix Lumber Company, the Enterprise Iron and Land Company, the town of Fort Frances, the Rainy River Improvement Company, the Ontario and Minnesota Power Company, the Rainy River Navigation Company, and the City of Winnipeg, the proposed diversion was carefully inquired into by the International Waterways Commission which, on November 15, 1906, rendered a report to the two Governments recommending, among other things, that the permit for diversion applied for be not granted without the concurrence of the Canadian Government.

The above recommendation was apparently successful in preventing steps being taken towards the actual construction of the project. It is, however, understood that the scheme has not been wholly abandoned and that it is still active in the Minnesota courts. It will probably be raised again before the International Joint Commission, and the interests adversely affected should be constantly alive to the importance of the question.

Water Supply for Greater Winnipeg Water District.

The city of Winnipeg has, during recent years, made careful investigation into the question of a suitable source of water supply. In July, 1906, a "Water Supply Commission," under chairmanship of Mr. J. H. Ashdown, was appointed under authority of a special Act passed by the Manitoba Legislature, for the purpose of investigating and reporting on the best available sources of supply. In order to secure the expert opinion necessary to a proper solution of the engineering and technical questions inseparable from an undertaking of this nature, a "Board of Engineers" was appointed consisting of J. H. Fuertes, C.E., of New York; G. C. Whipple, C.E., of the firm of Hazen and Whipple, Consulting Engineers, New York; R. S. Lea, C.E., of Montreal; and J. E. Schwitzer, C.E., Assitant Chief Engineer, Canadian Pacific Railway.

Several sources of supply were considered, among the more important of which were: a continuation of the present artesian well system; Shoal lake, tributary to the lake of the Woods; the Winnipeg river, and the Red river. After a careful study of the different proposals and full consideration of all aspects, and more particularly of the then financial position of the city in relation to both the water supply undertaking and to the municipal power proposals then taking form, the board reported in favour of the Winnipeg river as the most suitable source of supply, the water to be taken from a point just above the Seven Sisters rapids.

The recommendations of the board were not acted upon at the time, the city being fully occupied in the municipal hydro-electric undertaking at Point du Bois, and the matter lay dormant until the year 1913, when the Greater Winnipeg Water District composed of the cities of Winnipeg, St. Boniface, Transcona, Assiniboia, Fort Garry, St. Vital, and Kildonan was constituted a corporation, and the question was again brought under consideration. A new board of consulting engineers, consisting of J. H. Fuertes, C.E.; R. Hering, C.E., of New York; and F. P. Stearns, C.E., of Boston, had charge of the investigation. This board, in view of the satisfactory completion of the municipal power plant, and the consequent improved financial position of the city in respect to a large expenditure such as would be involved in securing a suitable water supply, made a more detailed study of the Shoal Lake proposition.

As a result of, and based on, the fuller data secured in this investigation, Shoal lake was recommended as offering the most satisfactory source of supply for the city, and active steps were taken towards getting the project under way.

Since Shoal lake is practically an arm of the lake of the Woods, receiving water from and discharging water into that lake as the surface level varies, it was considered a boundary water and, consequently, came under the jurisdiction of the International Joint Commission, in so far as any interference with its natural discharge conditions might be contemplated. It was necessary, therefore, that the city should secure the formal assent of the Joint Commission prior to commencing active construction work, in order that the project might be inaugurated on a strictly legal basis.

A formal petition was accordingly made requesting that the commission confirm the petitioners' right to take the water of Shoal lake and the lake of the Woods for the purpose of a domestic supply.

The aqueduct proposed provided for a capacity of 85,000,000 imperial gallons per day, which, on a basis of 100 gallons per inhabitant, allowed for a population of 850,000 people.

The Dominion Water Power Branch was interested in the application of the city in two respects: first, in the quantity of water withdrawn from the Shoal lake, and consequently from the powers of the Winnipeg river in Manitoba; and second, in the effect of the same on the levels of the lake of the Woods.

In so far as the quantity of water withdrawn was concerned, little objection could be raised, since domestic water supply must, at all times, receive first consideration in the disposal and utilization of river run-off. Again, the quantity of water (equivalent to 157 cubic feet per second) was not excessive. The effect of the withdrawal upon the surface level of the lake was, however, of more importance to the power interests under the jurisdiction of the Dominion Water Power Branch. One hundred and fifty-seven cubic feet per second for one year is equivalent to a depth of 1·42 inch on the lake of the Woods. This is stated more as illustrative of the comparatively small effect of the water supply withdrawal upon the storage question, than as being of any immediate concern to the question of regulation on the lake. Up to the present, there has been at all times a very great wastage of water at the lake outlets amounting to many times the quantity required for the city's water supply.

The hearing in the matter took place in Washington on January 13 and 14, 1914. The various interests affected were represented and the various arguments for and against were considered.

The question of the regulation of the lake was already before the commission in what was known as "the Lake of the Woods Reference," covered at length hereunder.

In view of the importance to the city of an immediate granting of the application in order that construction could be commenced at once, and of the consequent inadvisability of waiting for the definite settlement of the Lake of the Woods Reference, authority was secured from the municipal authorities by the city representatives at the hearing, to press for an immediate settlement of the question and risk a possible future adverse fixing of the low limit of lake regulation for power purposes.

As a result of the various representations made, the commission approved the application of the Water District in the following words:—

> "That the use and diversion of the waters of Shoal lake and of the lake of the Woods for domestic and sanitary purposes by the inhabitants of the Greater Winnipeg Water District, prayed for in the said application, be permitted, subject to the conditions contained in the statutes and orders in council herein above recited. And provided, further, that the water so to be diverted from Shoal lake and from the lake of the Woods be not used for other than domestic and sanitary purposes, that the present approval and permission shall in no way interfere with or prejudice the rights, if any, of any person, corporation, or municipality to damages or compensation for any injuries due in whole or in part to the diversion permitted and approved of, and that the quantity of water so taken and diverted shall never at any time exceed one hundred million gallons per day. And provided, further, that the present permission and order shall not be invoked or relied upon in any manner against the recommendations or report to be made by the commission on the reference to it respecting the levels of the lake of the Woods, and shall in no way interfere with the action of the commission in that regard.
>
> "Dated at Washington the fourteenth day of January, one thousand nine hundred and fourteen.

It will be noted that it is specifically provided in the above permission and order that the future fixing of lake levels is not prejudiced thereby. Other considerations as well will serve to prevent conflict between the question of water supply on one hand and lake regulation on the other.

The city of Winnipeg, through its municipally owned and operated plant at Point du Bois, is interested equally with other power interests on the lower river in the question of power regulation in the lake of the Woods, and must therefore give a sympathetic consideration to the fixing of the lower regulation limit at such an elevation as will ensure maximum utilization of the full power available at Point du Bois. Should this low limit interfere with the discharge of 85,000,000 gallons per day through the water supply intake during times of low water on the lake, it must be remembered that such periods will only be of very rare occurence, possibly once every two or three years, and then for only a month or so at a time. To meet such a contingency, a pumping plant to raise the water the one or two feet necessary could be cheaply provided.

Levels of the Lake of the Woods.

By far the most important reference placed before the International Joint Commission to date, in so far as the power situation on the Winnipeg river is affected, is that having to do with the levels of the lake of the Woods. The reference was jointly submitted to the commission by the Governments of Canada and the United States, for examination and report, with such conclusions and recommendations as might seem appropriate. It consists of the following questions:—

> (1) In order to secure the most advantageous use of the waters of the lake of the Woods and of the waters flowing into and from that lake on each side of the boundary for domestic and sanitary purposes, for navigation and transportation purposes, and for fishing purposes, and for power and irrigation purposes, and also in order to secure the most advantageous use of the shores and harbours of the lake and of the waters flowing into and from the lake, is it practicable and desirable to maintain the surface of the lake during the different seasons of the year at a certain stated level; and if so, at what level?
>
> (2) If a certain stated level is recommended in answer to question No. 1, and if such level is higher than the normal or natural level of the lake, to what extent, if at all, would the lake, when maintained at such level, overflow the lowlands upon its southern border, or elsewhere on its border, and what is the value of the lands which would be submerged?
>
> (3) In what way or manner, including the construction and operations of dams or other works at the outlets and inlets of the lake or in the waters which are directly or indirectly tributary to the lake, or otherwise, is it possible and advisable to regulate the volume, use, and outflow of the waters of the lake so as to maintain the level recommended in answer to question No. 1, and by what means or arrangement can the proper construction and operation of regulating works, or a system or method of regulation, be best secured and maintained in order to ensure the adequate protection and development of all the interests involved on both sides of the boundary, with the least possible damage to all rights and interests, both public and private, which may be affected by maintaining the proposed level?

This reference is still before the commission, and considerable progress has been made to date. Hearings have been held at International Falls and Warroad, in Minnesota, and at Kenora, in Ontario, and were attended by representatives of the Dominion of Canada, the state of Minnesota, the provinces of Ontario and Manitoba, the cities or towns of Fort Frances, International Falls, Warroad, Kenora, and Winnipeg, local boards of trade, and various navigation, lumbering, power, fishing, agricultural, and other interests. The principal interests concerned in the questions at issue were those connected with power and manufacturing, navigation, agriculture, and fishing. The reference has a vital bearing on the successful carrying out of a policy of power conservation in the watershed.

The Dominion Water Power Branch has taken a very active interest in the entire question of the lake of the Woods regulation. The power resources of the Winnipeg river in Manitoba, which come under the jurisdiction of the Dominion Water Power Branch, are of great magnitude; the investigation into these resources has been most extensive and complete, while the method of administration which is being adopted is far-reaching and involves the principles of fullest conservation of the power resources. It was an essential sequel to the power studies that the unexcelled storage possibilities of the lake of the Woods should receive careful consideration.

At the commencement of the Winnipeg river power and storage surveys, the storage opportunities of the lake of the Woods were recognized as an outstanding feature of the watershed, and as one of the exceptional advantages which it possessed in the interests of a comprehensive power system such as was contemplated. Steps were at once taken to gather all possible data relative to the past surface levels of the lake, to the discharges from the lake through the various outlets, to the history and general utilization of the outlets, to the artificial structures in the way of dams, bridges, mills, and power stations which have been built at the outlets and, in short, to secure all existing information which might have influenced the lake levels in the past and have a bearing on the future systematic regulation. In addition to the securing of past records, active steps were at once taken to establish metering stations at the outlets and to secure an accurate record of the daily discharge, as well as to maintain careful gauge readings of the lake surface level and of all vital head- and tailwater elevations.

The securing of the above data became increasingly necessary as a result of the conflict of interests which has arisen over the question of surface regulation, and while the full compilation of the material is not yet completed, nor a final study possible, sufficient has been gathered to fully establish the necessity for a measure of regulation on the lake if the full power resources of the river below are to be realized.

The discussion on storage has already pointed out the necessity of a very substantial regulation in the lake for the proper control of the run-off of the basin. It is advisable at this stage to summarize the more important results which will arise from adequate regulation and non-regulation respectively.

LAKE LEVELS.

Before examining into the question of regulation for power purposes in the Lake of the Woods, it is of interest to look again into the past surface-level records, since the conditions shown by them have a particular bearing on the question of future systematic control.

Table 20 lists the mean monthly levels of the lake of the Woods as based on the gauge records of the Ontario Department of Public Works, taken at the Keewatin traffic bridge, to which corrections have been applied as a result of a study and comparison of the surface-level records available around the lake.

The figures in table 20 are not published as definitely and finally setting out the lake levels over the period in question. A numerous and complicated series of gauge readings have been kept at different points around the lake by various parties interested. The collation and study of these records is now being carried on by Mr. S. S. Scovil of the Lake of the Woods Technical Board, and will result in an authoritative statement as to the lake levels prevailing in the past. The levels listed herein can, however, be taken as representing with very fair accuracy the surface conditions over the period covered. It shoud be pointed out that these figures represent average monthly elevations, and that daily records show much more extreme conditions.

The levels are given to Dominion Water Power Survey datum.[1]

The maximum mean monthly elevation recorded in the cycle is 1060·8 for the month of July, 1899, and for the month of October, 1907. A rise above elevation 1060 is of common occurrence, as is instanced by the twenty-one listed months showing higher records. The lowest average monthly surface level in the period is 1055·4, occurring in January, 1912, and making a maximum range between monthly averages of 5·4 feet for the period tabulated. The actual range between extremes of daily records was considerably higher.

RUN-OFF.

Reference to chapter III will give in detail the run-off data which have been secured to date in the Winnipeg drainage basin.

For a study of the storage and run-off conditions in the watershed, there are available continuous discharge records from 1907 to date, at three important points on the river system, i.e., at Slave falls on the power reach in Manitoba, at the outlets of the lake of the Woods, and at the outlet of Rainy lake. Upon these records have been based the statements herein as to the influence of the Lake of the Woods on the run-off of the Winnipeg river.

Since water-power is wholly and entirely dependent on run-off, the influence of the lake of the Woods on the power question is as direct and as complete as is its influence on the river flow.

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[1]Elevation 959·8 Water Power Survey = zero of the present gauge of the Ontario Department of Public Works at Keewatin.
Elevation 1053·3 Water Power Survey datum = zero of the present gauge at Warroad.
Zero of the Water Power Survey datum = 1·3 on the United States Coast and Geodetic Survey datum.

INFLUENCE OF THE LAKE OF THE WOODS ON THE RUN-OFF OF THE WINNIPEG RIVER BASIN.

The influence of the lake of the Woods on the run-off of the Winnipeg River basin is treated under three headings: first, the results arising from the incomplete measure of regulation now in operation on the lake; second, the results arising from the maintenance of the lake at one uniform level throughout the year, and from year to year; and third, the results arising from a properly and systematically operated system of power regulation and control on the lake.

(A) CONDITIONS RESULTING FROM PRESENT SYSTEM OF REGULATION.

The regulation of the surface level of the lake of the Woods is at present in control of the Keewatin Power Company, subject to supervision on the part of the Minister of Public Works of the province of Ontario for the protection of navigation interests. The regulation of the lake has not in the past been based upon a study of the general run-off conditions of the watershed, such records not being available for this purpose. It has consequently been of a somewhat irregular character, more with the object of meeting sudden and pressing local exigencies than with the idea of a permanent and systematic control meeting all requirements.

Even under such a measure of control as has been realized in the past, the benefits to the power reach below have been most marked. The plants of the Winnipeg Electric Railway Company and of the city of Winnipeg were not in operation prior to the inauguration of the present measure of control on the lake of the Woods, and consequently have not experienced the natural low run-off conditions which would have maintained without the present balancing effect of the lake. It is probable, therefore, that the beneficial effect of the present measure of regulation is not fully appreciated by these hydro-electric undertakings.

During the period since 1907 over which discharge records are available, the lowest daily flow recorded at Slave falls on the Lower Winnipeg was 11,700 cubic feet per second. This discharge occurred on March 27, 1911. Discharges in the neighbourhood of 12,000 cubic feet per second have been frequently recorded. For the purpose of convenient use, 12,000 cubic feet per second has been taken throughout this report as the minimum flow to be anticipated in the power reach under present conditions of regulation.

The maximum mean monthly record over the period in question is 52,820 cubic feet per second for the month of May, 1910, while the maximum daily flow recorded is 53,440 cubic feet per second on May 7 of the same year.

Over the same period the minimum mean monthly discharge from the lake of the Woods was 4,870 cubic feet per second, occurring in the month of July, 1912, and the minimum daily flow was 4,425 on July 21 of the same year. Mean monthly discharges below 5,500 cubic feet per second are of frequent occurrence. For the purpose of the present discussion, 5,500 cubic feet per second is therefore considered a *conservative* figure at which to place the minimum outflow from the lake under the present system of regulation.

The maximum mean monthly record from the lake over the period in question is 24,690 cubic feet per second occurring in May, 1910, while the maximum daily flow recorded is 25,238 cubic feet per second occurring in May 4 of the same year.

It might be pointed out here that the inflow from the English river below the outlets from the lake and above the Manitoba power reach necessitates the consideration in the following of two limiting flows along the respective reaches.

(B) [1]CONDITIONS RESULTING FROM NO POWER REGULATION ON THE LAKE.

Should the lake of the Woods reference be decided in the affirmative, that is to say, in favour of maintaining the lake surface at a fixed uniform level throughout the year, and from year to year, the effect on the run-off would be essentially the same as *the complete removal of the lake from the watershed* in so far as the question of its influencing or controlling the flow of the Winnipeg river is concerned.

The immediate result of maintaining a uniform flow would be the increasing of the present flood discharges, and the decreasing of the present minimum discharges. Furthermore, the effect would be to raise the flood discharges and to lower the low water discharges above and below what they would respectively have been under natural conditions of run-off in the basin. In other words, lower winter flows and higher spring and summer floods than have at any time been experienced in the past, would be experienced, due to the elimination of the natural balancing effect of the lake.

It is the low winter flow with which the power interests are most concerned.

From the run-off data which have been collated and secured in the field by the departmental engineers, it has been calculated that, with the influence of the lake of the Woods removed from the watershed, as it would be under conditions of a continuous and unchanging surface level, a minimum outflow of 3,600 cubic feet per second is to be anticipated from the lake, while a minimum flow of 7,000 is to be anticipated on the power reach of the Winnipeg river in Manitoba.

(C) CONDITIONS RESULTING FROM COMPREHENSIVE AND SYSTEMATICALLY CONTROLLED REGULATION ON THE LAKE.

A far-sighted properly controlled system of regulation for power purposes on the lake between definite fixed limits, and based on the definite run-off and storage data now in possession of the engineers of the department, will vastly improve the present surface level conditions on the lake of the Woods, the outflow from the lake, and the run-off available on the power reach in Manitoba.

The calculations which are now possible as a result of the field investigations and studies of the engineers of the Dominion Water Power Branch, show that with suitable regulation on the lake of the Woods and under the present condition of power development at the lake outlets, it will be a comparatively easy matter to ensure a minimum flow of 20,000 cubic feet per second on the power reach in Manitoba, and that a minimum flow of 12,000 cubic feet per second from the lake may be possible.

[1]In dealing with the question of one level, minimum flows only have been considered. An investigation of flood discharges would also be necessary.

On the other hand, a study of the lake distribution over the balance of the watershed, and assuming storage possible on the majority of these lakes, shows, from a review of the general run-off records, that if no regulation for power purposes is permissible on the lake of the Woods, the present discharge conditions can be but slightly bettered, even with complete regulation on these lakes. Also, such regulation, even if practicable, could only be secured by a very heavy expenditure for the construction of numerous storage dams, and for their maintenance and operation.

In considering regulation for power purposes on the lake of the Woods, it is important to note than an actual variation of some 6 feet has taken place in the past fifteen years; furthermore, that past control has been most irregular the low surface levels at times occurring during the summer season when navigation interests have been most adversely affected. At the same time, the result of this past regulation has not ensured from the lake a greater minimum outflow than 4,870 cubic feet per second, or than 11,700 cubic feet per second on the power reach in Manitoba.

Systematic regulation between fixed upper and lower limits can be so operated that past conditions of lake level will be greatly improved, at the same time maintaining high minimum flows. Reference is here made to plate 24, discussed at length in chapter V. This plate shows a mass curve study of the general run-off and the lake level conditions which might have been maintained from January 1, 1907 onwards, had a properly controlled system of power regulation been enforced at the lake outlets. The lower surface-level curve on this plate shows the actual conditions of lake level for the years 1907 to 1914 inclusive, over which run-off records are available. The upper curve shows a possible series of controlled levels for the same period. The *actual* conditions represented by the first curve ensured only 12,000 cubic feet per second in the Manitoba power reach, while those *assumed* for the second ensure 20,000 cubic feet per second, and at the same time supply more than sufficient water to properly operate the present power plants and mills at the lake outlets. The latter curve shows the result of systematic and intelligent power regulation. In this curve the greatest variation in lake level in the seven-year period is 3·1 feet, that is to say, although some 6 feet variation has taken place in the past seven years, only 3·1 feet would have been required to maintain the desired 20,000 cubic feet per second. While this measure of regulation would, under the conditions assumed, have ensured the 20,000 cubic feet per second desired, a somewhat larger measure of regulation is necessary to ensure this flow at all seasons under the fuller degree of development at the lake outlets which is to be anticipated, and under the more extreme run-off conditions which may occur in the future. It is well to note here that the eight-year cycle which has been studied in plate 24 includes a period of exceptionally low run-off.

Drawing the lake down to its lowest limit would in any event be a matter of very rare occurrence, and only necessary at long intervals of years. Again, the lowest stage on the lake would in the natural course of events occur about the end of March or the middle of April. In a normal year the lake would rise 0·7 foot in April, 0·9 foot in May, 0·8 foot in June, 0·5 foot in July, 0·5 foot in

August, 0·6 foot in September, 0·5 foot in October, and 0·4 foot in N[illegible] or practically 5 feet in the eight months named, and at the sam[illegible] time p[illegible] an abundant supply of water for the present power users at the lake outl[illegible]

(D) SUMMARY OF THE INFLUENCE OF THE LAKE OF THE WOOD[illegible] THE RUN OFF.

In brief the influence of the Lake of the Woods on the run-off of [illegible] nipeg river basin is as follows:

Present system of regulation results in a minimum flow of co[illegible] less than 5,500 cubic feet per second for the reach below the lake to [illegible]tion with the English river, and of somewhat less than 12,000 cubic feet [illegible] for the power reach in Manitoba.

No power regulation permissible on the lake would result in a minimum flow of about 3,600 cubic feet per second for the reach below the lake to the junction with the English river, and of 7,000 cubic feet per second for the power reach in Manitoba.

Systematically controlled regulation on the lake for power purposes would render possible a minimum flow of 12,000 cubic feet per second for the reach below the lake to the junction with the English river, and ensure 20,000 cubic feet per second for the power reach in Manitoba.

INFLUENCE OF THE LAKE OF THE WOODS ON THE POWER AVAILABLE IN THE WINNIPEG RIVER.

The lake of the Woods influences the power possibil[illegible]ies of the Winnipeg river in direct proportion to its influence on the run-off. This influence is discussed in detail hereunder, covering the entire series of power plants and possible sites of power development along the river from the lake of the Woods to lake Winnipeg. All development capacities are in terms of 24-hour horse-power at 75 per cent efficiency.

(A) *Outlets of the Lake of the Woods.* Three developments are at present in operation at the outlets from the lake of the Woods.

The Kenora municipal plant, constructed in 1906 and succeeding a prior plant constructed in 1892, has a present turbine installation of four units of 900 horse-power each (manufacturers' rating), or 3,600 horse-power in all. Two bays are still in reserve for the installation of two additional units. The power is used for lighting and municipal distribution in Kenora and Keewatin.

The Lake of the Woods Milling Company's mill "C," replacing a former smaller development, was placed in operation in 1907. The turbine capacity installed at present consists of two runners of 900 horse-power operating the mill, and one runner of 600 horse-power direct connected to a generator for lighting and hoisting purposes. The total turbine capacity (manufacturers' rating) is 2,400 horse-power.

The Lake of the Woods Milling Company's mill "A" was placed in operation about the year 1887. The present turbine installation consists of two horizontal turbines on one shaft rated at 2,400 horse-power, one wheel of 95 horse-power, two generator turbines of 360 horse-power each, and one fire pump turbine of

180 horse-power. The total turbine capacity installed (manufacturers' rating) is 3,395 horse-power. The power is used in running the milling machinery and in supplying light and power to the hoists, elevators, etc.

The total turbine capacity installed at the outlets from the lake is at present 9,395 horse-power. In view of the working conditions and of the use of certain runners as auxiliaries, only 60 per cent or 5,637 horse-power of this capacity is considered herein as continuously in use.

Plate 82 graphically illustrates the present conditions of the power situation at the lake outlets (fig. 2) and the comparative conditions which will result from no regulation (fig. 1), and systematically controlled regulation (fig. 3), respectively.

Present regulation means a total development capacity of 9,390 horse-power, i.e., 3,753 horse-power in reserve over and above the present continuously employed power, or practically the same as the turbine capacity now installed.

No power regulation on the lake means a development capacity of 6,140 horse-power or 503 horse-power in reserve over the present continuously employed power.

Systematically controlled regulation on the lake means a development capacity of 20,500 horse-power or 14,863 horse-power in reserve over the present continuously employed power.

A comparison of the above figures will concisely illustrate how greatly the industrial future of the communities at the outlets of the lake depends on the question of power regulation in the lake. No regulation means no further expansion without steam auxiliary, while complete regulation means 14,863 additional horse-power available for industrial expansion, or more than two and one -half times the present power capacity.

(B)—*White Dog falls.*—The Dominion Water Power Branch has made no detail field investigations with a view to ascertaining the concentration possibilities along the river from Kenora to the junction with the English river. Private investigations and reconnaissance observations, would indicate that a 45-foot head can be economically developed in this reach.

Present regulation on the lake of the Woods means a development capacity of 21,100 horse-power along this reach.

No power regulation on the lake of the Woods means a development capacity of 13,800 horse-power.

Systematically controlled regulation on the lake of the Woods means a development capacity of 46,100 horse-power.

(C)—*City of Winnipeg Municipal Plant at Point du Bois.*—The city of Winnipeg completed the initial installation of the municipal plant in 1911. This installation consisted of five 5,200 horse-power turbines. Three additional units have been installed during the past year of 7,000 horse-power capacity per unit, making a total present turbine installation of 47,000 horse-power. In addition to this, the city has constructed the headworks of eight additional bays, in order to duplicate the existing power station as soon as the market demands.

Plate 83 graphically illustrates the influence of the lake of the Woods regulation on the municipal undertaking.

Present regulation on the lake of the Woods means a development capacity of 46,100 horse-power at the city station.

No power regulation on the lake of the Woods means a development capacity of 26,900 horse-power at the city station.

Systematically controlled regulation on the lake of the Woods means a development capacity of 76,800 horse-power at the city station

The above indicates that with no regulation on the lake there would not be sufficient water to operate the present installation during times of low water, and the construction of a steam auxiliary in the city would be necessary in the immediate future. Even under the present condition of regulation on the lake, the minimum flow will be practically entirely utilized by the machinery now installed, leaving no power available for the second half of the power station yet to be completed.

To ensure not only the profitable completion of the duplicate section, but even the dependable use of the present section of the power station requires, therefore, that power regulation must be assured on the lake of the Woods.

(D)—*Slave Falls site.*—The Winnipeg River Power Investigations show that a head of 26 feet can be profitably developed at Slave falls.

Present regulation on the lake of the Woods means a development capacity at this site of 26,600 horse-power.

No power regulation on the lake of the Woods means a development capacity of 15,520 horse-power.

Systematically controlled regulation on the lake of the Woods means a development capacity of 44,400 horse-power.

(E)—*Upper Seven Sisters site.*—The power investigations covered herein show that a head of 29 feet can be profitably developed at the Upper Seven Sisters concentration. At this site, a portion only of the river flow is available, since the plant of the Winnipeg Electric Railway Company on the Pinawa channel requires an average flow of 8,000 cubic feet per second. The net result of this is that the Upper Seven Sisters site will be entirely unfavourable for development until such time as a fairly complete system of regulation is instituted.

Present regulation on the lake of the Woods means a development capacity of 9,900 horse-power at this site, after allowing 8,000 second-feet down the Pinawa channel.

No power regulation on the lake of the Woods means no development capacity at this site.

Systematically controlled regulation on the lake of the Woods means a development capacity of 29,600 horse-power at this site.

(F)—*Lower Seven Sisters site.*—A head of 37 feet can be profitably developed at the Lower Seven Sisters site. As is the case of the Upper Seven Sisters site, a portion only of the river flow is available, an average of 8,000 cubic feet per second being diverted down the Pinawa channel.

Present regulation on the lake of the Woods means a development capacity of 12,600 horse-power at this site after providing for the Pinawa Channel flow.

No power regulation on the lake of the Woods will completely cut off the flow from this reach during ordinary winter seasons, and render it entirely unfeasible of development.

Systematically controlled regulation on the lake of the Woods means a development capacity of 37,900 horse-power at this site.

It might be noted here that neither the Upper nor the Lower Seven Sisters site is capable of profitable development until a minimum flow in the neighbourhood of 20,000 cubic feet per second is assured in the power reach n Manitoba.

(G)—*Winnipeg Electric Railway Company's Plant on the Pinawa channel.*—The hydro-electric plant of the Winnipeg Electric Railway Company is located on the Pinawa channel of the Winnipeg river. The water supply necessary to properly operate the plant varies with the different conditions of load, but has been placed at an average of 8,000 cubic feet per second for purposes of convenient reference and as representing average conditions. The water is diverted into the channel by diversion weirs spanning the main river-bed. A normal head of 39 feet is developed at the plant.

The present installation of the power stations consists of four settings of four runners each, at 2,595 horse-power per setting, or 10,380 horse-power for the group; also five settings of four runners each, at 4,788 horse-power per setting, or 23,940 horse-power for the group. The above figures represent the manufacturers' rating at a 39-foot head and total to 34,320 horse-power for the entire plant.

The question of regulation on the lake of the Woods affects the Winnipeg Electric Railway Company's plant as directly but not in the same manner as it does the plants on the main river channel. Plate 84 illustrates graphically the influence of the lake of the Woods regulation on this plant.

Present regulation on the lake of the Woods results in difficulty in operating the company's plant during ordinary winter flow. This is instanced by the steps which have been successfully taken during the past two seasons by the company, through the Dominion Water Power Branch, to secure the removal of the logs from the Norman dam at the outlet of the lake, and to thereby augment run-off from lake of the Woods storage at such times as the flow in the Manitoba reach falls below 15,000 cubic feet per second. It is evident, therefore, that the present measure of regulation on the lake does not meet the actual present requirements of the Winnipeg Electric Railway Company.

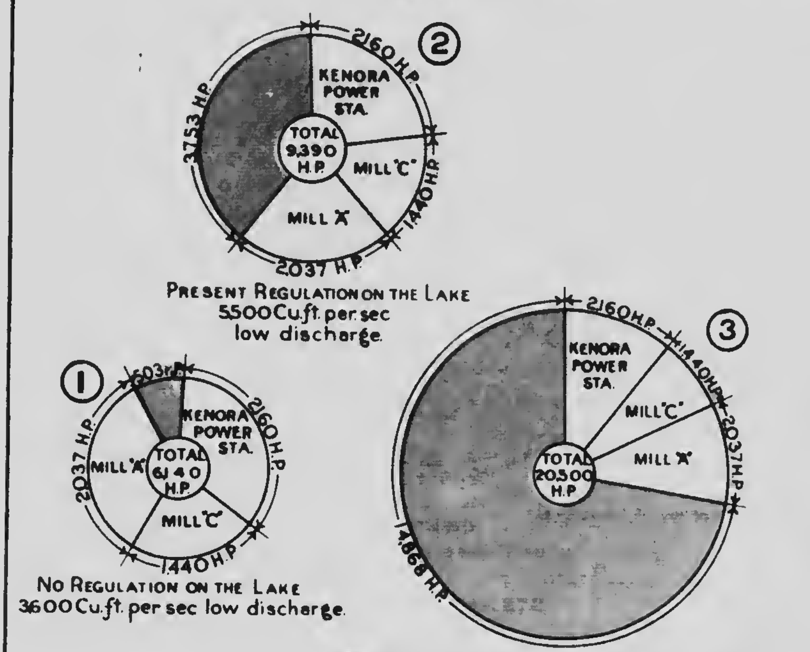
No power regulation on the lake of the Woods would reduce the minimum flow to 7,000 cubic feet per second. This is less than is frequently required at the plant for handling the heavy loads which the market demands, even if it were all diverted into the Pinawa channel. Such a diversion would leave the main river channel from the diversion dams to Whitemouth falls 8 miles down stream, entirely dry during the low-water season. Such conditions could not be permitted by the department.

The present diversion weirs of the company are not, however, at such an elevation as will divert the entire 7,000 second-feet into the Pinawa channel. At such times as 7,000 cubic feet per second forms the entire river flow, the weirs will divert approximately 5,000 cubic feet per second into the Pinawa, and discharge the remaining 2,000 down the Seven Sisters reach. To secure the full 7,000 cubic feet per second down the Pinawa, leaving the main channel dry, would, even if permitted by the department, necessitate expensive crest-raising alterations to the present diversion weirs.

PLATE NO. 82

DOMINIC[illegible] [illegible]ATER POWER BRANCH

J. B. CHALLIES, Superintendent

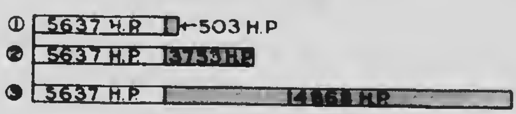


PRESENT REGULATION ON THE LAKE
5500 Cu.ft. per sec
low discharge.

NO REGULATION ON THE LAKE
3600 Cu.ft. per sec low discharge.

SYSTEMATICALLY CONTROLLED REGUTATION ON THE LAKE
12000 Cu.ft per sec low discharge

Comparisons of the TOTAL POWER available under above conditions of runoff.



LEGEND.

Power developed to date (60% installed turbine capacity)

Additional Power available under conditions stated in terms of 24 hour H.P. at 75% efficiency

DIAGRAM

SHOWING THE

INFLUENCE OF THE LAKE OF THE WOODS

ON THE

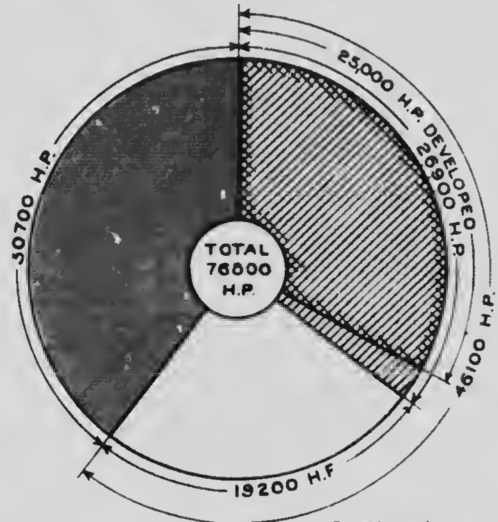
POWER SITUATIONS AT THE OUTLETS OF THE LAKE.

To accompany a report on POWER AND STORAGE INVESTIGATIONS
by J. T. JOHNSTON, B.A.Sc.

February 1, 1915

DOMINION WATER POWER BRANCH PLATE No. 83

J. B. CHALLIES, SUPERINTENDENT.



LEGEND

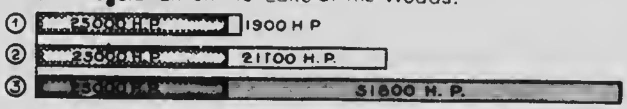
Developed Power to date

① Power available with **NO** regulation permitted on Lake of the Woods

② Power available under **PRESENT INCOMPLETE** regulation on the Lake of the Woods

③ Additional power available under **SYSTEMATICALLY CONTROLLED** regulation on the Lake of the Woods

Comparison of **TOTAL** power available under the above conditions of regulation on the Lake of the Woods.



NOTE – Power given in terms of 24 hour H.P. of 75% efficiency

DIAGRAM

SHOWING THE

INFLUENCE OF THE LAKE OF THE WOODS

ON THE

WINNIPEG CITY PLANT AT POINT DU BOIS

ON THE

WINNIPEG RIVER

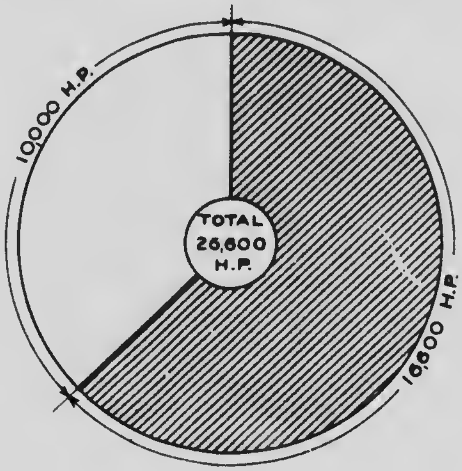
To accompany REPORT on POWER & STORAGE INVESTIGATIONS

by J. T. JOHNSTON B. A. Sc.

Mar. 31 1915

DOMINION WATER POWER BRANCH PLATE No. 84

J.B. CHALLIES, SUPERINTENDENT.

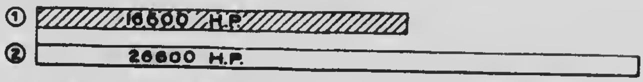


LEGEND

Power available with NO regulation permitted on the Lake ....

Power available under PRESENT regulation on the Lake ....

Comparison of TOTAL POWER available under the above conditions of regulation



NOTE- Power given in terms of 24 hour H.P. at 75% efficiency

DIAGRAM

SHOWING THE

INFLUENCE OF THE LAKE OF THE WOODS

ON THE

WINNIPEG ELECTRIC RAILWAY COMPANY'S PLANT

ON THE

PINAWA CHANNEL

To accompany REPORT on POWER & STORAGE INVESTIGATIONS
by J. T JOHNSTON B. A. Sc.

Feb. 1 1915

With no storage in the lake of the Woods, the present capacity of the Electric Railway Company's plant would be reduced under minimum flow conditions, to 16,600 horse-power.

Systematically controlled regulation on the lake of the Woods will permit the automatic diversion at all seasons of the full flow necessary to properly operate the company's plant, and with no possible complications, and will in addition render available for profitable development, 67,500 horse-power on the Seven Sisters reach.

(H)—*Upper Pinawa site.*—The Upper Pinawa site will operate under exactly the same conditions of flow as the plant of the Winnipeg Electric Railway Company; that is to say, under the present regulation, difficulty will be experienced in securing sufficient water during the season of low discharge on the river, while with no regulation permissible on the lake, about 5,000 cubic feet per second will be available for utilization.

Present regulation on the lake of the Woods means a development capacity of some 12,300 horse-power at this site.

No power regulation on the lake of the Woods means a development capacity of some 7,700 horse-power at this site.

Systematically controlled regulation on the lake of the Woods will not increase the output possible under present conditions, but will render it dependable at all seasons.

(I)—*McArthur site.*—The power investigations show that a head of 18 feet can be profitably developed at McArthur falls.

Present regulation on the lake of the Woods means a development capacity of 18,400 horse-power at this site.

No power regulation on the lake of the Woods means a development capacity of 10,760 horse-power at this site.

Systematically controlled regulation on the lake of the Woods means a development capacity of 30,700 horse-power.

(J)—*Du Bonnet site.*—Of the entire series of power sites investigated by the engineers of the Dominion Water Power Branch in connection with the power study of the Winnipeg river, the Du Bonnet site offered the best opportunities for commercial exploitation. The Winnipeg River Power Company has secured rights to the development of this site, based upon and in line with the departmental investigations and conclusions, and is at present actively engaged in construction operations. The head available here is 56 feet. The question as to the effect of regulation or non-regulation of the lake of the Woods is therefore of pressing importance to the power possibilities of the site. Reference to plate 85 will illustrate the situation.

Present regulation on the lake of the Woods means a development capacity of 57,300 horse-power at this site.

No power regulation on the lake of the Woods means a development capacity of 33,450 horse-power.

Systematically controlled regulation means a development capacity of 95,500 horse-power.

(K)—*Pine falls site.*—The proposed power concentration at Pine falls offers exceptional opportunities for successful development. A head of 37 feet is available.

Present regulation on the lake of the Woods means a development capacity of 37,900 horse-power at this site.

No power regulation on the lake of the Woods means a development capacity of 22,100 horse-power.

Systematically controlled regulation on the lake of the Woods means a development capacity of 63,100 horse-power.

Summary of the Influence of the Lake of the Woods on the Power Available in the Winnipeg River.

The above detail of the influence of the lake of the Woods on the available power of the Winnipeg river is graphically shown on place 86, and is concisely stated in table 47.

Table 47.—Effect of No Regulation and Systematic Regulation on the lake of the Woods, on the power possibilities and hydro-electric plants from the lake of the Woods to lake Winnipeg.

Site.	Power Available in 24-hour H.P. at 75% Efficiency.		
	No Regulation.	Present Regulation.	Systematic Regulation.
Pine Falls	22,100	37,900	63,100
Du Bonnet	33,450	57,300	95,500
McArthur	10,760	18,400	30,700
Lower Seven Sisters	00	12,600	37,900
Upper Seven Sisters	00	9,900	29,600
Upper Pinawa	7,700	12,300	12,300
Slave Falls	15,520	26,600	44,400
City Plant	26,900	46,100	76,800
White Dog Falls	13,800	21,100	46,100
Outlets of Lake of the Woods	6,140	9,390	20,500
Winnipeg Electric Railway Company	16,600	26,600	26,600
Total	152,970	278,190	483,500

Reference to table 47 indicates that the dependable power available on the entire reach of the Winnipeg river from Kenora to lake Winnipeg, under present conditions of regulation on the lake, is 278,190 horse-power. Under a system of uniform surface control on the lake, or, in other words, under conditions of no power regulation, this dependable power would be reduced to 152,970 horse-power, or by 45 per cent. Under a systematically and properly operated regulation of the lake, the dependable power would be increased to 483,500 horse-power or 74 per cent above the present power capacity and 215 per cent above that resulting from a system of no power regulation.

Summary of the Relation of the Lake of the Woods to the Power Resources of the Winnipeg River.

Hereunder are summarized briefly the outstanding features governing and governed by the relation of the lake of the Woods to the question of power development on the Winnipeg river below the lake. Certain of these features have already been enlarged upon in the foregoing, and are supplemented by the equally important considerations appended.

RELATION OF THE LAKE OF THE WOODS TO THE WATERSHED.

(1) The lake of the Woods has a surface area of 1,500 square miles.

(2) The total area of the Winnipeg river watershed is 53,200 square miles.

(3) The watershed above and tributary to the lake of the Woods has an area of 26,400 square miles, or practically one-half the total river watershed.

(4) Of the total area of the Winnipeg watershed, some 7,400 square miles possesses no suitable storage reservoirs, and the run-off from the same cannot be controlled.

Of the watershed area tributary to the lake of the Woods, 10,400 square miles has no lake area suitable for storage reservoir purposes other than the lake of the Woods.

Hence, if no storage privileges are permissible on the lake of the Woods, there will be a total of 17,800 square miles, or practically one-third of the basin from which there will be no opportunity to control or regulate the run-off.

(5) Permitting storage privileges on the lake of the Woods will increase the controllable area 45,800 square miles, or practically five-sixths of the watershed.

(6) The lake of the Woods dominates a drop of 347 feet in the Winnipeg river, capable of profitably developing under a regulated flow some 483,500 24-hour dependable horse-power.

EFFECT OF NON-STORAGE REGULATION ON THE LAKE OF THE WOODS.

The answering of the Lake of the Woods Reference in the affirmative, or, in other words, the maintenance of the lake surface at ***one uniform level***, thereby destroying the lake's regulating capacity for river control and power purposes, would result in the following:—

(1) The present minimum outflow from the lake would be reduced from 5,500 cubic feet per second to 3,600 cubic feet per second.

(2) The present minimum flow in the Manitoba power reach would be reduced from 12,000 cubic feet per second to 7,000 cubic feet per second.

(3) The maximum practical control of the balance of the watershed would not greatly better the present run-off conditions maintaining below the lake.

(4) The dependable power capacity of the river below the lake would be reduced from the present 278,190 horse-power to 152,970 horse-power, of which 53,000 horse-power is already developed.

(5) Practically no additional development above the present operated capacity could be carried out at the outlets from the Lake of the Woods without the addition of steam auxiliary.

(6) The present installation in the city of Winnipeg municipal plant at Point du Bois could not be operated during the low-water season.

(7) The present dependable output of the Winnipeg Electric Railway Company's plant on the Pinawa channel would be cut down by 10,000 horse-power.

EFFECT OF SYSTEMATIC REGULATION ON THE LAKE OF THE WOODS.

Systematic and comprehensive regulation for power purposes on the Lake of the Woods, based upon the detailed and reliable data now in the possession of the engineers of the Dominion Water Power Branch as a result of the power and storage investigations carried on in the basin, will result in the following:—

(1) The present minimum outflow from the lake may be increased to 12,000 cubic feet per second.

(2) A minimum flow of 20,000 cubic feet per second will be ensured in the power reach in Manitoba.

(3) The dependable power capacity of the river below the lake will be increased from the present 278,190 horse-power to 483,500 horse-power.

(4) The flow from the outlets of the lake will permit the development of 14,360 dependable horse-power in addition to the power now in use there.

(5) The Winnipeg municipal plant at Point du Bois can be developed to the maximum capacity of its designed installation.

(6) The Winnipeg Electric Railway' Company's plant on the Pinawa channel will have at all seasons ample water to fully operate its entire installation.

OUTSTANDING FEATURES RELATIVE TO REGULATION ON THE LAKE OF THE WOODS.

In addition to the foregoing, the following general features are particularly pertinent to the question of regulation for power purposes:—

(1) The Lake of the Woods is the *obvious and most natural reservoir* for the control and regulation of the river below. With simple repairs and improvements to the present outlet structures, the lake forms a perfect and ready-made reservoir, in shape for instant and complete regulation purposes.

(2) The lake has been subject to artificial regulation since the construction of the Norman dam in 1895, and partial regulation since 1887.

(3) Maintaining a uniform level on the lake would have the effect of *entirely removing it from the watershed* in so far as its effect on and relation to the run-off and power of the river is concerned, and would greatly accentuate the flood flows which have been experienced in the past both before and since the institution of the present regulation on the lake, in other words the *natural* regulating influence of the lake would be destroyed.

(4) The *natural* regulating influence of the lake will not be destroyed by systematic regulation, but, on the contrary, will be artificially perfected, and that at a less range in lake level than has occurred under natural conditions of run-off.

(5) The lake levels, if systematically controlled, will not be subject to the extremes and irregularities which have been experienced in the past. Extreme low water will be necessary only at intervals of several years.

(6) Experiences in the operation of *existing* hydro-electric developments below the lake show that a more systematic regulation of the lake than is now in practice is necessary to the proper operation of *present installations.*

(7) The use of the Lake of the Woods is *essential* to the ultimate storage and control policy which must be instituted for the proper conservation of the river resources as contemplated by the Dominion Water Power Branch, and covered in this report.

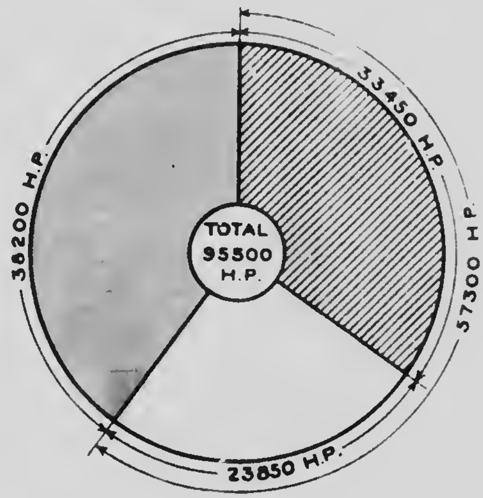
A review of the foregoing emphasizes how essential to present and future power development and to dependent industrial development in this district, is the question of an adequate regulation of the surface levels of the Lake of the Woods. The lake is, from its strategic location and its exceptional surface area, the controlling and essential reservoir for any conservation scheme of storage or run-off control which may be instituted in the watershed.

A careful study of past runoff records from the basin proves that a storage range of *at least five feet* on the lake is necessary to ensure an adequate regulation of its outflow in the interests af all powers on the Winnipeg river. Other interests concerned would require that such range should preferably be as near the upper limits of lake level as possible.

It is, therefore, from the power view point, entirely impossible to agree to the suggestion that the lake of the Woods be maintained continuously at one uniform surface level. Regulation on the lake between fixed limits is essential to the conservation of the power resources of the watershed.

DOMINION WATER POWER BRANCH — PLATE No. 85

J. B. CHALLIES, SUPERINTENDENT



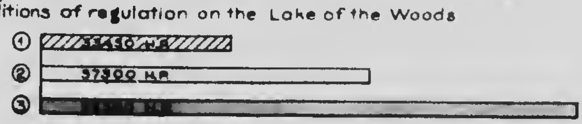
LEGEND

① Power available with **NO** regulation permitted on Lake of the Woods

② Power available under **PRESENT INCOMPLETE** regulatotion on the Lake of the Woods.

③ Additional power available under a **PROPERLY CONTROLLED** system of regulation on the Lake of the Woods

Comparison of **TOTAL POWER** available under the above conditions of regulation on the Lake of the Woods



Note - Power given in terms of 24 hour H.P. of 75% efficiency

DIAGRAM

SHOWING THE

INFLUENCE OF THE LAKE OF THE WOODS

ON THE

DU BONNET FALLS POWER SITE

ON THE

WINNIPEG RIVER

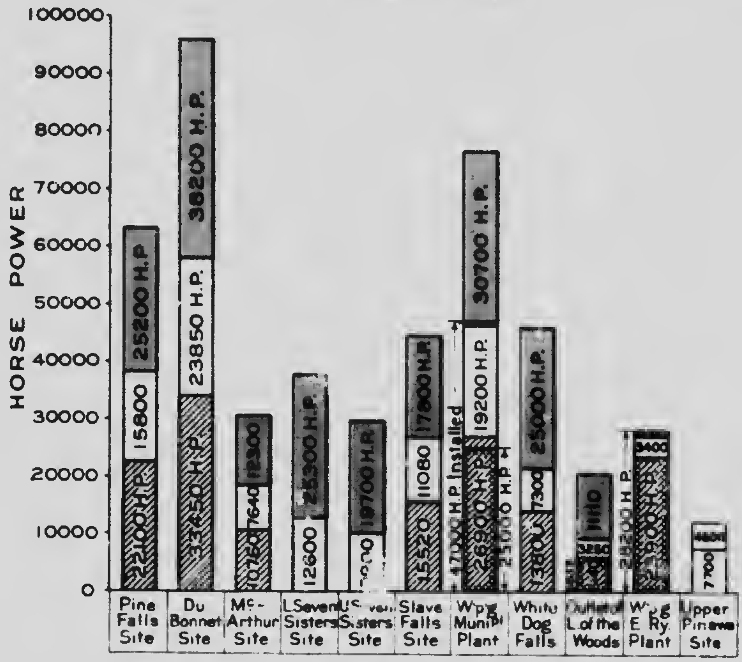
To accompany REPORT on POWER & STORAGE INVESTIGATIONS
by J. T. JOHNSTON B. A. Sc.

Feb. 1 1916

PLATE No. 86

DOMINION WATER POWER BRANCH

J. B. CHALLIES, SUPERINTENDENT



LEGEND

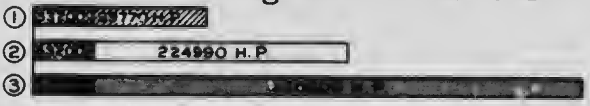
① Power available with NO regulation on the Lake

② Power available under PRESENT INCOMPLETE reg. on the Lake

③ Additional power available under a SYSTEMATICALLY CONTROLLED regulation on the Lake

Power already developed

Comparison of TOTAL POWER under the above conditions of regulation on the Lake



NOTE:–Power given in terms of 24 hour H.P. at 75% efficiency

DIAGRAM

SHOWING THE

INFLUENCE OF THE LAKE OF THE WOODS

ON EACH OF THE

AVAILABLE POWER SITES ON THE WINNIPEG RIVER

BELOW THE LAKE

To accompany REPORT on POWER & STORAGE INVESTIGATIONS

by J. T. JOHNSTON B. A. Sc.

Feb. 1 1915

REPORT

ON

THE WINNIPEG RIVER POWER AND STORAGE INVESTIGATIONS

APPENDIX I.

REPORT OF CONSULTING ENGINEER
J. B. McRAE, C.E.

APPENDIX I.

REPORT OF J. B. McRAE, C.E., CONSULTING ENGINEER

BOOTH BUILDING, OTTAWA, September 27, 1915.

J. B. CHALLIES, Esq., C.E.,
Superintendent of Water Powers,
Dominion Water Power Branch,
Ottawa.

DEAR SIR,—In the summer of 1911 the Dominion Water Power Branch began a systematic investigation of the power possibilities of the Winnipeg river in Manitoba. This work is now complete in as far as has been necessary to map out a comprehensive scheme of water-power development and enunciate a general policy for the proper control of the same, with due regard to future storage and regulation of the run-off. The history of the investigation, together with results and recommendations, may be found in the accompanying report of Mr. J. T. Johnston, hydraulic engineer of the Water Power Branch.

The value of such work cannot be overestimated. For proof of this, many cases of failure can be pointed to when works have been undertaken without sufficient data to warrant the large expenditures made. On the other hand, there are cases, though not so numerous, where power possibilities have been underestimated and future extensions thereby made more expensive than they otherwise would have been. Apart from the above, it is of interest to note that both during the progress of the work and since its completion, your department has been able to dictate conditions and give sound engineering advice, both of which have been cheerfully accepted, to applicants for power privileges. The Winnipeg river, situated as it is, is a heritage which should be safeguarded against irresponsible and unguided private enterprise. Plate No. 1 illustrates the relation of this great source of power to the city of Winnipeg and surrounding country. A study of table 1 shows the power available and estimated costs of same. These costs have been worked out separately for each development. The basis on which the estimates are made is treated on pages 182 and 183.

Attention is also directed to the "recommendations," pages 10, and 11. "Recommendation 10" is of particular importance, and it is to be hoped that the department will be allowed to keep up the good work and extend same along the lines recommended here.

These investigations were the first of their kind to be taken up by the Dominion Government, and it is fortunate that they fell into such competent hands as your assistant, Mr. Johnston, to whom credit is due in large measure for the excellent results obtained.

These results have made it possible to work out the comprehensive scheme of water-power development, already referred to, to the maximum extent of the unusual natural power possibilities of this river. Your department is now, and has been for sometime, in a position to dictate requirements for power developments which will conform to this scheme and ensure the complete development of the river to the best possible advantage.

The navigation features have been worked out entirely by Mr. Johnston, and are satisfactory, not only from a navigation standpoint, but also from the power point of view. It is very satisfactory to record that the engineers of the Dominion Department of Public Works have approved of the scheme in so far as navigation is concerned throughout the entire power reach.

Before closing, the writer wishes to endorse the report and recommendations without qualification; he also wishes to express his thanks to yourself for the many courtesies extended during the time he has acted as consultant to your department.

Yours faithfully,

J. B. McRAE.
M. Can. Soc. C.E.
M. Am. Soc. C.E.

REPORT

ON

THE WINNIPEG RIVER POWER AND STORAGE INVESTIGATIONS

APPENDIX II.

PROPOSED DEVELOPMENT OF THE WINNIPEG RIVER POWER COMPANY

APPENDIX II.

THE GREAT FALLS DEVELOPMENT.

(DU BONNET POWER SITE).

The Winnipeg River Power Company[1] has at present under way the development of the Du Bonnet site. This is the first power undertaking to acquire rights and commence construction operations on the river since the organization of the power survey, and it serves as an excellent illustration of the manner in which the interest of the investor and of the public are served by a careful and thorough investigation of a river's power resources, and by a pre-determined scheme of power development conserving fully all economically developable head.

In the case of the undertaking under discussion, the surveys of the department enabled the Winnipeg River Power Company to take immediate action towards the construction of the project, as soon as the authority for the same was secured from the department, without the necessity of carrying on long and expensive preliminary surveys.

The interests of the public were served by the preservation of a profitable power site at the McArthur falls, which, under the first proposals of the company, would have been rendered uneconomical of development.

The company has accepted the essential features of the departmental concentration at Du Bonnet falls as set out herein, i.e., the head- and tailwater levels, the Whitemud falls addition, the discharging capacity, and the general requirements as to stability of dam and contingent structures. Detail soundings and examination on the part of the company of the river channel at island No. 2, 3,000 feet below the Little du Bonnet falls, disclosed a distinct submerged rock ridge, presenting such favourable features as to warrant the location of the layout at this point. The principal consideration in adopting this location in preference to the site at the falls is the freedom which will be secured from ice troubles in the tail-race. This will become more evident when the Whitemud cut is made and a 10-foot lowering of the tail-race takes place.

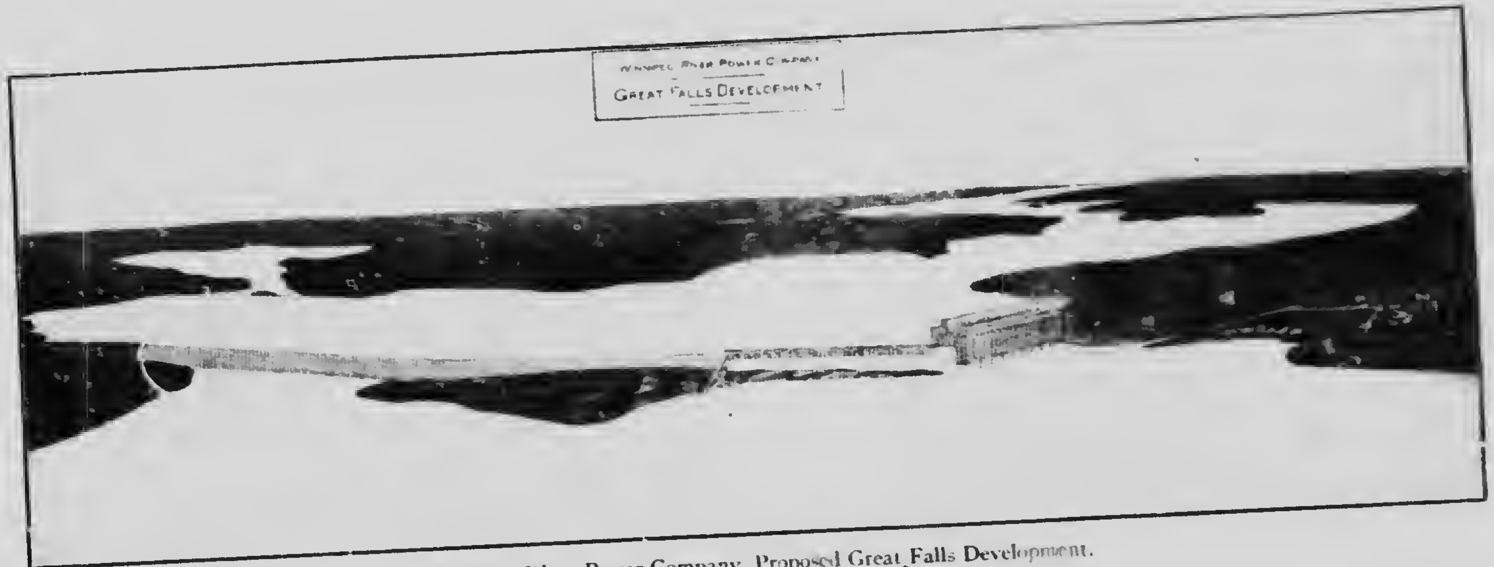
The development of the Du Bonnet power site under the name of the Great Falls development, forms a component link in the complete scheme of hydro-electric development which has been laid down as a result of the departmental power investigations, and by which it is intended that the entire power resources of the Winnipeg river in Manitoba will be fully conserved.

LAYOUT.[2]

The general layout (Plate 87) proposed consists of a power station spanning the channel to the left of island No. 2, tied in to the left river bank by a non-overflow concrete dam, 900 feet in length and with top elevation at 816. The power

[1]The Winnipeg River Power Company is controlled by the same interests as control the Winnipeg Electric Railway Company.

[2]The greater portion of the data relative to the layout and equipment have been secured from the plans and reports filed in the department by the Winnipeg River Power Company.



Winnipeg River Power Company, Proposed Great Falls Development.

station is joined to the right river bank by a gravity section concrete dam of the combined sluiceway and free spillway type, 2,100 feet in total length. A corewall embankment connects the free spillway with contour 816 on the right bank. A fishway is provided at the left abutment, and a log slide on the island, adjacent to the sluices.

Provision for the future inclusion of lockage facilities should such become necessary, is made on the right river bank.

The dam. The dam proposed is of solid concrete construction throughout the portion spanning the river channel and crossing island No. 2. The spillway section of the dam, 1,570 feet in length, with crest at elevation 808, provides exceptional facilities for the automatic control of flood flows. Twenty 20-foot sluices, with sills at elevation 794, are located on the island adjacent to the power station. Stoplog control is contemplated, and double gains are provided. The corewall embankment connecting the spillway section of the dam with the high ground on the right river bank has a 16-foot top with 2: 1 slopes, the corewall being bonded to the bedrock. The dam is continued as a solid non-overflow section, 900 feet in length with top at elevation 816, joining the power station with the left bank. The foundation conditions throughout, so far as they have been definitely investigated, show a firm granite bedrock

[1]*Power station.*—The plans of the power station as at present submitted to the department may be revised both as to layout and installation, prior to the commencement of construction operations. The station as now designed provides for the ultimate utilization of the entire regulated river flow, and will install eight 21,000-horsepower turbines, each running at a speed of 163·3 revolutions per minute, and requiring 4,100 cubic feet of water per second when operating under a head of 56 feet. These turbines will be of the four-runner horizontal shaft type, and will be placed in pits formed in the concrete substructure.

Adjacent to the turbine pits, in the downstream direction, is the generating room, in which are located the electric generators, exciters, and turbine governors. All apparatus requiring attendance and adjustment are thus placed close together, and hence will require the minimum operating staff. The generating room, being on the downstream side, will have ample light and ventilation.

Located on the level above the turbine pits and the generating room, are the low- and high-tension switch rooms and the transformer banks. The low- and high-tension switching apparatus has been so arranged as to permit all switching operations to be carried out in the most direct manner and in the shortest possible time, and also to provide the most direct system of connections from generators to transmission lines. On the same level are also located a storage battery room, and locker and rest rooms for the operating staff.

On the generating room level, at the shore end of the station, is the machine shop. On the control room level, directly above the machine shop and railroad track in the generating room, a large room for stores is provided.

[1]More recent studies made by the company engineers contemplate single runner vertical turbines. If these are adopted, the design of the power station will differ from that described herein.

On the roof levels are located the lightning arrestors, horn gaps, choke coils, air brake switches, and terminal towers for the transmission lines.

A railroad track will run to the generating room floor and extends to the rear wall of the house, with hatchways above in the floors of the storeroom and screen room for effectively handling apparatus.

Provision is made for steam-heating plant capable of maintaining proper temperature in the screen room, generating room, switch rooms, offices, control room, etc.

Plates 87 and 88 show the layout and section of the power-house.

Head Gates.—Each unit will be provided with two vertical operating steel headgates, arranged with rollers to minimize friction. Each gate will be 19 feet wide by 26 feet high, and when fully open will pass a flow of 4,100 cubic feet of water per second, at a velocity of approximately 4·5 feet per second.

Provision will be made for stoplogs, outside the screens and gates, affording ready access for inspection and repairs.

Screens.—Screens consisting of heavy steel bars supported on a steel framework attached to the substructure will be provided for preventing débris from entering the wheel pits.

Provision is made for cleaning the screens by reversing the direction of flow of the water and discharging the débris through drains to the tail-water.

Water Wheels or Turbines.—Each unit will consist of two double-runner horizontal turbines in tandem, and direct connected to the electric generator. Hydraulic governors located in the generating room will control the speed of the machines.

Electric Generators.—Eight electric generators are provided, each to be of 11,000-kilowatt capacity, normal rating at 30° Centigrade, with continuous overload capacity of 50 per cent. These machines will generate three-phase, 60-cycle alternating current at 12,000 volts. Individual exciters will be provided for each machine, direct connected to the shafts, and, in addition, an auxiliary motor-driven exciter will be provided and so connected that it may be substituted for any of the direct-connected exciters in case of breakdown.

Transformers.—Five banks of transformers, each consisting of three single-phase transformers, will be provided. Each transformer will be of 6,000-kilowatt normal rating capacity, and so designed as to safely withstand a continuous overload of 50 per cent. The low-tension voltage will be 12,000 volts, and the high-tension voltage will be 110 000 volts.

Switching and Protective Equipment.—The low-tension oil break switches, and all disconnecting switches will be motor operated. All disconnecting switches, instrument transformers and busses on the low-tension circuits will be placed in concrete structures. The bus reactances will be placed in enclosed pockets with doors opening into the low-tension switch room.

The high-ten ion switches will be of the oil break solenoid type, enclosed in iron tanks and placed directly on the floor of the high-tension switch room.

The lightning arresters will be of the electrolytic type, enclosed in iron tanks and located on the floor of the lightning arrester house.

The system of electrical connections provides means of connecting any generator to any transformer bank and line.

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ULTIMATE REGULATED WA
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WATER LEVEL WORKS COMPLETE
TAIL RACE
POWER HOUSE
SLUICEWAYS
ISLAND No 2
RIVER
WINNIPEG
NON-OVERFLOW
NORMAL REGULATED WATER
POWER HOUSE
SLUICEWAYS
SPILLWAY CREST ELEV
EARTH SURFACE
ROCK SURFACE
TAIL RACE EXCAVATION
HUNDRED FOOT STATIONS
PROFILE ALONG UPSTREAM FACE OF DAM LOOKING DOWNSTREAM

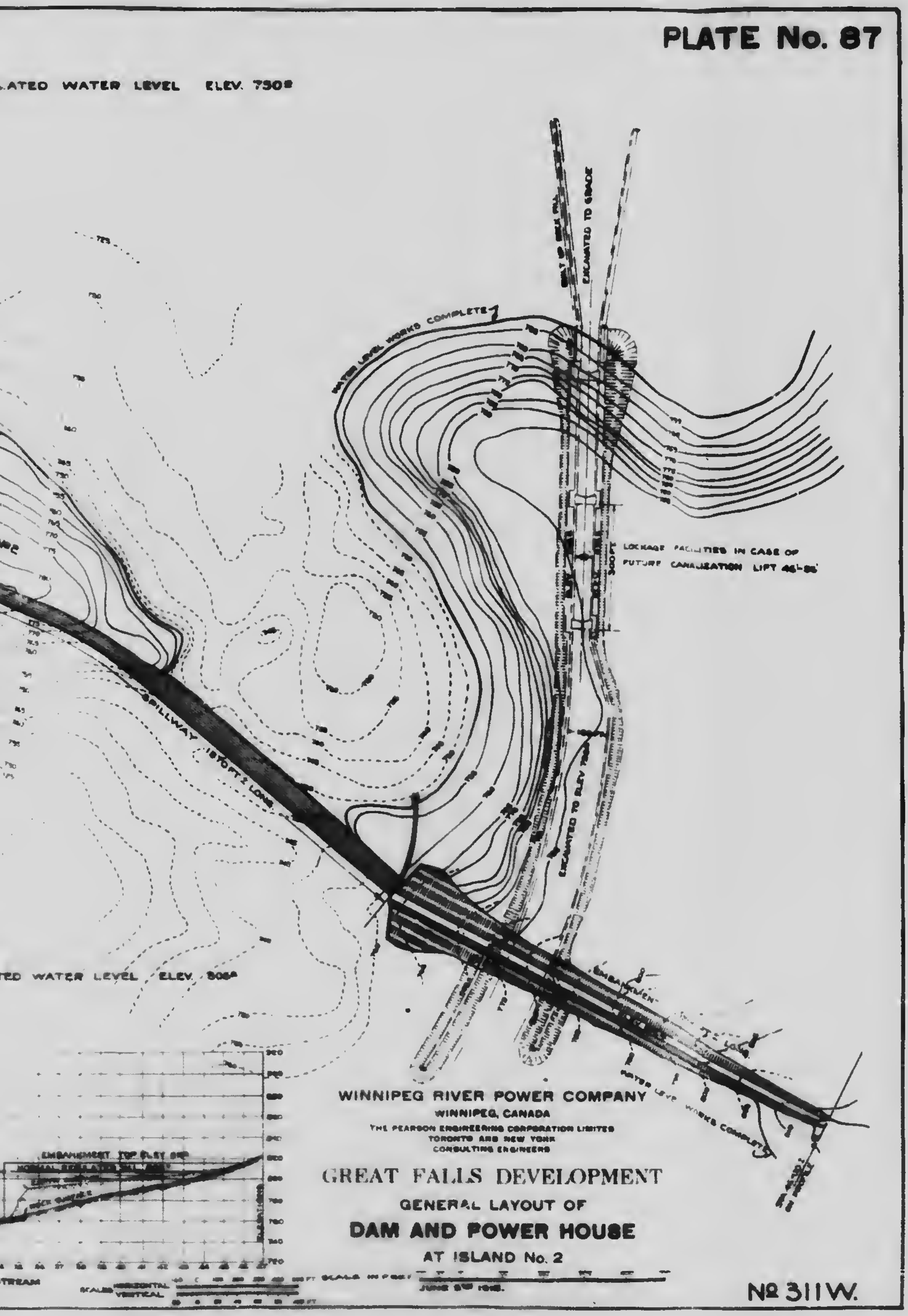
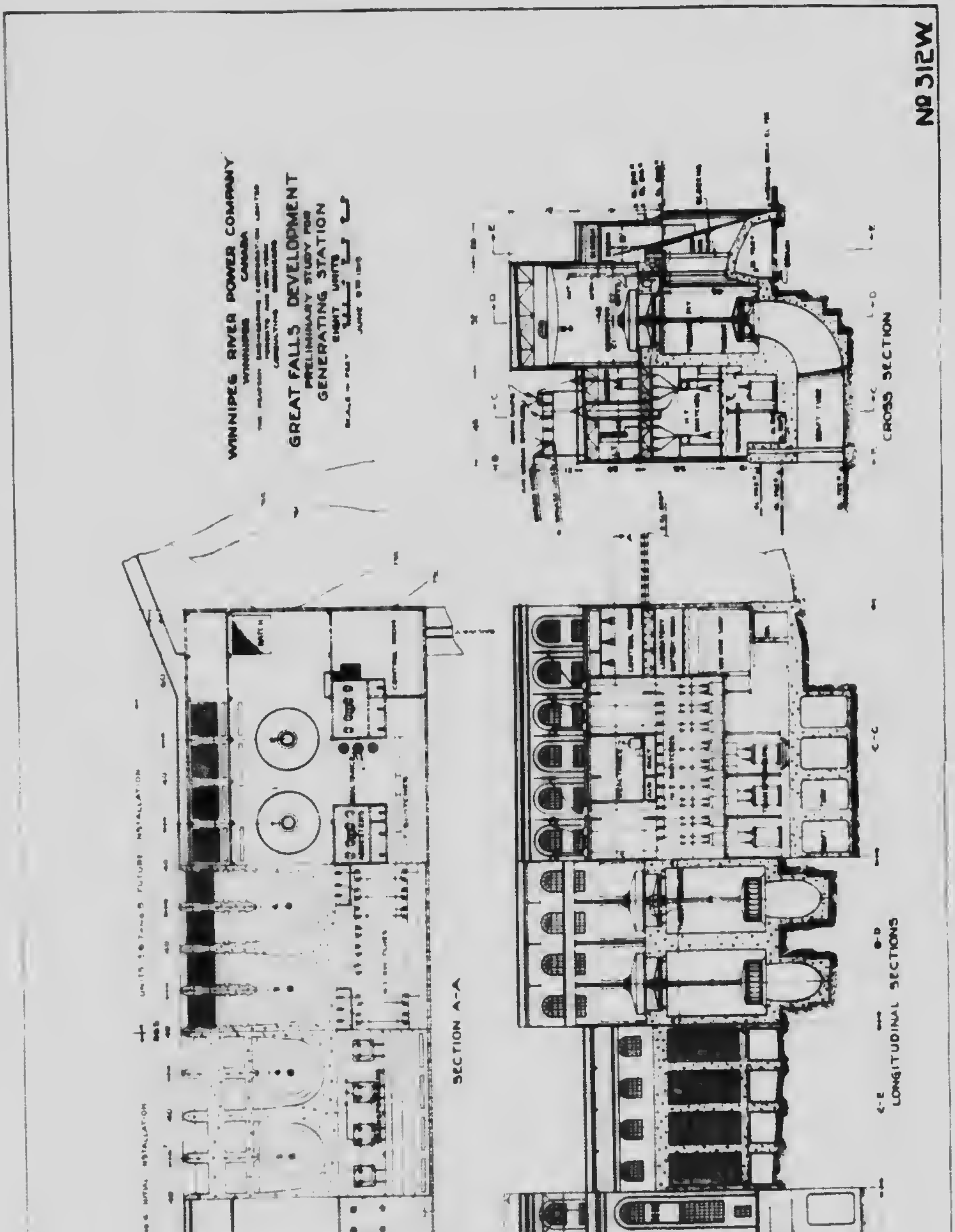


PLATE No. 87
ELEV. 730
SPILLWAY
EXCAVATED TO GRADE
WATER LEVEL WORKS COMPLETE
LOCKAGE FACILITIES IN CASE OF FUTURE CANALIZATION LIFT 46-86'
300 FT
EXCAVATED TO ELEV
EMBANKMENT
WATER LEVEL WORKS COMPLETE
WATER LEVEL ELEV. 808
EMBANKMENT TOP ELEV
WINNIPEG RIVER POWER COMPANY
WINNIPEG, CANADA
THE PEARSON ENGINEERING CORPORATION LIMITED
TORONTO AND NEW YORK
CONSULTING ENGINEERS
GREAT FALLS DEVELOPMENT
GENERAL LAYOUT OF
DAM AND POWER HOUSE
AT ISLAND No. 2
Nº 311 W.

PLATE No. 88



Nº 312W
WINNIPEG RIVER POWER COMPANY
GREAT FALLS DEVELOPMENT
PRELIMINARY STUDY FOR
GENERATING STATION
SECTION A-A
CROSS SECTION
LONGITUDINAL SECTIONS

PROPOSED INITIAL GENERATING INSTALLATION.

The initial development will consist of four complete units, viz., turbines, generators, transformers, and switching equipment. The hydraulic development will include dams, sluices, building, gates, etc., for the eight units, all sufficiently completed so that any of the four remaining generating units provided for may be installed without further construction work, except on the installation of the units themselves, which may be done at a minimum expense, and in the least time.

AVAILABLE POWER OUTPUT.

Without regulation at the Lake of the Woods, the maximum discharge of the Winnipeg river in abnormal years has reached 90,000 cubic feet per second, and the minimum discharge 12,000 cubic feet per second for three or four weeks in the year. The average run-off, from government records, is 45,000 cubic feet per second for high-water and 16,000 cubic feet per second for the low-water period.

The reservoir created by the dam at island No. 2 will have an area of 1,935 acres at elevation 808, the crest of the dam, and 1,600 acres at elevation 806 (two feet below the crest of the dam), thus furnishing a reserve supply of water of approximately 145,000,000 cubic feet, equivalent to 13,000 cubic feet per second for three hours. This reserve will produce 50,000 horse-power for three hours every day, in addition to the river's supply, taken at the rate of 16,000 cubic feet per second. At 46-foot fall, this rate of flow will produce 66,000 horse-power constant, and for three hours the output may be increased to 110,000 horse-power. The same water operating under 56 feet head, involving the excavation of the Whitemud falls canal, will produce a constant 82,000 horse-power, and for three hours an additional 63,000 horse-power, a total for three hours of 145,000 horse-power.

A regulated flow of at least 20,000 cubic feet per second minimum can readily be secured by proper control of the upper watershed, while a higher flow is also feasible.

Upon the basis of 25,000 cubic feet per second, there will be available under 46 feet head, Whitemud falls canal not excavated, a constant 90,000 horse-power, and 50,000 horse-power additional for three hours, or a total peak load capacity of 140,000 horse-power.

By utilizing Whitemud falls canal, the head is increased to 56 feet, and the power available will become constant 110,000 horse-power, and 63,000 horse-power additional for three hours, or a total peak load capacity of 173,000 horse-power.

The load factor at Winnipeg is between 60 per cent and 62 per cent, and under these conditions the peak load period could be extended to four hours without shortage of water.

TRANSMISSION LINES.

A double circuit transmission line will connect the plant direct with the step-down substation at Winnipeg, about 80 miles distant.

The lines will be three phase and supported on structural steel towers, 54 feet high. The insulator will be of porcelain and designed for ultimate operation of the lines at 110,000 volts.

Towers of special design will be provided at railway and river crossings, and other locations where necessary.

A second double circuit line will connect the power-house with the present plant at Pinawa, thence over the existing lines to Winnipeg. The company will thus have the advantages of a double loop connection between its sources of power and the consumers, assuring continuity of service.

ESTIMATES OF COST.

The cost estimates have been prepared for three steps in development; the first, including four units and utilizing 46 feet head; the second including eight units and utilizing 46 feet head; and the third including eight units, and utilizing Whitemud falls, giving 56 feet head.[1] The total capital cost of construction at the site, and not including transmission, is estimated by the company's engineers at $5,450,000, $5,902,000, and $6,767,000 for the three respective steps.

The preliminary engineering investigations carried out by the Winnipeg River Power Company were made by the J. G. White Engineering Corporation of New York, based upon field plans, and engineering data furnished by the Dominion Water Power Branch, and augmented by further detail work in the field on the part of the Company. The final analysis and design preparatory to commencing actual construction operations is being developed by the Pearson Engineering Corporation, Limited, of New York and Toronto; Mr. L. J. Hirt, C.E., Vice-President, with Mr. H. Hartwell, engineer in charge of design and construction at Winnipeg.

[1]These estimates furnish an excellent check on the estimates of the Du Bonnet site, 3,000 feet upstream, and hence on the estimates submitted herein covering the other proposed power concentrations on the river. The Du Bonnet site involves the same head- and tailwater elevations as the island No. 2 site. The total cost of the ultimate development is $6,767,000, according to the figures of the company's engineers, and as opposed to the departmental estimate of $6,551,000 for the Du Bonnet site.

REPORT

ON

THE WINNIPEG RIVER POWER AND STORAGE INVESTIGATIONS

APPENDIX III.

REPORT ON GEOLOGY OF WINNIPEG RIVER WATERSHED BY CHARLES CAMSELL, B.Sc., Ph.D.

APPENDIX III.

GEOLOGY OF THE WINNIPEG RIVER BASIN.

By CHARLES CAMSELL, B.Sc., Ph.D.

INTRODUCTION.

The following report on the geology of the Winnipeg River basin is compiled from the reports of officers of the Geological Survey who have at different times during the last thirty years reported on various portions of the basin.

For more detailed descriptions of certain portions of the district, the following reports should be consulted:—

Lawson, A. C.—On the Lake of the Woods region, with special reference to the Keewatin Belt of the Archean rocks. Annual Report, Geol. Surv. of Can. vol. I, 1885, part CC.

Lawson, A. C.—Report on the Geology of the Rainy Lake region. Annual Report, Geol. Surv. of Can. vol. iii, 1887-88, part F.

McInnes, W.—Report on the Geology of the area covered by the Seine River and Shebandowan Map Sheets, comprising portions of Rainy River and Thunder Bay districts. Annual Report, Geol. Surv. of Can., vol. x, 1897, part H.

McInnes, W.—District east of Manitou, Ont., Summary Report Geol. Surv. of Can., 1898, p. 87.

McInnes, W.—Rainy River District, Summary Report, Geol. Surv. of Can., 1899, p. 115.

McInnes, W.—Region southeast of Lac Seul, Summary Report, Geol. Surv. of Can., 1901, p. 89.

Tyrrell, J. B.—Report on the East Shore of Lake Winnipeg and adjacent parts of Manitoba and Keewatin. Annual Report Geol. Surv. of Can., vol. xi, 1898, part G.

Collins, W. H.—Report on a Geological Reconnaissance of the region traversed by the National Transcontinental Railway between Lake Nipigon and Clay lake, Ontario Geol. Surv., Can., No. 1059, 1909.

GENERAL PHYSICAL FEATURES.

The basin of the Winnipeg river lies on the southwestern border of the greatest of the main physiographic provinces into which Canada is naturally divisible, namely, the Laurentian Highland, or as it has sometimes been called the Canadian Shield. This province embraces the Labrador peninsula, northern

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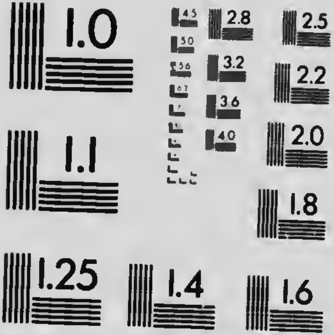

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Quebec, northern Ontario, and extends thence northwestward through northern Manitoba and Saskatchewan up to the Arctic ocean, completely encircling the great inland sea of Hudson bay...

In the far distant past of geologic time this province formed the original land area of North America, and to a large extent the continent was built out to the south and west by the materials eroded from that land area. It has probably remained a land area from pre-Cambrian times, and has consequently been continuously exposed to the eroding agencies of water and the atmosphere since that period. Its present topographic features are the result of that history and of the glaciation which completed its history. Probably hundreds of feet of its surface have been, in the course of ages, worn down and carried away and its surface has in that time been reduced from a mountainous character to one of subdued and rounded outline.

The whole basin has been heavily glaciated by a great ice-sheet which was accumulated in the region to the northeast and flowed over it to the southwest. This ice-sheet removed the decomposed surface of the rocks of the region and transported the materials so removed across the boundary line into the United States. On the retreat of the ice-sheet the region was left much as it is to-day, with its surface glaciated down to the undecomposed rock. Over this surface there is generally a marked absence of alluvium or drift, and only here and there patches of clay, sand, and gravel of glacial origin.

When viewed broadly, the topography of the basin of Winnipeg river is that of a broad plain sloping gradually to the west with elevations ranging from about 1,500 feet above the sea in the east to 710 feet at lake Winnipeg. In detail, however, it is exceedingly irregular and broken, with an uneven, hummocky, or mammillated surface. It is a country of numerous rockbound lakes and muskegs which occupy all the lower levels. The intervening areas are rocky, sparsely timbered hills which rarely rise more than 200 feet above the lakes.

Here and there areas of clay of greater or less extent cover the surface and obliterate the irregularities of the bedrock beneath. The most important of these clay areas occur in the vicinity of Dryden on the Canadian Pacific railway, at Lac Seul, and in the region towards the mouth of Rainy river and the southern end of lake of the Woods. The clay deposits are sediments that were laid down in lake basins formed at the front of the continental ice-sheet as it was retreating northward in the closing stages of the Glacial period.

The drainage system of the Winnipeg River basin is not well developed, and its streams flow, as a rule, in ill-defined valleys that are often merely chains of lakes connected with each other by short stretches of rapid, broken river. Except where they flow through areas of drift they carry little sediment, and this they soon deposit in the lakes which are perfect sedimentation basins.

Neither the Winnipeg river itself nor its tributaries are well graded in profile because they are young streams and have had neither time nor power since their beginning at the close of the Glacial period to cut deep or well-defined valleys. They are, as a rule, merely connecting links between the lakes, and their courses are dependent on chance irregularities of the rock floor. Owing to their youth and feeble cutting power, falls and rapids in them are numerous.

The region also is essentially a lake country, a feature which is due to the lack of any pronounced general slope to the region, and the mammillated or hummocky nature of the surface. These lakes serve to regulate the flow of the streams and act as conservation basins, so that there is no great difference between the extremes of high and low water. These characteristics make the whole Winnipeg River system excellent for power development.

The lakes of the basin are as a rule shallow rock basins whose positions and shapes have been determined mainly by the character and disposition of the rocks in which they have been excavated Lakes have been formed more readily in rocks of schistose or gneissic character, because such rocks are more susceptible to the action of decomposing and eroding agencies, than in the more massive granitoid rocks. The shapes of the lakes, too, are dependent very largely on the strike of the strata and the sirection of foliation, for after decomposition had affected the surface of the region to depths varying with the character and structure of the rocks, glacial ice removed the decomposed portion down to the unaltered rock, giving the surface the irregular hummocky character that it now has. The more deeply eroded portions were later filled with water to form the lakes.

GEOLOGY.

The entire region of the Winnipeg River basin (plate 89), with the exception of a narrow strip along the valley of Whitemouth river, is underlain by very ancient rocks of pre-Cambrian age. For the purposes of this description these rocks can be divided naturally according to age and composition into three distinct series, namely, Keweenawan, Laurentian, and Huronian-Keewatin The first of these is of little consequence, and consists of a few dykes. The second is the most important rock series, since it covers the widest area, and consists of crystalline igneous rocks of granitoid or gneissic character. The Huronian-Keewatin series includes, as well, certain rocks that are considered to be older, but the whole series consists mainly of schists and sediments that occur in detached elongated bands either on or intruded by the granites and gneisses.

Younger Paleozoic rocks of sedimentary origin overlap the pre-Cambrian rocks on the extreme western border of the Winnipeg River basin, but really they are of little consequence in this region.

Stratified deposits of clay and sand, and unstratified deposits of gravel of glacial origin are spread here and there over the surface of the older rocks.

The geological sequence, therefore, for the Winnipeg River basin may be summarized in the following table in which the formations are arranged in order of age:—

Pleistocene and Recent	Unconsolidated deposits of clay, sand, and gravel, mainly of glacial origin.
Ordovician	Limestone.
Keweenawan	Diabase dykes.
Laurentian	Granites and gneisses.
Huronian-Keewatin	Schists, limestones, slates, quartzites.

