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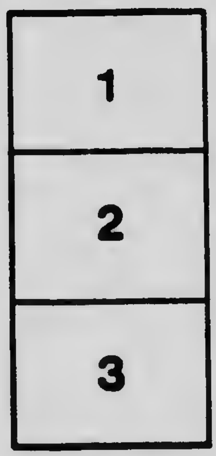

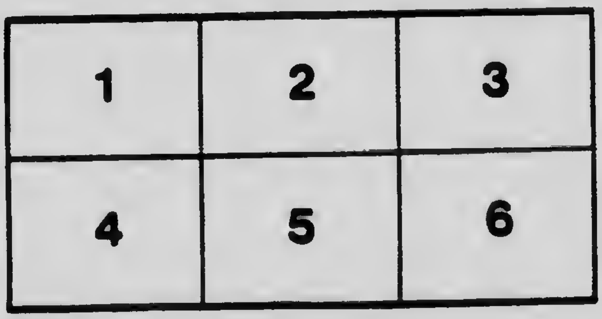

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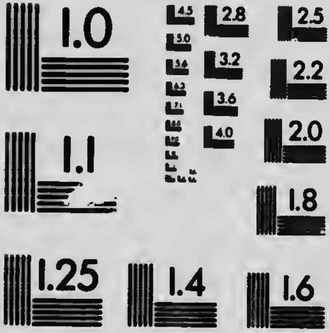

Frontispiece.

Outlet of Bow Lake. Photo by M. C. Hendry.

DEPARTMENT OF THE INTERIOR

WATER POWER BRANCH

J. B. CHALLIES, Superintendent.

WATER RESOURCES PAPER No. 2

REPORT

ON

BOW RIVER POWER AND STORAGE INVESTIGATIONS

SEASONS 1911-12-13

BY

M. C. HENDRY, B.A.Sc.

Prepared under the direction of the Superintendent of Water-Powers.

PRINTED BY ORDER OF PARLIAMENT.

OTTAWA
PRINTED BY J. DE L. TACHÉ, PRINTER TO THE KING'S MOST
EXCELLENT MAJESTY
1914

25e—1915.]

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 of the Bow River Power and Storage Investigations.

Respectfully submitted,

W. J. ROCHE,
Minister of the Interior.

OTTAWA, May 22, 1914.

DEPARTMENT OF THE INTERIOR,
OTTAWA, May 22, 1914.

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

SIR,—I have the honour to submit a report of the Bow River Power and Storage Investigations and to recommend that it be published as Water Resources Paper No. 2 of the Dominion Water Power Branch.

I have the honour to be, sir,

Your obedient servant,

W. W. CORY,
Deputy Minister of the Interior.

WATER POWER BRANCH, OTTAWA, August 29, 1914.

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

SIR:—Conservation of the waters of the Bow River is of the utmost moment for upon it directly depends the agricultural and industrial prosperity of a very large area of southern Alberta. Rising in the high and remote regions of the Rocky Mountains National Park, and, with its many tributaries, furnishing the most interesting and attractive feature of this world-famed scenic park, it emerges from the park only to be harnessed to supply energy for transmission many miles away to the City of Calgary for municipal purposes, street lighting, tramways, and for general commercial and industrial use. After furnishing this hydro-electric energy, the same waters have, by irrigation, converted thousands of acres of otherwise useless land into the most fertile and fruitful tracts within the Province.

At "first blush" it would appear that the two important uses of this water for irrigation, and for power, would result in serious conflict of interest. Fortunately the irrigation requirements occur during high water stages of the river, and storage on its upper waters would make it possible to conserve enough of the flood flow, not required for irrigation, to equalize the low flow during the winter months that may be necessary for power purposes. The present use and distribution, and the future conservation, of the water resources of the Bow river basin, constitute one of the most important problems before the Department of the Interior. In some of its phases this problem has already been solved, while in others it awaits solution, although a beginning has been made, and the lines of practicable progress have been fairly well marked out.

Realizing the importance of the Bow river waters to every phase of the development of the district through which it flows, and of the utmost necessity of having a practicable conservation scheme worked out and put into practice without delay, the Dominion Water Power Branch has made a thorough investigation of the water resources of the Bow River basin above Calgary. These investigations have been carried on to completion with all reasonable thoroughness and every possible despatch under the immediate direction of Mr. M. C. Hendry, B.A. Sc., who has acted throughout with the continuous advice and assistance of Mr. C. H. Mitchell of the Consulting Engineering firm of C. H. and P. H. Mitchell, Toronto. They have been surprisingly gratifying, showing that it is economically feasible to so regulate the flow of the Bow River, by means of storage works in its upper waters, as to warrant the development at six power sites of over 45,000 continuous 24-hour W.H. P., all within 50 miles of the City of Calgary. At the same time it has been shown, that the using of these waters for power purposes above Calgary need not conflict with the consumption of the same water below Calgary for irrigation purposes; rather would the regulation proposed for power purposes be a distinct advantage to the extension of existing irrigation systems to their ultimate capacity, and also insure in the future the instigation of additional irrigation projects.

Owing to the importance of Mr. Hendry's investigations, and of their direct bearing on the industrial development of central Alberta, I would recommend that they be published for general distribution as "Water Resources Paper No. 2" of the Dominion Water Power Branch.

Mr. Hendry's report is submitted for this purpose.

Respectfully submitted,

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

OTTAWA, May 22, 1914.

J. B. CHALLIES, ESQ.,
Superintendent Dominion Water Power Branch,
Department of the Interior,
Ottawa.

SIR,—I beg to submit herewith the manuscript of a report on Power and Storage Investigations on the Bow River west of Calgary.

In submitting this report I wish to acknowledge the loyal and efficient assistance of Mr. C. H. Attwood, Mr. K. H. Smith, and other members of my staff in collecting and arranging data for this report.

I have the honour to be, sir,

Your obedient servant,

M. C. HENDRY,
Chief Engineer.

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PLANS.

SESSIONAL PAPER No. 25e

MAPS AND PLANS—*Continued.*

PLANS—*Continued.*

CHAPTER I.

SUMMARY OF INVESTIGATIONS AND SURVEYS.

INTRODUCTION.

The Bow river is a typical mountain river. West of Calgary, it drains an area of 3,138 square miles, of which that part above the Kananaskis falls, 1,710 square miles in extent, may be considered to lie wholly in the Rocky mountains. It has a very steep slope, and in several places falls occur. The head-waters of the river lie at an elevation of about 6,500 feet above sea-level. The flow of the river is typical of all mountain streams, subject to sudden variation and greatly influenced by conditions of temperature. During the winter months the flow is much reduced, but in the hot summer months of June and July the floods occur and the variation between high and low water is very great. While no direct gaugings are available of flood discharges, it has been computed from levels taken by the Canadian Pacific Railway Company at Bow bridge and Kananaskis bridge, that, at Kananaskis falls, just below the mouth of Kananaskis river, flood of 45,000 c.f.s. has occurred. A low-water discharge of 550 c.f.s. has been recorded at the same point.

What may be termed the power-producing section of the river is a stretch about 30 miles long, well within feasible transmission distance of the logical power market, Calgary. The growth of that city is phenomenal, and as it is the distribution centre for a large district, many small manufactories have located there; others no doubt would follow the advent of cheap power. The city has control of its public utilities, that is street railway, waterworks, electric light, etc., so that it is itself in the market for power in rapidly increasing amounts. In addition to the city, there are other possible customers,—the Canadian Pacific Railway Company have recently erected large car shops near the city; there are also two cement plants, and some plants handling clay products.