Huronian-Keewatin.—Rocks of this group have a fairly wide distribution throughout the basin of Winnipeg river. They occur in irregular patches, usually elongated in an east-northeast direction, parallel to the strike of the strata of which they are made up.

This group of rocks consists of mica, hornblende, and chlorite schists, limestone, slate, quartzite, conglomerate and various altered forms of these rocks. The beds usually stand in vertical positions or dip at high angles, and they strike in general in an east-northeast direction. Though relatively hard rocks they are much more susceptible to eroding and decomposing influences than the granites, and consequently they often occupy lake basins. They are rocks that have been subjected to considerable compression and disturbance, and have thereby had planes of cleavage, shearing or schistosity developed in them, causing them to become less resistant to disintegration than they might otherwise have been.

The prevailing colours of these rocks are dark grey or green, and in texture they are usually fine grained.

The boundaries of this series of rocks are, as a rule, not clearly defined for the reason that they have been intruded by the granites and gneisses, and a wide contact zone of highly altered rock has been formed as a result. Tongues of the granite also project into these rocks and tend to obscure the sharpness of the contact line. The patches of Huronian-Keewatin rocks that are now found here and there are mere remnants of once more extensive sheets that probably extended over the whole region, but destruction and absorption by the granite batholiths and erosion have reduced these rocks to their present areal dimensions.

Laurentian.—For convenience in description in this report it has been deemed advisable to classify all the granites and gneisses and other massive crystalline igneous rocks under this head, although it is certain that many of the granite bodies are of later age and are intrusive into the true Laurentian. These rocks cover a greater area in the Winnipeg River basin than those of any other age or formation. They might be said to form the basement on which all the other geological formations of the region rest, or in which they have been sunk.

These rocks are all of igneous origin, and have crystallized out from fusion, some in massive form and others in which a gneissic or foliated structure has been induced. The commonest variety of the massive form is a true granite containing quartz, feldspar, and mica. In texture they are crystalline and of medium to coarse grain. Some phases have a pronounced porphyritic habit, with individual crystals, sometimes several inches long. In other varieties the mica is replaced by hornblende, either wholly or only in part. Basic dark-coloured phases of the massive varieties also occur, but they do not cover wide areas.

The gneissic varieties of the Laurentian are of the same mineral composition as the massive, and are differentiated only by their foliated character. They frequently mark the border of the massive bodies into which they grade insensibly without change of mineral constituents. Their gneissic characters have probably been induced by movement in the igneous mass during solidification, or else they represent portions of the Ke... n rocks that have been torn off by the igneous rock in the course of its intrusion, and recrystallized by it.

The granites are probably the most important building stones within the area of the Winnipeg River basin, but they are not all equally good. In strength, mineral composition, and durability they are generally suitable for all constru-tion purposes, but dynamic forces of compression have often ruined their structure for such purposes by developing lines of cleavage and fracture at inconvenient angles. The younger granites are, as a rule, more suitable for quarrying and building than the older granites, since they have suffered less from dynamic forces, and have retained their massive, unfractured, and unfoliated form. These granites, however, are not as widespread as the older granites and gneisses.

Keweenawan.—In the region bordering the Winnipeg River basin on the east, namely, about lake Nipigon, a large area is covered by a thick sheet of Keweenawan sediments and diabase. This sheet at one time extended westward into the basin of Winnipeg river, but on account of its erosion it is now only represented in the eastern portion of the basin by isolated patches of diabase which rest on the older rocks. The diabase lies in a horizontal attitude, and is usually found in the deeper valleys and along the shores of lakes.

Farther west the Keweenawan is represented by dykes of diabase which are found on lake of the Woods, Shoal lake, and in the Rainy Lake region. These dykes have a general northwest and southeast trend and are remarkable for their width and persistence.

Ordovician.—On the western edge of the basin of Winnipeg river the pre-Cambrian rocks pass out of sight underneath a cover of Ordovician rocks, whose eastern boundary follows a line drawn from the mouth of Winnipeg river to the southwest end of the lake of the Woods. These rocks are limestone and sandstone which, on account of a covering of glacial drift, are rarely exposed at the surface. The limestone quarries at Tyndall and Garson are in the Ordovician. The beds lie flat and the rock has a light grey, mottled colour. It makes a useful building stone.

Pleistocene and Recent.—The formations classed under this head are the loose unconsolidated materials of Glacial and post-Glacial origin which cover the surface of the older rocks more or less throughout the whole region. They are beds of stratified clays and sands laid down presumably in ancient lake basins, and irregular deposits of gravel of both Glacial and recent stream origin. The most extensive gravel deposits are of glacial origin and have been formed by streams flowing under or on the glacial ice-sheet, or they represent the beaches of now extinct glacial lakes.

The present rivers have not, as a rule, a great extent of beach gravels.

DETAILED GEOLOGY OF SOME OF THE POWER SITES.

Since the Dominion Water Power Branch is concerned only with the development of Winnipeg River power sites that lie inside the province of Manitoba it is unnecessary to present details of the geology of the various sites in the province of Ontario. At the same time, no geological investigations have ever been carried out in the Winnipeg River basin that had for their main purpose the study of the rocks relative to power development, consequently the references in the various reports to the geology at the proposed sites are of a very general and cursory character.

In a report on the East Shore of lake Winnipeg, J. B. Tyrrell describes the geology of Winnipeg river as far up as the mouth of Whitemouth river. At Pine falls, he says, "similar red granite and hornblende granitite are exposed, and little foliation is seen in the granite at the short portages above. No boulders are noticed along this stretch of the river, the country being all covered by a thick bed of alluvial blue clay. . . . From these portages to Silver falls . . . little rock is seen, the banks being of alluvial clay, sloping up gradually to woods of aspen. At the falls the rock is a red hornblende granitite." Above Silver falls the banks are composed of blue alluvial clay without pebbles or boulders, through which only two or three bosses of granite project.

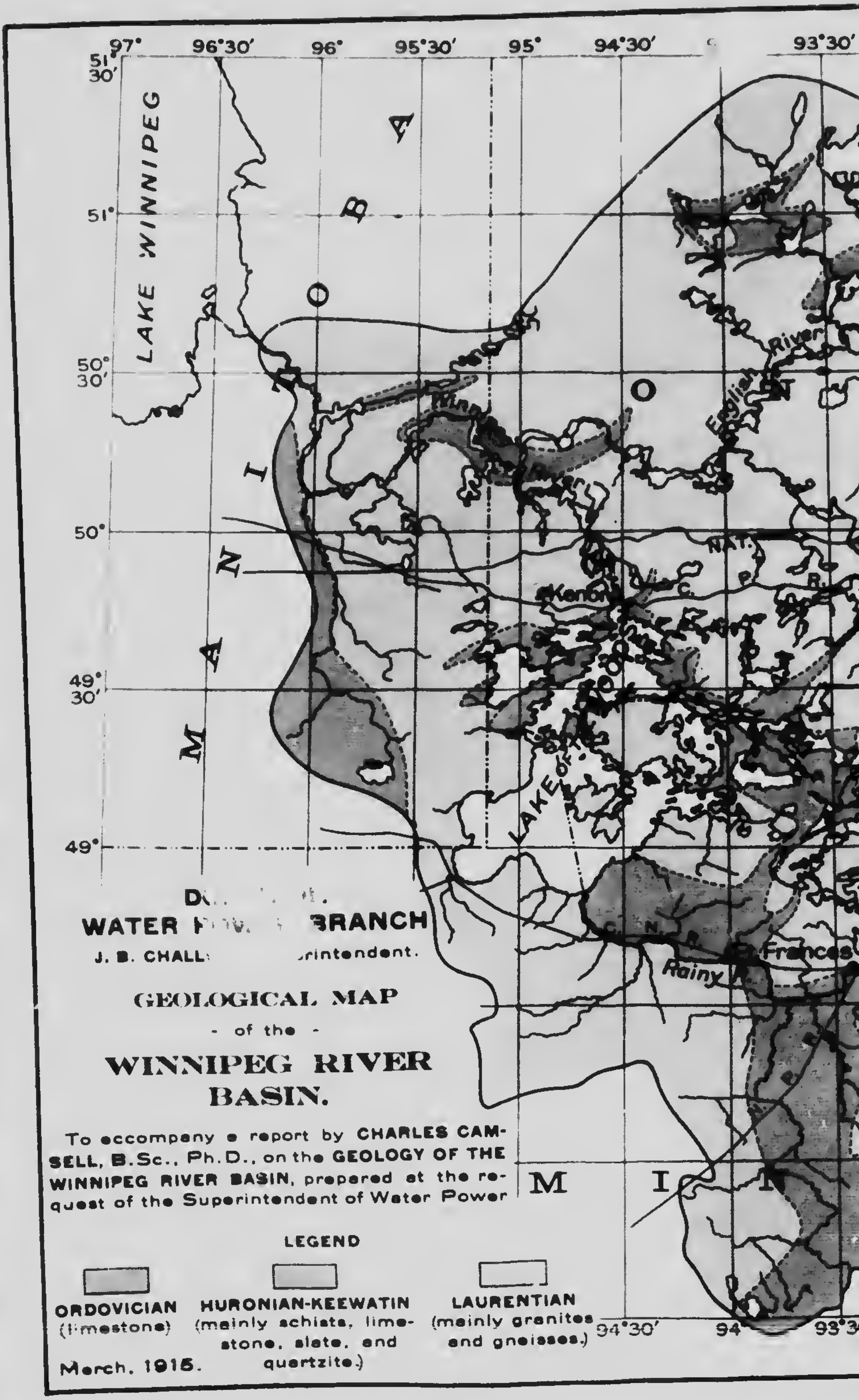
At Whitemud falls the river breaks over a mass of red granite containing a few inclusions of dark grey gneiss, and cut by many veins of red pegmatite.

The rock at Little du Bonnet falls is a hornblende granitite of light to dark grey colour. Above this to the Grand du Bonnet falls the river has low rocky banks, with clay generally filling the depressions, while at the falls knobs of granite protrude here and there through the surface clay.

The two falls between the Grand du Bonnet falls and Lac du Bonnet are known as McArthur falls, at each of which red granite containing inclusions of gneiss project in several places through the thin covering of alluvial material.

The shores of Lac du Bonnet are composed almost entirely of a coarse red micaceous granite which is massive and free from inclusions or pegmatite veins. About the mouth of Oiseau river, however, is a belt of red and green schists and gneisses which strikes up the valley of Oiseau river. These schists are of Huronian or Keewatin age and are the only rocks of this age on the Winnipeg river in Manitoba.

At the Seven Sisters falls the rock is said to be similar in character and composition to that at the previously mentioned falls.



97°
96°30′
96°
95°30′
95°
94°30′
93°30′
51° 30′
51°
50° 30′
50°
49° 30′
49°
LAKE WINNIPEG
M A N I T O B A
O N
English River
NAT.
Kenora
LAKE OF THE WOODS
Rainy
Frances
M I
DOM. ...
WATER P... BRANCH
J. B. CHALL... ...rintendent.
GEOLOGICAL MAP
- of the -
WINNIPEG RIVER
BASIN.
To accompany a report by CHARLES CAMSELL, B.Sc., Ph.D., on the GEOLOGY OF THE WINNIPEG RIVER BASIN, prepared at the request of the Superintendent of Water Power
LEGEND
ORDOVICIAN (limestone)
HURONIAN-KEEWATIN (mainly schists, limestone, slate, and quartzite.)
LAURENTIAN (mainly granites and gneisses.)
March, 1915.
94°30′
94°

PLATE No. 89

93°30'
93°
92°30'
92°
91°30
91°
90°30'
90°
51° 30'
Scale of Miles
10 0 10 20 30 40 50
51°
50° 30'
50°
49° 30'
49°
48° 30'
48°
47° 30'
River
LAC SEUL
TRANS.
Frances
93°30'
93°
92°
91°
90°30'
90°

REPORT

ON

THE WINNIPEG RIVER POWER AND STORAGE INVESTIGATIONS

APPENDIX IV.

WATER POWER REGULATIONS

APPENDIX IV.

WATER POWER REGULATIONS[1]

UNDER THE DOMINION LANDS ACT AND THE DOMINION FOREST RESERVES AND PARKS ACT.

Regulations made by His Excellency the Governor General in Council in virtue of the provisions of subsection 2 of section 35 of the Dominion Lands Act, 7-8 Edward VII, chapter 20, and by His Royal Highness the Governor General in Council in virtue of the provisions of subsection (b) of section 17 of the Dominion Forest Reserves and Parks Act, 1-2 George V, chapter 10, to govern the granting and administration of water-power rights in the provinces of Manitoba, Saskatchewan, Alberta, and in the Northwest Territories, and in Dominion Parks within the Railway Belt of British Columbia.

SECTION 35—DOMINION LANDS ACT—7-8 EDWARD VII, CHAPTER 20, AS AMENDED BY SECTION 6, CHAPTER 27 OF 4-5 GEORGE V.

35. Lands which are necessary for the protection of any water supply or lands upon which there is any water-power, or which border upon or being close to a water-power will be required or useful for the development and working of such water-power, shall not be open to entry for homestead, for purchased homestead, or pre-emption, or be sold or conveyed in fee by the Crown, but may only be leased under regulations made by the Governor in Council.

2. Subject to rights which exist or may be created under the Irrigation Act, the Governor in Council may make regulations: (*a*) for the diversion, taking or use of water for power purposes, and the granting of the rights to divert, take and use water for such purposes, provided that it shall be a condition of the diversion or taking of water that it shall be returned to the channel through which it would have flowed if there had been no such diversion or taking, in such manner as not to lessen the volume of water in the said channel; (*b*) for the construction on or through Dominion or other lands of sluices, races, dams or other works necessary in connection with such diversion, taking or use of water; (*c*) for the transmission, distribution, sale and use of power and energy generated therefrom; (*d*) for the damming of and diversion of any stream, watercourse, lake or other body of water for the purpose of storing water to augment or increase the flow of water for power purposes during dry season; (*e*) for fixing the fees, charges, rents, royalties or dues to be paid for the use of water for power purposes, and the rates to be charged for power or energy derived therefrom.

3. Any person who under such regulations is authorized to divert, take or use water for power purposes, or to construct works in connection with the diversion, taking or use of water for such purposes, shall for the purposes of his

[1]NOTE.—These regulations were made to apply to all forest reserves and parks by order of His Excellency the Governor General in Council, dated June 6, 1911, and by order of His Royal Highness, the Governor General in Council dated August 2, 1913, in virtue of the provisions of subsection (b) of section 17 of the Dominion Forest Reserves and Parks Act.

[1]NOTE.—These regulations were made to apply to all school lands by order of His Royal Highness, the Governor General in Council, dated the 9th of February, 1915.

[1]NOTE.—By virtue of the provisions of the Railway Belt Water Act, 2 George V, chapter 47, and the Railway Belt Water Act, 1913, 3-4 George V, chapter 45, all water within the Railway Belt of British Columbia is administrated under and in accordance with the provisions of the Water Act, 1909, and amendments thereto, by the province of British Columbia, except only the territory included within Dominion Parks.

undertaking have the powers conferred by the Railway Act upon railway companies, including those for the acquisition and taking of the requisite lands, so far as such powers are applicable to the undertaking and are not inconsistent with the provisions of this Act or the regulations thereunder, or with the authority given to such persons under such regulations—the provisions of the said Railway Act giving such powers being taken for the purposes of this section to refer to the undertaking of such person where in that Act they refer to the railway of the railway company concerned.

4. All maps, plans and books of reference showing lands other than Crown land necessary to be acquired by any such person for right of way or other purposes in connection with his undertaking shall be signed and certified correct by a duly qualified Dominion Land Surveyor.

5. Such maps, plans and books of reference shall be prepared in duplicate, and one copy thereof shall be filed in the office of the Minister at Ottawa, and the other shall be registered in the land titles office for the registration district which within the lands affected are situated.

6. The Minister, or such officer as he designates, shall in case of dispute, be the sole and final judge as to the area of land which may be taken by any person without the consent of the owner for any purpose in connection with any water-power undertaking.

Regulations Governing the Granting of Water-power Rights in the Provinces of Manitoba, Saskatchewan and Alberta, and in the Northwest Territories, including all Dominion Forest reserves and Parks, and in Dominion Parks within the Railway Belt of British Columbia.

Established and approved by orders of His Excellency the Governor General in Council dated June 2, 1909, June 8, 1909, April 20, 1910, January 24, 1911, August 12, 1911, and by orders of His Royal Highness, the Governor General in Council, dated August 2, 1913, and February 9, 1915, in virtue of the provisions of subsection 2 of section 35 of the Dominion Lands Act, 7-8 Edward VII, chapter 20.

DEFINITION OF WORKS.

1. Under these regulations the word "works" shall be held to mean and include all sluices, races, dams, weirs, tunnels, pits, slides, flumes, machine fixed to the soil, buildings and other structures for taking, diverting and storing water for power purposes, or for developing water-power and rendering the same available for use.

MODE OF APPLICATION.

2. Every applicant for a license to take and use water for power purposes shall file with the Minister of the Interior a statement in duplicate setting forth:—

(*a*) The name, address and occupation of the applicant.

(*b*) The financial standing of the applicant so far as it relates to his ability to carry out the proposed works.

(*c*) The character of the proposed works.

(*d*) The name, or if unnamed, a sufficient description of the river, lake or other source from which water is proposed to be taken or diverted.

(*e*) The point of diversion.

(*f*) The height of the fall or rapid of such river, lake or other source of water at high, medium and low stages, with corresponding discharges of water per second, reckoned approximately in cubic feet.

(*g*) A reasonably accurate description, and the area, of the lands required in connection with the proposed works, such lands, if in surveyed territory, to be described by section, township and range, or river or other lot, as the case may be, and a statement whether such lands are or are not Dominion lands.

(*h*) If such lands be not Dominion lands, then the applicant shall give the name of the registered owner in fee, and of any registered mortgagee or lessee thereof, and of any claimant in actual possession other than a registered owner, mortgagee or lessee.

(*i*) The minimum and maximum amount of water-power which the applicant proposes to develop, and the maximum amount of water which he desires for such purpose.

(*j*) Sketch plan showing approximate locations of the proposed works.

(*k*) Elevations of headwater and tailwater of the nearest existing works, if any, below and above the proposed works.

(*l*) Particulars as to any water to be taken, diverted or stored to the detriment of the operation of existing works, if any.

(*m*) Particulars as to any irrigation ditches or reservoirs, or other works for irrigation within the meaning of *The Irrigation Act*, in use or in course of construction within the vicinity of the proposed works, and which might affect or be affected by the operation of the proposed works.

APPLICATION BY A COMPANY.

3. If the applicant be an incorporated company, the statement shall, in addition to the foregoing information, set forth:—

(*a*) The name of the company.

(*b*) The names of the directors and officers of the company and their places of residence.

(*c*) The head office of the company in Canada.

(*d*) The amount of subscribed and paid-up capital, and the proposed method of raising further funds, if required, for the construction and operation of the proposed works.

(*e*) Copy of such parts of the charter or memorandum of association as authorize the application and proposed works.

APPLICATION BY A MUNICIPALITY.

4. If the applicant be a municipality, then, excluding the special information to be given by a company, the following information shall be given:—

(*a*) The location, area and boundaries of the municipality.

(*b*) The approximate number of its inhabitants.

(*c*) The present estimated value of the property owned by such municipality, and the value of the property subject to taxation by such municipality.

MINISTER MAY REQUEST FURTHER INFORMATION.

5. The Minister of the Interior shall have the power to call for such other plans and descriptions, together with such measurements, specifications, levels, profiles, elevations and other information as he may deem necessary, and the same shall be furnished by and at the expense of the applicant.

The Agreement for,—(*a*) A license for the diversion and use of water.
(*b*) A lease of the necessary lands.

6. Upon receipt and consideration of the application, and information accompanying same, the Minister of the Interior may, if he approves of the proposed works, enter into an agreement with the applicant, which agreement, in addition to usual conditions and covenants, shall contain clauses to provide as follows:—

(*a*) For a time within which the proposed works shall be begun.

(*b*) For a stated minimum amount of expenditure to be made in connection with the works annually during the term of the agreement.

(*c*) For a stated amount of water-power to be developed from the water applied for within a fixed period not exceeding five years.

(*d*) For summary cancellation of the agreement by the Minister if any of the above conditions have not been complied with.

(*e*) For defining and allotting the areas of Dominion lands within which the applicant may construct and operate the proposed works; and if there be no Dominion lands available for such purpose then for defining and allotting the lands in regard to which the applicant may exercise the powers given under section 35, subsection 3 of the *Dominion Lands Act*.

(*f*) For granting a license to the applicant, upon fulfilment of the said agreement, to take, divert and use for power purposes a stated maximum amount of water, in accordance with the application, and plans and specifications as approved by the Minister; the term of such license to be twenty-one years at a fixed fee payable annually, and such license to be renewable as provided for in these regulations.

(*g*) For granting a lease to the applicant of such Dominion lands as may be allotted under paragraph (*e*) of this section, and approved of by the Minister, such lease to be at a fixed rental, for a term of twenty-one years running concurrently with the said license, and renewable in like manner, and as near as may be subject to all the terms and conditions thereof. When there are no Dominion lands available for such purpose, or when other lands are considered by the Minister to be more suitable for such purpose, then the Minister shall define such lands in regard to which the applicant may exercise the powers given under section 35, subsection 3, of the *Dominion Lands Act*.

INSPECTION OF CONSTRUCTION WORK.

7. During the construction of any works for the development of water-power the Minister of the Interior, or any engineer appointed by him for that purpose, shall have free access to all parts of such works for the purpose of inspecting same, and ascertaining if the construction thereof is in accordance with the plans and specifications approved of by the Minister, and whether the terms of the agreement, as provided for in the preceding section, are being fulfilled.

THE LICENSE FOR THE DIVERSION AND USE OF WATER.

Upon fulfilment by the applicant of the conditions of the said agreement, the Minister of the Interior shall grant to the applicant a license as agreed upon, and such license shall contain clauses to provide as follows:—

(*a*) The term of the license shall be twenty-one years, renewable for three further consecutive terms of twenty-one years each, at a fixed fee payable annually and to be readjusted at the beginning of each term, as hereunder provided.

(*b*) At the expiry of each term of twenty-one years the Governor in Council, may, on the recommendation of the Minister, order and direct that the license and any lease granted in connection therewith be cancelled Provided that the Minister shall have given at least one year's notice to the licensee of intention so to cancel.

(*c*) If the licensee shall refuse to pay the license fee as readjusted by the Governor in Council, or as fixed by arbitrators chosen as provided in paragraph (*e*) hereunder, then in such case the Minister may renew the license at the former fee, or the Governor in Council may, on the recommendation of the Minister, order and direct that the license and any lease issued in connection therewith be cancelled.

(*d*) In either of the above cases compensation shall be paid to the licensee as provided for in paragraph (*e*) hereunder.

(*e*) On termination of the third renewal of such license, except in case of default on the part of the licensee in observance of any of the conditions thereof, or of any lease granted in connection therewith, compensation shall be paid for the works to the amount fixed by arbitration, one arbitrator to be appointed by the Governor in Council, the second by the licensee, and the third by the two so appointed. If the licensee fails to appoint an arbitrator within ten days after being notified by the Minister to make such appointment, or if the two arbitrators appointed by the Governor General in Council and the licensee fail to agree upon a third arbitrator within ten days after their appointment or within such further period as may be fixed by the Minister in either such cases such arbitrator, or third arbitrator, as the case may be, shall be appointed by the Judge of the Exchequer Court of Canada. In fixing the amount of compensation only the value of the actual and tangible works and of any lands held in fee in connection therewith shall be considered, and not the value of the rights and privileges granted, or the revenues, profits or dividends, being, or likely to be derived therefrom.

(*f*) The license shall state the maximum amount of water which the licensee may divert, store and use for power purposes, and shall provide for the return to the stream, or other source of water, of the full amount so diverted.

(*g*) The licensee shall develop such power as, in the opinion of the Minister, there shall be a public demand for, up to the full extent possible from the amount of water granted by the license.

(*h*) Upon a report being made by the Minister of the Interior to the Governor in Council that the licensee has not developed the amount of power for which there is a public demand, and which could be developed from the amount of water granted by the license, the Governor in Council may order to be developed and rendered available for public use the additional amount of power for which there is, in the opinion of the Minister, a public demand, up to the full extent possible from the amount of water granted by the license, and within a period to be fixed by the Minister, which period shall not be less than two years after the licensee or person in charge of the existing works shall have been notified of such order, and in default of compliance with such order the Governor in Council may direct that the license, together with any lease issued under these regulations shall be cancelled, and the works shall thereupon vest and become the property of the Crown without any compensation to the licensee.

(*i*) Upon a report being made by the Minister of the Interior to the Governor in Council that a greater amount of water-power could be developed advantageously to the public interests from the same stream or other source of water from which the existing works derive power and (1st) that the existing works could be enlarged or added to for such purpose, then the Governor in Council may authorize the Minister to offer the licensee the privilege of constructing and operating such enlarged or additional works at or in the vicinity of the existing works, and to grant such supplementary license as he may consider proper for such purpose, and if the licensee fail within six months thereafter to accept such offer, and in good faith to begin and carry on to completion such enlarged and additional works, and to complete same in accordance with plans and specifications approved of by the Minister, and within a fixed period not to exceed five years, and upon like conditions as the existing works were begun and completed; or (2nd) if the Minister shall report to the Governor in Council that the existing works, owing to their location or construction, cannot advantageously be enlarged or added to in order to develop further power sufficient to meet the probable demand, or would be a hindrance to other works contemplated for such purpose; or (3rd) that the existing works cannot, or will not, be any longer advantageously operated owing to the exercise of rights existing or created under the *Irrigation Act;* then in every such case, the Governor in Council may order and direct that the license, and any lease in connection therewith, and all rights thereunder, shall be cancelled, and the existing works shall thereupon vest in and become the property of the Crown: Provided always that in every such case compensation shall be paid to the licensee as provided for in paragraph (*e*) of section 8 of these regulations, together with a bonus apportioned as follows:—

(1) If the works have been in operation less than five years, a thirty per cent bonus upon the value of the works.

(2) If in operation more than five years, and less than ten years, a twenty-five per cent bonus.

(3) If in operation more than ten, and less than fifteen years, a twenty per cent bonus.

(4) If in operation more than fifteen, and less than twenty years, a fifteen per cent bonus.

(5) If in operation twenty years or more, a ten per cent bonus.

(*j*) That the license shall not be transferable without the written consent of the Minister, and that if the licensee fail to keep and observe all or any of the conditions of the license, or any renewal thereof, or of any lease to be issued in connection therewith, then the license, together with such lease, shall in every such case be subject to cancellation by the Exchequer Court on the application of the Crown.

(*k*) That a schedule of rates and prices to be charged to the public for the use of power shall first be submitted by the licensee to the Board of Railway Commissioners of Canada for adjustment and approval before being put into effect, and that no rates or prices for power shall be legal or enforceable until such schedule has been so adjusted and approved nor if they shall exceed the amount fixed by such schedule; and that such schedule shall be readjusted and approved by the Board every seven years during the term of the lease and license, and all renewals thereof.

(*l*) That for the purpose of ascertaining the quantity of power actually developed, or capable of being developed, from the amount of water granted by such license, the Minister, or any engineer appointed by him for that purpose, shall have free access to all parts of the works. and to all books, plans or records in connection therewith, bearing on the quantity of power developed, ar may make measurements, take observations and do such other things as he may consider necessary or expedient for such purpose, and the findings of the Minister, or such engineer, thereon shall be conclusive and binding upon the licensee.

(*m*) For the proper provision, as required by law, for the passage of logs and timber down the stream or other waterway affected by the works.

(*n*) For the erection and maintenance by the licensee of a durable and efficient fishway in the stream or other waterway affected by the works when so required by the proper officer or authority in that behalf.

(*o*) That the licensee shall have no right to any water beyond the amount stated in the license.

(*p*) For the indemnifying of the Crown against all actions, claims or demands against it by reason of anything done by the licensee in the exercise, or purported exercise, of the rights and privileges granted under the lease or license.

FORM OF AGREEMENTS AND LICENSES.

9. The agreements and licenses to be issued hereunder shall, subject always to the provisions of these regulations, be in such form and contain such provisions as the Minister may from time to time determine.

STORAGE OF WATER.

10. If at any time it is proposed by the applicant or the licensee to divert water from any lake or body of water for storage purposes, or to dam same in order to augment the flow of water in any stream from which water power is to be developed, the applicant or licensee shall, in addition to other information required under these regulations, file plans as follows:—

(*a*) A general plan in duplicate, on tracing linen, showing the location of such lake or other body of water, and the lands to be submerged or otherwise affected, and contour lines showing the water level at high and low stages, and the level to which it is proposed to raise such water for storage, and the estimated storage capacity of such lake or other body of water.

(*b*) A plan in duplicate, from actual survey, by a Dominion Land Surveyor, and certified to by him, showing the lands to be submerged or otherwise affected by the proposed storage; the name of the registered owner in fee of such lands, and of any registered mortgagee or lessee thereof, and of any claimant in actual possession other than a registered owner, mortgagee or [illegible]ee.

(*c*) A detail pla[illegible]uplicate on tracing linen, showing all dams and other works propose[illegible]e constructed in connection with such storage.

FORM OF AUTHORITY OF STORAGE OF WATER.

11. When the plans of such storage of water have been approved of by the Minister of the Interior, provision for same shall be made in the agreement for a license, or in the license itself, or in a supplementary license to be issued for such purpose, upon such terms and conditions as may appear to the Minister reasonable or expedient in the circumstances of each case, and subject to these regulations.

SMALL WATER-POWERS OF LESS CAPACITY THAN 200 HORSE-POWER.

12. If upon receipt and consideration of the information set out in sections 2, 3, 4 and 5, the water-power to be developed is found to have no greater capacity than 200 horse-power at the average low stage of water, the Minister may issue a lease and a license as may be required, authorizing the development of the proposed power; the lease and license to be for a period of ten years, subject to such special terms and conditions as may be considered advisable in each particular case and renewable if in the opinion of the Minister the power has been continuously and beneficially used.

REPORT

ON

THE WINNIPEG RIVER POWER AND STORAGE INVESTIGATIONS

APPENDIX V.

LIST OF BENCH MARKS

APPENDIX V.

LIST OF BENCH MARKS.

BENCH MARKS ESTABLISHED ALONG THE WINNIPEG RIVER IN CONNECTION WITH THE POWER SURVEY

No.	Elevation.	Description.	Location.
"A"	1,045·88	Copper bolt in concrete	In sill of side door, northwest corner of Kenora municipal power-house
"B"	1,064·09	Copper bolt in concrete	In centre of concrete base of tower of transmission line, 80 feet from Kenora municipal power house.
223	1,043·70	Chiselled and painted on rock	400 feet northeast of Kenora municipal power-house, on outcrop of rock on right bank, below power house.
220	1,046·73	Chiselled and painted on rock	About 450 feet above the head of Dalles rapids, on the left bank.
219	1,044·67	Chiselled and painted on rock	About 1,100 feet below island at foot of Dalles rapids, on left bank 400 feet below meter section.
218	1,036·16	Chiselled and painted on rock	At crest of First fall, south channel, Whitedog rapids, on right bank.
217	1,038·70	Chiselled and painted on rock	About 150 feet above crest of Second fall, south channel Whitedog rapids, on right bank.
216	1,017·92	Chiselled and painted on rock	About 100 feet above crest of Fourth fall, South channel, Whitedog rapids, on right bank.
215	1,002·59	Chiselled and painted on rock	On left bank at Fifth fall, South channel, Whitedog rapids.
214	997·39	Chiselled and painted on rock	East end of Island some ½ mile above First falls, close to left bank and near the mouth of the English river, on steep rocky bank
213	991·16	Chiselled and painted on rock	On left bank around bend from First falls, and some 100 yards from it, close to water's edge, on the top of a sheer rock several feet high.
212	989·51	Chiselled and painted on rock	On right bank on point across a wide expanse of the river below First falls, conspicuous from upstream.
211	989·67	Chiselled and painted on rock	On right bank some 100 feet west of E. bdy., sec. 22, tp. 15, r. 17, E.P.M., sheer rocky bank, conspicuous from swift water past interprovincial boundary.
210	991·06	Chiselled and painted on rock	On left bank some 100 ft. east of Wit. I.P.M.-XVII, XVI, XVII E. and VIII N. close to shore, on a sloping bank conspicuous from downstream looking south.
209	989·64	18-inch jack pine	Sec. 20 16 17 E.P.M., on left bank SW. of small island near bank.
208	988·85	18-inch poplar	On right bank on point opposite East end of a long narrow island and in sec. 19, tp. 16, r. 17 E.P.M., some 100 ft. upstream from E. bdy., sec. 24-16-16 E.P.M.
207	986·14	5-inch poplar	On right bank, on high point opposite west end of large island ("D" on township plan), in sec. 24 16 16, E.P.M. and close to E. bdy., sec. 23.
206	989·48	15-inch spruce	On southeastern side of island ("C" on township plan) near right bank in sec. 23 16 16 E.P.M.
205	987·16	8-inch poplar	On outbend of right bank opposite channel between islands ("A" and "B" on township plan), in sec. 22 16 16 E.P.M.
204	986·28	6-inch poplar	On right bank where the river bank bends to the north and the river widens to over half a mile at west end of island "A" and in sec. 22 16 16 E.P.M.
203	986·29	10-inch poplar	On right bank on point N. 38° W. from NW. point of island "A" and in SE. ¼, sec. 28 16 16 E.P.M.
202	984·51	10-inch poplar	On right bank on broad point above narrows, N. 56° W. from NW. point of island "A" and in SW. ¼, sec. 28-16-16 E.P.M.
201	985·85	20-inch spruce	On left bank on small rock point on west side of a broad point in SW. ¼ sec. 29 16 16 E.P.M., at edge of trees.
200	984·87	8-inch poplar	On left bank on small point in SE. ¼ sec. 29 16 16 E.P.M.
199	985·68	14 inch poplar	On left bank in SE. ¼ sec. 25 16 15 E.P.M., above swift water at Lamprey falls and opposite a small island.
198	983·34	9-inch poplar	On south end of island in rapids above Lamprey falls
197	984·22	15-inch spruce.	On left bank on point 700 ft. above Lamprey falls and opposite a small island.
196	984·27	12-inch spruce.	On left bank on point at head of Lamprey falls.
195	989·79	Jack pine stump 5 inches by 5 inches by 3 inches.	500 feet NW. of intake of Point du Bois power plant
194	987·96	Painted on concrete and marked 218·88 (city datum).	Pillar of verandah of staff house, Point du Bois, first pillar south of steps.
193	938·73	5-inch jack pine	On right bank on first rocky point below rapids which are situated some 200 yards downstream from transmission line on Point du Bois power plant, and in NW. ¼ sec. 25 15 14 E.P.M.

BENCH-MARKS ESTABLISHED ALONG THE WINNIPEG RIVER, Etc.—*Continued*

No.	Elevation	Description.	Location
193A	939·87	Chiselled and painted on rock	On right bank, south end of bay, below rapids situated some 200 yds. downstream from transmission line of Point du Bois power plant, on top of rock shore and in NW. ¼ sec. 25-15-14 E.P.M.
192	940·47	12-inch spruce	On right bank above Eight Foot falls, 375 feet west of rock cut and close to log shack S. 45° W. from ¼ W.P. on E. bdy., sec. 25-15-14 E.P.M.
192A	940·37	Chiselled and painted on rock	On right bank above Eight Foot falls 320 feet west of rock cut, 60 ft. NE. of shack and S. 44° W. from ¼ W.P. on E. bdy. sec. 25-15-14 E.P.M.
191	931·38	10-inch jack pine	Right bank below Eight Foot falls, 160 ft. SW. of lower end of rock cut and N. 31° W. from Wit. I.P. Stone M. 4 S. on E. bdy., sec. 25-15-14 E.P.M.
191A	930·02	Chiselled and painted on rock ..	Right bank below Eight Foot falls, 450 ft. SW. of rock cut and 8 ft. east of B.M. No. 191.
190	929·21	10-inch poplar ..	Right bank on point 1 mile south of Eight Foot falls and 220 feet S. 66° E. from ¼ W.P. on E. bdy. sec. 24-15-14 E.P.M.
190A	928·21	Chiselled and painted on rock ..	Right bank on point 1 mile south of Eight Foot falls and 205 feet S. 82° E. from ¼ W.P. on E. bdy. sec. 24-15-14, E.P.M.
190B	930·75	Chiselled and painted on rock .	On left bank on E. bdy. of sec. 24-15-14 E.P.M., some 200 ft west of trail to Hunt Club, on top of steep rock bank.
189	929·60	6-inch poplar .	Above Slave falls on right bank, 170 ft. N. 62° W. from "A" frame of cable meter station and 150 ft. east of log shack, SW. ¼ sec. 12-15-14 E.P.M.
189A	929·91	Chiselled and painted on rock ..	Above Slave falls on right bank 40 ft. S. 6° W. of "A" frame of cable meter station.
	952·62	6-inch poplar stump ..	Above Slave falls on right bank on E. bdy. sec. 11-15-14, E.P.M., some 125 ft. south on the line from the bank.
..	939·33	16-inch poplar stump ..	Below Slave falls on right bank, on E. bdy. sec. 11-15-14 E.P.M. and 165 ft. north of Wit. I. P. & M.
188	916·03	Jack pine stump	Below Slave falls on right bank, in sec. 2-15-14 E.P.M. 530 ft. S. 22° W. from Wit. I. P. sec. 11 and N. 60° E. from rock at mouth of Portage bay.
188A	912·33	Chiselled and painted on rock ..	Below Slave falls on right bank in sec. 2-15-14 E.P.M., 580 ft. S. 22° W. of Wit. I.P.M. on E. bdy. sec. 11, and 53 ft. S. 33° W. of B.M. No. 188.
....	939·72	Jack pine stump	Above Slave falls on left bank, 125 ft. SE. of support for cable of meter station, in SW. ¼ sec. 12-15-14 E.P.M.
....	967·41	Jack pine stump	Below Slave falls on left bank, due east of Wit. I.P.M. on E. bdy. sec. 11, and 540 feet from shore.
187	910·38	8-inch spruce.	Three-quarter mile below Slave falls on right bank at narrows between island and mainland, first swift water below Slave falls, sec. 2-15-14 E.P.M.
187A	917·32	Chiselled and painted on rock ...	On right bank at narrows between island and mainland, first swift water below Slave falls, 25 ft. SW. of B.M. No. 187, sec. 2-15-14 E.P.M.
186	908·63	5-inch jack pine ..	On right bank on short point in the middle of Scott's channel, 700 ft. down stream from I.P. of metering station of city of Winnipeg and S. 50° W. from hub on right on meter station, sec. 21-14-14 E.P.M.
186A	907·65	Chiselled and painted on rock ..	On right bank Scott's channel N. 30° E. from point on right bank at lower end of channel, above bay adjacent to point at lower end, sec. 21-14-14 E.P.M.
Sta. 79	903·15	Chiselled and painted on rock ...	On right bank at crest of Sturgeon falls. Referenced to 9-inch oak, 16 ft. NW., and 5-inch poplar 34 ft. E. sec. 8-14-14 E.P.M.
Sta. 79A	905·58	Chiselled and painted on rock ..	On middle of southern part of island at Sturgeon falls. Referenced to three jack pine trees 37·5 feet, 35 feet, and 14 feet in sec. 8-14-14 E.P.M.
185	912·27	5-inch oak.	On left bank above Sturgeon falls at head of portage in sec. 8-14-14 E.P.M.
185A	907·45	Chiselled and painted on rock ...	On left bank above Sturgeon falls, close to head of portage in sec. 8-14-14 E.P.M.
184	902·32	7-inch poplar	On left bank in sec. 13-14-13 E.P.M., on lower side of the neck of the "Barrier".
184A	903·73	Chiselled and painted on rock....	On left bank in sec. 13-14-13 E.P.M., on lower side of the neck of the "Barrier" on low rock.
183	899·05	10-inch dry jack pine.	On right bank at water's edge, 70 ft. above small diversion weir, 130 ft. downstream from E. bdy., sec. 2-14-12 E.P.M.
183A	901·18	Chiselled and painted on rock....	On right bank on sloping bank 80 ft. above small diversion weir, 125 ft. downstream from E. bdy., sec. 2-14-12 E.P.M., N 85° W. from Rock island forming part of weir.
182	895·58	7-inch poplar..	Sec. 2-14-12E. P.M., on right bank near water's edge, 150 ft. above Twin falls, 30 ft. above head of portage and N. 25° E. from northerly point of large island at head of falls.
182A	897·96	Chiselled and painted on rock....	Sec. 2-14-12 E.P.M. on right bank near water's edge, on top of steep rock 90 ft. above Twin falls and N. 45° W. from northerly point of large island at head of falls.
181	894·00	10-inch poplar..	At mouth of Loon river, on right bank and upstream some 650 feet from Wit. I.P.M., on E. bdy., sec. 3-14-12 E.P.M.
181A	893·25	Chiselled and painted on rock ...	At mouth of Loon river, on right bank, on flat rock 25 feet from water's edge and some 700 feet upstream from Wit. I.P.M. on E. bdy. sec. 3-14-12 E.P.M.
180	893·80	12-inch poplar	Sec. 3-14-12 E.P.M. on right bank opposite a small island midstream between the bank and a large island called Porcupine Island.

BENCH-MARKS ESTABLISHED ALONG THE WINNIPEG RIVER, ETC.—*Continued*

No.	Elevation.	Description.	Location.
180A	894·99	Chiselled and painted on rock	Sec. 4-14-12 E.P.M., on right bank, on an out-bend of the bank conspicuous from the river, on steep rocky bank opposite a small island midstream between the bank and Porcupine island.
179	894·42	12-inch poplar	Sec. 4-14-12 E.P.M., on right bank some 350 feet downstream from E. bdy., sec. 4, close to shore and opposite a group of bare rock islands, situated ¼ mile above first swift below Twin falls.
179A	891·35	Chiselled and painted on rock	Sec. 4-14-12 E.P.M., on right bank, on short wide point which is situated some 100 yards above first swift below Twin falls, located on top of rock bank and conspicuous from upstream.
178	894·80	15-inch poplar	Sec. 4-14-12 E.P.M., on right bank, on east side of point at foot of first swift below Twin falls and some 25 feet from shore.
178A	892·08	Chiselled and painted on rock	Sec. 4-14-12 E.P.M., on right bank, on point at foot of swift on vertical rock at water's edge and conspicuous from the up and down stream.
177	891·34	18-inch poplar	Sec. 4-14-12 E.P.M., on right bank N. 60° E. from W. [illegible] on N. bdy., sec. 12-13-12 E.P.M., and some 80 [illegible] stream from E. bdy. sec. 5.
177A	891·72	Chiselled and painted on rock	Sec. 4-14-12 E.P.M., on right bank, N. 50° E. from [illegible] point of rocky island, on E. bdy., sec. 5, and some 300 upstream from E. bdy., sec. 5; on vertical rock at w[illegible] edge, conspicuous from the river, up and down stream.
176	892·54	8-inch oak	Sec. 5-14-12 E.P.M., on right bank, on first rocky point at Seven Sisters falls some 1,000 feet downstream [illegible] bdy., sec. 5, and on W. side of point.
176A	891·38	Chiselled and painted on rock	Sec. 5-14-12, E.P.M., on right bank, on first rocky point [illegible] Seven Sisters falls, some 1,000 feet downstream fro[illegible] bdy. sec. 5, on top of bank, close to water's edge and [con]spicuous from up and down stream on the river.
175	894·40	12-inch poplar	Sec. 5-14-12 E.P.M., on right bank, N. 45° W. from low ro[illegible] bend to south of left bank and some 200 yds. down[illegible] from a small creek close to shore.
174	891·06	5-inch poplar	Sec. 11-12-12 E.P.M. on right bank, N. 72° W. from inters[ection] of south shore and E. bdy. sec. 31, above Seven Sis[ters] where the right bank bends to northeast and the [illegible] widens, located close to shore.
173	890·17	9-inch mountain ash	Sec. 31-13-12 E.P.M., on right bank, on point at head [illegible] water above Seven Sisters, at edge of vegetation.
173A	890·44	Chiselled and painted on rock	Sec. 31-13-12 E.P.M., on right bank, on point at head [illegible] water above Seven Sisters, on shelving rocky shore.
173B	890·86	Chiselled and painted on rock	Sec. 31-13-12 E.P.M., on top of small island near left ba[nk] at crest of First fall of Seven Sisters, conspicuous from [illegible]
172	882·46	10-inch jack pine	Sec. 36-13-11 E.P.M., on right bank, on point east [illegible] deep bay above Second fall of Seven Sisters at [illegible] of vegetation.
172A	882·28	Chiselled and painted on rock	Sec. 36-13-11 E.P.M., some 350 feet downstream fr[illegible] [bd]y. sec. 36, on right bank, on point East side of de[illegible] [ab]ove Second fall of Seven Sisters, on shelving rocky [illegible]
171	872·49	8-inch poplar	Sec. 36-13-11 E.P.M., on right bank, on west [illegible] at low point below Second fall of Seven Sisters.
171A	871·15	Chiselled and painted on rock	Sec. 36-13-11 E.P.M., on right bank, on low [illegible] below Second fall of Seven Sisters, conspicuous from the river from above Third falls on north side.
170	867·09	7-inch mountain ash	Sec. 36-13-11 E.P.M., on right bank, in bay to east of high point below Third falls, close to edge of vegetation.
170A	869·77	Chiselled and painted on rock	Sec. 36-13-11 E.P.M., on right bank, on high point, first below Third fall of Seven Sisters.
170B	869·67	Painted on rock	Sec. 36-13-11 E.P.M. on left bank, at foot of Third fall of Seven Sisters.
	898·90	4-inch balsam stump	On left bank south of river, at Third falls, on a traverse line which crosses the portage some 400 feet from its lower end and situated some 400 ft. north of portage.
169	864·71	8-inch poplar*	Sec. 35-13-11 E.P.M., some 500 ft. downstream from E. bdy. sec. 35, on right bank on an out-bend of the bank N. 66° W. from first high point below Third fall of Seven Sisters.
169A	864·87	Chiselled and painted on rock	Sec. 35-13-11 E.P.M., approx. ¼ mile downstream from E. bdy. sec. 35, on right bank NW. of large rocky island midstream, N. 63° E. small island and N. 80° W. from first high point below fall.
168	864·40	8-inch poplar	Sec. 35-13-11 E.P.M., on right bank, some 400 feet above Fourth fall.
168A	864·19	5-inch birch	Sec. 35-13-11 E.P.M., and downstream from E. bdy., sec. 26 some 300 yds., on left bank below Third fall, S. 33° W. of high point on right bank below falls, S. 15° E. of large rocky island midstream.
168B	863·88	Chiselled and painted on rock	Sec. 35-13-11 E.P.M., on right bank, in small bay close to head of Fourth fall, on steep rocky bank, conspicuous from upstream.
168C	866·58	Painted on rock	Sec. 35-13-11 E.P.M., on left bank, on sloping rock point at Fourth falls of Seven Sisters, facing upstream.
167	857·52	7-inch spruce	Sec. 35-13-11 E.P.M., on right bank on east side of bay, below first high point downstream from Fourth falls, at edge of vegetation.

BENCH-MARKS ESTABLISHED ALONG THE WINNIPEG RIVER, Etc.—*Continued*

No.	Elevation	Description	Location
167A	859·02	Chiselled and painted on rock	Sec. 35-14-11 E.P.M., on right bank, on first high point downstream from Fourth falls, on steep rock close to water's edge.
166	858·46	8-inch poplar	Sec. 34-14-11 E.P.M., and on an outbend of right bank N. 80° W. from where the left bank is intersected by E. bdy. sec. 34.
166A	857·62	Chiselled and painted on rock	Sec. 34-14-11 E.P.M., and downstream from E. bdy. sec. 34 some 400 yards, on an out-bend of right bank, N. 70° W. from where the left bank is intersected by E. bdy. sec. 34, and S. 45° W. from first high point below falls.
165	857·07	7-inch poplar	Sec. 34-14-11 E.P.M., on right bank, at head of lower portage of Seven Sisters, close to water's edge.
165A	856·55	Chiselled and painted on rock	Sec. 34-14-11 E.P.M., on right bank, at head of lower portage on rocky shore.
164	852·10	16-inch balm of Gilead	On right bank below Seven Sisters falls, at lower end of portage, on high bank at edge of trees.
164A	844·80	Chiselled and painted on rock	Sec. 33-14-11 E.P.M., on right bank, below Seven Sisters falls, in small deep bay at foot of falls, on top of sheer rocky shore.
	884·61	9-inch balsam	On E. bdy. 28-14-11 E.P.M., 580 feet south of witness post on left bank and 15 feet south of base line.
	855·42	11-inch balsam	Sec. 28-14-11 E.P.M., on right bank of Whitemouth river, across from house of Louis Brent.
	854·84	Chiselled and painted on rock	Sec. 28-14-11 E.P.M., on rocky shore of right bank of Whitemouth river, opposite small point above Whitemouth falls.
	845·94	Stump .	Sec. 33-14-11 E.P.M., close to shore of left bank, Winnipeg river, below Seven Sisters, some 200 yards downstream from low rocky point at mouth of Whitemouth river and opposite large rocky island at foot of falls.
163	851·68	7-inch oak	Sec. 33-14-11 E.P.M., on right bank, on point ¼ mile below Seven Sisters, and across from a clearing and close to edge of trees.
163A	840·96	Chiselled and painted on rock	Sec. 33-14-11 E.P.M., on rocky shore of right bank, on point ¼ mile below Seven Sisters and across from clearing, conspicuous from the river.
162	845·33	6-inch poplar	Sec. 4-14-11 E.P.M., on right bank above first "swift", below Seven Sisters, across from small island adjacent to left bank.
.	841·74	Stump .	Sec. 4-14-11 E.P.M., on left bank above low rocky point near head of first "swift" below Seven Sisters, close to shore.
161	850·00	16-inch oak	Sec. 4-14-11 E.P.M., on right bank, on south side of point, at bend in river about middle of first "swift" below Seven Sisters.
161A	840·75	Chiselled and painted on rock	Between secs. 4 and 5-14-11 E.P.M., on rocky shore of right bank, at bend in river about middle of first "swift" below Seven Sisters.
160	841·80	12-inch poplar	Sec. 8-14-11 E.P.M., on right bank, above a narrow strip of hay land and watercourse, N. 45° E. from creek on left bank, river bends to NW. downstream.
160A	834·26	Chiselled and painted on rock	Sec. 8-14-11 E.P.M., on right bank, below a low small rounded point and opposite a small creek on low rock outcrop.
159	841·30	16-inch poplar	Sec. 8-14-11 E.P.M., on an out-be… right bank, some 400 feet south of N. bdy. sec. 8 and cl… to shore.
158A	830·16	Chiselled and painted on rock	On right bank near head of rapids in sec. 17-14-11 E.P.M., and S. 60° W. from house of Charles Gustaffson, on low rock outcrop.
157	838·90	22-inch poplar	On right bank in SW. ¼ sec. 20-14-11 E.P.M., 150 feet west from log house of P. A. Larson, at edge of trees.
156	839·81	5-inch poplar	Sec. 29-14-11 E.P.M. close to shore, on right bank 670 feet north of N. bdy. sec. 20.
156A	829·78	Chiselled and painted on rock	Sec. 29-14-11 E.P.M., on right bank.
155	834·26	16-inch poplar	On right bank, near shore, in NW. ¼ sec. 29-14-11 E.P.M., and N. 70° E. of house of Olaf Dohlgren on left bank.
154	833·68	8-inch spruce	On left bank, in sec. 32-14-11 E.P.M., downstream at edge of trees, some ¼ mile from house of John Lonade.
152	826·50	8-inch poplar	Sec. 8-15-11 E.P.M., on right bank, close to shore and to summer cottages on first point upstream from island owned by Lac du Bonnet Mining & Development Co., on which is located a telephone pole.
152A	826·57	Chiselled and painted on rock	Sec. 8-15-11 E.P.M., on right bank, on low rocky shore, close to summer cottages on first point upstream from island owned by Lac du Bonnet Mining & Development Co.
151	8[illegible]·18	10-inch poplar	Sec. 27-15-11 E.P.M., on left bank, a lone tree on first rocky point upstream from city bridge and downstream from N. bdy. sec. 22, some 750 feet, at edge of vegetation.
150	828·30	16-inch poplar	Sec. 27-15-11 E.P.M., on left bank, some 500 feet upstream from city bridge, close to edge of vegetation.
	826·20	Chiselled on rock (marked 826·11)	Sec. 27-15-11 E.P.M., on left bank, some 100 feet upstream from bridge on top of highest rock and close to shore.
149	828·81	Blazed tree	Sec. 27-15-11 E.P.M., on left bank, close to edge of trees, some 800 feet downstream from fish company's ice house at city bridge.
149A	828·66	Chiselled and painted on rock ...	Sec. 27-15-11 E.P.M., on left bank, on rock point some 400 feet upstream from shack and S. 55° W. from fish company's storehouse which is on south side of point, located some ½ mile from city bridge.

BENCH MARKS ESTABLISHED ALONG THE WINNIPEG RIVER, ETC.—*Continued*

No.	Elevation	Description	Location
148	826.36	Blazed tree	Sec. 34-15-11 E.P.M., on left bank, some 100 feet upstream from E. bdy. sec. 34, on south side of point at first swift current below city bridge, close to shore.
148A	827.31	Chiselled and painted on rock	Sec. 34-15-11 E.P.M., some 250 feet upstream from E. bdy. sec. 34, on left bank, on south side of point at first swift water below city bridge, on steep rocky bank, conspicuous from upstream.
147A	825.75	Chiselled and painted on rock	Sec. 34-15-11 E.P.M., on left bank, some 150 feet downstream from E. bdy. sec. 34, on north side of point at first swift water below city bridge, on steep rocky bank, conspicuous from downstream.
147	826.98	Blazed tree	Sec. 34-15-11 E.P.M., on left bank, some 200 yards from E. bdy., sec. 34, on north side of point at first swift water below city bridge, close to shore.
146	826.00	Poplar tree	Sec. 27-16-11 E.P.M., on island at head of west channel, on south side of point, at edge of trees.
146A	827.84	Chiselled and painted on rock	Sec. 27-16-11 E.P.M., on left bank, at head of first swift water on west channel, on steep rocky bank, conspicuous from south.
145	826.65	5-inch jack pine	Close to E. bdy. sec. 27-16-11 E.P.M., on left bank, on top of point at First McArthur falls.
145A	827.05	Chiselled and painted on rock	Close to E. bdy., sec. 27-16-11 E.P.M., on left bank, on top of point at First McArthur falls.
144	825.37	8-inch oak tree	Sec. 27-16-11 E.P.M., on left bank, at top of bank 15 feet north of section line.
143	816.22	6-inch poplar	Sec. 35-16-11 E.P.M., on left bank, 100 yards above Second McArthur falls, on clay bank.
143A	819.47	Chiselled and painted on rock	Sec. 35-16-11 E.P.M., on left bank, 200 feet above Second McArthur falls, on rocky shore.
142	819.35	8-inch spruce	Sec. 35-16-11 E.P.M., on left bank, lower end of portage, at Second McArthur falls.
142A	819.61	Chiselled and painted on rock	Sec. 35-16-11 E.P.M., on left bank, on steep rocky bank to East of lower end of portage, at Second McArthur falls.
141	813.33	10-inch oak tree	West channel, Second McArthur falls, south side of point on island at end of rapids below falls, at edge of trees.
141A	812.99	Chiselled and painted on rock	On point out from B. M. No. 141.
140	811.00	9-inch poplar	North side of point at B. M. No. 141.
140A	811.16	Chiselled and painted on rock	West channel, Second McArthur falls, last point on island. South side on steep rock at water's edge, conspicuous going downstream.
	820.75	Stump	Northeast corner, 34-16-11 E.P.M., island at Second McArthur falls.
	831.70	Stump	On north boundary 35-16-11 E.P.M., 575 feet east of northeast corner 34-16-11 E.P.M., island at Second McArthur falls.
139	815.12	10-inch oak tree	SE. point, island below Second McArthur falls, on E. bdy., sec. 3-17-11 E.P.M.
139A	812.16	Chiselled and painted on rock	South side island below Second McArthur falls, on E. bdy. sec. 3-17-11 E.P.M., on steep rocky bank.
	818.78	Stump	Sta. 78 + 70 on left bank traverse in sec. 3-17-11 E.P.M.
	819.59	Stump	Left bank sec. 10-17-11 E.P.M., at sta. 29 + 61 on traverse from north boundary sec. 10.
138	813.63	18-inch poplar tree	Right bank, head of first narrows above Grand du Bonnet, at edge of trees.
138A	811.71	Chiselled and painted on rock	Head of first narrows above Grand du Bonnet, right bank, on shelving rocky point.
138B	812.86	Chiselled and painted on rock	Middle of first narrows above Grand du Bonnet, left bank, on steep rocky bank.
	831.81	Stump	Left bank traverse, first narrows above Grand du Bonnet, Station 27 + 19.
	819.40	Stump	North boundary 10-17-11 E.P.M., station 26 + 27 from northeast corner sec. 10.
	814.19	Stump	Right bank, lower end narrows, above Grand du Bonnet.
	810.13	Chiselled and painted on rock	Left bank, Initial Point of metering station, narrows above Grand du Bonnet, lower end of steep rocky bank.
137B	813.79	Chiselled and painted on rock	Left bank, head of Grand du Bonnet falls, on top of steep rocky shore.
	812.84	Stump, jack pine	South side island at head of Grand du Bonnet, traverse across.
	817.92	Stump, tamarac	Northeast corner, 14-17-11 E.P.M.
	813.27	Stump, poplar	Left bank, point above Grand du Bonnet, upper side.
137	813.58	8-inch poplar tree	Right bank, 200 feet downstream from head of Grand du Bonnet portage, close to edge of trees.
137A	810.77	Chiselled and painted on rock	Right bank, on large boulder at shore, some 100 yards above head of Grand du Bonnet falls.
136	804.55	6-inch poplar tree	80 feet down right bank from brink of falls, near edge of trees.
136A	808.45	Chiselled and painted on rock	30 feet north of B.M. No. 136, at Grand du Bonnet.
135	801.53	7-inch oak tree	First point below first pitch, right bank, Grand du Bonnet falls.

BENCH-MARKS ESTABLISHED ALONG THE WINNIPEG RIVER, ETC.—*Continued.*

No.	Elevation.	Description.	Location.
135A	805·55	Chiselled and painted on rock	First point below first pitch, right bank, Grand du Bonnet falls on shelving rocky shore.
134	805·99	8-inch poplar..................	Right bank, 300 feet above second pitch, Grand du Bonnet falls near edge of trees.
134A	805·81	Chiselled and painted on rock....	Right bank 50 feet above second pitch, Grand du Bonnet falls on top of rocky shore in small bay, at end of traverse line.
133	800·93	12-inch jack pine	Point on right bank 600 feet below second pitch, Grand du Bonnet, at top of bank.
133A	799·18	Chiselled and painted on rock....	Point on right bank 600 feet below second pitch, Grand du Bonnet falls on top of rock bank on north side of point.
132	795·02	5-inch poplar................	Right bank at shore on east side of bay above third pitch, 60 feet north of traverse line.
132A	796·73	Chiselled and painted on rock....	Right bank at shore on east side of bay above third pitch 10 feet south of traverse line on low rock outcrop.
131	781·27	8-inch poplar................	Right bank at foot of bank some 15 yards south of E. and W. traverse line, midway between third and fourth pitches of Grand du Bonnet.
131A	782·75	Chiselled and painted on rock....	500 feet below third pitch, right bank, on rocky shore 70 feet south of E. and W. traverse line, midway between third and fourth pitches.
130	776·66	6 inch poplar................	50 feet south of line at fourth pitch, on right bank, at foot of bank.
130A	779·26	Chiselled and painted on rock....	10 feet north of line at fourth pitch, at brink of falls, right bank.
129	778·48	6-inch oak..................	Right bank, 50 feet north of lower end of Long Portage.
129A	779·59	Chiselled and painted on rock....	Right bank, 85 feet north of lower end of Long Portage, at top of rock bank and facing out to river.
128	779·91	6-inch oak..................	South side of first point below Long Portage, right bank.
128A	778·87	Chiselled and painted on rock....	Right bank, south side of first point below Long Portage, conspicuous from end of portage.
127	777·74	8-inch poplar................	First point above Little du Bonnet, right bank 25 feet upstream from traverse line at foot of bank.
127A	776·27	Chiselled and painted on rock....	Right bank on first point above Little du Bonnet, 100 feet upstream from traverse line on rocky shore.
126	775·53	4-inch poplar................	350 feet above brink of Little du Bonnet, right bank, at edge of trees.
126A	777·16	Chiselled and painted on rock....	Right bank, some 150 yards above Little du Bonnet and 330 yards downstream from N. bdy., sec. 22-17-11 E.P.M., of rocky shore.
126B	775·70	Chiselled and painted on rock....	8 feet south of station 20 + 21 on north boundary 22-17-11 E.P.M., left bank, where line crosses small bay above falls.
125	775·35	Tree........................	600 feet below Little du Bonnet, right bank, 40 feet south of line, near edge of trees.
125A	769·04	Chiselled and painted on rock	Right bank at top of sheer rock 600 feet below Little du Bonnet and 40 feet south of line, conspicuous from river.
124	766·81	6-inch poplar................	First point below Little du Bonnet falls, right bank, at edge of trees.
124A	768·57	Chiselled and painted on rock ...	Right bank, first point below Little du Bonnet at shore.
..	811·41	Stump, poplar................	East boundary 21-17-11 E.P.M. sta. 78 + 40 from north east corner, sec. 9.
.	782·23	Stump, spruce................	22-17-11 E.P.M., 20 feet north of sta. 12 + 46 on offset east from station 75 + 00 on east boundary, 22-17-11 E.P.M.
..	782·16	Stump, spruce................	Station 11 + 96 on offset east from station 85 + 00 on east boundary 21-17-11 E.P.M.
.	781·82	Stump, oak..................	Station 20 + 77 on offset E. from station 95 + 00 on east boundary 21-17-11 E.P.M.
.	806·62	Stump, poplar................	Station 24 + 67 on north boundary 15-17-11 E.P.M. from northeast corner sec. 16.
.	824·85	Stump, poplar................	Station 26 + 73 left bank traverse in sec. 15 at point at foot of first pitch.
.	814·49	Stump, poplar................	Station 25 + 39 east boundary 16-17-11 E.P.M., from northeast corner sec. 9.
.	833·48	Stump, poplar................	Station 29 + 75 east boundary, 22-17-11 E.P.M. from northeast corner sec. 22.
.	815·88	Stump, poplar................	Station 20 + 06 east boundary, 22-17-11 E.P.M. from northeast corner sec. 22.
.	811·61	Stump, poplar................	Station 10 + 60 east boundary, 22-17-11 E.P.M. from northeast corner sec. 22.
.	811·31	Stump, poplar................	At northeast corner, sec. 22 = 0 + 00 of survey.
...	816·16	Stump, poplar................	Station 40 + 25 on traverse through section 23 northeast from east boundary sec. 22.
..	815·87	Stump, tamarack..............	Station 26 + 23 on east boundary 23 from northeast corner sec. 23.
....	833·85	Stump, poplar................	Station 8 + 19 on line east through sec. 23 from east boundary 22.
	817·35	Stump, poplar................	Station 12 + 62 on north boundary 23-17-11 E.P.M. from northeast corner sec. 22.
......	824·56	Stump, jack pine..............	Station 41 + 36 on north boundary 23-17-11 E.P.M., from northeast corner sec. 22.
......	835·70	Stump, jack pine..............	Station 19 + 79 on east boundary 27-17-11 E.P.M. from northeast corner sec. 22
.....	800·82	Stump, poplar................	Station 30 + 35 on east boundary 27-17-11 E.P.M. from northeast corner sec. 22.

BENCH-MARKS ESTABLISHED ALONG THE WINNIPEG RIVER, ETC.—*Continued.*

No.	Elevation.	Description.	Location
123	767·32	8-inch poplar	South end of island No. 2, ½ mile below Little du Bonnet
122	770·70	8-inch oak	Right bank, upper end of portage at Whitemud falls.
122A	768·48	Chiselled and painted on rock	Right bank, on shore downstream from upper end of portage some 50 feet on large boulder.
121	757·46	Gnarled oak	Right bank, 50 feet upstream from lower end of Whitemud portage.
121A	758·39	Chiselled and painted on rock	Right bank, on rocky shore at foot of Whitemud falls, lower end of small channel.
Sta. 34	775·22	Oak stump	Top right bank, to north of upper end of portage on traverse line.
Sta. 35	784·85	Birch stump	Left bank base line, head of falls, top of bank.
Sta. 36	783·49	Birch stump	Left bank base line, foot of falls, top of bank
120	755·15	20-inch oak	Sec. 1-18-10 E.P.M. on point of left bank, opposite homestead of E. Sandberg.
120A	755·30	12-inch birch	Sec. 1-18-10 E.P.M., in bay on right bank, close to shore on north side of road leading up to homesteads of E. Sandberg and C. Carlson.
119	752·90	6-inch poplar	Sec. 1-18-10 E.P.M., on left bank, at foot of bank some 150 feet N. 75° W. from W.P. on E. bdy. lot 1-18-10 E.P.M.
118	754·16	12-inch oak	Sec. 1-18-10 E.P.M., on left bank, on side of bank north of portage and close to head of Silver falls.
117	748·36	7-inch poplar	Sec. 1-18-10 E.M.P., on left bank, near foot of bank, at lower end of upper portage.
116	739·48	8-inch oak	Sec. 1-18-10 E.P.M., on left bank, near lower end of lower portage and some 50 yards to the east of it on top of open rocky ridge.
115	737·75	20-inch spruce	On left bank beyond small deep bay below Silver falls, at edge of trees, conspicuous from the river.
115A	734·56	Old stump	Lot 7-18-10 E.P.M., on left bank, 30 feet west of landing of L. Vincent, at foot of bank.
114	731·62	12-inch oak. . .	N. bdy. lot 10-18-10 E.P.M., on left bank, on point at foot of bank, first narrows below Silver falls.
113	732·60	12-inch oak	On point of left bank, at foot of bank down from church
112	734·10	8-inch oak	Near NE. corner lot 14-18-10 E.P.M., close to foot of left bank, at south end of point above Maskwa rapids.
111	740·06	5-inch mountain ash	Lot 16-18-10 E.P.M., on left bank, in bay above Maskwa rapids, near foot of bank, down from house.
110	731·81	12-inch poplar	Lot 18-18-10 E.P.M., on point of left bank, at second Maskwa rapids, near foot of bank, at upper side of point.
109	726·69	12-inch poplar	On left bank, some 650 feet upstream from E. bdy. lot 19-18-10 E.P.M. near foot of bank and S. 45° E. from island above Pine falls.
	728·51	Top of iron staple with ring	Lot 19-18-10 E.P.M., on left bank, at top of steep rock shore, 100 yards above head of canal.
108	728·21	5-inch oak	Lot 19-18-10 E.P.M., on island formed by canal, on rock to east of lower end of portage.
108A	721·53	Chiselled and painted on rock	E. bdy., lot 20-18-10 E.P.M., on left bank, on top of rocky shore, visible from downstream.
107	719·74	30-inch oak . . .	On right bank, on east side of first point below Maniton rapids, near foot of bank, near by Butcher's house.
106	722·01	12-inch spruce, marked 722·03	On upstream side of point of left bank at J. Arkinson's house, across and downstream from old mill.
105	740·68	24-inch poplar, marked 740·70	On left bank, south of road, at corner between Wm. Skeet and Sam Kinnard and 600 feet above English Mission.
104	725·09	9-inch poplar, marked 725·11	On left bank, 400 feet upstream from H. B. Co.'s dock, at edge of trees.

REPORT

ON

THE WINNIPEG RIVER POWER AND STORAGE INVESTIGATIONS

APPENDIX VI.

TEMPERATURE, PRECIPITATION AND EVAPORATION TABLES

APPENDIX VI.

TEMPERATURE, PRECIPITATION AND EVAPORATION TABLES.

Table 48.—Daily Records of Temperature at Winnipeg.

1912.

JANUARY.

Day of Month.	Temperature. Max.	Temperature. Min.	Temperature. Daily Range.	Mean Daily Temp.
°	°	°	°	°
1	−17·6	−22·3	4·7	−20·4
2	−13·1	−30·0	16·9	−21·5
3	−12·2	−24·8	12·6	−18·5
4	−16·6	−31·3	14·7	−24·0
5	−22·1	−34·9	12·8	−28·5
6	−22·8	−34·0	11·2	−28·1
7	− 3·1	−29·4	26·3	−16·1
8	− 8·8	−23·8	15·0	−16·3
9	−19·7	−32·7	13·0	−28·2
10	−27·5	−37·9	10·4	−32·7
11	−24·8	−41·3	16·5	−33·1
12	−10·8	−32·7	21·9	−21·8
13	− 0·9	−10·8	9·9	− 4·9
14	− 8·8	−24·4	15·6	−16·6
15	− 2·8	−32·7	29·9	−19·1
16	10·0	− 2·8	12·8	3·6
17	9·7	−11·8	21·5	− 1·0
18	−11·8	−24·9	13·1	−18·3
19	− 1·1	−20·5	19·4	−10·8
20	5·1	−13·7	18·8	− 4·3
21	3·2	−15·5	18·7	− 6·1
22	10·9	− 2·5	13·4	3·2
23	4·6	−11·5	16·1	− 3·4
24	4·9	− 7·8		1·4
25	3·9	− 6·1		1·1
26	− 0·3	−21·7	21·4	11·0
27	− 0·8	−25·3	24·5	13·0
28	15·2	−12·8	28·0	1·2
29	15·4	− 4·1	19·5	5·7
30	19·0	− 8·4	27·4	5·3
31	21·8	12·2	12·6	18·5
Means	− 3·2	−20·0	16·8	−11·6

FEBRUARY.

Day of Month.	Temperature. Max.	Temperature. Min.	Temperature. Daily Range.	Mean Daily Temp.
	°	°	°	°
1	15·9	−14·6	30·5	0·7
2	− 8·2	−20·6	12·1	−14·4
3	− 0·9	−18·5	17·6	− 9·7
4	11·8	− 3·2	15·0	4·3
5	15·2	8·0	7·2	11·6
6	9·8	− 5·5	15·3	2·1
7	0·1	−14·6	14·7	− 7·2
8	− 0·9	−17·4	16·5	− 9·2
9	6·9	−25·6	31·6	− 9·8
10	12·9	2·1	10·8	7·5
11	13·4	2·6	10·8	8·0
12	17·9	− 8·5	26·4	4·7
13	24·8	16·6	8·2	20·7
14	33·0	15·2	17·8	24·1
15	33·5	13·2	20·3	23·3
16	35·9	17·7	18·2	26·8
17	38·4	24·1	14·3	31·3
18	34·8	6·0	28·8	20·4
19	12·1	4·6	7·5	8·4
20	12·9	− 0·9	13·8	6·0
21	8·6	0·0	8·6	4·3
22	18·9	− 2·0	20·9	8·4
23	30·2	10·5	19·7	20·3
24	25·4	− 0·6	26·0	12·4
25	1·9	−21·0	22·9	− 9·5
26	8·8	−18·9	27·7	− 5·1
27	15·7	− 1·4	17·1	7·1
28	10·9	−11·3	22·2	− 0·2
29	5·5	−14·2	19·7	− 4·3
Means	15·3	− 2·7	18·0	6·3

MARCH.

Day of Month.	Max.	Min.	Daily Range.	Mean Daily Temp.
1	6·4	−17·6	24·0	− 5·6
2	13·9	−17·2	31·1	− 1·7
3	21·6	− 0·3	21·9	10·6
4	24·5	0·7	23·8	12·6
5	26·6	− 0·4	27·0	13·1
6	23·2	0·8	22·4	12·0
7	16·7	2·1	14·6	9·4
8	24·9	− 5·7	30·6	9·6
9	31·8	1·5	30·3	16·7
10	34·8	5·9	28·9	20·3
11	32·1	3·1	29·0	17·6
12	31·2	− 2·8	31·0	14·2
13	22·8	− 3·0	25·8	9·9
14	18·6	− 6·0	21·6	6·3
15	26·3	1·9	21·4	14·1
16	22·8	0·5	22·3	11·7
17	30·5	0·7	29·8	15·6
18	33·7	10·1	23·6	21·9
19	25·4	− 8·3	33·7	8·5
20	19·9	−10·9	30·8	4·5
21	19·8	− 2·3	22·1	8·8
22	29·7	9·9	19·8	19·8
23	31·1	7·4	26·7	20·7
24	41·5	10·1	31·4	25·8
25	38·7	21·6	17·1	30·1
26	37·4	11·2	26·2	24·3
27	38·4	29·0	9·4	33·7
28	37·6	20·3	17·3	29·0
29	28·4	12·9	15·5	20·6
30	28·0	12·3	15·7	20·1
31	38·1	− 0·9	39·0	18·6
Means	27·7	2·8	24·9	15·2

APRIL.

Day of Month.	Max.	Min.	Daily Range.	Mean Daily Temp.
1	39·6	32·0	7·6	35·8
2	52·0	17·6	34·4	34·8
3	64·9	32·0	32·9	48·4
4	75·1	36·8	38·3	56·0
5	64·3	39·9	24·4	52·1
6	41·6	30·4	11·2	36·0
7	39·1	21·7	17·1	30·4
8	55·3	36·8	18·5	46·0
9	50·0	26·0	21·0	38·0
10	62·2	32·6	29·6	17·4
11	57·9	30·3	27·6	44·1
12	52·2	28·3	23·9	40·3
13	43·4	33·1	10·3	38·2
14	38·8	32·8	6·0	35·8
15	34·6	28·7	5·9	31·7
16	42·0	22·0	20·0	32·0
17	52·5	24·9	27·6	38·7
18	54·8	29·2	25·6	42·0
19	60·2	30·5	29·7	15·3
20	53·9	33·0	20·9	13·5
21	45·6	25·3	20·3	35·1
22	55·6	26·0	29·6	40·8
23	52·2	38·5	13·7	45·3
24	62·3	31·7	30·6	47·0
25	71·2	42·1	29·1	56·6
26	59·3	31·8	27·5	45·6
27	36·6	18·1	18·5	27·3
28	47·8	33·4	14·4	40·6
29	55·9	25·1	30·8	40·5
30	49·8	38·8	11·0	44·3
Means	52·3	30·3	22·0	41·3

Table 48.—Daily Records of Temperature at Winnipeg—Continued.

1912.

MAY. Day of Month.	Temperature. Max.	Min.	Daily Range.	Mean Daily Temp.	JUNE. Day of Month.	Temperature. Max.	Min.	Daily Range.	Mean Daily Temp.
	°	°	°	°		°	°	°	°
1	49·9	40·8	9·1	45·3	1	78·8	46·9	31·9	62·8
2	54·1	40·0	14·1	47·1	2	70·9	46·5	24·4	58·7
3	74·0	42·8	31·2	58·4	3	64·2	47·0	17·2	56·6
4	66·3	48·1	18·2	57·2	4	62·1	45·2	16·9	53·7
5	58·2	43·2	15·0	50·7	5	63·5	39·0	24·5	51·2
6	53·9	42·1	11·8	48·0	6	67·1	33·3	33·8	50·2
7	52·5	31·8	20·7	42·1	7	72·3	44·1	28·2	58·2
8	61·5	40·2	21·3	50·8	8	72·1	44·9	27·2	58·5
9	71·8	48·0	23·8	59·9	9	76·7	51·5	25·2	64·1
10	59·7	42·0	17·7	50·8	10	73·1	57·8	15·3	65·4
11	64·5	32·1	32·4	48·3	11	75·5	47·2	28·3	61·4
12	55·9	32·3	23·6	44·1	12	78·5	44·6	33·9	61·6
13	55·9	25·8	30·1	40·9	13	77·3	48·3	29·0	62·8
14	57·1	41·7	15·4	49·4	14	77·0	56·1	20·9	66·5
15	55·4	34·5	20·9	44·9	15	68·3	48·2	20·1	58·3
16	68·9	37·6	31·3	53·3	16	56·9	41·4	15·5	49·2
17	66·4	38·9	27·5	52·6	17	64·5	44·3	20·2	54·4
18	54·0	35·0	19·0	44·5	18	78·4	40·8	37·6	59·6
19	60·1	38·7	21·4	49·4	19	74·1	52·6	21·5	63·3
20	64·0	42·0	22·0	53·0	20	77·5	43·0	34·5	60·2
21	66·3	34·5	31·8	50·4	21	84·0	47·0	37·0	65·5
22	59·1	46·9	12·2	53·0	22	89·1	58·2	30·9	73·6
23	66·5	45·0	21·5	55·7	23	94·8	61·2	33·6	78·0
24	73·9	42·9	31·0	58·4	24	98·2	63·4	34·8	80·8
25	82·1	51·1	31·0	66·6	25	88·2	58·8	29·4	73·5
26	84·9	52·1	32·8	68·5	26	83·4	47·5	35·9	65·5
27	77·2	57·3	19·9	67·3	27	91·6	64·1	27·5	77·8
28	64·9	49·2	15·7	57·0	28	96·8	67·0	29·8	81·9
29	[illegible]	46·1	24·9	58·5	29	97·9	75·6	22·3	86·8
30	79·5	56·0	23·5	67·8	30	94·3	62·3	32·0	78·3
31	76·4	53·8	22·6	65·1					
Means	64·7	42·3	22·4	53·5	Means	78·3	50·9	27·3	64·6

JULY. Day of Month.	Max.	Min.	Daily Range.	Mean Daily Temp.	AUGUST. Day of Month.	Max.	Min.	Daily Range.	Mean Daily Temp.
1	89·3	65·5	23·8	77·4	1	65·3	46·1	19·2	55·7
2	85·7	68·4	17·3	77·1	2	64·7	45·4	19·3	55·0
3	76·9	63·8	13·1	70·3	3	68·5	39·0	29·5	53·8
4	71·6	51·0	20·6	61·3	4	73·4	44·4	29·0	58·9
5	80·7	58·9	21·8	69·8	5	69·9	52·5	17·4	61·2
6	80·0	57·9	22·1	69·0	6	67·5	57·7	9·8	62·6
7	79·1	60·9	18·2	70·0	7	74·1	54·8	19·3	64·4
8	80·3	55·5	24·8	67·9	8	72·8	56·9	15·9	64·9
9	69·8	56·9	12·9	63·3	9	78·2	49·2	29·0	63·7
10	75·2	46·0	29·2	60·6	10	77·5	49·4	28·1	63·4
11	78·3	58·4	19·9	68·4	11	81·9	52·0	29·9	67·0
12	70·8	57·0	13·8	63·9	12	78·6	63·9	14·7	71·2
13	80·0	51·7	28·3	65·8	13	69·9	56·2	13·7	63·1
14	75·4	50·2	25·2	62·8	14	64·0	45·1	18·9	54·5
15	68·8	42·0	26·8	55·4	15	70·1	43·9	26·2	57·0
16	69·3	55·9	13·4	62·6	16	77·9	45·2	32·7	61·5
17	63·8	49·2	14·6	56·5	17	71·0	58·4	12·6	64·7
18	70·0	43·6	26·4	56·8	18	76·5	51·1	25·4	63·8
19	76·2	52·3	23·9	64·3	19	73·5	54·3	19·2	63·9
20	68·9	54·4	14·5	61·6	20	73·3	58·3	15·0	65·8
21	68·2	49·5	18·7	58·9	21	71·4	55·4	16·0	63·4
22	75·1	49·0	26·1	62·0	22	63·9	50·5	13·4	57·2
23	80·6	62·0	18·6	71·3	23	56·8	44·4	12·4	50·6
24	77·0	60·3	16·7	68·7	24	61·9	47·6	14·3	54·8
25	68·0	54·4	13·6	61·2	25	61·7	49·5	12·2	55·6
26	80·1	53·9	26·2	67·0	26	65·5	42·1	23·4	53·8
27	76·9	63·1	13·8	70·0	27	60·1	48·0	12·1	54·0
28	77·4	56·2	21·2	66·8	28	70·3	52·2	18·1	61·3
29	78·5	58·4	20·1	[illegible]	29	71·4	49·0	22·4	60·2
30	77·9	53·8	24·1	65·9	30	66·3	56·9	9·4	61·6
31	69·4	48·5	20·9	58·9	31	72·1	45·0	27·1	58·5
Means	75·5	55·1	20·3	65·3	Means	70·0	50·5	19·5	60·2

Table 48.—Daily Records of Temperature at Winnipeg—Continued.

1912.

SEPTEMBER.					OCTOBER.				
Day of Month.	Temperature. Max.	Temperature. Min.	Temperature. Daily Range.	Mean Daily Temp.	Day of Month.	Temperature. Max.	Temperature. Min.	Temperature. Daily Range.	Mean Daily Temp.
	°	°	°	°		°	°	°	°
1	70·9	56·6	14·3	63·7	1	70·2	37·5	32·7	53·8
2	72·8	44·3	28·5	58·6	2	70·1	40·8	29·3	55·5
3	74·5	55·7	18·8	65·1	3	67·8	43·5	21·3	55·6
4	78·0	60·3	17·7	69·1	4	74·9	42·2	32·7	58·6
5	85·9	64·3	21·6	75·1	5	62·6	44·4	18·2	53·5
6	73·7	51·8	21·9	62·8	6	45·4	37·9	7·5	41·6
7	70·9	46·2	24·7	58·5	7	58·8	35·7	23·1	47·3
8	72·1	50·1	22·0	61·1	8	57·5	41·7	15·8	49·6
9	73·1	56·0	17·1	64·5	9	48·0	33·9	14·1	41·0
10	64·1	50·9	13·2	57·5	10	41·6	32·5	9·1	37·0
11	78·5	47·1	31·4	62·8	11	50·3	32·7	17·6	41·5
12	75·3	52·0	23·3	63·7	12	53·8	34·3	19·5	44·1
13	66·1	54·0	12·1	60·1	13	63·5	32·6	30·9	48·0
14	56·1	39·9	16·2	48·0	14	58·2	35·8	22·4	47·0
15	51·7	36·6	15·1	44·1	15	60·1	32·0	28·1	46·0
16	57·4	46·2	11·2	51·8	16	72·9	41·0	31·9	57·0
17	62·2	47·1	15·1	54·7	17	62·8	38·9	23·9	50·9
18	70·5	43·3	27·2	56·9	18	57·9	38·9	19·0	48·4
19	61·9	46·8	15·1	54·4	19	46·3	34·1	12·2	40·2
20	56·0	49·9	6·1	52·9	20	51·5	38·1	13·4	44·8
21	52·2	44·8	7·4	48·5	21	42·8	26·4	16·1	34·6
22	51·9	38·0	12·9	44·5	22	44·4	20·7	23·7	32·6
23	50·3	40·4	9·9	45·3	23	4·9	31·6	23·3	43·2
24	43·9	35·2	9·7	39·6	24	5·1	39·6	16·5	47·9
25	43·3	33·3	10·0	38·3	25	56·1	30·4	25·7	43·2
26	46·8	31·1	15·7	38·9	26	46·6	43·6	3·0	45·1
27	49·6	30·7	18·9	40·2	27	53·1	25·6	27·5	39·4
28	46·0	32·5	13·5	39·2	28	45·4	30·1	15·3	37·7
29	51·8	26·2	25·6	39·0	29	33·1	24·0	9·1	28·6
30	61·2	31·7	29·5	46·5	30	34·0	17·1	16·9	25·5
					31	32·9	23·5	9·4	28·2
Means	62·3	44·8	17·5	53·5	Means	54·0	34·2	19·8	44·1

NOVEMBER.					DECEMBER.				
1	20·2	20·9	7·3	24·5	1	25·8	7·9	17·9	16·9
2	28·1	13·8	14·3	21·0	2	17·0	− 2·5	19·5	7·2
3	37·0	18·8	18·2	27·9	3	21·5	10·6	10·9	16·1
4	35·0	24·9	10·1	29·9	4	22·0	15·2	6·8	18·6
5	35·1	25·6	9·5	30·4	5	− 1·1	− 7·9	6·8	− 4·5
6	38·6	25·8	12·8	32·2	6	18·6	−11·5	30·1	3·6
7	41·0	25·2	15·8	33·1	7	11·9	− 5·0	16·9	3·4
8	35·3	29·6	5·7	32·4	8	25·2	−15·5	40·7	4·9
9	39·9	28·1	11·8	34·0	9	34·9	12·3	22·6	23·6
10	34·7	28·6	6·1	31·7	10	7·2	− 4·7	11·9	1·2
11	29·4	25·4	4·0	27·4	11	− 0·2	−15·2	15·4	− 7·7
12	28·5	23·8	4·7	26·1	12	−19·8	−19·9	23·7	2·0
13	33·1	27·0	6·1	30·1	13	21·4	1·7	19·7	11·6
14	31·3	28·5	2·8	29·9	14	26·1	13·4	12·7	19·7
15	32·0	26·4	5·6	29·2	15	19·1	13·1	6·0	16·1
16	33·2	21·2	12·0	27·2	16	22·1	17·6	4·5	19·9
17	38·3	21·3	17·0	29·8	17	22·2	19·9	2·3	21·0
18	49·3	28·6	20·7	38·9	18	19·3	16·4	2·9	17·9
19	41·0	27·2	13·8	31·1	19	18·4	13·7	4·7	16·0
20	43·7	29·4	14·3	36·6	20	5·5	1·4	4·1	3·5
21	35·1	28·8	6·3	31·9	21	5·5	− 3·7	9·2	0·9
22	34·7	26·3	8·4	30·5	22	28·5	− 2·2	30·7	13·2
23	24·9	19·2	5·7	22·0	23	20·9	12·9	8·0	16·9
24	26·9	20·5	6·4	23·7	24	24·7	11·0	13·7	17·8
25	35·4	19·5	15·9	27·4	25	21·8	4·9	16·9	13·3
26	29·8	20·7	9·1	25·2	26	16·2	5·1	11·1	10·7
27	24·4	16·4	8·0	20·4	27	39·1	3·9	35·2	21·5
28	38·4	21·9	16·5	29·2	28	35·8	18·4	17·4	27·1
29	24·1	20·4	3·7	23·2	29	24·1	17·1	7·0	20·6
30	31·9	18·2	13·7	25·1	30	28·9	10·9	18·0	19·9
					31	19·9	9·1	10·8	14·5
Means	33·9	23·7	10·2	28·8	Means	19·9	5·1	14·8	12·5

Mean Daily Temp.
°
62·8
58·7
56·6
53·7
51·2
50·2
58·2
58·5
64·1
65·4
61·4
61·6
62·8
66·5
58·3
49·2
54·4
59·6
63·3
60·2
65·5
73·6
78·0
80·8
73·5
65·5
77·8
81·9
86·8
78·3
64·6
55·7
55·0
53·8
58·9
61·2
62·6
64·4
64·9
63·7
63·4
67·0
71·2
63·1
54·5
57·0
61·5
64·7
63·8
63·9
65·8
63·4
57·2
50·6
54·8
55·6
53·8
54·0
61·3
60·2
61·6
58·5
60·2

Table 48.—Daily Records of Temperature at Winnipeg—Continued.

1913.

JANUARY.					FEBRUARY.				
Day of Month.	Temperature. Max.	Temperature. Min.	Temperature. Daily Range.	Mean Daily Temp.	Day of Month.	Temperature. Max.	Temperature. Min.	Temperature. Daily Range.	Mean Daily Temp.
	°	°	°	°		°	°	°	°
1	28·9	17·7	11·2	23·3	1	5·2	−21·4	26·6	− 8·1
2	− 0·6	− 9·9	9·3	− 5·2	2	2·6	−12·1	14·7	− 4·7
3	− 0·9	−13·5	12·6	− 7·2	3	− 9·3	−23·5	14·2	−16·4
4	2·7	−12·2	14·9	− 4·8	4	−11·8	−25·5	13·7	−18·7
5	−16·1	−20·7	4·6	−18·4	5	− 4·8	−22·6	17·8	−13·7
6	−16·8	−31·2	14·4	−24·0	6	3·5	−12·3	15·8	− 4·4
7	− 0·2	−24·4	24·2	−12·3	7	21·9	− 2·7	24·6	9·6
8	17·2	− 7·9	25·1	4·6	8	5·9	− 9·9	15·8	− 2·0
9	15·2	− 4·7	19·9	5·2	9	− 1·8	−20·0	18·2	−10·9
10	− 9·9	−18·4	8·5	−14·1	10	11·9	− 4·9	16·8	3·5
11	−20·2	−26·0	5·8	−23·1	11	− 9·7	−16·8	7·1	−13·3
12	−10·9	−29·4	18·5	−20·2	12	13·8	−24·3	38·1	− 5·3
13	6·1	−21·0	27·1	− 7·4	13	23·3	3·1	20·2	13·2
14	8·0	− 9·1	17·1	− 0·6	14	26·7	− 3·1	29·8	11·8
15	9·7	− 5·1	14·8	2·3	15	10·8	−10·2	21·0	0·3
16	8·2	1·8	6·4	5·0	16	13·6	2·9	10·7	8·2
17	− 9·8	−14·5	4·7	−12·1	17	24·8	10·0	14·8	17·4
18	2·5	−23·0	25·5	−10·3	18	28·3	21·5	6·8	24·9
19	− 2·4	−14·5	12·1	− 8·4	19	13·2	5·4	7·8	9·3
20	−17·2	−28·3	11·1	−22·8	20	10·9	− 4·4	15·3	3·2
21	− 7·9	−25·7	17·8	−16·7	21	11·4	−18·3	29·7	− 3·4
22	6·1	− 8·0	14·1	− 0·9	22	3·3	−16·8	20·1	− 6·8
23	− 5·8	−21·1	15·3	−13·5	23	12·8	−17·0	29·8	− 2·1
24	− 2·7	−21·2	18·5	−11·9	24	18·9	0·7	18·2	9·8
25	14·9	− 2·7	17·6	6·1	25	14·3	−31·1	45·4	− 8·4
26	5·6	−12·9	18·5	− 3·6	26	− 3·1	−27·8	24·7	−15·4
27	4·2	− 6·2	10·4	− 1·0	27	2·8	−23·2	26·0	−10·2
28	16·5	− 5·1	21·6	5·7	28	3·3	−12·0	15·3	− 4·3
29	17·2	12·6	4·6	14·9					
30	9·2	− 7·9	17·1	0·7					
31	− 9·7	−25·5	15·8	−17·6					
Means	1·3	−13·5	14·8	− 6·1	Means	8·6	−11·3	19·9	− 1·3

MARCH.					APRIL.				
Day of Month.	Max.	Min.	Daily Range.	Mean Daily Temp.	Day of Month.	Max.	Min.	Daily Range.	Mean Daily Temp.
1	−15·1	−24·5	9·4	−19·8	1	49·9	28·5	21·4	39·2
2	8·7	−25·7	34·4	− 8·5	2	44·8	34·4	10·4	39·6
3	0·3	−22·1	22·4	−10·9	3	42·8	33·1	9·7	38·0
4	26·8	−10·0	36·8	8·4	4	42·7	26·9	15·8	34·8
5	0·9	− 9·8	10·7	− 4·5	5	48·3	28·4	19·9	38·4
6	8·0	−20·7	28·7	− 6·4	6	47·9	30·2	17·7	39·0
7	29·9	−18·7	48·6	5·6	7	43·2	33·3	9·9	38·1
8	24·3	15·2	9·1	19·7	8	38·7	32·2	6·5	35·4
9	37·9	5·0	32·9	21·5	9	41·2	31·9	9·3	36·6
10	34·6	16·8	17·8	25·7	10	51·8	29·9	21·9	40·9
11	16·0	5·2	10·8	10·6	11	57·3	27·9	29·6	45·7
12	31·5	− 5·7	37·2	12·9	12	67·9	38·0	29·9	53·0
13	22·1	10·4	11·7	16·2	13	64·4	33·9	30·5	49·1
14	12·6	− 3·1	15·7	4·8	14	77·0	40·2	36·8	58·6
15	12·9	−12·8	25·7	0·0	15	75·3	39·9	35·4	57·6
16	13·6	− 7·9	21·5	2·9	16	74·4	47·8	26·6	61·1
17	18·9	0·0	18·9	9·5	17	65·7	46·8	18·9	56·3
18	10·9	0·5	10·4	5·7	18	61·5	31·9	29·6	46·7
19	8·2	− 0·7	8·9	3·7	19	61·1	29·5	31·6	45·[illegible]
20	10·2	−14·9	25·1	− 2·3	20	65·8	36·8	29·0	51·3
21	11·1	−11·1	22·2	0·0	21	77·8	45·0	32·8	61·4
22	21·8	− 3·3	25·1	9·2	22	73·8	53·9	19·9	63·9
23	18·9	− 1·3	20·2	8·8	23	62·7	44·5	18·2	53·6
24	11·4	− 4·1	15·5	3·6	24	52·2	34·1	18·1	43·1
25	16·1	− 8·1	24·2	4·0	25	42·8	29·4	13·4	36·1
26	17·8	− 8·3	26·1	4·8	26	38·5	19·4	19·1	26·9
27	24·7	− 7·3	32·0	8·7	27	54·3	24·0	30·3	39·2
28	38·7	19·3	19·4	29·0	28	68·1	37·0	31·1	52·5
29	41·8	31·9	9·9	36·9	29	75·4	40·3	35·1	57·9
30	40·0	26·9	13·1	33·4	30	58·5	36·8	21·7	47·6
31	46·4	25·0	21·4	35·7					
Means	19·4	− 2·1	21·5	8·7	Means	57·5	34·8	22·7	46·2

Table 48.—Daily Records of Temperature at Winnipeg.—Continued.

1911.

MAY.

Day of Month	Temperature. Max.	Min.	Daily Range.	Mean Daily Temp.
	°	°	°	°
1	44·9	30·7	14·2	37·8
2	49·1	24·1	25·0	36·6
3	50·1	34·1	15·8	42·2
4	59·9	38·0	21·9	49·0
5	55·0	31·8	23·2	43·4
6	55·3	22·1	33·2	38·7
7	52·9	28·5	24·4	40·7
8	47·2	22·9	24·3	35·0
9	52·8	23·0	29·8	37·9
10	63·2	31·8	31·4	47·5
11	59·8	47·0	12·8	53·4
12	64·3	34·7	29·6	49·5
13	43·4	26·2	17·2	34·8
14	53·8	30·4	21·4	42·1
15	60·1	39·8	20·3	49·9
16	55·8	37·5	18·3	46·7
17	51·8	39·5	12·3	45·6
18	51·2	30·0	21·2	40·6
19	58·9	26·6	32·3	42·7
20	57·8	42·1	15·7	50·0
21	62·0	42·8	19·2	52·4
22	70·1	45·3	24·8	57·7
23	64·4	50·2	14·2	57·3
24	61·1	37·6	23·5	49·3
25	71·0	40·2	30·8	55·6
26	80·2	50·7	29·5	65·5
27	88·2	51·1	37·1	69·6
28	83·8	56·9	26·9	70·4
29	79·8	60·7	19·1	70·2
30	81·8	49·2	32·6	65·5
31	84·2	57·9	26·3	71·0
Means	61·7	38·2	23·5	50·0

JUNE.

Day of Month.	Temperature. Max.	Min.	Daily Range.	Mean Daily Temp.
	°	°	°	°
1	72·2	45·0	27·2	58·6
2	68·8	52·5	16·3	60·6
3	69·1	37·1	31·7	53·1
4	77·2	45·0	32·2	61·1
5	78·1	51·2	26·9	64·6
6	56·0	40·0	16·0	48·0
7	60·9	33·8	27·1	47·4
8	70·0	36·8	33·2	53·4
9	73·9	43·6	30·3	58·7
10	78·3	52·0	26·3	65·2
11	86·0	56·9	29·1	71·4
12	88·8	64·0	24·8	76·4
13	89·6	61·9	27·7	75·8
14	88·2	59·9	28·3	74·0
15	85·9	62·1	23·8	74·0
16	69·0	53·5	15·5	61·2
17	66·4	40·8	25·6	53·6
18	71·1	48·1	23·0	59·6
19	76·2	48·2	28·0	62·2
20	76·2	49·5	26·7	62·9
21	82·0	45·1	36·9	63·5
22	86·5	60·0	26·5	73·3
23	87·0	64·8	22·2	75·9
24	91·2	68·4	22·8	79·8
25	79·3	64·8	14·5	72·0
26	62·8	49·9	12·9	56·4
27	66·0	53·1	12·9	59·5
28	87·3	59·2	28·1	73·3
29	90·9	75·0	15·9	83·0
30	75·2	62·5	12·7	68·8
Means	77·0	52·8	24·2	64·9

JULY.

Day of Month	Temperature. Max.	Min.	Daily Range.	Mean Daily Temp.
1	66·8	51·2	15·6	59·0
2	71·8	48·2	23·6	60·0
3	69·3	56·2	13·1	62·7
4	70·0	51·1	18·9	60·6
5	68·8	53·5	15·3	61·1
6	77·8	50·0	27·8	63·9
7	72·7	52·6	20·1	62·7
8	79·1	56·9	22·2	68·0
9	72·2	46·7	25·5	59·4
10	69·3	50·4	18·9	59·8
11	75·3	60·4	14·9	67·9
12	62·7	53·1	9·6	57·9
13	71·2	46·3	24·9	58·7
14	76·9	51·3	25·6	64·1
15	79·1	57·1	22·0	68·1
16	81·2	62·9	18·3	72·1
17	82·3	56·4	25·9	69·3
18	80·0	54·8	25·2	67·4
19	71·1	54·4	16·7	62·8
20	78·0	48·6	29·4	63·3
21	81·4	61·5	19·9	71·4
22	74·8	53·9	20·9	64·4
23	67·9	52·8	15·1	60·3
24	76·9	47·2	29·7	62·1
25	84·4	57·1	27·3	70·7
26	81·2	59·2	22·0	71·2
27	71·2	47·9	23·3	59·5
28	77·9	48·9	29·0	63·4
29	88·0	54·1	33·9	71·0
30	77·2	64·0	13·2	70·6
31	78·2	50·9	27·3	64·6
Means	75·3	53·5	21·8	64·4

AUGUST.

Day of Month.	Temperature. Max.	Min.	Daily Range.	Mean Daily Temp.
1	81·1	55·8	25·3	68·4
2	87·1	58·2	28·9	72·7
3	76·1	50·0	26·1	63·0
4	84·0	52·4	31·6	68·2
5	75·2	59·0	16·2	67·1
6	79·9	46·6	33·3	63·3
7	73·0	58·0	15·0	65·5
8	74·5	52·9	21·6	63·7
9	60·5	53·7	6·8	57·1
10	58·5	44·1	14·4	51·3
11	76·9	52·8	24·1	64·8
12	79·7	59·2	20·5	69·5
13	88·8	60·6	28·2	74·7
14	90·8	64·8	26·0	77·8
15	79·8	63·1	16·7	71·4
16	81·8	52·1	29·7	67·0
17	67·2	52·1	15·1	59·6
18	80·1	53·7	26·4	66·9
19	77·9	60·3	17·6	69·1
20	82·9	63·0	19·9	74·0
21	71·4	54·1	17·3	62·8
22	77·2	49·1	28·1	63·1
23	70·7	53·5	17·2	62·1
24	72·1	45·8	26·3	59·0
25	76·6	58·2	[illegible]·4	67·4
26	72·8	52·3	20·5	62·5
27	67·9	52·7	15·2	60·3
28	68·2	51·2	17·0	59·7
29	75·3	48·3	37·0	61·8
30	75·2	56·9	18·3	66·1
31	76·3	46·8	29·5	61·6
Means	76·1	54·2	21·9	65·2

Table 48.—Daily Records of Temperature at Winnipeg.—Concluded.

1913.

SEPTEMBER.

Day of Month.	Temperature. Max.	Min.	Daily Range.	Mean Daily Temp.
	°		°	
1	77·0	63·8	13·2	70·4
2	74·2	45·4	24·8	58·8
3	68·1	52·4	15·7	60·2
4	75·8	58·8	17·0	67·3
5	77·5	61·7	15·8	69·6
6	83·4	62·4	21·0	72·9
7	69·8	49·4	20·4	59·6
8	69·9	40·8	29·1	55·4
9	79·8	53·7	26·1	66·8
10	71·4	56·4	15·0	63·9
11	64·8	43·2	21·6	54·0
12	64·9	42·3	22·6	53·6
13	63·4	34·2	29·2	48·8
14	74·9	44·4	30·5	59·6
15	68·3	46·2	22·1	57·3
16	70·0	40·0	30·0	55·0
17	73·2	43·0	30·2	58·1
18	75·9	50·3	25·6	63·1
19	54·2	41·3	12·9	47·7
20	50·2	36·7	13·5	43·5
21	43·7	31·9	11·8	37·8
22	51·1	22·8	28·3	36·9
23	47·1	26·7	20·4	36·9
24	50·1	36·4	13·7	43·3
25	53·9	40·0	13·9	47·0
26	62·1	35·8	26·3	48·9
27	76·9	43·1	33·8	60·0
28	73·1	44·6	28·5	58·8
29	73·9	37·5	36·4	55·7
30	74·9	46·1	28·8	60·5
Means	67·0	44·4	22·6	55·7

OCTOBER.

Day of Month.	Temperature. Max.	Min.	Daily Range.	Mean Daily Temp.
		°	°	°
1	67·0	47·7	19·4	57·3
2	73·4	40·2	33·2	56·8
3	63·9	42·0	21·9	53·5
4	52·9	34·2	18·7	43·5
5	48·9	43·5	5·4	46·2
6	39·8	29·8	10·0	34·8
7	50·7	34·1	16·6	42·4
8	43·0	28·8	14·2	35·9
9	52·8	25·1	27·7	38·9
10	43·2	36·6	6·6	39·9
11	46·7	32·3	14·4	39·5
12	50·9	28·5	22·4	39·7
13	69·9	37·1	32·8	53·5
14	51·0	39·1	11·9	45·0
15	40·9	21·4	19·5	31·2
16	51·2	24·0	27·2	37·6
17	51·8	33·9	17·9	42·8
18	43·9	22·0	21·9	33·0
19	32·0	24·0	8·0	28·0
20	22·0	18·0	4·0	20·0
21	27·8	14·2	13·6	21·0
22	40·1	23·0	17·1	31·5
23	48·3	26·4	21·9	37·3
24	54·7	32·2	22·5	43·4
25	43·3	29·5	13·8	36·4
26	39·9	23·2	16·7	31·5
27	38·1	29·2	8·9	33·7
28	22·6	9·8	12·8	16·2
29	23·8	5·0	18·8	14·4
30	30·3	14·4	15·9	22·4
31	41·3	15·1	26·2	28·2
Means	45·5	27·9	17·6	36·7

NOVEMBER.

Day of Month.	Max.	Min.	Daily Range.	Mean Daily Temp.
1	48·8	26·2	22·6	37·5
2	47·2	29·3	17·9	38·2
3	34·5	24·9	9·6	29·7
4	54·9	20·3	34·6	37·6
5	55·9	35·1	20·8	45·5
6	52·6	30·6	22·0	41·6
7	36·1	31·0	5·1	33·6
8	33·9	21·0	12·9	27·4
9	19·2	14·0	5·2	16·6
10	25·2	6·7	18·5	16·0
11	34·3	19·2	15·1	26·7
12	37·5	28·4	9·1	33·0
13	26·9	15·5	11·4	21·2
14	30·9	8·3	22·6	19·6
15	37·6	24·3	13·3	30·9
16	49·6	30·9	18·7	40·3
17	51·2	33·7	17·5	42·4
18	32·7	22·4	10·3	27·6
19	34·6	22·1	12·5	28·3
20	44·0	19·7	24·3	31·9
21	33·5	24·9	8·6	29·2
22	29·7	21·6	8·1	25·6
23	37·6	21·0	16·6	29·3
24	43·4	19·7	23·7	31·6
25	29·9	21·7	8·2	25·8
26	35·7	22·1	13·6	28·9
27	38·3	32·0	6·3	35·1
28	41·3	33·9	7·4	37·6
29	36·3	33·2	3·1	34·8
30	32·1	28·0	4·1	30·0
Means	38·2	24·0	14·1	31·1

DECEMBER.

Day of Month.	Max.	Min.	Daily Range.	Mean Daily Temp.
1	34·5	27·8	6·7	31·1
2	33·7	26·0	7·7	29·9
3	38·9	22·7	16·2	30·8
4	48·2	28·3	19·9	38·3
5	39·7	22·8	16·9	31·2
6	30·6	13·9	16·7	22·3
7	24·5	3·0	21·5	13·7
8	36·8	10·8	26·0	23·8
9	40·1	26·2	13·9	33·2
10	37·9	18·4	19·5	28·1
11	48·8	25·1	23·7	37·0
12	37·7	17·8	19·9	27·7
13	42·2	15·1	27·1	28·7
14	26·5	9·8	16·7	18·1
15	37·7	20·0	17·7	28·9
16	41·3	26·5	14·8	33·9
17	27·5	17·8	9·7	22·6
18	33·6	8·7	24·9	21·2
19	13·7	5·1	8·6	9·4
20	20·1	− 3·0	23·1	8·5
21	8·4	− 7·1	15·5	0·7
22	22·5	1·1	21·4	11·8
23	15·9	1·4	14·5	8·6
24	− 0·8	− 7·2	6·4	− 4·0
25	4·8	−14·4	19·2	− 4·8
26	13·4	− 4·0	17·4	4·7
27	12·2	1·8	10·4	7·0
28	24·3	− 5·2	29·5	9·6
29	24·8	13·7	11·1	19·2
30	19·7	5·3	14·4	12·5
31	26·2	− 3·0	29·2	11·6
Means	27·9	10·5	17·4	19·2

Table 49.—Monthly Records of Temperatures at Winnipeg and Kenora, 1906-1914.

1906

Month	Winnipeg: Range of Temperature Degrees Fahr.			Winnipeg: Mean Temperatures Degrees Fahr.			Kenora: Range of Temperature Degrees Fahr.			Kenora: Mean Temperatures Degrees Fahr.		
	Max.	Min.	Mean	Max.	Min.	Daily	Max.	Min.	Mean	Max.	Min.	Daily
January												
February	38.1	−32.5	25.1	15.0	−10.4	2.3						
March	53.1	−19.5	23.4	27.8	1.1	15.8						
April	80.8	17.5	26.8	60.4	33.6	47.0						
May	84.0	17.8	25.1	61.4	36.2	48.8						
June	81.8	42.2	22.4	74.8	52.3	63.5						
July	89.0	46.5	21.1	75.7	56.6	66.2						
August	92.8	41.8	21.0	77.1	53.1	65.1						
September	99.0	41.0	21.7	71.6	46.9	60.7						
October	72.9	5.8	21.9	52.6	30.7	41.6						
November	47	−10.0	13.8	32.7	18.0	25.8						
December	30	−31.9	20.8	13.0	−7.8	2.6						
Yearly	99.0	−32.5	22.4	51.5	28.6	40.0						

NOTE.—Average of 11 months.

1907

Month	Winnipeg Max.	Winnipeg Min.	Winnipeg Mean	Winnipeg Mean Max.	Winnipeg Mean Min.	Winnipeg Daily	Kenora Max.	Kenora Min.	Kenora Mean	Kenora Mean Max.	Kenora Mean Min.	Kenora Daily
January	0	−48.6	20.4	−1.1	−21.6	−11.4	22.0	−38.0	16.2	−0.7	−17.0	−8.9
February	37.5	−38.0	22.1	15.8	−6.5	4.6	42.0	−37.0	18.1	13.9	−4.1	4.9
March	47.0	−11.6	20.9	28.0	7.1	17.5	50.0	−10.0	18.4	28.5	10.1	[2]19.3
April	53.8	5.2	16.3	36.4	20.4	28.4	52.0	5.0	15.7	33.5	17.8	25.7
May	74.3	10.9	25.0	52.8	27.7	40.2	68.0	16.0	13.7	42.2	28.5	35.3
June	90.2	42.1	24.1	73.8	49.6	61.7	89.0	69.0	20.2	71.9	51.7	61.8
July	87.5	40.0	24.3	78.9	54.5	66.7	85.0	45.0	2.4	77.8	56.4	67.1
August	85.2	38.2	20.4	71.5	51.1	61.3	83.0	41.0	19.8	69.1	39.3	50.2
September	77.4	21.8	20.8	61.4	40.7	51.1	78.0	28.0	17.1	58.1	40.8	49.4
October	69.4	13.6	23.5	50.9	27.4	[1]39.2	61.0	19.0	16.3	45.3	29.0	[3]37.1
November	54.1	−12.0	18.2	34.5	16.2	25.3	40.0	3.0	7.7	28.8	21.2	25.0
December	40.8	−49.5	18.1	23.[illegible]	5.1	14.2	41.0	−20.0	14.1	24.6	10.2	17.4
Yearly	90.2	−48.6	21.2	43.9	22.7	33.2	89.0	−38.0	15.0	44.1	21.5	32.8

NOTE.—[1]Records Oct. 2-8 (incl.) missing. [2]Records Mar. 14-17 (incl.) missing. [3]Records Oct. 5-12 (incl.) missing.

1908

Month	Winnipeg Max.	Winnipeg Min.	Winnipeg Mean	Winnipeg Mean Max.	Winnipeg Mean Min.	Winnipeg Daily	Kenora Max.	Kenora Min.	Kenora Mean	Kenora Mean Max.	Kenora Mean Min.	Kenora Daily
January	42.2	−36.0	20.4	17.8	−2.6	7.6	40.0	−39.0	43.8	15.1	1.3	8.2
February	38.0	−25.0	18.7	18.1	−0.6	8.7	38.0	−30.0	14.1	18.4	4.2	11.3
March	41.0	−22.0	23.7	21.3	−2.5	9.4	32.0	−26.0	21.1	16.9	−4.2	[1]6.3
April	73.6	2.2	22.8	51.4	28.5	40.0	60.0	−4.0	47.6	41.8	21.2	33.0
May	77.5	24.9	24.1	64.0	39.9	51.9						
June	88.0	32.4	22.0	73.1	51.0	62.0						
July	93.0	47.0	24.8	78.9	54.1	66.5						
August	91.0	34.2	24.8	74.3	49.5	61.9						
September	90.8	27.0	23.3	70.0	46.6	58.3						
October	69.3	23.2	46.0	54.3	35.4	44.4						
November	50.6	−5.5	14.2	35.4	21.2	28.3	48.0	−6.0	12.7	36.6	23.9	[2]30.2
December	31.5	−22.6	15.0	17.9	4.0	9.9						
Yearly	93.0	−36.0	20.9	47.8	26.8	37.3		−39.0				

NOTE.—[1]First 20 days only. [2]Last 15 days only.

1909

Month	Winnipeg Max.	Winnipeg Min.	Winnipeg Mean	Winnipeg Mean Max.	Winnipeg Mean Min.	Winnipeg Daily	Kenora Max.	Kenora Min.	Kenora Mean	Kenora Mean Max.	Kenora Mean Min.	Kenora Daily
January	39.1	−45.1	20.0	7.5	−12.5	−2.5	38.0	−44.0	16.2	7.0	−9.2	1.1
February	29.1	−33.8	19.9	10.2	−9.7	0.2	29.0	−37.0	19.1	12.2	−6.9	2.6
March	37.9	−18.5	20.1	27.2	7.1	17.1	43.0	−14.0	18.6	27.5	8.9	18.2
April	50.3	8.8	17.0	38.4	21.4	29.9	58.0	3.0	16.7	33.7	17.0	25.3
May	82.8	20.0	24.4	63.6	39.2	51.4	66.0	16.0	21.8	46.0	24.2	[1]35.1
June	90.0	33.7	27.2	77.1	49.9	63.5						
July	87.3	44.0	23.8	80.0	56.1	68.0						
August	92.6	35.0	23.2	78.5	55.3	66.9						
September	84.9	20.8	25.8	70.9	45.1	58.0						
October	82.0	10.7	19.7	52.4	32.7	42.5	78.0	14.0	10.8	41.1	36.3	38.7
November	59.4	−6.0	18.4	34.0	15.0	24.9	52.0	−2.0	10.3	29.3	19.0	24.1
December	35.8	−44.3	14.5	9.7	−4.8	2.5	35.0	−28.0	11.0	11.9	0.8	6.3
Yearly	92.6	−45.1	21.1	45.8	24.6	35.2		−44.0				

NOTE.—[1]May 1-5 (incl.) only.

Table 49.—*Monthly Records of Temperatures at Winnipeg and Kenora 1906-1914*—Continued.

1910.

Month.	Winnipeg. Range of Temperature Degrees Fahr. Max	Min	Mean	Winnipeg. Mean Temperatures Degrees Fahr. Max	Min	Daily	Kenora. Range of Temperature Degrees Fahr. Max	Min	Mean	Kenora. Mean Temperatures Degrees Fahr. Max	Min	Daily
January	31·9	−36·2	17·1	13·9	−3·2	5·4	23·0	−42·0	12·7	11·1	1·6	4·8
February	35·0	−31·2	21·7	9·5	−12·1	−1·3	31·0	−33·0	18·5	8·0	−10·6	−1·3
March	74·0	−4·2	23·6	41·9	23·2	31·0	70·6	0·0	14·6	35·9	21·3	28·6
April	74·9	15·3	25·2	55·1	30·2	42·8	70·6	8·4	18·6	46·6	28·0	37·3
May	75·5	19·3	27·3	62·4	35·1	48·8	71·0	20·6	13·7	47·3	33·6	40·4
June	99·2	31·4	27·2	82·1	53·8	68·0	98·5	[illegible]	24·1	77·9	53·8	65·9
July	95·5	47·3	26·3	81·8	55·6	68·7	92·0	50·1	30·4	82·3	62·0	72·2
August	93·1	30·1	20·3	75·3	48·6	62·2	89·0	33·0	19·9	76·0	56·1	[1]66·0
September	78·1	28·8	21·8	65·1	43·4	51·2	63·6	29·6	17·7	58·1	40·4	[2]49·2
October	78·2	18·8	21·2	57·3	[illegible]	46·6	70·0	20·0	13·6	47·9	32·3	40·6
November	37·6	−4·7	12·0	25·8	13·8	19·8	30·0	0·0	8·8	21·1	12·4	16·7
December	33·9	−42·0	20·0	15·9	4·1	5·9	21·0	−37·0	32·0	11·8	−0·3	5·7
Yearly	99·2	−42·0	22·3	49·1	26·8	38·9	98·5	−37·0	16·3	43·7	27·5	35·5

NOTE.—[1]No records for 18th or 31st. [2]No records for 13th.

1911.

Month.	W. Range Max	Min	Mean	W. Mean Max	Min	Daily	K. Range Max	Min	Mean	K. Mean Max	Min	Daily
January	20·4	−36·9	18·6	−0·3	−18·9	−9·5	23·0	−37·0	17·4	−0·8	−18·2	−9·5
February	35·5	−34·6	23·7	16·8	−3·0	6·1	36·0	−26·0	15·0	17·0	2·0	[1]9·5
March	52·5	−11·4	19·8	33·4	13·6	23·5	35·0	−11·0	11·5	23·2	8·6	15·9
April	79·9	4·9	23·0	52·8	29·8	41·3	70·0	−3·0	[illegible]	42·6	28·2	35·4
May	85·9	19·3	25·4	67·8	42·4	55·1	71·0	21·0	39·8	57·9	38·0	47·9
June	89·2	41·4	19·6	75·2	55·6	65·1	90·0	40·0	22·8	74·2	51·4	62·8
July	84·8	43·3	22·1	75·2	53·1	64·1	87·0	48·0	23·2	77·3	54·1	65·7
August	88·5	39·8	22·8	71·3	51·6	63·0	89·0	37·0	27·3	74·7	47·4	61·1
September	76·1	29·1	21·5	63·1	41·6	52·3	62·0	31·0	13·3	53·9	40·4	47·1
October	69·5	13·3	16·3	51·2	31·9	43·1	61·0	8·0	11·9	47·3	32·1	39·6
November	50·8	−13·9	18·1	25·9	8·7	17·8	38·0	−15·0	10·2	20·4	10·2	15·3
December	38·4	−31·4	13·1	18·8	5·7	12·3	32·0	−33·0	30·0	16·8	6·8	11·8
Yearly	89·2	−36·9	20·1	46·3	26·2	36·2	93·0	−37·0	15·9	42·0	25·1	33·5

NOTE.—[1]No records 11–20 (incl.).

1912

Month.	W. Range Max	Min	Mean	W. Mean Max	Min	Daily	K. Range Max	Min	Mean	K. Mean Max	Min	Daily
January	24·8	−41·3	16·8	−3·2	−23·0	−11·6	18·0	−35·0	15·6	−7·8	−23·9	−15·1
February	38·4	−25·6	18·6	15·3	−2·7	6·3	29·0	−32·0	16·6	9·1	−7·5	0·8
March	41·5	−17·6	24·9	27·7	2·8	15·2	33·0	−23·0	20·2	20·3	0·2	10·3
April	75·1	37·6	22·0	52·3	30·3	43·3	63·0	15·0	17·8	45·1	27·3	36·2
May	84·9	25·8	22·4	63·7	32·3	53·5	82·0	24·0	17·9	56·3	38·8	[1]47·8
June	98·2	33·3	27·3	78·3	50·9	63·6	96·0	33·0	21·8	75·0	53·2	[2]64·1
July	89·3	32·0	23·3	75·5	55·1	65·3	83·0	32·0	13·6	67·3	47·7	[3]57·5
August	81·9	39·6	39·5	70·4	51·5	60·2	80·0	31·0	21·3	67·0	45·6	56·3
September	85·9	26·2	17·5	62·3	41·8	53·5	78·0	25·0	15·5	57·1	41·6	49·4
October	73·0	17·1	19·8	53·6	31·2	33·1	65·0	26·0	15·7	45·9	30·2	38·1
November	49·3	13·8	10·2	33·9	23·7	28·8	45·0	15·0	9·8	33·1	23·3	[4]28·2
December	39·1	15·5	33·8	19·9	5·1	12·5	33·0	−21·0	11·8	15·4	3·6	9·5
Yearly	98·2	−41·3	39·5	45·3	25·4	35·1	96·0	−35·0	17·0	40·4	23·4	31·9

NOTE.—[1]No records 19th–21st incl. [2]No records 7th–12th, incl. [3]No records 2nd–6th and 9th–11th, incl. [4]No records 30th.

1913.

Month.	W. Range Max	Min	Mean	W. Mean Max	Min	Daily	K. Range Max	Min	Mean	K. Mean Max	Min	Daily
January	28·9	−31·2	33·8	1·3	−13·5	−6·1	25·0	−37·0	13·7	1·0	−13·7	−6·4
February	28·3	−31·3	19·9	8·6	−13·3	−1·3	28·0	−33·0	35·5	3·6	−12·0	−4·2
March	46·1	−25·7	23·5	19·3	−2·1	8·7	49·0	−31·0	21·6	23·1	0·2	11·1
April	77·8	39·1	22·7	57·5	33·8	45·2	68·0	18·0	17·1	48·2	30·9	39·6
May	88·2	22·1	23·5	61·7	38·2	50·0	84·0	23·0	23·4	56·6	32·7	44·3
June	91·2	33·8	24·2	77·0	52·8	64·9	93·0	33·0	24·2	76·5	52·3	64·4
July	88·0	46·3	21·8	75·3	53·8	64·4	81·0	43·0	28·1	73·5	48·0	[1]60·8
August	90·8	44·3	21·9	76·1	54·2	65·2	87·0	29·0	26·9	73·8	46·9	[2]60·4
September	84·4	22·8	22·6	67·4	41·3	55·7	74·0	20·0	25·1	61·6	36·5	49·0
October	73·4	5·6	37·6	45·5	27·9	36·7	61·0	6·0	13·4	40·5	27·1	33·8
November	55·9	6·7	14·3	38·2	24·0	31·1	48·0	−4·0	16·0	34·5	24·5	[3]29·5
December	42·8	−14·4	17·4	27·9	10·5	19·2	41·0	17·0	10·8	22·2	11·4	16·8
Yearly	91·2	−31·2	20·2	46·3	26·1	36·2	93·0	−37·0	19·3	42·8	23·7	33·3

NOTE.—[1]No records 3rd–5th and 15th–31st incl. [2]No records 1st–5th incl. [3]No records 8th and 9th.

Table 49.—Monthly Records of Temperatures at Winnipeg and Kenora 1906–1914—Concluded.

1914

Month.	Winnipeg: Range of Temperature Degrees Fahr.			Winnipeg: Mean Temperatures Degrees Fahr.			Kenora: Range of Temperature Degrees Fahr.			Kenora: Mean Temperatures Degrees Fahr.		
	Max.	Min.	Mean	Max.	Min.	Daily	Max.	Min.	Mean	Max.	Min.	Daily
January	44·6	−24·5	18·0	16·7	1·3	7·7	44·0	−40·0	15·0	14·4	−1·6	5·9
February	38·8	−40·5	20·4	1·4	−18·8	−8·7	41·0	−40·0	20·4	1·5	−18·8	−8·6
March	40·2	−16·4	18·0	29·4	14·4	20·1						19·5
April	66·0	9·6	18·4	45·4	26·9	36·1						32·1
May	82·1	22·1	25·7	68·1	42·4	55·2						50·7
June	88·8	45·0	24·4	75·4	51·6	64·2						60·4
July	94·4	47·0	23·0	84·9	60·[illegible]	72·0						68·2
August	94·6	48·5	26·1	74·0	51·5	62·8						
September	82·0	41·8	21·6	67·8	46·2	57·0						
October												
November												
December												
Yearly												

Precipitation Tables.

Table 50.—Monthly Precipitation Records in the vicinity of the Winnipeg River and Basin.

Year 1874-1875.

Month.	Precipitation in Inches			
	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	0·63			
November	1·09			
December	0·33			
January	0·70			
February	0·66			
March	0·24			
April	0·67			
May	3·34			
June	3·45			
July	1·76			
August	4·88			
September	0·86			
Total	18·61			

Year 1875-76.

Month.	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	1·38			
November	1·01			
December	0·98			
January	1·02			
February	1·41			
March	1·24			
April	0·46			
May	3·05			
June	4·50			
July	3·31			
August	9·42			
September	1·36			
Total	29·14			

Year 1876-77.

Month.	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	0·66			
November	2·55			
December	0·72			
January	0·42			
February	0·11			
March	1·08			
April	1·28			
May	5·39			
June	5·69			
July	3·24			
August	0·83			
September	3·02			
Total	21·99			

Year 1877-78.

Month.	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	0·78			2·28
November	0·70			1·80
December	2·23			1·40
January	0·30			0·35
February	1·20			0·85
March	2·49			1·15
April	3·98			4·82
May	3·76			3·49
June	3·99			2·37
July	5·47			0·81
August	1·53			2·00
September	1·80			4·97
Total	28·23			26·29

Table 50. Monthly Precipitation Records in the vicinity of the Winnipeg River and Basin —Continued.

Year 1878–79.

Month.	Precipitation in Inches			
	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	3·18			3·05
November	0·22			0·53
December	1·10			0·09
January	1·67			0·78
February	0·65			0·22
March	0·64			2·81
April	2·21			2·82
May	2·78			1·50
June	6·98			2·09
July	5·22			2·66
August	1·82			1·37
September	0·72			4·16
Total	27·52			25·08

Year 1879–80.

Month.	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	1·38			2·20
November	0·12			1·12
December	2·12			2·39
January	1·01			0·21
February	1·86			0·84
March	0·48			0·20
April	0·15			1·01
May	5·88			3·23
June	3·52			1·74
July	2·74			2·71
August	1·06			2·97
September	4·13			7·38
Total	28·38			26·33

Year 1880–81.

Month.	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	1·72			2·36
November	0·21			3·01
December	1·23			0·51
January	0·15			4·16
February	3·93			2·77
March	0·63			1·04
April	0·76			2·07
May	2·07			3·58
June	2·66			1·14
July	0·87			2·91
August	1·82			2·27
September	2·60			4·47
Total	18·68			30·62

Year 1881–82.

Month.	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	1·50			2·80
November	2·79			1·66
December	0·35			0·32
January	1·26			1·44
February	1·77			2·33
March	2·58			1·54
April	0·17			1·07
May	1·58			1·41
June	1·45			2·17
July	7·30			3·06
August	1·51			1·46
September	1·01			1·35
Total	23·37			20·70

Table 50.—Monthly Precipitation Records in the vicinity of the Winnipeg River and Basin—Continued.

Year 1882–83.

Month.	Precipitation in Inches.			
	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	3·79	....	....	3·88
November	1·06	....	....	0·92
December	2·00	....	....	0·72
January	0·65	....	....	1·08
February	0·68	....	....	0·60
March	0·29	....	....	1·41
April	1·02	....	....	0·11
May	1·35	....	....	0·90
June	3·48	....	....	4·14
July	1·77	....	....	3·24
August	2·96	....	....	1·88
September	1·96	....	....	1·54
Total	21·01	....	....	20·42

Year 1883–84.

Month.	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	3·68	....	....	1·89
November	1·25	....	....	4·15
December	0·92	....	....	1·81
January	0·61	....	....	0·89
February	1·37	....	....	1·08
March	1·20	....	....	1·90
April	2·69	....	....	1·42
May	0·87	....	....	2·47
June	2·97	....	....	1·07
July	1·32	....	....	1·92
August	6·91	....	....	4·23
September	3·75	....	....	4·41
Total	27·54	....	....	27·24

Year 1884–85.

Month.	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	1·52	....	....	4·35
November	0·83	....	....	0·73
December	1·11	....	....	1·29
January	0·23	....	....	0·23
February	0·44	....	....	0·54
March	1·12	....	....	1·12
April	1·82	....	....	2·55
May	1·94	....	....	1·43
June	3·05	....	....	3·28
July	2·65	....	....	4·25
August	1·99	....	....	1·44
September	0·74	....	....	1·66
Total	17·44	....	....	22·87

Year 1885–86.

Month.	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	0·59	....	....	0·37
November	0·84	....	....	1·55
December	1·22	....	....	0·42
January	0·61	....	....	1·09
February	0·50	....	....	1·76
March	0·38	....	....	0·62
April	1·73	....	....	1·92
May	1·19	....	....	0·73
June	1·20	....	....	1·91
July	0·67	....	....	1·63
August	1·17	....	....	1·25
September	4·75	....	....	7·54
Total	14·85	....	....	20·79

Table 50.—Monthly Precipitation Records in the vicinity of the Winnipeg River and Basin—Continued.

Year 1886-87.

Month.	Precipitation in Inches.			
	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	1·22	....	3·59	3·06
November	0·57	....	1·30	1·23
December	0·39	....	0·90	0·54
January	0·71	....	0·90	0·94
February	1·07	....	1·80	0·89
March	0·93	....	0·40	0·52
April	1·14	....	0·40	0·81
May	3·01	....	1·80	2·35
June	2·94	....	1·40	1·68
July	2·02	....	[illegible]	9·21
August	1·49	....	[illegible]	1·02
September	1·77	....	[illegible]	2·49
Total	17·26	....	23·32	24·74

Year 1887-88.

Month.	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	0·45	....	2·07	2·51
November	1·03	....	2·30	1·66
December	1·37	....	0·00	1·44
January	0·79	....	1·80	1·46
February	0·31	....	1·90	0·58
March	1·09	....	1·10	2·76
April	1·29	....	0·90	2·90
May	0·18	....	2·18	2·66
June	3·10	....	4·50	4·94
July	3·88	....	2·06	1·64
August	1·13	....	3·51	3·63
September	1·49	....	1·36	2·43
Total	16·11	....	21·58	28·61

Year 1888-89.

Month.	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	2·70	....	3·02	2·22
November	0·50	....	2·91	1·12
December	0·48	....	0·26	0·02
January	1·57	....	4·45	1·34
February	1·03	....	1·70	0·32
March	0·29	....	2·10	1·04
April	0·85	....	1·67	3·04
May	1·79	....	2·65	2·40
June	0·45	....	1·50	0·50
July	2·38	....	2·73	3·82
August	0·95	....	1·41	3·69
September	2·67	....	2·78	3·86
Total	15·66	....	27·18	23·37

Year 1889-90.

Month.	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	0·86	....	1·45	1·64
November	0·73	....	0·70	0·94
December	1·38	....	3·40	1·91
January	0·51	....	3·40	0·85
February	0·82	....	1·40	1·05
March	1·54	....	1·20	0·54
April	1·20	....	0·22	0·89
May	2·10	....	1·55	2·09
June	2·46	....	1·35	2·66
July	5·01	....	2·37	5·20
August	3·05	....	1·53	2·29
September	3·06	....	2·11	2·58
Total	23·32	....	20·68	22·64

Table 50.—Monthly Precipitation Records in the vicinity of the Winnipeg River and Basin—Continued.

Year 1890–91

Month.	Precipitation in Inches.			
	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	3·67		1·60	1·26
November	0·43		1·10	0·59
December	0·46		1·60	0·26
January	0·78		1·15	0·39
February	0·88		2·15	0·36
March	0·38		2·40	1·01
April	1·13		1·95	0·83
May	0·92		3·73	0·62
June	4·72		2·43	0·93
July	1·94		4·45	4·16
August	3·00		3·53	3·16
September	2·20		4·90	3·24
Total	21·41		30·99	16·72

Year 1891–92.

Month.	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	1·05		1·90	2·39
November	1·18		0·60	0·75
December	1·01		1·40	2·68
January	0·53		0·80	0·23
February	0·60		0·90	0·32
March	1·60		0·60	0·69
April	2·55		2·26	2·90
May	1·85		2·05	1·84
June	1·40		3·06	1·19
July	3·57		3·40	2·14
August	3·73		8·37	4·02
September	0·86		2·10	3·08
Total	19·93		27·44	22·23

Year 1892–93.

Month.	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	0·84		1·75	1·13
November	2·26		1·00	1·10
December	0·10		0·40	0·30
January	1·88		1·50	1·36
February	1·52		2·00	2·02
March	0·22		1·20	0·92
April	2·30		1·60	3·09
May	2·23		0·95	0·79
June	3·87		4·36	3·98
July	5·42		3·53	1·39
August	1·52		2·62	2·02
September	0·66		0·86	3·39
Total	22·82		21·77	21·19

Year 1893–94.

Month.	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	1·35		1·07	2·60
November	2·34		0·70	[illegible]
December	0·62		1·80	1·08
January	1·16		0·00	0·93
February	1·00		0·70	0·04
March	1·63		0·70	1·53
April	3·56		3·76	2·26
May	0·58		2·58	2·73
June	2·40		3·40	1·16
July	0·63		2·91	3·24
August	0·77		1·42	1·17
September	2·18		3·[illegible]	1·77
Total	18·22		23·02	19·02

Table 50. Monthly Precipitation Records in the vicinity of the Winnipeg River and Basin—Continued.

Year 1894–95.

Month.	Precipitation in Inches.			
	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	1·79		5·15	5·27
November	1·87		1·70	1·26
December	0·57		0·90	1·16
January	1·54		1·00	0·71
February	1·18		[illegible]	0·75
March	0·55		0·60	0·96
April	0·62		2·58	2·60
May	3·71		3·37	2·58
June	2·31		4·40	2·89
July	3·30		3·31	3·01
August	1·01		3·01	1·96
September	1·14		3·80	4·27
Total	19·62		30·55	27·42

Year 1895–96.

Month.	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	0·33		2·01	1·20
November	0·95		1·90	0·58
December	0·22		2·20	1·96
January	1·03		0·50	0·55
February	0·42		0·40	0·21
March	1·85		0·60	0·76
April	5·64		1·50	3·00
May	5·32		3·45	4·10
June	3·96		3·07	2·04
July	2·01		4·79	1·75
August	1·51		4·65	1·73
September	1·96		4·25	1·41
Total	25·20		32	19·29

Year 1896–97.

Month.	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	1·01		1·80	3·15
November	1·31		1·90	2·62
December	0·27		0·50	0·16
January	0·89		0·50	0·73
February	0·89		2·10	0·86
March	1·58		1·00	0·92
April	1·01		0·30	1·45
May	1·59		1·60	2·06
June	2·31		1·75	3·39
July	5·38		6·05	6·53
August	1·00		5·40	4·65
September	0·34		1·30	1·12
Total	17·58		24·20	27·64

Year 1897–98.

Month.	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	1·33		1·20	1·44
November	0·72		1·40	1·06
December	0·55		1·20	0·46
January	0·89		0·80	0·51
February	1·07		1·40	0·46
March	2·56		1·40	0·87
April	0·98		0·00	0·07
May	0·89		1·30	3·06
June	6·10		8·05	6·94
July	1·77		6·85	1·58
August	2·15		2·40	2·42
September	2·50		6·60	5·40
Total	21·51		32·60	27·27

Table 50.—Monthly Precipitation Records in the vicinity of the Winnipeg River and Basin—Continued.

Year 1898-99.

Month.	Precipitation in Inches.			
	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	5·67	....	2·70	2·78
November	2·00	....	2·00	0·77
December	0·61	....	0·60	0·28
January	1·77	....	1·50	0·50
February	0·84	....	1·80	0·57
March	0·36	....	1·00	0·34
April	2·17	....	0·75	2·57
May	2·20	....	0·13	3·40
June	3·68	....	1·50	3·84
July	1·96	....	2·26	3·52
August	3·42	....	4·20	3·76
September	0·91	....	3·70	3·65
Total	25·59	....	22·14	25·98

Year 1899-1900.

October	1·85	1·82	2·00	1·79
November	0·55	0·58	0·30	1·34
December	0·11	0·56	0·30	1·25
January	1·05	1·70	1·30	0·85
February	0·20	0·62	0·00	0·20
March	0·68	0·30	0·60	0·29
April	0·30	0·57	0·20	0·50
May	0·11	0·31	0·60	0·36
June	1·85	1·54	2·60	2·48
July	4·06	4·58	3·11	3·33
August	3·66	7·33	5·91	6·77
September	4·22	5·09	5·12	6·14
Total	18·64	25·00	22·04	25·30

Year 1900-01.

October	0·94	3·46	[2]2·25	5·20
November	0·84	1·25	[2]1·46	0·67
December	0·67	1·20	[2]1·09	0·30
January	0·81	2·25	[1]1·38	0·84
February	0·90	0·55	[2]1·28	0·06
March	0·26	0·75	[1]1·12	0·66
April	1·93	0·04	[1]1·27	1·57
May	0·36	1·47	[1]2·05	0·95
June	10·07	3·88	4·10	3·76
July	3·12	2·93	4·65	6·24
August	1·70	2·53	3·95	2·92
September	3·80	1·70	2·35	1·98
Total	25·40	22·01	26·95	25·15

Note.—[1]Average of 20 years. [2]Average of 19 years.

Year 1901-02.

October	0·46	0·82	2·00	2·47
November	0·06	0·60	2·10	0·71
December	0·43	1·10	0·90	0·35
January	0·12	0·13	1·40	0·50
February	0·54	0·48	0·00	0·26
March	2·88	1·22	1·05	0·40
April	1·33	1·05	2·10	0·55
May	3·87	0·84	3·30	1·89
June	3·46	5·76	2·85	5·18
July	1·33	3·00	2·10	3·03
August	0·93	2·04	4·35	3·01
September	2·01	2·06	2·90	1·99
Total	17·42	19·10	25·05	20·34

Table 50. Monthly Precipitation Records in the vicinity of the Winnipeg River and Basin—Continued.

Month.	Precipitation in Inches.			
	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
Year 1902-03.				
October	1·23	1·40	2·80	2·78
November	1·02	0·70	1·85	1·77
December	1·50	1·38	1·90	0·46
January	0·38	1·10	1·70	0·23
February	0·10	0·55	1·00	0·29
March	1·08	1·30	0·30	0·95
April	0·51	1·05	1·10	1·81
May	3·40	3·64	0·70	3·17
June	0·19	1·58	1·20	1·60
July	3·05	2·47	5·65	3·29
August	2·00	3·66	1·50	1·97
September	2·77	1·56	3·70	5·56
Total	17·46	23·09	23·40	23·88
Year 1903-04.				
October	0·69	1·42	3·85	2·71
November	1·50	1·00	1·55	0·35
December	1·02	1·28	0·80	0·18
January	0·17	0·18	1·30	0·23
February	0·85	0·83	0·90	0·18
March	3·00	2·30	1·50	1·11
April	0·16	0·81	0·30	0·36
May	1·77	1·78	4·25	2·31
June	4·22	2·50	2·80	3·36
July	5·55	5·33	4·75	2·91
August	1·62	1·67	3·40	2·65
September	1·88	3·27	3·95	3·41
Total	22·43	26·85	29·15	19·82
Year 1904-05.				
October	1·51	0·81	1·00	3·62
November	0·32	0·63	0·90	0·58
December	1·65	2·12	0·60	1·43
January	0·20	0·15	0·00	0·22
February	0·27	0·62	1·20	0·29
March	1·78	1·25	4·60	1·43
April	0·25	0·04	1·11	1·32
May	3·35	2·24	1·45	2·14
June	4·62	5·55	3·25	2·36
July	4·35	3·51	5·11	7·33
August	1·41	4·18	1·20	1·30
September	1·56	3·69	4·50	4·58
Total	21·27	24·79	25·55	26·60
Year 1905-06.				
October	1·03	2·45	1·80	2·31
November	1·13	1·41	1·80	2·70
December	0·41	0·15	0·20	0·10
January	1·33	1·40	0·50	0·15
February	0·21	0·75	[2]1·28	0·52
March	0·54	0·10	0·80	0·55
April	1·64	0·20	1·10	0·53
May	2·97	3·90	3·35	2·97
June	6·30	4·84	3·50	5·88
July	3·37	1·12	2·55	3·60
August	1·33	6·65	[1]3·27	2·34
September	1·51	0·90	[1]3·43	1·15
Total	21·77	23·87	23·58	23·13

Note.—[1]Average of 20 years. [2]Average of 19 years.

Table 50.—Monthly Precipitation Records in the vicinity of the Winnipeg River and Basin— Continued.

Year 1906-07.

Month	Precipitation in Inches.			
	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	0·21	0·20	....	2·18
November	1·87	[1]1·35	....	4·29
December	1·26	1·50	....	0·55
January	2·12	2·50	....	1·03
February	0·27	0·55	....	0·80
March	1·12	1·58	....	1·63
April	0·99	1·10	....	1·01
May	0·97	0·30	....	0·88
June	1·54	2·68	....	0·74
July	3·98	5·10	....	5·94
August	3·90	6·45	....	5·06
September	0·69	3·25	....	3·26
Total	18·92	26·56	....	27·37

Note.—[1]Approximate.

Year 1907-08.

Month	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	0·40	0·65	....	2·47
November	0·72	0·90	....	1·05
December	0·18	0·25	....	0·02
January	0·74	0·30	....	0·47
February	1·80	1·20	....	1·67
March	1·83	0·60	....	0·57
April	1·75	1·05	....	2·82
May	3·01	[1]2·50	....	2·85
June	3·11	[1]3·30	....	3·70
July	1·76	[1]4·04	....	1·96
August	2·14	[1]3·93	....	3·71
September	1·89	[1]3·13	....	1·08
Total	19·33	22·15	....	22·37

Note.—[1]Average of 13 years.

Year 1908-09.

Month	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	2·21	[2]2·03	....	1·00
November	0·55	[1]0·20	....	1·99
December	0·65	0·50	....	2·73
January	0·73	[1]0·60	....	1·20
February	0·76	0·40	....	0·56
March	2·67	0·85	....	0·66
April	1·58	[illegible]	....	0·64
May	1·25	[illegible]	....	1·20
June	1·54	[illegible]	....	0·57
July	3·84	[3]4·03	....	5·17
August	4·75	[3]3·93	....	3·05
September	0·60	[3]3·43	....	2·61
Total	21·13	22·03	....	21·38

Note.—[1]Approximate. [2]Average of 25 years. [3]Average of 13 years.

Year 1909-10.

Month	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	0·52	2·00	....	1·49
November	0·89	[1]1·60	....	2·63
December	3·99	3·82	....	1·20
January	0·25	0·10	....	0·71
February	1·56	[1]0·30	....	0·79
March	1·65	3·30	....	0·23
April	1·49	3·30	....	1·62
May	1·65	1·30	....	0·76
June	2·38	0·26	....	0·54
July	0·80	0·50	....	2·85
August	2·13	1·25	....	1·47
September	2·75	3·80	....	3·42
Total	20·07	21·53	....	17·71

Note.—[1]Approximate.

Table 50.—Monthly Precipitation Records in the vicinity of the Winnipeg River and Basin—Concluded.

Year 1910-11.

Month.	Precipitation in Inches.			
	Winnipeg.	Kenora.	Savanne.	Pt. Arthur.
October	1·08	2·60		2·46
November	1·27	2·46		1·29
December	1·87	0·90		0·41
January	0·13	0·90		0·56
February	0·71	[1]0·65		1·28
March	0·28	0·10		0·73
April	2·57	2·10	..	0·67
May	6·38	3·90		2·36
June	2·77	2·60		6·23
July	2·96	7·81		3·01
August	2·43	4·80		2·96
September	2·13	3·70		2·91
Total	24·58	31·84		24·87

Note.—[1]Average of 14 years.

Year 1911-12.

October	1·81	2·30	......	1·65
November	0·59	0·10	......	1·52
December	0·59	1·50	......	1·05
January	0·30	0·15	......	0·26
February	0·18	0·40	......	0·33
March	0·30	0·90	......	0·36
April	2·25	3·20	......	2·50
May	3·59	9·60	......	3·03
June	0·91	4·80	......	1·75
July	6·11	8·80	......	1·97
August	1·61	4·50	......	2·54
September	5·49	7·50	......	4·97
Total	23·79	41·35	......	21·93

Year 1912-13.

October	1·15	4·20	......	1·20
November	0·11	0·00	......	0·42
December	0·78	0·20	......	0·78
January	0·75	0·80	......	0·54
February	0·61	0·90	......	0·56
March	0·36	0·65	......	1·22
April	0·41	0·60	......	0·75
May	0·53	[1]1·29	......	3·43
June	3·27	2·09	......	2·11
July	2·09	3·84	......	6·26
August	4·71	4·27	......	2·87
September	1·27	1·02	......	3·85
Total	16·04	19·86	......	24·29

Note.—[1]This and all subsequent records at Kenora obtained by Dominion Water Power Branch.

Year 1913-14.

October	0·77	3·21	......	3·73
November	0·75	1·35	......	1·27
December	0·26	0·05	......	0·08
January	0·79	1·30	......	0·97
February	0·83	0·42	......	0·39
March	0·59	0·36	......	0·94
April	0·75	1·79	......	1·37
May	0·53	1·87	......	3·43
June	1·46	4·67	......	1·30
July	7·14	3·80	......	2·30
August	2·05	2·12	......	4·48
September	2·28	4·07	......	2·70
Total	18·20	25·01	......	22·96

Table 51. Meteorological Data secured in connection with the evaporation station established by the Dominion Water Power Branch at Keewatin on the Lake of the Woods.

MAY 1913

Day	Temperature in Degrees Fahrenheit				Velocity Wind.	Direction Wind.	Barometer.	Evaporation.	Rain.	Humidity.
	Lake.	Tank	Air	Mean Day.	Miles per hour.		Inches.	Inches.	Inches.	Per cent.
1										
2								Set tank		
3			47		3.46			0.00	0.015	
4			47		0.54			0.01	0.195	
5					0.54					
6					3.77			Set tank		
7					5.70					
8			44		5.70 6.98			0.11		
9			50		3.48			0.11		
10			50		2.6[illegible]			0.21		
11					5.82					
12			44		5.82			0.07	0.150	
13			32		6.32			0.00	0.160	
14			37		4.15			0.05		
15			38		3.88			0.00	0.030	
16					3.88			0.01	0.160	
17			40		3.22			0.00	0.065	
18	44		44		6.97			0.06	0.020	
19	42		43		6.97			0.00	0.005	
20	43		48		2.50			0.07		
21	46		50		5.48			0.10	0.030	
22	47		59		5.18 1.80			0.05		
23	46	47	50⅓		3.25			0.005	0.285	
24	48	50	51		4.11			0.09		
25	47	48	58					0.16		
26	49	52	63					0.05		
27	50	54	75					0.04	0.020	
28	51	53	65					0.03	0.010	
29	51	56	66					0.00	0.040	
30	55	56	57					0.02		
31	51	53	60					0.06	0.100	
Total								1.36	1.285	
Average								0.051	0.041	

Table 51. Meteorological Data secured in connection with the evaporation station established by the Dominion Water Power Branch at Keewatin on the Lake of the Woods—Continued.

JUNE, 1913

Day.	Temperature in Degrees Fahrenheit				Velocity Wind	Direction Wind	Barometer.	Evaporation	Rain	Humidity
	Lake	Tank	Air	Mean Day	Miles per hour		Inches	Inches	Inches	Per cent
1	52·0	54·0	66·0	55·5	8·00			0·01		
2	51·0	52·0	56·0	53·0	2·83			0·09	0·26	
3	50·0	51·0	56·0	49·0	1·93			0·01		
4	52·0	53·0	60·0	51·5	6·45			0·11		
5	52·0	53·0	58·0	52·0	3·00				0·34	
6	51·0	52·0	50·0	43·0	[illegible]			0·07		
7	52·0	54·0	58·0	46·5	[illegible]			0·13		
8	54·0	55·0	65·0	51·0	2·11	SE NW		0·10		
9	56·0	57·0	60·0	59·0	3·19	SE NW	29·81	0·10		48·0
10	54·0	55·0	61·0	58·0	1·92	SW SW	29·61 29·16	0·10		54·0 68·0
11	55·0	57·0	68·0	61·0	6·07	SW SW	29·11	0·10		53·0
12	56·0	58·0	75·0	67·0	3·88	S NW	29·26	0·01		61·0
13	60·0	61·5	69·0	70·0	4·81	SW NE	29·24 29·16	0·02	0·38	77·0 81·0
14	63·0	61·0	72·0	66·0	3·27	E SE	29·06 28·96	0·03		74·0 81·0
15	66·0	68·0	80·0	68·5	5·59	SW W	29·21	0·48	0·01	47·0
16	64·0	64·5	68·0	61·0	8·76	N N.	29·36 29·16	0·11		71·0 60·0
17	[illegible]	60·5	63·0	54·5	2·33		29·16 29·16	0·13		64·0 75·0
18	62·5	62·5	71·5	59·0	1·06	SE. SW	29·11 29·40	0·06		64·0 76·0
19	63·0	63·5	78·5	65·0	1·36	SW.	29·37 29·11	0·06		65·0 56·0
20	61·5	62·0	80·0	61·5	3·41	NE. N	29·32 29·31	0·09		44·0 44·0
21	65·0	64·8	72·5	60·5	1·31	NW SW	29·40 29·36	0·13		44·0 84·0
22	68·0	69·0	90·0	63·0	4·90	SE. S.	29·31	0·05		37·0
23	66·0	67·5	72·5	67·5	4·51	SW. E.	29·01 [illegible]			53·0 90·0
24	65·5	66·0	81·0	72·5	1·15	E. S.	[illegible] 28·86	0·13		42·5 63·0
25	66·0	67·0	75·0	70·0	5·93	SW SW.	28·76 28·86	0·08	0·27	63·0 66·0
26	65·5	66·0	76·0	64·0	5·65	N. N.	29·11 29·26	0·18		42·0 38·0
27	65·0	64·5	58·0	53·5	5·85	NE. NE.	29·10 29·26	0·03	0·55	
28	67·0	67·0	71·0	67·5	1·57	E. E.	29·15 29·16	0·06	0·28	85·0 78·0
29	70·0	70·0	94·0	69·0	4·58	SE. SE.	29·11	0·02		49·0
30	68·5	69·0	73·0	64·5	8·26	SW. SW.	28·90 28·96	0·16	0·06	62·0 54·0
Total	....	....			....	......	......	2·25	2·09	
Average	59·9	60·8	....	59·9	....	......	......	0·080	0·070	

***Table 51.—Meteorological Data secured in connection with the evaporation station established by the Dominion Water Power Branch at Keewatin on the Lake of the Woods.*—Continued.**

JULY, 1913.

Day.	Temperature, in Degrees Fahrenheit.				Velocity Wind.	Direction Wind.	Barometer.	Evaporation.	Rain.	Humidity.
	Lake	Tank.	Air.	Mean Day.						
					Miles per hour		Inches	Inches	Inches.	Per cent.
1	66·0	66·0	59·0		6·17	N.	29·20	0·08		
	69·0	69·0	71·0	57·0	6·13	N.	29·31	0·05		58·0
2	67·0	67·0	68·0		0·52	SW.	29·30	0·06		55·0
	68·0	67·0	67·0	56·5	3·79	SE.	29·06	0·07		76·0
3	67·0	67·0	75·0		5·09	SW.	28·99	0·06		48·0
	66·0	66·0	60·0	[illegible]	2·72	SE	29·16	0·08	0·01	100·0
4	66·0	65·0	58·0		2·72	N.	29·31	0·06		89·0
	66·0	66·0	59·0	56·5	11·11	SW.	29·22	0·07		
5	65·0	65·0	61·0		6·36	N.	29·06	0·01	0·73	94·0
	66·0	66·0	52·0	53·0	7·07	N.	29·26	0·01	0·08	81·0
6					3·07	SW.				29·0
	70·0	71·0	80·0	60·5	2·19	SW.	29·51	0·08	0·01	
7	69·0	68·0	73·0		1·50	W.	29·28	0·07		60·0
	67·0	68·0	66·0	61·0	3·14	SW.	29·16	0·07		80·0
8	66·0	66·0	76·0		5·95	W.	29·01	0·01		45·0
	65·0	65·0	62·5	65·0	21·00	W.	28·94	0·17	0·01	79·0
9	65·0	63·8	56·0		5·23	NW.	29·26	0·10		65·0
	65·5	66·0	63·0	58·0	5·72	NW.	29·37	0·13		56·0
10	65·8	65·0	62·5		1·71	S.	29·31			65·0
	66·0	66·5	68·5	56·5	5·68	E.	29·15	0·06		57·0
11	65·6	64·8	63·0		8·56	S.	28·86	0·05	0·99	90·0
	65·5	64·5	60·0	54·7	8·42	S.	28·76	0·02	0·22	89·0
12	65·0	63·6	58·5		8·41	SE.	28·65	0·05	0·62	89·0
	64·6	63·5	56·0	49·0	10·31	SE.	28·80	0·04	0·23	88·0
13	65·6	66·0	63·0		1·51	NW.	29·17	0·01		58·0
	68·0	65·5	67·0	58·5	3·19	NW.	29·21	0·08	0·02	36·0
14	64·5	63·5	58·0		3·19	SE.	29·31	0·05		77·0
	68·5	69·5	73·0	58·5	2·91	SE.	29·35	0·05		68·0
15	66·0	66·0	63·0		4·30	S.	29·13	0·09		72·0
	67·0	67·5	69·5	63·0	3·74	S.	29·41	0·03		79·0
16	66·0	66·3	65·0		2·75	SE.	29·15	0·03	0·18	80·0
	69·0	70·0	72·0	66·5	1·31	S.	29·10	0·03	0·01	86·0
17	66·0	65·5	61·8		2·45	S.	29·15	0·02		75·0
	67·9	69·0	75·0	61·5	5·80	NW.	29·42	0·08		44·0
18	65·8	65·6	69·7		4·30	SW.	29·40	0·02		75·0
	66·0	66·5	65·5	66·0	9·18	NW.	29·37	0·08		62·0
19	66·0	65·0	62·0		6·40	NW.	29·39	0·03		79·0
	66·5	66·0	58·0	63·0	6·99	N.	29·43	0·05	0·09	61·0
20					1·99	N.		0·02		
	6[illegible]·0	68·5	68·0	62·0	2·96	SW.	29·52	0·00	0·01	65·5
21	67·5	67·0	64·5		4·97	NW.	29·22	0·13		82·0
	67·1	68·5	71·5	67·0	7·03	NW.	29·20	0·05	0·13	54·5
22	67·0	66·2	65·5		4·98	NW.	29·15	0·04		64·0
	67·5	67·5	60·5	60·2	10·80	NE.	29·15	0·06	0·11	78·5
23	66·0	65·0	57·0		5·18	N.	29·30	0·05		74·0
	66·0	66·0	56·5	59·5	4·33	N.	29·36	0·10		66·0
24	66·5	65·5	59·0		6·77	W.	29·38	0·03		75·0
	67·0	67·0	67·0	59·0	5·00	N.	29·30	0·08		50·0
25	66·5	66·0	66·0		3·52	SW.	29·20	0·01		66·0
	68·0	69·2	77·0	67·0	5·23	SW.	29·15	0·08		52·0
26	66·0	65·0	64·5		3·73	S.	29·00	0·04		82·0
	66·5	67·0	71·0	67·0	3·63	SW.	29·00	0·06		73·0
27	67·0	67·0	62·0		8·74	NW.	29·20	0·06		57·0
	67·0	66·5	63·0	61·0	10·58	NW.	29·30	0·06	0·06	62·5
28	66·0	65·0	62·5		2·41	W.	29·36	0·04		72·0
	67·0	67·0	68·5	59·0	5·09	SW.	29·33	0·04		59·0
29	66·0	66·0	69·0		3·30	S.	29·24	0·06		72·0
	70·0	71·0	79·0	75·0	3·75	SW.	29·20	0·05		57·0
30	67·0	68·0	72·0		3·66	SE.	29·10	0·01		82·0
	70·5	71·5	78·0	74·5	5·35	W.	29·16	0·00		57·0
31	65·5	65·5	62·0		8·93	W.	29·18	0·07		60·0
	67·0	67·0	72·0	63·0	11·11	W.	29·25	0·12		46·0
Total								3·39	3·84	
Average	66·0	66·0		61·[illegible]				0·056	0·124	

Table 51.—*Meteorological Data secured in connection with the evaporation station established by the Dominion Water Power Branch at Keewatin on the Lake of the Woods*—Continued.

AUGUST 1913

Day	Temperature in Degrees Fahrenheit				Average Wind	Direction Wind	Barometer	Evaporation	Rain	Humidity
	Lake	Tank	Air	Mean Day	Miles per hour		Inches	Inches	Inches	Per cent
1	69·0	69·5	72·0		6·08	W	29·[illegible]	0·08		61·0
	68·0	69·[illegible]	58·0	68·0	4·14	NW	29·[illegible]	0·0[illegible]		40·0
2	67·0	67·0	72·0		6·46	W	29·33	0·08		[illegible]
	68·0	70·[illegible]	81·0	71·0	7·56	NW	29·[illegible]	0·03		49·0
3	68·5	69·0	68·0		7·44	NW	29·45	0·08		[illegible]
	70·5	72·0	76·0	66·0	6·88	W	29·45	0·06		[illegible]
4	67·5	67·0	64·0		0·80	W	29·44	0·08		65·0
	68·5	68·5	70·0	64·0	[illegible]·56	W	29·35	0·08		60·0
5	67·5	67·0	65·0		[illegible]·08	N	29·27	0·05		70·0
	68·0	69·0	70·0	65·5	4·08	N	29·40	0·10		48·0
6	6[illegible]·0	66·0	59·0		1·90	N	29·18	0·04		[illegible]8·0
	70·0	70·0	69·0	62·0	2·06	S.	29·15	0·09		55·0
7	67·5	66·0	61·[illegible]		[illegible]·22	S	29·10	0·09		68·0
	66·0	67·0	65·0	63·5	6·88	S	28·90	0·03	0·69	90·0
8	66·0	65·0	58·0		4·41	W	28·87	0·04	0·54	[illegible]7·0
	67·0	6[illegible]·0	64·5	60·0	7·89	W	28·97	0·0[illegible]	0·21	8[illegible]·0
9	67·0	66·0	64·0		1·9[illegible]	N	29·15	0·08		79·0
	67·0	65·5	54·0	[illegible]2·5	5·00	N	29·45	0·08	0·01	74·0
10	66·0	65·5	59·0		7·[illegible]	SE	29·51	0·08		53·0
	65·0	61·8	59·0	52·0	7·35	SE.	29·4[illegible]	0·10		73·0
11	65·0	61·0	54·5		7·05	SE.	29·3[illegible]	0·01	0·[illegible]3	91·0
	65·8	66·8	64·2	56·0	1·33	S	29·3[illegible]	0·01	0·01	81·5
12	65·6	65·8	68·0		1·56	SW	29·33	0·01		88·0
	68·8	[illegible]	67·0	69·0	0·07	S	29·41	0·04		67·0
13	6[illegible]·2	68·0	77·0		0·64	S.	29·26	0·02		88·0
	71·0	72·6	75·0	73·0	4·18	S	29·30	0·02		82·0
14	70·0	70·0	71·0		1·67	S	29·06	0·02		86·0
	71·0	76·0	81·0	74·0	4·93	S	29·40	0·05		86·0
15	70·0	69·0	69·0		6·00	S.	29·20	0·00		61·0
	71·0	70·0	78·0	67·5	2·08	W.	29·50	0·0[illegible]	1·78	86·0
16	68·0	69·0	61·0		2·86	SW.	29·25	0·04		75·0
	71·0	71·0	64·0	64·5	2·42	W.	29·3[illegible]	0·02		79·0
17	71·0	74·0	64·0				29·40	0·02		61·0
	74·0	72·0	64·0	51·0	[illegible]·40	NW	29·52	0·16		55·0
18	68·0	67·0	66·0		4·44	E.	29·51	0·09		[illegible]1·0
	70·8	70·0	71·8	63·0	3·85	S	29·55	0·04		65·0
19	68·0	68·0	66·0		7·37	SE	29·50	0·075		76·0
	69·2	70·0	68·2	68·0	4·62	SW.	29·45	0·04	0·035	85·0
20	69·0	69·0	71·0		2·48	N	29·45	0·05		86·0
	74·3	73·0	68·5	72·0	3·46	W	29·36	0·05		62·0
21	69·0	68·0	65·0		7·92	[illegible]	29·25	0·05	0·20	74·0
	66·0	67·0	61·0	61·5	11·93	N.	29·46	0·12	0·44	79·0
22	6[illegible]·0	66·0	60·0		5·34	NE	29·49	0·04		89·0
	71·0	70·0	68·0	61·0	1·57	NW.	29·10	0·05		66·0
23	68·0	68·0	66·8		6·08	W.	29·35	0·07		71·0
	68·0	6[illegible]·0	66·5	59·0	6·42	N.	29·40	0·09		55·5
24	69·0	[illegible]	65·0		3·46	SW	29·38	0·09		62·0
	68·0	68·0	65·9	55·0	6·00	NW	29·20	0·04		75·0
25	68·0	66·0	66·0		6·00	NW	29·05	0·075	0·015	76·0
	69·0	71·0	72·5	58·0	17·17	NW.	29·21	0·08		46·0
26	66·0	66·0	62·0		9·48	N.	29·25	0·09		69·0
	67·0	67·0	60·0	60·5	6·30	N.	29·36	0·06		94·0
27	67·0	66·0	62·0		1·91	SE.	29·35	0·04		84·0
	67·0	67·0	63·0	58·5	5·88	SE.	29·30	0·03	0·08	90·0
28	66·0	65·0	58·0		4·[illegible]	W.	29·36	0·07	0·30	83·0
	67·0	67·0	59·0	58·0	15·60	NW.	29·18	0·08	0·09	[illegible]9·0
29	66·0	64·0	58·0		8·98	NW.	29·22	0·04		83·0
	66·0	66·0	60·0	60·5	6·72	NW.	29·17	0·07		84·0
30	65·0	65·0	63·0		2·46	SW.	29·10	0·02		79·0
	68·0	70·0	72·0	61·5	2·49	SW.	29·13	0·04		65·0
31	...	...	...	...	33·00	SE.	...	...		...
	67·0	68·0	65·0	54·5	3·30	SE.	29·26	0·08		57·0
Total	...					...		3·42	4·58	
Average	68·2	68·2		62·3	...	...		0·057	0·118	...

Table 51.—Meteorological Data secured in connection with the evaporation station established by the Dominion Water Power Branch at Keewatin on the Lake of the Woods—Continued.

SEPTEMBER 1913.

Day.	Temperature in Degrees Fahrenheit				Velocity Wind.	Direction Wind.	Barometer.	Evaporation.	Rain.	Humidity.
	Lake.	Tank.	Air.	Mean Day.	Miles per hour.		Inches.	Inches.	Inches.	Per cent.
1	67·0	68·0	71·0		6·60	SE.	29·00	0·13		69
	67·0	68·0	70·0	68·5	5·14	S.	29·05	0·06	0·03	81
2	64·0	63·0	60·0		7·46	NW.	29·39	0·04		78
	66·5	68·0	60·0	60·0	6·67	NW.	29·50	0·06		71
3	66·0	64·0	58·0		2·48	SE.	29·57	0·05		72
	66·0	66·0	62·0	56·5	6·88	SE.	29·46	0·06		79
4	66·0	64·0	58·0		7·91	SE.	29·34	0·13		80
	66·0	66·0	64·0	59·5	6·74	SE.	29·35	0·04		90
5	66·0	65·0	64·5		4·36	SE.	29·31	0·04		87
	68·0	70·5	74·0	67·0	3·28	SE.	29·29	0·02		80
6	66·0	67·0	[illegible]		2·05	SE.	29·25	0·01		90
	72·0	76·0	[illegible]9·0	74·5	1·76	SE.	29·25	0·10	0·02	88
7	66·0	64·0	58·0		5·83	NW.	29·41	0·01		89
	66·0	66·0	60·0	62·5	10·76	NW.	29·60	0·07	0·23	68
8	66·0	64·0	60·0		2·52	S.	29·70	0·07		68
	66·0	65·0	61·0	54·5	2·76	S.	29·60	0·08		68
9	65·0	64·0	58·0		6·86	SE.	29·15	0·08		67
	66·0	68·0	69·0	62·0	9·48	SE.	29·24	0·10		68
10	65·0	64·0	61·0		5·22	NW.	29·36	0·13		89
	66·0	68·0	66·0	63·0	2·45	NW.	29·40	0·07	0·47	66
11	63·0	62·0	50·0		4·02	NW.	29·45	0·07		81
	64·0	63·0	56·0	55·0	1·32	NW.	29·50	0·15		55
12	64·0	60·0	50·0		7·24	N.	29·51	0·09		77
	63·0	65·0	59·0	50·0	2·98	N.	29·52	0·09		53
13	62·0	58·0	41·0		3·37	E.	29·46	0·06		92
	64·0	64·0	55·0	61·5	4·98	E.	29·40	0·11		60
14					7·38	SE.				
	63·0	61·0	56·0	59·0	7·51	S.	29·17	0·10		77
15	64·0	63·0	58·0		5·21	NW.	29·31	0·155	0·175	83
	64·0	64·0	58·0	55·5	3·31	SW.	29·45	0·07		83
16	63·0	61·0	54·0		0·39	SW.	29·47	0·025		94
	65·0	63·0	60·0	57·0	0·84	SW.	29·50	0·06	0·005	68
17	63·0	61·0	54·0		0·63	SW.	29·45	0·01		88
	64·0	64·0	62·0	61·0	2·17	SW.	29·36	0·05		79
18	63·0	63·0	62·0		0·51	SW.	29·20	0·01		69
	64·0	64·0	66·0	61·0	7·06	S.	29·00	0·08		71
19	64·0	61·0	60·0		7·39	W.	29·32	0·01		92
	63·0	60·0	60·0	47·5	7·56	W.	28·80	0·13	0·06	84
20	61·0	57·0	40·0		14·30	NW.	29·12	0·15		84
	60·0	57·0	38·0	41·5	21·96	NW.	29·21	0·12		67
21					27·50	N.	29·26		0·015	62
	60·0	59·0	42·0	39·5	13·50	NE.		0·12		
22	59·0	57·0	38·0		1·98	NE.	29·25	0·10		91
	59·0	57·0	43·0	35·0	3·29	SW.	29·25	0·08		49
23	59·0	54·0	43·0		4·52	SE.	29·35	0·08		78
	59·0	54·0	43·0	38·0	3·41	SE.	29·35	0·08		78
24	58·0	54·0	43·0		3·31	NE.	29·30	0·07	0·01	85
	58·0	54·0	41·5	41·5	2·34	NE.	29·30	0·03		84
25	57·0	53·0	41·0		0·62	SW.	29·25	0 01		85
	57·0	56·0	50·0	43·0	4·37	W.	29·20	0·04		62
26	56·0	52·0	41·0		2·99	NW.	29·15	0·06		84
	58·0	60·0	61·0	49·0	21·37	NW.	29·32	0·98		50
27	57·0	55·0	52·0		4·06	SW.	29·25	0·05		75
	58·0	56·0	72·0	57·0	9·13	SW.	29·22	0·09		42
28	58·0	58·0	59·0		4·48	W.	29·10	0·05		68
				59·5	2·02	NE.				
29	56·0	54·0	48·0			SE.	29·18	0·08		87
	59·0	61·0	62·0		3·18	SE.	29·25	0·04		60
30	56·0	58·0	54·0			SE.	29·19	0·03		88
	60·0	63·0	74·0		2·87	SW.	29·20	0 01		47
Total								4·68	1·01	
Average	62·6	61 6		51·9				0·072	0·034	

Table 51.—Meteorological Data secured in connection with the evaporation station established by the Dominion Water Power Branch at Keewatin on the Lake of the Woods—Continued.

OCTOBER 1913.

Day.	Temperature in Degrees Fahrenheit. Lake.	Tank.	Air.	Mean Day.	Velocity Wind.	Direction Wind.	Barometer.	Evaporation.	Rain.	Humidity.
					Miles per hour.		Inches.	Inches.	Inches.	Per cent.
1.	57	57	56			NW.		0·02		
	57	57	62	55	10·3		28·85	0·06		85
2	57	56	50		5·5	SW.		0·06	0·045	
	58	59	62	53	4·4	SW.	28·80	0·05		63
3	57	56	50		4·4	SW.				
	57	57	56	55	2·9	NW.	28·62	0·07		80
4	56	55	46		2·5	NE.		0·05		
	57	54	49	45	2·8	NE.	28·87	0·05		79
5	55	51	42		6·7	NE.		0·03	0·64	
	55	54	42	40	6·6	NE.	28·77	0·04	0·32	84
6	54	53	40		4·4	NE.		0·04	0·04	
	54	53	43	38	9·4	NE.	28·73	0·03		80
7	54	52	41		2·7	SW.		0·03		
	51	52	44	43	11·8	SW.	28·80		0·73	89
8	55	57	53		3·8	NE.		0·03		
	55	56	55	42	2·0	NE.	28·90			70
9	55	56	55		2·7	NE.		0·02		
	56	55	59	47	3·5	NE.	28·85	0·02	0·08	85
10	55	56	59		1·4	S.		0·92		
	55	54	45	46	4·1	SE.	28·41	0·03	0·98	94
11	54	53	48		4·7	SW.		0·06		
	51	52	50	40	4·0	NW.	28·55	0·08		
12	52	50	48		8	SW.	28·85	0·11		
	52	53	48	40	4·6	SW.	28·95	0·02	0·02	90
13.	52	51	52		5·9	SE.	28·80	0·03		
	54	57	62	52	11·0	SE.	28·73	0·01		83
14	53	52	55		6·4	SW	28·65	0·41		
	52	52	46	49	7·9	NW	28·82	0·06		74
15.	52	50	39		0·4	NW	29·15	0·08		
	52	52	45	37	4·6		29·10	0·05		62
16	52	49	39		2·8	NE.	29·25			
	51	51	42	37	2·5	NE.	29·25	0·07		64
17	50	48	41		0·8	S.	29·47	0·04		
	50	50	44	42	8·4	SE.	29·06	0·08		74
18	50	49	40		5·8	NW.	28·94	0·05		
	50	50	38	38	5·6	NW.	28·90	0·06		72
19	49	47	27		5·6	N.	28·96	0·04		
	48	45	28	30	8·6	N.	28·99	0·05		70
20	48	44	26		5·6	N.	28·70	0·04		
	47	43	20	30	4·6	N.	28·72	0·06		73
21	46	43	20		2·6	NW.	28·70	0·03		
	46	44	22	19	3·3	N.	28·67	0·03		74
22	46	44	30		3·0	SE.	28·67	0·06		
	46	45	35	27	3·9	S.	28·67	0·01		100
23.	46	45	36		3·4	S.	28·50	0·02		
	46	45	38	33	5·9	S.	28·40	0·02	0·16	95
24	46	45	38		3·7	NW.	28·73	0·07		
	46	46	41	37	5·5	NW.	28·80	0·03	0·02	84
25	46	45	37		3·9	NW.	28·84	0·04	0·03	
	46	45	37	40	4·4	NW.	28·92	0·01	0·06	91
26	45	43	32		4·9	NW.	29·00	0·04		
	45	43	32	33	4·9		28·95	0·01		100
27	44	43	34		5·5	NW.	28·72	0·02		
	47	43	35	30	4·2	NW.	28·70	0·01		77
28	43	40	31		5·4	NW.	29·08			
	43	44	21	20	7·2	NW.	29·13		0·14	88
29	43	40	17		2·2	NE.	29·10			
	43	40	21	19			29·13			97
30	42	40	24			SW.	29·10			
	42	40	27	24	4·7	SW.	29·46			87
31	41	40	26		4·6	SW.	29·20			
	41	42	37	31	10·2	SW.	29·16			63
Total								2·15	3·34	
Average	50·2	49·1		37·8				0·043	0·108	

Table 51.—Meteorological Data secured in connection with the evaporation station established by the Dominion Water Power Branch at Keewatin on the Lake of the Woods—Continued.

NOVEMBER, 1913.