Departmental Policy.

The constant growing demand for cheap power for municipal and manufacturing purposes has made the question of water-power development in Western Canada one of vital importance. Fortunately a well-considered and cautious policy of water-power administration has been determined upon, and regulations put into force which afford every reasonable protection to the public in the way of rentals, periodic revisions, control of rates, limited grants, etc., and at the same time foster legitimate private initiative and afford reasonable financial rewards for private skill and efficiency. The Water-power Regulations are set out in full in Appendix V. So far as the administration of the regulations is concerned, it is the policy of the department to afford every possible assistance to the development of water-powers which have any reasonable assurance of economic utilization. In fact, the practice of the department is to carry on sufficient investigations by way of field surveys, etc., as will make it possible for the department to prove the economic features of power possibilities that might be expected to be possible of commercial development within a reasonable time. Such investigations have been carried on throughout the West, but more particularly on those rivers where there are several power sites all within range of immediate use.

It is considered that such investigations should precede 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. Such investigation, supervision and control by departmental 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.

Necessity for Investigation.

The Bow river was the first of the Rocky Mountain streams to be investigated by the Department of the Interior as to its power-producing and storage possibilities. The department was called upon to deal with certain applications for power rights on the Bow and on the Elbow rivers; before these could be dealt with in a satisfactory way, it was necessary to have definite and independent information of the situation; this was especially necessary on account of there being overlapping or conflict between several of the applications, as on the Elbow river and on the Bow river at Kananaskis falls.

The growing demand for cheap power, due to the rapid development of the district of which Calgary is the centre, also necessitated steps being taken toward gathering general information on the subject.

It has been shown above that the fluctuation in the flow of the river is great; in order, therefore, that the river might be improved from a power-producing standpoint, some method of regulation and control was necessary. Under natural conditions, the amount of power produced by the river during the six months' period of low flow, would be but a small part of that amount capable of being produced during the remainder of the year, and it was with a view to gathering information in regard to these questions that the investigations embodied in this report were instituted.

Organization and Scope of Investigation.

In April, 1911, the work in the district was organized. The field work was carried on under my immediate direction as Chief Engineer, with the general advice and assistance of Mr. C. H. Mitchell, C.E., M. Inst. C.E.; M. Can. Soc. C.E.; of the Consulting Engineering firm of C.H. & P.H. Mitchell, Toronto, and one of the Board of Consulting Engineers to the Dominion Government, in connection with water-power matters in Western Canada. The work to be undertaken was comprehensive in its scope, calling for an investigation into the power and storage possibilities on the Elbow river, and the Bow river west of Calgary and including all its tributaries. Consequently a reconnaissance of the whole basin was made with surveys of all possible sites and storage basins. In addition, the inspection and approval of plants existing or building in the district was included in the work. Owing to the lack of run-off data at critical points in the river and its tributaries, additional gauging stations were established; this was done by the Irrigation Branch, at the instance and expense of the Water Power Branch. Prior to the work of the Water Power Branch, most of the work of stream gauging had been carried on only during the open-water season, and little data was available as to the flow during the winter months. The former stations, and those established at this time for these investigations were:—

SESSIONAL PAPER No. 25e

Metering Stations—Table No. I.

Stations in existence prior to 1911—
1. Elbow river at Calgary.
2. Bow river at Calgary.
3. Jumping Pound.
4. Bow river at Morley.
5. Devil's creek at Minnewanka.
6. Spray river at Banff.
7. Bow river at Banff.
8. Bow river at Laggan.

Stations newly established.
1. Pipestone creek.
2. Cascade creek at Bankhead.
3. Kananaskis river.
4. Ghost river.

The work instituted in 1911 was continued during 1912, and completed in that year.

The following is a résumé of the work accomplished in the two seasons:—

Reconnaissance.

The reconnaissance of the following was made by Mr. C. H. Mitchell and the writer: Elbow river, Kananaskis river and Kananaskis lakes, Spray river and tributaries and the Spray lakes, Bow lake, Hector lake, Pipestone creek, Johnston creek. Redearth creek, Brewster creek, Baker creek, Forty mile creek, and Ghost river were visited by the writer alone. A reconnaissance, preliminary to the survey on the power-producing portion of the Bow river was also made. The different creeks and lakes examined in these trips were either eliminated as being unsuitable for power or storage purposes, or accepted as feasible and some general scheme for development settled on. In the latter case, a field party was then put on the ground to carry out the investigations in greater or less details.

Surveys.

Surveys were made of the following: Elbow river, between the east boundary oı section 14, township 22, range 6, west of the 5th meridian and the north boundary of section 29, township 21, range 6, west of the 5th meridian, particular attention being given to the topography in those portions in section 4, 16, 15, and part of 14, township 22, range 6. During the seasons of 1911-12, a topographical survey was made of about 30 miles of the Bow river from the Canadian Pacific Railway bridge above Kananaskis falls down, particular attention being given to the several power sites. Also topographical surveys were made of Bow lake, lake Minnewanka and the basin of the Spray lakes, with a view to the creation of storage.

Results of Surveys.

The results of these surveys are summarized in the following tables 2 and 3:—

Storage Basins—Table No. 2.

Basin.	Capacity.
Bow lake	27,400 acre-feet.
Spray lake	171,000 "
Lake Minnewanka	44,700 " (created).
" auxiliary	14,200 "
Total above Calgary on Bow river	243,100 "
" " with auxiliary	257,300 "
Elbow river	23,000 "
Total above Calgary, including auxiliary at Minnewanka	280,300 "

Power Sites—Table No. 3.

Site.	Pondage above Dam, in acres.	Head in feet.
Bow river—		
1. Kananaskis falls	122·25	70 (building).
2. Horseshoe falls	98·47	70 (operating).
3. Bow Fort	205·19	66
4. Mission	353·09	47
5. Ghost	786·10	50
6. Radnor	241·50	44
Cascade river—		
At Minnewanka Dam	... .	64
Elbow river—		
Canyon development	....	215

Results of Storage Investigation.

The effect of storage on the river can best be noted at two points, one of which may be taken as at the Calgary Power Company's plant, at the Horseshoe falls, and the other below the mouth of the Elbow river. At the former site, the effect of all the storage on the Bow above Calgary is noted; and at the second, the effect of the storage on the Bow and Elbow combined. The mean flow for the low-water months, as recorded at Horseshoe falls, has been found to be as low as 745 c.f.s.; by means of the storage that has been, and may still be created, it is anticipated that this can be raised to at least 1,500 second-feet. Below the mouth of the Ghost, this would be increased to 1,600 c.f.s. At Calgary, below the mouth of the Elbow, the storage on that stream becomes effective, and it is expected that a flow approaching 2,000 c.f.s. may be obtained.

The effect of storage upon the power output of the river over that due to the natural flow, may be seen by a glance at the following tables, Nos. 4 and 5:—

Power Output of Bow River—Table No. 4.

Power site.	Natural Flow continuous Wheel H.-P.	Regulated Flow continuous Wheel H.-P.
1. Kananaskis falls	3,820	9,545
2. Horseshoe falls	3,820	9,545
3. Bow Fort	3,600	9,000
4. Mission	2,565	6,410
5. Ghost	3,780	7,275
6. Radnor	2,800	6,400
Total	19,785	48,175

Giving an increased continuous output of 28,390 wheel horse-power.