Day.	Temperature in Degrees Fahrenheit.				Velocity Wind.	Direction Wind.	Barometer.	Evaporation.	Rain.	Humidity.
	Lake.	Tank.	Air.	Mean Day.						
					Miles per hour.		Inches.	Inches.	Inches.	Per cent.
1	41	39	33	....	3·6	S.W.	28·97	0·03	....	....
	41	41	41	37	6·7	S.W.	29·27	0·05	....	74
2	41	43	38	....	1·5	S.	28·79	0·02	....	....
	42	44	43	41	18·3	Calm	29·09	0·05	....	76
3	41	40	34	....	2·2	N.W.	28·96	....	....	....
	41	39	28	30	7·8	N.W.	29·26	0·06	....	79
4	41	40	37	....	4·0	S.W.	29·02	0·05	....	....
	41	42	49	28	[illegible]	S.W.	29·32	0·09	....	67
5	41	41	42	....		S.W.	28·70	0·03	....	....
	41	42	44			S.W.	29·00	0·04	....	63
6	41	40	41	....		S.E.	28·49	0·03	....	....
	41	44	45		[illegible]	S.E.	28·79	0·02	....	88
7	41	40	33	....	[illegible]	N.W.	28·73	0·02	....	....
	41	40	20		12·9	N.W.	29·03	Ice.	0·75	95
8	....	....	20	....	1·7	N.W.	29·03	....	....	....
	....	....	29	26	5·6	N.W.	29·33	....	....	87
9	....	....	22	....	1·7	N.W.	29·10	....	....	....
	....	....	14	27	6·2	N.W.	29·40	....	....	72
10	....	....	10	....	2·4	N.W.	29·08	....	....	....
	....	....	18	11	2·5	N.W.	29·38	....	....	....
11	....	....	26	....	2·5	S.	28·70	....	....	....
	....	....	33	24	5·0	S.	29·00	....	0·05	84
12	....	....	30	....	4·3	S.W.	28·66	....	....	....
	....	....	35	33	5·0	S.	28·96	....	....	95
13	....	....	25	....	5·2	W.	28·85	....	....	....
	....	....	24	27	9·1	N.W.	29·15	....	....	87
14	....	....	14	....	5·5	S.	29·13	....	....	....
	....	....	25	21	3·0	S.W.	29·43	....	....	96
15	....	....	32	....	2·6	W.	28·95	....	....	....
	....	....	35	28	9·2	W.	29·25	....	....	100
16	....	....	36	....	3·9	S.W.	28·64	....	....	....
	....	....	....	35	6·1	S.	28·94	....	....	91
17	....	....	41	....	2·5	S.	28·60	....	....	....
	....	....	46	40	3·8	S.W.	28·90	....	....	80
18	....	....	25	....	6·5	N.W.	28·85	....	....	....
	....	....	28	30	6·1	W.	29·15	....	....	88
19	....	....	36	....	2·7	S.W.	28·55	....	....	....
	....	....	28	29	10·1	W.	28·85	....	....	85
20	....	....	35	....	3·0	S.W.	28·58	....	....	....
	....	....	39	34	7·3	S.W.	28·88	....	....	79
21	....	....	38	....	1·3	Calm	28·48	0·03	....	....
	....	....	33	35	7·2	N.W.	28·78	0·01	0·02	95
22	....	....	27	....	11·4	N.W.	28·82	....	....	....
	....	....	28	27	13·5	N.W.	29·12	....	....	89
23	....	....	30	....	1·2	N.W.	28·92	....	....	....
	....	....	35	32	3·3	N.	29·22	....	0·05	69
24	....	....	34	....	9·4	S.E.	28·92	....	....	....
	....	....	35	32	3·7	W.	29·22	....	....	72
25	....	....	30	....	2·8	N.W.	28·82	....	....	....
	....	....	30	24	7·5	N.W.	29·12	....	....	73
26	....	....	24	....	3·4	N.W.	29·05	....	....	....
	....	....	29	30	5·8	S.E.	29·35	....	....	76
27	....	....	32	....	5·9	S.E.	29·02	....	....	....
	....	....	37	35	4·2	S.E.	29·32	....	....	86
28	....	....	36	....	2·3	S.E.	29·00	....	....	....
	....	....	39	38	2·6	S.W.	29·30	....	....	96
29	....	....	39	....	4·3	S.W.	28·94	....	....	....
	....	....	36	35	4·9	S.W.	29·24	....	0·46	100
30	....	....	33	....	4·2	N.W.	29·03	....	....	....
	....	....	32	33	1·4	S.E.	29·33	....	0·02	95
Total	....	....	....	....	....	....	....	....	1·35	....
Average	....	....	....	31·6	....	....	....	....	0·045	....

Table 51.—Meteorological Data secured in connection with the evaporation station established by the Dominion Water Power Branch at Keewatin on the Lake of the Woods—Continued.

DECEMBER, 1913.

Day.	Temperature in Degrees Fahrenheit.				Velocity Wind.	Direction Wind.	Barometer.	Evaporation.	Rain.	Humidity.
	Lake.	Tank.	Air.	Mean Day.						
					Miles per hour.		Inches.	Inches.	Inches.	Per cent.
1			32		2·2	S.E.				
			32	32	1·3	N.W.	29·10			95
2			32		1·[illegible]	N.W.				
			32	33	[illegible]·7	W.	29·28			90
3			29		3·9	S.W.				
			35	[illegible]1	3·9	S.W.	29·27			95
4			32		7·4	S.W.				
			41	37	5·0	S.W.	29·09			86
5			28		3·1	N.W.				
			35	34	1·5	N.W.	28·95			85
6			28		4·5	N.W.				
			20	24	17·0	N.W.	28·96			68
7						N.W.				
			12	12	5·3	N.W.	29·11			
8			22		4·1	S.W.				
			27	25	7·1	S.W.	28·95			94
9			29		2·9	S.W.				
			32	29	10·1	N.W.	28·81			89
10			23		6·0	N.W.				
			31	27	2·4	S.	28·92			88
11			27		2·8	S.W.				
			34	31	2·6	W.	28·75			89
12			22		2·5	S.E.				
			29	26	1·0	Calm	28·83			88
13			22		0·7	S.W.				
				26	4·5		28·88			86
14										
				19			29·05			
15			27			S.				
			28	27	4·2	S.E.	28·82			88
16			25		2·1	S.W.				
			35	30	10·0	S.W.	28·71			78
17			27		10·2	N.				
			25	25	7·4	N.	28·89			75
18			14		0·9	N.				
			25	19	4·7	N.E.	28·90			
19			12		3·3	N.				
			12	13	5·8	N.W.	28·81			
20			0		6·4	N.W.				
			12	8			28·73			
21			−1		6·3	N.W.				
			5	5	2·5	N.W.	28·82			
22			9		1·7	S.E.				
			17	12	2·2	S.E.	28·86			
23			18		3·2	S.E.				
			20	16	1·6	S.E.	28·78			
24			10		6·0	N.W.				
			3	5			28·92			
25			−9		3·0	S.E.				
				−2			29·01			
26			13		3·1	S.E.				
			11	10	2·2	E.	28·90			
27			10		1·5	N.E.				
			13	9	1·4	N.W.	28·97			
28			10		1·4	N.W.				
			19	10	7·2	S.	28·85			
29			16		10·0	N.W.				
			17	18	4·4	S.W.	28·82			
30			22		4·0	N.W.				
			17	20	2·9	N.	28·87			
31			9		3·1	S.				
			21	16	5·1	S.	28·75			
Total										
Average				20·2						

Table 51.—Meteorological Data secured in connection with the evaporation station established by the Dominion Water Power Branch at Keewatin on the Lake of the Woods—Continued.

JANUARY, 1914.

Day.	Temperature in Degrees Fahrenheit. Lake.	Tank.	Air.	Mean Day.	Velocity Wind.	Direction Wind.	Barometer.	Evaporation.	Rain.	Humidity.
					Miles per hour.		Inches.	Inches.	Inches.	Per cent.
1					6·3	SW.				
	32		25	24	2·8	S.				
2					1·2	N.				
	32		23	21	2·7	N.				
3					3·3	N.				
	32		13	14	1·0	N.				
4					2·0	SE.				
	32		8	9	3·2	SE.				
5					1·7	S.				
	32		18		14·1	SW.				
6					8·2	W.				
	32		27		6·1	W.				
7					2·3	SE.				
	32		30		4·1	NW.				
8					2·6	[illegible]				
	32		23		3·1				0·42	
9					4·0	N.				
	32		7		3·7	N.			0·27	
10					1·4	SW.				
	32		3		1·8	SW.				
11						W.				
	32		− 8		0·97	W.				
12						SE.				
	32		−13		1·1	SE.				
13					3·9	SE.				
	32		9		7·3	SE.				
14					5·5	S.				
	32		19		8·0	NW.				
15					6·6	E.				
	32		18		4·0	E.				
16					4·1	NW.				
	32		17		-4·5	NW.			0·18	
17					1·6	S.				
	32		18	15	3·9	E.				
18						SE.				
	32		30	22	5·0					
19					1·9	N.				
	32		30	26	5·2	NE.				
20					6·0	NW.				
	32		4	5	4·8	W.				
21					3·7	S.				
	32		− 8	− 7	5·6	SE.				
22					2·0	S.				
	32		− 7	− 4	3·3	SE.				
23					3·5	W.				
	32		4	− 2	9·2	W.			0·105	
24					-5·3	SW.				
	32		−17	−16	3·8	S.				
25					2·0	SE.				
	32		− 9	−10	2·3	S.				
26					2·3	E.				
	32		2	− 3	6·2	N.				
27					3·2	N.				
	32		− 2	− 3	1·1	E.			0·104	
28					3·2	E.				
	32		20	5	8·8	SE.				
29					5·0	W.				
	32		− 9	− 5	20·0	W.				
30					5·9	SE.				
	32		− 9	2	2·4	E.				
31					7·2	W.				
	32		2	− 6	14·7	NW.			0·26	
Total									1·34	
Average	32								0·043	

Table 51.—Meteorological Data secured in connection with the evaporation station established by the Dominion Water Power Branch at Keewatin on the Lake of the Woods—Continued.

FEBRUARY 1914.

Day.	Temperature in Degrees Fahrenheit.				Velocity Wind.	Direction Wind.	Barometer.	Evaporation.	Rain.	Humidity.
	Lake.	Tank.	Air.	Mean Day.						
					Miles per hour.		Inches.	Inches.	Inches.	Per cent.
1			−10							
				5			28·75			
2			−10		1·4	NE.				
			13	10	6·6	N.	28·75		0·11	
3			−1		1·3	NW.				
			4	−1	2·5	N.	28·95			
4			−5		1·6	N.				
			−2	−4	1·7	N.	29·05			
5			−29		0·8	W.				
			−10	−20	7·0	W.	29·10			
6			−32		1·5	SW.				
			−6	−20	1·0	S.	29·00			
7			7		0·9	S.				
			−3	−20	0·5	S.	28·80			
8			−20		5·4	SE.				
			−10	−15	5·5	W.	28·70			
9			−31		6·3	W.				
			−16	−22	7·0	W.	28·75			
10			−36		1·9	N.				
			−16	−23	1·3	NW.	29·15			
11			−40		3·5	W.				
			−14	−20	0·9	S.	29·40			
12			−36		0·1	S.				
			−6	−15	3·3	SE.	29·35			
13			3		5·0	S.				
			2	0	8·2	W.	29·00			
14			−17		6·7	W.				
			4	−5	2·7	W.	29·10			
15										
			1	−8	3·5	S.	28·75			
16			−18		6·4	E.				
			4	−6	0·7	E.	28·80		0·09	
17			−22		1·5	NW.				
			8	−2	1·3	SE.	28·85			
18			−2		4·0	W.				
			1	−4	14·7	NW.	28·85			
19			−26		5·2	SW.				
			−3	−12	1·7	E.	29·00			
20			−20		1·6	S.				
			11	0			28·85			
21			−6		7·4	W.				
			−9	−10	9·0	N.	28·75			
22			−26		3·9	NW.				
			−4	−20	2·7	W.	28·20			
23			−22		1·8	S.				
			8	−6	3·0	SE.	28·25			
24			8		5·0	SW				
			18	11	6·6	S.	28·95			
25			20		3·1	SE				
			31	20	3·0	SE.	28·75			
26			22		3·4	S.				
			36	24	2·9	S.	28·90			
27			31		5·1	S.				
			40	32	14·2	S.	28·45			
28			−1		14·0	W.				
			−1	2			28·70		0·22	
Total									0·32	
Average				−1·6					0·015	

Table 51.—Meteorological Data secured in connection with the evaporation station established by the Dominion Water Power Branch at Keewatin on the Lake of the Woods—Continued.

MARCH, 1914.

Day.	Temperature in Degrees Fahrenheit. Lake.	Tank.	Air.	Mean Day.	Velocity Wind.	Direction Wind.	Barometer.	Evaporation.	Rain.	Humidity.
					Miles per hour.		Inches.	Inches.	Inches.	Per cent.
1	......	......	−20 8	4	11·4	S.	28·72	......	......	......
2	......	......	12 20	21	20·1 6·9	SE. SE.	28·31	......	......	......
3	......	......	22 33	24	3·9 9·2	W. W.	28·42	......	......	......
4	......	......	22 35	21	3·4 5·9	SE. E.	28·04	......	0·09	......
5	......	......	30 34	30	4·0 2·2	NE. NE.	28·21	......	......	......
6	......	......	27 32	28	0·9 4·5	N. NE.	28·51	......	0·26	......
7	......	......	14 30	20	2·3 1·8	N. NE.	28·70	......	......	......
8	......	......	0 26	12	....	....	29·05	......	......	......
9	......	......	0 20	10	1·3 2·2	NE. NE.	28·92	......	......	......
10	......	......	6 25	15	2·8 2·0	NE. NE.	29·27	......	......	......
11	......	......	− 4 25	12	4·8 6·4	SE. SW.	28·65	......	......	......
12	......	......	13 33	24	4·7 5·7	W. NW.	28·52	......	......	......
13	......	......	26 42	32	3·5 3·7	S. S.	28·14	......	......	......
14	......	......	20 40	31	4·1 2·8	NW. S.	28·28	......	......	......
15	......	......	38 40	36	...... 8·5	...... W.	27·82	......	0·01	......
16	......	......	13 20	16	16·3 18·8	NW. NW.	28·26	......	......	......
17	......	......	8 22	10	4·2 19·3	NW. NW.	28·63	......	......	......
18	......	......	2 18	7	3·4 3·6	N. N.	28·80	......	......	......
19	......	......	− 1 18	4	1·7 1·7	E. SE.	28·82	......	......	......
20	......	......	9 27	12	1·7 1·4	SE. NW.	28·70	......	......	 65
21	......	......	0 19	7	5·1 0·9	NW. SW.	28·89	......	......	......
22	......	......	16 20	17	0·1 7·2	N. NW.	28·65	......	......	......
23	......	......	12 32	22	9·0 11·3	W. SW.	28·26	......	......	 79
24	......	......	24 26	23	2·8 4·2	W. N.	28·28	......	......	[illegible]
25	......	......	8 20	13	6·3 6·4	N. N.	28·15	......	......	......
26	......	......	12 17	14	2·6 1·6	S. N.	28·38	......	......	......
27	......	......	12 27	14	3·3 2·7	NE. SE.	28·68	......	......	 76
28	......	......	29 35	30	4·3 2·8	S. N.	28·48	......	......	89 91
29	......	......	30 37	32	...... 2·4	...... SE.	29·15	......	......	......
30	......	......	28 47	32	3·7 2·4	S. S.	28·76	......	......	77 73
31	......	......	32 40	33	3·3 2·4	S. N.	28·34	......	......	79 76
Total	......	......	......	......	......	......	......	......	0·36	......
Average	......	......	......	19·6	......	......	......	......	0·012	......

***Table 51.—Meteorological Data secured in connection with the evaporation station established by the Dominion Water Power Branch at Keewatin on the Lake of the Woods*—Continued.**

APRIL, 1914.

Day.	Temperature, in Degrees Fahrenheit.				Velocity Wind.	Direction Wind.	Barometer.	Evaporation.	Rain.	Humidity.
	Lake.	Tank.	Air.	Mean Day.	Miles per hour.		Inches.	Inches.	Inches.	Per cent.
1			36		1·4	N.				82
2	31		39 28	31	1·9 5·5	NW. N.	28·64		0·23	84 77
3	31		26 20	26	6·9 5·9	N. NW.	28·70		0·08	88
4	34		29 20	22	7·8 6·2	W. NW.	28·85			89
5	34		29 32	22	11·1 5·0	NW. SW.	28·80			35 71
6	34		32 32	24	5·0 3·7	S. W.	28·65			79 90
7	34		28 10	26	1·2 4·9	N. N.	28·57			75
8	34		26 20	14	6·8 1·6	NW. N.	28·95		0·23	75
9	31		34 26	22	4·3 4·2	NW. S.	28·90			81 88
10	35		41 34	21	8·1 5·2	S. NW.	28·40			81 90
11	34		27 20	27	1·3 8·1	S.	27·97			65
12	32		49 45	26	1·1 3·2	W. NW.	28·27			77
13	33		29	20	2·2 2·8	SE.	28·30			89
14	33		50 35	40	2·7 1·8	S. N.	[illegible]			71 82
15	35		49 43	39	2·0 4·5	N. W.	28·58			67 78
16	35		57 42	44	4·4 4·6	NW. W.	28·47			77
17	36		17	43	3·6 2·6	E. N.	28·62			85 89
18	36		49 37	45	2·3 5·6	N. NW.	28·60		0·05	80 94
19	36		30	33	9·1 12·3	N. NE.	28·17		0·29	
20			32 28	24	1·4	S.	28·65		0·87	90
21	34		38 36	32	10·3 1·8	S. NW.	28·35	0·13		83 56
22	35		10 32	34	15·0 3·1	W. S.	28·65	0·06	0·01	81 96
23	35		51 39	34	2·7 4·4	S. S.	28·90	0·01		75 92
24	36		47 45	40	7·0 4·4	SE. SE.	28·70	0·03		86 89
25	36		49 41	42	4·1 1·4	SE. S.	28·60	0·01	0·02	71 85
26	36		49 53	43	2·0 2·0	S. S.	28·37	0·02	0·01	87 75
27			56 36	48	5·1	N.	28·47	0·05		82 73
28	37		36 30	32	6·7 10·0	NE. NE.	28·75	0·01		65 89
29	35		38 36	30	13·2 7·5	N. N.	28·80			83 91
30	35		54 44	37	3·6 4·2	SE. S.	28·95	0·18		48 69
	36		45	35	3·4	S.	28·95	0·01		79
Total								0·54	1·79	
Average	34·7			32·1				0·054	0·060	

Table 51.—Meteorological Data secured in connection with the evaporation station established by the Dominion Water Power Branch at Keewatin on the Lake of the Woods—Continued.

MAY 1914.

Day.	Temperature in Degrees Fahrenheit.				Velocity Wind.	Direction Wind.	Barometer.	Evaporation.	Rain.	Humidity.
	Lake.	Tank.	Air.	Mean Day	Miles per hour.		Inches.	Inches.	Inches.	Per cent.
1	37		43 63	50	4·0 4·4	S. SW.	28·65	0·01 0·02	0·02	88·0 51·0
2	38		54 64	52	4·2 2·6	SW. S.	28·44			76·0 77·0
3	48		51	48	3·0 4·8	SE. SW.	28·35			94·0
4	38		52 67	56	2·1 1·8	NE. NE.	28·40			94·0 67·0
5	38		58 70	54	3·8 5·4	S. S.	28·40			77·0
6	38		43 42	40	3·2 6·5	S. NE.	28·45			92·0 88·0
7	38		46 64	44	3·8 4·3	E. N.	28·70			93·0 57·0
8	40		60	44	2·7 7·0	S. SW.	28·65			63·0
9	40		56	45	3·5 2·8	S. NW.	28·40	0·02		77·0
10	39		48	40	5·1	N.	28·75			79·0
11	39	38	44		2·2 4·0	NE NE.	28·95			78·5
12	38	38	44	48	2·2 7·2	S. W.	29·00			85·0
13	40	40	53 55	44	5·0 5·3	NE. NE.	28·95	0·08 0·01		75·0 49·0
14	42	42	48 66	43	2·6 4·7	N. W.	29·00	0·08 0·01		87·0 62·0
15	42	42	52 55	44	2·2 3·6	S. S.	28·90	0·02 0·00		63·0 52·0
16	42	42	60 72	52	2·8	N.	28·80	0·06 0·00		67·0 45·0
17	43	44	62 63	58	5·4 8·3	S. S.	28·75			60·0 60·0
18	42	42	58 60	56	5·7 6·2	S. W.	28·75		0·04	73·0 76·0
19	46	46	63 58	54	1·8 3·0	S. S.	28·70		0·29 0·25	74·0 72·0
20	48	48	56 72	55	2·4 2·0	S. S.	28·70		0·01	83·0 72·0
21	44	44	50 56	49	1·0 19·8	W. NW.	28·75		0·04	87·0 77·0
22	43	43	46 52	45	1·8 9·5	S. S.	28·80	0·03	0·02	87·0 50·0
23	46	46	50 61	45	4·3 3·5	W. W.	28·72	0·06 0·02		50·0 49·0
24	48	48	59 67	55	3·6 4·8	SE. S.	28·45	0·05		67·0 74·0
25	47	48	64 77	60	4·4 49·1	S. W.	28·20		0·38	89·0 53·0
26	47	48	63 75	60	45·0 32·2	W. W.	28·47	0·02		84·0 63·0
27	48	48	64 74	58	5·0 3·6	S. S.	28·78	0·02		70·0 54·0
28	50	50	63 59	56	2·5 6·8	S. S.	28·60	0·03	0·43	74·0 89·0
29	49 50	50 52	56 64	55	34·2 24·4	W. W.	28·57		0·72	88·0 52·0
30	49 51	49 53	60 73	57	4·8 9·0	S.	28·73	0·05 0·03		58·0 44·0
31				55			28·80			
Total								0·62	1·87	
Average	43·4			50·7				0·031	0·060	

Table 51.—Meteorological Data secured in connection with the evaporation station established by the Dominion Water Power Branch at Keewatin on the Lake of the Woods—Continued.

JUNE 1914

Day.	Temperature in Degrees Fahrenheit.				Velocity Wind.	Direction Wind.	Barometer.	Evaporation.	Rain.	Humidity.
	Lake.	Tank.	Air.	Mean Day.	Miles per hour		Inches.	Inches.	Inches.	Per cent.
1	52 57	52 58	57·5		6·7	S.				
2	53 57	53 58	70·5 61·6	60	2·2 2·7	W. S.	28·80	0·18		91 86
3	53	54	74·0 64·0	60	4·0 4·4	S. S.	28·63	0·04		87 78
4	53	54	65·0 58·0	62	8·0 13·2	S.	28·50	0·05	1·72	90 80
5	52 55	52 56	68·0 54·0	55	14·4 13·3	E. E.	28·65	0·04 0·03		88 67
6	54	54	68·0 56·0	56	14·2 14·3	SE. S.	28·65	0·06 0·06		88 71
7		60	70·0 74·0	60	8·4 6·2	E. SE.	28·45			82 81
8	64 64	62 64	77·0 67·0	70	4·7	SW.	28·42			74 63
9	58	59	79·0 63·0	76	3·6 6·6	SE. W.	28·87		0·42	75 79
10	57 60	57 61	76·0 66·0	64	7·7 10·4	SW.	28·53		4·25 4·12	84 59
11	56	56	72·0 58·0	63	13·0 3·9	W. NW.	28·45	0·04 0·03		90 86
12	57 60	57 60	64·0 61·0	55	7·7 4·7	W. W.	28·70	0·03 0·04	0·02	88 70
13	58 59	58 60	74·0 60·0	55	10·1 4·5	NW. SE.	28·73	0·04 0·05		88 74
14	60 60	60 60	70·0 78·0	58	12·2 27·2	SW. N.	28·90	0·05 0·05		83 48
15	59 64	58 64	66·0 63·0	60	10·6 3·4	N. S.	28·94	0·06 0·02		46 44
16	60 60	60 60	76·0 68·0	60	4·4 5·3	SW SW.	29·00	0·05 0·05		64 82
17	60 66	60	76·0 67·0	60	11·2	SW.	29·13	0·05		85 66
18	58 60	68 58	73·0 48·0	65	7·0 5·0	SW. NE.	28·65	0·03		90 85
19	58	60 57	64·0 54·0	56	14·1 10·9	NE. NE.	28·65	0·05 0·08		86 65
20	61		62·0 61·0	50	4·4	SW.	28·70	0·06		76 64
21	63 66	63 66	79·0 74·0	72	6·8 8·7	W. NE.	28·70	0·05		90 57
22	64 62	64 62	73·0 61·0	62	5·0	S.	28·85	0·08 0·03		61 57
23	63 62	63 62	70·0 70·0	60	5·2 9·3	W. SW.	28·60	0·03	0·09 0·05	89 81
24	62	62	68·4	62	6·9	W.	28·55			86 ..
25	64 61	64 61	69·0 62·0	60	12·3 6·4	NW. N.	28·85	0·12 0·08		85 95
26	63 64	63 60	63·0 62·0	54	4·5 2·4	N. SE.	28·85	0·06		79 55
27	64 61	63 63	74·0 61·0	56	10·3 12·8	SE. E.	28·76	0·06 0·26		74 43
28	62 64	62 64	66·0 68·0	62	14·2 3·3	E. S.	28·65	0·03 0·09		89 64
29	63 63	63 62	66·0 67·0	58	1·7	S.	28·76	0·09 0·03		62 64
30	63	63	71·0 65·0	60	3·7 2·7	NW. SW.	28·85	0·05 0·09		71 64
				58	1·7	S.	28·75	0·03		
Total								2·46	4·67	
Average	59·9	59·9		60·3				0·061	0·456	

Table 51.—Meteorological Data secured in connection with the evaporation station established by the Dominion Water Power Branch at Keewatin on the Lake of the Woods—Continued.

JULY 1914.

Day.	Temperature in Degrees Fahrenheit.				Velocity Wind.	Direction Wind.	Barometer.	Evaporation.	Rain.	Humidity.
	Lake.	Tank.	Air.	Mean Day.	Miles per hour.		Inches.	Inches.	Inches.	Per cent.
1						N.				
	65	65	75	65	2·3	NW.	28·53	0·16	0·02	78
2	61	61	68		5·5	SW.				81
	66	65	75	64	5·8	SW.	28·55	0·05		70
3	64	54	69		5·0	SW.		0·02		85
	68	70	73	68	2·9	W.	28·45	0·06	0·07	73
4	66	66	72		1·2	S.				77
	73	74	78	62	2·9	S.	28·59	0·00	0·01	60
5	68	68	74		2·8	S.		0·04		78
	73	70	78	70	6·1	S.	28·52	0·04		75
6	70	70	72		7·3	W.		0·00	0·01	86
	67	67	67	65	12·7	W.	28·35	0·02		75
7	66	66	61		11·5	N.				70
				68	5·1	N.	28·75			
8	68	68	66		2·8	S.		0·18		73
	69	69	71	64	6·3	SE.	28·59			
9	69	69	71		5·2	SE.			0·43	86
				76	5·7	SE.	28·53	0·00		
10	69	69	70		4·8	SW.		0·02	0·01	83
	69	70	73	68	1·0	SW.	28·53	0·06	0·03	81
11					6·8	SE.		0·02		95
				65	8·0	E.	28·48			
12	70	70	69		1·7	N.				
				66			28·41		1·05	95
13	70	71	74		10·6	N.		0·04	0·01	86
	73	74	80		7·5	SW.	28·52	0·05		79
14	73	73	77		4·7	SW.		0·03		87
	75	76	79	70	21·0	S.	28·43			
15	72	72	71		22·9	SW.		0·10	0·46	100
	73	73	70	71			28·60	0·05		95
16	69	69	61		8·7	W.		0·00		94
	70	70	66	58	11·8	W.	28·83	0·07	0·07	90
17	68	68	49		11·5	N.		0·01	0·19	100
	70	70	66	55	9·6	SW.	28·15	0·13	0·01	80
18	68	68	63		3·5	SW.		0·09	0·00	79
	70	71	70	63	7·0	SW.	28·57	0·05	0·01	72
19	70	70	65		4·7			0·05		90
	70	71	70	64	1·9		28·69	0·08		90
20	68	69	72		4·7	E.		0·01		75
	76	77	84	73	1·9		28·60	0·02		84
21	71	71	75		3·9	S.		0·05		74
	73	73	77	76	8·6	W.	28·66			79
22	69	69	65		5·2	W.		0·08	1·00	80
	71	71	73	66			28·47	0·03		65
23	69	69	65		3·8	SW.		0·03		85
	68			67	4·6	SW.	28·50			85
24	70	70	69		2·3	SW.		0·09		81
	73	73	74	71	10·7	SW.	28·52	0·06	0·02	74
25	74	74	78		13·9	SW.		0·01	0·02	87
	73	73	79	72	14·6	SW.	28·44			68
26	75	76	82			S.		0·12	0·12	76
	74	74	82	77	7·5	S.	28·60	0·01		80
27	73	73	74		6·3	S.		0·03	0·01	86
	76	76	83	75	9·5	S.	28·58	0·09		49
28	74	74	72		7·7	SW.		0·09		82
	73	73	77	73		SW.	28·72	0·02		74
29	73	73	65		6·4	S.		0·10		85
	73	74	72	71	4·6	S.	28·68	0·04		86
30	72	72	68		3·2	SW.		0·06	0·22	95
	75	75	77	72	1·5	SW.	28·56	0·04		96
31	71	71	62		6·0	W.		0·04		94
	75	75	75	72	4·6	W.	28·65			100
Total								2·46	3·80	
Average	70·6	70·8		68·2				0·052	0·123	

Table 51.—Meteorological Data secured in connection with the evaporation station established by the Dominion Water Power Branch at Keewatin on the Lake of the Woods—Continued.

AUGUST 1914

Day.	Temperature in Degrees Fahrenheit. Lake	Tank	Air	Mean Day	Velocity Wind	Direction Wind	Barometer.	Evaporation	Rain.	Humidity.
					Miles per hour		Inches.	Inches.	Inches.	Per cent.
1	73	73	71					0.03		
2	75 76	75 76	76 76		0.8 4.1	W. NE.	28.45	0.01 0.06		60 70
3	73 72	73 72	70 66		3.3	W.	28.64	0.15		48 68
4	75	75	82		10.3 1.9	NW. SE.	28.17	0.02	0.65	90 61
5	77 72	77 72	83 67		4.5 9.3	SW. NW.	28.50	0.04 0.01		80
6	72 71	72 71	72 62		12.0 6.1	NW. NW.	28.29	0.18 0.16		95 77
7	72 69	72 69	68 62		1.2 1.3	W. SE.	28.48	0.12 0.12		84 58
8	71 71	73 71	78 68		6.1	SE.	28.43	0.16 0.08		74 60
9	71 70	71 70	70 66		5.8 2.8	[illegible] W.	28.15	0.06		81 71
10	71 71	71 70	66 62		1.0	N.	28.30	0.12 0.08		66 90
11	71 68	71 68	64 61		5.3	NW.	28.51	0.12 0.05		71 74
12	70 70	70 70	67 65		3.1 3.1	W. SW.	28.68	0.06 0.08		79 75
13	69 68	69 68	62 62		6.9 4.5	S. W.	28.57	0.06 0.02		75 79
14	68 68	68 68	62 60		11.3 9.7	NW. N.	28.51	0.09 0.09		59 50
15	69 67	69 67	66 62		6.2 1.8	NW. N.	28.52	0.06 0.02		84 71
16	68 73	68 71	62 82		5.1 1.1	E. S.	28.41	0.05 0.09	0.01 0.23	89 69
17	68	68	65		4.3	N.	28.28	0.07		48
18	69 69	70 69	79 62		3.8 1.8	N. N.	28.46	0.06 0.05	0.16	80 85
19	72 69	72 68	75 62		1.2 2.3	N. N.	28.61	0.05 0.02		89 58
20	72 68	72 68	72 66		2.3 0.7	S. W.	28.61	0.02 0.03		89 65
21	70	70	69		5.4 2.9	NW. N.	28.61	0.05		80 43
22	68	68	65		2.1 2.7	N. SE.	......	0.12		
23	68 68	68 68	60 58		9.6	N.	28.55	0.07	0.25	85 89
24	66 66	66 61	55 50		5.7	E.	28.63	0.04 0.15	0.15	83 [illegible]
25	68 64	68 61	56 52		4.3 6.5	NE. E.	28.76	0.03 0.12		74 77
26	64 65	61 65	52 54		9.5 5.2	NE. NE.	28.84	0.03 0.08	0.21	75 88
27	64 61	64 64	59 51		4.0 0.2	N. E.	28.72	0.03 0.03	0.14	76 89
28	54 61	64 64	62 59		1.2 3.9	S. S.	28.77	0.06 0.09		88 79
29	64 64	64 64	61 58	......	6.8 6.5	S. W.	28.54			89 79
30	66 64	66 64	65 59	......	3.5 1.5	S.	28.28	0.04 0.03	0.47 0.07	89 90
31	66 64 66	66 64 66	64 62 72	......	5.1 5.5	S. W.	28.43 28.60	0.09 0.03 0.03	0.03 0.30	89 90 89 82
Total.....	......	......	......	......	......			3.57	2.07	......
Average......	68.9	68.8	......	......	......	......	......	0.069	0.067	......

Table 51.—Meteorological Data secured in connection with the evaporation station established by the Dominion Water Power Branch at Keewatin on the Lake of the Woods.—Continued

SEPTEMBER 1914

Day.	Temperature in Degrees Fahrenheit: Lake.	Tank.	Air.	Mean Dew	Velocity Wind.	Direction Wind.	Barometer.	Evaporation.	Rain.	Humidity.
					Miles per hour		Inches	Inches	Inches	Per cent.
1	64	[illegible]	56		4 8	W		0 06		88
	62	[illegible]	58		4 9	W	28 32	0 09		89
2	62	[illegible]	52		8 4	W		0 03		88
	63	63	54		9 0	W	28 34	0 05	0 10	88
3	60	60	48		14 1	NW				87
	63	63	64		12·6	NW	28 49	1 05		70
4	63	63	52		4 4	W		0 1?		88
	64	64	64		3 5	SE.	28 52	0 06		75
5	[illegible]	62	56		2 8	E.		0 02		77
	[illegible]	60	55		9 4	E	28·34	0 05	0 14	82
6					3 6	NE				
	60	59	[illegible]				28 50	0 14	0 17	74
7					7 8	E.				
							28 05			
8		59	53		3 2	E.		0·16		[illegible]
	60				2 6	E	28 90			
9	60	60	57		7 6	S		0 06		83
	[illegible]	58	55		12 0	S	28 75		0 06	94
10	59	59	57		5 0	SW			0 53	83
	62	62	65		3 6	S	28 [illegible]	0 [illegible]		78
11					2 1	S				
	65	66	67		2·5	S	28 54	0 08		76
12	62	62	63		6 6	S		0 02		84
							28 71			
13					16·7	S.				
							28 60			
14					10 2	W			0 87	...
					13 8	S	28 5?			
15	60	60	56		4 9	S.				82
	62	62	59		8·5	S	28 [illegible]			68
16	60	60	59		14·5	W			0·92	81
	60	60	60		11·2	W	28 [illegible]			65
17	59	59	52		1 5	S				88
	63	63	66		8 0	S	28 83	0 0?		58
18	59	59	59		9 7	S		0 0?	0 05	89
	61	61	64		9 7	SE	28 63			90
19					7 4	S				
					9 2	SW.	28 75		1 11	
20.					3 9	NW				
							28 62		0 12	
21					4 8	W		0·05		
	60	60	51		9 7	N	28·41	0 04		87
22	58	58	41		14 9	NW		0 ?4		79
	59	59	46		14 4	NW	28 44			89
23	59	59	51		3·4	W		0 07		84
	60	60	56		1 7	E	28 48	0 06		69
24	56	56	41		8·4	N		0 06		82
	57	57	59		8 4	N.	28 54	0 01		[illegible]
25.	56	56	53		2·4	S		0 05		[illegible]
	59	59	61		5 5	S	28 [illegible]	0 06		74
26	58	58	55		4·[illegible]	S.		0 12		91
	60	60	63		3 0	NE.	28 61			70
27.	[illegible]	62	62		10 5	SE.				[illegible]
							28 67	0 09		
28					13 2	S				
	58	58	55		4·5	S	28 52	0 10		[illegible]
29	58	58	54		5·0	NW.		0 02		94
	58	58	55		3·4	NW.	28 67	0 08		82
30	57	57	56		4·4	S				79
	60	60	65		4 8	S.	28 64			64
Total.								3·01	4·07	
Average	60·3	60·2						0·097	0·136	

***Table 51.—Meteorological Data secured in connection with the evaporation station established by the Dominion Water Power Branch at Keewatin on the Lake of the Woods*—Continued.**

OCTOBER 1914

Day	Temperature, in Degrees Fahrenheit: Lake.	Tank	Air.	Mean Day	Velocity Wind.	Direction Wind.	Barometer.	Evaporation.	Rain.	Humidity.
					Miles per hour		Inches.	Inches.	Inches.	Per cent.
1	57 58	57 58	58 70		5·0 8·[illegible]	SE SE.		0·08		83
2	60 61	60 61	64 68	...	6·3	S.	28·47	0·06 0·06		70 77
3	59 58	59 58	64 65	65	7·[illegible] 10·7	SE S	[illegible]·32	0·00 0·08		74 75
4	60 62	60 62	61 69	66	10·1	SE.	28·25	0·06 0·00		75 79
5	60 59	62 58	64 58	65	4·6 [illegible]	SE S	28·[illegible]	0·02 0·00		72 85
6	58	58	51	58	0·[illegible]	E.	28·50	0·08 [illegible]	0·32 0·03	83 94
7	58	58	44	55	2·1 2·0	S NE	28·67	0·06		71
8	57	57	48	54	4·3	E.	28·55	0·08	....	..
9	58	58	57	52	[illegible]·0	W	28·37	[illegible]	0·07	94
10	56 58	56 58	50 48	53	5·1 8·4	SW SW	[illegible]8·37	0·01	0·55	87
11	56 56	56 56	42 42		4·8	NW.	28·30	0·28 0·05	1·64 0·11	87 85
12	54 54	54 54	36 38	[illegible]	9·8 6·3	NE NE	28·48	0·02 0·02	0·16	92 91
13	54 56	54 56	40 48	40	1·7 1·4	NE NW.	28·86	0·30 0·04		91 76
14	51 54	54 54	44 52	49	5·5 [illegible]	W. [illegible]	29·20	0·02 0·10		87 85
15	54 56	54 56	46 56	47	6·1 5·5	[illegible] [illegible]	28·70	0·01 0·06		88 93
16	54 56	54 56	52 62	53	5·6 7·4	SW SW	28·54	0·02 0·04		77 88
17	54 56	54 56	44 58	54	2·0 3·7	NE E.	28·32	0·04 0·04		89 93
18	56	56	56	54	11·5	SE.	28·[illegible]	0·04		89 82
19	51 56	51 56	54 58	57	10·2 5·1	SW. SW.	28·18	0·02		88
20	54 56	54 56	54 62	56	2·4 9·2	SW. SW	28·16	0·02 0·04		77 88
21	56 56	56 56	46 58	58	3·8 2·1	N. E.	28·41	0·02 0·02		84 86
22	54 56	54 56	54 60	52	8·4 9·6	SE. SE.	28·73	0·02 0·04		83 88
23	54 54	54 54	42 48	55	11·6 14·1	N. NW.	28·65	0·02 0·08	0·20	89 92
24	52 52	52 52	42 50	49	4·8 13·5	SW. W.	[illegible]·73	0·04 [illegible]·03	0·01	[illegible] 92
25	52 50	52 50	42 38	46	10·6	NW.	28·71	0·06 0·04	0·02	87 92
26	46 46	46 46	20 30	40	15·1 11·1	NW. NW	28·53	0·02 0·08		83 85
27	48 48	48 48	34 41	24	8·1 12·9	W. W.	28·83	0·06 0·14		[illegible] [illegible]
28	48 48	48 48	38 42	35	7·0 6·7	N NW.	28·43	0·06 0·04		85 83
29	48 48	48 48	38 48	40	8·6 11·2	W. NW.	28·34	0·04 0·06		85 91
30	48 48	48 48	42 54	43	1·8 5·2	S. S.	28·49	0·04 0·04		97 92
31	48 50	48 50	46 52	45 53	3·5 4·8	S. S.	[illegible]	0·04		82 93
Total	...	......	....	......	......	....				
Average	54·[illegible]	54·3		49·8	.....	....				

Table 51.—Meteorological Data secured in connection with the evaporation station established by the Dominion Water Power Branch at Keewatin on the Lake of the Woods—Continued.

NOVEMBER, 1914.

Day.	Temperature in Degrees Fahrenheit.				Velocity Wind.	Direction Wind.	Barometer.	Evaporation.	Rain.	Humidity.
	Lake.	Tank.	Air.	Mean Day.						
					Miles per hour.		Inches.	Inches.	Inches.	Per cent.
1	48	48	40		8·0	N.		0·01	0·01	84
	48	48	40	43			28·36	0·01		76
2	47	48	40		9·2	SE.		0·08		88
	46	46	40	41	14·5	SE.	28·37	0·04		89
3	47	47	44		7·3	W.		0·04		85
	48	48	45	44	10·3	W.	28·05	0·05	0·02	79
4	46	46	35		12·4	NW.		0·03	0·49	91
	47	46	36	36	16·7	NW.	28·51	0·03	0·03	91
5					8·5	N.				
	46	46	32	31	2·9	NW.	28·58	0·14		74
6					4·5	E.				
	46	44	33	35			28·39	0·01		52
7					12·8	NW.				
	45	44	32	31	4·6	W.	28·53	0·10		79
8	44	44	38		11·6	W.		0·06	0·0[illegible]	71
	41	44	35	35		SW.	28·55	0·03	0·02	95
9	43	42	33		5·0	SE.		0·02		95
				37		SE.	28·25			
10	43	42	34		10·4	W.		0·06		90
	44	44	41	38	10·5	W.	28·31	0·02		62
11	42	44	22		11·2	NW.		0·05		93
	41	40	28	27	7·3	NW.	28·62			41
12	36	32	15		6·9	E.				
	38	37	25	22	5·8	E.	28·60	0·48		50
13	38	36	27		3·9	W.				82
	36	34	26	26	4·3	W.	28·18	0·02		82
14	34	33	22		10·4	E.				79
				24			28·25			
15										
				25	8·6	NW.	28·36		0·01	
16	32		12		15·3	NW.				
	32		9	16	14·4	NW.	28·59			
17					9·9	W.				
	34		4	2	9·9	NW.	28·68			
18			8		8·9	N.				
	33		1	5	16·2	NW.	28·71		0·01	
19			10		9·3	W.				
	33		12	8	2·9	S.	28·15			
20			20		8·3	S.				
	33		21	22	3·9	W.	28·26			94
21			23		9·4	NW.				
	34			19	16·2	NW.	28·51			85
22			8		8·4					
	33		13	12	2·1		28·75			
23			22		5·7	S.				
			31	26			28·49			100
24			23		6·2	SW.				59
	34			32	6·6	SW.	28·49			
25			30		9·1	SW.				95
	34		39·5	35	2·2	S.	28·17			92
26			36·0		9·4	NW.				
	33		19·0	30	15·9	N.	28·32			100
27			9·5		4·6	S.				
	33		23·0	17	5·1	S.	28·69			100
28			27·0		6·9	S.				
	33		39·5	35	8·9	S.	28·35			88
29			41·0							80
	31		37·5	38			28·32			81
30			26·0		5·0	N.				91
	34		33·0	37	6·1	N.	28·48			76
Total									0·31	
Average	39·3			27·7					0·010	

Table 51.—Meteorological Data secured in connection with the evaporation station established by the Dominion Water Power Branch at Keewatin on the Lake of the Woods—Concluded.

DECEMBER, 1914.

Day.	Temperature in Degrees Fahrenheit. Lake.	Tank.	Air.	Mean Day.	Velocity Wind.	Direction Wind.	Barometer.	Evaporation.	Rain.	Humidity.
					Miles per hour.		Inches.	Inches.	Inches.	Per cent.
1	33		33 23	29.0	7.2 5.9	E. W.	28.13		0.10	95 73
2			18 49	20.0	7.4	NW.	28.70		0.10	92 77
3	31		22	26.0	6.2	S.	28.78			
4	32		28	27.0	6.5 4.7	S. S.	28.76			100
5			28 22	28.0	13.9 4.4	S. S.	28.84			100
6			29 23	28.0			28.89			94 87
7	33		20	27.0			29.03			
8			46 4	17.0	11.1 4.9	N. N.	29.12			
9			8 1	6.0	6.1 1.1	N. S.	29.15			
10	32		15 13	9.5	1.9 1.8	SW. W	28.88			
11	32		15 3	10.0	3.0	S. W.	28.58			
12	32		10 −12	7.0	1.0	W	28.12			
13			−11 −20	−3.0	1.1 2.1	N.	28.59			
14			−12 −19	−12.0	21.9	W.	28.61			
15			−8 −2	−12.0			28.86			
16			0 2	−1.0			28.71			
17			13 12	6.0			28.33			
18			13 13	13.0			28.21			
19			9 10	10.0			28.48			
20			11 −2	7.0			28.11		0.20	
21			22 −1	11.0			28.29			
22			−22 −19	−18.0			28.18			
23				15.0			28.55			
24			−28	−28.0			28.70			
25			−21 −7	−11.0			28.75			
26			−8 3	−4.0			28.12			
27			−7	3.0			28.68			
28			9 −9	3.0			28.28			
29			−7 20	−6.0			28.67			
30				−14.0			28.32			
31			7 13	8.0			28.30			
Total									0.40	
Average				4.33					0.013	

REPORT

ON

THE WINNIPEG RIVER POWER AND STORAGE INVESTIGATIONS

APPENDIX VII.

RUN-OFF TABLES

APPENDIX VII.

RUN-OFF OF THE WINNIPEG RIVER WATERSHED.

TABLES 52 TO 69.

Data in tables 52 to 69 have been obtained by the field officers of the Dominion Water Power Branch, with the exception of the Fort Frances records, which have been supplied through the courtesy of the Dominion Department of Public Works, and of the Water Resources Branch of the United States Geological Survey.

WINNIPEG RIVER AT POINT DU BOIS.

Location of Gauge.—At the bay in tail-race of the city of Winnipeg's power plant on the Winnipeg river at Point du Bois.

Records available.—January 23, 1907, to December 31, 1914.

Drainage areas.—To Slave falls, 49,700 square miles. To Otter falls, 50,550 square miles.

Gauge.—Vertical staff, rock bolted to granite ledge, datum unchanged since established.

Discharge Measurements.—From 1907 to 1910, discharge measurements were made at Otter falls by Pratt & Ross for the Winnipeg Electric Street Railway Company; and by the engineers of the city of Winnipeg at the Barrier. In both cases the measurements have been referred to the gauge at Point du Bois, Otter falls and the Barrier being respectively 20 and 12 miles below same. Daily discharges based on Point du Bois gauge have been computed for Otter falls from the above measurements.

In October, 1911, a gauging station was established by the Manitoba Hydrographic Survey above Slave falls, which is some 6 miles below Point du Bois. At this station, a staff gauge and cable equipment were installed, and continuous discharge measurements have been made.

During the season of 1912, when a detailed survey of Slave falls was made by the Manitoba Hydrographic Survey, continuous gauge readings were recorded at Point du Bois and Slave falls. These were checked by a gauge installed midway between Slave and Eight Foot falls, the latter falls being the only break in the river between Slave falls and Point du Bois. By these records, comparison was made with the discharges obtained by using the gauge heights at Point du Bois, and it was found that for a period of a month the results were the same.

Regulation.—From October, 1911, the operation of the power plant at Point du Bois has caused a daily fluctuation in gauge height, but, as noted above, these fluctuations have in the past compensated in a month or less. Continuous gauge readings in 1913 have shown that a single discharge from daily gauge readings may vary one or two per cent from the mean of the days continuous readings. An automatic gauge is now being installed at the meter section at Slave falls in order to eliminate errors from this variation.

In the winter of 1910-11, a cut was made through Eight Foot falls, to reduce tail-race level at Point du Bois during high discharge. On account of this, the discharge curve for Otter falls is not applicable later than June, 1911.

Winter Flow.—The bay on which the gauge is located is open throughout the winter, and is controlled by Eight Foot falls, 1 mile below; the metering station also has an open discharge. Because of this the open-water rating curve has been used in computing the winter flow, though it may give discharges 5 to 10 per cent high during January and February of previous years.

Table 52.—Discharge Measurements of Winnipeg River at Otter and Slave Falls, Manitoba.

Date.	Hydrographer.	Meter No.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
			Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec. ft.
1906							
Mar. 7	Col. Ruttan					160·5	19,876[1]
Sept. 15	J. B. Challies						25,433[2]
1907							
Aug. 1	Pratt and Ross for Winnipeg Street Railway					162·2	31,047[3]
Aug. 2	" "					162·2	30,600[4]
Oct. 31	" "					164·2	41,300[5]
1908							
July 14	Pratt and Ross for Street Railway Co					164·2	43,000[5]
Nov. 7	" "					162·0	28,700[5]
1909							
May 24	Pratt and Ross for Winnipeg Street Railway					161·0	26,360[5]
July 17	" "					161·25	26,000[5]
Oct. 8	" "					160·70	22,500[5]
Nov. 8						160·55	21,770[5]
1910							
July 28	Pratt and Ross for Street Railway Co					162·25	29,375[5]
1911							
Feb. 4, 6, 7.	Stamford for City of Winnipeg		280·5	5,475	2·26	159·26	12,375[6]
Feb. 13, 14, 15.	"			5,691	2·28	159·26	13,256[6]
May 7	Pratt and Ross for Street Railway					159·42	13,450[7]
May 19	" "					159·87	15,800[7]
Oct. 13, 14.	A. M. Beale for Water Power Survey	3	269	7,272	3·59	161·80	26,115[8]
Oct. 29	" "	1	269	7,218	3·68	161·70	26,391[8]
Dec. 6, 7 8, 9.	A. M. Beale and Alex Pirie	1	610	21,910	1·10	160·68	24,145[9]
Dec. 6, 7, 8, 9.	"	1	610	21,910	1·11	160·68	24,320[10]

[1]Just above falls at Point du Bois. One foot ice cover. Gauge height approximated.
[2]Float measurement.
[3]Below diversion dam and Pinawa channel. Two channels measured.
[4]Barrier chute.
[5]Otter Falls.
[6]At city meter station 10 miles below Pointe du Bois, Man., section, ice cover; check measurements.
[7]Otter Falls, ice measurement.
[8]Slave Falls.
[9]One and a half miles above Grand du Bonnet Falls. 0·2 and 0·8 method under ice.
[10]One and a half miles above Grand du Bonnet Falls. Vert. vel. curve method under ice.

NOTE.—All measurements for years 1912-13-14 are at Slave Falls.

Table 52.—Discharge Measurements of Winnipeg River at Otter and Slave Falls, Manitoba—Continued.

Date.	Hydrographer.	Meter No.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
			Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec. ft.
1912.							
May 8	A. M. Beale	1,197	260	6,761	2·91	160·52	19,675
May 14	G. H. Burnham	1,197	264	7,014	3·26	161·20	22,865
May 28	A. M. Beale	1,197	273	7,366	3·65	161·88	26,887
June 4	E. B. Patterson	1,196	261	7,542	3·85	162·15	28,036
June 6	G. H. Burnham	1,187	277	7,565	3·95	162·50	29,882
June 10	E. B. Patterson	1,197	277	7,536	3·92	162·25	29,543
June 17	W. H. Richardson	1,197	273	7,139	3·80	162·09	28,207
June 24	"	1,197	272	7,396	3·67	161·90	27,111
July 6	"	1,197	272	7,238	3·56	161·75	25,780
July 8	"	1,197	271	7,237	3·55	161·78	25,692
July 14	"	1,197	274	7,446	3·54	161·76	26,358
July 15	"	1,197	271	7,446	3·58	161·77	26,656
July 16	"	1,197	272	7,473	3·60	161·79	26,901
July 17	"	1,197	271	7,473	3·54	161·80	26,453
July 18	"	1,197	271	7,416	3·52	161·78	26,209
July 19	"	1,197	274	7,473	3·55	161·75	26,528
July 20	"	1,197	274	7,473	3·55	161·76	26,528
Aug. 20	Alex Pirie	1,197	272	7,369	3·74	161·98	27,560
Oct. 23	"	1,197	293	7,934	4·36	163·28	34,628
Nov. 21	"	1,162	291	7,785	3·95	162·85	30,761
Dec. 31	"	1,162	274	7,430	3·64	162·40	27,095
1913.							
Mar. 5	A. Pirie	1,169	268	6,717	2·85	160·65	19,110
May 1	"	1,186	266	6,943	3·30	160·89	22,912
June 24	S. C. O'Grady	285	281	7,850	4·16	162·96	34,098
July 18	A. Hannington	285	277	7,522	4·03	162·11	30,290
Oct. 1	C. O. Allen	1,135	264	7,268	2·96	161·03	21,513
Nov. 5	"	1,135	256	6,535	2·54	159·92	16,600
1914.							
Jan. 13	E. B. Patterson	1,197	255	6,119	2·17	159·4	13,268
Feb. 11	C. O. Allen	1,197	254	5,954	2·00	159·53	11,922[1]
April 8	"	1,197	255	6,169	2·36	159·60	14,584
May 6	G. J. Lamb	1,375	257	6,517	2·59	159·85	16,876
May 18	"	1,375	260	6,681	2·81	160·15	18,774
May 24	"	1,375	262	6,781	2·95	160·60	20,004
June 4	A. Pirie	1,939	274	7,481	3·85	162·12	28,829
June 5	"	1,939	274	7,480	3·85	162·12	28,839
June 9	"	1,939	280	7,775	4·18	162·62	32,500
June 10	"	1,939	280	7,775	4·24	162·72	32,938
June 11	"	1,939	280	7,788	4·27	162·77	33,306
June 13	"	1,939	281	7,820	4·29	162·82	33,615
June 15	"	1,939	281	7,820	4·30	162·95	33,638
June 22	"	1,939	290	7,917	4·38	163·10	34,713
June 23	"	1,939	282	7,877	4·32	163·12	34,310
June 24	"	1,939	284	7,896	4·36	163·12	34,428
June 26	"	1,939	293	7,951	4·45	163·12	35,394
June 29	"	1,939	293	7,964	4·45	163·27	35,459
June 30	"	1,939	294	7,994	4·46	163·32	35,683
July 3	"	1,939	294	8,023	4·52	163·35	36,366
July 7	"	1,939	293	7,965	4·49	163·32	35,672
July 13	"	1,939	295	8,063	4·53	163·38	36,561
July 14	"	1,939	295	8,063	4·55	163·40	36,759
July 15	"	1,939	295	[illegible]	4·55	163·36	36,690
July 18	"	1,939	295	[illegible]	4·50	163·35	36,310
July 20	"	1,939	294	[illegible]	4·50	163·35	36,173
July 22	"	1,939	294	[illegible]	4·55	163·10	36,605
July 23	"	1,939	291	[illegible]	4·57	163·32	36,381
July 24	"	1,939	294	[illegible]	4·55	163·30	36,592
July 25	"	1,939	293	8,0..	4·23	163·36	33,855
July 28	"	1,939	293	8,001	4·44	163·28	35,529
July 29	"	1,939	293	7,989	4·52	163·30	36,116
July 30	"	1,939	292	7,960	4·45	163·28	35,429
July 31	"	1,939	292	7,932	4·41	163·15	34,957
Aug. 1	"	1,939	292	7,932	4·38	163·11	34,744
Aug. 3	"	1,939	292	7,932	4·34	163·08	34,468
Aug. 4	"	1,939	294	7,896	4·32	163·14	34,115
Aug. 5	"	1,939	284	7,834	4·30	163·06	33,689
Aug. 6	"	1,939	281	7,834	4·27	163·00	33,416
Sept. 10	"	1,939	272	7,322	3·58	[illegible]	26,282
Sept. 11	"	1,939	271	7,292	3·55	161·67	25,942
Sept. 14	"	1,939	271	7,292	3·57	161·70	26,049
Sept. 15	"	1,939	271	7,292	3·54	161·62	25,834

[1]Partial ice cover.

Table 52.—Discharge Measurements of Winnipeg River at Otter and Slave Falls, Manitoba—Concluded.

Date.	Hydrographer.	Meter No.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
			Feet.	Sq.-ft.	Ft. per sec.	Feet.	Sec. ft.
1911.							
Sept. 16	"	1,939	269	7,260	3·38	161·62	24,608
Sept. 17	"	1,939	269	7,234	3·51	161·65	25,416
Sept. 18	"	1,939	269	7,234	3·47	161·57	25,105
Sept. 19	"	1,939	269	7,208	3·45	161·52	24,938
Sept. 22	"	1,939	269	7,234	3·49	161·67	25,223
Sept. 23	"	1,939	269	7,260	3·53	161·67	25,597
Sept. 24	"	1,939	269	7,234	3·51	161·65	25,376
Sept. 25	"	1,939	269	7,231	3·50	161·62	25,301
Sept. 28	"	1,939	269	7,260	3·50	161·62	25,388
Sept. 29	"	1,939	269	7,234	3·44	161·66	24,911
Sept. 30	"	1,939	269	7,234	3·46	161·57	25,048
Oct. 1	"	1,939	269	7,207	3·44	161·60	24,801
Oct. 2	"	1,939	269	7,207	3·43	161·50	24,705
Oct. 7	"	1,939	269	7,207	3·43	161·57	24,639
Oct. 8	"	1,939	269	7,207	3·41	161·55	24,574
Oct. 26	"	1,760	265	7,088	3·32	161·32	23,533
Oct. 28	"	1,760	264	7,061	3·24	161·12	22,877
Oct. 29	"	1,760	263	7,031	3·21	161·07	22,570
Oct. 30	"	1,760	263	7,031	3·21	161·12	22,570
Oct. 31	"	1,760	262	7,001	3·19	161·07	22,333
Nov. 2	"	1,760	262	7,001	3·21	161·12	22,472
Nov. 3	"	1,760	261	6,974	3·15	160·95	21,967
Nov. 5	"	1,760	261	6,948	3·14	160·92	21,817
Nov. 6	"	1,760	261	6,948	3·14	160·87	21,817
Nov. 7	"	1,760	261	6,921	3·05	160·85	21,109
Nov. 9	"	1,760	261	6,974	3·20	161·05	22,317
Nov. 10	"	1,760	260	6,893	3·03	160·80	20,886
Nov. 11	"	1,760	260	6,893	3·02	160·77	20,817
Nov. 13	"	1,760	259	6,892	3·01	160·95	20,745
Nov. 19	"	1,760	259	6,865	2·98	160·77	20,458
Nov. 20	"	1,760	259	6,865	2·98	160·77	20,458
Nov. 21	"	1,760	258	6,813	2·98	160·72	20,303
Nov. 23	"	1,760	259	6,865	3·01	160·77	20,664
Nov. 24	"	1,760	259	6,839	2·96	160·80	20,243
Nov. 25	"	1,760	259	6,839	2·98	160·77	20,380
Nov. 27	"	1,760	258	6,813	2·97	160·72	20,235
Nov. 28	"	1,760	258	6,813	2·96	160·70	20,166
Nov. 30	"	1,760	259	6,839	2·98	160·75	20,380
Dec. 2	"	1,760	259	6,839	2·98	160·77	20,380
Dec. 4	"	1,760	259	6,813	2·97	160·80	20,235
Dec. 5	"	1,760	259	6,813	2·96	160·75	20,166
Dec. 9	"	1,760	258	6,787	2·89	160·65	19,614
Dec. 10	"	1,760	259	6,787	2·89	160·67	19,614

Table 53.—Daily Discharge of the Winnipeg River at Otter Falls in Manitoba.

[Drainage area, 50,550 square miles.]

1907.

Day.	January.		February.		March.		April.		May.		June.	
	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	.....	.....	61·80	27,860	60·4	19,180	60·0	16,700	59·6	14,400	60·8	21,660
2	.....	.....	61·75	27,550	60·4	19,180	59·9	16,100	59·7	14,950	60·8	21,660
3	.....	.....	61·75	27,550	60·3	18,560	59·8	15,500	59·6	14,400	60·8	21,660
4	.....	.....	61·80	27,860	60·2	17,940	59·7	14,950	59·6	14,400	60·8	21,660
5	.....	.....	62·0	29,100	60·3	18,560	59·6	14,400	59·6	14,400	60·9	22,280
6	.....	.....	62·0	29,100	60·4	19,180	59·6	14,400	59·6	14,400	61·0	22,900
7	.....	.....	61·8	27,860	60·3	18,560	59·6	14,400	59·7	14,950	61·2	24,140
8	.....	.....	61·6	26,620	60·1	19,180	59·6	14,400	59·8	15,500	61·2	24,140
9	.....	.....	61·2	24,140	60·2	17,940	59·6	14,400	59·7	14,950	61·2	24,140
10	.....	.....	61·2	24,140	60·1	17,320	59·6	14,400	59·7	14,950	61·2	24,140
11	.....	.....	61·2	24,140	60·0	16,700	59·6	14,400	59·7	14,950	61·4	25,380
12	.....	.....	61·2	24,140	60·2	17,940	59·6	14,400	59·7	14,950	61·6	26,620
13	.....	.....	60·6	20,420	60·2	17,940	59·6	14,400	59·7	14,950	61·8	27,860
14	.....	.....	60·8	21,660	60·2	17,940	59·6	14,400	59·7	14,950	61·8	27,860
15	.....	.....	60·4	19,180	60·3	18,560	59·6	14,400	59·7	14,950	62·0	29,100
16	.....	.....	60·4	19,180	60·1	17,320	59·6	14,400	59·7	14,950	62·0	29,100
17	.....	.....	60·4	19,180	60·1	17,320	59·6	14,400	59·7	14,950	62·0	29,100
18	.....	.....	60·3	18,560	60·1	17,320	59·6	14,400	59·8	15,500	62·2	30,340
19	.....	.....	60·6	20,420	60·1	17,320	59·6	14,400	60·0	16,700	62·2	30,340
20	.....	.....	60·5	19,800	60·1	17,320	59·6	14,400	60·1	17,320	62·2	30,340
21	.....	.....	60·6	20,420	60·0	16,700	59·6	14,400	60·1	17,320	62·3	30,960
22	.....	.....	60·4	19,180	59·9	16,100	59·6	14,400	60·2	17,940	62·4	31,580
23	61·5	26,000	60·4	19,180	59·9	16,100	59·6	14,400	60·2	17,940	62·5	32,200
24	61·5	26,000	60·5	19,800	59·8	15,500	59·6	14,400	60·1	17,320	62·6	32,820
25	61·5	26,000	60·6	20,420	59·8	15,500	59·6	14,400	60·1	17,320	62·6	32,820
26	61·5	26,000	60·8	21,660	59·8	15,500	59·6	14,400	60·2	17,940	62·6	32,820
27	.....	26,700	60·7	21,040	59·8	15,500	59·6	14,400	60·3	18,560	62·6	32,820
28	.....	27,400	60·6	20,420	59·8	15,500	59·6	14,400	60·4	19,180	62·7	33,440
29	61·85	28,170	.....	.....	59·9	16,100	59·6	14,400	60·5	19,800	62·7	33,440
30	61·85	28,170	.....	.....	60·0	16,700	59·6	14,400	60·5	19,800	62·7	33,440
31	61·85	28,170	.....	.....	60·0	16,700	.....	.....	60·6	20,420	.....	.....

Day.	July.		August.		September.		October.		November.		December.	
1	62·7	33,440	62·2	30,340	62·9	34,680	63·6	39,020	64·2	42,740	64·2	42,740
2	62·8	34,060	62·3	30,969	63·0	35,300	63·6	39,020	64·2	42,740	64·2	42,740
3	62·8	34,060	62·2	30,340	63·0	35,300	63·8	40,260	64·2	42,740	64·2	42,740
4	62·7	33,440	62·2	30,340	63·0	35,300	63·8	40,260	64·2	42,740	64·2	42,740
5	62·8	34,060	62·2	30,340	63·0	35,300	64·0	41,500	64·2	42,740	64·1	42,120
6	62·7	33,440	62·2	30,340	63·1	35,920	64·2	42,740	64·2	42,740	64·1	42,120
7	62·8	34,060	62·2	30,340	63·2	36,540	64·2	42,740	64·2	42,740	64·0	41,500
8	62·7	33,440	62·2	30,340	63·2	36,540	64·2	42,740	64·2	42,740	64·0	41,500
9	62·6	32,820	62·2	30,340	63·2	36,540	64·2	42,740	64·2	42,740	64·0	41,500
10	62·5	32,200	62·2	30,340	63·2	36,540	64·2	42,740	64·2	42,740	64·0	41,500
11	62·5	32,200	62·2	30,340	63·2	36,540	64·2	42,740	64·2	42,740	63·8	40,260
12	62·5	32,200	62·2	30,340	63·2	36,540	64·2	42,740	64·2	42,740	63·8	40,260
13	62·4	31,580	62·2	30,340	63·2	36,540	64·3	43,360	64·2	42,740	63·8	40,260
14	62·4	31,580	62·2	30,340	63·3	37,160	64·2	42,740	64·2	42,740	63·7	39,640
15	62·4	31,580	62·2	30,340	63·4	37,780	64·2	42,740	64·2	42,740	63·6	39,020
16	62·4	31,580	62·2	30,340	63·4	37,780	64·2	42,740	64·2	42,740	63·6	39,020
17	62·4	31,580	62·2	30,340	63·4	37,780	64·2	42,740	64·2	42,740	63·6	39,020
18	62·4	31,580	62·2	30,340	63·4	37,780	64·2	42,740	64·2	42,740	63·6	39,020
19	62·4	31,580	62·2	30,340	63·4	37,780	64·2	42,740	64·2	42,740	63·6	39,020
20	62·4	31,580	62·4	31,580	63·4	37,780	64·2	42,740	64·2	42,740	63·5	38,400
21	62·4	31,580	62·6	32,820	63·4	37,780	64·3	43,350	64·2	42,740	63·4	37,780
22	62·4	31,580	62·6	32,820	63·4	37,780	64·4	43,980	64·2	42,740	63·4	37,780
23	62·4	31,580	62·6	32,820	63·4	37,780	64·3	43,360	64·2	42,740	63·4	37,780
24	62·4	31,580	62·6	32,820	63·4	37,780	64·3	43,360	64·2	42,740	63·3	37,160
25	62·4	31,580	62·6	32,820	63·4	37,780	64·3	43,360	64·2	42,740	63·4	37,780
26	62·3	30,960	62·6	32,820	63·4	37,780	64·3	43,360	64·2	42,740	63·4	37,780
27	62·2	30,340	62·6	32,820	63·6	39,020	64·3	43,360	64·2	42,740	63·3	37,160
28	62·2	30,340	62·6	32,820	63·6	39,020	64·3	43,360	64·1	42,120	63·2	36,540
29	62·2	30,340	62·6	32,820	63·6	39,020	64·3	43,360	64·1	42,120	63·2	36,540
30	62·2	30,340	62·7	33,440	63·6	39,020	64·2	42,740	64·1	42,120	63·2	36,540
31	62·2	30,340	62·8	34,060	.....	.....	64·2	42,740	.....	.....	63·2	36,540

Table 53.—Daily Discharge of the Winnipeg River at Otter Falls in Manitoba—Continued.

1908.

Day.	January.		February.		March.		April.		May.		June.	
	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	63·2	36,540	64·8	40,260	62·7	33,440	61·8	27,860	62·0	29,100	64·5	38,100
2	64·2	36,540	63·9	40,880	62·6	32,820	62·0	29,300	62·1	29,720	63·5	38,400
3	63·3	37,160	63·8	40,260	62·6	32,820	61·9	28,480	62·1	29,720	64·5	38,400
4	63·3	37,160	63·6	39,020	62·5	32,200	61·8	27,860	62·1	29,720	63·5	38,400
5	64·2	36,540	64·8	40,260	62·5	42,200	62·0	29,100	62·4	29,720	63·5	38,400
6	63·2	36,540	63·8	40,260	62·5	32,200	62·0	29,100	62·2	30,340	64·5	38,400
7	64·3	37,160	63·8	40,260	62·5	32,200	62·0	29,300	62·1	29,720	63·5	38,400
8	63·2	36,540	64·8	40,260	62·6	32,820	61·9	28,480	62·2	40,340	64·5	38,400
9 ..	64·2	36,540	63·6	39,020	62·7	33,340	61·9	28,480	62·2	30,340	64·6	39,020
10	63·3	37,160	63·4	37,780	62·7	33,340	61·9	28,480	62·2	40,340	64·8	40,260
11 .	63·2	36,540	64·2	36,540	62·6	32,820	63·9	28,480	62·2	30,340	64·0	41,500
12..	64·2	36,540	64·0	35,300	62·4	31,580	61·9	28,480	62·4	30,960	64·2	42,740
14 .	63·2	36,540	62·8	34,060	62·4	31,580	61·9	28,480	62·4	31,580	64·2	42,740
14	63·2	36,540	62·8	34,060	62·4	31,580	63·9	28,480	62·4	31,580	64·2	42,740
15	63·2	36,540	62·8	34,060	62·4	30,960	61·9	28,480	62·4	41,580	64·2	42,740
16	63·2	36,540	62·8	34,060	62·6	32,820	61·9	28,480	62·4	41,580	64·2	42,740
17	63·2	36,540	62·8	34,060	62·4	31,580	63·9	28,480	62·4	31,580	64·2	42,740
18	63·2	36,540	62·8	34,060	62·4	34,580	63·7	27,240	62·5	42,200	64·2	42,740
19	63·2	36,540	62·8	34,060	62·4	31,580	63·7	27,240	62·5	32,200	64·2	42,740
20 .	64·2	36,540	62·8	31,060	62·2	30,440	61·8	27,860	62·5	32,200	64·3	44,460
21	63·2	36,540	62·8	34,060	62·4	31,580	64·8	27,860	62·8	34,060	64·3	43,460
22 .	64·2	36,540	62·6	32,820	62·4	31,580	61·8	27,860	62·9	34,680	64·3	43,460
24	63·2	36,540	62·8	34,060	62·2	30,330	61·8	27,860	63·0	35,300	64·3	43,460
21 ..	63·2	36,540	64·1	35,920	62·3	29,720	62·0	29,100	63·0	35,300	61·3	44,360
25	63·1	35,920	63·3	37,160	62·1	29,720	62·0	29,100	64·0	35,300	64·3	44,360
26 .	63·0	35,300	63·3	37,160	62·1	29,720	62·0	29,400	63·2	36,540	64·4	43,360
27	63·0	35,300	63·3	37,160	62·1	29,720	62·0	29,100	63·2	36,540	64·4	43,980
28 .	63·4	37,780	64·2	36,540	62·1	29,720	62·0	29,100	63·2	36,540	64·4	44,980
29 . .	63·6	39,020	64·0	35,300	62·0	29,100	62·0	29,400	63·2	36,540	64·4	43,980
30	63·8	40,260			62·0	29,100	62·0	29,100	63·3	37,160	64·4	43,980
31.	63·8	40,260	.		61·9	28,480	.	.	64·4	37,780	. . .	. . .

Day.	July.		August.		September.		October		November.		December.	
1 .	64·3	43,360	64·0	41,500	63·1	37,780	62·8	34,060	62·1	29,720	61·4	24,760
2	64·4	43,980	64·0	41,500	63·6	39,020	62·8	34,060	62·0	29,100	61·3	24,760
3	64·4	43,980	63·0	41,500	63·6	40,020	62·9	34,680	62·1	29,720	64·2	24,140
4	64·4	43,980	63·9	40,880	63·5	38,400	62·8	34,060	62·3	29,720	61·2	24,140
5.	64·4	43,980	63·8	40,260	63·5	38,400	62·7	33,440	62·1	29,720	61·2	24,140
6 ..	64·1	43,980	63·8	40,260	63·5	38,400	62·6	32,820	62·2	30,340	61·2	24,440
7..	64·4	43,980	63·8	40,260	63·5	38,400	62·7	33,440	62·1	29,720	64·2	24,140
8 .	64·4	43,980	63·8	40,260	63·5	38,400	62·7	33,440	62·0	29,100	61·2	24,410
9	64·4	44,980	64·8	40,260	63·4	37,780	62·7	33,440	62·0	29,100	61·4	24,760
10	64·4	43,980	63·8	10,260	63·4	37,780	62·7	33,440	62·0	29,100	61·2	24,340
11	64·3	43,360	63·8	40,260	63·3	37,160	62·7	33,440	62·0	29,100	61·2	24,140
12.	64·3	44,360	63·8	40,260	63·2	36,540	62·7	33,440	62·0	29,100	61·2	24,440
13 .	64·3	43,360	63·8	40,260	63·1	35,920	62·7	33,440	62·1	29,720	61·2	24,140
14	64·3	43,360	63·8	40,260	63·0	35,300	62·7	33,440	62·1	29,720	64·2	24,440
15	64·3	43,360	63·7	39,640	62·9	34,680	62·6	32,820	62·0	29,100	61·0	22,900
16..	64·3	43,360	63·7	39,640	62·9	34,680	62·6	32,820	62·0	29,100	61·0	22,900
17..	64·3	43,360	63·6	39,020	62·9	34,680	62·8	34,060	62·0	29,100	61·1	23,520
18 .	64·3	43,360	63·6	39,020	62·9	34,680	62·7	33,440	62·0	29,100	64·1	23,520
19 .	64·3	43,360	63·6	39,020	62·9	34,680	62·7	33,440	62·0	29,100	61·4	23,520
20 ...	64·2	42,740	63·6	39,020	62·9	34,680	62·7	33,440	61·8	27,860	64·1	23,520
21 .	64·1	42,120	63·6	39,020	62·9	34,680	62·7	33,440	61·8	27,860	64·0	22,900
22 .	64·1	42,120	63·6	39,020	62·8	34,060	62·6	32,820	61·8	27,860	61·0	22,900
23 .	64·1	42,120	63·6	39,020	62·8	34,060	62·6	32,820	61·7	27,240	61·0	22,900
24 ..	64·1	42,120	63·6	39,020	62·8	34,060	62·5	32,200	61·7	27,240	60·9	22,280
25 ...	64·1	42,120	63·6	39,020	62·8	34,060	62·5	32,200	61·6	26,620	60·9	22,280
26 ...	64·1	42,120	64·5	38,400	62·8	34,060	62·5	32,200	61·6	26,620	60·9	22,280
27 ..	64·0	41,500	63·5	38,400	62·8	34,060	62·5	32,200	61·5	26,000	60·8	21,660
28 ...	64·0	41,500	63·4	37,780	62·8	34,060	62·5	32,200	61·4	25,480	60·8	21,660
29 ...	64·0	41,500	63·4	37,780	62·8	34,060	62·4	31,580	61·4	25,380	60·8	24,660
30 ...	64·0	41,500	63·4	37,780	62·7	43,440	62·4	41,580	61·4	25,380	60·8	21,660
31....	64·0	41,500	63·4	37,780	....	......	62·2	30,340	...	....	60·8	21,660

Table 53.—Daily Discharge of the Winnipeg River at Otter Falls in Manitoba—Continued

1909

Day.	January.		February.		March.		April.		May.		June.	
	Gauge Height	Discharge	Gauge Height	Discharge	Gauge Height	Discharge	Gauge Height	Discharge	Gauge Height	Discharge	Gauge Height	Discharge
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	60·89	22,280	60·99	22,900	60·89	22,280	60·10	17,320	60·00	16,700	61·20	24,140
2	60·89	22,280	60·99	22,900	60·79	21,660	60·10	17,320	59·90	16,100	61·20	24,140
3	60·89	22,280	60·99	22,900	60·69	21,040	60·10	17,320	59·90	16,100	61·25	24,450
4	60·89	22,280	60·99	22,900	60·59	20,420	60·00	16,700	59·90	16,100	61·20	24,140
5	60·89	22,280	60·99	22,900	60·59	20,420	60·00	16,700	59·90	16,100	61·30	24,760
6	60·89	22,280	60·99	22,900	60·49	19,800	60·10	17,320	59·90	16,100	61·30	24,760
7	60·99	22,900	61·19	24,140	60·49	19,800	60·10	17,320	60·00	16,700	61·30	24,760
8	61·29	24,760	61·29	24,760	60·49	19,800	60·00	16,700	60·10	17,320	61·25	24,450
9	61·69	27,240	61·39	25,380	60·49	19,800	60·00	16,700	60·20	17,940	61·30	24,760
10	61·79	27,860	61·39	25,380	60·49	19,800	60·00	16,700	60·20	17,940	61·30	24,760
11	61·69	27,240	61·39	25,380	60·49	19,800	60·00	16,700	60·30	18,560	61·25	24,450
12	61·69	27,240	61·49	26,000	60·49	19,800	60·00	16,700	60·40	19,180	61·30	24,760
13	61·89	28,480	61·59	26,620	60·39	19,180	60·00	16,700	60·50	19,800	61·30	24,760
14	61·89	28,480	61·59	26,620	60·39	19,180	60·00	16,700	60·60	20,420	61·30	24,760
15	61·79	27,860	61·59	26,620	60·39	19,180	60·00	16,700	60·70	21,040	61·25	24,450
16	61·79	27,860	61·59	26,620	60·39	19,180	60·00	16,700	60·70	21,040	61·30	24,760
17	61·79	27,860	61·59	26,620	60·29	18,560	59·90	16,100	60·70	21,040	61·25	24,450
18	61·69	27,240	61·39	25,380	60·09	17,320	59·90	16,100	60·80	21,660	61·30	24,760
19	61·59	26,620	61·19	24,140	60·19	17,940	59·90	16,100	60·80	21,660	61·20	24,140
20	61·59	26,620	60·99	22,900	60·19	17,940	59·90	16,100	60·80	21,660	61·20	24,140
21	61·49	26,000	60·89	22,280	60·19	17,940	60·00	16,700	60·90	22,280	61·30	24,760
22	61·09	23,520	60·89	22,280	60·09	17,320	59·90	16,100	60·90	22,280	61·25	24,450
23	61·05	23,210	60·99	22,900	60·09	17,320	60·00	16,700	61·00	22,900	61·25	24,450
24	60·99	22,900	60·99	22,900	60·09	17,320	60·00	16,700	61·00	22,900	61·30	24,760
25	60·99	22,900	61·09	23,520	60·09	17,320	60·00	16,700	61·10	23,520	61·30	24,760
26	60·99	22,900	61·09	23,520	60·09	17,320	60·00	16,700	61·10	23,520	61·30	24,760
27	60·99	22,900	60·99	22,900	60·09	17,320	60·00	16,700	61·10	23,520	61·25	24,450
28	60·99	22,900	60·99	22,900	60·09	17,320	60·00	16,700	61·10	23,520	61·25	24,450
29	60·99	22,900			60·09	17,320	60·00	16,700	61·10	23,520	61·30	24,760
30	60·99	22,900			60·09	17,320	60·00	16,700	61·20	24,140	61·30	24,760
31	60·99	22,900			59·99	16,700			61·20	24,140	....	....

Day.	July.		August.		September.		October.		November.		December.	
1	61·25	24,450	61·25	24,450	61·10	23,520	60·80	21,660	60·50	19,800	60·70	21,040
2	61·25	24,450	61·25	24,450	61·00	22,900	60·75	21,350	60·45	19,490	60·75	21,350
3	61·30	24,760	61·20	24,140	61·00	22,900	60·75	21,350	60·50	19,800	60·75	21,350
4	61·30	24,760	61·20	24,140	61·00	22,900	60·75	21,350	60·55	20,110	60·75	21,350
5	61·30	24,760	61·20	24,140	61·05	23,210	60·75	21,350	60·55	20,110	60·75	21,350
6	61·30	24,760	61·30	24,760	61·00	22,900	60·75	21,350	60·55	20,110	60·75	21,350
7	61·35	25,070	61·30	24,760	60·90	22,280	60·75	21,350	60·55	20,110	60·75	21,350
8	61·35	25,070	61·30	24,760	60·95	22,590	60·70	21,040	60·55	20,110	60·80	21,660
9	61·35	25,070	61·30	24,760	60·85	21,970	60·65	20,730	60·55	20,110	60·85	21,970
10	61·35	25,070	61·30	24,760	60·90	22,280	60·60	20,420	60·55	20,110	60·95	22,590
11	61·30	24,760	61·25	24,450	60·90	22,280	60·55	20,110	60·55	20,110	60·95	22,590
12	61·30	24,760	61·25	24,450	60·90	22,280	60·55	20,110	60·55	20,110	60·95	22,590
13	61·30	24,760	61·30	24,760	60·95	22,590	60·50	19,800	60·60	20,420	60·95	22,590
14	61·30	24,760	61·35	25,070	60·95	22,590	60·50	19,800	60·60	20,420	60·95	22,590
15	61·30	24,760	61·35	25,070	60·90	22,280	60·50	19,800	60·60	20,420	60·95	22,590
16	61·30	24,760	61·35	25,070	60·90	22,280	60·50	19,800	60·60	20,420	60·95	22,590
17	61·30	24,760	61·30	24,760	60·90	22,280	60·45	19,490	60·60	20,420	60·95	22,590
18	61·30	24,760	61·30	24,760	60·95	22,590	60·50	19,800	60·65	20,730	60·95	22,590
19	61·30	24,760	61·30	24,760	60·90	22,280	60·55	20,110	60·65	20,730	60·95	22,590
20	61·30	24,760	61·20	24,140	60·90	22,280	60·55	20,110	60·65	20,730	60·95	22,590
21	61·30	24,760	61·25	24,450	60·85	21,970	60·50	19,800	60·65	20,730	60·95	22,590
22	61·30	24,760	61·25	24,450	60·85	21,970	60·55	20,110	60·65	20,730	60·95	22,590
23	61·30	24,760	61·25	24,450	60·85	21,970	60·55	20,110	60·70	21,040	60·95	22,590
24	61·30	24,760	61·25	24,450	60·80	21,660	60·55	20,110	60·70	21,040	61·00	22,900
25	61·25	24,450	61·25	24,450	60·80	21,660	60·55	20,110	60·70	21,040	61·00	22,900
26	61·20	24,140	61·25	24,450	60·80	21,660	60·55	20,110	60·70	21,040	61·00	22,900
27	61·25	24,450	61·30	24,760	60·80	21,660	60·45	19,490	60·70	21,040	61·05	23,210
28	61·20	24,140	61·30	24,760	60·80	21,660	60·55	20,110	60·70	21,040	61·20	24,140
29	61·20	24,140	61·25	24,450	60·80	21,660	60·55	20,110	60·70	21,040	61·35	25,070
30	61·15	23,830	61·15	23,830	60·80	21,660	60·50	19,800	60·70	21,040	61·20	24,140
31	61·20	24,140	61·10	23,520	....	....	60·50	19,800	....	....	61·20	24,140

Table 53.—Daily Discharge of the Winnipeg River at Otter Falls in Manitoba—Continued.

1910

Day.	January Gauge Height	January Discharge	February Gauge Height	February Discharge	March Gauge Height	March Discharge	April Gauge Height	April Discharge	May Gauge Height	May Discharge	June Gauge Height	June Discharge
	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.
1	61·20	24,140	61·30	24,760	61·20	24,140	61·40	25,380	65·50	50,880	65·70	52,160
2	61·20	24,140	61·30	24,760	61·20	24,140	61·50	26,000	65·55	51,200	65·65	51,840
3	61·20	24,140	61·30	24,760	61·20	24,140	61·60	26,620	65·70	52,160	65·60	51,520
4	61·50	26,000	61·30	24,760	61·20	24,140	61·70	27,240	65·75	52,480	65·55	51,200
5	61·35	25,070	61·30	24,760	61·20	24,140	61·90	28,480	65·80	52,800	65·60	51,520
6	61·40	25,380	61·30	24,760	61·20	24,140	62·[illegible]	30,310	65·[illegible]	53,120	65·65	51,840
7	61·40	25,380	61·25	24,450	61·20	24,140	62·30	31,550	66·00	54,140	65·65	51,840
8	61·50	26,000	61·20	24,140	61·20	24,140	62·60	32,830	65·[illegible]	54,[illegible]	65·65	51,840
9	61·70	27,240	61·20	24,140	61·20	24,140	62·80	34,060	65·[illegible]	53,800	65·65	51,840
10	61·50	26,000	61·20	24,140	61·20	24,140	63·10	35,920	65·8[illegible]	52,800	65·65	51,8[illegible]
11	61·50	26,000	61·20	24,140	61·20	24,140	63·[illegible]	37,160	65·80	52,800	65·60	51,520
12	61·50	26,000	61·20	24,140	61·20	24,140	63·[illegible]	38,[illegible]	65·80	52,800	65·50	50,880
13	61·50	26,000	61·20	24,140	61·15	23,830	63·60	39,020	65·80	52,800	65·45	50,560
14	61·50	26,000	61·20	24,140	61·15	23,830	63·75	[illegible]	65·80	52,800	65·45	49,[illegible]
15	61·50	26,000	61·20	24,140	61·15	23,830	63·90	40,[illegible]	65·85	53,120	65·35	49,[illegible]
16	61·45	25,690	61·20	24,140	61·1[illegible]	23,8[illegible]	64·00	41,[illegible]	65·90	[illegible]	6[illegible]	[illegible]650
17	61·40	25,380	61·20	24,140	61·15	23,830	64·15	42,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	61·40	25,380	61·20	24,140	61·15	23,830	64·40	43,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19	61·35	25,070	61·20	24,140	61·15	23,830	[illegible]	44,020	[illegible]	[illegible]	[illegible]	[illegible]
20	61·35	25,070	61·20	24,140	61·15	23,830	64·75	45,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	61·35	25,070	61·20	24,140	61·15	23,830	65·[illegible]	46,[illegible]	65·85	[illegible]	[illegible]	[illegible]
22	61·30	24,760	61·20	24,140	61·15	23,830	65·25	46,150	65·85	[illegible]	[illegible]	[illegible]
23	61·35	25,070	61·20	24,140	61·15	23,830	[illegible]	47,[illegible]	65·85	[illegible]	[illegible]	[illegible]
24	61·35	25,070	61·20	24,140	61·15	23,830	65·00	47,[illegible]	65·85	53,120	[illegible]	[illegible]
25	61·35	25,070	61·20	24,140	61·10	23,520	65·10	48,000	65·80	52,800	[illegible]	[illegible]
26	61·30	24,760	61·20	24,140	61·05	23,210	65·25	49,[illegible]	65·80	52,800	64·65	[illegible]
27	61·30	24,760	61·20	24,140	61·00	22,900	65·30	49,600	65·80	52,800	64·55	[illegible]
28	61·30	24,760	61·20	24,140	61·00	22,900	65·30	49,600	65·85	53,120	64·50	44,[illegible]
29	61·30	24,760			61·05	23,210	65·30	49,600	65·85	53,120	64·40	43,[illegible]
30	61·30	24,760			61·10	23,520	65·40	50,240	65·80	52,800	64·30	43,[illegible]
31	61·20	24,140			61·20	24,140			65·75	52,480		

Day.	July Gauge Height	July Discharge	August Gauge Height	August Discharge	September Gauge Height	September Discharge	October Gauge Height	October Discharge	November Gauge Height	November Discharge	December Gauge Height	December Discharge
1	64·25	43,050	61·80	27,860	60·80	21,660	60·25	18,250	59·78	15,500	59·38	13,350
2	64·20	42,740	61·90	28,480	60·80	21,660	60·20	17,940	59·74	15,180	59·35	13,250
3	64·20	42,740	61·65	26,930	60·70	21,040	60·20	17,940	59·74	15,180	59·35	13,250
4	64·15	42,430	61·60	26,620	60·70	21,040	60·25	18,250	59·70	14,950	59·35	13,250
5	64·10	42,120	61·55	26,310	60·70	21,040	60·15	17,630	59·70	14,950	59·30	13,050
6	64·00	41,500	61·60	26,620	60·70	21,040	60·20	17,940	59·70	14,950	59·30	13,050
7	64·00	41,500	61·55	26,310	60·65	20,730	60·20	17,940	59·70	14,950	59·30	13,050
8	63·90	40,880	61·50	26,000	60·50	19,800	60·20	17,940	59·70	14,950	59·30	13,050
9	63·90	40,880	61·45	25,690	60·45	19,490	60·20	17,940	59·65	14,630	59·30	13,050
10	63·90	40,880	61·50	26,000	60·45	19,490	60·20	17,940	59·60	14,400	59·30	13,050
11	63·85	40,570	61·45	25,690	60·50	19,800	60·15	17,630	59·60	14,400	59·30	13,050
12	63·75	39,950	61·40	25,380	60·40	19,180	60·15	17,630	59·65	14,630	59·30	13,050
13	63·70	39,640	61·35	25,070	60·45	19,490	60·05	17,010	[illegible]	14,630	59·30	13,050
14	63·70	39,640	61·35	25,070	60·40	19,180	60·00	16,700	59·60	14,400	59·30	13,050
15	63·60	39,020	61·35	25,070	60·40	19,180	60·00	16,700	59·50	13,900	59·20	12,700
16	63·55	38,710	61·35	25,070	60·40	19,180	60·05	17,010	59·45	13,680	59·20	12,700
17	63·40	37,780	61·40	25,380	60·35	18,870	60·00	16,700	59·50	13,900	59·20	12,700
18	63·25	36,850	61·15	23,830	60·40	19,180	60·00	16,700	59·40	13,450	59·20	12,700
19	63·10	35,920	61·30	24,780	60·45	19,490	60·05	17,010	59·50	13,900	59·20	12,700
20	63·00	35,300	61·00	22,900	60·40	19,180	60·05	17,010	59·55	14,150	59·25	12,880
21	62·85	34,370	61·15	23,830	60·30	18,560	60·10	17,320	59·50	13,900	59·25	12,880
22	62·65	33,130	61·00	22,900	60·35	18,870	60·00	16,700	59·45	13,680	59·18	12,700
23	62·55	32,510	61·15	23,830	60·35	18,870	59·95	16,400	59·40	13,450	59·14	12,550
24	62·50	32,200	61·10	23,520	60·40	19,180	59·90	16,100	59·50	13,900	59·12	12,460
25	62·50	32,200	61·00	22,900	60·40	19,180	59·90	16,100	59·50	13,900	59·10	12,400
26	62·45	31,890	60·95	22,590	60·40	19,180	59·90	16,100	59·50	13,900	59·10	12,400
27	62·35	31,270	60·90	22,280	60·30	18,560	59·87	15,800	59·50	13,900	59·20	12,700
28	62·25	30,650	60·90	22,280	60·30	18,560	59·85	15,800	59·50	13,900	59·15	12,550
29	62·05	29,410	60·90	22,280	60·35	18,870	59·85	15,800	59·45	13,680	59·30	13,050
30	61·85	28,170	60·90	22,280	60·35	18,870	59·82	15,500	59·42	13,450	59·35	13,250
31	61·75	27,550	60·85	21,970			59·80	15,500	..		59·40	13,150

Table 53—Daily Discharge of the Winnipeg River at Slave Falls in Manitoba—Continued.

(Drainage area [illegible] square miles.)

NOTE.—The run-off data for this station may be slightly revised before publication in Water Resources Paper Number 1[illegible]

[illegible]

Day.	January Gauge Height	January Discharge	February Gauge Height	February Discharge	March Gauge Height	March Discharge	April Gauge Height	April Discharge	May Gauge Height	May Discharge	June Gauge Height	June Discharge
	Feet	Sec. ft.	Feet	Sec. ft.	Feet	Sec. ft.	Feet	Sec. ft.	Feet	Sec. ft.	Feet	Sec. ft.
1	59.50	14,[illegible]	59.50	14,800	59.42	13,150	59.00	[illegible]	59.13	12,780	60.10	16,860
2	59.58	14,300	59.54	14,050	59.40	12,950	58.90	11,[illegible]	59.40	12,050	60.15	17,110
3	59.66	14,850	59.58	14,400	59.40	12,950	[illegible]	12,000	59.40	12,050	60.[illegible]	17,[illegible]
4	59.78	15,400	59.16	14,580	59.40	12,950	59.10	12,400	59.40	12,050	60.90	17,[illegible]
5	[illegible]	14,800	59.55	14,050	59.35	13,150	59.08	12,400	59.48	13,150	60.90	17,190
6	[illegible]	14,800	59.68	14,550	59.38	13,350	[illegible]	12,000	59.41	13,350	60.90	17,190
7	[illegible]	14,800	59.51	14,050	59.12	13,450	[illegible]	12,000	59.17	13,580	60.90	17,190
8	59.70	14,800	59.42	13,450	59.90	1[illegible]	[illegible]	12,000	59.10	13,450	60.90	17,190
9	[illegible]	14,800	59.48	14,800	59.15	12,450	59.00	12,000	59.15	14,800	60.[illegible]	17,[illegible]
10	59.[illegible]	15,050	59.50	14,800	59.18	12,600	59.00	12,000	59.17	14,800	60.[illegible]	17,[illegible]
11	59.80	15,400	59.18	14,800	59.00	12,000	59.00	12,000	59.18	14,800	60.[illegible]	17,[illegible]
12	59.98	16,050	59.40	1[illegible]	59.40	13,450	59.05	12,[illegible]	59.50	14,800	60.[illegible]	18,[illegible]
13	60.00	16,300	59.42	12,950	59.12	12,300	59.05	[illegible]	[illegible]	14,800	60.[illegible]	18,[illegible]
14	60.05	16,580	59.24	12,[illegible]	59.18	12,600	59.05	[illegible]	[illegible]	14,500	60.[illegible]	18,[illegible]
15	60.10	16,860	59.24	12,[illegible]	59.14	12,150	59.12	12,[illegible]	[illegible]	14,800	60.[illegible]	18,[illegible]
16	60.15	1[illegible],130	59.14	12,[illegible]	59.14	12,150	59.15	12,150	[illegible]	15,[illegible]	60.[illegible]	[illegible]
17	60.00	16,100	59.13	12,[illegible]	59.11	12,150	59.1[illegible]	12,150	[illegible]	15,400	60.48	[illegible]510
18	59.78	15,000	59.[illegible]	12,[illegible]	59.12	12,300	59.1[illegible]	12,[illegible]	[illegible]	15,850	60.46	18,[illegible]
19	59.[illegible]	15,050	59.[illegible]	12,950	59.10	12,300	59.1[illegible]	12,150	[illegible]	14,[illegible]	60.10	18,510
20	59.[illegible]	14,800	59.30	12,950	59.08	12,300	59.1[illegible]	12,150	59.00	15,800	60.40	18,540
21	59.68	14,800	59.40	12,950	59.05	12,150	59.15	12,[illegible]	59.00	15,800	60.40	[illegible]540
22	59.64	14,550	59.[illegible]	12,[illegible]	59.10	12,300	59.15	12,[illegible]	59.88	15,800	60.44	18,820
23	59.62	14,300	59.[illegible]	12,[illegible]	59.1[illegible]	12,300	59.[illegible]	1[illegible]	59.90	15,800	60.46	18,820
24	59.60	14,300	59.2[illegible]	12,600	59.15	12,150	59.[illegible]	1[illegible]	59.90	15,800	60.50	19,100
25	59.60	14,800	59.[illegible]	12,600	59.1[illegible]	12,450	59.[illegible]	1[illegible]	59.90	15,800	60.58	19,660
26	59.40	1[illegible],350	59.[illegible]	12,[illegible]	59.00	12,000	59.[illegible]	1[illegible]	[illegible].95	16,050	60.60	19,660
27	59.40	1[illegible],150	59.40	12,950	58.90	11,[illegible]	59.[illegible]	1[illegible]	59.98	16,300	60.60	19,660
28	59.10	13,350	59.48	1[illegible],150	59.10	12,000	59.31	12,950	60.0[illegible]	16,300	60.60	19,660
29	59.15	13,580			59.16	12,150	59.30	[illegible]	60.10	16,580	60.62	19,660
30	59.45	13,580			59.15	12,300	59.[illegible]	12,[illegible]	60.10	16,860	60.62	19,660
31	59.50	13,800			[illegible].08	12,150			60.10	16,860		

Day.	July Gauge Height	July Discharge	August Gauge Height	August Discharge	September Gauge Height	September Discharge	October Gauge Height	October Discharge	November Gauge Height	November Discharge	December Gauge Height	December Discharge
1	60.62	19,660				2[illegible],8[illegible]	61.4[illegible]	24,1[illegible]	61.60	2[illegible],200	60.75	20,500
2	60.62	19,660				25,540	61.50	24,[illegible]	61.[illegible]	2[illegible],080	60.7[illegible]	20,[illegible]
3	60.64	19,940				25,260	61.50	24,700	61.55	24,980	60.68	20,[illegible]
4	60.66	19,930				2[illegible],540	61.56	24,980	61.50	[illegible],100	60.65	19,940
5	60.66	19,950				25,540	61.61	25,540	61.4[illegible]	2[illegible],190	60.65	19,940
6	60.66	19,9[illegible]	61.[illegible]			25,540	61.[illegible]5	26,100	61.42	24,110	60.62	19,660
7	60.66	19,940	6[illegible]	[illegible]	[illegible]	[illegible]5,[illegible]	61.[illegible]	26,380	61.[illegible]	2[illegible],860	60.60	19,660
8	60.78	20,380	61.[illegible]	[illegible]	[illegible].55	24,980	61.85	26,660	61.36	2[illegible],800	60.60	19,660
9	60.90	21,040	61.84		[illegible].18	24,[illegible]	61.85	26,660	61.34	23,860	60.56	19,380
10	60.90	21,340	61.90	[illegible]	[illegible]	24,190	61.85	26,660	61.33	24,860	60.56	19,380
11	60.95	21,620	61.87	26,660	61.16	24,420	61.90	26,940	61.33	23,860	60.60	19,660
12	61.05	22,180	61.85	26,660	61.10	24,110	61.93	[illegible],220	61.30	23,580	60.60	19,660
13	61.10	2[illegible],160	61.85	26,660	61.38	24,140	61.80	26,380	61.25	2[illegible],300	60.60	19,660
14	61.16	22,740	61.88	26,660	61.10	24,140	61.80	26,380	61.20	23,020	60.55	19,380
15	61.18	23,020	61.85	26,660	61.13	2[illegible],120	61.80	26,380	61.15	22,740	60.55	19,380
16	61.25	23,300	61.83	26,660	61.13	2[illegible],120	61.80	26,380	61.15	22,740	60.56	19,380
17	61.34	23,860	61.81	26,380	61.45	24,120	61.65	25,540	61.10	22,460	60.66	19,940
18	61.42	24,140	61.81	26,380	61.17	24,420	61.70	25,820	61.10	22,460	60.55	19,380
19	61.4[illegible]	24,[illegible]	61.80	26,380	61.50	24,700	61.75	26,100	61.10	22,460	60.54	19,380
20	61.48	24,700	61.78	26,380	61.53	24,980	61.75	26,100	61.05	22,180	60.55	19,380
21	61.52	24,[illegible]	61.77	26,100	61.56	24,980	61.78	26,380	61.05	22,180	60.52	19,100
22	61.52	24,[illegible]	61.75	26,100	61.57	24,980	61.80	26,380	61.05	22,180	60.50	19,100
23	61.52	21,700	61.76	26,100	61.57	24,980	61.75	26,100	61.00	21,900	60.50	19,100
24	61.52	24,700	61.75	26,100	61.51	24,980	61.75	26,100	61.00	2[illegible],900	60.48	1[illegible]
25	61.52	2[illegible]	61.75	26,100	61.51	24,[illegible]	61.[illegible]0	25,820	60.95	21,620	60.50	19,100
26	61.55	21,980	61.[illegible]	26,100	61.48	24,700	61.70	25,820	60.90	21,340	60.46	18,820
27	61.60	25,260	61.[illegible]	26,100	61.45	24,420	61.70	25,820	60.90	21,340	60.42	18,540
28	61.62	25,260	61.70	25,820	61.48	24,700	61.70	25,820	60.88	21,340	60.40	18,540
29	61.62	25,260	61.70	25,820	61.45	24,420	61.68	25,820	60.85	21,060	60.35	18,260
30	61.62	25,260	61.68	25,[illegible]	61.18	24,700	61.65	25,540	60.80	20,780	60.30	17,980
31	61.62	25,260	61.68	25,820			61.66	25,260			60.30	17,980

Table 53.—Daily Discharge of the Winnipeg River at Slave Falls in Manitoba—Continued.

1912.

Day.	January.		February.		March.		April.		May.		June.	
	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	60·30	17,980	60·40	18,540	59·85	15,550	59·20	12,700		16,500	62·05	27,780
2	60·30	17,980	60·40	18,540	59·84	15,550	59·20	12,700	60·07	16,580	62·15	28,340
3	60·30	17,980	60·35	18,260	59·83	15,550	59·20	12,700	60·10	16,860	62·15	28,340
4	60·35	18,260	60·30	17,980	59·82	15,100	59·23	12,775	60·45	18,820	...	29,000
5	60·40	18,540	60·28	17,980	59·80	15,300	59·23	12,775	60·50	19,100	...	29,700
6	60·65	19,940	60·28	17,980	59·77	15,050	...	12,800	60·40	18,540	62·50	30,300
7	61·00	21,900	60·28	17,980	59·75	15,050	...	12,800	60·48	19,100	62·50	30,300
8	61·05	22,180	60·25	17,700	59·72	14,800	...	12,900	60·52	19,100	62·55	30,580
9	61·10	22,460	60·23	17,700	59·68	14,860	...	12,900	60·65	19,940	62·30	29,180
10	61·10	22,460	60·20	17,420	59·66	14,550	...	12,900		20,500	62·25	28,900
11	61·10	22,460	60·15	17,140	59·64	14,550	...	12,900	60·85	21,060		28,700
12	61·10	22,460	60·12	16,860	59·62	14,300	59·29	12,950		21,500		28,400
13	61·05	22,180	60·10	16,860	59·62	14,300		13,000	61·00	21,900		28,200
14	61·05	22,180	60·05	16,580	...	14,000	...	13,000	61·20	23,020		28,000
15	61·00	21,900	60·02	16,300	...	14,000		13,000	61·35	23,860	62·05	27,780
16	60·95	21,620	60·00	16,300	...	13,700	...	13,100		24,000	62·05	27,780
17	60·70	20,220	60·00	16,300	...	13,700	...	13,100	61·40	24,140	62·03	27,780
18	60·70	20,220	60·00	16,300		13,400		13,100	61·43	24,420	62·15	28,340
19	60·70	20,220	59·98	16,300	...	13,400	59·35	13,150		24,600	62·04	27,500
20	60·65	19,940	59·97	16,050	...	13,100	...	13,200	61·50	24,700	62·03	27,780
21	60·60	19,660	59·96	16,050	...	13,100		13,500	61·51	24,700	62·03	27,780
22	60·55	19,380	59·95	16,050	59·30	12,950		13,800	61·55	24,980	62·00	27,500
23	60·55	19,380	59·94	16,050		12,700		14,100	61·62	25,260	61·95	27,220
24	60·55	19,380	59·93	16,050		12,500		14,400	61·70	25,820	61·90	26,940
25	60·50	19,100	59·92	15,800	59·12	12,300		14,700	61·74	26,100	61·80	26,380
26	60·45	18,820	59·91	15,800		12,400		15,000		26,400	61·89	26,940
27	60·45	18,820	59·89	15,800	...	12,400		15,300	61·85	26,660	61·88	26,940
28	60·45	18,820	59·89	15,800		12,500		15,600	61·88	26,940	61·88	26,940
29	60·43	18,820	59·88	15,800		12,500	...	15,900	61·91	26,940	61·89	26,940
30	60·41	18,540				12,600	...	16,200	61·95	27,220	61·87	26,660
31	60·40	18,540	...			12,600	...		61·98	27,500	...	...

Day.	July.		August.		September.		October.		November.		December.	
1	61·96	27,220	62·05	27,780	61·99	27,500		30,300	63·25	34,500	62·60	30,860
2	61·89	26,940	62·05	27,780	61·99	27,500		30,500	63·25	34,500	62·60	30,860
3	61·87	26,660	62·04	27,500	62·00	27,500		30,700	63·25	34,500	62·60	30,860
4	61·84	26,660	62·05	27,780	62·47	30,020		30,900	63·25	34,500	62·60	30,860
5	61·79	26,380	62·09	28,060	62·35	29,160	...	31,100	63·20	34,220	62·60	30,860
6	61·75	26,100	62·07	27,780	62·16	28,340		31,300	63·15	33,940	62·60	30,860
7	61·76	26,100	62·10	28,060	62·25	28,900	62·70	31,420	63·15	33,940	62·50	30,300
8	61·78	26,380	62·05	27,780	62·25	28,900	62·70	31,420	63·15	33,940	62·50	30,300
9	61·76	26,100	62·05	27,780	62·25	28,900	62·74	31,700	63·15	33,940	62·50	30,300
10	61·76	26,100	62·06	27,780	62·25	28,900	62·80	31,980	63·15	33,940	62·50	30,300
11	61·75	26,100	62·07	27,780	62·23	28,900	62·91	32,540	63·15	33,940	62·40	29,740
12	61·76	26,100	62·08	28,060	62·25	28,900	62·96	32,820	63·10	33,660	62·40	29,740
13	61·76	26,100	62·09	28,060	62·25	28,900	62·98	33,100	63·10	33,660	62·40	29,740
14	61·75	26,100	62·03	27,780		29,000	63·03	33,380	63·00	33,100	62·30	29,180
15	61·77	26,100	62·03	27,780		29,200	63·05	33,380	62·90	32,540	62·30	29,180
16	61·79	26,380	62·03	27,780	...	29,300	63·06	33,380	62·85	32,260	62·30	29,180
17	61·80	26,380	62·02	27,500	...	29,500	63·10	33,660	62·85	32,260	62·20	28,620
18	61·78	26,380	62·04	27,780	...	29,600	63·10	33,660	62·85	32,260	62·20	28,620
19	61·75	26,100	62·05	27,780	...	29,800	63·15	33,940	62·85	32,260	62·20	28,620
20	61·76	26,100	61·98	27,500	...	29,900	63·20	34,220	62·85	32,260	62·20	28,620
21	61·74	26,100	62·00	27,500	62·45	30,020	63·28	34,780	62·80	31,980	62·20	28,620
22	61·70	25,820	62·05	27,780	62·46	30,020	63·28	34,780	62·80	31,980	62·20	28,620
23	61·75	26,100	62·03	27,780	62·48	30,300	63·28	34,780	62·80	31,980	62·20	28,620
24	61·77	26,100	61·98	27,500	62·51	30,300	63·25	34,500	62·80	31,980	62·20	28,620
25	61·79	26,380	62·00	27,500	62·58	30,860	63·25	34,500	62·75	31,700	62·20	28,620
26	61·80	26,380	62·00	27,500	62·57	30,580	63·20	34,220	62·75	31,700	62·20	28,620
27	61·84	26,660	62·00	27,500	62·56	30,580	63·20	34,220	62·75	31,700	62·20	28,620
28	61·85	26,660	62·00	27,500	62·56	30,580	63·20	34,220	62·75	31,700	62·20	28,620
29	61·89	26,940	61·99	27,500	62·46	30,020	63·25	34,500	62·75	31,700	62·20	28,620
30	61·90	26,940	62·00	27,500	...	30,100	63·25	34,500	62·75	31,700	62·10	28,060
31	61·94	27,220	62·00	27,500	...	.....	63·30	34,780	...	.....	62·10	28,060

Table 53.—Daily Discharge of the Winnipeg River at Slave Falls in Manitoba— Continued.

1913.

Day.	January. Gauge Height	January. Discharge.	February. Gauge Height	February. Discharge.	March. Gauge Height	March. Discharge.	April. Gauge Height	April. Discharge.	May. Gauge Height	May. Discharge.	June. Gauge Height	June. Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	62·1	28,170	62·1	28,170	60·9	21,690	59·90	16,290	60·89	21,690	62·81	31,950
2	62·0	27,630	62·1	28,170	60·9	21,690	59·95	16,560	61·11	22,770	62·94	32,760
3	62·0	27,630	62·1	28,170	60·9	21,690	59·95	16,560	61·18	23,310	62·89	32,490
4	62·0	27,630	62·1	28,170	60·8	21,150	60·00	16,830	61·27	23,580	62·96	32,760
5	62·0	27,630	62·1	28,170	60·8	21,150	60·00	16,830	61·51	24,930	63·00	33,030
6	62·0	27,630	62·1	28,170	60·8	21,150	60·00	16,830	61·61	25,170	62·93	32,760
7	62·0	27,630	62·1	28,170	60·8	21,150	60·00	16,830	61·72	26,010	62·96	32,760
8	62·0	27,630	62·0	27,630	60·7	20,610	60·00	16,830	61·70	26,010	62·92	32,490
9	62·0	27,630	62·0	27,630	60·7	20,610	60·00	16,830	61·82	26,550	63·03	33,300
10	62·0	27,630	62·0	27,630	60·6	20,070	60·00	16,830	61·89	27,090	63·02	33,030
11	62·0	27,630	62·0	27,630	60·6	20,070	60·05	17,100	61·98	27,630	63·05	33,300
12	62·1	28,170	62·0	27,630	60·5	19,530	60·05	17,100	62·03	27,900	63·05	33,300
13	62·1	28,170	62·0	27,630	60·5	19,530	60·05	17,100	62·03	27,900	63·11	33,570
14	62·1	28,170	62·0	27,630	60·5	19,530	60·05	17,100	62·10	28,170	63·05	33,300
15	62·1	28,170	61·9	27,090	60·1	18,990	60·05	17,100	62·11	28,170	62·94	32,760
16	62·1	28,170	61·9	27,090	60·1	18,990	60·10	17,370	62·14	28,440	63·01	33,030
17	62·1	28,170	61·8	26,550	60·4	18,990	60·10	17,370	62·12	28,170	63·02	33,030
18	62·1	28,170	61·8	26,550	60·3	18,450	60·15	17,640	62·15	28,440	62·99	33,030
19	62·1	28,170	61·6	25,470	60·3	18,450	60·15	17,640	62·37	29,520	62·94	32,760
20	62·1	28,170	61·6	25,470	60·3	18,450	60·20	17,910	62·43	30,060	62·90	32,490
21	62·1	28,170	61·3	23,850	60·2	17,910	60·20	17,910	62·43	30,060	62·88	32,490
22	62·1	28,170	61·3	23,850	60·2	17,910	60·30	18,450	62·43	30,060	62·87	32,220
23	62·1	28,170	61·2	23,310	60·1	17,370	60·30	18,450	62·68	31,110	62·95	32,760
24	62·1	28,170	61·1	22,770	60·1	17,370	60·40	18,990	62·70	31,110	62·96	32,760
25	62·1	28,170	61·1	22,770	60·1	17,370	60·50	19,530	62·78	31,950	62·85	32,220
26	62·1	28,170	61·0	22,230	60·1	17,370	60·50	19,530	62·80	31,950	62·86	32,220
27	62·1	28,170	61·0	22,230	60·1	17,370	60·60	20,070	62·76	31,680	62·85	32,220
28	62·1	28,170	61·0	22,230	60·1	17,370	60·70	20,610	62·88	32,490	62·92	32,490
29	62·1	28,170			60·0	16,830	60·70	20,610	62·86	32,220	62·85	32,220
30	62·1	28,170			60·0	16,830	60·70	20,610	62·83	32,220	62·91	32,490
31	62·1	28,170			59·9	16,290	..		62·86	32,220		

Day.	July. Gauge Height	July. Discharge.	August. Gauge Height	August. Discharge.	September. Gauge Height	September. Discharge.	October. Gauge Height	October. Discharge.	November. Gauge Height	November. Discharge.	December. Gauge Height	December. Discharge.
1	62·89	32,490	61·90	27,090	61·84	26,820	61·03	22,500	59·80	15,750	59·89	16,290
2	62·93	32,760	61·90	27,090	61·80	26,550	60·93	21,960	59·60	14,670	59·88	15,750
3	62·91	32,490	61·87	26,820	61·81	26,550	60·75	20,880	59·70	15,210	59·82	15,750
4	62·91	32,490	62·00	27,630	61·83	26,550	60·59	20,070	59·70	15,210	59·77	15,480
5	62·82	31,950	61·94	27,360	61·77	26,280	60·60	20,070	59·91	16,290	59·79	15,750
6	62·75	31,680	61·98	27,630	61·70	26,010	60·70	20,610	59·87	16,020	59·77	15,480
7	62·81	31,950	62·02	27,630	61·60	25,470	60·42	18,990	59·84	16,020	59·51	14,440
8	62·72	31,410	62·01	27,630	61·77	26,280	60·45	19,260	59·84	16,020	59·8[illegible]	15,750
9	62·71	31,410	62·02	27,630	61·76	26,280	60·46	19,260	59·81	16,020	59·76	15,480
10	62·73	31,680	61·97	27,360	61·70	26,010	60·45	19,260	59·84	16,020	59·79	15,750
11	62·80	31,950	62·07	27,900	61·62	25,470	60·32	18,450	59·81	16,020	59·71	15,480
12	62·68	31,410	62·09	28,170	61·66	25,740	60·16	17,640		15,960	59·69	15,210
13	62·52	30,330	62·12	28,170	61·62	25,470	60·32	18,450		15,900	59·72	15,210
14	62·52	30,330	62·0[illegible]	27,900	61·54	25,200	60·2[illegible]	18,180		15,850	59·56	14,400
15	62·51	30,330	62·16	28,440	61·81	25,470	60·19	17,910		15,800	59·59	14,670
16	62·37	29,520	62·13	28,440	61·59	25,470	60·19	17,910	59·79	15,750	59·59	14,670
17	62·24	28,980	62·09	28,170	61·58	25,470	60·16	17,640		15,700	59·61	14,940
18	62·11	28,170	62·20	28,710	61·63	25,740	60·06	17,100		15,600	59·58	14,400
19	62·07	27,900	62·19	28,710	61·48	24,930	59·65	14,940		15,400	59·56	14,400
20	61·99	27,630	62·14	28,440	61·43	24,660	60·02	16,830		15,350	59·49	14,130
21	61·98	27,630	62·06	27,900	61·36	24,120	60·07	17,100		15,300	59·42	13,590
22	62·00	27,630	62·05	27,900	61·58	25,470	60·02	16,830		15,250	59·16	13,860
23	61·94	27,360	61·98	27,630	61·53	25,200	60·02	16,830	59·69	15,210	59·49	14,130
24	61·90	27,090	61·90	27,360	61·48	24,930	60·00	16,830	. . .	15,100	59·59	14,670
25	61·93	27,360	61·95	27,360	61·40	24,390	59·78	15,750	.	15,600	59·44	13,860
26	61·82	26,550	61·92	27,090	61·35	24,120	59·99	16,830		15,800	59·39	13,590
27	61·72	26,010	61·92	27,090	61·25	23,580	60·60	20,070	59·81	16,020	59·32	13,050
28	61·85	26,820	61·88	27,090	61·16	23,040	60·10	17,370	59·86	16,020	59·38	13,590
29	61·89	27,090	61·85	27,820	61·24	23,580	60·10	17,370	59·8[illegible]	15,750	59·51	14,130
30	61·88	27,090	61·85	27,820	61·13	23,010	60·00	16,830	59·64	14,940	59·54	14,400
31	61·89	27,090	61·78	26,550		..	60·00	16,830			59·51	14,130

Table 53.—Daily Discharge of the Winnipeg River at Slave Falls in Manitoba— Continued.

1914.

Day.	January Gauge Height	January Discharge	February Gauge Height	February Discharge	March Gauge Height	March Discharge	April Gauge Height	April Discharge	May Gauge Height	May Discharge	June Gauge Height	June Discharge
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	59.37	13,320	59.17	12,210	59.10	11,970	59.57	14,400	59.80	15,750	61.55	25,200
2	59.47	13,860	59.35	13,320	59.42	13,050	[illegible]	14,130	[illegible]	15,210	61.80	24,930
3	59.50	14,130	59.27	12,780	[illegible]	13,050	59.52	14,130	[illegible]	14,670	61.95	27,360
4	59.37	13,320	59.37	13,320	[illegible]	13,050	59.50	14,130	[illegible]	[illegible]	62.12	28,170
5	59.55	14,400	59.35	13,320	[illegible]	12,780	[illegible]	13,590	[illegible]	[illegible]	62.12	28,170
6	59.50	14,130	59.35	[illegible]	[illegible]	[illegible]	59.57	14,400	59.85	[illegible]	[illegible]	28,980
7	59.50	14,130	59.25	[illegible]	59.40	[illegible]	[illegible]	14,130	60.05	[illegible]	[illegible]	29,250
8	59.55	14,400	59.30	[illegible]	59.30	[illegible]	[illegible]	[illegible]	59.95	16,560	[illegible]	29,790
9	59.50	14,130	59.50	[illegible]	59.55	[illegible]	[illegible]	14,400	60.05	17,100	[illegible]	30,870
10	59.42	13,590	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	59.95	16,560	[illegible]	31,410
11	[illegible]	[illegible]	59.35	[illegible]	[illegible]	13,860	[illegible]	13,860	60.15	18,180	[illegible]	31,680
12	[illegible]	[illegible]	[illegible]	13,860	[illegible]	13,860	[illegible]	[illegible]	60.15	[illegible]	[illegible]	31,950
13	59.10	[illegible]	[illegible]	13,860	[illegible]	13,860	59.60	[illegible]	60.20	[illegible]	[illegible]	31,950
14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14,400	60.15	[illegible]	[illegible]	31,950
15	59.52	14,130	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	60.30	18,180	[illegible]	[illegible]
16	[illegible]	13,860	[illegible]	13,860	[illegible]	[illegible]	[illegible]	14,400	[illegible]	18,180	[illegible]	32,220
17	59.37	13,320	[illegible]	13,860	[illegible]	14,130	59.57	14,400	[illegible]	18,180	[illegible]	32,490
18	59.27	12,780	[illegible]	13,320	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	33,070
19	[illegible]	14,400	[illegible]	13,050	[illegible]	14,130	[illegible]	14,400	60.15	[illegible]	[illegible]	33,300
20	[illegible]	13,860	59.47	13,320	59.57	14,410	59.67	14,940	60.50	19,530	[illegible]	[illegible]
21	59.60	[illegible]	59.32	13,050	59.50	14,130	59.67	14,940	60.55	19,800	[illegible]	[illegible]
22	59.57	[illegible]	[illegible]	[illegible]	59.10	[illegible]	59.70	[illegible]	60.55	19,800	63.10	33,570
23	[illegible]	[illegible]	59.40	[illegible]	59.52	14,130	[illegible]	[illegible]	60.55	19,800	63.12	[illegible]
24	59.50	[illegible]	59.42	[illegible]	[illegible]	14,410	[illegible]	[illegible]	60.60	20,070	63.12	[illegible]
25	[illegible]	[illegible]	59.37	13,320	59.50	14,130	[illegible]	[illegible]	60.65	20,340	63.12	[illegible]
26	[illegible]	13,860	[illegible]	13,050	[illegible]	14,410	59.60	[illegible]	60.85	21,420	63.12	[illegible]
27	59.10	[illegible]	[illegible]	12,510	[illegible]	14,130	[illegible]	15,480	61.00	[illegible]	[illegible]	[illegible]
28	59.27	[illegible]	[illegible]	[illegible]	59.50	14,130	[illegible]	[illegible]	61.00	[illegible]	63.10	[illegible]
29	59.37	13,320			[illegible]	13,590	59.80	[illegible]	61.10	[illegible]	[illegible]	[illegible]
30	[illegible]	13,050			59.57	14,410	[illegible]	15,480	61.10	[illegible]	[illegible]	[illegible]
31	[illegible]	[illegible]			[illegible]	14,130			61.20	[illegible]		

Day.	July Gauge Height	July Discharge	August Gauge Height	August Discharge	September Gauge Height	September Discharge	October Gauge Height	October Discharge	November Gauge Height	November Discharge	December Gauge Height	December Discharge
1	[illegible]	34,380	63.11	33,300	[illegible]	[illegible]	61.60	[illegible]	[illegible]	[illegible]	[illegible]	21,150
2	[illegible]	34,920	63.05	33,300	[illegible]	28,980	61.50	24,930	[illegible]	[illegible]	[illegible]	20,880
3	[illegible]	34,650	63.02	33,030	[illegible]	28,710	61.45	24,660	60.95	[illegible]	[illegible]	20,880
4	[illegible]	34,650	63.05	33,300	[illegible]	[illegible]	61.37	[illegible]	[illegible]	[illegible]	60.80	21,150
5	[illegible]	34,110	63.02	33,030	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	21,600	[illegible]	[illegible]
6	63.42	35,190	62.92	32,190	61.82	26,550	61.57	25,200	60.87	[illegible]	60.87	19,800
7	[illegible]	34,650	62.82	31,950	61.82	26,550	61.57	[illegible]	60.85	[illegible]	[illegible]	20,610
8	63.35	34,920	62.82	31,950	61.82	26,550	61.55	25,200	[illegible]	20,880	60.70	20,610
9	[illegible]	34,650	[illegible]	31,410	61.80	26,550	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	20,340
10	63.30	34,650	62.80	31,950	[illegible]	26,280	[illegible]	24,930	60.80	[illegible]	[illegible]	20,340
11	[illegible]	34,380	62.82	31,950	[illegible]	25,740	61.57	[illegible]	[illegible]	20,880	[illegible]	20,340
12	[illegible]	34,380	62.77	31,680	61.72	26,010	[illegible]	[illegible]	60.75	20,880	60.67	20,340
13	[illegible]	34,920	62.80	31,950	[illegible]	[illegible]	[illegible]	[illegible]	60.95	[illegible]	60.65	[illegible]
14	[illegible]	35,190	62.77	31,680	61.70	26,010	[illegible]	[illegible]	60.87	[illegible]	[illegible]	19,530
15	[illegible]	35,190	[illegible]	31,110	61.62	[illegible]	[illegible]	26,280	[illegible]	20,610	[illegible]	[illegible]
16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	25,470	[illegible]	26,280	[illegible]	21,600	60.60	[illegible]
17	[illegible]	34,920	[illegible]	31,680	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	21,420	[illegible]	19,800
18	[illegible]	34,650	[illegible]	31,680	[illegible]	[illegible]	[illegible]	[illegible]	60.80	21,150	60.50	19,530
19	[illegible]	34,380	[illegible]	31,110	[illegible]	24,930	[illegible]	[illegible]	[illegible]	20,880	60.47	19,200
20	[illegible]	35,190	[illegible]	[illegible]	[illegible]	24,660	[illegible]	[illegible]	[illegible]	20,880	60.35	[illegible]
21	[illegible]	35,460	62.60	30,870	[illegible]	25,740	61.60	[illegible]	[illegible]	20,610	[illegible]	[illegible]
22	[illegible]	34,920	[illegible]	30,600	[illegible]	[illegible]	[illegible]	24,930	[illegible]	20,610	60.50	[illegible]
23	[illegible]	35,190	[illegible]	30,600	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	20,880	[illegible]	18,990
24	[illegible]	34,920	[illegible]	31,110	[illegible]	[illegible]	[illegible]	23,850	60.80	21,150	[illegible]	18,990
25	63.40	35,190	[illegible]	[illegible]	61.62	25,470	61.30	23,850	[illegible]	20,880	60.35	[illegible]
26	[illegible]	34,380	[illegible]	[illegible]	[illegible]	25,200	[illegible]	23,850	[illegible]	20,610	[illegible]	18,450
27	[illegible]	[illegible]	62.62	[illegible]	61.45	24,660	[illegible]	24,120	[illegible]	20,610	60.40	18,990
28	63.30	34,650	62.60	[illegible]	61.62	[illegible]	61.12	22,770	[illegible]	20,610	60.47	19,260
29	[illegible]	34,380	[illegible]	[illegible]	61.60	[illegible]	[illegible]	22,500	[illegible]	20,610	[illegible]	19,260
30	[illegible]	34,110	62.40	[illegible]	61.57	25,200	[illegible]	[illegible]	60.75	20,880	[illegible]	19,260
31	63.11	33,300	[illegible]	[illegible]			61.07	22,500			[illegible]	18,990

Table 54.—Monthly Discharge of Winnipeg River at Otter Falls in Manitoba.

(Drainage area, 50,550 square miles.)

Month	Discharge in Second-Feet				Run-off Depth in inches on Drainage Area
	Maximum	Minimum	Mean	Per square mile	
1907					
January	[illegible] 170	26 000	[illegible] 960	0.533	0.615
February	29 400	18 500	[illegible] 880	0.455	0.474
March	19 180	18 500	17 320	0.343	0.395
April	16 160	14 400	14 590	0.289	0.322
May	[illegible] 420	14 400	16 [illegible]	0.3[illegible]	0.372
June	35 440	21 600	28 030	0.555	0.619
July	34 060	[illegible]	32 [illegible]	0.634	0.731
August	34 060	[illegible] 340	31 810	0.630	0.715
September	39 [illegible]	[illegible] 680	[illegible] 440	0.[illegible]	0.8[illegible]0
October	43 [illegible]	39 020	42 [illegible]	0.841	0.9[illegible]0
November	42 [illegible]40	41 470	[illegible] 680	0.844	0.943
December	[illegible]	36 540	[illegible]	0.[illegible]	0.90[illegible]
The Year	[illegible]	14 400	[illegible]	0.[illegible]	[illegible]
1908					
January	40 260	37 400	[illegible]	0.[illegible]	0.841
February	40 880	32 830	[illegible]	0.[illegible]	0.755
March	33 440	28 [illegible]	31 580	0.624	0.716
April	29 400	[illegible]	[illegible] 500	0.[illegible]	0.630
May	[illegible] 80	29 400	[illegible] 600	0.[illegible]	0.[illegible]
June	45 980	38 400	41 6[illegible]0	0.824	0.9[illegible]
July	43 980	41 800	42 980	0.850	0.980
August	54 800	[illegible]	[illegible]	0.[illegible]	0.962
September	[illegible]	33 4[illegible]	[illegible] 900	0.[illegible]10	0.[illegible]
October	34 680	29 340	33 040	0.654	0.[illegible]
November	30 340	[illegible]	28 400	0.56[illegible]	0.6[illegible]
December	[illegible]	[illegible] 600	[illegible]	0.467	0.532
The Year	43 980	[illegible] 600	33 [illegible]	0.6[illegible]	[illegible]
1909					
January	[illegible] 480	22 [illegible]	[illegible]	0.490	0.565
February	26 6[illegible]0	[illegible]	[illegible] 480	0.4[illegible]	0.498
March	[illegible]	16 [illegible]	[illegible] 820	0.3[illegible]	0.429
April	[illegible]	6 400	16 [illegible]	0.3[illegible]	0.369
May	[illegible] 140	16 400	[illegible] 300	0.403	0.463
June	[illegible]	[illegible] 440	[illegible] 500	0.486	0.542
July	[illegible]	[illegible] 830	24 650	0.488	0.[illegible]
August	[illegible]	[illegible]	[illegible] 830	0.488	0.560
September	[illegible]	[illegible] 600	[illegible] 900	0.441	0.49[illegible]
October	[illegible] 600	19 [illegible]	[illegible] 330	0.40[illegible]	0.464
November	[illegible] 030	19 [illegible]	[illegible] 470	0.40[illegible]	0.45[illegible]
December	[illegible]	[illegible] 030	[illegible] 830	0.445	0.5[illegible]
The Year	[illegible] 480	16 100	[illegible] 010	0.4[illegible]	[illegible]
1910					
January	[illegible]	[illegible] 440	[illegible]	0.499	[illegible]
February	[illegible]	[illegible] 440	[illegible]	0.[illegible]	[illegible]
March	[illegible]	[illegible]	[illegible]	0.[illegible]	0.[illegible]
April	[illegible]	[illegible]	[illegible]	0.[illegible]	0.[illegible]
May	[illegible]	[illegible] 880	[illegible]	[illegible]	[illegible]
June	57 [illegible]	44 [illegible]	48 [illegible]	[illegible]	[illegible]
July	43 [illegible]	[illegible]	[illegible]	[illegible]	0.841
August	[illegible] 480	[illegible]	[illegible]	0.48[illegible]	0.564
September	[illegible]	[illegible]	[illegible]	[illegible]	0.[illegible]
October	[illegible]	45 [illegible]	[illegible]	[illegible]	0.[illegible]
November	47 500	43 450	44 [illegible]	[illegible]	0.415
December	43 450	42 400	[illegible]	[illegible]	[illegible]
The Year	57 [illegible]	[illegible] 400	[illegible]	0.[illegible]	[illegible]

Table 54.—Monthly Discharge of Winnipeg River at Slave Falls in Manitoba.

[Drainage area, 49,700 square miles.]

NOTE.—The run-off data for this station may be slightly revised before publication in Water Resources Paper Number 4.

Month.	Discharge in Second-feet.				Run-off Depth in inches on Drainage Area.
	Maximum.	Minimum.	Mean.	Per square mile.	
1911					
January	17,140	13,350	14,820	0·298	0·344
February	14,550	12,600	13,280	0·267	0·278
March	13,350	11,700	12,540	0·253	0·291
April	12,950	11,700	12,390	0·249	0·279
May	16,860	12,780	14,770	0·297	0·343
June	19,660	16,860	18,340	0·369	0·412
July	25,260	19,660	22,900	0·461	0·531
August	26,940	25,260	26,130	0·526	0·606
September	25,820	24,110	24,810	0·499	0·558
October	27,220	24,420	25,960	0·517	0·602
November	25,260	20,780	22,950	0·462	0·516
December	20,500	17,980	19,340	0·389	0·448
The Year	27,220	11,700	19,018	0·383	5·24
1912					
January	22,460	17,980	20,080	0·404	0·466
February	18,540	15,800	16,840	0·339	0·353
March	15,550	12,300	13,820	0·278	0·321
April	16,200	12,700	13,570	0·273	0·305
May	27,500	16,500	22,800	0·459	0·529
June	30,580	26,380	28,100	0·566	0·632
July	27,220	25,820	26,380	0·531	0·612
August	28,060	27,500	27,710	0·558	0·646
September	30,860	27,500	29,410	0·592	0·655
October	34,780	30,300	33,070	0·665	0·767
November	34,500	31,700	32,610	0·656	0·732
December	30,860	28,060	29,400	0·592	0·682
The Year	34,780	12,300	24,483	0·493	6·70
1913					
January	28,170	27,630	27,996	0·563	0·649
February	28,170	22,230	26,115	0·525	0·548
March	21,690	16,290	19,095	0·384	0·443
April	20,610	16,290	17,817	0·359	0·401
May	32,190	21,690	28,370	0·571	0·658
June	33,570	31,950	32,733	0·658	0·736
July	32,760	26,010	29,503	0·594	0·684
August	28,730	26,550	27,695	0·557	0·642
September	26,820	23,040	25,263	0·508	0·568
October	22,500	14,940	18,276	0·368	0·424
November	16,290	14,670	15,662	0·315	0·352
December	16,290	13,050	14,722	0·296	0·342
The Year	33,570	13,050	23,609	0·475	6·45
1914					
January	14,670	12,510	13,703	0·276	0·318
February	14,100	11,700	13,233	0·267	0·278
March	14,670	11,970	13,815	0·279	0·321
April	15,750	13,590	14,580	0·294	0·328
May	23,310	14,670	18,745	0·377	0·435
June	34,650	24,930	31,480	0·634	0·708
July	35,460	33,300	34,735	0·698	0·806
August	33,300	29,790	31,550	0·635	0·732
September	29,790	24,660	26,170	0·526	0·588
October	26,550	22,500	24,805	0·499	0·575
November	22,700	20,610	21,[illegible]	0·428	0·477
December	21,150	18,450	19,840	0·399	0·460
The Year	35,460	11,700	21,995	0·443	6·04

PINAWA CHANNEL AT CONTROL DAM.

Location of Gauge.—Immediately below the control dam of the Winnipeg Electric Railway Company, near the head of the Pinawa channel.

Records available.—Gauge records are available over the open-water season for the years 1908, 1909, 1910, 1911, 1912, and 1914.

Gauge.—Vertical staff gauge, rock bolted.

Channel.—Permanent, artificial rock cut.

Discharge measurements.—During the years 1907 to 1911, inclusive, discharge measurements were made at this station by the engineers of the Winnipeg Electric Railway Company. From 1912 to date, measurements have been secured by the officers of the Manitoba Hydrographic Survey.

Winter Flow.—The open-water discharge curve is not applicable during the winter season.

Control.—The flow through the channel is dependent upon the elevation of the water level above the diversion weirs of the Winnipeg Electric Railway Company. This water level varies directly with the stage in the river, as the weirs act as free spillways. The discharge through the channel can be completely cut off by placing stoplogs in the control dam.

Table 55.—Discharge Measurements of the Pinawa Channel of the Winnipeg River at Control Dam.

NOTE.—Gauge heights refer to Upper gauge at Control Dam.

Date.	Hydrographer	Meter No.	Width	Area of Section	Mean Velocity.	Gauge Height	Discharge
1907.			Feet	Sq. ft.	Ft. per sec.	Feet.	Sec. ft.
Aug. 2	W. E. S. R. Co.					101.3[illegible]	[illegible]574
Aug. 11	"					101.45	[illegible]582
Oct. 8	"					102.10	6,[illegible]00
1908							
April 3	"					10[illegible].75	1,421
July 12 and 14	"					104.90	5,644[2]
Nov. [illegible] and 8	"					104.60	5,706[3]
1909.							
Ma[illegible] 24	"					104.40	4,545
May 24	"					104.75	[illegible],650[2]
July 17	"					105.00	[illegible]
1910							
Mar. 9	"					104.80	8,515
May 5	"					104.80	10,858
July 28	"					105.40	6,832
1911							
May 19	"					102.60	8,984
1912.							
May 11	A. M. Beale	1,196	131.5	1,657	5.84	10[illegible].00	9,[illegible]
June 1	G. H. Burnham	1,187	132.0	1,783	5.68	10[illegible]	10,014
June 22	"	1,187	131.5	1,758	5.[illegible]8	10[illegible]	10,159
July 17	"	1,187	131.5	1,[illegible]	5.75	10[illegible]	9,879

[1]Meter measurement over Spillway. [2]Weir measurement over Spillway. [3]Meter measurement over Spillway.

Table 55.—Discharge Measurements of the Pinawa Channel of the Winnipeg River at Control Dam.—Concluded.

NOTE.—Gauge heights refer to Upper gauge at Control Dam.

Date.	Hydrographer	Meter No.	Width	Area of Section	Mean Velocity	Gauge Height	Discharge.
1913.			Feet.	Sq. ft.	Ft. per sec.	Feet	Sec. ft.
Mar. 28	G. H. Burnham	1,486	131.5	1,746	4.29	103.51	7,497
July 16	S. C. O'Grady	1,445	131.5	1,758	5.68	103.67	9,986
July 28	"	1,445	131.5	1,705	5.71	103.36	9,738
1914.							
Jan. 15	F. B. Patterson	1,496	131.5	1,661	4.64	102.90	7,721
Feb. 17	W. J. Ireland	1,469	131.5	1,715	4.05	103.30	6,951
May 1	M. S. Madden	1,445	131.2	1,594	4.88	102.31	7,780
May 26	"	1,445	131.2	1,661	5.01	102.92	8,335
June 5	"	1,445	131.2	1,751	5.29	103.50	9,265
June 12	"	1,445	131.2	1,778	5.25	103.75	9,332
June 19	"	1,445	131.2	1,791	5.55	103.85	9,939
June 29	"	1,497	131.2	1,804	5.34	103.90	9,613
July 8	"	1,497	131.2	1,847	5.16	104.00	9,526
July 23	F. B. Patterson	1,497	131.2	1,796	5.65	103.91	10,157
July 27	L. C. Wilson	1,497	131.2	1,796	5.77	103.91	10,355
Aug. 1	"	1,497	131.2	1,781	5.88	103.87	10,484
Aug. 4	"	1,497	131.2	1,781	5.79	103.82	10,320
Aug. 5	"	1,497	131.2	1,781	5.75	103.79	10,241
Aug. 8		1,497	131.2	1,772	5.82	103.71	10,323
Aug. 19	P. K. Telford	1,497	131.2	1,750	5.99	103.68	10,495

Table 56.—Daily Discharge of the Pinawa Channel of the Winnipeg River at Control Dam.

1908

Day	May Gauge Height	May Discharge.	June Gauge Height	June Discharge	July Gauge Height	July Discharge.	August Gauge Height	August Discharge	September Gauge Height	September Discharge	October Gauge Height	October Discharge
	Feet.	Sec. ft.	Feet.	Sec. ft.	Feet	Sec. ft.	Feet	Sec. ft.	Feet	Sec. ft.	Feet.	Sec. ft.
1	100.75	7,025	98.80	5,520	98.90	5,590	98.80	5,520	99.00	5,660	99.00	5,660
2	100.75	7,025	98.70	5,450	98.80	5,520	98.80	5,520	99.05	5,695	99.00	5,660
3	100.70	6,980	98.70	5,450	98.85	5,555	98.80	5,520	99.05	5,695	99.00	5,660
4	100.70	6,980	98.70	5,450	98.90	5,590	98.80	5,520	99.05	5,695	99.00	5,660
5	100.70	6,980	98.70	5,450	98.90	5,590	98.80	5,520	99.10	5,730	99.00	5,660
6	100.75	7,025	98.70	5,450	98.90	5,590	98.80	5,520	99.10	5,730	99.00	5,660
7	100.75	7,025	98.70	5,450	98.90	5,590	98.90	5,590	99.10	5,730	99.00	5,660
8	100.20	6,560	98.70	5,450	98.90	5,590	98.85	5,555	99.10	5,730	99.00	5,660
9	99.70	6,165	98.65	5,417	98.90	5,590	98.85	5,555	99.10	5,730	99.00	5,660
10	99.70	6,165	98.65	5,417	98.90	5,590	98.85	5,555	99.00	5,660	99.00	5,660
11	99.70	6,165	98.75	5,485	98.85	5,555	98.90	5,590	99.00	5,660	99.00	5,660
12	99.80	6,240	98.80	5,520	98.80	5,520	98.90	5,590	99.00	5,660	99.00	5,660
13	99.20	5,800	99.00	5,660	98.85	5,555	98.90	5,590	99.00	5,660	99.00	5,660
14	99.20	5,800	99.00	5,660	98.85	5,555	98.90	5,590	99.00	5,660	99.00	5,660
15	99.20	5,800	99.00	5,660	98.85	5,555	98.90	5,590	99.00	5,660	99.00	5,660
16	99.20	5,800	99.00	5,660	98.85	5,555	98.95	5,625	99.00	5,660	99.00	5,660
17	99.20	5,800	99.00	5,660	98.85	5,555	98.95	5,625	99.00	5,660	99.00	5,660
18	99.20	5,800	99.00	5,660	98.80	5,520	98.95	5,625	99.00	5,660	99.00	5,660
19	99.20	5,800	99.00	5,660	98.80	5,520	98.95	5,625	99.00	5,660	99.00	5,660
20	99.15	5,765	99.00	5,660	98.85	5,555	98.95	5,625	99.00	5,660	99.00	5,660
21	99.50	6,015	98.90	5,590	98.85	5,555	98.90	5,590	99.00	5,660	99.00	5,660
22	99.50	6,015	98.90	5,590	98.85	5,555	98.90	5,590	99.00	5,660	99.00	5,660
23	99.50	6,015	99.00	5,660	98.85	5,555	98.90	5,590	98.90	5,590	99.00	5,660
24	99.50	6,015	98.90	5,590	98.85	5,555	98.90	5,590	98.90	5,590	99.10	5,730
25	99.50	6,015	98.95	5,625	98.80	5,520	98.90	5,590	98.90	5,590	99.30	5,870
26	99.50	6,015	98.90	5,590	98.80	5,520	98.90	5,590	99.00	5,660	99.50	6,015
27	99.50	6,015	98.90	5,590	98.80	5,520	98.90	5,590	99.10	5,730	99.50	6,015
28	99.60	6,090	98.90	5,590	98.80	5,520	99.00	5,660	99.00	5,660	99.50	6,015
29	99.60	6,090	98.90	5,590	98.80	5,520	99.00	5,660	99.00	5,660	99.50	6,015
30	99.60	6,090	98.90	5,590	98.80	5,520	99.00	5,660	99.00	5,660	99.40	5,940
31	99.30	5,870			98.80	5,520	99.00	5,660			99.40	5,940

Table 56.—Daily Discharge of the Pinawa Channel of the Winnipeg River at Control Dam—Continued.

1909

Day.	May.		June		July.		August		September		October	
	Gauge Height	Discharge	Gauge Height	Discharge	Gauge Height	Discharge	Gauge Height	Discharge	Gauge Height	Discharge	Gauge Height	Discharge
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	100·30	6,640	99·85	6,280	98·60	5,385	98·60	[illegible]	98·50	5,370	99·00	5,660
2	100·30	6,640	99·70	6,165	98·70	5,[illegible]	98·50	5,370	98·50	5,370	99·00	5,660
3	100·30	6,640	99·85	6,280	98·60	5,385	98·60	5,385	98·50	5,370	99·00	5,660
4	100·30	6,640	99·85	6,280	98·60	5,385	98·60	5,385	98·70	5,450	98·70	5,450
5	100·40	6,720	98·40	5,080	98·65	5,415	98·50	5,370	98·70	5,450	98·70	5,450
6	100·50	6,800	98·40	5,080	98·65	5,415	98·60	5,385	98·70	5,450	98·70	5,450
7	100·60	6,890	98·05	5,080	98·65	5,415	98·40	5,260	98·80	5,500	99·00	5,800
8	100·60	6,890	98·05	5,080	98·70	5,450	96·70	4,330	98·50	5,370	99·00	5,800
9	100·70	6,980	98·15	5,110	98·70	5,450	98·50	5,370	98·50	5,370	99·00	5,800
10	100·80	7,070	98·15	5,110	98·70	5,450	98·70	5,370	98·50	5,370	99·10	5,830
11	100·90	7,160	98·10	5,080	98·70	5,450	98·50	5,370	98·50	5,370	99·90	5,900
12	101·00	7,260	98·15	5,110	98·70	5,450	98·50	5,370	98·50	5,370	99·90	6,015
13	101·05	7,310	98·20	5,140	98·70	5,450	98·50	5,370	98·50	5,370	99·90	6,015
14	101·30	7,550	98·15	5,110	98·90	5,500	98·50	5,370	98·50	5,370	99·90	6,015
15	100·00	6,400	98·15	5,110	98·90	5,500	98·50	5,370	98·50	5,370	99·90	6,015
16	99·00	5,660	98·15	5,110	98·90	5,500	98·50	5,370	98·50	5,370	99·50	6,015
17	99·90	5,800	98·15	5,110	99·00	5,660	98·50	5,370	98·50	5,370	99·50	6,015
18	99·24	5,878	98·10	5,080	99·00	5,660	98·50	5,370	99·00	5,660	99·50	6,015
19	99·60	6,090	98·10	5,080	99·05	5,695	98·50	5,320	99·00	5,660	99·90	6,015
20	99·60	6,090	98·10	5,080	99·05	5,695	98·50	5,320	99·00	5,660	100·90	6,560
21	99·60	6,090	98·10	5,080	99·10	5,730	98·50	5,370	99·00	5,660	100·90	6,560
22	99·70	6,165	98·15	5,110	99·10	5,730	98·50	5,320	99·00	5,660	100·90	6,560
23	99·65	6,127	98·10	5,080	99·10	5,730	98·50	5,370	99·00	5,660	100·90	6,560
24	99·65	6,127	98·25	5,170	99·10	5,730	98·50	5,370	99·00	5,660	100·90	6,560
25	99·65	6,127	98·30	5,200	99·10	5,730	98·20	5,140	99·00	5,660	100·90	6,560
26	99·55	6,052	98·30	5,200	99·10	5,730	98·20	5,140	99·00	5,660	100·90	6,560
27	99·55	6,052	98·30	5,200	98·60	5,385	98·20	5,140	99·00	5,660	100·65	6,935
28	99·75	6,202	98·50	5,320	98·50	5,320	98·20	5,140	99·00	5,660	100·70	6,980
29	99·70	6,165	98·60	5,385	98·50	5,320	97·30	4,630	99·00	5,660	100·70	6,980
30	99·80	6,240	98·60	5,385	98·50	5,320	98·20	5,140	99·00	[illegible]	100·70	6,980
31	99·80	6,240			98·50	5,320	98·20	5,140			100·70	6,980

Note.—[illegible] August 10–30 the rating [illegible]

1910

Day	May		June		July		August		September		October	
1	104·[illegible]	[illegible]	[illegible]	[illegible]	99·6	6,090	99·1	[illegible]	[illegible]	5,660	[illegible]	[illegible]
2	104·[illegible]	[illegible]	[illegible]	[illegible]	99·6	6,090	99·1	[illegible]	99·0	5,660	[illegible]	[illegible]
3	104·[illegible]	[illegible]	[illegible]	[illegible]	99·6	6,090	99·1	[illegible]	99·0	5,660	[illegible]	[illegible]
4	104·[illegible]	[illegible]	104·1	[illegible]	[illegible]	6,015	[illegible]	[illegible]	99·0	5,660	[illegible]	[illegible]
5	104·[illegible]	[illegible]	[illegible]	[illegible]	99·4	[illegible]	[illegible]	[illegible]	99·0	5,660	[illegible]	5,800
6	104·[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	99·1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	104·[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	99·1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	104·[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	99·1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	104·[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	99·1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	104·[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	104	[illegible]	104·0	[illegible]	[illegible]	6,015	98·9	[illegible]	98·9	5,900	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6,015	98·9	[illegible]	98·9	5,900	[illegible]	[illegible]
13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	98·8	[illegible]	98·9	5,900	[illegible]	[illegible]
14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	98·8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	104·[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6,015	98·8	[illegible]	98·9	[illegible]	[illegible]	[illegible]
16	104·[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	98·8	[illegible]	98·9	[illegible]	[illegible]	[illegible]
17	104·[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	98·8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	98·9	[illegible]	[illegible]	6,015
19	104·[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	98·8	[illegible]	[illegible]	[illegible]	[illegible]	6,015
20	104·[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	98·8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	104·[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22	104·[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	100·[illegible]	[illegible]
23	104·[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	100·1	[illegible]
24	104·[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	98·9	[illegible]	[illegible]	[illegible]	100·1	[illegible]
25	104·[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	100·1	[illegible]
26	104	[illegible]	100·[illegible]	[illegible]	[illegible]	[illegible]	98·9	[illegible]	[illegible]	6,600	100·1	[illegible]
27	104	[illegible]	100·0	[illegible]	[illegible]	[illegible]	98·9	[illegible]	[illegible]	[illegible]	100·1	[illegible]
28	104·[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	98·9	[illegible]	[illegible]	[illegible]	100·1	[illegible]
29	104·[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	100	6,800
30	104·[illegible]	[illegible]	99·8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6,600	[illegible]	100·[illegible]	6,800
31	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]			100·[illegible]	[illegible]

Note.—[illegible]
[illegible]

Table 56.—*Daily Discharge of the Pinawa Channel of the Winnipeg River at Control Dam*—Continued.

1911.

Day.	May.		June.		July.		August.		September.		October.	
	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	102·0	8,300	102·6	8,975	102·9	9,350	103·2	9,725	103·1	9,600	103·1	9,600
2	102·0	8,300	102·6	8,975	103·0	9,475	103·2	9,725	103·1	9,600	103·1	9,600
3	102·1	8,110	102·7	9,100	103·0	9,475	103·2	9,725	103·1	9,600	103·1	9,600
4	102·1	8,410	102·7	9,100	103·0	9,475	103·2	9,725	103·1	9,600	103·1	9,600
5	102·1	8,410	102·7	9,100	103·0	9,475	103·2	9,725	103·1	9,600	103·1	9,600
6	102·1	8,410	102·7	9,100	103·0	9,475	103·2	9,725	103·1	9,600	103·1	9,600
7	102·1	8,410	102·7	9,100	103·0	9,475	103·2	9,725	103·1	9,600	103·1	9,600
8	102·1	8,410	102·7	9,100	103·0	9,475	103·2	9,725	103·1	9,600	103·1	9,600
9	102·2	8,520	102·8	9,225	103·0	9,475	103·2	9,725	103·1	9,600	103·1	9,600
10	102·2	8,520	102·8	9,225	103·1	9,600	103·2	9,725	103·1	9,600	103·1	9,600
11	102·2	8,520	102·8	9,225	103·1	9,600	103·2	9,725	103·1	9,600	103·2	9,725
12	102·3	8,630	102·8	9,225	103·1	9,600	103·2	9,725	103·1	9,600	102·5	8,850
13	102·3	8,630	102·8	9,225	103·1	9,600	103·2	9,725	103·1	9,600	102·1	8,410
14	102·3	8,630	102·8	9,225	103·1	9,600	103·2	9,725	103·1	9,600	102·1	8,410
15	102·4	8,740	102·8	9,225	103·1	9,600	103·2	9,725	103·1	9,600	101·9	8,190
16	102·4	8,740	102·8	9,225	103·1	9,600	103·2	9,725	103·1	9,600	101·7	7,970
17	102·4	8,740	102·8	9,225	103·1	9,600	103·2	9,725	103·1	9,600	101·5	7,760
18	102·4	8,740	102·9	9,350	103·1	9,600	103·2	9,725	103·1	9,600	101·1	7,360
19	102·4	8,740	102·9	9,350	103·1	9,600	103·2	9,725	103·1	9,600	100·9	7,160
20	102·4	8,740	102·9	9,350	103·2	9,725	103·2	9,725	103·1	9,600	100·8	7,070
21	102·5	8,850	102·9	9,350	103·2	9,725	103·2	9,725	103·1	9,600	100·8	7,070
22	102·5	8,850	102·9	9,350	103·2	9,725	103·2	9,725	103·1	9,600	100·8	7,070
23	102·5	8,850	102·9	9,350	103·2	9,725	103·2	9,725	103·1	9,600	100·8	7,070
24	102·5	8,850	102·9	9,350	103·2	9,725	103·2	9,725	103·1	9,600	100·8	7,070
25	102·5	8,850	102·9	9,350	103·2	9,725	103·2	9,725	103·1	9,600	100·8	7,070
26	102·6	8,975	102·9	9,350	103·2	9,725	103·2	9,725	103·1	9,600	100·8	7,070
27	102·6	8,975	102·9	9,350	103·2	9,725	103·2	9,725	103·1	9,600	100·8	7,070
28	102·6	8,975	102·9	9,350	103·2	9,725	103·2	9,725	103·1	9,600	100·8	7,070
29	102·6	8,975	102·9	9,350	103·2	9,725	103·2	9,725	103·1	9,600	100·8	[illegible]
30	102·6	8,975	102·9	9,350	103·2	9,725	103·2	9,725	103·1	9,600	100·8	7,070
31	102·6	8,975	......	......	103·2	9,725	103·2	9,725	...	...	100·8	7,070

NOTE.—Below gauge height 102·50 the rating curve is not well defined.

1912.

Day.	May.		June.		July.		August.		September.		October.	
1	102·5	8,850	103·5	10,100	......	......	.	.....	..		...	
2	102·7	9,100	103·5	10,100	......				..			
3	102·7	9,100	103·5	10,100	.....				..			
4	102·7	9,100	103·6	10,225	....							
5	102·7	9,100	103·6	10,225	....							
6	102·8	9,225	103·6	10,225	..							
7	102·8	9,225	103·6	10,225								
8	102·8	9,225	103·6	10,225					103·4	9,975		
9	102·8	9,225	103·6	10,225								
10	102·9	9,350	103·6	10,225								
11	102·9	[illegible]	103·6	10,225			101·0	[illegible]				
12	102·9	[illegible]	103·6	10,225								
13	102·9	[illegible]	103·6	10,225								
14	103·0	9,475	103·6	10,225								
15	103·1	9,600	103·6	10,225								
16	103·1	9,600	103·3	10,100					103·1	9,975		
17	103·1	9,600	103·5	10,100	103·2	9,725						
18	103·1	9,600	103·5	10,100								
19	103·2	9,725	103·5	10,100								
20	103·2	9,725	103·4	9,975								
21	103·2	9,725	103·4	9,975	103·[illegible]	[illegible]					103·8	10,4[illegible]5
22	103·3	9,850	103·1	9,975								
23	103·3	9,850	103·1	9,975								
24	103·3	9,850	103·4	9,975								
25	103·3	9,850										
26	103·3	9,850		.....								
27	103·3	9,850					103[illegible]	9,[illegible]				
28	103·3	9,975					103	[illegible]				
29	103·4	9,975					103·[illegible]	9,7[illegible]				
30	103·5	10,100										
31	103·5	10,100										

Table 56. Daily Discharge of the Pinawa Channel of the Winnipeg River at Control Dam—Continued.

1913.

Day	June Gauge Height	June Discharge	July Gauge Height	July Discharge
	Feet	Sec.-ft.	Feet	Sec.-ft.
1	103.60	10,200		
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15	103.70	10,400		
16			103.50	10,400
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				

1914.

Day	May Gauge Height	May Discharge	June Gauge Height	June Discharge	July Gauge Height	July Discharge	August Gauge Height	August Discharge	September Gauge Height	September Discharge	October Gauge Height	October Discharge
	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet.	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.
1	102.20	8,500			103.89	10,600	[illegible]	10,400	103.44	10,000	¹103.10	9,600
2	102.20	8,500			103.90	10,600	[illegible]	10,400	103.40	10,000	¹103.10	9,600
3	102.20	8,500			103.93	10,600	[illegible]	10,400	[illegible]	9,950	103.10	9,600
4	102.25	8,500			103.93	10,600	[illegible]	10,400	103.35	9,900	¹103.10	9,600
5	102.30	8,650			103.91	10,600	103.69	10,300	103.30	9,850	¹103.05	9,550
6	102.40	8,750			103.90	10,600	103.65	10,300	103.29	9,850	¹103.05	9,550
7	102.50	8,850			103.90	10,600	103.60	10,200	103.28	9,800	103.05	9,550
8	102.40	8,750			103.90	10,600	103.65	10,300	103.26	9,800	¹103.07	9,750
9	102.40	8,750			[illegible]	10,600	[illegible]	10,300	103.23	9,750	¹103.10	9,600
10					103.90	10,600	[illegible]	10,300	[illegible]	9,750	¹103.10	9,600
11					103.87	10,600	103.62	10,300	[illegible]	9,750	¹[illegible]	9,650
12			103.65	10,300	[illegible]	10,600	103.61	10,300	[illegible]	9,750	[illegible]	9,650
13			103.65	[illegible]	[illegible]	[illegible]	103.59	[illegible]	[illegible]	9,700	¹[illegible]	9,650
14			[illegible]	[illegible]	[illegible]	[illegible]	103.59	10,200	103.15	9,650	¹103.20	9,750
15			¹[illegible]	10,400	[illegible]	[illegible]	103.59	10,200	[illegible]	9,650	103.20	9,750
16			¹103.70	10,400	103.93	10,600	103.59	10,200	[illegible]	9,600	¹103.20	9,750
17			¹[illegible]	10,400	103.90	[illegible]	[illegible]	10,200	103.13	[illegible]	¹[illegible]	9,750
18			[illegible]	10,400	103.87	[illegible]	[illegible]	[illegible]	103.13	9,650	¹[illegible]	9,750
19			103.80	10,500	[illegible]	[illegible]	[illegible]	10,200	[illegible]	9,650	103.20	9,750
20			103.80	10,500	[illegible]	[illegible]	[illegible]	[illegible]	103.10	9,600	¹[illegible]	9,750
21			103.80	10,500	[illegible]	[illegible]	[illegible]	10,200	[illegible]	[illegible]	¹103.15	9,650
22			103.81	[illegible]	[illegible]	10,500	[illegible]	[illegible]	103.10	[illegible]	103.15	9,650
23			103.80	10,500	103.81	10,500	[illegible]	[illegible]	¹[illegible]	9,650	¹103.15	[illegible]
24			103.82	10,500	103.81	10,500	[illegible]	[illegible]	103.15	9,650	¹103.10	9,600
25			103.82	10,500	[illegible]	10,500	[illegible]	[illegible]	[illegible]	9,650	¹[illegible]	9,600
26			103.83	10,500	[illegible]	[illegible]	[illegible]	[illegible]	¹[illegible]	9,650	103.08	9,500
27			103.84	10,500	[illegible]	[illegible]	[illegible]	[illegible]	103.15	9,650	¹103.06	9,500
28			103.83	10,500	[illegible]	[illegible]	[illegible]	[illegible]	¹[illegible]	9,650	¹103.00	9,400
29			103.84	10,500	[illegible]	10,500	[illegible]	[illegible]	¹[illegible]	9,600	102.95	9,400
30			103.90	10,600	[illegible]	10,400	103.51	[illegible]	103.10	9,600	¹102.90	9,350
31					[illegible]	[illegible]	103.48	10,100			¹102.90	9,350

NOTE: Gauge height marked ¹ interpolated.

Table 57.—Monthly Discharge of the Pinawa Channel of the Winnipeg River at Control Dam.

Month	Discharge in Second Feet		
	Maximum	Minimum	Mean
1908			
May	7,025	5,800	6,250
June	5,660	5,417	5,550
July	5,690	5,520	5,550
August	5,660	5,5[illegible]0	5,600
September	5,[illegible]30	5,590	5,650
October	6,015	5,660	5,750
1909			
May	7,560	5,860	6,150
June	6,660	5,080	5,300
July	5,[illegible]30	5,320	5,500
August	5,885	1,100	5,200
September	5,660	5,430	5,550
October	6,[illegible]80	[illegible]150	6,150
1910			
[illegible]	11,[illegible]25	10,725	11,000
[illegible]	10,850	6,[illegible]40	9,500
[illegible]	6,000	5,730	5,900
[illegible]	5,[illegible]30	5,530	5,600
[illegible]	5,[illegible]50	5,590	5,600
[illegible]	6,800	5,740	6,900
1911			
May	8,975	8,300	8,700
June	9,350	8,975	9,250
July	9,[illegible]25	9,350	9,600
August	9,725	9,725	9,750
September	9,600	9,600	9,600
October	9,725	7,[illegible]60	8,200
1913			
May	10,100	8,850	9,250
June	10,225	9,9[illegible]5	*10,000
July			
August			
September		7,260	
1914			
June	10,600	10,300	*10,400
July	10,700	10,400	10,600
August	10,300	10,100	10,200
September	10,000	9,600	9,700
October	9,[illegible]50	9,350	9,600

NOTE.—Discharges marked thus * [illegible] estimated.

WEST BRANCH WINNIPEG RIVER AT NORTH TUNNEL ISLAND.

NOTE. Records at this station have been used in computing the discharge since 1907 for the western outlet and Keewatin mills. This rating is only applicable for the period subsequent to the damming of the eastern outlet in 1906. The discharges in Tables 58 and 59 record the above discharges of the western outlets plus that of the eastern outlet, i.e., the total outflow from the Lake of the Woods.

Location of Gauge.—On pile at south end of traffic bridge below Keewatin.

Records available. January 1, 1907, to December 31, 1914.

Drainage area.—26,400 square miles. This applies to the combined flow of the West and East branches of the Winnipeg river at the Lake of the Woods outlets.

Gauge.—Vertical staff. Previous to June 29, 1912, gauge heights were obtained from the Ontario Department of Public Works. They were referred to a chain gauge located in the tail-race of mill A, Lake of the Woods Milling Co., Keewatin. On the above date a gauge was established by the Manitoba Hydrographic Survey on the traffic bridge below Keewatin.

Channel.—Permanent, rock

Discharge measurements. Discharge measurements for the purposes of rating the station have been made since 1912 at a section 1 mile below the station, on the north side of Tunnel island, by the Manitoba Hydrographic Survey.

Winter Flow. Discharge measurements indicate that the open-water discharge curve is applicable during winter months.

Control. The flow is controlled by the operation of the Norman dam and the Lake of the Woods Milling Company's power plants. Some 12 miles downstream from the station the river breaks into two narrow channels, one through the Dalles and one through Throat rapids, both acting as partial controls on the discharging capacity of the river.

Accuracy. The estimated daily discharges, as tabulated from 1907 to 1912, are based on gauge heights furnished by the Ontario Department of Public Works. These records are at times in error, and the estimated discharges are therefore subject to correction.

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)

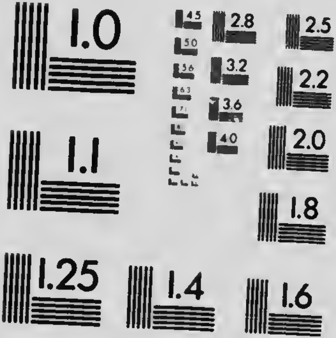


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Table 58.—Total Daily Discharge of the Winnipeg River at Outlets of Lake of the Woods, Ontario.

Note.—The run-off data for this station may be slightly revised when the investigations of the Lake of the Woods Technical Board are completed.

[Drainage area, 26,400 square miles.]

1907.

Day.	January.		February.		March.		April.		May.		June.	
	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	......	12,080	......	11,530	......	10,980	......	10,100	......	10,430	......	11,420
2	......	12,080	......	11,530	......	10,980	......	10,100	......	10,430	......	11,420
3	......	12,080	......	11,530	......	10,980	......	10,100	......	10,430	......	11,420
4	......	12,080	......	11,420	......	10,980	......	10,100	......	10,430	......	11,530
5	......	11,860	......	11,420	......	10,760	......	10,100	......	10,540	......	11,640
6	......	11,860	......	11,420	......	10,760	......	10,100	......	10,540	......	12,740
7	......	11,860	......	11,420	......	10,760	......	10,100	......	10,760	......	13,180
8	......	11,860	......	11,420	......	10,760	......	10,320	......	10,760	......	13,290
9	......	11,860	......	11,310	......	10,760	......	10,320	......	10,870	......	13,490
10	......	11,860	......	11,310	......	10,760	......	10,320	......	10,870	......	13,400
11	......	11,860	......	11,310	......	10,760	......	10,320	......	10,980	......	13,730
12	......	11,860	......	11,310	......	10,760	......	10,320	......	11,090	......	14,060
13	......	11,860	......	11,310	......	10,760	......	10,320	......	11,310	......	14,280
14	......	11,860	......	11,310	......	10,760	......	10,320	......	11,420	......	14,500
15	......	11,860	......	11,200	......	10,760	......	10,320	......	11,420	......	14,500
16	......	11,860	......	11,200	......	10,760	......	10,320	......	11,530	......	14,720
17	......	11,860	......	11,200	......	10,760	......	10,320	......	11,420	......	14,720
18	......	11,860	......	11,200	......	10,650	......	10,320	......	11,420	......	14,720
19	......	11,860	......	11,090	......	10,650	......	10,320	......	11,530	......	14,830
20	......	11,860	......	11,090	......	10,540	......	10,320	......	11,530	......	14,940
21	......	11,860	......	11,090	......	10,540	......	10,320	......	11,640	......	14,940
22	......	11,640	......	11,090	......	10,540	......	10,320	......	11,640	......	14,940
23	......	11,640	......	11,090	......	10,540	......	10,320	......	11,640	......	15,160
24	......	11,640	......	11,090	......	10,430	......	10,320	......	11,640	......	15,160
25	......	11,530	......	11,090	......	10,430	......	10,320	......	11,640	......	15,160
26	......	11,530	......	10,980	......	10,320	......	10,320	......	11,420	......	15,160
27	......	11,530	......	10,980	......	10,320	......	10,320	......	11,420	......	15,160
28	......	11,530	......	10,980	......	10,320	......	10,430	......	11,420	......	15,160
29	......	11,530	......	......	......	10,210	......	10,430	......	11,420	......	15,380
30	......	11,530	......	......	......	10,210	......	10,430	......	11,420	......	15,380
31	......	11,530	......	......	......	10,100	......	......	......	11,420	......	......

	July.		August.		September.		October.		November.		December.	
1	......	15,160	......	12,740	......	15,054	......	19,687	......	21,466	......	20,347
2	......	15,160	......	12,520	......	15,287	......	19,797	......	21,477	......	20,439
3	......	14,940	......	12,300	......	15,494	......	19,687	......	21,447	......	20,386
4	......	14,940	......	12,300	......	15,494	......	20,127	......	21,227	......	20,290
5	......	15,160	......	12,520	......	15,714	......	20,127	......	21,243	......	20,277
6	......	14,940	......	12,520	......	15,824	......	20,347	......	21,451	......	20,164
7	......	14,940	......	12,300	......	15,934	......	20,347	......	21,469	......	20,183
8	......	14,720	......	12,300	......	16,154	......	20,347	......	21,459	......	20,127
9	......	14,720	......	12,300	......	16,044	......	20,581	......	21,258	......	20,164
10	......	14,720	......	12,080	......	16,044	......	20,581	......	21,241	......	19,936
11	......	14,500	......	12,080	......	16,154	......	20,691	......	21,247	......	19,988
12	......	14,060	......	12,080	......	16,264	......	20,787	......	21,028	......	19,878
13	......	14,060	......	12,300	......	16,264	......	20,787	......	21,480	......	19,755
14	......	14,060	......	12,080	......	16,484	......	20,787	......	21,480	......	19,794
15	......	14,060	......	12,300	......	16,581	......	20,787	......	21,461	......	19,674
16	......	14,060	......	12,300	......	16,814	......	20,787	......	21,477	......	19,520
17	......	14,[illegible]	......	12,080	......	16,801	......	20,801	......	21,227	......	19,574
18	......	14,060	......	12,520	......	17,131	......	20,897	......	21,241	......	19,526
19	......	11,060	......	12,520	......	17,254	......	20,897	......	21,020	......	19,438
20	......	13,620	......	12,960	......	17,254	......	21,007	......	21,040	......	19,410
21	......	13,620	......	13,721	......	17,571	......	21,007	......	21,034	......	19,439
22	......	13,400	......	13,721	......	17,914	......	21,007	......	20,827	......	19,250
23	......	13,180	......	13,941	......	18,341	......	21,227	......	20,810	......	19,398
24	......	13,180	......	14,149	......	18,574	......	21,227	......	20,677	......	19,379
25	......	13,180	......	13,954	......	18,794	......	21,227	......	20,590	......	19,307
26	......	13,180	......	14,284	......	19,247	......	21,328	......	20,374	......	19,307
27	......	13,290	......	14,601	......	19,247	......	21,461	......	20,374	......	19,399
28	......	13,400	......	14,724	......	19,357	......	21,417	......	20,371	......	19,389
29	......	13,400	......	14,834	......	19,687	......	21,667	......	20,372	......	19,202
30	......	13,180	......	14,834	......	19,687	......	21,672	......	20,385	......	19,379
31	......	12,740	......	14,821	......	......	......	21,447	......	......	......	19,376

Table 58.—Total Daily Discharge of the Winnipeg River at Outlets of Lake of the Woods, Ontario.—Continued

1908.

Day.	January.		February.		March.		April.		May.		June.	
	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	....	19,278	....	19,002	....	17,04	....	16,95[illegible]	....	16,855	....	21,050
2	....	19,308	....	18,870	....	17,07[illegible]	....	16,951	....	16,841	....	24,066
3	....	19,295	....	18,870	....	17,078	....	16,841	....	17,075	....	21,286
4	....	19,300	....	18,892	....	17,286	....	16,841	....	17,061	....	21,506
5	....	19,241	....	18,780	....	17,288	....	16,841	....	17,061	....	22,166
6	....	19,345	....	18,670	....	17,385	....	17,061	....	16,951	....	[illegible] 266
7	....	19,348	....	18,671	....	17,382	....	17,061	....	17,061	....	[illegible]284
8	....	19,325	....	18,434	....	17,597	....	17,061	....	17,061	....	23,064
9	....	19,327	....	18,413	....	17,597	....	16,951	....	17,061	....	23,061
10	....	19,347	....	18,430	....	17,710	....	16,841	....	17,171	....	23,064
11	....	19,418	....	18,430	....	17,714	....	16,841	....	17,391	....	23,284
12	....	19,234	....	18,320	....	17,707	....	16,811	....	17,515	....	23,724
13	....	19,414	....	18,321	....	17,597	....	16,841	....	18,065	....	23,724
14	....	19,404	....	18,319	....	17,607	....	16,841	....	18,285	....	23,914
15	....	19,261	....	18,321	....	17,487	....	16,841	....	18,395	....	23,504
16	....	19,267	....	18,193	....	17,499	....	16,841	....	18,395	....	23,504
17	....	19,261	....	18,193	....	17,492	....	16,811	....	18,395	....	23,284
18	....	19,277	....	18,101	....	17,187	....	16,841	....	18,615	....	23,284
19	....	19,247	....	18,100	....	17,377	....	16,855	....	18,850	....	23,064
20	....	19 250	....	18,102	....	17,377	....	16,855	....	19,071	....	23,064
21	....	19,261	....	18,102	....	17,377	....	16,855	....	19,070	....	23,064
22	....	19,045	....	17,882	....	17,267	....	16,855	....	19,275	....	22,844
23	....	1[illegible] 050	....	17,863	....	17,281	....	16,855	....	19,290	....	22,844
24	....	1[illegible] 044	....	17,880	....	17,171	....	16,855	....	[illegible],275	....	22,844
25	....	18,944	....	17,683	....	17,207	....	16 855	....	19,290	....	22,811
26	....	18,917	....	17,687	....	17,171	....	16,965	....	19,730	....	22,624
27	....	18,942	....	17,468	....	17,061	....	16,965	....	20,170	....	22,624
28	....	18,829	....	17,468	....	17,061	....	16,965	....	20,406	....	22,624
29	....	18,834	....	17,262	....	17,061	....	16,965	....	20,846	....	22,642
30	....	18,913	....	....	....	17,061	....	16,951	....	20,940	....	22,642
31	....	18,830	....	....	....	16,951	....	....	....	21,066	....	....