SUMMARY OF EFFECT OF THE STORAGE IN THE BOW RIVER BASIN UPON DEVELOPED AND UNDEVELOPEL ATER-POWERS.
TABLE NO. 5.

Proposed Site or Plant.	Natural Flow.								Regulated Flow.						
	Elev. of Crest of Dam.	Working Head. in feet.	Rated H.P. of Turbines installed or proposed.	Min. Mean Monthly Flow in C.F.S.	Available H.P. with Flow in Col. 5.	H.P. Yrs. Available in Average year with wheel Capacity in Col. 4.	Possible Turbine Output 24 hr. power 60% of Time.	H.P. Yrs. Available from water using wheel Capacity in Col. 8.	Min. Regulated Flow in C.F.S.	H.P. Yrs. added within proposed capacity of wheels.	H.P. Yrs. available from Regulated Flow as in Col. 10	Possible Turbine Output 24 hr. Power 60% of Time.	H.P. Yrs. Available from water with Turbine Capacity as in Col. 13.	Continuous H.P. available with Flow in Col. 10.	H.P. Yrs. added from Storage with Flow as in Col. 10.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
DEVELOPED.															
1. Kananaskis	4,155	70'	11,600	720	4,580	8,887	7,400	6,643	1,500	2,138	7,847	11,110	10,754	9,545	1,698
2. Horseshoe Falls	4,082	70'	19,500	720	4,580	12,087	7,400	6,643	1,500	2,171	7,847	11,110	10,754	9,545	1,698
UNDEVELOPED.															
3. Bow Fort	4,010	66'	*13,200	720	4,320	9,421	6,950	6,262	1,500	2,053	7,407	10,420	10,089	9,000	1,593
4. Mission	3,865	47'	*10,500	720	3,760	7,161	4,930	4,450	1,[illegible]	1,493	5,277	7,510	7,260	6,410	1,132
5. Ghost	3,812·5	50'	*10,500	820	3,730	7,669	5,710	5,194	1,600	1,544	6,085	8,420	8,150	7,275	1,188
6. Radnor	3,760	44'	*10,500	820	3,280	7,207	5,345	4,589	1,600	1,375	5,345	7,450	7,210	6,400	1,055

*These capacities provide for an over-development of from 44 per cent to 64 per cent, and are taken arbitrarily; also they provide for considerable load fluctuations.

Cascade River.—
Minnewanka dam..........................1,165 wheel horse-power.
Elbow River.—
Canyon site..............................3,900 " "

SUMMARY.

In table No. 5, a summary is shown of the effects of storage upon the developed and undeveloped water-powers within the power-producing portions of the Bow river:*

(NOTE —This table is compiled from diagrams on plates Nos. 20, 21, 22, 23, and 24, and shows the effect of storage upon the river for different assumptions. On plate No. 7 is a profile of the power section of the river. It shows the relation of the head and tail-waters of the different plants to one another.)

ESTIMATES OF COST.

Estimates of cost have been prepared that provide for the complete development of the three storage basins, including one already built—four additional power plants and new duplicate transmission lines sufficient to carry the total output from the four plants, together with adequate receiving equipment at Calgary. While these estimates are preliminary only, and are for the purposes of obtaining a comparison of costs and of arriving at the commercial possibilities of the project as a whole, they have been conservatively computed and it is thought they are ample to cover all contingencies based upon present day labour and market conditions. These are summarized in tables Nos. 6 and 7.

STORAGE DEVELOPMENT.—TABLE NO. 6.

Site.	Capacity Acre-feet.	Estimated Cost.	Cost per Acre-foot.
		$	$ cts.
Bow lake	27,400	105,000	3·83
Spray lake	171,000	514,000	2·98
Minnewanka	44,700	145,000	3·24
" (with auxiliary)	58,900	145,000	2·46
Elbow river	23,000	200,000	8·70

POWER DEVELOPMENTS.—TABLE NO. 7.

Site.	Head in feet.	Continuous output wheel horse-power.	Estimated cost of plant, including cost of storage.	Estimated cost of power per k.w.hr. delivered in Calgary on 50 per cent load factor basis, including storage, transmission lines, etc.
			$	Cts.
Bow fort	66	9,000	924,970	0·49
Mission	47	6,410	851,100	0·60
Ghost	50	7,275	892,500	0·57
Radnor	44	6,400	807,460	0·59

NOTE—With reference to the foregoing it may be of interest to note that in April, 1913, a comprehensive report was made for the City of Calgary, wherein it was shown that electric power generated by a steam coal-fired plant and sold on a basis of a 50% load factor, would cost, delivered at generator terminals without transformation or transmission, from 0·85 cent down to 0·74 cent per k.w. hour as the size of the plant increased from 5,000 k.w. to 45,000 k.w. capacity.

SIMILAR INVESTIGATIONS.

Precedents are not wanting for work of the description carried out by the Water Power Branch, either in Canada or in foreign countries. The most extensive work of this kind in Canada has been carried on by the Hydro-Electric Commission of Ontario. In the United States similar work has been done by several of the states in conjunction with the United States Geological Survey; among those that should be mentioned, in which work along the lines of water-power investigation have been carried on are: The states of New York, Maine, Minnesota and Washington.

ONTARIO.

In Ontario, the Hydro-Electric Commission has investigated a large number of possible water-powers in various parts of the province, and reported upon them. For a number of these, estimates of the cost of development were made in some detail, and are to be found in the reports issued by them at various times. There is a difference, however, between the object of the investigation made by the commission and the investigations here presented; the former were carried on with the object of ascertaining what could be done in the way of power production by the commission, whereas the investigations carried on by the Water Power Branch have been with the object of supplying information to the public on the subject, and procuring information upon which the best administration of the water-powers could be based.

NEW YORK STATE.

The work of the New York State Conservation Commission, which supersedes that formerly carried on by the Water Supply Commission, is rather wider in its scope than that of the Water Power Branch. The work carried on by the Water Supply Commission is now under the Division of Inland Waters of the New York State Conservation Commission; this work is outlined in their reports as follows:—

1. Water storage and conservation for power purposes.
2. Hydraulic development.
3. River improvement.
4. Drainage.
5. Water supply and sewerage.
6. Inspection and supervision of hydraulic structures.

It will be seen from the above that the work is very similar in many ways to that of the Water Power Branch in Canada. With regard to the different sites investigated by them, preliminary plans and estimates have been prepared as has been done in this report.

STATE OF MAINE.

The state of Maine Water Storage Commission was established in 1909 under the laws of the state, and consolidated with the state Survey Commission in 1911. An extract from section 5 of the Act reads as follows:—

> "The commission shall also report..................on the present development of the water-powers in the state, with reference to the general plan proposed, so that the legislature may have before it a comprehensive summary of the possibilities that lie in the development of the water-powers in the state as a natural resource, and the necessary steps that should be taken by the state to further increase and conserve them."

According to the second annual report, 1912, considerable progress has been made. This report contains the results of investigations on several rivers of the state, and the conclusions reached; also the records of stream flow and precipitation. The question of power rates is dealt with, a list being published of the principal power producers of the state together with the output of the different plants, the rates charged, etc.; a valuable article on the cost of power by Mr. Seth A. Moulton, is also included.

In connection with the records of stream flow and precipitation it might be noted that, in all the states where investigations of water storage and power are being carried on an arrangement is entered into between the state and the U.S. Geological Survey whereby stream gaugings, etc., are made under the direction of the latter, advantage being taken of the experience and highly efficient organization of that branch of the public service.