Day.	July.		August.		September.		October.		November.		December.	
1	....	22,624	....	20,884	....	19,370	....	17,[illegible]61	....	14,013	....	11,364
2	....	22,404	....	20,864	....	19,347	....	17,061	....	14,041	....	11,379
3	....	22,404	....	20,754	....	19,110	....	16,884	....	13,924	....	11,168
4	....	22,195	....	20,877	....	19,128	....	16,858	....	13,926	....	11,180
5	....	22,194	....	20,653	....	18,872	....	17,066	....	13,813	....	11,222
6	....	22,404	....	20,647	....	18,863	....	16,855	....	13,814	....	11,141
7	....	22,404	....	20,428	....	18,851	....	16,415	....	13,827	....	11,011
8	....	22,624	....	20,661	....	18,639	....	16,201	....	14,007	....	10,800
9	....	22,184	....	20,644	....	18,638	....	16,455	....	13,796	....	10,577
10	....	22,404	....	20,429	....	18,634	....	16,463	....	13,822	....	10,795
11	....	22,404	....	20,323	....	18,432	....	16,449	....	13,601	....	10,575
12	....	22,184	....	20,314	....	18,397	....	16,231	....	13,600	....	10,572
13	....	21,964	....	20,213	....	18,180	....	13,381	....	13,607	....	10,270
14	....	21,964	....	20,322	....	18,199	....	15,356	....	13,494	....	10,350
15	....	21,744	....	20,350	....	17,973	....	15,148	....	13,353	....	10,349
16	....	21,744	....	20,204	....	17,983	....	14,714	....	12,931	....	10,354
17	....	21,524	....	20,428	....	17,981	....	14,954	....	12,500	....	10,354
18	....	21,524	....	20,429	....	18,200	....	14,879	....	12,266	....	10,582
19	....	21,524	....	20,645	....	18,013	....	14,666	....	11,826	....	10,137
20	....	21,634	....	20,430	....	17,755	....	14,694	....	11,826	....	10,118
21	....	21,741	....	20,218	....	17,740	....	14,675	....	11,810	....	10,353
22	....	21,304	....	20,213	....	17,941	....	14,907	....	11,562	....	10,334
23	....	21,304	....	19,981	....	17,735	....	14,911	....	11,594	....	10,328
24	....	21,304	....	19,987	....	17,516	....	14,925	....	11,596	....	10,317
25	....	21,541	....	20,000	....	17,527	....	14,687	....	11,599	....	10,315
26	....	21,304	....	19,801	....	17,320	....	14,470	....	11,820	....	10,320
27	....	21,084	....	19,783	....	17,295	....	14,472	....	11,600	....	10,303
28	....	21,084	....	19,565	....	17,295	....	14,469	....	11,602	....	10,322
29	....	21,084	....	19,786	....	17,528	....	14,253	....	11,571	....	10,316
30	....	21,084	....	19,769	....	17,520	....	14,258	....	11,600	....	10,320
31	....	21,085	....	19,575	....	....	....	14,262	....	....	....	10,343

Table 58.—Total Daily Discharge of the Winnipeg River at Outlets of Lake of the Woods, Ontario—Continued.

1909.

Day.	January.		February.		March.		April.		May.		June.	
	Gauge Height	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height	Dis-charge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	......	10,360	......	9,542	......	10,549	......	11,095	......	10,416	......	11,730
2	......	10,360	......	9,481	......	10,528	......	11,021	......	10,163	......	11,940
3	......	10,360	......	9,909	......	10,745	......	11,007	......	[illegible]	......	11,951
4	......	10,360	......	9,919	......	10,730	......	10,757	......	[illegible]	......	11,986
5	......	10,140	......	9,957	......	10,780	......	11,082	......	10,718	......	11,743
6	......	10,140	......	9,754	......	10,722	......	11,229	......	10,754	......	11,515
7	......	10,209	......	9,701	......	10,591	......	11,101	......	10,684	......	11,935
8	......	10,199	......	9,819	......	10,761	......	11,026	......	10,405	......	11,931
9	......	10,239	......	9,793	......	10,948	......	11,011	......	10,357	......	11,974
10	......	10,194	......	9,848	......	10,824	......	10,807	......	10,625	......	11,732
11	......	10,139	......	9,848	......	10,803	......	10,812	......	11,050	......	11,516
12	......	10,241	......	9,875	......	10,695	......	11,171	......	11,010	......	11,503
13	......	10,247	......	9,915	......	10,716	......	11,323	......	10,920	......	11,294
14	......	10,238	......	9,812	......	10,777	......	11,316	......	10,967	......	11,714
15	......	10,233	......	9,938	......	10,998	......	11,304	......	10,950	......	11,725
16	......	10,229	......	9,898	......	11,074	......	11,265	......	10,544	......	11,730
17	......	10,169	......	10,131	......	11,047	......	11,025	......	10,884	......	11,735
18	......	10,178	......	10,123	......	11,008	......	10,571	......	11,129	......	11,739
19	......	9,955	......	10,307	......	10,987	......	10,610	......	11,286	......	11,892
20	......	9,693	......	10,328	......	10,957	......	10,788	......	11,589	......	11,729
21	......	9,714	......	10,137	......	10,980	......	10,805	......	11,577	......	11,701
22	......	9,700	......	10,316	......	11,119	......	10,889	......	11,566	......	11,674
23	......	9,698	......	10,308	......	11,127	......	10,873	......	11,210	......	11,931
24	......	9,475	......	10,401	......	11,139	......	10,857	......	11,321	......	11,931
25	......	9,490	......	10,397	......	11,142	......	10,058	......	11,717	......	11,924
26	......	9,465	......	10,597	......	11,143	......	10,421	......	11,495	......	11,711
27	......	9,476	......	10,509	......	11,128	......	10,706	......	11,507	......	11,509
28	......	9,514	......	10,507	......	10,968	......	10,370	......	11,510	......	11,931
29	......	9,527	......	......	......	11,066	......	10,423	......	11,735	......	11,921
30	......	9,561	......	......	......	11,016	......	10,437	......	11,545	......	11,918
31	......	9,536	......	......	......	11,101	......	......	......	11,723	......	......

Day.	July.		August.		September.		October.		November.		December.	
1	......	11,730	......	11,726	......	11,756	......	12,439	......	11,735	......	12,158
2	......	11,932	......	11,737	......	12,015	......	12,206	......	12,064	......	12,172
3	......	11,929	......	11,914	......	12,123	......	11,852	......	12,190	......	12,174
4	......	11,717	......	11,713	......	12,059	......	12,123	......	12,154	......	11,884
5	......	11,939	......	11,713	......	11,737	......	12,411	......	12,139	......	11,613
6	......	11,716	......	11,562	......	11,758	......	12,222	......	12,116	......	11,970
7	......	11,711	......	11,725	......	11,718	......	12,227	......	11,639	......	12,120
8	......	11,934	......	11,290	......	11,787	......	11,856	......	11,842	......	12,133
9	......	12,050	......	11,689	......	11,690	......	12,036	......	12,036	......	12,045
10	......	12,068	......	11,694	......	11,697	......	11,852	......	11,869	......	12,050
11	......	11,731	......	11,742	......	11,864	......	11,352	......	11,920	......	11,900
12	......	11,721	......	11,663	......	11,749	......	11,609	......	12,138	......	11,546
13	......	11,930	......	11,359	......	11,586	......	11,839	......	11,989	......	11,836
14	......	11,946	......	11,539	......	11,602	......	11,839	......	11,672	......	11,930
15	......	11,953	......	11,509	......	11,928	......	12,043	......	12,112	......	11,982
16	......	11,950	......	11,683	......	[illegible]	......	12,079	......	12,110	......	11,973
17	......	11,954	......	11,914	......	[illegible]	......	11,429	......	12,162	......	11,965
18	......	11,729	......	11,897	......	[illegible]	......	11,524	......	12,141	......	11,812
19	......	11,918	......	11,834	......	11,736	......	12,074	......	12,135	......	11,614
20	......	11,930	......	11,506	......	12,108	......	12,100	......	12,035	......	11,853
21	......	11,929	......	11,539	......	11,915	......	12,327	......	11,719	......	11,953
22	......	11,739	......	11,499	......	11,931	......	12,332	......	12,004	......	11,928
23	......	11,751	......	11,772	......	12,032	......	12,335	......	12,136	......	11,967
24	......	11,935	......	11,773	......	12,202	......	11,853	......	12,125	......	11,957
25	......	11,718	......	11,980	......	12,450	......	12,069	......	12,195	......	11,605
26	......	11,912	......	11,975	......	11,827	......	12,309	......	12,239	......	11,530
27	......	11,919	......	11,978	......	11,963	......	12,122	......	12,183	......	11,819
28	......	11,909	......	11,775	......	12,214	......	12,086	......	11,710	......	11,977
29	......	11,751	......	11,727	......	12,229	......	12,080	......	12,012	......	11,982
30	......	11,751	......	11,536	......	12,227	......	11,904	......	12,112	......	11,974
31	......	11,763	......	11,534	......	......	......	11,626	......	......	......	11,967

Table 58.—Total Daily Discharge of the Winnipeg River at Outlets of Lake of the Woods, Ontario.—Continued.

1910.

Day.	January. Gauge Height.	January. Discharge.	February. Gauge Height.	February. Discharge.	March. Gauge Height.	March. Discharge.	April. Gauge Height.	April. Discharge.	May. Gauge Height.	May. Discharge.	June. Gauge Height.	June. Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	......	11,848	......	11,656	......	11,889	......	20,907	......	21,540	......	23,[illegible]
2	......	11,636	......	11,766	......	11,930	......	21,090	......	21,815	......	21,058
3	......	11,906	......	11,770	......	11,601	......	20,854	......	25,031	......	23,971
4	......	12,000	......	11,787	......	11,601	......	21,155	......	26,238	......	23,772
5	......	12,001	......	11,794	......	11,585	......	21,312	......	25,222	......	23,593
6	......	11,977	......	11,565	......	11,707	......	21,487	......	24,991	......	23,724
7	......	11,552	......	11,761	......	11,705	......	21,468	......	21,919	......	23,725
8	......	11,656	......	11,750	......	11,696	......	21,496	......	24,550	......	22,844
9	......	11,424	......	11,910	......	11,719	......	21,371	......	24,516	......	22,398
10	......	11,630	......	11,921	......	11,896	......	20,987	......	21,845	......	21,740
11	......	11,706	......	11,902	......	13,596	......	21,260	......	21,701	......	21,284
12	......	11,738	......	11,665	......	13,336	......	21,665	......	25,145	......	20,830
13	......	11,740	......	11,548	......	12,826	......	21,680	......	25,121	......	21,131
14	......	11,719	......	11,787	......	12,973	......	21,669	......	21,913	......	21,004
15	......	11,488	......	11,915	......	12,918	......	21,746	......	24,556	......	21,125
16	......	11,356	......	11,679	......	13,142	......	21,631	......	24,862	......	21,106
17	......	11,546	......	11,913	......	13,150	......	21,487	......	25,111	......	21,093
18	......	11,703	......	11,921	......	13,332	......	21,749	......	24,592	......	20,995
19	......	11,685	......	11,781	......	13,377	......	22,191	......	24,981	......	20,956
20	......	11,708	......	11,572	......	13,109	......	22,358	......	24,704	......	21,094
21	......	11,699	......	11,833	......	13,408	......	22,381	......	25,082	......	21,318
23	......	11,607	......	11,935	......	13,415	......	22,825	......	24,213	......	21,226
23	......	11,340	......	11,931	......	17,783	......	22,735	......	24,515	......	21,083
24	......	11,558	......	11,920	......	17,918	......	22,501	......	23,920	......	21,057
25	......	11,675	......	11,918	......	18,141	......	22,770	......	24,428	......	21,150
26	......	11,676	......	11,704	......	18,208	......	23,233	......	24,584	......	20,958
27	......	11,643	......	11,583	......	17,835	......	23,707	......	24,346	......	21,079
28	......	11,663	......	11,789	......	17,980	......	24,117	......	24,667	......	21,437
29	......	11,562	......	......	......	18,259	......	24,813	......	[illegible]	......	21,205
30	......	11,327	......	......	......	19,766	......	24,949	......	23,988	......	21,254
31	......	11,575	......	......	......	20,402	......	......	......	24,100	......	......

Day.	July.		August.		September.		October.		November.		December.	
1	......	20,921	......	13,986	......	11,584	......	11,135	......	9,360	......	8,560
2	......	20,862	......	11,167	......	11,793	......	10,760	......	9,207	......	8,581
3	......	20,745	......	14,190	......	11,795	......	11,160	......	9,045	......	8,335
4	......	20,192	......	13,970	......	11,739	......	11,445	......	8,613	......	7,957
5	......	20,375	......	13,970	......	11,796	......	11,488	......	9,121	......	8,305
6	......	20,457	......	11,150	......	11,813	......	11,192	......	8,217	......	8,437
7	......	20,449	......	13,722	......	12,046	......	11,233	......	8,634	......	8,362
8	......	17,351	......	13,791	......	12,092	......	11,100	......	8,846	......	8,214
9	......	16,525	......	13,982	......	11,936	......	10,563	......	8,869	......	8,210
10	......	16,098	......	13,760	......	11,749	......	10,364	......	8,957	......	8,216
11	......	15,996	......	13,518	......	11,735	......	10,416	......	8,957	......	7,809
12	......	15,988	......	13,394	......	12,084	......	10,428	......	8,917	......	8,042
13	......	15,764	......	17,508	......	11,711	......	10,431	......	8,478	......	8,187
14	......	15,560	......	17,419	......	11,809	......	9,983	......	8,645	......	8,168
15	......	15,513	......	12,957	......	11,960	......	9,832	......	8,899	......	8,170
16	......	15,364	......	13,049	......	11,968	......	9,458	......	8,868	......	8,196
17	......	14,952	......	12,893	......	11,960	......	9,766	......	9,010	......	8,070
18	......	15,067	......	12,671	......	11,539	......	10,154	......	8,996	......	7,660
19	......	14,858	......	12,785	......	11,919	......	10,188	......	8,712	......	8,085
20	......	14,664	......	12,455	......	11,822	......	10,026	......	8,272	......	8,172
21	......	14,800	......	12,189	......	11,864	......	9,721	......	8,654	......	8,169
22	......	14,588	......	12,195	......	11,881	......	9,746	......	8,719	......	8,170
23	......	14,574	......	12,253	......	11,656	......	9,345	......	8,800	......	8,073
24	......	14,374	......	12,153	......	11,703	......	9,489	......	8,551	......	8,004
25	......	14,310	......	12,397	......	11,231	......	9,545	......	8,790	......	7,721
26	......	14,131	......	12,157	......	11,192	......	9,594	......	8,818	......	7,651
27	......	14,349	......	11,943	......	11,362	......	9,542	......	8,276	......	7,818
28	......	14,352	......	11,748	......	11,671	......	9,599	......	8,681	......	7,982
29	......	14,017	......	12,268	......	11,640	......	9,512	......	8,720	......	7,916
30	......	13,913	......	11,886	......	11,441	......	9,053	......	8,828	......	8,005
31	......	13,713	......	11,564	......	......	......	9,329	......	......	......	7,991

Table 58.—Total Daily Discharge of the Winnipeg River at Outlets of Lake of the Woods, Ontario—Continued.

1911.

Day.	January. Gauge Height.	January. Discharge.	February. Gauge Height.	February. Discharge.	March. Gauge Height.	March. Discharge.	April. Gauge Height.	April. Discharge.	May. Gauge Height.	May. Discharge.	June. Gauge Height.	June. Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	....	7,788	....	7,304	....	7,125	....	8,628	....	8,717	....	8,522
2	....	7,987	....	7,212	....	7,129	....	8,593	....	9,161	....	8,517
3	....	8,088	....	7,247	....	7,140	....	8,618	....	9,159	....	8,753
4	....	8,084	....	7,066	....	7,064	....	8,861	....	9,152	....	8,585
5	....	8,088	....	6,732	....	6,602	....	9,018	....	9,154	....	8,657
6	....	8,081	....	7,117	....	6,586	....	9,008	....	9,100	....	9,041
7	....	7,993	....	7,269	....	6,829	....	9,114	....	8,645	....	9,149
8	....	7,502	....	7,218	....	6,888	....	8,971	....	8,791	....	9,172
9	....	7,802	....	7,236	....	6,927	....	8,558	....	9,116	....	9,152
10	....	7,985	....	7,236	....	6,548	....	8,815	....	9,007	....	9,048
11	....	7,976	....	7,241	....	6,161	....	9,096	....	9,011	....	8,707
12	....	7,988	....	6,733	....	6,420	....	9,085	....	9,156	....	8,662
13	....	7,838	....	7,117	....	6,424	....	9,201	....	8,950	....	9,019
14	....	7,987	....	7,230	....	6,955	....	9,181	....	8,473	....	9,127
15	....	7,586	....	7,201	....	6,957	....	9,312	....	8,558	....	9,150
16	....	7,891	....	7,129	....	6,962	....	8,813	....	8,927	....	9,151
17	....	7,970	....	7,187	....	6,957	....	8,936	....	8,851	....	9,160
18	....	7,975	....	6,940	....	6,954	....	9,153	....	8,799	....	8,624
19	....	7,784	....	6,713	....	6,455	....	9,171	....	8,851	....	8,829
20	....	7,763	....	7,035	....	6,589	....	9,292	....	8,904	....	9,326
21	....	7,675	....	7,131	....	7,011	....	9,174	....	8,453	....	8,797
22	....	7,283	....	7,116	....	7,066	....	9,174	....	8,315	....	8,540
23	....	7,381	....	7,164	....	7,068	....	8,806	....	8,688	....	9,149
24	....	7,551	....	7,142	....	6,937	....	8,835	....	8,375	....	9,374
25	....	7,534	....	7,151	....	7,049	....	9,144	....	8,599	....	8,870
26	....	7,554	....	6,817	....	6,575	....	9,122	....	8,273	....	9,041
27	....	7,160	....	7,187	....	6,894	....	9,109	....	8,546	....	9,487
28	....	7,254	....	7,147	....	7,054	....	9,148	....	8,208	....	9,176
29	....	6,886	....	....	....	7,047	....	9,172	....	8,421	....	8,747
30	....	6,997	....	....	....	6,591	....	8,695	....	8,727	....	8,901
31	....	7,286	....	....	....	6,581	....	....	....	8,718	....	....

Day.	July. Gauge Height.	July. Discharge.	August. Gauge Height.	August. Discharge.	September. Gauge Height.	September. Discharge.	October. Gauge Height.	October. Discharge.	November. Gauge Height.	November. Discharge.	December. Gauge Height.	December. Discharge.
1	....	8,779	....	8,566	....	6,872	....	5,806	....	5,911	....	5,450
2	....	8,719	....	8,341	....	6,776	....	5,991	....	5,919	....	5,612
3	....	8,821	....	8,343	....	6,725	....	6,214	....	5,745	....	5,094
4	....	9,123	....	8,235	....	6,598	....	6,015	....	5,779	....	5,463
5	....	8,796	....	8,230	....	6,982	....	6,185	....	5,112	....	5,629
6	....	8,789	....	8,100	....	6,601	....	6,196	....	5,564	....	5,680
7	....	8,930	....	8,138	....	6,751	....	6,481	....	5,907	....	5,690
8	....	9,097	....	8,122	....	6,768	....	5,778	....	5,785	....	5,563
9	....	8,815	....	8,125	....	6,401	....	5,601	....	5,736	....	5,675
10	....	9,003	....	8,160	....	6,196	....	6,029	....	5,716	....	5,078
11	....	9,139	....	8,131	....	6,247	....	6,213	....	5,817	....	5,306
12	....	8,748	....	8,244	....	6,722	....	6,046	....	5,272	....	5,581
13	....	9,091	....	7,988	....	6,903	....	6,254	....	5,490	....	5,443
14	....	9,46[illegible]	....	8,248	....	7,124	....	6,268	....	5,749	....	5,666
15	....	7,16	....	8,250	....	7,311	....	5,498	....	5,751	....	5,701
16	....	8,730	....	8,261	....	7,116	....	5,769	....	5,775	....	5,695
17	....	8,806	....	8,201	....	6,562	....	6,230	....	5,306	....	5,193
18	....	9,125	....	8,045	....	6,796	....	6,228	....	5,496	....	5,384
19	....	9,118	....	8,396	....	6,948	....	6,062	....	5,210	....	5,696
20	....	9,155	....	7,479	....	7,180	....	6,102	....	5,625	....	5,695
21	....	8,748	....	8,107	....	6,980	....	6,065	....	5,653	....	5,669
22	....	9,214	....	7,955	....	7,029	....	5,349	....	5,675	....	5,660
23	....	8,754	....	7,951	....	6,921	....	5,682	....	5,617	....	5,686
24	....	8,792	....	7,940	....	6,295	....	5,971	....	5,626	....	5,165
25	....	8,540	....	7,926	....	5,940	....	5,891	....	5,546	....	5,113
26	....	8,310	....	7,750	....	6,519	....	5,866	....	5,143	....	5,469
27	....	8,314	....	7,293	....	6,567	....	5,999	....	5,371	....	5,714
28	....	8,314	....	7,459	....	6,339	....	5,924	....	5,688	....	5,790
29	....	8,570	....	7,300	....	6,723	....	5,408	....	5,733	....	5,804
30	....	8,525	....	7,419	....	6,555	....	5,480	....	5,800	....	5,786
31	....	8,563	....	6,799	....	....	....	5,777	....	....	....	5,288

Table 58.—Total Daily Discharge of the Winnipeg River at Outlets of Lake of the Woods, Ontario—Concluded.

1912.

Day.	January.		February.		March.		April.		May.		June.	
	Gauge Height.	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height.	Discharge.	Gauge Height	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	......	5,246	......	5,532	......	6,267	......	6,020	......	6,455		6,466
2	......	5,592	......	5,485	......	6,25[illegible]	......	6,189	......	6,611		5,178
3	......	5,726	......	5,698	......	5,767	......	6,296	......	6,571		4,978
4	......	5,698	......	5,171	......	6,071	......	6,289	......	5,956		5,942
5	......	5,533	......	5,574	......	6,066	......	6,287	......	6,754	......	6,282
6	......	5,363	......	5,656	......	6,019	......	6,305	......	6,422	......	6,137
7	......	5,275	......	5,722	......	6,097	......	6,106	......	6,670	......	5,568
8	......	5,637	......	5,744	......	6,070	......	6,120	......	6,8[illegible]4	......	5,121
9	......	5,855	......	5,748	......	6,109	......	6,291	......	6,843	......	4,962
10	......	5,816	......	5,717	......	5,731	......	6,191	......	6,843	......	4,761
11	......	5,812	......	5,219	......	5,920	......	6,324	......	6,878	......	4,831
12	......	5,787	......	5,481	......	6,242	......	6,330	......	6,382	......	4,913
13	......	5,760	......	5,750	......	6,129	......	6,382	......	6,640	......	5,597
14	......	5,301	......	5,702	......	6,136	......	5,722	......	7,006	......	5,584
15	......	5,431	......	5,793	......	6,152	......	6,090	......	7,015	......	5,60[illegible]
16	......	5,633	......	5,856	......	6,085	......	6,286	......	6,968	......	5,603
17	......	5,576	......	5,978	......	5,619	......	6,396	......	6,716	......	5,516
18	......	5,690	......	5,158	......	5,985	......	6,315	......	6,747	......	5,710
19	......	5,647	......	5,830	......	6,180	......	6,338	......	5,980	......	5,842
20	......	5,551	......	6,083	......	6,184	......	6,373	......	6,280	......	5,853
21	......	5,153	......	6,121	......	6,137	......	5,851	......	6,548	......	5,826
22	......	5,422	......	5,945	......	6,088	......	6,089	......	6,568	......	5,565
23	......	5,612	......	6,238	......	5,885	......	6,138	......	6,635	......	4,975
24	......	5,618	......	6,102	......	5,616	......	6,496	......	6,527	......	5,015
25	......	5,551	......	5,596	......	6,001	......	6,495	......	6,370	......	5,274
26	......	5,703	......	5,954	......	6,161	......	6,557	......	5,806	......	5,296
27	......	5,681	......	6,275	......	5,809	......	6,619	......	5,783	......	5,306
28	......	5,266	......	6,321	......	6,131	......	6,006	......	6,345	......	5,238
29	......	5,272	......	6,261	......	6,410	......	6,311	......	6,036	......	5,197
30	......	5,522	......	......	......	5,817	......	6,607	......	6,330	......	4,674
31	......	5,531	......		......	5,464	......	......	......	6,174	......	......

Day.	July.		August.		September.		October.		November.		December.	
1	......	4,475	......	5,262	......	4,756	......	5,825	......	11,675	......	11,034
2	......	4,436	......	5,208	......	5,209	......	5,904	......	11,782	......	10,881
3	......	4,959	......	5,287	......	5,891	......	5,901	......	10,657	......	11,397
4	......	4,893	......	4,726	......	5,723	......	6,899	......	11,154	......	11,378
5	......	4,956	......	5,114	......	5,804	......	6,102	......	11,669	......	11,385
6	......	5,025	......	5,491	......	5,207	......	7,461	......	11,674	......	11,411
7	......	4,591	......	5,454	......	5,283	......	8,647	......	11,550	......	11,416
8	......	4,665	......	5,021	......	4,955	......	9,240	......	9,996	......	11,228
9	......	4,555	......	5,518	......	5,136	......	9,239	......	9,761	......	11,375
10	......	5,061	......	5,521	......	5,283	......	9,574	......	8,552	......	11,752
11	......	5,002	......	5,018	......	5,470	......	9,746	......	8,648	......	11,848
12	......	5,106	......	5,300	......	5,466	......	9,773	......	9,467	......	11,856
13	......	5,017	......	5,523	......	5,550	......	8,883	......	10,679	......	11,831
14	......	4,580	......	5,602	......	5,577	......	9,414	......	11,122	......	11,796
15	......	4,562	......	5,664	......	5,330	......	9,881	......	11,208	......	11,429
16	......	5,111	......	5,665	......	5,451	......	10,197	......	11,117	......	11,648
17	......	4,969	......	5,673	......	5,481	......	10,744	......	10,452	......	11,808
18	......	5,122	......	5,106	......	5,285	......	11,086	......	10,787	......	11,842
19	......	4,904	......	5,138	......	5,205	......	11,308	......	11,233	......	11,816
20	......	4,875	......	5,590	......	5,289	......	10,321	......	11,043	......	11,851
21	......	4,425	......	5,747	......	5,351	......	10,618	......	11,258	......	11,86[illegible]
22	......	4,605	......	5,752	......	5,169	......	10,776	......	11,398	......	11,232
23	......	4,907	......	5,815	......	5,361	......	11,747	......	11,618	......	11,250
24	......	5,111	......	5,890	......	5,525	......	11,628	......	10,822	......	11,543
25	......	5,097	......	5,230	......	5,660	......	11,605	......	11,175	......	11,193
26	......	5,072	......	5,314	......	5,753	......	11,294	......	11,620	......	11,558
27	......	5,197	......	5,276	......	5,695	......	10,412	......	11,840	......	11,687
28	......	4,672	......	5,554	......	5,828	......	10,771	......	12,010	......	11,709
29	......	4,970	......	5,815	......	5,447	......	11,212	......	11,960	......	11,065
30	......	5,079	......	5,677	......	5,660	......	11,496	......	11,795	......	11,437
31	......	4,980	......	5,431	......	......	......	11,660	......	......	......	11,594

Table 58.—Total Daily Discharge of the Winnipeg River at Outlets of Lake of the Woods, Ontario—Continued.

1913

Day.	January.		February.		March.		April.		May.		June.	
	Gauge Height.	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	.....	11,553	.....	11,708	.....	6,981	.....	6,686	.....	16,325	.....	19,605
2	.....	11,581	.....	11,517	.....	6,978	.....	6,616	.....	16,122	.....	19,719
3	.....	11,739	.....	11,475	.....	7,208	.....	6,204	.....	16,646	.....	20,474
4	.....	11,819	.....	11,482	.....	7,410	.....	6,039	.....	15,798	.....	20,531
5	.....	11,311	.....	11,403	.....	7,306	.....	6,011	.....	16,000	.....	20,701
6	.....	11,535	.....	11,391	.....	7,279	.....	5,817	.....	16,710	.....	20,782
7	.....	11,837	.....	11,358	.....	7,236	.....	6,119	.....	16,968	.....	20,709
8	.....	11,716	.....	11,241	.....	7,147	.....	6,410	.....	16,911	.....	19,937
9	.....	11,802	.....	10,751	.....	6,632	.....	6,738	.....	17,070	.....	19,863
10	.....	11,584	.....	10,712	.....	6,388	.....	6,450	.....	17,180	.....	20,579
11	.....	11,605	.....	10,739	.....	7,178	.....	6,200	.....	16,277	.....	20,703
12	.....	11,166	.....	10,621	.....	7,269	.....	6,181	.....	16,376	.....	20,444
13	.....	11,336	.....	10,446	.....	7,306	.....	5,898	.....	17,559	.....	20,319
14	.....	11,586	.....	10,298	.....	7,317	.....	5,915	.....	18,347	.....	20,118
15	.....	11,461	.....	10,152	.....	7,353	.....	6,075	.....	19,238	.....	19,647
16	.....	11,565	.....	9,361	.....	6,625	.....	6,456	.....	19,579	.....	19,570
17	.....	11,617	.....	9,258	.....	6,484	.....	6,866	.....	19,697	.....	20,273
18	.....	11,637	.....	9,045	.....	7,182	.....	7,106	.....	19,050	.....	20,582
19	.....	11,172	.....	8,747	.....	7,176	.....	7,205	.....	18,978	.....	20,582
20	.....	11,473	.....	8,340	.....	7,343	.....	6,432	.....	19,252	.....	20,561
21	.....	11,659	.....	8,043	.....	7,350	.....	6,651	.....	19,720	.....	20,451
22	.....	11,707	.....	7,664	.....	7,404	.....	9,237	.....	20,128	.....	19,685
23	.....	11,733	.....	6,948	.....	6,575	.....	10,938	.....	20,806	.....	19,674
24	.....	11,693	.....	6,848	.....	6,486	.....	12,702	.....	19,503	.....	19,927
25	.....	11,640	.....	7,138	.....	7,072	.....	14,132	.....	19,223	.....	20,136
26	.....	11,225	.....	7,250	.....	6,955	.....	14,827	.....	19,232	.....	20,042
27	.....	11,358	.....	7,081	.....	7,0?2	.....	14,186	.....	19,469	.....	19,850
28	.....	11,588	.....	6,895	.....	6,915	.....	14,542	.....	19,880	.....	19,768
29	.....	11,489	.....	.....	.....	6,905	.....	15,705	.....	20,223	.....	18,882
30	.....	11,508	.....	.....	.....	6,090	.....	16,023	.....	20,383	.....	18,837
31	.....	11,583	.....	.....	.....	6,101	.....	.....	.....	20,443	.....	.....

Day.	July.		August.		September.		October.		November.		December.	
1	.....	18,674	.....	15,875	.....	1?,555	.....	8,407	.....	8,447	.....	8,287
2	.....	18,786	.....	15,734	.....	14,380	.....	8,562	.....	7,317	.....	8,682
3	.....	19,476	.....	14,921	.....	14,140	.....	8,552	.....	7,612	.....	8,857
4	.....	19,604	.....	14,867	.....	2?6	.....	8,437	.....	8,217	.....	8,842
5	.....	18,570	.....	14,664	.....		.....	6,977	.....	8,332	.....	8,477
6	.....	17,704	.....	14,923	.....		.....	7,997	.....	8,392	.....	8,087
7	.....	17,142	.....	14,981	.....		.....	8,217	.....	8,422	.....	6,827
8	.....	16,964	.....	15,170	.....		.....	8,412	.....	8,147	.....	7,327
9	.....	15,596	.....	15,150	.....		.....	8,347	.....	7,087	.....	7,792
10	.....	13,871	.....	14,665	.....		.....	8,542	.....	7,337	.....	7,962
11	.....	13,341	.....	14,704	.....	[illegible]	.....	8,342	.....	8,317	.....	8,057
12	.....	13,338	.....	14,955	.....	13,928	.....	7,592	.....	8,337	.....	8,277
13	.....	12,652	.....	14,997	.....	13,959	.....	8,027	.....	8,302	.....	8,122
14	.....	13,224	.....	14,952	.....	13,725	.....	8,352	.....	8,202	.....	7,112
15	.....	13,096	.....	15,212	.....	13,699	.....	8,322	.....	8,142	.....	7,187
16	.....	13,194	.....	15,267	.....	13,908	.....	8,352	.....	6,997	.....	7,657
17	.....	13,224	.....	14,850	.....	13,934	.....	8,342	.....	7,692	.....	8,082
18	.....	13,246	.....	14,550	.....	14,021	.....	8,497	.....	8,112	.....	8,407
19	.....	12,931	.....	14,668	.....	14,264	.....	7,272	.....	8,287	.....	8,127
20	.....	12,237	.....	14,648	.....	13,811	.....	7,212	.....	8,612	.....	8,237
21	.....	12,267	.....	14,731	.....	12,207	.....	8,337	.....	8,257	.....	7,632
22	.....	12,519	.....	15,009	.....	13,440	.....	8,147	.....	8,482	.....	7,692
23	.....	12,715	.....	14,951	.....	11,430	.....	8,277	.....	7,422	.....	8,232
24	.....	14,119	.....	14,681	.....	10,609	.....	8,347	.....	7,777	.....	8,482
25	.....	15,061	.....	14,593	.....	10,576	.....	8,427	.....	8,432	.....	7,572
26	.....	15,201	.....	14,655	.....	10,551	.....	7,547	.....	8,582	.....	7,952
27	.....	14,751	.....	15,058	.....	10,074	.....	7,752	.....	8,627	.....	8,457
28	.....	14,960	.....	14,426	.....	7,260	.....	8,417	.....	8,627	.....	7,652
29	.....	15,487	.....	14,582	.....	8,421	.....	8,552	.....	8,702	.....	7,992
30	.....	15,720	.....	14,832	.....	8,542	.....	8,580	.....	7,592	.....	8,642
31	.....	15,831	.....	14,017	.....	.....	.....	8,482	.....	.....	.....	8,797

Table 58.—Total Daily Discharge of the Winnipeg River at Outlets of Lake of the Woods, Ontario—Continued.

1911

Day	January.		February.		March.		April.		May.		June.	
	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1		8,697		7,817		10,602		10,017		10,163		16,594
2		8,792		7,717		10,607		10,012		10,363		16,944
3		8,767		8,112		10,517		10,007		10,323		17,119
4		7,987		8,157		10,197		10,127		10,278		17,262
5		7,667		8,182		10,542		9,737		10,273		17,391
6		7,832		7,857		10,542		9,212		10,193		17,331
7		7,792		7,812		10,632		10,057		10,828		17,039
8		8,277		7,417		9,982		10,032		11,008		17,479
9		8,657		7,507		10,172		9,967		10,743		17,821
10		8,752		7,727		10,657		9,352		9,948		18,301
11		8,032		7,752		10,682		9,372		10,070		18,356
12		8,172		7,737		10,752		9,297		11,100		18,371
13		8,567		7,842		10,822		8,852		11,260		18,481
14		8,617		7,892		10,707		9,087		11,223		17,959
15		8,687		7,712		9,702		9,512		11,365		18,011
16		8,417		7,517		9,712		9,312		11,209		17,979
17		8,172		7,752		10,282		9,347		10,760		17,782
18		7,557		7,717		10,482		9,607		11,493		18,094
19		7,327		8,082		10,362		9,557		11,925		18,551
20		7,737		8,207		10,597		10,217		12,370		18,792
21		7,997		8,167		10,597		10,157		13,005		18,576
22		7,532		8,442		9,982		10,447		13,480		19,044
23		7,407		8,732		10,037		9,872		13,625		19,867
24		7,467		9,777		10,277		9,907		13,245		20,166
25		7,077		10,017		10,222		9,887		13,555		20,259
26		7,147		10,332		10,232		9,812		14,315		20,352
27		7,657		10,657		10,267		8,927		15,300		20,302
28		7,787		11,172		10,217		10,222		16,363		19,737
29		7,967		......		9,812		10,537		16,880		19,786
30		8,077		......		9,662		10,462		17,078		19,891
31		8,077		......		9,812		......		16,875		......

Day	July.		August.		September.		October.		November.		December.	
1	......	19,421	......	19,419	......	13,842	......	13,321	......	9,506	......	10,015
2	......	19,482	......	19,201	......	13,562	......	13,325	......	9,626	......	10,131
3	......	19,541	......	19,317	......	13,562	......	13,313	......	9,736	......	10,210
4	......	19,582	......	19,591	......	13,577	......	12,658	......	9,795	......	10,179
5	......	19,619	......	19,625	......	13,742	......	13,092	......	9,739	......	10,081
6	......	19,581	......	19,545	......	13,367	......	13,397	......	9,751	......	8,739
7	......	19,671	......	19,289	......	13,617	......	13,447	......	9,735	......	9,150
8	......	20,059	......	19,159	......	13,857	......	13,517	......	9,361	......	9,413
9	......	19,994	......	18,943	......	13,732	......	13,557	......	9,476	......	9,414
10	......	20,229	......	18,897	......	13,892	......	13,612	......	9,864	......	9,554
11	......	20,019	......	18,860	......	13,497	......	12,850	......	9,937	......	9,133
12	......	19,834	......	18,836	......	13,667	......	12,822	......	9,950	......	9,111
13	......	19,881	......	18,765	......	13,181	......	13,179	......	9,945	......	8,687
14	......	19,939	......	18,633	......	13,732	......	12,386	......	9,917	......	9,605
15	......	20,149	......	18,583	......	13,742	......	11,115	......	9,306	......	10,019
16	......	20,311	......	18,457	......	13,903	......	10,671	......	9,343	......	10,115
17	......	20,371	......	18,567	......	13,667	......	10,333	......	9,415	......	9,944
18	......	20,476	......	18,612	......	13,864	......	9,487	......	9,824	......	9,844
19	......	19,944	......	18,917	......	13,565	......	9,866	......	10,065	......	9,825
20	......	20,019	......	19,272	......	13,215	......	10,421	......	10,065	......	8,926
21	......	19,811	......	19,332	......	13,329	......	10,260	......	9,989	......	9,573
22	......	19,866	......	19,112	......	13,492	......	10,436	......	9,601	......	10,056
23	......	19,859	......	18,497	......	13,253	......	9,752	......	10,402	......	0,141
24	......	19,857	......	18,887	......	13,475	......	9,581	......	10,520	......	0,029
25	......	19,794	......	18,917	......	13,242	......	9,521	......	10,708	......	9,589
26	......	19,694	......	16,592	......	13,138	......	9,707	......	10,604	......	9,604
27	......	19,644	......	15,590	......	12,903	......	9,817	......	10,601	......	8,973
28	......	19,959	......	14,972	......	13,187	......	9,795	......	10,362	......	9,428
29	......	20,171	......	14,127	......	13,322	......	10,126	......	9,980	......	10,030
30	......	20,286	......	13,877	......	13,377	......	10,091	......	10,015	......	10,081
31	......	20,218	......	13,7[illegible]7	......	......	......	9,852	......	......	......	10,000

Table 59.—Monthly Discharges of Winnipeg River at the Outlet of the Lake of the Woods.

(Drainage Area, 26,400 square miles.)

NOTE.—The run-off data for this station may be slightly revised when the investigations of the Lake of the Woods Technical Board are completed.

Month	Discharge in Second-Feet.				Run-off.
	Maximum.	Minimum.	Mean.	Per Square Mile.	Depth in inches on Drainage Area.
1907.					
January	12,080	11,530	11,790	0·417	0·515
February	11,530	10,980	11,250	0·426	0·411
March	10,980	10,100	10,610	0·403	0·465
April	10,440	10,100	10,280	0·390	0·435
May	11,610	10,130	11,170	0·423	0·488
June	15,380	[illegible]	14,000	0·530	0·592
July	15,160	12,741	11,055	0·532	0·614
August	11,831	12,080	12,730	0·482	0·556
September	19,687	15,051	17,080	0·617	0·722
October	21,672	19,687	20,790	0·788	0·908
November	21,480	[illegible]	21,075	0·798	0·891
December	20,430	[illegible]	19,730	0·747	0·862
The Year	21,672	10,100	14,560	0·551	7·49
1908					
January	19,418	18,829	19,190	0·727	0·839
February	19,002	17,262	18,230	0·691	0·720
March	17,714	16,951	17,340	0·657	0·758
April	17,061	16,811	16,900	0·640	0·714
May	21,066	16,811	18,470	0·700	0·807
June	23,941	21,050	22,830	0·865	0·966
July	22,624	21,081	21,800	0·826	0·953
August	20,881	19,565	20,300	0·769	0·887
September	19,370	17,295	18,200	0·690	0·770
October	17,066	11,253	15,420	0·581	0·674
November	14,041	11,562	12,810	0·485	0·542
December	11,379	10,118	10,580	0·401	0·462
The Year	23,941	10,118	17,670	0·670	9·09
1909					
January	10,360	9,465	9,970	0·378	0·436
February	10,597	9,481	10,040	0·380	0·396
March	11,143	10,528	10,910	0·413	0·477
April	11,323	10,058	10,870	0·412	0·459
May	11,735	10,168	11,040	0·418	0·483
June	11,986	11,291	11,770	0·446	0·497
July	12,068	11,711	11,850	0·449	0·518
August	11,980	11,290	[illegible]695	0·443	0·511
September	12,450	11,586	[illegible]40	0·452	0·505
October	12,439	11,352	[illegible]05	0·455	0·525
November	12,239	11,639	[illegible]20	0·455	0·508
December	12,174	11,530	[illegible]915	0·452	0·521
The Year	12,450	9,465	11,345	0·430	5·84
1910					
January	12,001	11,327	11,660	0·442	0·510
February	11,943	11,548	11,790	0·447	0·465
March	20,402	11,585	14,260	0·540	0·624
April	24,949	20,854	22,120	0·838	0·935
May	25,238	23,920	24,690	0·935	1·079
June	24,058	20,830	21,870	0·828	0·924
July	20,921	13,713	16,290	0·617	0·712
August	17,508	11,564	13,270	0·503	0·580
September	12,092	11,192	11,750	0·445	0·497
October	11,488	9,053	10,180	0·386	0·445
November	9,360	8,217	8,787	0·333	0·371
December	8,584	7,654	8,110	0·307	0·355
The Year	25,238	7,654	14,570	0·55	7·50

Table 59.—Monthly Discharges of Winnipeg River at the Outlet of the Lake of the Woods.—Concluded.

Month.	Discharge in Second-Feet				Run-off
	Maximum.	Minimum.	Mean.	Per Square Mile.	Depth in inches on Drainage Area.
1911					
January	8,088	6,886	7,700	0·292	0·33
February	7,393	6,711	7,110	0·269	0·281
March	7,110	6,420	6,845	0·259	0·299
April	9,312	8,558	8,995	0·341	0·380
May	9,161	8,208	8,770	0·332	0·383
June	9,087	8,517	8,945	0·339	0·378
July	9,361	7,465	8,770	0·332	0·383
August	8,566	6,799	7,985	0·303	0·349
September	7,311	5,910	6,715	0·254	0·284
October	6,381	5,349	5,915	0·228	0·260
November	5,919	5,112	5,615	0·2[illegible]	0·237
December	5,801	5,078	5,540	0·[illegible]	0·242
The Year	9,487	5,078	7,110	0·284	3·81
1912					
January	5,855	5,154	5,555	0·210	0·243
February	6,391	5,171	5,795	0·220	0·229
March	6,26[illegible]	5,164	6,010	0·228	0·263
April	6,619	5,722	6,270	0·238	0·265
May	7,045	5,784	6,505	0·246	0·284
June	6,466	4,661	5,135	0·2[illegible]	0·230
July	5,197	4,425	4,870	0·185	0·213
August	5,890	4,736	5,430	0·206	0·237
September	5,828	4,756	5,125	0·206	0·229
October	11,717	5,835	9,720	0·368	0·425
November	12,010	8,553	10,990	0·417	0·465
December	11,861	10,884	11,520	0·436	0·504
The Year	12,010	4,425	6,965	0·261	3·59
1913.					
January	11,837	11,166	11,560	0·438	0·506
February	11,708	6,818	9,570	0·363	0·378
March	7,440	6,090	6,990	0·265	0·305
April	16,023	5,847	8,550	0·321	0·361
May	20,806	15,798	18,370	0·696	0·803
June	[illegible]782	18,847	21,100	0·762	0·850
July	19,604	13,337	15,023	0·569	0·656
August	15,875	13,017	1[illegible],880	0·561	0·650
September	14,585	[illegible],200	13,100	0·496	0·554
October	8,580	7,212	8,180	0·310	0·358
November	8,702	7,087	8,090	0·306	0·312
December	8,8[illegible]	[illegible]	8,050	0·305	0·352
The Year	[illegible]	[illegible]	1[illegible],872	0·450	6·12
1914.					
January	[illegible]92			0·304	0·350
February	[illegible],172	[illegible]		0·317	0·330
March	10,822	[illegible]		0·391	0·451
April	10,547	[illegible]	[illegible]	0·370	0·413
May	17,078	9,[illegible]	[illegible]	0·466	0·548
June	20,352	16,[illegible]	[illegible]	0·706	0·780
July	20,476	19,[illegible]	[illegible]	0·754	0·870
August	19,625	13,[illegible]	[illegible]	0·[illegible]	0·796
September	13,903	12,90[illegible]		0·[illegible]	0·572
October	13,612	9,[illegible]48		0·[illegible]	0·501
November	10,708	9,[illegible]		0·[illegible]	0·419
December	10,210	8,[illegible]		0·373	0·430
The Year	20,476	7,077		0·475	6·45

Table 60.—Discharge Measurements in head-race of Kerora power station.

1911.

No.	Date.		Forebay Gauge	Discharge	Est. Weir.	Net Discharge	Load.	Head.	Efficiency.
			Feet.	Sec.-ft.	Sec.-ft.	Sec.-ft.	K.W.	Feet.	Per cent.
1	February	21	97·67	1,047·8	19·8	1,028·0	1,059	22·89	54·2
2		"	97·65	1,329·7	19·1	1,310·6	1,323	22·74	52·6
3		25	97·65	1,312·0	19·1	1,292·9	1,389	22·58	56·2
4		"	97·65	1,242·1	19·1	1,223·0	1,359	22·58	58·4
5		"	97·65	1,282·0	19·1	1,262·9	1,340	22·58	55·5
6		"	97·65	1,309·0	19·5	1,289·5	1,359	22·65	55·0
7		26	97·66	1,394·5	19·5	1,375·0	1,314	22·50	55·3
8	March	2	97·67	711·3	19·5	691·8	810	23·15	59·3
9		"	97·61	776·7	18·8	757·9	836	23·29	55·9
10		3	97·68	1,393·3	20·2	1,373·1	1,351	22·59	55·3
11		"	97·68	1,461·9	20·2	1,441·7	1,610	22·47	58·6
12		"	97·68	1,506·1	[illegible]	1,486·2	1,668	22·33	59·1
13		7	97·65	1,259·3	19·1	1,240·3	1,372	22·60	57·8
14		"	97·65	1,312·3	19·1	1,293·2	1,357	22·60	51·8
15		"	97·64	1,236·4	18·7	1,217·7	1,316	22·59	56·5
16		"	97·69	1,251·7	20·6	1,231·1	1,282	22·74	51·0
17		"	97·68	1,212·2	20·2	1,220·0	1,267	22·68	54·0
18		"	97·68	1,200·1	20·2	1,180·2	1,265	22·68	55·8
19		"	97·69	1,255·6	20·5	1,235·1	1,284	22·70	54·0
20		8	97·71	1,249·8	21·3	1,228·5	1,2[illegible]	22·78	51·0
21		"	97·70	1,201·9	20·9	1,181·0	[illegible]	22·77	55·1
22		"	97·68	1,239·3	20·2	1,219·1	1,236	22·73	52·8
23		"	97·69	1,223·7	20·6	1,203·1	1,250	22·74	54·0
24		"	97·67	1,249·3	19·8	1,229·5	1,266	22·76	53·5
25			97·66	1,266·4	19·5	1,246·9	1,307	22·69	54·5
26		"	97·66	1,262·6	19·5	1,243·1	1,275	22·61	53·5
27		9	97·73	815·6	22·8	792·8	717	23·29	45·8
28		"	97·75	771·5	22·8	748·7	767	23·29	51·9
29		"	97·76	776·6	23·2	753·4	727	23·31	48·9
30		"	97·77	765·4	23·6	741·8	710	23·42	48·2
31		"	97·78	719·0	24·0	695·0	702	23·52	50·8
32		"	97·77	718·8	24·6	725·2	696	23·49	48·2
33		"	97·76	613·0	23·2	589·8	672	23·46	57·2
34		10	7·70	1,451·4	20·9	1,431·5	1,567	22·59	57·2
35		"	97·71	1,538·0	21·3	1,516·7	1,607	22·52	55·5
36		"	97·70	1,468·8	20·9	1,447·9	1,622	22·48	58·8
37		15	97·70	1,441·7	20·9	1,420·8	1,613	22·69	59·2
38		"	97·70	1,541·2	20·9	1,520·3	1,639	22·62	56·2
39		"	97·69	1,439·2	20·5	1,418·7	1,607	22·54	59·4
40		19	97·68	1,303·8	20·2	1,283·6	1,351	22·68	54·7
41		"	97·68	1,270·2	20·2	1,250·0	1,354	22·68	56·3
42		"	97·68	1,279·7	20·2	1,259·5	1,354	22·68	56·1
43		"	97·69	1,202·9	20·6	1,182·3	1,317	22·71	58·8
44		20	97·71	1,265·6	22·4	1,241·2	1,321	22·76	55·1
45		"	97·74	1,318·2	22·4	1,295·8	1,340	22·76	53·6
46		"	97·74	1,317·7	22·4	1,295·3	1,341	22·76	53·8
47		"	97·74	1,269·6	22·4	1,247·2	1,318	22·76	[illegible]
48	April	4	97·80	693·5	24·7	668·8	520	23·54	39·9
49		"	97·81	729·3	25·3	704·2	536	23·54	[illegible]
50		"	97·82	754·6	25·5	729·1	549	23·54	[illegible]
51		"	97·82	712·8	25·5	687·3	519	23·59	37·8
52		"	97·82	643·7	25·5	618·2	428	23·63	34·7
53		"	97·80	687·4	24·7	662·7	496	23·55	37·5
54		"	97·81	702·9	25·1	677·8	501	23·57	37·0
55		5	97·80	657·2	24·7	632·5	547	23·55	43·3
56		"	97·82	671·7	25·5	646·2	519	23·61	40·1
57		"	97·82	666·5	25·5	641·0	552	23·57	43·1
58		"	97·82	710·6	25·5	685·1	529	23·56	38·7
59		"	97·82	691·4	25·5	665·9	527	23·56	39·7
60		"	97·83	618·5	25·9	592·6	394	23·62	33·3
61		"	97·83	668·1	25·9	642·2	505	23·60	39·4
62		"	97·83	562·6	25·9	536·7	527	23·58	49·1
63		"	97·83	719·8	25·5	694·3	525	23·59	37·8
64		"	97·83	620·4	25·9	594·5	527	23·54	44·6
65		"	97·81	709·0	25·1	683·9	506	23·57	37·1
66		24	98·26	1,376·6	44·7	1,331·9	1,176	23·10	45·1
67		"	98·26	1,259·0	44·7	1,214·3	1,204	23·05	50·8

RAINY RIVER AT INTERNATIONAL FALLS, MINN.

Location of Gauge.—At the steamboat dock, half a mile below the dam at International Falls.

Records available.—March 1, 1907, to December 31, 1912.

Drainage area.—14,600 square miles.

Gauge.—Vertical staff installed by the United States Geological Survey, April 20, 1911, at the American steamboat dock below the falls. Prior to this date gauge heights, furnished through the courtesy of the Minnesota and Ontario Power Company, were read on a gauge located just below the dam, first on the Canadian side but later on the American side. The zero of the survey gauge is 460·99 feet above that of the power company's gauge, when the slope of the river between the two points is considered.

Channel.—Practically permanent.

Discharge measurements.—Discharge measurements prior to 1911 were made by means of a boat and cable at a section several hundred yards below the gauge, where an island divides the river into two channels. Since 1911, measurements have been made above the island, where the river flows in one channel and the velocities are better distributed.

Winter Flow.—Ice rarely forms in the long stretch of water below the dam, but it does form at the rapids below the open stretch, causing serious backwater at the gauge, amounting at times to more than 2 feet. During 1909 and 1910 the monthly flow during the winter has been estimated indirectly from records of flow through the turbines as kept by the power company. During 1911 and 1912 the winter flow has been estimated directly from records of flow through the turbines, as computed by the Canadian Department of Public Works. Winter estimates for periods previous to 1910 can be considered only approximate.

Artificial control.—The dam above the gauging station raises the water level in Rainy Lake to such an extent as to cause a large increase in the storage. Since the dam and power-house have been in operation, practically no water has passed over the crest, the entire flow of the river going through the turbines and sluice gates. The plant is run on a 24-hour basis, so that with the exception of the Sunday flow the discharge is fairly uniform, though it does not represent the natural flow.

Table 61.—Daily Discharge of Rainy River at Fort Frances, Ontario.

[Drainage Area, 14,400 square miles.]

1911.

Day.	August.		September.		October.		November.		December.	
	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1				6,480		5,180		4,970		5,630
2				6,515		4,110		4,850		5,615
3				6,586		5,250		4,090		4,815
4				5,835		5,505		4,400		4,605
5				6,056		5,500		4,220		5,570
6				6,415		5,560		4,260		5,575
7				6,180		5,220		4,770		5,605
8				6,300		4,475		4,785		5,690
9				6,120		4,160		5,012		6,095
10				5,700		4,680		4,987		5,090
11				5,690		5,470		4,760		4,635
12				5,980		5,480		4,315		5,645
13				5,990		5,490		4,250		5,670
14		4,820		5,950		5,050		5,060		5,660
15		6,750		5,930		4,180		5,350		5,650
16		6,730		5,990		4,100		5,420		5,705
17		6,470		4,948		4,675		5,445		4,940
18		6,385		4,415		5,300		5,555		4,370
19		6,650		6,055		5,490		3,070		5,670
20		5,134		5,838		5,170		3,895		5,700
21		4,847		5,660		4,880		5,630		5,679
22		6,540		5,660		4,500		5,620		5,700
23		6,585		5,570		4,180		5,595		5,640
24		6,711		4,595		5,015		5,915		1,080
25		6,510		4,225		5,435		6,190		2,000
26		6,740		5,150		5,445		5,110		5,355
27		5,294		5,270		5,475		4,090		5,990
28		4,968		5,550		5,260		5,620		6,100
29		6,500		5,520		4,410		5,650		6,085
30		6,510		5,560		3,960		5,625		5,705
31		6,500				4,840				3,330

Table 61.—Daily Discharge of Rainy River at Fort Frances, Ontario—Continued.

1912.

Day.	January.		February.		March.		April.		May.		June.	
	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec. ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	......	4,490	......	5,085	......	4,856	......	3,953	......	5,880	......	6,315
2	......	5,695	......	5,440	......	4,888	......	5,022	......	5,885	......	5,410
3	......	5,665	......	5,815	......	4,497	......	5,028	......	5,915	......	5,325
4	......	5,695	......	4,620	......	4,402	......	4,997	......	6,190	......	6,437
5	......	5,640	......	3,995	......	5,101	......	5,002	......	5,250	......	6,382
6	......	5,815	......	5,105	......	5,037	......	4,983	......	4,795	......	6,410
7	......	4,450	......	5,090	......	5,090	......	3,725	......	6,185	......	6,305
8	......	3,995	......	5,050	......	5,402	......	3,616	......	6,570	......	6,159
9	......	5,725	......	4,985	......	5,063	......	5,049	......	6,610	......	5,971
10	......	5,720	......	4,870	......	4,205	......	5,068	......	6,692	......	5,889
11	......	5,725	......	4,105	......	4,108	......	5,096	......	6,731	......	6,267
12	......	5,940	......	3,990	......	5,105	......	5,119	......	5,135	......	6,239
13	......	6,220	......	5,030	......	5,060	......	5,052	......	4,800	......	6,283
14	......	3,700	......	5,035	......	5,025	......	4,031	......	6,090	......	6,312
15	......	5,030	......	5,000	......	5,016	......	4,109	......	6,695	......	6,255
16	......	5,855	......	5,009	......	4,960	......	5,100	......	6,690	......	5,570
17	......	5,930	......	5,017	......	3,828	......	5,060	......	6,350	......	5,730
18	......	5,900	......	4,119	......	3,890	......	5,045	......	6,355	......	6,042
19	......	5,915	......	3,976	......	4,812	......	5,055	......	4,855	......	6,093
20	......	5,915	......	5,035	......	5,045	......	5,048	......	5,200	......	6,180
21	......	4,700	......	5,014	......	5,096	......	4,130	......	6,730	......	6,201
22	......	4,320	......	5,057	......	5,095	......	3,950	......	6,713	......	6,115
23	......	5,915	......	5,063	......	5,004	......	5,045	......	6,720	......	5,823
24	......	5,920	......	5,014	......	3,560	......	5,055	......	6,770	......	5,693
25	......	5,875	......	4,169	......	4,429	......	5,385	......	6,577	......	6,190
26	......	5,760	......	4,080	......	5,070	......	5,800	......	4,892	......	5,835
27	......	5,495	......	5,068	......	5,022	......	5,900	......	5,175	......	5,969
28	......	4,255	......	5,066	......	5,057	......	4,597	......	6,680	......	5,853
29	......	3,935	......	5,056	......	5,090	......	4,348	......	6,495	......	5,555
30	......	5,080	......	......	......	4,910	......	5,865	......	6,350	......	5,267
31	......	5,080	......	......	......	4,012	......	......	......	5,811	......	......

Day.	July.		August.		September.		October.		November.		December.	
1	......	6,078	......	10,091	......	6,418	......	7,279	......	7,087	......	5,801
2	......	5,660	......	10,072	......	5,892	......	7,202	......	7,122	......	6,433
3	......	5,880	......	10,077	......	6,470	......	7,039	......	6,181	......	6,725
4	......	5,472	......	9,462	......	8,408	......	7,089	......	6,095	......	7,001
5	......	5,402	......	8,953	......	8,490	......	7,078	......	7,199	......	6,868
6	......	5,905	......	9,825	......	8,363	......	6,199	......	7,146	......	6,655
7	......	5,394	......	9,837	......	7,997	......	6,543	......	7,100	......	6,149
8	......	5,835	......	9,714	......	7,254	......	7,060	......	7,073	......	5,828
9	......	6,932	......	9,333	......	7,266	......	7,060	......	6,791	......	5,860
10	......	7,013	......	9,332	......	8,057	......	7,039	......	6,175	......	6,913
11	......	8,074	......	8,442	......	7,962	......	7,045	......	5,998	......	6,973
12	......	8,285	......	8,299	......	7,799	......	7,100	......	6,568	......	6,972
13	......	8,218	......	8,208	......	7,831	......	......	......	6,923	......	6,952
14	......	7,576	......	8,246	......	7,880	......	6,664	......	7,020	......	6,675
15	......	7,494	......	7,965	......	7,260	......	7,083	......	6,955	......	5,412
16	......	8,613	......	7,048	......	7,234	......	7,044	......	7,041	......	5,532
17	......	8,835	......	7,528	......	7,812	......	7,047	......	5,261	......	7,267
18	......	8,148	......	7,720	......	7,579	......	6,852	......	6,511	......	6,987
19	......	6,981	......	7,530	......	6,996	......	6,987	......	6,999	......	6,850
20	......	7,604	......	8,416	......	6,923	......	6,594	......	7,015	......	6,989
21	......	8,633	......	8,194	......	6,588	......	5,824	......	7,089	......	6,762
22	......	8,405	......	6,865	......	5,910	......	7,076	......	7,033	......	5,900
23	......	8,936	......	6,728	......	6,063	......	7,111	......	7,051	......	4,650
24	......	9,012	......	6,932	......	6,930	......	7,070	......	6,174	......	6,581
25	......	8,940	......	5,885	......	7,315	......	7,056	......	5,978	......	5,011
26	......	9,061	......	6,166	......	8,892	......	7,078	......	7,002	......	4,591
27	......	8,105	......	6,614	......	8,223	......	6,135	......	7,054	......	5,995
28	......	8,572	......	6,839	......	7,179	......	5,927	......	7,017	......	6,549
29	......	9,946	......	7,055	......	6,980	......	6,968	......	6,687	......	5,762
30	......	9,569	......	7,152	......	7,024	......	7,076	......	6,422	......	5,137
31	......	10,087	......	7,177	......	......	......	7,112	......		......	6,751

*Table 61.—Daily Discharge of Rainy River at Fort Frances, Ontario—*Continued.

1913.

Day.	January.		February.		March.		April.		May.		June.	
	Gauge Height	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	......	6,805	......	6,841	......	6,850	......	6,846	......	6,826	......	5,535
2	......	6,795	......	5,647	......	5,602	......	6,246	......	6,831	......	6,216
3	......	6,827	......	6,385	......	5,675	......	5,870	......	6,814	......	6,960
4	......	6,978	......	6,864	......	6,749	......	6,187	......	5,978	......	6,852
5	......	5,980	......	6,887	......	6,751	......	6,634	......	6,331	......	6,868
6	......	5,216	......	6,895	......	6,900	......	4,406	......	6,827	......	6,904
7	......	6,858	......	6,853	......	6,905	......	5,438	......	6,827	......	6,820
8	......	6,796	......	6,900	......	6,919	......	6,621	......	6,814	......	6,273
9	......	6,892	......	5,738	......	5,840	......	6,801	......	6,881	......	6,343
10	......	6,920	......	5,849	......	5,725	......	6,865	......	6,820	......	6,795
11	......	6,921	......	6,879	......	6,750	......	6,792	......	5,938	......	6,870
12	......	5,778	......	6,884	......	6,780	......	6,783	......	6,172	......	6,911
13	......	6,124	......	6,878	......	6,716	......	5,883	......	6,761	......	6,902
14	......	6,911	......	6,872	......	6,798	......	5,419	......	6,788	......	7,052
15	......	6,932	......	6,853	......	6,739	......	6,715	......	6,730	......	6,729
16	......	6,941	......	5,618	......	5,464	......	6,837	......	6,765	......	6,398
17	......	6,909	......	5,477	......	5,653	......	6,801	......	6,820	......	7,492
18	......	6,947	......	6,865	......	6,730	......	6,716	......	5,994	......	7,410
19	......	6,015	......	6,877	......	6,747	......	6,751	......	6,163	......	7,336
20	......	5,073	......	6,853	......	6,682	......	5,324	......	6,772	......	7,473
21	......	6,956	......	6,894	......	6,752	......	6,254	......	6,796	......	7,468
22	......	6,945	......	6,844	......	6,715	......	6,368	......	6,777	......	6,689
23	......	6,909	......	5,631	......	5,598	......	6,706	......	6,760	......	7,324
24	......	6,937	......	6,054	......	4,921	......	6,758	......	6,785	......	7,814
25	......	6,955	......	6,864	......	6,840	......	6,726	......	6,162	......	7,840
26	......	5,896	......	6,847	......	6,813	......	6,746	......	6,088	......	7,856
27	......	6,273	......	6,830	......	6,811	......	5,873	......	6,749	......	8,798
28	......	6,856	......	6,830	......	6,775	......	6,180	......	6,550	......	8,832
29	......	6,928	......	......	......	6,800	......	6,696	......	6,889	......	9,673
30	......	6,977	......	......	......	5,946	......	6,913	......	6,896	......	9,863
31	......	6,981	......	......	......	5,990	......	......	......	6,906	......	......

	July.		August.		September.		October.		November.		December.	
1	......	11,023	......	9,490	......	5,251	......	6,126	......	5,965	......	5,823
2	......	11,058	......	8,829	......	6,328	......	6,892	......	5,406	......	6,980
3	......	11,004	......	9,223	......	6,935	......	6,980	......	5,445	......	6,987
4	......	11,606	......	9,048	......	7,019	......	6,970	......	6,110	......	6,540
5	......	11,438	......	9,134	......	6,703	......	6,456	......	6,055	......	6,077
6	......	11,503	......	9,139	......	6,997	......	6,040	......	5,994	......	6,542
7	......	10,343	......	9,176	......	5,885	......	8,565	......	6,080	......	5,430
8	......	10,106	......	10,414	......	7,262	......	6,435	......	6,075	......	5,877
9	......	9,633	......	10,022	......	6,821	......	6,633	......	5,493	......	6,901
10	......	10,820	......	9,503	......	7,016	......	6,920	......	5,759	......	6,930
11	......	13,475	......	8,758	......	7,014	......	6,940	......	6,105	......	6,864
12	......	13,510	......	9,108	......	6,964	......	6,207	......	6,100	......	6,963
13	......	12,246	......	9,076	......	7,010	......	7,389	......	6,135	......	6,944
14	......	13,539	......	9,207	......	6,238	......	7,170	......	5,889	......	6,222
15	......	14,493	......	9,264	......	6,455	......	6,932	......	6,222	......	6,391
16	......	13,715	......	8,968	......	6,960	......	6,257	......	5,310	......	6,974
17	......	14,576	......	8,758	......	7,094	......	6,360	......	5,242	......	6,778
18	......	14,243	......	8,654	......	7,000	......	6,150	......	6,115	......	6,988
19	......	15,290	......	9,019	......	6,985	......	6,048	......	6,005	......	6,988
20	......	14,019	......	8,914	......	6,975	......	5,545	......	6,440	......	6,966
21	......	13,187	......	9,136	......	6,535	......	6,080	......	5,675	......	6,205
22	......	13,221	......	9,118	......	6,909	......	6,140	......	6,558	......	5,945
23	......	13,254	......	8,888	......	7,060	......	6,105	......	6,237	......	6,095
24	......	13,331	......	6,232	......	7,026	......	6,100	......	6,468	......	6,118
25	......	13,225	......	7,229	......	7,015	......	6,120	......	6,780	......	4,908
26	......	13,262	......	7,022	......	6,994	......	5,474	......	7,175	......	4,608
27	......	12,802	......	6,965	......	6,915	......	5,550	......	6,931	......	5,201
28	......	12,844	......	7,005	......	6,121	......	6,070	......	6,979	......	6,225
29	......	13,292	......	6,967	......	6,600	......	6,105	......	6,606	......	5,525
30	......	13,732	......	6,665	......	7,030	......	6,026	......	5,519	......	6,095
31	......	9,794	......	5,660	......	......	......	6,075	......	......	......	6,299

Table 61.—Daily Discharge of Rainy River at Fort Frances, Ontario—Continued.

1914.

Day.	January.		February.		March.		April.		May.		June.	
	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height	Discharge.	Gauge Height.	Discharge.	Gauge Height	Discharge.	Gauge Height.	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	......	6,070	......	6,439	......	6,164	......	6,898	......	6,868	......	7,874
2	......	6,097	......	6,586	......	6,418	......	6,998	......	6,784	......	8,834
3	......	6,933	......	6,949	......	6,980	......	6,912	......	5,988	......	8,976
4	......	6,251	......	7,000	......	6,896	......	6,892	......	6,396	......	9,013
5	......	5,492	......	7,020	......	6,956	......	6,050	......	6,598	......	8,749
6	......	6,935	......	6,938	......	6,942	......	6,320	......	6,798	......	8,792
7	......	6,877	......	6,976	......	6,922	......	6,936	......	6,840	......	6,646
8	......	6,870	......	6,468	......	5,775	......	6,916	......	6,788	......	7,753
9	......	6,785	......	6,482	......	6,394	......	6,918	......	6,752	......	9,054
10	......	6,856	......	6,970	......	7,064	......	6,928	......	5,997	......	9,421
11	......	6,218	......	6,978	......	7,006	......	6,910	......	6,214	......	8,906
12	......	6,536	......	7,078	......	7,030	......	6,077	......	6,802	......	8,415
13	......	6,961	......	7,050	......	6,986	......	6,244	......	6,814	......	8,860
14	......	6,953	......	6,944	......	7,916	......	6,902	......	6,842	......	6,673
15	......	6,957	......	6,312	......	5,589	......	6,895	......	6,846	......	7,203
16	......	6,980	......	6,436	......	6,384	......	6,894	......	6,818	......	8,686
17	......	7,021	......	7,280	......	6,950	......	6,932	......	6,269	......	8,953
18	......	6,245	......	6,744	......	7,002	......	6,852	......	6,272	......	9,126
19	......	6,455	......	6,978	......	7,022	......	5,878	......	6,804	......	9,070
20	......	6,920	......	7,042	......	7,006	......	6,280	......	6,818	......	9,050
21	......	6,950	......	8,023	......	7,016	......	6,900	......	6,864	......	6,968
22	......	6,921	......	5,967	......	6,180	......	6,834	......	6,832	......	7,644
23	......	6,959	......	6,410	......	6,392	......	6,868	......	6,856	......	8,745
24	......	6,957	......	6,974	......	6,958	......	6,878	......	6,102	......	8,916
25	......	6,326	......	6,988	......	6,850	......	6,876	......	6,620	......	9,466
26	......	7,140	......	7,018	......	6,944	......	6,052	......	7,398	......	9,504
27	......	7,036	......	6,998	......	6,928	......	6,252	......	7,432	......	9,104
28	......	6,958	......	7,020	......	6,928	......	6,862	......	7,940	......	6,606
29	......	7,004	......	......	......	6,056	......	6,796	......	8,630	......	8,198
30	......	6,936	......	......	......	6,270	......	6,856	......	8,954	......	8,670
31	......	6,685	......	......	......	6,880	......	......	......	6,963	......	......

Day.	July.		August.		September.		October.		November.		December.	
1	......	7,778	......	10,703	......	10,410	......	10,520	......	7,601	......	11,040
2	......	8,316	......	8,331	......	10,580	......	10,510	......	8,935	......	10,929
3	......	8,966	......	9,081	......	10,540	......	10,005	......	10,839	......	11,069
4	......	8,416	......	10,981	......	10,528	......	7,019	......	10,778	......	10,853
5	......	6,184	......	10,854	......	10,528	......	8,651	......	10,821	......	10,399
6	......	7,216	......	10,937	......	7,630	......	10,353	......	10,781	......	7,458
7	......	10,058	......	10,772	......	4,270	......	10,570	......	10,788	......	8,272
8	......	9,829	......	10,895	......	9,216	......	10,454	......	8,271	......	10,661
9	......	10,346	......	8,816	......	10,599	......	10,482	......	9,170	......	11,171
10	......	10,669	......	9,021	......	10,600	......	10,540	......	10,788	......	10,711
11	......	10,739	......	10,907	......	10,590	......	7,641	......	10,810	......	10,740
12	......	7,815	......	10,948	......	10,570	......	8,833	......	10,800	......	10,938
13	......	10,756	......	10,902	......	7,713	......	10,508	......	10,506	......	7,225
14	......	11,023	......	10,855	......	8,889	......	9,966	......	9,946	......	8,681
15	......	10,953	......	10,877	......	10,600	......	9,269	......	7,783	......	9,308
16	......	10,933	......	7,730	......	10,522	......	9,660	......	8,959	......	10,218
17	......	11,376	......	8,618	......	10,520	......	9,680	......	10,285	......	9,290
18	......	11,819	......	10,654	......	10,513	......	7,456	......	10,762	......	9,925
19	......	9,503	......	10,746	......	10,500	......	8,371	......	11,134	......	9,991
20	......	10,472	......	10,599	......	8,045	......	10,533	......	10,744	......	6,911
21	......	12,061	......	10,578	......	8,848	......	10,462	......	11,145	......	7,834
22	......	12,441	......	10,549	......	10,512	......	10,671	......	8,192	......	9,121
23	......	12,775	......	8,549	......	10,542	......	10,991	......	9,190	......	9,313
24	......	12,541	......	8,871	......	10,505	......	10,397	......	11,059	......	9,666
25	......	12,445	......	10,607	......	10,515	......	7,007	......	10,911	......	3,448
26	......	10,773	......	10,609	......	10,414	......	8,977	......	10,891	......	1,224
27	......	11,503	......	10,628	......	8,187	......	10,648	......	10,003	......	3,710
28	......	12,262	......	10,658	......	8,673	......	10,848	......	9,416	......	8,318
29	......	12,522	......	10,628	......	10,520	......	10,808	......	8,317	......	9,950
30	......	11,247	......	7,735	......	10,385	......	10,801	......	8,171	......	10,410
31	......	10,657	......	8,725	......	......	......	10,739	......	......	......	10,017

Table 61.—Daily Discharge of Rainy River at Fort Frances, Ontario—Concluded.

1915.

Day.	January.		February.	
	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1		10,092		7,153
2		10,320		8,292
3		6,610		8,175
4		9,030		8,291
5		10,460		8,083
6		10,052		8,281
7		10,057		6,792
8		10,277		7,193
9		10,360		8,245
10		6,981		8,247
11		8,635		8,360
12		10,352		8,178
13		10,330		7,746
14		10,137		
15		8,595		
16		9,565		
17		9,183		
18		8,220		
19		9,555		
20		9,545		
21		9,508		
22		9,451		
23		8,882		
24		7,938		
25		8,714		
26		9,425		
27		8,807		
28		8,564		
29		9,090		
30		9,201		
31		7,529		

Table 62.—Monthly Discharges of Rainy River at Fort Frances.

[Drainage Area 14,400 square miles.]

Month.	Discharge in Second-Feet.				Run-off.
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on Drainage area.
1907					
January		....	5,883	0·409	0·472
February		....	3,641	0·253	0·263
March	....		4,910[1]	0·341	0·394
April	6,265	4,338	4,995	0·344	0·384
May	7,710	4,480	6,070	0·422	0·487
June	11,500	9,500	10,200	0·709	0·791
July	13,700	11,700	13,000	0·904	1·042
August	19,760	15,170	17,470	1·214	1·400
September	20,800	19,760	20,110	1·098	1·559
October	20,460	18,850	19,760	1·373	1·584
November	18,850	16,550	17,700	1·230	1·372
December			13,000[1]	0·904	1·042
The year		....	11,391	0·792	10·79
1908					
January	....		12,000[1]	0·834	0·962
February	....	....	8,410[1]	0·584	0·608
March		....	7,010[1]	0·489	0·564
April	....	....	6,020[1]	0·418	0·466
May		....	7,940[1]	0·552	0·636
June		....	11,430[1]	0·794	0·886
July	14,260	12,220	13,060	0·908	1·047
August	13,430	11,570	12,680	0·882	1·017
September	11,850	10,090	10,740	0·747	0·832
October	10,900	8,710	9,680	0·672	0·776
November	8,630	6,720	7,510	0·522	0·582
December		....	5,701	0·396	9·457
The year		....	9,350	0·650	8·83
1909					
January		....	5,170[1]	0·359	9·414
February	....	....	4,740[1]	0·329	0·343
March	....	....	5,500[1]	0·382	0·441
April	6,240	484	3,250	0·226	0·252
May	8,430	726	4,220	0·293	0·338
June	10,900	976	6,850	0·476	0·531
July	11,300	9,020	10,600	0·736	0·850
August	13,700	7,320	10,600	0·736	0·850
September	10,300	7,940	9,250	0·643	0·717
October	10,300	7,020	9,050	0·628	0·726
November	8,860	3,520	5,400	0·375	0·419
December		....	10,000[1]	0·695	0·802
The year	....	....	7,052	0·490	6·68
1910					
January	....	....	9,680[1]	0·672	0·776
February	....	....	9,680[1]	0·672	0·700
March		....	10,750[1]	0·748	0·862
April	13,600	6,000	10,600	0·736	0·822
May	12,500	7,970	10,600	0·736	0·850
June	11,900	8,590	10,000	0·695	0·775
July	9,780	3,610	6,630	0·461	0·532
August	6,820	3,740	5,280	0·367	0·423
September	5,370	4,950	5,080	0·353	0·391
October	6,640	2,340	5,120	0·356	0·410
November	7,600	1,755	5,280	0·367	0·409
December	....	....	4,300	0·299	0·345
The year	....	....	7,750	0·539	7·30

[1]Estimated.

Table 62.—Monthly Discharges of Rainy River at Fort Frances—Concluded.

Month.	Discharge in Second-Feet.				Run-off.
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on Drainage area.
1911					
January	....	....	2,860[1]	0·199	0·229
February	....	....	2,380[1]	0·165	0·172
March	....	....	2,540[1]	0·176	0·203
April	4,000	2,170[1]	3,020	0·210	0·234
May	6,210	2,740	4,600	0·320	0·369
June	8,240	3,740	5,740	0·399	0·445
July	6,840	1,900	3,970	0·276	0·318
August	7,220	3,570	6,560	0·456	0·526
September	6,880	4,730	5,990	0·416	0·464
October	5,890	4,320	5,210	0·362	0·418
November	6,070	4,020	5,410	0·376	0·419
December	....	....	5,900[1]	0·410	0·473
The year	....	....	4,514	0·314	4·27
1912					
January	6,220	3,700	5,330	0·370	0·427
February	5,840	3,980	4,830	0·336	0·349
March	5,100	3,560	4,740	0·329	0·380
April	5,900	3,620	4,850	0·337	0·376
May	6,770	4,800	6,090	0·423	0·488
June	6,420	5,240	6,020	0·418	0·467
July	10,100	5,150	7,680	0·534	0·616
August	10,100	5,880	8,120	0·564	0·651
September	8,890	5,890	7,360	0·512	0·570
October	7,280	5,820	6,880	0·478	0·552
November	7,200	5,260	6,730	0·468	0·522
December	7,267	4,591	6,280	0·436	0·504
The year	10,100	3,560	6,243	0·434	5·90
1913					
January	6,978	5,073	6,620	0·460	0·530
February	6,900	5,477	6,561	0·456	0·474
March	6,919	4,921	6,420	0·446	0·514
April	6,913	4,406	6,405	0·445	0·497
May	6,906	5,938	6,620	0·460	0·531
June	9,863	5,535	7,274	0·506	0·564
July	15,290	9,633	12,597	0·876	1·010
August	10,414	5,660	8,544	0·594	0·685
September	7,262	5,251	6,770	0·470	0·525
October	8,565	5,474	6,318	0·439	0·506
November	7,175	5,242	6,129	0·426	0·475
December	6,988	4,608	6,309	0·438	0·506
The year	15,290	4,406	7,214	0·501	6·82
1914					
January	7,140	5,492	6,718	0·467	0·536
February	8,023	5,967	6,823	0·474	0·493
March	7,064	5,589	6,707	0·466	0·538
April	6,998	5,878	6,694	0·465	0·519
May	8,95[illegible]	5,988	6,866	0·477	0·550
June	9,5[illegible]	6,606	8,464	0·588	0·656
July	12,[illegible]	6,184	10,464	0·727	0·839
August	10,984	7,730	10,044	0·698	0·805
September	10,600	4,270	9,749	0·677	0·756
October	10,991	7,019	9,787	0·680	0·784
November	11,145	7,783	9,927	0·690	0·770
December	11,171	1,224	8,994	0·625	0·721
The year	12,775	1,224	8,436	0·586	7·97

[1]Estimated.

KETTLE [illegible]R AT CHAUDIÈRE FALLS (KETTLE FALLS).

Location of Gauge.—At a point on the Canadian mainshore, 200 feet above the falls on the Canadian channel at the outlet of Namakan lake.

Records available.—August 8, 1912, to May 12, 1913.

Drainage area.—7,060 square miles.

Channels.—Permanent, bed-rock.

Discharge Measurements.—Discharge measurements have been made by the Manitoba Hydrographic Survey since August, 1912. As the Kettle falls are divided by an Island, this necessitated measurements at sections above each falls; the combined flow of both sections giving the total discharge from Namakan lake. The sections in both cases are directly above the crest of the falls.

Winter Flow.—As the gauge is located just above the falls on the Canadian channel, the station is not affected by back-water, and the open water discharge table is applicable.

Table 63.—Discharge measurements at Chaudière falls (Kettle falls) Rainy river.

[Drainage Area, 7,060 square miles.]

INTERNATIONAL CHANNEL.

Date.	Hydrographer.	Meter No.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
1912.			Feet.	Sq.-ft.	Ft. per sec.	Feet.	Sec.-ft.
Aug. 8	S. S. Scovil	1,374	213	4,351	0·769	3·34	3,345
Sept. 6	Alex. Pirie	1,197	213	4,353	0·680	2·72	2,960
Sept. 9	W. H. Richardson	1,374	213	4,318	0·643	2·77	2,775
Sept. 30	A. Pirie	1,187	213	4,341	0·587	2·32	2,548
Nov. 4	R. H. Nelson	1,196-7	213	4,156	0·481	1·65	1,999
Nov. 2	R. H. Nelson	1,196-7	213	4,193	0·485	1·66	2,037
1913.							
Jan. 10	A. Pirie	1,462	208	3,981	0·33	0·80	1,312
Jan. 10	"	1,462	208	3,981	0·328	0·80	1,298
Mar. 17	"	1,186	210	3,888	0·284	0·27	1,105
May 31	"	1,197	223	5,246	1·22	6·08	6,375

CANADIAN CHANNEL.

Date.	Hydrographer.	Meter No.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
1912.							
Aug. 8	S. S Scovil	1,374	119·5	1,273	1·127	8·36	1,435
Sept. 6	A. [illegible]ie	1,197	115·0	1,207	0·902	2·71	1,088
Sept. 9	W [illegible] Richardson	1,374	118·0	1,181	0·797	2·73	942
Sept. 29	A. [illegible]e	1,187	114·5	1,198	0·752	2·375	901
Sept. 30	[illegible]	1,187	114·5	1,191	0·700	2·31	834
Nov. 2	R. [illegible] Nelson	1,196-7	108·0	1,100	0·496	1·675	546
Nov. 4	"	1,196-7	108·0	1,184	0·517	1·66	561
1913.							
Jan. 9	A. Pirie	1,462	102·0	975	0·336	0·80	328
Jan. 9	"	1,462	102·0	975	0·333	0·80	324
Mar. 15	"	1,186	102·0	936	0·226	0·28	212
May 31	"	1,197	182·5	1,719	2·38	6·06	4,088

Table 64.—Daily discharge at Chaudière falls (Kettle falls) Rainy river (both channels.)

[Drainage Area, 7,060 square miles.]

1912.

Day.	July.		August.		September.		October.		November.		December.	
	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	......	......		......	2·63	3,790	2·29	3,255	1·73	2,534	1·20	1,989
2	......	......		......	2·59	3,710	2·20	3,115	1·68	2,479	1·20	1,989
3	......	......		......	2·53	3,632	2·18	3,115	1·65	2,446	1·20	1,989
4	......	......		......	2·53	3,632	2·22	3,115	1·64	2,436	1·20	1,989
5	......	......		......	2·72	3,870	2·23	3,185	1·60	2,393	1·20	1,989
6	......	......		......	2·70	3,870	2·24	3,185	1·58	2,372	1·20	1,989
7	......	......		......	2·70	3,870	2·25	3,185	1·55	2,339	1·19	1,979
8	......	......	3·34	4,997	2·70	3,870	2·22	3,115	1·52	2,307	1·15	1,942
9	......	......	......	4,997	2·80	4,035	2·20	3,115	1·52	2,307	1·10	1,896
10	......	......	3·34	4,997	2·80	4,035	2·18	3,115	1·50	2,286	1·10	1,896
11	......	......	3·33	4,997	2·80	4,035	2·17	3,047	1·49	2,276	1·10	1,896
12	......	......	3·23	4,814	2·80	4,035	2·16	3,047	1·49	2,276	1·10	1,896
13	......	......	3·33	4,997	2·78	4,035	2·15	3,047	1·48	2,265	0·90	1,718
14	......	......	3·16	4,637	2·71	3,870	2·15	3,047	1·45	2,235	0·90	1,718
15	......	......	3·14	4,637	2·70	3,870	2·10	2,980	1·43	2,215	0·90	1,718
16	......	......	3·08	4,550	2·68	3,870	2·08	2,980	1·48	2,265	0·80	1,636
17	......	......	3·07	4,462	2·62	3,710	2·07	2,917	1·45	2,235	0·80	1,636
18	......	......	3·05	4,462	2·59	3,710	2·02	2,855	1·40	2,184	0·80	1,636
19	......	......	3·01	4,375	2·52	3,555	1·95	2,792	1·42	2,204	1·00	1,803
20	......	......	2·98	4,375	2·52	3,555	1·94	2,780	1·45	2,235	1·00	1,803
21	......	......	2·96	4,289	2·48	3,555	1·92	2,755	1·40	2,184	1·00	1,803
22	......	......	2·90	4,205	2·46	3,479	1·90	2,730	1·38	2,164	1·00	1,803
23	......	......	2·85	4,119	2·40	3,405	1·87	2,695	1·36	2,141	0·90	1,718
24	......	......	2·84	4,119	2·42	3,405	1·86	2,684	1·34	2,124	0·90	1,718
25	......	......	2·81	4,035	2·42	3,405	1·83	2,649	1·32	2,104	0·90	1,718
26	......	......	2·75	3,952	2·40	3,405	1·80	2,615	1·30	2,084	0·90	1,718
27	......	......	2·73	3,952	2·35	3,329	1·78	2,592	1·36	2,144	0·90	1,718
28	......	......	2·75	3,952	2·35	3,329	1·72	2,523	1·40	2,184	0·90	1,718
29	......	......	2·73	3,952	2·38	3,405	1·70	2,500	1·30	2,084	0·90	1,718
30	......	......	2·71	3,870	2·31	3,255	1·72	2,523	1·36	2,144	0·90	1,718
31	......	......	2·69	3,870	......	......	1·77	2,581	......	......	0·90	1,718

1913.