State of Washington.

The work being carried on by the state of Washington in conjunction with the United States Geological Survey, is under the direction of the state Geological Board. It is similar to that being done by the Water Power Branch, and the results of the investigations to date are set forth in two papers, part I and part II, entitled "Water Powers of the Cascade Range". The field work carried on has been stream gauging in conjunction with the United States Geological Survey, and the surveys of the rivers and lakes to determine the possibilities of storage and power; these surveys have been more in the nature of a reconnaissance than in detail, the purpose being, to quote from the report, "to show the power resources of the basins described, and to indicate in a general way the relative value of the individual power privileges."

Other Examples.

In this connection it might also be mentioned that there are certain rivers that have been developed by private interests. One notable example of this is in Massachusetts, on the Deerfield river (see *Engineering Record*, February 1-8-15, 1913). This project is mentioned on account of its close resemblance in many respects to the Bow river project as to head, discharge, and storage development; the plants operating under the lower heads, namely, at Scott's bridge, Shelbourne falls, Bardwell's bridge, upper and lower plants, are practically the same as those on the Bow, built and projected as described in this report, and the flow of the stream is of nearly the same volume, so that the power output of the plants is approximately the same as for those proposed on the Bow river.

To compare the two projects, a partial list is here given of the plants on the Deerfield river taken from the *Engineering Record*, February 1, 1913. See Table No. 8.

Plants on the Deerfield River, Mass., U.S.A.—Table No. 8.

Plant.	Average net head.	Normal water sec.-ft.	Installed capacity K.W.	Poundage 4-7 flash board Ac.-ft.
Scott's Bridge, Plant 4	64	1,350	6,000	400
Shelbourne's Falls, Plant 3	64	1,350	6,000	160
Bardwell's Bridge, Upper Plant 2	58	1,480	6,000	400
Bardwell's Bridge, Lower Plant	40	1,500	4,000	
Stillwater Bridge	40	1,500	4,000	
Total			26,000	

Note.—There are other plants in this system but they are omitted, being of higher heads.

The storage in this project is developed at two points, one basin having a capacity of 2,500 million cubic feet and the other 4,500 million cubic feet, or a total of approximately 161,000 acre-feet, 10,000 acre-feet less than the capacity of the Spray lake basin herein proposed.

Recommendations.

In a letter published as an appendix to this report, Mr. C. H. Mitchell, C.E., consulting engineer on these investigations, has made certain recommendations in regard to the further carrying out of the work instituted; also as to the operation and control of the works proposed; a summary of these recommendations are here given:—

1. That the investigations on the Bow river basin be continued for the purpose of making the data more complete and useful in the subsequent operation of the project.
2. That the Government undertake the further construction of storage reservoirs and regulating works and provide for the repayment of their cost by means of annual rentals charged to users of water.
3. That a scheme for operating these storage reservoirs and for regulating and controlling the discharge of the river be adopted and put into practical working effect by the Government, and that the annual cost of same be charged to the users in the same manner as the original cost.
4. That as soon as this project is put into working effect, or sooner, the existing storage works at lake Minnewanka should be acquired and their regulation and operation be taken over by the Government according to the terms of the existing agreement with the power company.

Acknowledgments.

Acknowledgment is here made for information placed at the disposal of the branch and embodied in the report.

To Mr. F. H. Peters, Commissioner of Irrigation, also to Mr. P. M. Sauder, Chief Hydrographer of the Irrigation Branch, Department of the Interior, for stream flow and other data for the district.

To the Calgary Power Company and its officials for hearty co-operation and for information relative to the discharge of the Bow river, plans, cost data, etc.

To the city of Calgary for information bearing upon the power market.

Acknowledgment is also made for meteorological records and data made use of in this report and placed at the disposal of the Water Power Branch by the Meteorological Service, Department of Marine and Fisheries.

In compiling the report, the works of many authorities have been consulted; these are acknowledged and references given where quoted.

CHAPTER II.

BOW RIVER.

General.

The portion of the Bow river dealt with in this report may be generally described as that part lying west of Calgary, and including Elbow river which forms a tributary of the Bow and joins the latter stream within the city limits of Calgary.

The Bow river has its head-waters on the main continental divide and flows in a general south-easterly direction, roughly paralleling the summit of the mountain ranges for the first hundred miles of its course. On account of this, the main stream and many of its tributaries have their sources at high altitudes and are, to a very great extent, glacier fed. (See reproduction pages 1 and 12.)

Fall.

From the head-waters to Kananaskis falls, at the confluence of the Kananaskis and Bow rivers, a distance of about 90 miles, the fall is about 2750 feet. From Kananaskis falls to Calgary, at the junction with the Elbow river, a distance of about 55 miles, the drop is 720 feet.

Drainage Area.

The drainage area of the Bow river above Calgary is 3,138 square miles, exclusive of the area drained by the Elbow river. Of this area, 1,710 square miles lie above Kananaskis falls and may be considered as lying entirely within the mountains. The remaining 1,428 square miles are in the foot-hills, and this section extends as far east as Calgary.

Discharge.

The discharge of the Bow river varies greatly from season to season. The flow during the high-water period, which occurs during the summer months, being many times that of the low-water period, the latter occurring during the winter months. The great variation is the main drawback to economical power development on the river.

Records of the discharge of the river at various points have been kept more or less continuously since 1909. From these a diagram has been drawn (see Plate No. I.), which shows the discharge of the river as recorded at Banff, Horseshoe falls and Calgary.

Topographical Features.

From Bow lake, the source of the river, down to Laggan, the river flows for the most part through a wide valley. In this section the banks of the stream are low, and the flats themselves are in many places very swampy, so much so that, in any but very dry seasons, it is necessary to keep to the high ground along the shoulder of the mountains when traversing the valley.

Below Laggan, as far as Kananaskis falls, the valley traversed is wide, flat, and covered with gravel; the stream is tortuous in its course, the banks being low and dry. In two or three places in the main valley above Banff, small lakes occur, probably formed by the damming off of part of the old river course by ear