Day.	January.		February.		March.		April.		May.		June.	
1	0·90	1,718	0·60	1,486	0·30	1,297	0·23	1,259	2·65	3,790	6·30	10,990
2	0·90	1,718	0·60	1,486	0·30	1,297	0·23	1,259	2·75	3,952	6·50	11,400
3	0·80	1,636	0·60	1,486	0·30	1,297	0·25	1,270	2·85	4,119	6·68	11,810
4	0·80	1,636	0·60	1,486	0·30	1,297	0·25	1,270	2·95	4,289	6·78	12,015
5	0·80	1,636	0·60	1,486	0·30	1,297	0·26	1,275	3·05	4,462	6·94	12,322
6	0·80	1,636	0·60	1,486	0·30	1,297	0·26	1,275	3·05	4,462	7·02	12,425
7	0·80	1,636	0·50	1,418	0·30	1,297	0·26	1,275	3·20	4,725	7·10	12,630
8	0·80	1,636	0·50	1,418	0·30	1,297	0·26	1,275	3·35	4,997	7·12	12,630
9	0·80	1,636	0·50	1,418	0·30	1,297	0·27	1,281	3·42	5,090	7·16	12,732
10	0·80	1,636	0·50	1,418	0·20	1,243	0·27	1,281	3·50	5,280	7·22	12,835
11	0·80	1,636	0·50	1,418	0·20	1,243	0·27	1,281	3·60	5,470	7·22	12,835
12	0·80	1,636	0·50	1,418	0·24	1,264	0·28	1,286	3·80	5,865	7·22	12,835
13	0·80	1,636	0·50	1,418	......	1,270	0·32	1,309	3·72	5,665	7·22	12,835
14	0·80	1,636	0·50	1,418	......	1,281	0·48	1,406	3·80	5,865	......	......
15	0·80	1,636	0·50	1,418	0·28	1,286	0·58	1,472	4·00	6,275	......	......
16	0·80	1,636	0·50	1,418	0·28	1,286	0·72	1,576	4·10	6,480	......	......
17	0·80	1,636	0·40	1,357	0·27	1,281	0·85	1,677	4·22	6,685	......	......
18	0·80	1,636	0·40	1,357	0·27	1,281	1·00	1,803	4·30	6,890	......	......
19	0·80	1,636	0·40	1,357	0·27	1,281	1·10	1,896	4·40	7,095	......	......
20	0·70	1,561	0·40	1,357	0·26	1,275	1·28	2,065	4·45	7,197	......	......
21	0·70	1,561	0·40	1,357	0·26	1,275	1·40	2,184	4·60	7,505	......	......
22	0·70	1,561	0·40	1,357	0·26	1,275	1·50	2,286	4·70	7,710	......	......
23	0·70	1,561	0·40	1,357	0·27	1,281	1·65	2,446	4·82	7,915	......	......
24	0·70	1,561	0·40	1,357	0·28	1,286	1·75	2,558	4·90	8,118	......	......
25	0·70	1,561	0·40	1,357	0·29	1,292	1·90	2,730	5·00	8,325	......	......
26	0·70	1,561	0·30	1,297	0·28	1,286	2·05	2,917	5·15	8,532	......	......
27	0·70	1,561	0·30	1,297	0·28	1,286	2·15	3,048	5·25	8,737	......	......
28	0·60	1,486	0·30	1,297	0·28	1,286	2·30	3,255	5·38	9,145	......	......
29	0·60	1,486	......	......	0·27	1,281	2·42	3,405	5·50	9,350	......	......
30	0·60	1,486	......	......	0·25	1,270	2·50	3,555	5·78	9,965	......	......
31	0·60	1,486	......	......	0·23	1,259	......	......	6·05	10,477	......	......

Table 65.—Monthly Discharge at Chaudière Falls (Kettle falls) Rainy River (both channels.)

[Drainage Area, 7,060 square miles.]

Month.	Discharge in Second-Feet.				Run-Off
	Maximum.	Minimum.	Mean.	Per square mile	Depth in inches on Drainage area
1912.					
August[1]..	4,997	3,870	4,400	0·620	(·553)
September	4,035	3,255	3,681	0·519	0·579
October	3,255	2,500	2,898	0·408	0·471
November	2,531	2,081	2,255	0·317	0·355
December	1,989	1,636	1,812	0·255	0·294
1913.					
January	1,718	1,486	1,602	0·226	0·260
February	1,486	1,297	1,400	0·197	0·205
March	1,297	1,243	1,282	0·180	0·208
April	3,555	1,259	1,896	0·267	0·298
May	10,477	3,790	6,595	0·928	1·070
June[2]	12,835	10,990	12,330	1·737	(·840)

[1]24 days only. [2]13 days only.

WHITEMOUTH RIVER, NEAR WHITEMOUTH, MANITOBA.

Location of Gauge.—On general traffic bridge of Whitemouth village.

Records available.—May 29, 1912, to December 31, 1914.

Drainage area.—1,400 square miles.

Gauge.—Vertical staff, fastened to foundation pile of traffic bridge.

Bench-Mark.—Permanent bench-mark, consisting of iron staple embedded in top of concrete pile on left bank of river west of road. Elevation 100.

Channel.—River flowing in straight channel between clay banks, but to date no indication of shifting or change in section.

Discharge measurements.—Discharge measurements have been made since May 29, 1912, from the traffic bridge by the field officers of the Manitoba Hydrographic Survey.

Winter Discharge. The discharge rating curve applies only to open-water conditions.

Table 66.—Discharge measurements of Whitemouth river at Whitemouth, Manitoba.

[Drainage Area, 1,400 square miles.]

Date.	Hydrographer.	Meter No.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
1912			Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
May 29	G. H. Burnham	1187	162	990·5	2·20	1·86	2,179
June 20	"	1187	151	629·4	1·07	2·18	673
July 13	"	1187	158	749·9	1·41	3·08	1,057
" 15	"	1187	158·5	858·1	1·67	3·70	1,133
Aug. 9	W. G. Warden	1187	149·7	699·6	1·30	2·95	910
Sept. 3	"	1187	149·7	845·0	1·59	3·72	1,343
Oct. 15	R. H. Nelson	1187	172·0	936·8	2·02	1·48	1,892
1913.							
Jan. 24	A. Pirie	1469	110·0	188·6	0·115	1·22	27[1]
April 18	"	1186	154·0	752·0	1·65	3·29	1,241
May 9	G. Ebner	1186	151·0	732·1	1·38	2·92	1,010
Aug. 15	W. J. Ireland	1469	143·0	578·0	0·68	1·95	392
Sept. 21	C. O. Allen..	1435	136·0	512·2	0·30	1·14	153
1914.							
Jan. 20	E. J. Budge.	1467	140	207	0·07	0·78	15[1]
Mar. 16	W. J. Ireland	1462	99	97	0·20	0·88	20[1]
May 20	A. Pirie..	1939	137	636	1·13	2·46	719
July 27	M. S. Madden..	1760	[illegible]	609	0·76	2·09	467
Aug. 18	J. A. Page.	1920	136	443	0·09	1·17	41
Sept. 4	H. Boyd.	1919	142	492	0·26	1·40	125
Oct. 7	M. S. Madden.	1911	142	522	0·30	1·51	158
Nov. 3	"	1912	147	580	0·77	2·08	451
" 30	C. O. Allen.	1911	140	408	0·36	1·42	146[1]
Dec. 28	M. S. Madden	1462	125	260	0·07	1·09	17[1]

[1]Ice measurements.

Table 67.—Daily discharge records of Whitemouth river at Whitemouth, Man.

(Drainage Area, 1,100 square miles.)

1912.

Day.	January. Gauge Height	January. Discharge.	February. Gauge Height	February. Discharge.	March. Gauge Height	March. Discharge	April. Gauge Height	April. Discharge.	May. Gauge Height	May. Discharge.	June. Gauge Height	June. Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1											76·80	1,760
2											76·18	1,570
3											76·35	1,500
4											76·53	1,600
5											76·58	1,630
6												1,570
7											[illegible]	1,440
8											76·19	1,110
9											76·07	1,340
10											75·67	1,110
11											75·66	1,100
12											75·17	1,000
13											75·15	987
14											75·11	964
15											75·25	874
16											75·21	850
17											74·99	724
18											74·97	713
19											74·91	696
20											74·93	690
21											74·79	610
22											74·63	579
23											74·61	508
24											74·59	496
25											74·59	496
26											74·58	491
27											74·56	479
28											74·54	468
29									77·25	2,010	74·43	405
30									77·26	2,020	74·20	325
31									76·99	1,860	...	...

Day.	July. Gauge Height	July. Discharge.	August. Gauge Height	August. Discharge.	September. Gauge Height	September. Discharge.	October. Gauge Height	October. Discharge.	November. Gauge Height	November. Discharge.	December. Gauge Height	December. Discharge.
1	74·19	271	75·75	1,160	76·12	1,370	77·22	2,000	76·35	1,500	...	...
2	74·09	226	75·49	1,010	76·16	1,390	77·13	1,910	76·39	1,520	...	...
3	73·97	181	75·38	947	76·15	1,390	76·97	1,850	76·45	1,560	...	...
4	73·94	172	75·06	764	76·29	1,410	76·91	1,840	76·36	1,510	...	...
5	73·93	169	75·05	759	76·68	1,690	76·86	1,790	76·29	1,170	...	...
6	74·33	318	75·03	747	76·56	1,620	76·83	1,770	76·20	1,410	...	...
7	74·38	377	75·07	770	76·47	1,570	76·77	1,740	76·07	1,340	...	...
8	74·77	599	75·18	833	76·36	1,510	77·00	1,870	75·96	1,280	...	...
9	74·98	719	75·37	941	76·32	1,480	77·25	2,010	75·87	1,230	...	...
10	75·03	747	75·37	941	76·37	1,510	77·25	2,010	75·81	1,190	...	...
11	75·07	770	75·36	935	76·42	1,540	77·21	2,010	75·76	1,160	...	...
12	75·06	764	75·36	935	76·43	1,550	77·20	1,980	75·73	1,150	...	...
13	75·59	1,070	75·17	827	76·43	1,550	77·16	1,960	75·67	1,110	...	...
14	75·9	1,250	75·10	787	76·41	1,530	77·05	1,900	75·64	1,100	...	...
15	76·17	1,400	75·02	741	76·38	1,520	76·92	1,820	75·61	1,080	...	...
16	76·22	1,430	74·97	713	76·63	1,660	76·64	1,660	75·57	1,060	...	...
17	76·22	1,430	74·83	633	76·75	1,730	76·55	1,610	75·57	1,060	...	...
18	76·21	1,420	74·77	599	76·70	1,700	76·37	1,510	75·51	1,020	...	...
19	76·21	1,420	74·73	576	76·63	1,660	76·36	1,510	75·47	1,000	...	...
20	75·91	1,250	74·51	451	76·40	1,530	76·33	1,490	75·45	987	...	...
21	75·83	1,200	74·49	439	76·98	1,860	76·17	1,400	75·36	935	...	...
22	75·73	1,150	74·57	485	77·43	2,120	76·09	1,350	75·31	906	...	...
23	75·84	1,210	74·67	542	77·53	2,170	75·97	1,280	75·23	861	...	...
24	76·03	1,320	74·80	616	77·59	2,210	75·87	1,230	75·39	...	...	...
25	76·18	1,400	74·86	650	77·57	2,200	75·66	1,110	75·61	...	...	...
26	76·25	1,410	74·89	667	77·53	2,170	75·51	1,020	75·77	...	...	...
27	76·29	1,470	74·91	679	77·45	2,130	75·93	1,260	75·83	...	...	...
28	76·37	1,510	74·95	702	77·44	2,120	76·11	1,360	75·87	...	...	...
29	76·26	1,450	74·97	713	77·35	2,070	76·21	1,420	75·87	...	...	...
30	76·12	1,470	75·37	941	77·30	2,040	76·27	1,450	75·87	...	...	...
31	75·93	1,260	75·97	1,280	...	...	76·29	1,470	...	...	...	...

NOTE.—Ice conditions from November 23. Not sufficient information to compute daily discharges.

Table 67.—Daily discharge records of Whitemouth river at Whitemouth, Man.—Continued.

1913.

Day.	January. Gauge Height	January. Discharge	February. Gauge Height	February. Discharge	March. Gauge Height	March. Discharge	April. Gauge Height	April. Discharge	May. Gauge Height	May. Discharge	June. Gauge Height	June. Discharge
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1									75·78	1,180	74·[illegible]	588
2									75·74	1,150	74·[illegible]	570
3									75·66	1,110	74·70	560
4									75·60	1,070	74·70	560
5									75·57	1,060	74·70	560
6									75·51	1,040	74·78	605
7									75·45	987	75·06	7[illegible]4
8							[illegible]·56	2,150	75·45	987	74·9[illegible]	[illegible]
9							77·[illegible]	2,410	75·3[illegible]	941	74·88	662
10							77·8[illegible]	2,[illegible]	75·37	941	74·80	616
11							78·[illegible]7	2,600	75·41	964	[illegible]	[illegible]
12							78·[illegible]	2,850	75·39	[illegible]	[illegible]	[illegible]
13							77·[illegible]	2,[illegible]	75·3[illegible]	93[illegible]	[illegible]	[illegible]
14							77·41	2,1[illegible]0	75·33	918	[illegible]	[illegible]
15							77·33	2,0[illegible]0	75·25	873	[illegible]	[illegible]
16							77·[illegible]	2,0[illegible]0	75·15	816	[illegible]	[illegible]
17							77·21	1,900	75·07	770	[illegible]	[illegible]
18							75·[illegible]4	1,[illegible]50	75·0[illegible]	7[illegible]0	[illegible]	[illegible]
19							75·[illegible]	1,[illegible]	75·03	737	[illegible]	[illegible]
20							75·70	1,130	74·97	713	[illegible]	[illegible]
21							75·67	1,110	74·94	696	[illegible]	[illegible]
22							75·66	1,110	74·90	[illegible]	[illegible]	[illegible]
23							75·91	1,[illegible]50	74·90	673	[illegible]	[illegible]
24							76·01	1,[illegible]	74·88	662	[illegible]	[illegible]
25							76·11	1,360	74·86	650	[illegible]	[illegible]
26							76·47	1,400	74·84	639	[illegible]	[illegible]
27							76·47	1,400	74·80	616	[illegible]	[illegible]
28							76·15	1,390	74·80	616	[illegible]	[illegible]
29							76·07	1,310	74·78	605	[illegible]	[illegible]
30							75·95	1,270	74·75	588	[illegible]	[illegible]
31									74·73	5[illegible]		

NOTE.—Discharge curve not defined above gauge height 7[illegible]·30. [illegible] conditions until A[illegible] information to compute discharges.

Day.	July. Gauge Height	July. Discharge	August. Gauge Height	August. Discharge	September. Gauge Height	September. Discharge	October. Gauge Height	October. Discharge	November. Gauge Height	November. Discharge	December. Gauge Height	December. Discharge
1	74·81	622	73·91	163	74·53	462	73·83	143	74·71			
2	74·98	749	73·87	154	74·48	431	73·79	133	74·68			
3	74·96	707	73·84	138	74·40	388	73·74	117	74·66			
4	74·94	690	73·79	133	74·38	377	73·69	113	74·44			
5	74·81	622	73·73	121	74·33	348	73·74	121	74·31			
6	74·73	576	73·73	121	74·28	320	73·78	131	74·26	[illegible]		
7	74·64	525	73·67	110	74·21	282	73·76	127	74·24	282		
8	74·51	451	73·63	102	74·16	258	73·74	123	74·21	282		
9	74·51	451	73·59	96	74·08	222	73·83	143	74·17	262		
10	74·45	417	73·56	92	74·13	244	73·94	163	74·13	214		
11	74·53	462	73·53	89	74·24	298	74·03	202	74·09	226		
12	74·63	519	73·53	89	74·07	218	75·03	[illegible]	74·05	210		
13	75·21	850	73·49	84	74·05	210	75·20	841	74·05	210		
14	75·50	1,020	74·07	218	74·00	190	75·46	992	74·05	210		
15	75·55	1,040	74·29	325	73·93	169	75·51	1,020	74·05	210		
16	75·71	1,130	74·68	548	73·91	163	75·54	1,040	74·05			
17	75·40	958	75·07	770	73·83	143	75·48	1,000	74·05			
18	75·28	890	75·21	850	73·91	163	75·39	952	74·05			
19	75·06	764	75·16	824	74·03	202	75·42	969	74·05			
20	75·99	724	75·11	793	73·99	187	75·35	930	74·05			
21	74·81	622	75·08	776	73·96	178	75·34	918	74·05			
22	74·65	531	74·99	724	73·95	175	75·23	861	74·05			
23	74·65	531	74·93	690	73·93	169	75·22	855	74·05			
24	74·58	491	74·91	679	73·93	169	75·15	816	74·05			
25	74·53	462	74·83	633	73·91	163	75·11	793	74·05			
26	74·41	394	74·83	633	73·87	153	75·05	759	74·05			
27	74·27	314	74·74	582	73·88	155	74·96	707	74·05			
28	74·14	248	74·66	530	73·86	150	75·01	736	74·05			
29	74·14	244	74·63	519	73·83	143	74·98	719	74·05			
30	74·00	190	74·57	485	73·81	138	74·96	707	74·05			
31	74·99	187	74·59	496			74·81	622	74·05			

Table 57.—Daily discharge records of Whitemouth river at Whitemouth, Man.—Continued.

1911.

Day.	January. Gauge Height	January. Discharge	February. Gauge Height	February. Discharge	March. Gauge Height	March. Discharge	April. Gauge Height	April. Discharge	May. Gauge Height	May. Discharge	June. Gauge Height	June. Discharge
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1							73·58		74·70	594	75·11	810
2							73·58		74·81	622	75·11	810
3							73·58		74·86	650	77·21	2,010
4							73·58		75·41	907	77·67	2,250
5							73·58		75·57	1,060	77·19	1,980
6							73·58		75·81	1,190	76·28	1,460
7							73·58		75·93	1,260	76·10	1,350
8							73·58		75·97	1,280	76·35	1,500
9							73·58		75·71	1,130	76·72	1,710
10							73·58		75·43	975	76·62	1,650
11							73·58		75·36	945	76·74	1,720
12							73·58		75·27	884	76·46	1,560
13							73·58		75·27	884	76·23	1,450
14							73·58		75·12	798	75·94	1,270
15							73·58		74·98	719	75·72	1,140
16							73·98		74·89	667	75·48	1,000
17							74·69		74·76	594	75·24	867
18							75·55		74·61	508	75·20	844
19							76·02		74·57	485	75·15	816
20							76·08		74·79	610	75·13	804
21							76·16	1,490	75·09	781	75·01	736
22							76·23	1,430	75·21	850	75·01	736
23							76·01	1,310	75·32	912	74·97	713
24							75·76	1,160	75·32	912	74·82	627
25							75·76	1,160	75·34	924	74·69	553
26							75·43	975	75·36	935	74·62	513
27							75·17	827	75·28	890	74·47	428
28							74·96	707	75·24	867	74·39	382
29							74·93	690	75·18	833	74·31	347
30							74·76	593	75·37	941	74·19	271
31									75·32	912		

NOTE.—Ice conditions from January 1, to April 20; not sufficient information to compute daily discharges.

Day.	July. Gauge Height	July. Discharge	August. Gauge Height	August. Discharge	September. Gauge Height	September. Discharge	October. Gauge Height	October. Discharge	November. Gauge Height	November. Discharge	December. Gauge Height	December. Discharge
1	74·19	271	74·22	287	73·87	154	74·05	210	74·39	382	73·86	
2	74·42	399	74·14	218	73·85	148	73·96	178	74·31	347	73·83	
3	74·46	422	74·08	222	73·79	133	73·91	163	74·33	347	73·87	
4	74·49	439	74·06	214	73·83	143	73·88	155	74·49	439	73·87	
5	74·49	439	74·03	202	73·79	[illegible]	73·91	163	74·48	434	73·88	
6	74·48	434	73·98	184	73·75	125	73·89	158	74·46	422	73·88	
7	74·48	434	73·93	166	73·75	125	73·89	158	74·37	371	73·87	
8	74·46	422	73·84	145	73·75	125	73·92	166	74·37	371	73·87	
9	74·35	360	73·77	129	73·73	121	74·06	214	74·33	351	73·85	
10	74·27	315	73·71	117	73·75	125	74·79	610	74·31	354	73·85	
11	74·08	222	73·67	110	73·77	129	75·61	1,080	74·33	348	73·83	
12	74·80	616	73·65	106	73·79	[illegible]	75·59	1,070	74·26	309	73·85	
13	77·11	1,950	73·56	92	73·79	133	75·55	1,040	74·26	309	73·85	
14	76·62	1,650	73·54	90	73·81	138	75·55	1,040	74·21	282	73·81	
15	76·34	1,190	73·54	90	73·84	145	75·51	1,020	74·16	258	73·8	
16	75·99	1,290	73·48	84	73·88	155	75·43	975	74·12	240	73·83	
17	75·71	1,150	73·51	90	73·91	163	75·36	945	74·11	235	73·83	
18	75·44	987	73·60	97	73·87	153	75·31	907	74·08	222	73·83	
19	75·42	969	73·60	97	73·87	154	75·25	873	74·08	222	73·73	
20	75·38	917	73·53	89	73·87	153	75·22	855	74·08	222	73·62	
21	75·40	901	73·49	84	73·89	158	75·18	833	74·08	222	73·52	
22	75·26	878	73·47	82	74·00	190	75·18	833	[1]74·00	190	73·55	
23	75·13	804	73·47	82	74·16	258	75·01	736	[1]74·00	190	73·55	
24	75·04	753	73·69	113	74·19	271	74·89	667	[1]74·00	190	73·52	
25	74·92	684	73·71	117	74·24	298	74·76	593	73·93	169	73·53	
26	74·77	599	73·76	127	74·24	298	74·74	582	73·93	169	73·53	
27	74·61	508	73·81	138	74·20	276	74·69	553	73·93	169	73·53	
28	74·52	456	73·83	143	74·15	253	74·61	508	73·93	169	73·49	
29	74·46	422	73·85	148	74·09	226	74·55	474	[1]73·90	160	73·49	
30	74·38	377	73·87	153	74·06	214	74·51	451	73·85	146	73·43	
31	74·38	377	73·89	158			74·44	405			73·41	

NOTE.—Marked thus [1], interpolated, ice conditions from November 18; not sufficient information to compute daily discharges for December.

Table 68.—Monthly discharge of Whitemouth [illegible] at Whitemouth, Man.

[Drainage Area, 1,400 square miles.]

Month	Discharge in Second Feet				Run-off.
	Maximum	Minimum	Mean	Per square mile.	Depth in inches on Drainage area.
1912					
May[1]			2,000	1·429	1·645
June	1,360	425	914	0·674	0·752
July	1,510	169	991	0·709	0·817
August	1,280	409	770	0·550	0·634
September	2,210	1,170	1,740	1·246	1·379
October	2,010	1,020	1,630	1·164	1·342
November[1]			1,000	0·714	0·797
December[1]			100	0·071	0·082
1913					
January[1]			25	0·018	0·021
February[1]			25	0·018	0·019
March[1]			25	0·018	0·021
April[1]			1,600	1·143	1·275
May	1,180	576	846	0·597	0·688
June	764	160	420	0·300	0·335
July	1,130	187	592	0·421	0·488
August	850	83	405	0·289	0·333
September	462	138	229	0·164	0·182
October[1]	1,040	114	597	0·426	0·491
November[1]			230	0·164	0·183
December[1]			50	0·036	0·041
The year			420	0·300	4·079
1914					
January[1]			15	0·011	0·013
February[1]			10	0·007	0·007
March[1]			20	0·014	0·016
April[1]			450	0·321	0·358
May	1,280	485	855	0·611	0·701
June	2,250	271	1,080	0·772	0·861
July	1,950	222	708	0·506	0·583
August	287	82	136	0·097	0·112
September	208	121	174	0·124	0·138
October	1,080	155	600	0·428	0·494
November[1]	439	146	274	0·195	0·218
December[1]			50	0·036	0·042
The year			364	0·260	3·517

[1]Estimated.

Table 69.—Miscellaneous Discharge Measurements in Winnipeg River Watershed.

Date.	Stream.	Tributary to	Location.	Discharge in Second Feet
Aug. 3, 1912	Rainy River	Lake of the Woods	Beaudette	10,824
" 21, 1912	"	" "	"	8,287
Sept. 4, 1912	"	" "	"	5,411
Oct. 4, 1912	"	" "	Emo	10,119
Nov. 7, 1912	"	" "	"	6,482
Jan. 14, 1914	"	" "	"	6,155
Mar. 21, 1914	"	" "	"	6,876
Aug. 10, 1912	Creek	Rainy Lake	in Hale Bay	1·0
" 11, 1912	Pipestone River	"		7·1
" 13, 1912	Rat River	"		No flow.
" 14, 1912	Seine "	"		1,592·1
" 15, 1912	Creek	"	in Seine Bay	
" 15, 1912	Creek No. 2.	"	"	
" 17, 1912	Rocky Inlet Creek	"		No flow.
" 20, 1912	Big Canoe River	"		216·4
" 21, 1912	Little Canoe River.	"		6·8
" 22, 1912	Manitou River	"		815·5
" 24, 1912	Ash River	"		1·0
" 25, 1912	Small Creek	"	in Ash Bay	0·5
" 25, 1912	"	"	in Alexandra Bay	0·5
" 26, 1912	North-West Bay River	"		202·8
" 27, 1912	White Fish Creek	"		11·0
" 27, 1912	Brownlee's Creek	"		0·6
" 28, 1912	Small Creek	"	nr. Brownbee's in N. W. Bay	0·1
" 28, 1912	Lost Creek	"		7·0
" 29, 1912	Outlet of Wegg's Lake	"		0·7
" 29, 1912	Creek	"	in Brown's Inlet	(Est.) 0·5
" 30, 1912	Grassy Narrows Creek	"		0·1
" 31, 1912	Wasaw Creek	"		0·2
Sept. 1, 1912	Frog Cree	"		5·4

RUN-OFF DATA OF THE WINNIPEG RIVER WATERSHED.

TABLES 70 TO 91.

Data in Tables 70 to 91 were obtained by the field officers of the Hydro-Electric Commission of the province of Ontario, and published herein through the courtesy of the commission. The data are also available to the public in the Seventh Annual Report of the Commission.

SEINE RIVER AT SKUNK RAPIDS.

Location.—About 200 feet above Skunk rapids, and 1 mile upstream from the Canadian Northern Railway bridge. One-half mile north of the C. N. R. tracks, and 1 mile west of La Seine station, in the District of Rainy River.

Records Available.—Discharge measurements, August to December, 1914. Daily gauge heights, September 22 to December 31, 1914.

Drainage Area.—3,483 square miles.

Gauge.—Vertical steel staff gauge with enamelled face, graduated in feet and inches, and located near La Seine station, on the Canadian Northern railway. The zero on the gauge is at an elevation of 87·73 feet, which is referred to a bench mark (assumed elevation 100·00) painted on a large boulder, on the right bank of the river, 6 feet from a 6-inch poplar tree used as a final point for soundings. The initial point is on the left bank and consists of a 2-inch spruce tree, blazed and marked I.P. with white paint. "H. E. P. Comm." is painted on the rock directly below the spruce tree.

Channel.—Straight for about 500 feet above and 200 feet below the station to the rapids. The right bank of the river curves into a point at the rapids forming a narrow channel. The velocity of the river is slow and the banks are high, rocky and wooded. This land has been burnt over, but most of the trees are still standing. The bed of the stream is sandy and clean, with a few boulders near the right bank. One channel exists at all stages.

Discharge Measurements.—Made from canoe by means of a small Price current meter.

Accuracy.—As only a few discharge measurements were made up to the present time, there are not sufficient data to make accurate estimates of the daily discharge. Tables of daily gauge height, daily discharge, and monthly discharge will be prepared when records are available.

Observer.—C. Rose, La Sei[illegible], Ont.; P.O., Banning, Ont.

Table 70.—Discharge Measurements at Skunk rapids, Seine river, Ontario.

[Drainage area, 3,483 square miles.]

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq.-ft.	Ft. per sec.	Feet.	Sec.-ft.
1914.						
Aug. 14	J. R. Taylor	194·9	2,000	0·66	8·84	1,329
Sept. 22	"	199·4	2,079	0·804	9·33	1,674
Oct. 13	"	198·5	2,061	0·73	9·15	1,522
Nov. 10	"	195·4	2,000	0·642	8·88	1,284
Dec. 5[1]	"	185·0	1,8[illegible]	0·57	8·25	1,059

[1]Boat and ice measurement. River partly frozen.

Table 71.—Daily Discharge at Skunk rapids, Seine river, Ontario.

[Drainage Area, 3,483 square miles.]

1914

Day.	September.		October.		November.		December.	
	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1			9·08	1,460	8·92	1,320		
2			9·08	1,460	8·90	1,362		
3			9·06	1,442	8·92	1,320		
4			9·06	1,442	8·91	1,341		
5			9·06	1,442	8·90	1,302		
6			9·06	1,442	8·90	1,302		
7			9·06	1,442	8·90	1,302		
8			9·04	1,425	8·90	1,302		
9			9·04	1,425	8·90	1,302		
10			9·06	1,442	8·88	1,285		
11			9·13	1,503	8·85	1,260		
12			9·13	1,503	8·83	1,240		
13			9·15	1,520	8·85	1,260		
14			9·15	1,520	8·85	1,260		
15			9·13	1,503	8·85	1,260		
16			9·11	1,485	8·84	1,250		
17			9·09	1,469	8·78	1,198		
18			9·07	1,450	8·77	1,190		
19			9·03	1,415	8·77	1,190		
20			9·00	1,390	8·75	1,171		
21			8·98	1,372	8·74	1,162		
22	9·33	1,675	8·97	1,362	8·73	1,154		
23	9·27	1,625	9·03	1,415	8·73	1,154		
24	9·26	1,616	9·04	1,425	8·71	1,138		
25	9·27	1,625	9·04	1,425	8·70	1,130		
26	9·20	1,562	9·02	1,407	8·69	1,121		
27	9·17	1,537	9·00	1,390	8·67	1,104		
28	9·16	1,530	8·98	1,372	8·67	1,104		
29	9·11	1,485	8·96	1,352	8·67	1,104		
30	9·08	1,460	8·95	1,345	8·67	1,104		
31			8·94	1,337				

Table 72.—Monthly Discharge at Skunk rapids, Seine river, Ontario.

[Drainage Area, 3,483 square miles.]

Month.	Discharge in Second Feet.			Discharge in Second-Feet per Square Mile.			Run-Off.
	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Depth in inches on Drainage Area.
1914							
October	1,520	1,337	1,431	0·44	0·38	0·411	0·47
November	1,320	1,104	1,220	0·38	0·32	0·350	0·39

TURTLE RIVER AT MOUNTAIN RAPIDS.

Location.—About 300 feet above Mountain rapids, and about 8 miles from the Olive Mine, 12 miles from Mine Centre, which is on the Canadian Northern railway, in the Rainy River district.

Records Available.—Monthly discharge measurements, August to December, 1914. Daily gauge heights, August 9 to December 31, 1914.

Drainage Area.—1,841 square miles.

Gauge.—Vertical steel staff gauge with enamelled face, graduated in feet and inches, and fastened on a crib pier at the Canadian Northern Railway sawmill, 12 miles from the station. The gauge is located 1,000 feet south of the mouth of Little Turtle river, on the east shore of Little Turtle lake. Zero on gauge (elevation 83·89) is referred to a bench-mark established on a rock with white paint, on the left bank of the river, 4 feet south of a blazed pine tree, marked I.P. with white paint, which is used as the initial point for soundings. The elevation of this bench-mark is 96·00, which is referred to another bench-mark (assumed elevation 100·00) established on a rock with white paint, 35 feet northeast of the gauge, at the Canadian Northern Railway mill at Mine Centre.

Channel.—Straight for about 1,000 feet above and below the station, the water running slowly. The banks are high, wooded, and rocky. The bed of the stream is sandy and clean, one channel existing at all stages.

Discharge Measurements.—Made from a canoe with a small Price current-meter.

Control.—The river is used extensively for log driving, and the log jams in Otter falls affect the section somewhat.

Accuracy.—As only a few discharge measurements were made up to the present time, there are not sufficient data to make accurate computations of the daily discharge. Additional tables of daily gauge height, daily discharge, and monthly discharge will be prepared and published when sufficient records are available.

Observer.—W. R. Miller, Mine Centre, Ont.

Table 73.—Discharge Measurements of Turtle river at Mountain rapids, Ontario.

[Drainage Area, 1,841 square miles.]

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
1914.		Feet.	Sq.-ft.	Ft. per sec.	Feet.	Sec.-ft.
Aug. 11	J. R. Taylor	168·4	2,947	0·29	92·47	850
Sept. 23	"	167·8	2,948	0·407	92·43	1,202
Oct. 12	"	169·1	3,033	0·412	92·93	1,250
Nov. 5	"	168·1	2,964	0·39	92·58	1,161
Dec. 19[1]	"	161·0	2,518	0·089	90·39	224

[1] Ice measurement—jam at Otter Falls.

MANITOU RIVER AT DEVIL'S CASCADES.

Location.—About 150 feet below the old dam, at the head of the Devil's Cascades, Rainy River district.

Records Available.—Monthly discharge measurements, July to December, 1914. Daily gauge heights, July 15 to November 31, 1914.

Drainage Area.—440 square miles.

Gauge.—An inclined steel staff, graduated in feet and inches, and located on the face of the old dam. The zero of the gauge is at an elevation of 139·38 feet, referred to a bench-mark (elevation 147·37) painted on a rock, 1 foot east of the initial point of soundings. Owing to the gauge not being vertical in the face plane, 0·3 foot per foot of staff reading is to be subtracted from the staff reading before adding to gauge zero for water levels.

Channel.—Straight for about 150 feet above and 400 feet below the station. The right bank is high, rocky, wooded, and not liable to overflow, but the left bank is low and wooded, with a gradually rising bank, which is not liable to overflow unless the dam is operated. The bed of the stream is composed of rock, and the current is slow, one channel existing at all stages.

Discharge Measurements.—Made from canoe or ice, by a small Price current-meter.

Control.—Several dams exist on the river between the section and Manitou lake, which are not in operation at present. The operation of the dam just above the station causes fluctuations at the gauge.

Accuracy.—As only a few discharge measurements were made, there are not sufficient data to make accurate computations of the daily discharge. Table of daily gauge height, daily discharge, and monthly discharge will be prepared when sufficient records are available.

Observer.—S. H. Baldwin, Box No. 250, Fort Frances, Ont.

Table 74.—Discharge Measurements of Manitou river, Devil's Cascades, Ontario.

[*Drainage area, 440 square miles.*]

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
July 15	C. C. McLennan	110·0	494	0·577	4·83	284
Aug. 13	J. R. Taylor	98·6	483	0·56	4·69	271
Sept. 19	"	99·0	455	0·47	4·40	214
Oct. 11	"	98·7	463	0·506	4·52	234
Nov. 3	"	98·5	454	0·48	4·45	219
Dec. 17	"	94·3	474	0·43	4·35	194

Table 75.—Daily discharge of Manitou river, Devil's Cascades, Ontario.

[Drainage Area, 440 square miles.]

1914.

Day.	July.		August.		September.		October.		November.		December.	
	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	....	....	4·81	287	4·50	230	4·44	220	4·44	220	....	....
2	....	....	4·79	283	4·50	230	4·42	220	4·44	220	....	....
3	....	....	4·77	279	4·42	216	4·42	220	4·44	220	....	....
4	....	....	4·75	276	4·37	207	4·40	212	4·42	216	....	....
5	....	....	4·73	272	4·35	203	4·40	212	4·42	216	....	....
6	....	....	4·73	272	4·35	203	4·40	212	4·42	216	....	....
7	....	....	4·71	268	4·37	207	4·42	216	4·40	212	....	....
8	....	....	4·71	268	4·37	207	4·44	220	4·35	203	....	....
9	....	....	4·71	268	4·35	203	4·46	224	4·35	203	....	....
10	....	....	4·71	268	4·35	203	4·48	227	4·33	199	....	....
11	....	....	4·71	268	4·33	199	4·50	230	4·35	203	....	....
12	....	....	4·69	264	4·35	203	4·50	230	4·38	208	....	....
13	....	....	4·69	264	4·37	207	4·50	230	4·42	216	....	....
14	....	....	4·67	261	4·37	207	4·50	230	4·46	224	....	....
15	4·87	298	4·67	261	4·35	203	4·48	227	4·50	230	....	....
16	4·87	298	4·65	257	4·35	203	4·48	227	4·50	230	....	....
17	4·92	307	4·65	257	4·37	207	4·46	224	4·50	230	....	....
18	4·94	310	4·65	257	4·37	207	4·46	224	4·50	230	....	....
19	4·94	310	4·62	252	4·40	212	4·48	227	4·50	230	....	....
20	5·00	321	4·62	252	4·40	212	4·48	227	4·50	230	....	....
21	5·04	329	4·62	252	4·39	210	4·50	230	4·50	230	....	....
22	5·04	329	4·60	248	4·42	216	4·50	230	4·50	230	....	....
23	5·00	321	4·60	248	4·42	216	4·50	230	4·48	227	....	....
24	4·98	318	4·60	248	4·44	220	4·50	230	4·48	227	....	....
25	4·98	318	4·60	248	4·44	220	4·50	230	4·48	227	....	....
26	4·98	318	4·60	248	4·44	220	4·50	230	4·48	227	....	....
27	4·96	314	4·60	248	4·44	220	4·48	227	4·50	230	....	....
28	4·92	307	4·58	245	4·48	226	4·46	224	4·50	230	....	....
29	4·90	303	4·56	241	4·48	226	4·46	224	4·50	230	....	....
30	4·87	298	4·54	238	4·46	224	4·44	224	4·50	230	....	....
31	4·85	294	4·52	234	....	....	4·44	220	....	....	....	....

Table 76.—Monthly discharge of Manitou river, Devil's Cascades, Ontario.

[Drainage area, 440 square miles.]

1914.

Month.	Discharge in Second-Feet.			Discharge in Second-Feet per Square Mile.			Run-off.
	Maximum.	Minimum	Mean.	Maximum.	Minimum.	Mean.	Depth in inches on Drainage area.
August	287	234	259	0·65	0·53	0·588	0·68
September	230	199	212	0·52	0·45	0·482	0·54
October	230	212	224	0·52	0·48	0·511	0·59
November	230	199	222	0·52	0·45	0·503	0·56
The period	287	199	231	0·65	0·45	0·52	2·37

FOOTPRINT RIVER AT RAINY LAKE FALLS.

Location.—One hundred feet above the crest of the lowest fall, at the mouth of the Footprint river, where it flows into the northwest bay of Rainy lake, on Indian reserve 17A, district of Rainy River.

Records Available.—Monthly discharge measurements, July to December, 1914. Daily gauge heights, September 18 to December 31, 1914.

Drainage Area.—588 square miles.

Gauge.—Vertical steel staff gauge, graduated in feet and inches, and attached to a poplar tree 26·2 feet from the initial point. The zero on the gauge (elevation 102·26) is referred to a bench-mark painted on the ledge of a rock on right bank 6·7 feet upstream from initial point for soundings. Rod held on dot inside of circle marked B.M. in white paint (elevation 110·51).

Channel.—About 40 feet above the station the channel curves to the left and then runs straight for about 140 feet, dropping into Rainy lake. The banks are high, rocky, wooded, and not liable to overflow. The right bank has been burnt over. The bed of the river contains large boulders, and one channel exists at all stages.

Discharge Measurements.—Made from canoe with small Price current-meter. The initial point for soundings is marked Initial Point, H.E.P.C. on a rock ledge on the right bank, and 4·75 feet downstream from the point marked Initial Point, P.W.D., and 6·7 feet from the bench-mark.

Control.—Occasional operations of the dam at Footprint lake cause fluctuations in the river a[illegible]e.

Accuracy.—As only a few discharge measurements were made up to the present time, there are not sufficient data to make accurate computations of the daily discharge. Tables of daily gauge height, daily discharge, and monthly discharge will be prepared when sufficient records are available.

Observer.—John Lyons, Fort Frances, Ont.

Table 77.—Discharge measurements of Footprint river at Rainy Lake falls, Ontario.

[Drainage area, 588 square miles.]

Date.		Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
1914			Feet.	Sq. ft.	Ft per sec.	Feet.	Sec.-ft.
July	14	C. C. McLennan	65·7	165	4·11	103·49	681
Aug.	12	J. R. Taylor	61	130	2·72	102·86	356
Sept.	18	"	54·3	101	2·38	102·38	242
Oct.	10	"	54·3	101	2·34	102·36	238
Nov.	1	"	45·9	57	1·83	101·47	105
Dec.	17	"	48·2	67	1·74	101·70	118

Table 78.—Daily discharge records of Footprint river at Rainy lake falls, Ontario.

[Drainage area, 588 square miles].

1914.

Day.	September.		October.		November.		December.	
	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	...	...	102·38	242	101·47	106	...	...
2	...	...	102·38	242	101·45	102	...	...
3	...	...	102·38	242	101·45	102	...	...
4	...	...	102·36	238	101·45	102	...	...
5	...	...	102·36	238	101·45	102	...	...
6	...	...	102·36	238	101·45	102	...	...
7	...	...	102·36	238	101·45	102	...	...
8	...	...	102·36	238	101·45	102	...	...
9	...	...	102·36	238	101·45	102	...	...
10	...	...	102·36	238	101·45	102	...	...
11	...	...	102·36	238	101·45	102	...	...
12	...	...	102·35	235	101·45	102	...	...
13	...	...	102·36	238	101·45	102	...	...
14	...	...	102·36	238	101·45	102	...	...
15	...	...	102·36	238	101·45	102	...	...
16	...	...	102·36	238	101·45	102	...	...
17	...	...	102·36	238	101·45	102	...	...
18	102·38	242	102·36	238	101·45	102	...	...
19	102·38	242	102·36	238	101·45	102	...	...
20	102·34	233	102·36	238	101·45	102	...	...
21	102·34	233	102·36	238	101·45	102	...	...
22	102·38	242	102·36	238	101·45	102	...	...
23	102·38	242	102·36	238	105·68	102	...	...
24	102·38	242	102·36	238	105·68	102	...	...
25	102·38	242	102·36	238	105·68	102	...	...
26	102·38	242	102·36	238	105·68	102	...	...
27	102·34	233	102·36	238	105·68	102	...	...
28	102·38	242	102·36	238	105·68	102	...	...
29	102·38	242	102·36	238	105·68	102	...	...
30	102·38	242	102·36	238	105·68	102	...	...
31	...	...	102·36	238	...	...	...	...

Table 79.—Monthly discharge of Footprint river at Rainy lake falls. Ontario.

[Drainage area, 588 square miles.]

1914.

Month.	Discharge in Second-Feet.			Discharge in Second-Feet per square mile.			Run-off.
	Maximum.	Minimum	Mean.	Maximum.	Minimum.	Mean.	Depth in inches on Drainage area.
September	242	238	238	0·41	0·40	0·405	0·46
October	106	102	102	0·18	0·17	0·173	0·19

WABIGOON RIVER AT WABIGOON FALLS.

Location.—About 100 feet below the lowest fall on the Wabigoon river, and 3 miles from the mouth of the Wabigoon river discharging into the English river, district of Kenora.

Records Available.—Monthly discharge measurements, June to November, 1914.

Drainage Area.—1,026 square miles.

Gauge.—Vertical steel staff with enamelled face, graduated in feet and inches and screwed to a 5-inch hewn spruce post, firmly wedged and braced to the left bank, about 200 feet above the metering station. The zero on the gauge (elevation 11·37) is referred to a bench-mark (elevation 120·07) on a nail driven in a 4-inch tamarac stump located 2 feet upstream from the gauge. The initial point for soundings is on the right bank, painted I.P., S. 12° E. on a blazed 5-inch poplar tree.

Channel.—Straight for about one-half mile above and 100 feet below the station to the falls. Both banks are high, rocky, wooded, and will not overflow. The bed of the stream is composed of rock, with a few boulders and weeds at the right bank. The current is sluggish above the station, but swift just above the falls. There is a slight backwater at the left bank.

Discharge Measurements.—Made from canoe and ice with a small Price current meter.

Table 80.—Discharge Measurements of Wabigoon River, at Wabigoon Falls, Ontario,

[*Drainage area, 1,026 square miles.*]

1914.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
1914		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
June 8	C. C. McLennan	248·0	3,658	0·91	114·88	3,312
July 17	"	247·6	3,458	0·74	114·05	2,569
Aug. 4	"	246·0	3,220	0·54	113·04	1,732
Sept. 14	"	217·0	2,957	0·37	112·04	1,103
Nov. 8	"	239·5	3,081	0·44	112·52	1,374
Dec. 21	"	217·0	2,907	0·30	111·73	900

WABIGOON RIVER NEAR QUIBELL.

Location.—About 200 feet above the second fall from the G. T. P. railway bridge which spans the first fall, or one-half mile north of the railway. One-half mile from Quibell station on the Grand Trunk Pacific railway, Quibell township, district of Kenora.

Records Available.—Monthly discharge measurements, June to November, 1914. Daily gauge heights, August 1 to November 30, 1914.

Drainage Area.—1,612 square miles.

Gauge.—Vertical staff gauge consisting of 9 feet of enamelled steel plate, graduated in feet and inches and screwed to a 5-inch hewn spruce post, firmly wedged and secured to a rock on the right bank of the river. The elevation of the zero mark is 24·26, which is referred to a bench-mark (elevation 33·67) located just below the gauge.

Channel.—Straight for about 1,200 feet above the station, where the stream enters from the right bank, making an angle of 90°. For about 200 feet below the station the river is straight and then narrows into a fall. The water is sluggish, and banks are high, rocky, and wooded. There are a few boulders apparent in the bed of the stream. One channel exists at all stages.

Discharge Measurements.—Made from a canoe by a small Price current-meter.

Control.—The Dryden Timber and Power Company operate a dam and power plant at Dryden, on the Wabigoon river.

Accuracy.—As only a few discharge measurements are made up to the present time, there are not sufficient data to make accurate estimates of the daily discharge.

Observer.—D. C. Warner, Quibell, Ont.

Table 80A.—Discharge Measurements of Wabigoon River, rear Quibell, Ont.,

1914.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. Feet.	Feet per Sec.	Feet.	Sec-feet.
1914.						
June 4	P. V. Binns	124·0	1,484	1·82	95·32	2,703
July 18	"	110·0	1,258	1·20	93·34	1,503
Aug. 1[1]	"	84·4	720	1·72	26·59	1,237
Sept. 17	"	85·5	736	1·83	26·81	1,347
Oct. 5	"	83·8	703	1·62	2[illegible]·36	1,138
Nov. 11	"	81·2	648	1·29	25·73	841

[1]New section established.

Table 81.—Daily Discharge Records of Wabigoon River, near Quibell, Ontario.

[Drainage Area, 1,612 square miles.]

1914.

Day.	August.		September.		October.		November.		December.	
	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	26·59	1,255	25·76	860	26·67	1,295	26·05	1,000	....	....
2	26·54	1,230	25·75	855	26·59	1,255	26·05	1,000	....	....
3	26·55	1,235	25·75	855	26·52	1,220	26·05	1,000	....	....
4	26·51	1,215	25·74	845	26·50	1,210	26·05	1,000	....	....
5	26·51	1,215	25·72	840	26·42	1,170	26·05	1,000	....	....
6	26·50	1,210	25·68	825	26·39	1,155	26·02	985	....	....
7	26·51	1,215	25·67	815	26·34	1,130	26·01	980	....	....
8	26·43	1,175	25·63	805	26·30	1,115	25·94	945	....	....
9	26·43	1,175	25·59	785	26·26	1,095	25·84	895	....	....
10	26·47	1,195	25·68	825	26·43	1,175	25·80	880	....	....
11	26·34	1,130	25·72	840	26·59	1,255	25·76	860	....	....
12	26·22	1,075	25·83	[illegible]	26·67	1,295	25·75	855	....	....
13	26·18	1,055	25·84	895	26·68	1,300	25·76	860	....	....
14	26·18	1,055	25·89	920	26·68	1,300	25·76	860	....	....
15	26·18	1,055	25·93	940	26·68	1,300	25·76	860	....	....
16	26·17	1,050	26·09	1,015	26·67	1,295	25·76	860	....	....
17	26·17	1,050	26·77	1,340	26·59	1,255	25·83	890	....	....
18	26·09	1,015	27·26	1,580	26·58	1,250	25·80	830	....	....
19	26·05	985	27·51	1,705	26·43	1,175	25·76	860	....	....
20	26·01	980	27·47	1,680	26·42	1,170	25·76	860	....	....
21	25·97	955	27·26	1,580	26·26	1,095	25·75	855	....	....
22	25·9[illegible]	940	27·12	1,504	26·26	1·095	25·72	840	....	....
23	25·[illegible]7	955	27·09	1,495	26·25	1,090	25·68	825	....	....
24	25·89	920	27·17	1,535	26·24	1,085	25·68	825	....	....
25	25 34	895	27·18	1,540	26·25	1,090	25·67	815	....	....
26	25·80	880	27·24	1,570	26·14	1,035	25·67	815	....	....
27	25·82	885	27·17	1,535	26·10	1,020	25·67	815	....	....
28	25·80	880	27·93	1,910	26·09	1,015	25·66	810	....	....
29	25·76	860	26·77	1,340	26·09	1,015	25·68	825	....	....
30	25·76	860	26·70	1,305	26·09	1,015	25·66	810	....	....
31	25·76	860	....	....	26·08	1,010	....	....	....	....

Table 82.—Monthly Discharge of Wabigoon River, near Quibell, O

[Drainage Area, 1,612 square miles.]

1914.

Month.	Discharge in Second-feet.			Discharge in Second-feet per square mile.			Run-off.
	Maximum.	Minimum	Mean	Maximum	Minimum	Mean	Depth in. inches on drainage area.
August	1,255	860	1,050	0·78	0·53	0·651	0·75
September	1,910	785	1,181	1·19	0·49	0·732	0·81
October	1,300	1,010	1,160	0·81	0·63	0·719	0·83
November	1,000	810	885	0·62	0·50	0·549	0·61
December	.....	.....				.....	.....
The period	1,910	785	1,069	1·19	0·49	0·66	3·00

EAGLE RIVER AT EAGLE RIVER.

Location.—At the highway bridge, 1,000 feet south of the Canadian Pacific Railway crossing of the river, and above the Cascades, in the township of Aubrey, Kenora district. This river is a branch of the Wabigoon river.

Records Available.—Monthly discharge measurements, January to November, 1914. Daily gauge heights, February 12 to December 31, 1914.

Drainage Area.—933 square miles.

Gauge.—Vertical steel staff gauge with enamelled face, graduated in feet and inches, and located on the south face of the bridge crib, near the southeast corner, next to the left bank of the river. The zero on the gauge (elevation 1,172·99) is referred to a bench-mark (elevation 1,193·22) consisting of the head of a spike driven horizontally in the face of the water tank near the bridge, on the main line of the Canadian Pacific railway. Another bench-mark, at an elevation of 1,176·56 is painted on a rock, on the left bank, a few feet above the cross-section.

Channel.—Straight for about 100 feet above the station, with the water running slowly. Below the section the channel is straight for about 20 feet, with swift water running to the fall over the Cascades. The banks are clean, high, rocky, and not liable to overflow. The bed consists of solid rock, and is practically permanent. At extreme high water the flow is cut up by the bridge piers, but under normal conditions the flow is all through one channel.

Discharge Measurements.—Made from the highway bridge with a Price current-meter.

Accuracy.—This is nearly an ideal section. The sum of the differences between curve and measured dischagges for same gauge heights is 3·09 per cent of the sum of those measured discharges.

Observer.—J. Nelson, Eagle River, Ont.

Table 83.—Discharge Measurements of Eagle river at Eagle River, Ontario.

[*Drainage Area, 913 square miles.*]

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
1914.						
Jan. 8	C. C. McLennan	36·0	114	1·85	1173·55	212
Feb. 12	"	35·5	109	1·81	1173·53	197
Mar. 20	"	35·0	108	1·72	1173·83	187
Mar. 26	"	35·0	105	1·78	1173·49	189
Mar. 26	"	35·0	105	1·79	1173·49	189
Mar. 27	"	35·0	108	1·81	1173·51	197
Apr. 25	"	35·0	115	1·79	1173·66	206
April 25	"	35·0	115	1·76	1173·66	203
June 9	R. M. Carmichael	86·0	190	3·83	1175·24	730
June 9	"	86·0	190	3·78	1175·21	721
June 9	"	86·0	190	3·83	1175·24	731
June 9	"	86·0	190	3·79	1175·24	724
June 10	"	87·5	200	4·14	1175·41	831
June 10	"	87·5	200	4·11	1175·41	824
July 30	"	81·0	194	3·70	1175·16	718
July 31	"	81·0	194	3·56	1175·11	689
Sept. 2	C. C. McLennan	50·0	154	2·59	1174·41	398
Sept. 2	"	50·0	154	2·59	1174·41	399
Sept. 3	"	19·5	145	[illegible]	[illegible]	365
Sept. 3	"	49·5	145	[illegible]	1174·28	366
Sept. 18	P. V. Burns	52·5	158	3·08	1174·55	486
Sept. 23	"	51·8	157	2·92	1174·59	459
Oct. 7	"	50·6	148	2·68	1174·47	390
Oct. 7	"	50·6	148	2·68	1174·46	397
Nov. 12	"	46·1	113	2·61	1174·10	375

Table 84.—Daily Discharge Records of Eagle river at Eagle River, Ontario.

(*Drainage Area, 913 square miles.*)

1914.

Day.	January. Gauge Height	January. Discharge.	February. Gauge Height	February. Discharge.	March. Gauge Height	March. Discharge.	April. Gauge Height	April. Discharge.	May. Gauge Height	May. Discharge.	June. Gauge Height	June. Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	....	....			1,173·51	193	1,173·50	191	1,173·70	227	1,174·65	477
2	....	....			1,173·53	196	1,173·51	193	1,173·68	224	1,174·67	485
3	....	....			1,173·53	196	1,173·52	194	1,173·72	232	1,174·72	502
4	....	....			1,173·53	196	1,171·51	193	1,173·81	250	1,174·78	526
5	....	....			1,173·51	193	1,173·51	193	1,173·80	248	1,174·80	533
6	....	....			1,173·51	193	1,173·51	193	1,173·84	256	1,174·80	533
7	....	....			1,173·51	193	1,173·51	193	1,173·84	263	1,174·80	533
8	....	....			1,173·53	193	1,173·51	193	1,173·93	275	1,174·90	568
9	....	....			1,173·53	196	1,173·51	193	1,173·93	275	1,175·24	730
10	....	....			1,173·53	196	1,173·51	193	1,173·97	284	1,175·11	831
11	....	....	....	....	1,173·53	196	1,173·51	193	1,173·97	281	1,175·49	883
12	....	....	1,173·53	196	1,173·51	193	1,173·49	188	1,173·97	284	1,175·49	883
13	....	....	1,173·55	198	1,173·51	193	1,171·18	186	1,173·95	278	1,175·59	918
14	....	....	1,173·53	196	1,173·51	193	1,173·49	188	1,173·94	278	1,175·51	960
15	....	....	1,173·53	196	1,173·53	196	1,173·48	186	1,173·97	284	1,175·55	920
16	....	....	1,173·53	196	1,173·53	196	1,173·49	188	1,173·99	289	1,175·56	891
17	....	....	1,173·57	203	1,171·53	196	1,173·51	193	1,174·01	295	1,175·56	993
18	....	....	1,173·57	203	1,173·55	198	1,173·53	196	1,174·03	299	1,175·53	908
19	....	....	1,173·57	203	1,173·55	198	1,173·58	201	1,174·03	299	1,175·61	960
20	....	....	1,173·57	203	1,173·53	196	1,173·62	210	1,174·13	324	1,175·53	920
21	....	....	1,173·53	196	1,173·49	188	1,173·63	216	1,174·22	345	1,175·53	908
22	....	....	1,173·53	196	1,173·47	185	1,173·65	217	1,174·19	345	1,175·53	908
23	....	....	1,173·55	193	1,173·45	181	1,173·65	217	1,174·22	345	1,175·56	993
24	....	....	1,173·51	193	1,173·45	181	1,173·65	217	1,174·31	369	1,175·53	908
25	....	....	1,173·55	198	1,173·47	185	1,173·66	219	1,174·36	388	1,175·56	908
26	....	....	1,173·51	193	1,173·47	185	1,173·66	219	1,174·38	393	1,175·53	908
27	....	....	1,173·51	193	1,173·53	190	1,173·66	219	1,174·38	393	1,175·45	855
28	....	....	1,173·49	188	1,173·51	193	1,173·68	224	1,174·48	420	1,175·45	?55
29	....	....	....	....	1,173·51	193	1,173·68	224	1,174·47	417	1,175·45	855
30	....	....	....	....	1,173·51	193	1,173·70	227	1,174·53	438	1,175·45	855
31	....	....	....	....	1,173·51	193	....	....	1,174·65	477	....	....

Table 84.—Daily Discharge Records of Eagle river—Concluded.

Day.	July. Gauge Height	July. Discharge.	August. Gauge Height	August. Discharge.	September. Gauge Height	September. Discharge.	October. Gauge Height	October. Discharge	November. Gauge Height	November. Discharge.	December. Gauge Height	December. Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	1,175·44	846	1,175·16	689	1,174·34	378	1,174·49	423	1,174·33	373	1,174·26	355
2	1,175·43	883	1,175·14	678	1,174·40	397	1,174·51	430	1,174·36	388	1,174·22	345
3	1,175·47	868	1,175·16	689	1,174·26	355	1,174·49	423	1,174·34	[illegible]	1,174·22	345
4	1,175·41	831	1,175·11	663	1,174·20	340	1,174·45	410	1,174·36	[illegible]	1,174·20	340
5	1,175·45	855	1,175·09	654	1,174·07	307	1,174·41	398	1,174·34	378	1,174·20	340
6	1,175·49	883	1,175·11	663	1,174·20	340	1,174·38	394	1,174·32	373	1,174·10	335
7	1,175·47	868	1,175·09	654	1,174·20	340	1,174·38	394	1,174·28	361	1,174·18	335
8	1,175·45	855	1,175·07	646	1,174·18	335	1,174·38	394	1,174·32	374	1,174·18	335
9	1,175·38	816	1,174·99	609	1,174·16	330	1,174·36	388	1,174·32	374	1,174·16	330
10	1,175·30	765	1,174·95	594	1,174·18	335	1,174·36	388	1,174·32	373	1,174·18	335
11	1,175·28	754	1,174·95	594	1,174·20	340	1,174·38	394	1,174·32	374	1,174·18	345
12	1,175·36	805	1,174·95	594	1,174·24	351	1,174·38	394	1,174·24	351	1,174·16	340
13	1,175·41	831	1,174·95	594	1,174·28	361	1,174·41	398	1,174·22	345	1,174·16	340
14	1,175·45	855	1,174·99	609	1,174·32	374	1,174·49	423	1,174·20	340	1,174·16	340
15	1,175·47	868	1,174·91	576	1,174·36	388	1,174·53	438	1,174·22	345	1,174·16	340
16	1,175·38	816	1,174·82	542	1,174·43	404	1,174·53	438	1,174·20	340	1,174·16	340
17	1,175·30	765	1,174·82	542	1,174·53	438	1,174·54	438	1,174·26	355	1,174·16	330
18	1,175·44	846	1,174·80	533	1,174·57	450	1,174·55	444	1,174·16	340	1,174·16	340
19	1,175·34	787	1,174·78	526	1,174·59	456	1,174·53	438	1,174·24	354	1,174·16	340
20	1,175·32	775	1,174·74	509	1,174·61	462	1,174·53	440	1,174·26	355	1,174·16	330
21	1,175·30	765	1,174·72	502	1,174·61	462	1,174·49	423	1,174·24	351	1,174·16	330
22	1,175·24	730	1,174·68	488	1,174·61	462	1,174·49	423	1,174·22	345	1,174·16	330
23	1,175·28	754	1,174·66	480	1,174·63	474	1,174·49	423	1,174·24	351	1,174·16	330
24	1,175·32	775	1,174·61	462	1,174·55	441	1,174·49	423	1,174·26	355	1,174·14	326
25	1,175·36	805	1,174·57	450	1,174·53	438	1,174·47	417	1,174·28	361	1,174·14	326
26	1,175·24	730	1,174·53	438	1,174·53	438	1,174·32	373	1,174·28	364	1,174·11	318
27	1,175·16	689	1,174·49	423	1,174·53	438	1,174·36	388	1,174·28	361	1,174·14	326
28	1,175·24	730	1,174·47	417	1,174·51	430	1,174·34	378	1,174·26	355	1,174·14	326
29	1,175·16	689	1,174·45	410	1,174·49	423	1,174·32	373	1,174·28	361	1,174·14	326
30	1,175·13	678	1,174·41	398	1,174·49	423	1,174·32	373	1,174·28	361	1,174·14	326
31	1,175·16	689	1,174·39	393			1,174·34	378			1,174·11	318

Table 85.—Monthly Discharge of Eagle river at Eagle River, Ontario.

(Drainage Area 933 square miles.)

1914.

Month.	Discharge in Second-Feet. Maximum	Discharge in Second-Feet. Minimum	Discharge in Second-Feet. Mean.	Discharge in Second-Feet per Square Mile. Maximum.	Discharge in Second-Feet per Square Mile. Minimum	Discharge in Second-Feet per Square Mile. Mean.	Run-Off. Depth in inches on Drainage Area.
January	....	......	.....	....	....	....	....
February	.....	.....	.....	.....	.....	.....	....
March	198	181	193	0·21	0·19	0·21	0·24
April	227	186	202	0·24	0·20	0·22	0·24
May	477	224	315	0·51	0·24	0·34	0·39
June	994	477	798	1·06	0·51	0·85	0·95
July	883	678	791	0·95	0·74	0·85	0·98
August	689	393	548	0·74	0·42	0·59	0·68
September	474	307	396	0·51	0·33	0·42	0·47
October	444	373	408	0·48	0·40	0·44	0·50
November	388	330	360	0·42	0·35	0·39	0·44
December	355	318	322	0·38	0·34	0·34	0·39
The period	994	181	434	1·06	0·19	0·49	5·28

ENGLISH RIVER AT EAR FALLS.

Location.—At the foot of Lac Seul, about 3 miles below Pine Ridge, Hudson's Bay Company post, and about one-quarter mile above Upper Ear falls, Kenora district.

Records Available.—Monthly discharge measurements, July to October, 1914. Daily gauge heights, read at the main Hudson's Bay Company post, 75 miles above the section on Lac Suel, but do not give the fluctuations at the gauging section.

Drainage Area.—Not measured.

Gauge.—Vertical steel staff with enamelled face, graduated in feet and inches, and screwed to a 6-inch hewn spruce post, which is firmly wedged in a rock on the left bank, 200 feet below a 2-inch poplar, which is painted with white paint and used as the initial point for soundings. The zero on the gauge (elevation 115·14) is referred to a bench-mark (elevation 122·78) painted on a rock 5 feet above the gauge. Another bench-mark (elevation 122·08) is located at the head of the falls, 30 feet west of the portage entrance, directly below the section.

Channel.—Straight for about 400 feet above and 300 feet below the station, to the Upper Ear falls. Both banks are high, rocky, and wooded, and will not overflow. The bed of the stream is composed of rock with a little gravel, apparently stable. The current is sluggish, flowing through one channel at all stages.

Discharge Measurements. Made from a canoe with a small Price current-meter.

Accuracy.—Backwater on the left bank at certain stages of the river, causes difficulties in making accurate measurements of the discharge.

Table 86.—Discharge Measurements of English River at Ear Falls, Ontario.

Date	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge
		Feet.	Sq. ft.	Ft. Per sec	Feet.	Sec.-ft.
1914						
July 4	P. V. Binns	339·0	8,786	1·01	120·02	8,906
Aug 10	"	338·6	8,749	1·06	119·85	9,318
Sept. 12	C. C. McLennan	337·0	8,643	0·85	119·52	7,408
Oct. 30	P. V. Binns	345·1	8,562	0·79	119·28	6,801

ENGLISH RIVER AT MANITOU FALLS.

Location.—About 800 feet above the first chute of the Manitou falls, and 5 miles below the old Mattawa Hudson's Bay Company post, Kenora district. Cedar river enters the English river one-half mile below the metering station, after which the English river flows west.

Records Available.—Monthly discharge measurements, July to October, 1914.

Drainage Area.—Not measured.

Gauge.—Vertical steel staff with enamelled face, graduated in feet and inches, and screwed to a 6-inch hewn pine post firmly wedged and wired to the right bank, 15 feet south of the initial point, which consists of a 2-inch blazed jack pine, about 800 feet above the first fall. The zero of the gauge (elevation 89·42) is referred to a bench-mark (elevation 100·43) painted on a rock 2·5 feet southeast of the initial point. It is also referred to a bench-mark (assumed elevation 100·00) located on the left bank, 800 feet south of the section and at the head of the falls, 50 feet west of the head of the portage.

Channel.—At a point 1,200 feet above the station, the river turns to the right into a comparatively straight stretch, and opens into a weedy marsh or small lake 800 feet below the section, just above the falls. Both banks are high, rocky, and wooded, and will not overflow. The current is sluggish and flows through one channel at all stages.

Discharge Measurements.—Made from a canoe with a small Price current-meter.

Table 87.—Discharge Measurements of English River at Manitou Falls, Ontario.

Date	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
1914		Feet	Sq. ft.	Ft. per sec.	Feet.	Sec. ft.
July 4	C. C. McLennan	190·7	3,881·86	2·46	94·46	9,555
Aug. 9	"	195·7	3,961·21	2·59	93·84	10,279
Sept. 30	"	185·9	3,721·1	2·30	92·68	8,580
Oct. 31	"	184·0	3,619·01	2·28	92·09	8,257

ENGLISH RIVER NEAR OAK LAKE FALLS.

Location.—About 1 mile above the upper fall of Oak Lake falls, and about one-half mile below Wilcox lake, district of Kenora.

Records Available.—Monthly discharge measurements, August to November, 1914.

Drainage Area.—Not measured.

Gauge.—A bench-mark gauge located on a rock in the river at the station near the right bank. The initial point for soundings is established on the left bank, and consists of the head of a nail driven into the blazed side of a 12-inch poplar, painted I. P. N. 70° W.

Channel.—Straight for about 300 feet above and one-half mile below the station. Both banks are high, rocky, wooded, and not liable to overflow. The bed of the stream is rocky and practically permanent. The current is sluggish at the station, but swift through the little rapids 800 feet below, after which it becomes sluggish to the head of the falls. One channel exists at all stages.

Discharge Measurements.—Made from a canoe with a small Price current-meter.

Table 88.—Discharge Measurements of English River at Oak Lake Falls, Ontario.

Date	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
1914		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
Aug. 7	C. C. McLennan	397·2	7,011	1·68	197·11	11,344
Sept. 27	"	390·9	6,774	1·41	196·50	9,568
Nov. 5	"	387·7	6,672	1·30	196·25	8,698
Dec. 23	"	382·0	6,429	1·11	195·64	7,131

ENGLISH RIVER AT STURGEON FALLS.

Location.—Located about 300 feet above the lowest of the three falls known as Sturgeon falls, district of Kenora.

Records Available.—Monthly discharge measurements, from June to October, 1914.

Drainage Area.—Not measured.

Gauge.—Vertical steel staff with enamelled face, graduated in feet and inches, and screwed to a 5-inch hewn spruce post, firmly wedged and braced to the left bank, about 150 feet below the station. The zero of the gauge (elevation 91·52) is referred to a bench-mark (assumed elevation 100·00) on the left bank, 10 feet from the initial point and 2 feet below the line of the section. The initial point for soundings is blazed on the edge of a 6-inch poplar on the left bank and marked I.P.N. 10° E.

Channel.—There are deep bays on both sides of the river above the station, from which point the water flows in a comparatively straight channel gradually narrowing towards the head of the falls. Both banks are high, rocky, wooded, and will not overflow. The bed is composed of rock with a little sand in the centre of the river. The velocity is low at the left bank, slight backwater existing at higher stages.

Discharge Measurements. Made from a canoe with a small Price current-meter.

Control.—The Dryden Timber and Power Company operate a dam on the Wabigoon river, which is a tributary stream.

Table 89.—Discharge Measurements of English River at Sturgeon Falls, Ontario.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
1914						
June 12	C. C. McLennan	362	8,829	1·36	93·85	11,996
July 14	"	388	9,397	1·53	95·36	14,403
Sept. 11	"	354	8,620	1·29	93·25	11,089
Oct. 22	"	357	8,724	1·31	93·55	11,444

ENGLISH RIVER AT CARIBOU FALLS.

Location.—About 1,200 feet above Caribou Falls, the lowest falls on the river, district of Kenora.

Records Available.—Monthly discharge measurements, May to October, 1914.

Drainage Area.—Not measured.

Gauge.—Vertical staff located on the left bank of the river, 25·6 feet north of a blazed jack pine, which is used as the initial point for soundings. The zero on the gauge (elevation 100·00) is referred to a bench-mark (elevation 109·45) painted on the point of a rock, 16 feet south of the blazed jack pine.

Channel.—Above the station the channel takes a sharp 90 degree curve to the right, thence flowing comparatively straight to the head of the falls. Both banks are high, rocky, and wooded, and not liable to overflow. The bed of the stream is rocky, with large boulders or protruding shelves of rock and practically permanent. The water near the left bank is still.

Discharge Measurements.—Made from a canoe and raft with a small Price current-meter.

Control.—The Dryden Timber and Power Company operate a plant on the Wabigoon river, a tributary stream.

Table 90.—Discharge Measurements of English River at Caribou Falls, Ontario.

Date.		Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
1914			Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec. ft.
May	25	C. C. McLennan	236	10,051	0.87	101·72	8,785
June	14	"	239	10,214	1·43	102·92	14,606
July	11	"	240	10,342	1·53	103·17	15,812
Sept.	5	"	239	10,165	1·18	102·36	12,061
"	6	"	239	10,169	1·19	102·39	12,162
"	6	"	239	10,165	1·19	102·36	12,188
"	7	"	239	10,180	1·17	102·36	11,935
"	7	"	239	10,166	1·09	102·35	11,182
"	8	"	239	10,164	1·16	102·33	11,774
Oct.	20	"	240	10,191	1·22	102·45	12,409
Dec.	14	"	236	10,020	0·88	101·75	8,885

Table 91.—Miscellaneous Discharge Measurements by the Hydro-Electric Power Commission of the Province of Ontario. in Winnipeg River Watershed in Ontario.

River.	Date.	Discharge in sec.-ft.	Location.
White Fish	Jan. 1906	207	White Fish falls.
"		146	Below Penache lake.
Winnipeg	Oct. 14, 1905	5,321	Eastern outlet.
"	April 8, 1906	4,490	"
"	Oct. 16, 1905	899	L. of W. Milling Co. head-race.
"	Oct. 16, 1905	400	Keewatin Lumber Co.
"	Oct. 18, 1905	21,794	Western outlet.
"	Dec. 17, 1914	8,537	Minaki.
"	Oct. 17, 1914	546	Whitedog (north channel).
"	Dec. 15, 1914	354	Whitedog (north channel).
"	Oct. 18, 1914	12,221	Whitedog (south channel).
"	Jan. 20, 1914	7,661	Whitedog falls.
"	Dec. 16, 1911	8,788	Whitedog falls.
York	Oct. 7, 1913	136	Below High falls.
"	Oct. 8, 1913	181	Below Bancroft.
English	May 26, 1906	6,740	Pelican falls.
"	June 2, 1906	6,702	Manitou rapids.
Rainy	Oct. 25, 1905	14,145	Fort Frances.
"	April 1, 1906	6,805	Fort Frances.
"	Sept. 26, 1910	5,229	Fort Frances.
Seine	July 9, 1906	1,842	Island falls.
Wabigoon	Oct. 9, 1905	206	Dryden.

RUN-OFF OF THE WINNIPEG RIVER WATERSHED.

TABLES 92 TO 102.

Data in tables 92 to 100 were obtained by the field officers of the Water Resources Branch of the United States Geological Survey, and published herein through courtesy of George Otis Smith, Director of the Survey. The data for the years 1911 and 1912 for the Big Fork, the Little Fork and the Vermilion rivers are also available to the public in Water-Supply Papers Nos. 305 and 325, respectively, published by the Geological Survey. The records for the Kawishiwi river for the years 1905, 1906 and 1907 were compiled by the Minnesota Canal and Power Company,and are published in the report of the Water Resources Investigation of Minnesota, 1909-12, by the State Drainage Commission.

BIG FORK RIVER AT BIG FALLS, MINN.

Location.—At Big falls, about 500 feet below the lower end of the rapids.

Records Available.—August 27, 1909 to November 12, 1910.

Drainage Area.—1,320 square miles.

Gauge.—Vertical staff. The gauge was originally located at the Minnesota and international bridge above the falls, but jams at that point caused so much trouble that on June 10, 1911, the station was moved to its present site, the new gauge being set to read approximately 1 foot lower than the old gauge. Gauge heights for 1911 have been referred to the present gauge, and gauge heights for 1912 were taken at this gauge.

Channel.—Although the channel is practically permanent in itself, it is, for the greater part of the year, full of logs.

Discharge Measurements.—Made from a car an' [illegible]able, one-fourth mile below the gauge.

Winter Flow.—Daily discharge, January 1 to M[illegible] estimated, because of ice, from discharge measurements, gauge heights, [illegible]imatologic records, and discharge of adjacent drainage areas, as follows: January 1 to 31, 30 second-feet, varying from about 40 to 25 second-feet; February 1 to 29, 30 second-feet, varying from about 25 to 40 second-feet; March 1 to 31, 35 second-feet, varying from about 40 to 30 second-feet.

Accuracy.—The formation of log jams throughout the river's course makes it impossible to so place a gauge that the relation between gauge heights and discharge will be constant for any extended period. Owing to the inability to secure weekly measurements, no estimates of flow can b[illegible]en except during the period of ice, when the effect of log jams is relatively unimportant, and the mean monthly discharge can be estimated from the current-meter measurements. The discharge for the entire year can be approximately estimated by determining the relation between the discharge of Little Fork and Big Fork rivers at the times of discharge measurements, assuming such relation to hold at other times, and then using it in conjunction with the gauge heights at Big falls to estimate the flow of the Big Fork.

References.—United States Geological Survey Water Supply Papers 305 and 325.

Table 92.—Discharge Measurements of Big Fork River at Big Falls, Minnesota.

[Drainage area, 1,320 square miles.]

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
1909		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
Aug. 27	G. A. Gray	266	1,510		4·66	960·0
Oct. 1	"	246	1,210		4·10	535·0
1910						
July 22	Robert Follansbee				2·78	65·0[1]
1911						
June 10	S. B. Soulé				7·07	1,760·0[2]
" 12	"				3·89	193·0[3]
Dec. 13	"				2·65	65·5[4]
1912						
Jan. 23	S. B. Soulé				2·33	26·0[5]
Feb. 27	"				2·30	37·2[6]
April 1	"				2·24	27·0[7]
" 1	"				2·24	28·0[8]
May 21	"				5·06	951·0
Aug. 8	"				3·13	97·0[9]
Dec. 20	"				2·40	46·0[10]
1913						
Jan. 16	Soulé					28·0
1914						
Aug. 13	Stewart	115	341		3·65	418·0

[1]Estimated from rough measurement.
[2]Measurement made from Mo. I. Ry. bridge.
[3]Measurement made from cable station.
[4]Complete ice cover, average thickness 0·7 foot. Measured at cable station.
[5]Ice cover 1·24 foot thick, water surface to top of ice 0·29 foot.
[6]Ice cover 1·27 foot thick, water surface to top of ice 0·32 foot.
[7]Section 40 feet below edge of highway bridge.
[8]Section 25 feet below edge of highway bridge.
[9]Backwater from logs.
[10]Complete ice cover at gauge; open water at measuring section at foot of rapids.

Table 93.—Daily Discharge Records of Big Fork River at Big Falls, Minnesota.

[Drainage area, 1,520 square miles.]

1909.

Day.	August.		September.		October.		November.	
	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	......	......	......	812	......	536	......	1,140
2	......	......	......	731	......	492	......	1,070
3	......	......	......	628	......	470	......	1,000
4	......	......	......	574	......	465	......	955
5	......	......	......	530	......	460	......	918
6	......	......	......	481	......	460	......	854
7	......	......	......	465	......	445	......	805
8	......	......	......	415	......	445	......	770
9	......	......	......	400	......	470	......	770
10	......	......	......	375	......	552	......	738
11	......	......	......	366	......	679	......	712
12	......	......	......	348	......	784	......	628
13	......	......	......	360	......	840	......	580
14	......	......	......	360	......	840	......	552
15	......	......	......	375	......	840	......	525
16	......	......	......	385	......	875	......	......
17	......	......	......	395	......	910	......	......
18	......	......	......	375	......	910	......	......
19	......	......	......	430	......	948	......	......
20	......	......	......	470	......	1,100	......	......
21	......	......	......	514	......	1,340	......	......
22	......	......	......	616	......	1,820	......	......
23	......	......	......	738	......	2,140	......	......
24	......	......	......	784	......	2,140	......	......
25	......	......	......	777	......	2,100	......	......
26	......	......	......	718	......	1,960	......	......
27	......	978	......	653	......	1,780	......	......
28	......	1,040	......	604	......	1,600	......	......
29	......	1,110	......	580	......	1,430	......	......
30	......	1,069	......	552	......	1,310	......	......
31	......	948	......	......	......	1,210	......	......

Table 93.—Daily Discharge Records of Big Fork River at Big Falls, Minnesota—Concluded.

1910.

Day.	January.		February.		March.		April.		May.		June.	
	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec. ft.	Feet.	Sec. ft.	Feet.	Sec. ft.
1							6·90	2,960	6·32	2,390	4·76	1,030
2							7·15	3,200	6·21	2,320	4·72	1,000
3							7·25	3,300	5·98	2,070	4·65	948
4							7·20	3,260	6·35	2,120	4·52	854
5							6·80	2,860	6·10	2,180	4·68	970
6							6·82	2,880	6·05	2,110	4·82	1,080
7							6·95	3,000	6·12	2,200	4·79	1,050
8							6·88	2,940	6·02	2,110	4·68	970
9							6·86	2,920	5·92	2,020	4·59	903
10							6·60	2,660	5·85	1,960	4·52	854
11							6·42	2,490	5·60	1,730	4·41	777
12							6·25	2,330	5·32	1,490	4·39	764
13							6·18	2,260	5·08	1,280	4·56	882
14							6·08	2,170	4·86	1,110	4·51	817
15							6·12	2,200	4·72	1,000	4·41	777
16							6·30	2,380	5·02	1,240	4·35	738
17							7·45	3,500	5·38	1,540	4·30	705
18							8·22	4,310	5·56	1,690	4·26	779
19							8·68	4,790	5·62	1,750	4·21	646
20							6·62	4,730	5·48	1,620	4·11	586
21							8·58	4,690	5·35	1,510	3·96	503
22							8·19	4,280	5·28	1,450	4·15	610
23							7·60	3,660	5·42	1,570	4·00	525
24							7·32	3,380	5·31	1,500	3·89	465
25							7·00	3,060	5·26	1,410	3·81	425
26							6·58	2,640	5·20	1,380	3·76	400
27							6·40	2,470	5·15	1,340	3·71	375
28							6·28	2,360	5·05	1,260	3·64	343
29							6·15	2,230	4·91	1,170	3·60	325
30							6·28	2,360	4·88	1,120	3·54	301
31									4·81	1,070		

Day.	July.		August.		September.		October.		November		December	
1	3·49	281	2·95	108	2·59	48	3·26	196	3·52	293		
2	3·41	249	2·90	95	2·65	40	3·29	206	3·48	277		
3	3·36	231	2·86	86	2·80	72	3·35	227	3·39	242		
4	3·34	224	2·91	98	2·82	77	3·31	211	3·32	217		
5	3·28	203	2·86	86	2·92	100	3·24	[illegible]	3·29	206		
6	3·38	238	2·80	72	2·96	110	3·20		3·22	182		
7	3·31	214	2·75	61	2·91	98	3·16	[illegible]	3·16	163		
8	3·26	196	2·70	50	2·86	86	3·19	172	3·12	151		
9	3·20	175	2·69	48	2·85	81	3·21	179	3·01	130		
10	3·16	163	2·65	40	2·94	105	3·25	192	2·92	100		
11	3·42	253	2·65	42	2·95	108	3·28	203	2·89	91		
12	3·35	228	2·80	72	2·91	98	3·35	227	2·81	74		
13	3·28	203	2·86	86	2·89	93	3·42	253				
14	3·22	182	2·82	77	2·98	115	3·50	285				
15	3·11	148	2·79	70	2·95	108	3·62	334				
16	3·00	120	2·76	63	2·92	100	3·61	329				
17	2·94	105	2·74	59	2·91	98	3·59	321				
18	2·86	86	2·70	50	2·98	115	3·55	305				
19	2·80	72	2·66	42	2·94	105	3·65	347				
20	2·75	61	2·64	38	2·91	98	3·78	410				
21	2·75	[illegible]	2·86	86	2·89	93	3·81	425				
22	2·74	59	2·81	74	2·96	110	3·79	415				
23	......	82	2·74	59	3·00	120	3·75	395				
24	2·94	105	2·68	46	2·98	115	3·72	380				
25	2·95	108	2·79	70	2·94	105	3·69	366				
26	2·90	95	2·71	52	2·96	110	3·69	366				
27	2·85	84	2·62	34	3·01	122	3·76	400				
28	2·96	110	2·80	72	3·11	148	3·75	395				
29	2·96	110	2·80	72	3·19	172	3·71	375				
30	2·91	98	2·76	63	3·25	192	3·69	366				
31	3·00	120	2·71	52	......	...	3·61	329				

NOTE.—Discharge for 1910 based on a rating curve not well defined.

Table 94.—Monthly Discharge of Big Fork River at Big Falls, Minn.

[Drainage area, 1,320 square miles.]

Month.	Discharge in Second-Feet.				Run-off.	Accuracy
	Maximum.	Minimum	Mean.	Per square mile.	Depth in inches on Drainage Area.	
1909.						
August 27–31	1,110	948	1,030	0·780	0·15	B.
September	812	348	527	0·399	0·45	B.
October	2,140	445	1,040	0·788	0·91	B.
November	1,140	....	660	0·500	0·56	C.
1910.						
April	4,790	2,170	3,080	2·33	2·60	D.
May	2,420	1,000	1,650	1·25	1·44	C.
June	1,080	301	714	0·541	0·60	C.
July	281	59	150	0·114	0·13	C.
August	108	34	65·3	0·049	0·06	C.
September	192	40	105	0·080	0·09	C.
October	425	163	295	0·223	0·26	B.
November 1–12	293	74	177	0·134	0·06	C.

LITTLE FORK RIVER AT LITTLE FORK, MINN.

Location.—At the lower of the two highway bridges in Little Fork, in section 9, township 68 N., range 25 W., 1½ miles above the mouth of Beaver brook.

Records Available.—June 23, 1909, to December 31, 1914.

Drainage Area.—1,720 square miles.

Gauge.—Vertical staff.

Channel.—Practically permanent, except for temporary backwater from log jams at the railroad bridge below the station.

Discharge Measurements.—Made from the bridge.

Artificial Control.—The river is used throughout the spring and summer for log driving. There are, however, no logging dams on the river, so that the flow is natural.

Winter Flow.—The river is completely frozen over at the station from November to April.

Accuracy.—Conditions at the station are favourable, and the records of flow should be reliable.

References.—United States Geological Survey Water Supply Papers Nos. 305, 325 and 355.

Table 95.—Discharge Measurements of Little Fork River at Little Fork, Minnesota.