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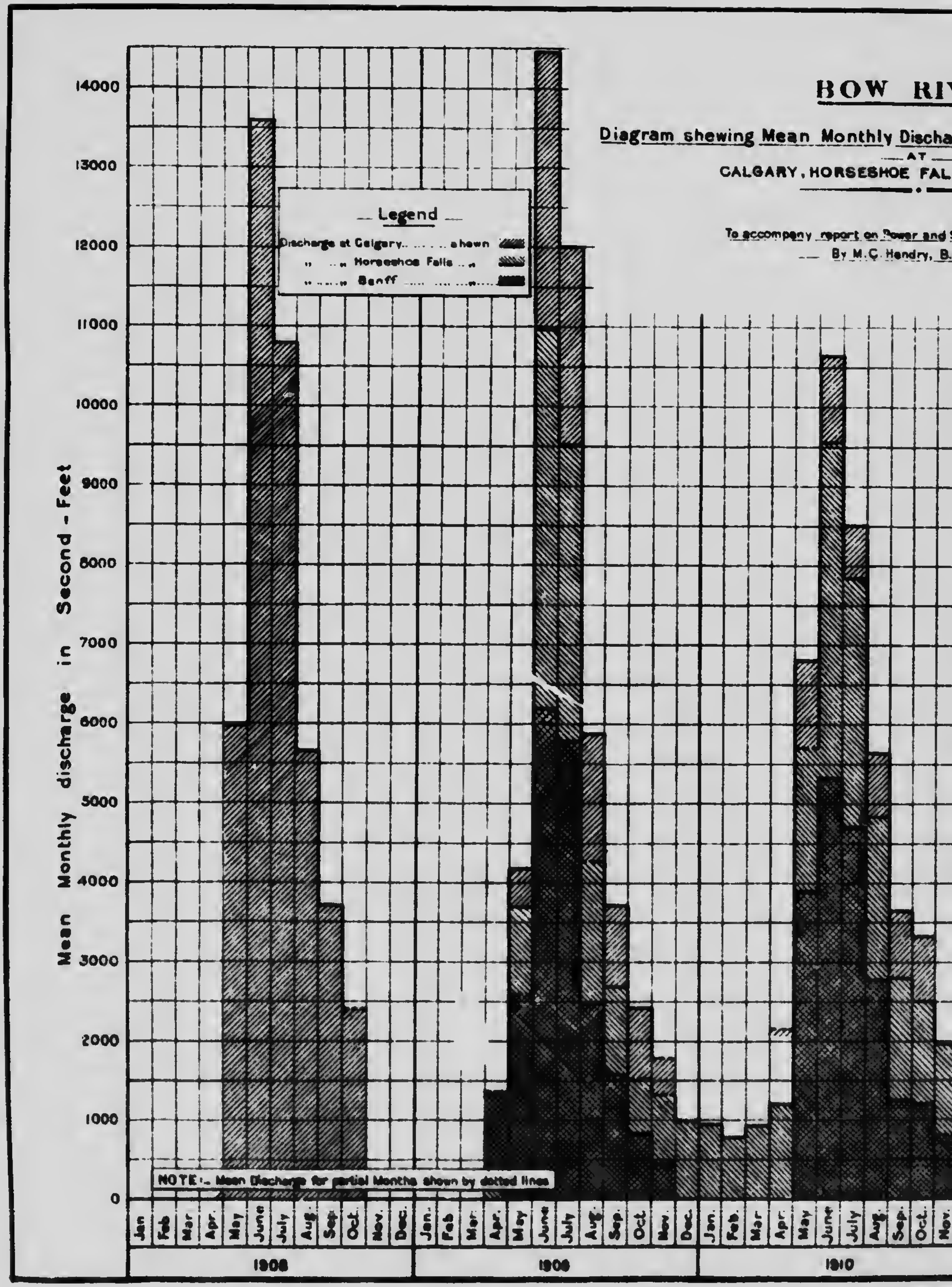

BOW RI
Diagram shewing Mean Monthly Discha
AT
CALGARY, HORSESHOE FAL
To accompany report on Power and
By M.C. Hendry, B.
Legend
Discharge at Calgary .... shewn
" " Horseshoe Falls " "
" " Banff " "
NOTE :- Mean Discharge for partial Months shown by dotted lines
Mean Monthly discharge in Second - Feet
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Jan. Feb. Mar. Apr. May June July Aug. Sep. Oct. Nov. Dec.
1908
1909
1910

PLATE I


W RIVER
hly Discharge from Jan. 1908 to Dec. 1912
AT
SHOE FALLS, AND BANFF
n Power and Storage Investigation
C. Hendry, B.A.Sc.
C.H. Mitchell Consulting Engineer
M.C. Hendry Chief Engineer
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Mean Monthly discharge in Second - Feet
Aug. Sep. Oct. Nov. Dec.
Jan. Feb. Mar. Apr. May June July Aug. Sep. Oct. Nov. Dec.
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1911
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material carried down from the surrounding mountains. Below Banff, near Exshaw, the river widens out and covers the greater part of the valley.

At Kananaskis falls an abrupt change in the topography of the country takes place; this, it may be said, is due to the fact that the river leaves the mountains proper here, and flows out into the foot-hills. These conditions may be said to continue as far as Calgary.

Divisions of the River.

For purposes of description, the part of the river lying above Calgary will be divided into two parts, exclusive of the Elbow river, which will be dealt with separately. The upper part of the river lying above Kananaskis falls will be referred to as the storage section of the river, while that part lying below Kananaskis falls and as far down as the city of Calgary will be referred to as the power-producing section.

Power Section of the River.

From Kananaskis falls nearly to Calgary, the river flows through a wide valley for long stretches; the river proper is confined, however, to its channel by steep banks that at different points are rocky cliffs of considerable height, running as high as from 100 to 150 feet. Generally these cut banks have long sloping banks opposite to them, but in places the river channel is canyon-like for short stretches, lending itself to power development and hence the designation.

This topography is generally typical of the river, from Kananaskis falls to Calgary.

Storage Section of the River.

The storage section of the river, a stretch of approximately 90 miles in length, lies to the west of Kananaskis falls, and entirely in the mountains. The Bow river rises at an altitude of 6,860 feet above mean sea-level; Bow lake, which is practically its source, lies at an altitude of 6,420 feet, and offers the first and highest site for storage in the Bow basin. About 12 miles below Bow lake, Hector lake, which is at an elevation of 5,700 feet, empties into the Bow. (See reproduction page 14.).

From Hector lake to a point near Laggan, a distance of 15 miles, the river falls about 650 feet, or about 43 feet per mile. About 2 miles above Laggan, it is joined by Bath creek from the west, and just below Laggan, by the Pipestone creek from the north. Between the outlet of Hector lake and Bath creek, a number of small streams join the Bow, but on account of the smallness of their discharge during cold weather, they are not worthy of notice.

Between Laggan and Banff, a distance of 35 miles, the river falls 540 feet, approximately 16 feet per mile. The river valley is very wide in this section, the banks of the river low and the stream swift-flowing; there are no distinct drops, what is practically a continual swift exists between the two points. In this stretch the volume of the river is augmented on the south side by the waters of the Chalet creek, the outflow of Moraine lake, and the waters of Vermilion, Redearth, and Brewster creeks; there are also many others, which are too small for notice as they have no discharge during the low water or winter season. On the north side there are several creeks of importance—Pipestone, Baker, Johnson, and Fortymile being the largest. All of these creeks are short, and rise at considerable elevations; those entering from the south side commence on the main divide, and have their source, for the most part, in the glaciers to be found along the summit of the mountain range. (See reproduction page 12.) The creeks entering from the north are longer, and their slopes are not so steep, although their sources are at considerable elevations, ranging from

7,500 to over 8,000 feet above mean sea-level. These streams are not fed by glaciers to the same extent as those entering from the south, but derive their flow mostly from the yearly fall of snow which is melted during the hot summer months: their discharge is therefore greatest during hot weather, and is greatly effected by the temperature conditions.

Crow Foot Glacier. Photo by M. C. Hendry.

Bow Glacier. Photo by M. C. Hendry.

From Banff to Kananaskis falls the nature of the topography is not materially changed, except that the mountains are generally lower, the valley is wider and the river more meandering. Between these two points the fall is 380 feet in a distance of 30 miles, about 13 feet per mile, and some of this occurs as a direct fall at the Spray falls in Banff, at the beginning of the section. Three streams of importance add their waters to those of the Bow in this stretch of river: the Spray, entering from the south at Banff, just below the Spray falls; the Cascade, which also forms the outlet of lake Minnewanka, enters from the north, about 4 miles below the mouth of the Spray; the Kananaskis, joining the main stream from the south, just above the falls of the same name.

The important streams contributing their waters to the Bow river will be dealt with in greater detail in another part of the report, merely their location relative to the main river being given here.

Lakes of the Storage Section.

Nearly all the streams flowing into the Bow river have, at or near their source, a lake of greater or less size. Those belonging to the first class are Bow and Hector lakes, already mentioned; lake Minnewanka, Spray lakes and Kananaskis lakes, the last two forming part of the water system of the same name. Amongst the other lakes belonging to this basin that might be mentioned is lake Louise, its outlet is Chalet creek; this lake is famed for its beauty the world over. Then there are Ptarmigan and Baker lakes at the head-waters of Baker creek, also Redoubt lake on the same stream; Moraine lake, another lake of great beauty in the valley of the Ten Peaks, which empties into the Bow by way of a stream of the same name; Boom lake, at the head of Vermilion creek, and Shadow lake forming one of the sources of Redearth creek. These lakes may be termed storage basins, and have the effect of regulating, to a considerable extent, the streams to which they belong.

Stream Beds of Storage Section.

The mountain streams in this district all have the same characteristic bed. In very few instances does the river flow over bare rock, and then only for very short lengths of the stream; generally speaking, this condition is to be met with upon the tributaries and only in places where the stream passes through a canyon. With these exceptions the river and stream bottoms may be described as being composed of gravel and detritus, which overlies the rocky bed of the streams to a depth of many feet. In some places the bed of the river is in the nature of a large gravel flat where, during the low water period, the river will generally follow a number of small channels; these channels are continually changing; during the high-water period the entire flat may be covered.

The material forming the river bed is transported from point to point during the high-water periods, and deposited in pockets behind the rocky ridges extending across its path, as bars and shoals. The greater part of the main river channel has been formed in this way and also the channels of the tributaries. In many places the whole valley has become filled for a width of several hundred yards, and on the Bow river these are, in places, of very considerable area. (See reproduction page 14.)

Underflow.

The nature of the river beds, formed as they are by gravel and detritus overlying bedrock is very favourable to underflow. There is no doubt that in these mountain streams, the underflow forms a very considerable portion of the natural discharge of the river, but the relation which it bears to the surface flow must necessarily vary, and will depend to a large extent upon the slope of the stream and the depth to which the bedrock is covered by the porous material forming the stream bed.

Photo by M. C. Hendry.

Bow River below Hector Lake.

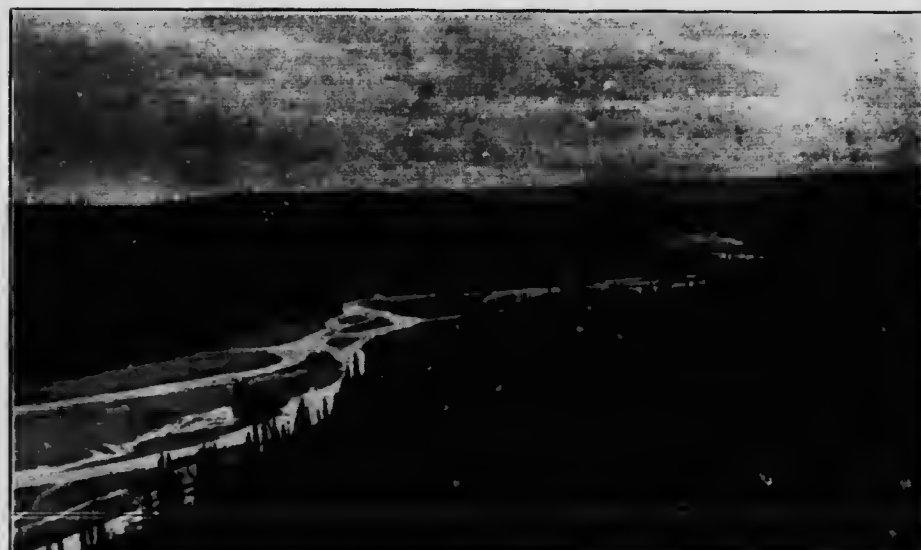

Photo by M. C. Hendry.

Ghost River Flats.

During the high-water period the underflow is relatively small, but during the low-water period, which corresponds to the winter season, the underflow may be expected to form a very large proportion of the discharge, and in the smaller streams there is no doubt that at times it forms the total flow. This underflow has a very considerable effect upon the results of gaugings made in the streams, causing results to be obtained which do not truly represent conditions.

CHAPTER III.

ICE.

One of the problems which confronts the engineer in the design of a water-power development in Canada is the method to be adopted for eliminating or minimizing the effect of ice upon plant operation and power production. The effect of the ice upon the present plants in operation upon the Bow river is not a direct one; so far no great trouble has been experienced in operating the plant due to ice blocking the water entrances, nevertheless the presence of ice in the river has a marked effect upon the power production, and it cannot be overlooked in the study of any future development.

Before looking into the effect of ice upon the operation of a plant, it will be well to examine the formation of the ice itself, and by this means aim at a possible method of dealing with the question.

There are three kinds of ice which, owing to their effect upon the operation of water-power plants, are of interest to the engineer; these are,—board or sheet ice, [illegible] ice and anchor ice.

SHEET ICE.

Sheet ice is that kind of ice which is formed upon the surface of lakes, smooth-flowing rivers, ponds, etc. The process of formation is an interesting one, and begins with the arrival of cold weather. As the season advances, the water on the surface gives up its heat by surface radiation, convection currents are set up, the cold surface water falls and the warmer water below rises; this in turn gives up its heat; by a continuation of this process, the temperature of the whole body of water is gradually lowered until it reaches 39° F.; at that temperature convection ceases, and the water on the surface is cooled down until freezing point, 32° F., is reached. The first indication of the formation of ice is the presence of long needle-shaped crystals on the surface, these rapidly increase in number and size until finally the whole surface is covered; this surface layer becomes more compact, and the ice increases in thickness, as the underlying water gives up its heat by conduction through the ice; the rate of growth diminishes, however, as the thickness of the sheet increases.

When the ice sheet is once formed, radiation to a very great extent ceases; this is due to the fact that the ice is seldom clear, and is generally snow covered and the heat rays are unable to penetrate under such conditions; if the ice was clear and solid, the heat rays could then penetrate, and the loss of heat from the water below would go on at a much more rapid rate, and consequently the growth of ice would be more rapid.

The presence of any sheet ice in a river immediately above a power plant has a beneficial effect upon its operation rather than the reverse; the reason for this will be understood after the subject of frazil and anchor ice has been dealt with.

FRAZIL ICE.

Frazil ice, known also as "slush ice," is perhaps the ice formation which has the most serious effects upon water-power operations. It is always formed in the open channels where the current is too swift or turbulent to allow the formation of sheet ice, and its formation is dependent upon disturbance or agitation, consequently swift turbulent streams are very prolific in its production; it occurs in needles, the fineness of which are due to the amount of agitation; in such places as rapids, and at the foot of falls, these needles are very fine, but they increase in size and thickness where the flow is less rapid and disturbed. Frazil ice is always surface formed, but the ice crystals rapidly become distributed throughout the whole body of water; this gives rise to the saying that the water is "thick." This condition occurs only during a period of extreme cold, combined with great surface agitation, due to rapids in the river, or wind; the direction of the wind relative to the flow of the river has a varying effect on production of frazil, a wind blowing upstream produces more frazil than one blowing downstream, on account of increased surface agitation.