[Drainage area, 1,720 square miles.]

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
1909.		Feet.	Sq. ft.	Ft. per sec.	Feet	Sec. ft.
July 4	G. A. Gray	122	201		5·52	237
" 24	Robert Follansbee	122	184		5·41	190
Aug. 26	G. A. Gray	133	452		7·66	910
Sept. 30	"	132	445		7·50	821
1910.						
June 21	C. R. Adams	136	214		5·30	180
July 22	Robert Follansbee	54	826		4·82	87
1911.						
April 4	C. R. Adams				10·80	1,400[1]
" 18	Robert Follansbee				15·46	3,730[2]
" 19	"				15·00	3,580[2]
June 9	S. B. Soulé				11·06	2,390
July 15	"				5·20	144
Dec. 12	"				6·00	156[3]
1912.						
Jan. 21	S. B. Soulé				5·52	64[4]
Feb 26	"				5·76	73[5]
Mar. 30	"				5·94	67[6]
May 20	"				12·31	2,290[7]
" 20	"				12·23	2,230[7]
June 14	"				6·83	610
" 14	"				6·83	605
Aug. 6	W. G. Hoyt				5·28	131[8]
Dec. 19	S. B. Soulé				5·82	113[9]
1913.						
Jan. 15	S. B. Soulé	96	104	0·76	5·58	78[10]
Feb. 18	"	91	868	0·61	5·50	53[10]
May 1	"	151	1,420	2·51	13·32	3,560[11]
July 30	B. J. Peterson	142	397	1·51	6·88	598
Dec. 26	S. B. Soulé	112	194	1·20	6·82	233[10]
1914.						
Jan. 26	S. B. Soulé	94	138	0·83	6·28	115[10]
Feb. 25	"	76	112	0·73	6·12	82[10]
May 16	"	152	1,080	2·22	11·25	2,400[12]
Aug. 14	J. B. Stewart	129	204	1·35	5·79	276
Dec. 15	S. B. Soulé	85	141	0·84	6·02	118[10]
1915.						
Jan. 19	S. B. Soulé	75	107	0·79	6·16	85[11]

[1] Ice-cover.

[2] Backwater from log jamb.

[3] Under complete ice cover about 300 feet above gauge. Average thickness of ice 0·71 foot. Water about 0·15 foot above ice.

[4] Ice cover, thickness 1·19 foot; water to top ice, 0·28 foot.

[5] " " 1·60 " " 0·07 "

[6] " " 1·78 " " 0·00 "

[7] Log jamb on railway bridge about 2 miles below gauge.

[8] Backwater from log boom.

[9] Ice cover, 0·68 foot thick.

[10] Complete ice cover.

[11] Some logs running, but not lodged anywhere.

[12] Logs running.

Table 96.—Daily Discharge Records of Little Fork River at Little Fork, Minnesota.

(Drainage Area 1,720 square miles.)

1909.

Day.	June.		July.		August.		September.		October.		November.	
	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.
	Feet	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	.....			240		247		1,040		708	.....	1,360
2	.....			237		224		900		634	.....	1,210
3	.....			221		208		757		614	.....	1,170
4	.....			208		215		667		518	.....	1,090
5	.....			199		237		640		463	.....	980
6	.....			193		291		512		393	.....	932
7	.....			181		304		440		371	.....	864
8	.....			184		502		405		344	.....	802
9	.....			178		852		371		347	.....	621
10	.....			166		896		330		377	.....	680
11	.....			118		1,650		291		422	.....	750
12	.....			137		3,760		286		472	.....	691
13	.....			141		4,120		266		487	.....	598
14	.....			166		4,380		266		487	.....	.....
15	.....			160		1,210		254		518	.....	.....
16	.....			160		980		217		598	.....	.....
17	.....			156		3,650		242		630	.....	.....
18	.....			161		3,120		228		687	.....	.....
19	.....			189		2,070		257		698	.....	.....
20	.....			193		1,860		247		778	.....	.....
21	.....			193		1,260		268		1,230	.....	.....
22	.....			197		1,080		288		2,010	.....	.....
23	.....	377		193		932		366		2,340	.....	.....
24	.....	360		184		908		382		2,700	.....	.....
25	.....	333		252		908		640		2,700	.....	.....
26	.....	307		291		868		920		2,560	.....	.....
27	.....	296		307		852		988		2,410	.....	.....
28	.....	281		347		868		988		2,180	.....	.....
29	.....	268		358		1,050		920		1,660	.....	.....
30	.....	261		328		1,080		802		1,600	.....	.....
31	.....			286		1,140				1,490		

Table 96.—Daily Discharge Records of Little Fork river at Little Fork, Minnesota— Continued.

1910.

Day.	January.		February.		March.		April.		May.		June.	
	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet	Sec.-ft.	Feet.	Sec.-ft.
1									8·88	1,300	6·75	565
2									8·65	1,290	6·58	512
3									8·12	1,190	6·40	457
4									8·16	1,080	6·40	457
5									7·95	1,000	6·45	472
6									7·70	900	6·10	157
7									7·19	816	6·45	472
8									7·35	768	6·60	518
9									7·25	732	6·55	502
10									7·01	650	6·35	412
11							10·58	2,200	6·79	578	6·21	411
12							10·05	1,940	6·80	581	6·05	358
13							9·68	1,750	6·69	516	6·00	344
14							9·35	1,600	6·58	512	5·95	330
15							9·10	1,190	6·50	487	5·75	278
16							9·60	1,720	6·40	457	5·62	247
17							10·80	2,310	6·35	412	5·58	237
18							14·95	4,580	6·40	457	5·51	228
19							15·60	5,000	6·39	451	5·46	210
20							15·25	4,770	6·38	451	5·38	193
21							15·00	4,610	6·62	524	5·28	172
22							14·32	4,200	6·78	575	5·21	158
23							12·95	3,430	7·00	647	5·16	148
24							11·92	2,870	7·10	680	5·10	137
25							11·20	2,530	7·15	698	5·01	126
26							10·75	2,280	7·00	647	5·00	119
27							10·25	2,040	7·00	647	4·96	112
28							9·90	1,860	7·00	647	4·96	112
29							9·55	1,690	7·10	680	5·60	242
30							9·10	1,490	7·06	667	5·70	266
31									6·82	588		

Day.	July.		August.		September.		October.		November.		December.	
1	5·42	201	5·72	271	4·83	91	5·00	119	5·30	176		
2	5·35	186	5·48	215	4·84	92	5·30	176	5·21	158		
3	5·15	146	5·32	180	4·86	96	5·40	197	5·18	172		
4	4·92	105	5·28	172	4·75	79	5·45	208	5·30	176		
5	5·02	123	5·28	172	4·40	40	5·10	197	5·10	197		
6	4·95	110	5·20	156	4·70	72	5·40	197				
7	4·80	86	5·05	128	4·75	79	5·30	176				
8	4·78	83	5·00	119	4·84	92	5·30	176				
9	4·72	75	5·00	119	4·80	86	5·25	166				
10	4·75	79	4·95	110	4·85	94	5·18	152				
11	4·96	112	4·85	94	4·85	94	5·10	137				
12	5·00	119	4·95	110	4·86	96	5·10	137				
13	5·00	119	4·95	116	4·90	102	5·18	152				
14	4·88	99	4·90	102	4·88	99	5·15	146				
15	5·02	123	4·98	116	4·80	86	5·10	137				
16	5·02	123	4·95	110	4·71	73	5·05	128				
17	5·15	146	4·92	105	4·70	72	5·00	119				
18	5·20	156	4·95	110	4·80	86	5·00	119				
19	4·90	102	4·98	116	4·78	83	5·38	193				
20	4·90	102	4·98	116	4·76	80	5·20	156				
21	4·88	99	4·96	112	4·90	102	5·22	160				
22	5·10	137	4·95	110	4·96	112	5·20	156				
23	5·15	146	4·93	107	4·89	100	5·19	154				
24	5·02	123	4·95	110	4·80	86	5·20	156				
25	5·02	123	4·95	110	4·80	86	5·30	176				
26	5·08	133	4·95	110	4·80	86	5·30	176				
27	5·08	133	4·95	110	4·80	86	5·30	176				
28	5·85	304	4·86	96	4·80	86	5·30	176				
29	6·10	371	4·85	94	4·86	96	5·30	176				
30	6·05	358	4·83	91	5·00	119	5·30	176				
31	5·85	304	4·83	91			5·30	176				

NOTE.—Discharges computed from a rating curve well defined below 1,000 second-feet.

Table 96.—Daily Discharge Records of Little Fork river at Little Fork, Minnesota— Continued.

1911.

Day.	January. Gauge Height	January. Discharge.	February. Gauge Height	February. Discharge.	March. Gauge Height	March. Discharge.	April. Gauge Height	April. Discharge.	May. Gauge Height	May. Discharge.	June Gauge Height	June Discharge.
	Feet.	Sec.-ft.	Feet	Sec.-ft	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet	Sec.-ft.
1								900	9·18	1,540	8·11	1,190
2								1,000	9·05	1,480	9·20	1,540
3								1,150	8·90	1,410	9·70	1,770
4								1,400	8·65	1,300	10·10	1,950
5								1,400	8·30	1,150	10·80	2,260
6								1,450	7·90	989	10·92	2,420
7								1,500	7·65	890	11·50	2,610
8								1,570	7·40	793	10·80	2,260
9								1,400	7·35	774	11·20	2,460
10								1,420	7·20	719		2,540
11								1,410	7·40	793		2,540
12								1,790	7·55	850		2,530
13								1,800	7·58	862		2,530
14								1,850	7·65	890		2,520
15								1,950	7·68	911		2,510
16								3,000	7·69	905	..	2,500
17								3,100	7·58	862		2,500
18								3,740	7·95	1,010	10·01	1,920
19								3,580	8·50	1,240	9·72	1,780
20								3,470	8·35	1,170	9·05	1,480
21							12·60	3,160	8·20	1,110	8·19	1,190
22							12·60	3,160	8·50	1,340	7·91	993
23							12·25	2,980	8·70	1,320	7·15	811
24							11·80	2,760	8·55	1,250	7·09	669
25							11·34	2,540	7·70	909	7·00	617
26							10·75	2,210	7·70	909	6·81	581
27							10·42	2,050	7·95	1,010	6·18	476
28							10·00	1,900	9·31	1,590	6·47	443
29							9·59	1,721	9·20	1,510	6·24	406
30							9·38	1,630	8·30	1,190	6·18	390
31									8·10	1,040		

Day.	July. Gauge Height	July. Discharge	August Gauge Height	August Discharge	September. Gauge Height	September. Discharge	October. Gauge Height	October. Discharge	November. Gauge Height	November. Discharge	December. Gauge Height	December. Discharge
1	6·08	364	7·05	665	6·42	458	6·20	398	5·80	289		
2	6·09	365	7·40	793	6·32	429	6·21	398	5·80	289		
3	5·80	312	7·25	738	6·05	454	6·26	412	5·80	289		
4	5·72	269	7·16	705	5·94	425	6·35	438	5·80	289		
5	5·65	252	7·12	690	6·10	368	6·50	482	5·80	289		
6	5·62	245	6·95		6·35	438	6·49	479	5·80	289		
7	5·58	245	6·95		6·65	529	6·40	452	5·80	289		
8	5·50	216	7·15		7·30	756	6·35	438	5·80	289		
9	5·42	198	7·05	668	7·15	811	6·25	409	5·80	289		
10	5·37	186	6·88	605	7·70	909	6·18	390	..	..		
11	5·35	182	6·75	562	7·72	917	6·05	354	..	..		
12	5·31	173	6·35	448	7·70	909	5·95	328	..	..		
13	5·26	163	6·51	485	7·60	870	5·95	328	..	..		
14	5·22	151	6·59	510	7·50	831	5·92	320	..	..		
15	5·20	150	6·60	514	7·30	756	5·90	315	..	..		
16	5·20	150	6·42	458	7·15	701	5·92	320	..	..		
17	5·20	150	6·32	429	6·80	578	6·00	341	..	..		
18	5·20	150	6·30	424	6·50	482	6·00	341	..	..		
19	5·19	148	6·12	373	6·50	482	6·10	368	..	..		
20	5·19	148	5·96	331	6·40	452	6·10	368	..	..		
21	5·20	150	5·80	280	6·32	429	6·10	368	..	..		
22	5·20	150	5·95	328	6·10	368	6·05	351	..	..		
23	5·16	142	5·89	289	5·95	328	6·00	341	..	..		
24	5·20	150	5·75	276	5·90	315	5·95	328	..	..		
25	5·24	158	5·74	274	5·95	328	5·80	289	..	..		
26	5·25	160	5·96	333	5·85	302	5·80	289	..	..		
27	5·39	191	6·15	382	5·80	289	5·78	281	..	..		
28	5·61	250	6·42	458	5·90	315	5·72	269	..	..		
29	5·68	259	6·31	426	6·35	438	5·70	264	..	..		
30	5·60	240	6·30	424	6·25	409	5·76	279	..	..		
31	6·00	513	6·30	423		....	5·80	289				

NOTE (Year 1911).—Daily discharge computed from a rating curve well defined—below 3,000 second-feet. Discharge estimated April 1 to 7 because of backwater from ice, and April 12 to 20 and June 10 to 17 because of log jams below. Discharge, November 10 to December 31 estimated, because of ice, from one discharge measurement, gauge observer's notes and climatologic records. Mean discharge, November 10 to 30 estimated 175 second feet varying from about 140 to 280 second-feet. Mean discharge, December 1 to 31 estimated 145 second-feet, varying from about 110 to 156 second-feet.

Table 96.—Daily Discharge Records Little Fork river at Little Fork, Minnesota—
Continued.

1912

Day.	January.		February.		March.		April.		May.		June.	
	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1										2,000		910
2										2,040		970
3									10.40	2,080	8.00	1,030
4									10.60	2,180	7.10	793
5									11.60	2,660	7.10	793
6									11.70	2,710	7.40	793
7									12.40	3,060	7.50	831
8									12.70	3,210	7.30	756
9									12.80	3,110	7.40	793
10									12.60	3,160	7.20	719
11									12.50	3,110	6.20	395
12									12.60	3,160	6.50	482
13							10.50	2,130	12.90	3,310	6.70	545
14							10.00	1,900	12.80	3,260	6.80	578
15							9.80	1,820		2,910	6.70	515
16							9.30	1,590		.160	6.60	513
17							8.90	1,410		2,910	6.50	482
18							9.00	1,460		2,660	6.50	482
19							8.80	1,360		2,360	6.60	513
20							8.70	1,320		2,360	6.70	515
21							8.50	1,230		2,140	6.90	612
22							8.40	1,190		1,860	6.80	578
23							8.10	1,070		1,720	6.60	513
24							7.40	793		1,500	6.50	482
25							7.20	719		1,190	6.30	223
26							7.70	909	8.90	1,410	6.20	395
27							9.20	1,540	8.50	1,230	6.00	311
28							9.90	1,860	8.40	1,190	5.80	289
29								1,900	8.10	1,070	5.70	264
30								1,950	7.40	793	5.70	264
31										850		

Table 96.—Daily Discharge Records of Little Fork river at Little Fork, Minnesota—Continued.

1912

Day.	July		August.		September		October.		November		December.	
	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	6·20	395		160	5·80	289	8·00	1,030	6·00	341		180
2	7·30	756		140	5·85	302	7·90	989	6·00	341		180
3	7·20	719		150	5·80	289	7·60	870	6·00	341		180
4	6·60	513		130	5·75	276	7·10	703	6·00	341		180
5	6·30	423		112	8·80	1,360	7·20	719	6·00	341		180
6	6·00	341		130	8·20	1,110	7·10	683	6·00	341		180
7	6·00	341		140	8·70	1,320	7·10	683	6·00	341		180
8	6·10	368		140	8·60	1,280	6·80	578	6·00	341		180
9	6·00	341		140	8·70	1,320	6·60	513	6·00	341		180
10	6·00	341		140	8·60	1,280	6·80	578	6·00	341		180
11	5·80	289		130	8·10	1,090	6·80	578	6·00	341		180
12	5·80	289		130	7·60	870	6·70	545	5·95	328		180
13	.....	289		130	7·80	949	6·80	578	5·95	328		180
14	......	368		112	7·50	831	6·60	513	5·90	315		180
15	.....	341		112	7·20	719	6·70	545	5·90	315		180
16		264		97	7·00	647	6·70	545	5·90	315		180
17	....	240		112	6·80	578	6·60	513		300		180
18		240		121	6·60	513	6·50	482		300		180
19		216		130	6·20	395	6·40	452		300		105
20	...	193		140	5·90	315	6·40	452		300		105
21	...	204		130	5·90	315	6·20	395		300		105
22	..	193		130	6·00	341	6·30	423		300		105
23		193		130	6·30	423	6·30	423		300		105
24		193		130	6·60	513	6·20	395		300		105
25	.. ..	193		130	6·90	612	6·10	368		300		105
26		194		130	7·20	719	6·10	368		300		105
27	....	204	...	130	7·30	756	5·95	328		300		105
28		193		150	7·70	909	5·80	289		300		105
29		193		216	7·90	989	6·10	368		300		105
30		193		260	7·00	647	6·10	368		300		105
31	.....	193	.....	264	...	....	6·00	341	.....	....	.....	105

NOTE.—Daily discharge computed from a discharge rating table that is well defined for unobstructed channel conditions. Daily discharge interpolated, April 29 to May 2 and July 23 and 24, and daily gauge heights as published reduced 1·5 foot to enter discharge rating table May 15 to 25, because of log jams. Gauge heights reduced 0·2 foot to enter discharge rating table July 13 to August 31 because of effect of floating log. Discharge interpolated, May 31 to June 2. Discharge, January 1 to April 12 and November 17 to December 31 estimated, because of ice, from climatolor c records, discharge measurements, and observer's reports, as follows: January 1 to 31, 85 second-feet, varying from about 130 to 60 second-feet; February 1 to 29, 75 second feet, varying from about 80 to 70 second-feet; March 1 to 31 70 second-feet; April 1 to 12, 650 second-feet, varying from about 70 to 2,000 second-feet; November 17 to 30, 300 second-feet, varying from about 315 to 285 second-feet; December 1 to 31, 150 second-feet, varying from about 250 to 100 second-feet.

Table 96.—Daily Discharge Records of Little Fork river at Little Fork, Minnesota—Concluded.

1911.

Day	January.		February.		March.		April.		May.		June.	
	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1		90		60		85		100	13·3	3,540	13·2	3,490
2		90		60		85		100	12·4	3,060	13·3	3,540
3		90		60		85		100	12·3	3,010	12·9	3,320
4		90		60		85		100	12·7	3,220	12·4	3,060
5		90		60		85		100	13·2	3,490	11·8	2,760
6		90		60		85		100	13·2	3,490	12·4	3,060
7		90		60		85		100	13·0	3,380	14·2	4,040
8		90		60		85		100	12·2	2,960	15·6	4,810
9		90		60		85		100	12·0	2,860	15·5	4,760
10		90		60		85		150	11·4	2,560	14·3	4,100
11		90		60		85	8·9	1,500	10·6	2,180	13·2	3,490
12		90		60		85	8·8	1,500	10·4	2,080	12·8	3,270
13		90		60		85	12·6	1,500	10·2	2,000	11·8	2,760
14		90		60		85	16·4	1,500	10·0	1,900	11·0	2,360
15		75		60		85	17·2	1,500	10·2	2,000	9·8	1,820
16		75		60		85	18·2	1,500	10·6	2,180	9·4	1,640
17		75		60		85	16·6	5,360	13·4	3,600	9·7	1,770
18		75		55		85	15·8	4,920	16·4	5,250	9·4	1,640
19		75		55		85	15·4	4,700	16·1	5,080	9·4	1,640
20		75		55		85	15·0	4,480	15·7	4,860	9·0	1,460
21		75		55		85	14·0	3,930	13·6	3,710	9·0	1,460
22		75		55		85	13·7	3,760	13·8	3,820	8·9	1,410
23		75		55		85	13·9	3,880	14·5	4,200	8·6	1,280
24		75		55		85	14·0	3,930	14·4	4,150	8·2	1,110
25		75		55		85	14·3	4,100	13·7	3,760	7·8	949
26		75		55		85	15·6	4,810	12·5	3,110	7·8	949
27		75		55		85	16·4	5,250	11·5	2,610	7·6	870
28		75		55		85	16·1	5,080	10·8	2,260	8·1	1,070
29		75				85	15·2	4,590	11·1	2,410	8·4	1,190
30		75				85	14·7	4,340	11·8	2,760	8·6	1,280
31		75				85			12·7	3,220		

Day	July.		August.		September.		October.		November.		December.	
1	8·8	1,360	6·5	482	5·8	289	6·3	423	6·9	612		1,680
2	8·6	1,280	6·1	368	5·8	289	6·4	452	6·4	452		1,680
3	8·4	1,190	5·75	276	5·9	315	6·5	482	6·1	368		1,680
4	8·1	1,070	5·6	240	6·0	341	7·7	909	5·7	264		1,680
5	8·8	1,360	5·7	264	6·0	341	8·1	1,070	5·7	264		950
6	9·2	1,540	5·7	264	6·1	368	8·6	1,280	5·9	315		950
7	9·4	1,640	5·75	276	6·2	395	9·2	1,540		300		950
8	9·2	1,540	5·8	289	6·3	423	9·8	1,820		300		950
9	8·6	1,280	5·85	302	6·3	423	10·4	2,080		300		950
10	7·9	989	5·8	289	6·6	513	10·6	2,180		300		950
11	7·6	870	5·9	315	6·8	578	10·8	2,260		300		950
12	8·0	1,030	5·9	315	7·2	719	10·6	2,180		300		950
13	9·4	1,640	5·9	315	7·0	647	10·5	2,130		300		950
14	9·5	1,680	5·9	315	6·9	612	10·1	1,950		300		950
15	9·4	1,640	5·9	315	6·8	578	9·5	1,680		300		950
16	9·4	1,640	5·85	302	6·9	612	8·9	1,410		300		280
17	9·6	1,720	5·85	302	6·8	578	8·6	1,280		300		280
18	9·9	1,860	5·75	276	6·8	578	8·3	1,150		300		280
19	10·0	1,900	5·7	264	6·6	513	8·0	1,030		300		280
20	9·6	1,720	5·65	252	6·5	482	8·0	1,030		300		280
21	9·4	1,640	5·8	289	6·4	452	7·7	909		930		280
22	9·3	1,590	6·2	395	6·4	452	7·2	719		930		280
23	9·2	1,540	6·0	341	6·4	452	7·2	719		930		280
24	9·0	1,460	5·95	328	6·3	423	7·3	756		930		280
25	8·7	1,320	5·9	315	6·3	423	7·6	870		930		280
26	8·2	1,110	5·95	328	6·3	423	7·8	949		930		280
27	7·6	870	5·9	315	6·3	423	8·0	1,030		930		280
28	7·2	719	5·9	315	6·3	423	8·3	1,150		930		280
29	7·0	647	5·9	315	6·3	423	8·2	1,110		930		280
30	6·8	578	5·9	315	6·3	423	7·8	949		930		280
31	6·7	545	[illegible]	[illegible]			7·4	793				280

NOTE.—Daily discharge computed from a well-defined rating curve. Discharge estimated, because of ice, from gauge heights, observer's notes, three discharge measurements, and climatic records, as follows.—Jan. 1-14, 90 second-feet; Jan. 15-31, 75 second-feet; Feb. 1-17, 60 second-feet; Feb. 18-28, 55 second-feet; Mar. 1-31, 85 second-feet; Apr. 1-9, 100 second-feet; and Apr. 10-16, 1,500 second-feet. Discharge also estimated from November 7 to December 31.

Table 96.—Daily Discharge Records of Little Fork River at Little Fork, Minnesota—Concluded.

1914.

Day.	January.		February.		March.		April.		May.		June.	
	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	....	150	....	112	....	78	....	383	15·5	4,760	9·2	1,540
2	....	150	....	112	....	78	....	383	17·3	5,340	8·9	1,410
3	....	150	....	112	....	78	....	383	18·3	5,930	8·7	1,320
4	....	150	....	112	....	78	....	383	18·7	6,520	8·6	1,280
5	....	150	....	112	....	78	....	383	18·3	6,300	8·3	1,150
6	....	150	....	97	....	78	....	383	18·6	6,160	7·9	989
7	....	150	....	97	....	78	....	383	17·8	6,020	7·5	831
8	....	150	....	97	....	78	....	383	16·9	5,520	7·4	793
9	....	150	....	86	....	78	....	383	15·8	4,920	12·8	3,270
10	....	150	....	86	....	78	....	383	15·2	4,590	14·6	4,260
11	....	150	....	86	....	78	....	383	14·4	4,150	14·2	4,040
12	....	150	....	86	....	86	....	383	13·6	3,710	13·1	3,440
13	....	150	....	86	....	86	....	383	13·0	3,380	12·0	2,860
14	....	150	....	86	....	86	....	383	12·4	3,060	11·0	2,360
15	....	150	....	86	....	86	....	383	11·7	2,710	10·3	2,040
16	....	115	....	86	....	86	10·2	383	11·2	2,460	10·0	1,900
17	....	115	....	86	....	86	13·1	2,260	10·8	2,260	9·6	1,720
18	....	115	....	86	....	114	16·3	2,260	10·2	2,000	9·2	1,540
19	....	115	....	78	....	114	16·8	2,260	10·3	2,040	9·5	1,680
20	....	115	....	78	....	114	15·8	2,260	10·6	2,180	8·6	1,280
21	....	115	....	78	....	114	15·2	2,260	11·2	2,460	7·8	949
22	....	115	....	78	....	114	14·6	2,260	12·1	2,910	7·4	793
23	....	115	....	78	....	114	14·2	2,260	12·6	3,160	6·8	578
24	....	115	....	78	....	114	13·9	2,260	12·0	2,860	6·4	452
25	....	115	....	78	....	114	12·4	3,060	11·1	2,410	6·0	341
26	....	115	....	78	....	114	12·0	2,860	10·4	2,080	6·4	452
27	....	115	....	78	....	114	11·7	2,710	10·9	2,310	6·8	578
28	....	115	....	78	....	114	12·0	2,860	10·0	1,900	7·4	793
29	....	115	....	....	....	114	13·3	3,540	10·1	1,950	7·8	949
30	....	115	....	....	....	114	14·4	4,150	9·8	1,820	8·6	1,280
31	....	115	....	....	....	114	....	....	9·5	1,680	....	....

Day.	July.		August.		September.		October.		November.		December.	
1	8·8	1,360	6·5	482	6·8	578	....	395	....	513	....	230
2	9·2	1,540	6·2	395	6·7	545	....	368	....	513	....	230
3	9·6	1,720	6·1	368	6·7	545	....	341	....	513	....	230
4	9·9	1,860	6·0	341	6·8	578	....	341	....	545	....	230
5	9·8	1,820	5·85	302	7·0	647	....	315	....	545	....	230
6	9·0	1,460	5·8	289	7·2	719	....	328	....	578	....	230
7	8·2	1,110	5·6	240	7·3	756	....	395	....	578	....	230
8	7·7	909	5·5	216	7·1	683	....	452	....	578	....	230
9	7·6	870	5·7	264	7·0	647	....	452	....	545	....	230
10	7·8	949	5·7	264	6·9	612	....	482	....	545	....	230
11	8·0	1,030	5·8	289	6·8	578	....	513	....	482	....	230
12	8·4	1,190	5·9	315	6·8	578	....	545	....	452	....	230
13	14·4	4,150	6·0	341	6·5	482	....	578	....	452	....	230
14	16·4	5,250	5·9	315	6·4	452	....	578	....	452	....	230
15	16·1	5,080	5·75	276	6·6	513	....	647	....	452	....	230
16	15·4	4,700	5·7	264	7·1	683	....	612	....	423	....	230
17	14·4	4,150	5·8	289	7·5	831	....	578	....	423	....	230
18	13·6	3,710	5·9	315	7·5	831	....	545	....	423	....	230
19	12·7	3,220	6·0	341	7·6	870	....	513	....	423	....	230
20	11·8	2,760	6·1	368	7·6	870	....	513	....	452	....	230
21	11·0	2,360	6·3	423	7·8	949	....	482	....	452	....	230
22	10·0	1,900	6·6	513	8·0	1,030	....	482	....	452	....	230
23	9·0	1,460	6·7	545	8·2	1,110	....	482	....	423	....	230
24	7·9	989	6·8	578	8·2	1,110	....	578	....	423	....	230
25	7·1	683	7·0	647	8·0	1,030	....	612	....	452	....	230
26	7·4	793	7·0	647	7·6	870	....	647	....	452	....	230
27	7·2	719	6·9	612	7·2	719	....	647	....	452	....	230
28	6·7	545	6·8	578	7·0	647	....	612	....	452	....	230
29	6·4	452	6·8	578	6·7	545	....	612	....	452	....	230
30	6·2	395	6·8	578	6·4	452	....	578	....	452	....	230
31	6·3	423	6·9	612	....	....	....	545	....	....	....	230

NOTE.—Discharge records January 1 to April 24, and from December 1 to December 31, estimated.

Table 97.—Monthly Discharge of Little Fork River at Little Fork, Minnesota.

[Drainage area, 1,720 square miles.]

Month.	Discharge in Second-Feet.				Run-off.	Accuracy
	Maximum.	Minimum	Mean.	Per Square mile.	Depth in inches on Drainage Area.	
1909.						
June 23–30	377	261	310	0·180	0·05	A.
July	358	137	212	0·123	0·14	A.
August	4,380	208	1,540	0·895	1·03	C.
September	1,030	228	516	0·300	0·33	B.
October	2,700	344	1,080	0·628	0·72	B.
November 1–13	1,360	598	680	0·395	0·19	B.
1910.						
April 11–30		1,490	2,720	1·58	1·17	B.
May	1,390	442	703	0·409	0·47	A.
June	565	112	309	0·180	0·20	A.
July	371	75	149	0·087	0·10	A.
August	271	91	125	0·073	0·08	A.
September	119	40	88	0·051	0·06	A.
October	208	119	163	0·095	0·11	A.
November			160	0·093	0·10	B.
1911.						
April	3,730	900	2,100	1·22	1·36	B.
May	1,590	719	1,080	0·628	0·72	A.
June	2,610	390	1,680	0·977	1·09	B.
July	513	142	212	0·123	0·14	A.
August	793	274	492	0·286	0·33	A.
September	917	289	529	0·308	0·34	A.
October	482	264	356	0·207	0·24	A.
November	289		209	0·122	0·14	C.
December			145	0·084	0·10	C.
1912.						
January			85	0·049	0·06	C.
February			75	0·044	0·05	C.
March			70	0·041	0·05	B.
April			1,130	0·657	0·73	C.
May	3,310	793	2,270	1·32	1·52	B.
June	1,030	264	588	0·342	0·38	B.
July	756	193	304	0·177	0·20	C.
August	264	97	140	0·081	0·09	C.
September	1,360	276	735	0·427	0·48	C.
October	1,030	289	539	0·313	0·36	B.
November			318	0·185	0·21	C.
December			150	0·087	0·10	C.
The Year	3,310		535	0·311	4·23	
1913.						
January			82	0·048	0·06	C.
February			58	0·034	0·04	C.
March			85	0·049	0·06	D.
April			2,470	1·440	1·61	C.
May	5,250	1,900	3,180	1·850	2·13	B.
June	4,810	870	2,350	1·370	1·53	B.
July	1,900	545	1,320	0·767	0·88	A.
August	482	240	309	0·180	0·21	A.
September	719	289	464	0·270	0·30	A.
October	2,260	423	1,240	0·721	0·83	B.
November			526	0·306	0·34	C.
December	1,680		698	0·406	0·47	C.
The Year			1,065	0·620	8·46	
1914.						
January			132	0·077	0·09	C.
February			89	0·052	0·05	C.
March			95	0·056	0·06	C.
April			1,450	0·843	0·91	C.
May	6,520	1,680	3,540	2·060	2·38	B.
June	4,260	341	1,560	0·907	1·01	B.
July	5,250	395	1,920	1·120	1·29	B.
August	647	216	406	0·236	0·27	B.
September	1,110	452	715	0·416	0·46	B.
October	647	315	509	0·296	0·341	
November			478	0·278	0·310	
December			230	0·134	0·154	
The Year			927	0·540	7·35	

VERMILION RIVER BELOW LAKE VERMILION, NEAR TOWER, MINNESOTA.

Location.—Just below the dam at outlet of lake Vermilion in section 2, township 63 N, range 17 W, in St. Louis county, 4 miles above the mouth of Two Mile creek, which enters from the west.

Records Available.—May 17, 1911, to December 31, 1914.

Drainage Area.—507 square miles.

Gauge.—Vertical staff; datum unchanged.

Channel.—Practically permanent.

Discharge Measurements.—Made from car and cable just below the gauge section.

Artificial Control.—At the outlet of Vermilion lake, a few hundred feet above the gauge, there is a dam which is used to raise the elevation of the lake for aid in navigation. There are no gates in the dam, but on July 19, 1912, it was repaired. For a period after this date the flow was lower than normal, as there was less leakage. The lak[illegible]tly greater storage capacity, at the present time, so that the flow [illegible] winter period of 1912-13 was somewhat larger than it would hav[illegible] had not the dam been repaired.

Winter Flow.—Owing to the heavy fall at the gauge section, amounting to 20 feet in 200 yards, there is little or no backwater from ice during the winter months.

Accuracy.—Conditions are favourable for fairly accurate results, the only uncertainty being some inaccuracy in the discharge measurements, owing to the very rocky section.

References.—United States Geological Survey, Water Supply Papers Nos. 305, 325 and 355.

Table 98.—Discharge Measurements of Vermilion River below Lake Vermilion, near Tower, Minnesota.

[Drainage area, 507 square miles]

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
1911.						
May 31	C. J. Emerson	....	....	....	1·94	518·0
June 30	"	....	....	....	1·88	486·0
July 30	S. B. Soulé	....	....	....	1·32	262·0
Oct. 8	"	....	....	....	0·93	173·0
1912.						
Jan. 16	S. B. Soulé	....	....	....	0·69	140·0
Mar. 7	"	....	....	....	0·52	97·6
" 7	W. G. Hoyt	....	....	....	0·52	103·0[1]
Oct. 16	S. B. Soulé	....	....	....	0·58	105·0
1913.						
July 2	S. B. Soulé	47	154	5·90	2·63	908·0
" 2	"	47	153	5·95	2·62	912·0
Oct. 7	B. J. Peterson	24	53	1·39	0·32	73·0
" 7	"	24	52	1·40	0·32	73·0
1914.						
May 20	S. B. Soulé	128	754	1·42	2·91	1,070·0[2]
" 21	"	144	959	1·03	2·85	991·0[3]

[1] Open water, regular section.
[2] Measurement from boat about 4,000 feet below gauge. Control clear.
[3] Measurement from boat about 6,000 feet below gauge.

Table 99.—Daily Discharge Records of Vermilion River below Lake Vermilion, near Tower, Minnesota.

[Drainage area, 507 square miles.]

1911.

Day.	January.		February.		March.		April.		May.		June.	
	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1											1·90	490
2											1·90	490
3											1·95	515
4											1·90	490
5											1·90	490
											1·90	490
											1·90	490
8											1·95	515
9											1·95	515
10											2·05	568
11											2·03	556
12											2·01	546
13											2·00	540
14											2·00	540
15											2·00	540
16											1·95	515
17									1·95	515	1·92	500
18									2·00	540	1·91	495
19									2·10	595	1·90	490
20									2·00	540	2·15	622
21									1·95	515	2·10	595
22									2·00	540	2·05	568
23									2·05	568	2·05	568
24									2·00	540	2·00	540
25									1·95	515	2·00	540
26									1·90	490	1·95	515
27									1·90	490	1·95	515
28									1·90	490	1·90	490
29									1·90	490	1·90	490
30									1·90	490	1·90	490
31									1·95	515		

Day.	July.		August.		September.		October.		November.		December.	
1	1·90	490	1·35	272	0·90	167	0·85	158	0·71	132	0·70	130
2	1·85	466	1·35	272	0·90	167	0·85	158	0·68	127	0·70	130
3	1·80	442	1·33	266	0·90	167	0·84	156	0·66	124	0·70	130
4	1·75	420	1·33	266	0·90	167	0·84	156	0·64	120	0·70	130
5	1·73	411	1·32	263	0·90	167	0·85	158	0·62	117	0·70	130
6	1·72	407	1·32	263	1·00	187	0·85	158	0·60	114	0·70	130
7	1·71	402	1·33	266	1·50	321	0·85	158	0·60	114	0·70	130
8	1·60	358	1·32	263	1·50	321	0·84	156	0·60	114	0·70	130
9	1·60	358	1·32	263	1·50	321	0·84	156	0·60	111	0·70	130
10	1·50	321	1·31	260	1·30	257	0·84	156	0·60	114	0·70	130
11	1·45	304	1·31	260	1·20	231	0·84	156	0·60	114	0·70	130
12	1·40	287	1·30	257	1·10	208	0·85	158	0·60	114	0·70	130
13	1·35	272	1·30	257	1·10	208	0·84	156	0·60	114	0·70	130
14	1·33	266	1·25	244	1·10	208	0·84	156	0·60	114	0·70	130
15	1·30	257	1·25	244	1·10	208	0·84	156	0·60	114	0·70	130
16	1·35	272	1·20	231	1·10	208	0·84	156	0·60	114	0·70	130
17	1·35	272	1·20	231	1·00	187	0·85	158	0·62	117	0·70	130
18	1·30	257	1·20	231	1·00	187	0·86	159	0·63	119	0·70	130
19	1·30	257	1·25	244	0·98	183	0·86	159	0·65	122	0·70	130
20	1·20	231	1·25	244	0·96	179	0·85	158	0·68	127	0·70	130
21	1·10	208	1·25	244	0·94	175	0·84	156	0·70	130	0·70	130
22	1·30	257	1·22	236	0·90	167	0·83	154	0·70	130	0·70	130
23	1·30	257	1·20	231	0·90	167	0·82	152	0·70	130	0·70	130
24	1·30	257	1·10	208	0·90	167	0·80	148	0·70	130	0·70	130
25	1·30	257	1·10	208	0·90	167	0·78	144	0·70	130	0·70	130
26	1·35	272	1·00	187	0·90	167	0·76	141	0·70	130	0·70	130
27	1·35	272	1·00	187	0·90	167	0·74	137	0·70	130	0·70	130
28	1·35	272	1·00	187	0·88	163	0·72	131	0·70	130	0·70	130
29	1·32	263	1·00	187	0·86	159	0·71	132	0·70	130	0·70	130
30	1·32	263	0·90	167	0·85	158	0·70	130	0·70	130	0·70	130
31	1·32	263	0·90	167			0·70	130			0·70	130

NOTE (Year 1911).—Discharge computed from a well defined rating curve.

Table 99.—Daily Discharge Records of Vermilion River below Lake Vermilion, near Tower, Minnesota—Continued.

1912.

Day.	January.		February.		March.		April.		May.		June.	
	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	0·70	130	0·65	122	0·54	106	0·45	93	1·10	208	2·00	540
2	0·70	130	0·65	122	0·52	103	0·45	93	1·20	231	2·00	540
3	0·70	130	0·65	122	0·52	103	0·45	93	1·30	257	2·00	540
4	0·70	130	0·65	122	0·52	103	0·45	93	1·40	287	1·95	515
5	0·70	130	0·65	122	0·52	103	0·45	93	1·50	321	1·95	515
6	0·70	130	0·65	122	0·52	103	0·45	93	1·60	358	1·95	515
7	0·70	130	0·65	122	0·52	103	0·45	93	1·70	398	1·90	490
8	0·70	130	0·65	122	0·50	100	0·48	97	1·75	420	1·90	490
9	0·70	130	0·65	122	0·50	100	0·50	100	1·80	442	1·90	490
10	0·70	130	0·65	122	0·50	100	0·50	100	1·90	490	1·90	490
11	0·70	130	0·64	120	0·50	100	0·50	100	1·90	490	1·95	515
12	0·70	130	0·63	119	0·50	100	0·52	103	2·00	540	1·95	515
13	0·70	130	0·63	119	0·50	100	0·54	106	2·00	540	1·90	490
14	0·70	130	0·62	117	0·46	94	0·55	107	2·05	568	1·85	466
15	0·70	130	0·62	117	0·44	92	0·55	107	2·05	568	1·85	466
16	0·70	130	0·61	116	0·42	89	0·55	107	2·05	568	1·80	442
17	0·70	130	0·61	116	0·42	89	0·57	110	2·05	568	1·80	442
18	0·68	127	0·60	114	0·42	89	0·60	114	2·05	568	1·80	442
19	0·68	127	0·60	114	0·42	[illegible]	0·63	119	2·10	595	1·80	442
20	0·68	127	0·60	114	0·42	[illegible]	0·65	122	2·10	595	1·75	420
21	0·68	127	0·60	114	0·42	89	0·68	127	2·10	595	1·75	420
22	0·65	122	0·60	114	0·42	89	0·70	130	2·10	595	1·75	420
23	0·65	122	0·60	114	0·42	89	0·70	130	2·05	568	1·75	420
24	0·65	122	0·60	114	0·42	89	0·70	130	2·05	568	1·70	398
25	0·65	122	0·60	114	0·42	89	0·75	139	2·05	568	1·70	398
26	0·65	122	0·60	114	0·43	90	0·80	148	2·05	568	1·65	378
27	0·65	122	0·58	111	0·44	92	0·85	158	2·05	568	1·65	378
28	0·65	122	0·56	108	0·45	93	0·85	158	[illegible]·00	540	1·60	358
29	0·65	122	0·54	106	0·45	93	0·90	167	[illegible]	540	1·55	340
30	0·65	122	......	......	0·45	93	0·95	1[illegible]		540	1·55	340
31	0·65	122	......	......	0·45	93	......	......		540	......	......

Day.	July.		August.		September.		October.		November.		December.	
1	1·55	340	0·65	122	0·55	107	0·60	114	0·50	98	0·50	98
2	1·50	321	0·65	122	0·55	107	0·60	114	0·50	98	0·50	98
3	1·50	321	0·65	122	0·55	107	0·60	114	0·50	98	0·50	98
4	1·45	304	0·60	114	0·55	107	0·60	114	0·50	98	0·50	98
5	1·40	287	0·60	114	0·60	114	0·60	114	0·50	98	0·50	98
6	1·40	287	0·60	114	0·60	114	0·60	114	0·50	98	0·50	98
7	1·40	287	0·60	114	0·60	114	0·60	114	0·50	98	0·50	98
8	1·35	272	0·60	114	0·60	114	0·60	114	0·50	98	0·50	98
9	1·35	272	0·55	107	0·60	114	0·60	114	0·50	98	0·50	98
10	1·30	257	0·55	107	0·60	114	0·60	114	0·50	98	0·50	98
11	1·25	244	0·55	107	0·60	114	0·60	114	0·50	98	0·50	98
12	1·25	244	0·55	107	0·60	114	0·60	114	0·50	98	0·50	98
13	1·25	244	0·55	107	0·60	114	0·60	114	0·50	98	0·50	98
14	1·30	257	0·50	100	0·60	114	0·60	114	0·50	98	0·50	98
15	1·25	244	0·50	100	0·60	114	0·60	114	0·50	98	0·50	98
16	1·25	244	0·50	100	0·60	114	0·60	114	0·50	98	0·50	98
17	1·25	244	0·50	100	0·60	114	0·60	114	0·50	98	0·50	98
18	0·80	148	0·50	100	0·60	114	0·60	114	0·50	98	0·50	98
19	0·80	148	0·50	100	0·60	114	0·60	114	0·50	98	0·50	98
20	0·70	130	0·50	100	0·60	114	0·55	106	0·50	98	0·50	98
21	0·70	130	0·50	100	0·60	114	0·55	106	0·50	98	0·50	98
22	0·70	130	0·50	100	0·60	114	0·55	106	0·50	98	0·50	98
23	0·70	130	0·50	100	0·60	114	0·55	106	0·50	98	0·50	98
24	0·70	130	0·50	100	0·60	114	0·55	106	0·50	98	0·50	98
25	0·65	122	0·50	100	0·60	114	0·55	106	0·50	98	0·50	98
26	0·65	122	0·55	107	0·60	114	0·55	106	0·50	98	0·50	98
27	0·65	122	0·55	107	0·60	114	0·55	106	0·50	98	0·50	98
28	0·65	122	0·55	107	0·60	114	0·55	106	0·50	98	0·50	98
29	0·65	122	0·55	107	0·60	114	0·55	106	0·50	98	0·50	98
30	0·[illegible]5	122	0·55	107	0·60	114	0·55	106	0·50	98	0·50	98
31	0·65	122	0·55	107	......	......	0·55	106	......	......	0·50	98

Table 99.—Daily Discharge Records of Vermilion River below Lake Vermilion, near Tower, Minnesota—Continued.

1913

Day.	January.		February.		March.		April.		May.		June.	
	Gauge Height	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	0·50	98	0·50	98	0·50	98	0·52	101		212	3·70	1,290
2	0·50	98	0·50	98	0·50	98	0·52	101		218	3·30	1,290
3	0·50	98	0·50	98	0·50	98	0·52	101		222	3·40	1,360
4	0·50	98	0·50	98	0·50	98	0·52	101		226	3·40	1,360
5	0·50	98	0·50	98	0·50	98	0·52	101	1·20	231	3·40	1,360
6	0·50	98	0·50	98	0·50	98	0·52	101	1·30	257	3·50	1,420
7	0·50	98	0·50	98	0·50	98	0·52	101	1·30	257	3·50	1,420
8	0·50	98	0·50	98	0·50	98	0·52	101	1·40	287	3·50	1,420
9	0·50	98	0·50	98	0·50	98	0·52	101	1·40	287	3·50	1,420
10	0·50	98	0·50	98	0·50	98	0·52	101	1·40	287	3·50	1,420
11	0·50	98	0·50	98	0·50	98	0·52	101	1·40	287	3·50	1,420
12	0·50	98	0·50	98	0·50	98	0·52	101	1·40	287	3·40	1,360
13	0·50	98	0·50	98	0·50	98	0·55	106	1·40	287	3·40	1,360
14	0·50	98	0·50	98	0·50	98	0·55	106	1·40	287	3·40	1,360
15	0·50	98	0·50	98	0·50	98	0·55	106	1·50	321	3·40	1,360
16	0·50	98	0·50	98	0·50	98	.....	112	1·60	358	3·40	1,360
17	0·50	98	0·50	98	0·50	98	.....	119	1·70	398	3·30	1,290
18	0·50	98	0·50	98	0·50	98	.....	125	1·80	442	3·20	1,230
19	0·50	98	0·50	98	0·50	98	.....	132	1·80	442	3·20	1,230
20	0·50	98	0·50	98	0·50	98	.....	138	2·00	510	3·20	1,230
21	0·50	98	0·50	98	0·50	98	.....	145	2·00	540	3·10	1,170
22	0·50	98	0·50	98	0·50	98	.....	152	2·50	810	3·00	1,110
23	0·50	98	0·50	98	0·50	98	.....	158	3·00	1,110	3·00	1,110
24	0·50	98	0·50	98	0·50	98	.....	165	3·10	1,170	3·00	1,110
25	0·50	98	0·50	98	0·50	98	.....	172	3·20	1,230	2·90	1,050
26	0·50	98	0·50	98	0·50	98	.....	179	3·20	1,230	2·90	1,050
27	0·50	98	0·50	98	0·50	98	.....	186	3·20	1,230	2·80	990
28	0·50	98	0·50	98	0·50	98	.....	193	3·20	1,230	2·80	990
29	0·50	98	.....	.....	0·50	98	.....	200	3·30	1,290	2·80	990
30	0·50	98	.....	.....	0·50	98	.....	205	3·30	1,290	2·70	930
31	0·50	98	.....	.....	0·50	98	.....	.....	3·30	1,290	.....	.....

K.M.

Day.	July.		August.		September.		October.		November.		December.	
1	2·80	990	1·85	466	0·33	74	0·22	60	0·48	95	0·62	117
2	2·70	930	1·95	515	0·33	71	0·22	60	0·48	95	0·65	122
3	2·60	870	1·85	466	0·33	74	0·24	63	0·48	95	0·65	122
4	2·60	870	1·90	490	0·33	74	0·24	63	0·50	98	0·65	122
5	2·50	810	1·80	442	0·33	74	0·27	66	0·52	101	0·68	127
6	2·50	810	1·65	378	0·33	74	0·30	70	0·52	101	0·68	127
7	2·35	728	1·25	244	0·33	74	0·32	73	0·50	98	0·68	127
8	2·40	755	1·20	231	0·33	74	0·32	73	0·50	98	0·68	127
9	2·35	728	1·10	208	0·33	74	0·32	73	0·50	98	0·68	127
10	2·30	700	0·85	158	0·33	71	0·32	73	0·50	98	0·68	127
11	2·40	755	0·65	122	0·33	74	0·32	73	0·50	98	0·65	122
12	2·35	728	0·60	114	0·33	74	0·35	76	0·50	98	0·65	122
13	2·20	645	0·55	106	0·33	74	0·40	83	0·50	98	0·65	122
14	2·25	672	0·53	103	0·33	74	0·45	90	0·50	98	0·65	122
15	2·20	645	0·50	98	0·33	74	0·45	90	0·50	98	0·65	122
16	2·25	672	0·50	98	0·33	74	0·45	90	0·55	106	0·65	122
17	2·20	645	0·50	98	0·33	74	0·48	95	.....	106	0·65	122
18	2·30	700	0·50	98	0·33	74	0·48	95	0·55	106	0·65	122
19	2·25	672	0·50	98	0·28	68	0·48	95	0·55	106	0·65	122
20	2·20	645	0·45	90	0·28	68	0·48	95	0·55	106	0·65	122
21	2·10	590	0·45	90	0·28	68	0·48	95	0·55	106	0·65	122
22	2·20	645	0·40	83	0·25	64	0·48	95	0·55	106	0·65	122
23	2·05	565	0·40	83	0·23	62	0·48	95	0·55	106	0·65	122
24	2·20	645	0·40	83	0·23	62	0·48	95	0·55	106	0·65	122
25	2·15	618	0·35	76	0·23	62	0·48	95	0·55	106	.....	122
26	2·15	618	0·35	76	0·23	62	0·48	95	0·55	106	0·65	122
27	2·00	540	0·35	76	0·23	62	0·48	95	0·55	106	0·65	122
28	2·10	590	0·35	76	0·23	62	0·48	95	0·55	106	0·65	122
29	1·95	515	0·35	76	0·23	62	0·48	95	0·58	111	0·65	122
30	1·80	442	0·35	76	0·23	62	0·48	95	0·60	114	0·65	122
31	1·90	490	0·35	76	.....	.....	0·48	95	.....	.....	0·65	122

NOTE.—Discharge from April 16 to May 4 estimated.

Table 99.—Daily Discharge Records of Vermilion River below Lake Vermilion, near Tower, Minnesota—Concluded.

1914.

Day.	January.		February.		March.		April.		May.		June.	
	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	0·65	122	0·62	117	0·70	130	0·66	124	1·65	378	2·50	810
2	0·65	122	0·62	117	0·70	130	0·66	124	1·80	442	2·50	810
3	0·65	122	0·62	117	0·70	130	0·66	124	2·00	540	2·50	810
4	0·65	122	0·65	122	0·70	130	0·65	122	2·05	565	2·50	810
5	0·65	122	0·65	122	0·70	130	0·65	122	2·10	590	2·50	810
6	0·65	122	0·65	122	0·70	130	0·65	122	2·20	645	2·50	810
7	0·65	122	0·65	122	0·70	130	0·65	122	2·40	755	2·50	810
8	0·65	122	0·65	122	0·70	130	0·64	120	2·40	755	2·50	810
9	0·65	122	0·65	122	0·70	130	0·64	120	2·40	755	2·45	782
10	0·62	117	0·65	122	0·70	130	0·64	120	2·40	755	2·45	782
11	0·62	117	0·68	127	0·70	130	0·62	117	3·00	1,110	2·40	755
12	0·62	117	0·68	127	0·68	127	0·62	117	3·00	1,110	2·40	755
13	0·62	117	0·68	127	0·68	127	0·62	117	3·00	1,110	2·40	755
14	0·62	117	0·68	127	0·68	127	0·61	116	3·00	1,110	2·40	755
15	0·62	117	0·68	127	0·68	127	0·61	116	3·00	1,110	2·40	755
16	0·62	117	0·68	127	0·68	127	0·60	114	3·00	1,110	2·35	728
17	0·62	117	0·68	127	0·68	127	0·61	116	2·90	1,050	2·30	700
18	....	117	0·68	127	0·68	127	0·66	124	2·90	1,050	2·25	672
19	0·62	117	0·68	127	0·68	127	0·69	128	2·90	1,050	2·00	540
20	0·62	117	0·68	127	0·68	127	0·73	135	2·90	1,050	2·00	540
21	0·62	117	0·68	127	0·68	127	0·76	141	2·90	1,050	2·00	540
22	0·62	117	0·70	130	0·68	127	0·78	144	2·80	990	2·00	540
23	0·62	117	0·70	130	0·68	127	0·78	144	2·80	990	2·00	540
24	0·62	117	0·70	130	0·68	127	0·79	146	2·80	990	2·00	540
25	0·62	117	0·70	130	0·68	127	0·85	158	2·80	990	2·00	540
26	0·62	117	....	130	0·68	127	0·91	169	2·80	990	1·95	515
27	0·62	117	....	130	0·68	127	0·96	179	2·70	930	1·95	515
28	0·62	117	....	130	0·68	127	1·15	220	2·60	870	1·95	515
29	0·62	117	....	....	0·68	127	1·40	287	2·60	870	1·90	490
30	0·62	117	....	....	0·68	127	1·55	334	2·60	870	1·90	490
31	0·62	117	....	....	0·68	127	....	....	2·50	810	....	....

Day.	July.		August.		September.		October.		November.		December.	
1	1·90	490	1·80	442	1·20	231	....	208	....	171	....	117
2	1·90	490	1·80	442	1·20	231	....	208	....	171	....	117
3	1·90	490	1·80	442	1·20	231	....	208	....	167	....	117
4	1·90	490	1·70	398	1·20	231	....	208	....	167	....	117
5	1·90	490	1·70	398	1·20	231	....	208	....	167	....	117
6	1·90	490	1·65	378	1·15	220	....	208	....	163	....	117
7	1·85	466	1·60	358	1·10	208	....	208	....	163	....	117
8	1·85	466	1·55	340	1·10	208	....	208	....	163	....	117
9	1·90	490	1·50	321	1·20	231	....	208	....	158	....	117
10	1·90	490	1·50	321	1·20	231	....	208	....	158	....	117
11	1·90	490	1·45	304	1·15	220	....	198	....	158	....	117
12	1·90	490	1·45	304	1·20	231	....	198	....	152	....	114
13	1·95	515	1·40	287	1·20	231	....	198	....	152	....	114
14	2·00	540	1·35	272	1·20	231	....	198	....	148	....	114
15	2·00	540	1·30	257	1·20	231	....	187	....	148	....	114
16	2·00	540	1·30	257	1·20	231	....	187	....	144	....	114
17	2·00	540	1·30	257	1·20	231	....	187	....	144	....	114
18	2·00	540	1·30	257	1·20	231	....	187	....	139	....	114
19	2·00	540	1·30	257	1·20	231	....	187	....	139	....	114
20	2·00	540	1·30	257	1·20	231	....	187	....	134	....	114
21	1·95	515	1·30	257	1·20	231	....	187	....	134	....	114
22	1·90	490	1·30	257	1·20	231	....	183	....	130	....	114
23	1·90	490	1·30	257	1·20	231	....	183	....	130	....	114
24	1·90	490	1·30	257	1·20	231	....	183	....	127	....	114
25	1·90	490	1·30	257	1·20	231	....	183	....	127	....	114
26	1·90	490	1·25	244	1·20	231	....	177	....	122	....	114
27	1·90	490	1·25	244	1·15	220	....	177	....	122	....	114
28	1·90	490	1·20	231	1·15	220	....	177	....	117	....	111
29	1·85	466	1·20	231	1·10	208	....	177	....	117	....	111
30	1·80	442	1·20	231	1·10	208	....	171	....	117	....	111
31	1·80	442	1·20	231	....	....	....	171	....	....	....	111

Table 100.—Monthly Discharge of Vermilion River below Lake Vermilion, near Tower, Minnesota.

[Drainage Area, 507 square miles.]

Month.	Discharge in Second-Feet.				Run Off.	Accuracy.
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on Drainage Area.	
1911.						
May 17-31	595	490	522	1·03	0·57	A.
June	622	490	524	1·040	1·16	A.
July	490	208	309	0·609	0·70	A.
August	272	167	236	0·466	0·54	A.
September	321	158	197	0·389	0·43	A.
October	159	130	152	0·300	0·35	B.
November	132	114	122	0·211	0·27	B.
December	130	130	130	0·256	0·30	B.
1912.						
January	130	122	127	0·250	0·29	A.
February	122	106	117	0·231	0·25	A
March	106	89	95	0·188	0·22	A.
April	177	93	117	0·231	0·26	A.
May	595	208	490	0·966	1·11	A.
June	540	340	454	0·895	1·00	A.
July	340	122	209	0·412	0·48	B.
August	122	100	107	0·211	0·24	B.
September	114	107	113	0·223	0·25	B.
October	114	106	111	0·219	0·25	B.
November	98	98	98	0·193	0·22	B.
December	98	98	98	0·193	0·22	B.
The Year	595	89	178	0·351	4·80	....
1913.						
January	98	98	98	0·193	0·22	B.
February	98	[illegible]	98	0·193	0·20	B.
March	98	98	98	0·193	0·22	B.
April	(205)	(101)	130	0·256	0·29	C.
May	1,290	212	598	1·180	1·36	B.
June	1,420	930	1,250	2·470	2·76	A.
July	990	442	685	1·350	1·56	A.
August	515	76	177	0·349	0·40	A.
September	74	62	69	0·138	0·15	B.
October	95	60	83	0·165	0·19	B.
November	114	95	102	0·201	0·22	A.
December	127	117	123	0·243	0·28	A.
The Year	427	199	293	0·578	7·85	
1914.						
January	122	117	118	0·233	0·27	A.
February	130	117	125	0·247	0·26	A.
March	130	127	128	0·252	0·29	A.
April	334	114	145	0·286	0·32	A.
May	1,110	378	884	1·740	2·01	A.
June	810	490	674	1·330	1·48	A.
July	540	412	497	0·980	1·13	A.
August	442	231	298	0·588	0·68	A.
September	231	208	226	0·446	0·50	A.
October	208	171	192	0·379	0·44	....
November	171	117	145	0·286	0·32	....
December	....	....	115	0·227	0·26	....
The Year	....	....	296	0·583	7·96	

KAWISHIWI RIVER NEAR WINTON.

Location.—At the logging dam at the outlet of Garden lake in section 20, township 62 N., range 11 W., about 3 miles east of Winton, Minnesota.

Records Available.—June 21, 1905, to June 30, 1907 These records are furnished through the courtesy of the Minnesota Canal and Power Company, by whom they were compiled.

Records from October 14, 1912, to December 31, 1914, were secured by the International Joint Commission co-operating with the United States Geological Survey.

Drainage Area.—1,200 square miles.

Gauge.—Vertical staff, read at 8 a.m. and 5 p.m.; the mean is taken as the mean for the day.

Method of Compiling Records.—Obtained by recording the flow through the five sluiceways of the logging dam, which were closed by Taintor gates. The coefficient for each sluiceway was obtained by current-meter.

Regulation.—The flow at Garden lake outlet is almost wholly controlled by logging reservoirs, and the daily records do not represent the natural variation in run-off.

References.—Report of Water Resources investigations of Minnesota 1909-1912 by the State Drainage Commissions, and the Report to the International Joint Commission, by Arthur V. White and Adolph F. Meyer, Consulting Engineers, 1915.

Table 100A.—Discharge Measurements of Kawishiwi River near Winton, Minn.

[Drainage Area, 1,200 square miles.]

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
1912.						
Oct. 13	Soulé	77	417	1·96	2·31	818[1]
" 11	"	75	260	0·42	0·72	109[2]
" 14	"	120	520	3·40	3·69	1,770[3]
" 15	"	150	674	4·27	4·98	2,880[4]
1913.						
April 29	Soulé	102	515	3·30	3·63	1,700
" 30	"	72	229	0·35	0·62	81
Sept. 12	Peterson	76	274	0·60	0·89	163
" 13	"	77	404	2·00	2·32	810
1914.						
May 22	Soulé	150	609	3·48	4·21	2,120[5]

[1] One 12-foot gate in Garden Lake dam open.
[2] Gates closed. Represents leakage.
[3] One 12-foot and one 16-foot gate open.
[4] One 12-foot, one 16 foot, and one 20-foot gate open.
[5] Gauge checked with level and found correct.

Table 101.—Daily Discharge Records of Kawishiwi River near Winton, Minnesota.

[Drainage area, 1,200 square miles.]

1905

Day.	January.		February.		March.		April.		May.		June.	
	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												1,340
22												1,912
23												1,960
24												1,994
25												2,231
26												2,174
27												1,082
28												2,903
29												2,921
30												2,900
31												

Day.	July.		August.		September.		October.		November.		December.	
1		1,693		2,320		0		3,426		1,238		1,083
2		2,650		2,342		228		3,211		1,210		1,083
3		2,070		1,645		910		2,899		1,210		1,109
4		1,900		2,050		988		1,158		1,158		1,109
5		3,192		1,613		1,180		1,898		1,131		1,134
6		3,192		1,877		1,134		2,659		1,131		1,158
7		3,766		3,018		1,159		2,123		1,109		1,158
8		4,131		2,901		2,286		1,350		1,083		1,158
9		3,737		1,693		2,200		1,361		1,060		1,158
10		3,736		2,118		1,302		1,768		1,060		1,158
11		3,159		2,550		1,100		2,339		1,039		1,158
12		2,985		1,810		1,807		1,711		972		1,158
13		2,818		2,315		2,534		1,341		850		1,158
14		2,562		846		2,659		1,088		888		1,158
15		3,088		203		2,290		933		908		1,158
16		3,370		1,172		2,098		843		928		1,099
17		3,097		2,605		193		775		928		1,070
18		2,386		2,194		850		734		928		1,070
19		122		1,887		2,435		775		820		1,070
20		1,800		1,606		2,387		820		629		1,050
21		3,243		1,406		2,353		887		671		1,021
22		2,608		1,288		2,332		964		700		1,021
23		2,422		739		2,656		1,033		903		1,021
24		887		0		3,426		1,109		1,288		908
25		1,025		0		[illegible]		1,158		1,185		975
26		1,878		130		3,554		1,210		1,134		951
27		912		622		3,719		1,265		1,109		931
28		2,102		622		3,790		1,288		1,083		931
29		2,000		392		[illegible]		1,265		1,060		910
30		1,149		0		3,581		1,265		1,060		880
31		2,300		0				1,238				880

Table 101.—Daily Discharge Records of Kawishiwi River near Winton, Minnesota—Continued.

1906

Day.	January.		February.		March.		April.		May.		June.	
	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height	Dis-charge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	....	856	....	506	....	360	....	276	....	1,682	....	2,585
2	....	837	....	506	....	360	....	289	....	1,840	....	2,920
3	....	837	....	523	....	360	....	289	....	1,836	....	2,444
4	....	837	....	506	....	360	....	289	....	1,889	....	2,351
5	....	810	....	506	....	360	....	308	....	1,930	....	2,911
6	....	783	....	506	....	360	....	300	....	2,105	....	3,146
7	....	760	....	491	....	345	....	315	....	2,650	....	1,146
8	....	731	....	491	....	345	....	315	....	2,057	....	3,096
9	....	731	....	474	....	345	....	330	....	2,172	....	3,074
10	....	731	....	474	....	345	....	330	....	2,880	....	3,020
11	....	713	....	474	....	345	....	345	....	2,706	....	3,094
12	....	695	....	474	....	330	....	360	....	2,150	....	3,327
13	....	695	....	458	....	330	....	416	....	2,370	....	2,764
14	....	676	....	458	....	330	....	474	....	1,795	....	3,144
15	....	660	....	435	....	330	....	506	....	1,836	....	2,685
16	....	660	....	435	....	330	....	579	....	2,057	....	2,843
17	....	660	....	435	....	330	....	660	....	2,913	....	3,070
18	....	642	....	416	....	320	....	760	....	3,087	....	2,846
19	....	642	....	416	....	315	....	856	....	3,212	....	2,940
20	....	621	....	400	....	315	....	931	....	3,055	....	2,378
21	....	621	....	400	....	315	....	1,024	....	3,008	....	2,830
22	....	600	....	400	....	300	....	1,158	....	2,987	....	2,062
23	....	600	....	400	....	300	....	1,265	....	3,091	....	1,344
24	....	579	....	380	....	308	....	1,491	....	3,113	....	2,259
28	....	579	....	380	....	300	....	1,730	....	3,005	....	2,387
26	....	579	....	360	....	300	....	2,389	....	2,634	....	2,251
27	....	560	....	360	....	308	....	1,654	....	2,605	....	2,623
28	....	540	....	360	....	300	....	2,307	....	2,605	....	1,232
29	....	540	....	....	....	289	....	2,600	....	2,565	....	1,870
30	....	540	....	....	....	289	....	2,580	....	2,446	....	2,050
31	....	523	....	....	....	289	....	....	....	2,559	....	....

Day.	July.		August.		September.		October.		November.		December.	
1	....	2,276	....	455	....	400	....	276	....	400	....	660
2	....	1,152	....	1,150	....	360	....	276	....	400	....	642
3	....	1,095	....	214	....	400	....	276	....	416	....	621
4	....	1,[illegible]05	....	750	....	400	....	263	....	416	....	600
[illegible]	....	1,860	....	524	....	400	....	250	....	400	....	579
	....	830	....	0	....	380	....	263	....	400	....	579
	....	880	....	795	....	380	....	276	....	400	....	579
	....	920	....	0	....	416	....	276	....	416	....	540
	....	930	....	848	....	435	....	300	....	435	....	523
.0	....	950	....	1,275	....	435	....	330	....	435	....	506
11	....	962	....	1,070	....	435	....	330	....	435	....	506
12	....	985	....	830	....	416	....	330	....	491	....	491
13	....	1,050	....	780	....	400	....	330	....	540	....	474
14	....	1,275	....	708	....	400	....	315	....	592	....	474
15	....	985	....	702	....	360	....	300	....	680	....	474
16	....	950	....	525	....	345	....	300	....	783	....	474
17	....	1,546	....	550	....	330	....	289	....	931	....	474
18	....	830	....	600	....	315	....	289	....	975	....	474
19	....	810	....	560	....	300	....	276	....	998	....	435
20	....	830	....	523	....	289	....	289	....	998	....	435
21	....	840	....	523	....	289	....	300	....	975	....	458
22	....	840	....	523	....	276	....	330	....	931	....	416
23	....	830	....	523	....	276	....	330	....	910	....	400
24	....	800	....	523	....	263	....	330	....	837	....	400
25	....	745	....	523	....	300	....	330	....	783	....	400
26	....	740	....	506	....	289	....	330	....	783	....	380
27	....	710	....	491	....	300	....	330	....	760	....	360
28	....	1,422	....	474	....	289	....	345	....	731	....	360
29	....	585	....	458	....	276	....	360	....	695	....	360
30	....	1,181	....	435	....	276	....	380	....	676	....	360
31	....	455	....	400	....	....	....	400	....	....	....	360

Table 101.—Daily Discharge Records of Kawishiwi River near Winton, Minnesota.—Continued.

1907

Day.	January.		February.		March.		April.		May.		June.	
	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1		345		263		200		222		510		5,000
2		345		263		210		235		506		5,200
3		340		263		210		235		491		5,250
4		330		263		210		250		458		5,200
5		330		250		210		263		435		5,100
6		330		250		210		276		416		4,900
7		330		250		210		276		405		4,710
8		330		250		210		276		50		4,550
9		315		250		200		289		59		4,350
10		315		250		200		300		66		4,130
11		315		235		200		315		552		4,000
12		315		235		200		330		816		3,475
13		300		235		200		330		1,265		3,700
14		300		235		200		315		1,141		3,110
15		300		222		200		[illegible]		1,366		2,917
16		300		222		200		380		981		2,981
17		300		222		200		380		80		3,245
18		300		222		200		380		81		2,900
19		300		222		190		380		1,129		2,695
20		289		210		190		400		2.214		1,327
21		289		210		190		400		2.270		1,601
22		289		210		190		415		2,400		2,600
23		289		210		190		0		1,100		3,810
24		289		210		200		0		2,390		3,700
25		289		200		200		951		1,677		3,475
26		276		200		210		0		3,716		3,120
27		276		200		210		880		3,810		1,669
28		276		200		222		837		4,120		986
29		276		200		210		731		4,415		973
30		263		......		222		621		4,710		539
31		263		......		210		......		4,760		....

Table 101.—Daily Discharge Records of the Kawishiwi River—Continued. *(Records of the International Joint Commission co-operating with the United States Geological Survey.)*

1912.

Day.	July.		August.		September		October.		November.		December	
	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height.	Dis-charge.	Guage Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height.	Dis-charge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet	Sec.-ft.
1												314
2												310
3												302
4												290
5												278
6												270
7												262
8												235
9												235
10										930		235
11												235
12												235
13												235
14								250		747		226
15								346				216
16								559				214
17								608				213
18								478				208
19								460		304		206
20								583		40		203
21								440		98		200
22								276		283		197
23								250		205		196
24								440		302		195
25								358		512		194
26								122		465		193
27								305		414		192
28										382		191
29										352		190
30										327		189
31												188

Table 101. Daily Discharge Records of the Kawishiwi River—Continued. (Records of the International Joint Commission co-operating with the United States Geological Survey)

1911

Day.	January		February.		March		April.		May		June.	
	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.	Gauge Height	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.	Feet	Sec.-ft.
1		186		150		133		143		2,400		[1]1,950
2		185		148		133		147		2,360		[1]1,710
3		184		146		131		149		2,340		1,480
4		182		145		132		154		2,300		1,110
5		180		144		131		155		2,180		88
6		177	...	143		130		157		1,640		504
7		174	....	142		129		159		1,030		2,380
8		172		140		128		161		1,210		2,840
9		170		139		127		163		920		3,380
10		168		139		127		165		975		3,170
11		165		138		127		167		133		3,190
12		163		137		127		169		113		3,040
13		161		136		127		170		332		3,210
14		163		135		127		220		851		3,220
15		163		134		127		306		1,600		3,190
16		161		[illegible]		127		339		2,230		2,460
17	....	163	....	133		128		369		2,680		2,130
18	...	161	....	133		129		400		1,860		2,960
19		163		133		130		432		1,910		2,120
20		162		133		131		465		2,180		1,990
21		162		133		132		546		2,930		2,960
22		161		131		133		640		2,610		2,240
23		160		131		131		[illegible]		2,070		2,840
24		159		133		134		854		1,920		2,630
25		158		133		134		1,050		2,580		2,480
26	....	157		133		135		1,210		2,980		2,740
27	....	156		133		136		1,410		3,190		2,140
28	......	154		133		137		1,580		[1]2,890		2,120
29	......	153				138		1,750		[1]2,650		2,010
30	....	152				139		1,270		[1]2,420		1,980
31		151			...	141				[1]2,180		

NOTE.—[1]Estimated

Day	July.	August.	September.	October.	November.	December.
1	905	390	304	182		747
2	1,030	590	441	387	930	742
3	1,040	600	794	487	1,050	736
4	1,060	128	[illegible]	365	1,940	730
5	1,060	127	256	625	908	720
6	1,060	289	445	448	817	714
7	1,050	347	163	387	817	703
8	105	616	272	729	817	698
9	1,340	130	816	262	817	687
10	736	130	239	436	1,363	682
11	940	494	331	655	1,309	676
12	1,040	541	464	618	1,270	671
13	989	530	394	823	1,220	661
14	1,380	110	326	[illegible]	1,190	[illegible]
15	1,050	541	670	[illegible]	1,140	645
16	1,300	130	157	1,100	1,130	610
17	1,020	133	157	1,110	1,110	630
18	536	555	157	1,010	1,080	625
19	736	381	652	1,490	868	620
20	738	116	317	1,490	575	610
21	716	474	154	1,470	585	580
22	820	571	157	1,340	590	561
23	906	182	301		590	541
24	742	381	807		347	522
25	1,110	554	262		[illegible]	[illegible]
26	1,490	351	266			
27	1,440	652	322			
28	1,730	[illegible]	363			
29	1,790	364	621			
30	1,640	378	[illegible]			
31	1,020	113				428

Table 101.--Daily Discharge Records of the Kawishiwi River—Concluded. *(Records of theInternational Joint Commission co-operating with the United States Geological Survey.)*

1914.

Day.	January.		February.		March.		April.		May.		June.	
	Gauge Height.	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height	Dis-charge.	Gauge Height	Dis-charge.
	Feet.	Sec.-ft.	Feet.	Sec. ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	......	423	......	314	......	235	......	190	......	996	......	2,612
2	......	418	......	311	......	70	......	190	......	1,120	......	2,520
3	......	409	......	308	......	15	......	190	......	1,178	......	3,800
4	......	400	......	306	......	15	......	190	......	1,131	......	4,475
5	......	396	......	303	......	15	......	187	......	1,252	......	3,870
6	......	391	......	300	......	15	......	187	......	1,727	......	3,870
7	......	382	......	297	......	60	......	187	......	2,432	......	3,870
8	......	374	......	294	......	163	......	187	......	2,831	......	2,914
9	......	369	......	292	......	60	......	183	......	2,895	......	2,520
10	......	365	......	289	......	15	......	183	......	3,690	......	2,520
11	......	356	......	286	......	70	......	183	......	3,973	......	2,241
12	......	356	......	283	......	247	......	180	......	3,684	......	1,146
13	......	356	......	280	......	243	......	180	......	3,740	......	1,545
14	......	356	......	277	......	239	......	141	......	3,490	......	[1]1,131
15	......	356	......	274	......	235	......	48	......	3,192	......	1,518
16	......	356	......	272	......	231	......	49	......	2,920	......	1,200
17	......	356	......	269	......	231	......	51	......	2,568	......	2,144
18	......	356	......	266	......	231	......	290	......	2,630	......	[1]2,180
19	......	356	......	263	......	227	......	345	......	2,457	......	1,999
20	......	356	......	260	......	227	......	239	......	2,286	......	1,200
21	......	356	......	257	......	227	......	247	......	2,643	......	1,131
22	......	356	......	254	......	227	......	258	......	2,401	......	......
23	......	356	......	252	......	227	......	274	......	2,080	......	1,863
24	......	356	......	250	......	224	......	178	......	2,090	......	......
25	......	356	......	247	......	216	......	73	......	1,464	......	1,131
26	......	350	......	245	......	216	......	71	......	2,120	......	......
27	......	344	......	242	......	212	......	75	......	1,949	......	......
28	......	338	......	239	......	201	......	623	......	2,018	......	2,520
29	......	332	......	......	......	197	......	960	......	2,246	......	......
30	......	326	......	......	......	197	......	879	......	2,695	......	2,020
31	......	320	......	......	......	194	......	......	......	2,928	......	......

[1]Note.—Estimated.

Day.	July.		August.		September.		October.		November.		December.	
1	......	1,996	......	1,638	......	667	......	880	......	242	......	197
2	......	1,503	......	1,719	......	924	......	1,480	......	794	......	197
3	......	1,380	......	1,104	......	918	......	1,618	......	615	......	197
4	......	1,996	......	841	......	965	......	495	......	610	......	197
5	......	2,020	......	271	......	931	......	725	......	600	......	197
6	......	2,004	......	502	......	1,015	......	730	......	595	......	197
7	......	1,324	......	868	......	976	......	736	......	590	......	197
8	......	1,355	......	337	......	977	......	736	......	600	......	197
9	......	1,709	......	176	......	792	......	1,488	......	600	......	197
10	......	2,930	......	515	......	981	......	665	......	595	......	235
11	......	2,950	......	696	......	743	......	453	......	585	......	235
12	......	......	......	805	......	770	......	792	......	580	......	235
13	......	......	......	823	......	776	......	714	......	575	......	215
14	......	......	......	829	......	898	......	829	......	824	......	235
15	......	......	......	836	......	1,032	......	485	......	2,020	......	235
16	......	......	......	805	......	1,105	......	1,093	......	1,590	......	235
17	......	......	......	784	......	737	......	381	......	1,320	......	235
18	......	......	......	811	......	964	......	692	......	1,117	......	215
19	......	......	......	799	......	782	......	687	......	956	......	235
20	......	1,124	......	272	......	675	......	687	......	817	......	235
21	......	860	......	170	......	805	......	682	......	709	......	235
22	......	810	......	414	......	805	......	676	......	615	......	235
23	......	930	......	330	......	1,113	......	564	......	440	......	235
24	......	342	......	817	......	1,327	......	531	......	274	......	235
25	......	1,493	......	1,052	......	785	......	662	......	235	......	235
26	......	857	......	981	......	1,342	......	635	......	197	......	235
27	......	703	......	866	......	698	......	630	......	163	......	235
28	......	720	......	1,127	......	1,267	......	524	......	163	......	235
29	......	759	......	854	......	656	......	142	......	163	......	235
30	......	1,322	......	972	......	793	......	406	......	163	......	235
31	......	1,443	......	1,444	......	......	......	906	......	......	......	

Table 102.—Monthly Discharge of the Kawishiwi River near Winton, Minnesota.

Month.	Discharge in Second-Feet.				Run-off.
	Maximum.	Minimum	Mean.	Per square mile.	Depth in inches on Drainage Area.
1905.					
June 21-30	2,921	1,082	2,052	1·71	
July	4,131	422	2,470	2·06	2·38
August	3,018	0	1,422	1·18	1·36
September	3,790	0	2,086	1·74	1·94
October	3,426	734	1,493	1·24	1·43
November	1,288	629	1,016	0·847	0·945
December	1,185	880	1,065	0·888	1·02
The period	4,131	0	1,658	1·38	9·08
1906.					
January	856	523	672	0·560	0·646
February	506	360	444	0·370	0·385
March	360	289	326	0·272	0·314
April	2,600	276	904	0·753	0·840
May	3,212	1,682	2,446	2·04	2·35
June	3,327	1,344	2,690	2·24	2·50
July	2,276	455	1,012	0·843	0·972
August	1,275	0	588	0·490	0·565
September	435	263	348	0·290	0·324
October	400	250	310	0·258	0·297
November	998	400	654	0·515	0·608
December	660	360	477	0·398	0·459
The Year	3,327	0	906	0·755	10·26
1907.					
January	345	263	303	0·252	0·290
February	263	200	230	0·192	0·200
March	222	190	204	0·170	0·196
April	951	0	368	0·307	0·342
May	4,760	50	1,572	1·31	1·51
June	5,250	539	3,389	2·82	3·15
The period	5,250	0	1,011	0·822	5·69

Table 102.—Monthly Discharge Records of the Kawishiwi River—Continued. (*Records of the International Joint Commission co-operating with the United States Geological Survey.*)

Month.	Discharge in Second-Feet.				Run-off.
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on Drainage Area.
1912.					
October 14–27	609	105	....	....	....
November 19–30	512	40	....	....	....
December	314	188	227	....	0·22
1913.					
January	186	151	165	....	0·16
February	150	133	137	....	0·12
March	141	127	131	....	0·13
April	1,750	143	520	....	0·49
May	3,190	133	1,930	....	1·88
June	3,380	88	2,290	....	2·16
July	1,790	305	1,060	....	1·03
August	652	120	357	....	0·35
September	816	154	367	....	0·35
October	1,680	262	968	....	0·94
November	1,363	145	806[1]	....	0·73
December	747	428	614	....	0·60
The Year	3,380	88	779	....	8·94
1914.					
January	423	320	364	....	0·35
February	314	239	276	....	0·24
March	247	15	167	....	0·16
April	960	48	241	....	0·23
May	3,973	996	2,414	....	2·35
June	4,475	1,131	2,318[2]	....	1·82
July	2,950	342	1,415[3]	....	1·02
August	1,719	170	789	....	0·77
September	1,342	656	907	....	0·85
October	1,618	142	733	....	0·71
November	2,020	163	645	....	0·61
December	235	197	224	....	0·22
The Year	4,475	15	874	....	9·33

[1] Mean of 29 days. [2] Mean of 25 days. [3] Mean of 23 days.

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CLASSIFIED LISTS OF REPORTS

The Reports published by the Dominion Water Power Branch with the exception of the Annual Reports, have been called Water Resources Papers, and have been numbered 1, 2, etc.

Annual Reports previous to 1913 are included with the Annual Report of the Department of the Interior, and can be secured from the Secretary of the Department.

Annual Report for 1912-13, published 1914. Out of print.

Annual Report for 1913-14, published 1915.

Annual Report for 1914-15. In Press.

WATER RESOURCES PAPER No. 1.—Report of the Railway Belt Hydrographic Survey for 1911-12, by P. A. Carson, B.A., D.L.S., Chief Engineer. Published 1914.

WATER RESOURCES PAPER No. 2.—Report of Bow River Power and Storage Investigations (Bow river west of Calgary,) by M. C. Hendry, B.A.Sc., Chief Engineer in charge of surveys. Published 1914.

WATER RESOURCES PAPER No. 3.—Report on Power and Storage Investigations, Winnipeg river, by J. T. Johnston, B.A.Sc., Chief Hydraulic Engineer, Dominion Water Power Branch. Published 1915.

WATER RESOURCES PAPER No. 4.—Report of the Manitoba Hydrographic Survey to end of year 1914, by M. C. Hendry, B.A.Sc., Chief Engineer. In Press.

WATER RESOURCES PAPER No. 5.—Preliminary Report on the Pasquia Reclamation Project, by T. H. Dunn, C.E., O.L.S., Chief Engineer in charge of Reclamation Survey. Published 1914. Out of print.

WATER RESOURCES PAPER No. 6.—Report on cost of various sources of power for pumping in connection with the South Saskatchewan Water Supply Diversion Project, by H. E. M. Kensit, M.I.E.E. and Mem. Am. Inst. E. E. Mem. Can. Soc. C. E. Published 1914. Out of print.

WATER RESOURCES PAPER No. 7.—Report on the Manitoba Water Powers, by D. L. McLean, S. S. Scovil, and J. T. Johnston, compiled for the Manitoba Public Utilities Commission. Published 1914.

WATER RESOURCES PAPER No. 8.—Report of the British Columbia Hydrographic Survey for 1913, by R. G. Swan, B.A.Sc., Chief Engineer. Published 1915.

WATER RESOURCES PAPER No. 9.—Report of Red River Navigation Surveys, by S. S. Scovil, B.Sc., Assistant Chief Engineer of Manitoba Hydrographic Survey. In course of preparation.

WATER RESOURCES PAPER No. 10.—General Guide for Compilation of Water Power Reports of Dominion Water Power Branch, prepared by J. T. Johnston, B.A.Sc., Chief Hydraulic Engineer. Published 1915. Limited edition.

WATER RESOURCES PAPER No. 11.—Final Report on the Pasquia Reclamation Project, by T. H. Dunn, C.E., O.L.S., Chief Engineer in charge of Reclamation Survey. Published 1915.

WATER RESOURCES PAPER No. 12.—Report on Small Water Powers in Western Canada, and discussion of sources of power for the Farm, by A. M. Beale, B.Sc. Published 1915.

WATER RESOURCES PAPER No. 13.—Report on the Coquitlam-Buntzen Hydro-Electric Development, by G. R. G. Conway, M. Inst. C.E., M. Can. Soc. C.E., Chief Engineer of the British Columbia Electric Railway Company, Limited. In press.

WATER RESOURCES PAPER No. 14.—Report of the British Columbia Hydrographic Survey for 1914 by R. G. Swan, B.A.Sc., Chief Engineer. Published 1915.

WATER RESOURCES PAPER No. 15.—Report on the Water Powers of Alberta and Saskatchewan by C. H. Attwood, O.L.S., Chief Engineer Alberta and Saskatchewan Power Surveys. In course of preparation.

WATER RESOURCES PAPER No. 16.—Water Powers of Canada. A series of five pamphlets in one volume covering the water power situation in Canada prepared for distribution at the Panama-Pacific Exposition, San Francisco, 1915, by G. R. G. Conway, Consulting Engineer, Toronto, Percival H. Mitchell, E.E., Consulting Engineer, Toronto, H. G. Acres, Hydraulic Engineer Hydro-Electric Power Commission Ontario, F. T. Kaelin, Asst. Chief Engineer Shawenegan Power Co., Montreal, Quebec, K. H. Smith, Engineer, Nova Scotia Water Power Commission, Halifax, N.S. Puhlished 1915.

WATER RESOURCES PAPER No. 17.—Canadian Hydraulic Power Development and Electric Power in Canadian Industry, by Charles H. Mitchell, C.E., Consulting Engineer to Dominion Water Power Branch.