The conditions that make for the greatest production of frazil ice are a dull stormy day, with wind upstream; a great amount of frazil may be produced upon a clear cold night with wind, but on a clear cold day with wind there is not so great a quantity formed, due to the absorption of heat from the sun's rays at the water surface. Professor H. T. Barnes, in his book on "Ice Formation" says that: (1) "A stretch of open water makes a very much greater quantity of ice in the form of frazil crystals than could be produced as a surface sheet, if the water were sufficiently quiet to allow such to grow." It is this production of frazil which gives rise to so much trouble, the stream becoming blocked with the mass. Where an ice sheet exists, conditions are often aggravated, the frazil blocking the waterway underneath, at times causing complete stoppage of flow.

Anchor Ice.

Anchor ice, "ground ice," the German name "Grundeis" and the French-Canadian term "moutonne" are among the many names given to this particular form of ice. As this list of names would indicate, it has attracted very widespread attention, and a number of scientists have published papers in which its formation has been discussed. The name "anchor ice" perhaps best describes it, and is the one by which it is most widely known in this country.

The peculiar feature which gives it this name is the fact that it is formed upon the bottom of the rivers or streams. Many theories as to the reason of the formation of ice upon the bottom have been advanced. That as set forth in a paper by Rev. Dr. Farquharson, which he published in 1835 and 1841, and quoted by Dr. Barnes in his work[2] is generally accepted as the correct one. He attributes the formation of anchor ice to the radiation of heat from the surface of the stream's bed.

It is remarked that this cooling by radiation, and consequent formation of anchor ice, occurs only in streams whose beds are composed of gravel, stones and boulders, but not in clay or mud-bottomed streams; also that the formation of the ice is greatest on the rocks and stones of dark colour.

The formation of anchor ice is most rapid during a clear, cold night (conditions which are favourable to rapid radiation). On a clear, cold day, the sun's rays affect the formation; in fact, it is universally noted that on the appearance of the sun in the morning, the ice becomes loosened from the botton and rises to the surface; its appearance when floating has given rise to the French-Canadian term, "moutonne," on account of its resemblance to the backs of white sheep.

It has been noted in connection with anchor ice, that its formation does not occur under cover; a bridge spanning a stream retards radiation and prevents its formation, and it is seldom found where the stream is covered with an ice sheet.

(1) Page 105, "Ice Formation," by Prof. H. T. Barnes.
(2) Page 108, "Ice Formation," by Prof. H. T. Barnes.

The names frazil and anchor ice are often confused and are frequently used as being interchangeable; the term "anchor ice" being used to designate ice found attached to the bottom, regardless of the method of formation.

Professor Barnes says that:[1] "In a shallow, smooth-flowing river, we are more likely to have anchor ice formed in excess, whereas in a deep and turbulent stream we are likely to have more frazil. It is hardly likely, however, that there will be a great difference in the amount of frazil formed in either case; it will probably be that more or less anchor ice will appear in proportion."

The Montreal Flood Commission in their report deal exhaustively with the question of ice formation. The following is an extract from that report:—

> "The terms 'anchor ice' and 'frazil ice' are indifferently applied to the same material, but the first evidently is most applicable to this ice when found in the bottom of the river. In one respect the two are identical, that is, both are exclusively the production of open water. There is no formation of either when or where the surface is covered with ice, and whereas large formations of both take place in the beginning of winter over the vast surface below Lachine rapids, the further formation of this ice ceases as soon, and whenever the ice-bridge is formed. Frazil, as distinguished from anchor ice, is formed over the whole unfrozen surface above and below Lachine rapids, between Prescott and the tide-water and wherever there is a surface current or wind agitation to prevent the formation of bordage ice, while anchor or anchored ice, except in the shallowest portions of the current, does not appear in the deeper water until zero weather sets in."

In this report the formation of anchor ice is not ascribed to radiation from the river bottom, but rather to the cooling of its surface through the contact with the frazil-charged water. Proceeding with the description on anchor ice, the report says:—

> "On the approach of mild weather, it becomes detached from the bottom, sometimes bringing up with it gravel and stones, and may be seen as a dark-coloured mass bursting up all over the surface with considerable force, and with a hissing sound, which rises a foot or more above the surface, but, falling back, shows only a few inches floating above it. Out of the portion above the surface, the water quickly drains, and it becomes white as snow."

This is the appearance giving rise to the term "moutonne" mentioned before.

In respect to the name "anchor ice" being applied to frazil ice, this is due, in the case of water-power developments, to the action of the frazil under certain conditions. Where the head-race of a development is open, allowing the frazil direct access to the intake without having to pass under an ice sheet, it practically becomes anchor ice, because as it comes in contact with the racks and intake structure it adheres to them and rapidly cuts off the water; under these conditions there is no difference between anchor and frazil ice, once the latter has become attached to the structures. As a matter of fact, it is this action of the frazil which causes the trouble directly to plant operations, as it is generally formed in the greatest quantity. The action of the anchor ice proper is to cut off the flow of water in the stream bed; when the anchor ice is floating the conditions are improving.

Winter Conditions.

One condition which requires attention in a study of this kind is the effect of ice upon the discharge of the river, for the formation of frazil and anchor ice in the bed of these rivers and streams has a very marked influence upon their

(1) Pages 110-111 "Ice Formation," by Prof. H. T. Barnes.

Photo by M. C. Hendry

Ice Conditions—Cascade River.

Photo by M. C. Hendry.

Ice Conditions—Cascade River.

discharge. Lying, as they do, at considerable elevations, the temperature obtaining during the winter months is low and, owing to the steep slope of the streams, their flow is turbulent, thus the necessary conditions are present for the formation of frazil ice. The conditions for the formation of anchor ice are also good, for in many places the stream is too swift to allow an ice sheet to be formed; the water is clear and generally shallow, the nights are cloudless and cold; in consequence anchor ice is formed in great quantities.

The formation of frazil and anchor ice in the mountain streams causes their discharge to be very fluctuating, and accentuates the variation in flow during the low-water period.

Winter Conditions as Affecting Plant Operation.

The successful operation of a water plant in winter, on the rivers of Canada, depends in a large measure on the method of providing for or eliminating the ice troubles which are always to be met with.

In the foregoing, the conditions favourable to the formation of the several kinds of ice to be met with have been explained, also the relation of one kind of ice encountered, to another. Of the three principal kinds, sheet or board ice is the least detrimental to operation; in fact if board ice were the only kind to be dealt with, the trouble would be negligible. Where the channels are small, however, and where anchor and frazil have been formed above, great trouble may be experienced, due to the lodging of this frazil and loosened anchor ice, under the sheet, for frazil ice, in the presence of sheet ice, attaches itself to the under side of the latter, and where the channels are small, the whole flow of the stream may become blocked, overflow will then occur and a great proportion of the stream flow be lost. (Reproductions pages 19, 20, 24 and 25, illustrate these conditions.)

One of the best methods, however, of avoiding frazil and anchor ice troubles, is by obtaining a pond of sufficient size and depth in the immediate vicinity and above the intake of the plant, which will readily freeze over; the ice sheet obtained will, to a great extent, eliminate any troubles with frazil or anchor ice.

If the entrance to the power plant is a channel restricted in size, the ice sheet will be a hindrance, rather than a benefit, if there is open water above. In such a case it is much better to be without a sheet of ice, and instead make provision for handling the accumulation of frazil and anchor ice in the head works. There have been many attempts made to deal with this problem, but it generally degenerates into a brute force combat. In many plants provision is made for passing masses of frazil ice through the wheels by raising the racks in sections, currents are then induced to pass across the face of the racks, so that the floating ice, etc., may be carried off.

The great trouble with frazil ice is due to its freezing on the racks and the wheels, finally stopping the supply of water. With regard to the racks, this has been usually due, in a large measure, to the fact that the upper ends of the bars composing them have been left protruding above the water for 2 or 3 feet exposed to the very cold air; in such a position these bars become chilled to the bottom, and even when only cooled to two or three one-thousandths of a degree below freezing point, it is sufficient to cause the frazil ice to adhere to the bars and commence the clogging process. This trouble may be eliminated to a great extent by making the upper part of the rack of wood, and keeping the metal bars entirely submerged, thus preventing the conduction of heat from bars to the atmosphere, and the consequent cooling below freezing point. Besides this method of submerging the metal of the racks, schemes have been brought forward for heating them, such as using hollow bars through which steam may be driven. In many plants instead of this, the head works are housed and heated, not only to provide a good working room for the men fighting the ice, but also to prevent the subcooling of the racks. One of the most successful schemes has been that employed by one of the plants in Ottawa; there the tops of the bars are encased with sheeting, steam pipes being also enclosed; by this means ice troubles have been prevented to a great extent. The use of a live steam jet in the wheel case and guide vanes to prevent the freezing or clogging up of the wheel entrance has been quite successful in several plants.

CHAPTER IV.

METEOROLOGICAL PHENOMENA.

RAINFALL.

General.

The importance of a study of precipitation in connection with the flow of streams cannot be emphasized too much; its influence on stream flow is a very direct one and, without study, the erroneous conclusion is reached that the relation between precipitation and run-off is a simple one. A little time spent in the study of the question soon reveals the fallacy of this assumption, for the relationship is anything but simple, being influenced by a great many physical features of a rather indeterminate nature.

The collection of precipitation data all over the country has been carried on for a comparatively long term of years, whereas data regarding the run-off of streams are rather meagre; if, therefore, some general relation can be established between rainfall and run-off, the study of the streams from the standpoint of power production can be placed upon a more satisfactory basis. In the West, and particularly in that part of the eastern slope of the Rockies in which we are interested, run-off data have been collected for a very short term of years, and only during the last three has a continuous record of the discharge been kept; thus the importance of a general relationship between recorded precipitation and run-off is all the more apparent.

The distribution of rainfall in any district or part of the country is not uniform. The records throughout Canada, generally, except in the eastern provinces, do not extend over a sufficiently long period, nor are the stations widely enough scattered to define areas in which certain amounts of rainfall may be expected. In the West, an examination of the available records seems to indicate a general conformation to conditions found to the south, in the United States; that is, that the lines of equal rainfall are generally north and south, or roughly parallel to the mountain ranges; there are of course divergences due to local influences.

Relation of Precipitation to Altitude.

Generally speaking, precipitation decreases with the increase in altitude; it has been found in travelling westward away from the Atlantic that as the country rises, the rainfall decreases. This general rule, however, does not seem to apply to the particular case we are studying, namely, the precipitation in the valley of the Bow river; in fact, the direct opposite is apparently the case both here and in practically all the territory forming the eastern slope of the Rockies. An examination of the records will show that as the altitude increases on the eastern slope, the precipitation increases; special local influences are at work here, however, the mountain ranges in which are situated the sources of the rivers, causing this reversal of the general rule.

The warm, moisture-laden winds from the Pacific are first intercepted by the mountains of the Coast range and deflected upwards to mingle with cold air currents or to come in contact with land at a lower temperature; becoming chilled below the temperature of saturation, they deposit some of the moisture as snow or rain as they pass over the mountains, giving rise to the heavy precipitation near the coast, the greatest recorded on the continent. They then pass over a stretch of low-lying land, depositing but little moisture until the Selkirk range is reached, where the process is repeated. When the Rocky mountains are reached the humidity of the air has become much reduced, but the low temperatures reached at the higher altitudes is sufficient to cause more precipitation; therefore, in the Bow River basin, with which we are dealing and which is on the eastern slope of the Rockies, it is at the higher altitudes that the greatest precipitation occurs. The alternation of mountain ranges with stretches of country of low altitude is accepted as the cause of the arid and semi-arid regions to be found to the east of the continental divide.

Value of Records.

In making a study of rainfall in any district, it should be borne in mind that the average precipitation gives only a relative view of the question, as great variation from the average annual precipitation may occur at different points in the district. In this regard no general law can be made to apply; the number of conditions contributing are so great and variable that, for special purposes, a detailed study of the rainfall in the locality is necessary.

When studying precipitation records extending over a given period, it is necessary to know what value may be attached to them. Sir Alexander Binnie has given this question careful consideration in a paper published in the proceedings of the Institution of Civil Engineers, vol. 109, pages 89 to 172. He reached the conclusion that for records extending over a period of twenty-five years, the mean obtained would be within 2 per cent of the true mean. The conclusions reached by Mr. Rafter in a discussion of this paper were: that, for a period of five to ten years, the probable extreme difference from the mean would be 15 per cent, and of ten to fifteen years, 4.75 per cent. Other authorities have expressed the opinion that it is necessary to have records for a period as great as forty years in order that the mean may represent the true mean precipitation within five per cent.

Ice Conditions—Cascade River. Photo by M. C. Hendry.

Accuracy of Records.

In Canada, the recording stations are all under the direction of the Meteorological Service, and a standard method of obtaining the records is adopted. It is to be noted, however, that the placing of the recording instruments can have a very great influence upon the accuracy of the records. To arrive at the average precipitation upon a district, it is necessary that as many records as possible in the area to be considered should be available, as conclusions based upon records from a limited number of stations are liable to be considerably in error. An ideal condition under which to study rainfall data would be attained if the stations were uniformly distributed over the territory, or placed along each branch of the stream of which the relation between run-off and precipitation was to be established.

Photo by M. C. Hendry.

Ice Conditions—Cascade River.

Distribution of Precipitation.

A study of the periodical distribution of the rainfall is interesting. Generally this distribution throughout the year, from year to year, is fairly constant in any district, but is different in different districts; for instance, there is a similarity in the distribution in the different localities along the Pacific coast; the same may be said of the territory to the east of the Rockies, while that portion around the Great Lakes has its typical distribution.

Two tables showing the fluctuation in the annual precipitation recorded at Banff and Calgary have been prepared, and appear at the end of the report. At Banff, the records are available at intervals from 1890 to 1896, from which year they are continuous to date; during that period, the maximum precipitation occurred in 1902, 30.59 inches being recorded, and the minimum was 10.33 inches in 1903; the mean yearly precipitation for twenty years is 19.13 inches. At Calgary, the records are available from 1885 to date, during which interval the lowest recorded annual precipitation occurred in 1892, 7.91 inches being the amount; and in 1902, the maximum precipitation occurrred, 34.57 inches being recorded; the mean yearly precipitation over the period of twenty-seven years is 16.10 inches.

Owing to the scattered location of the recording stations in the district—at Banff, Calgary, and Jumping Pound (from the latter, only partial records are available)—they do not truly represent the conditions obtaining in the basin.

As has been mentioned before, the precipitation increases in this locality with the altitude; the altitude of the station at Calgary is approximately 3,400, that at Jumping Pound about 4,200, and at Banff 4,525 feet, and an examination of the records will show a greater precipitation at Banff and Jumping Pound than at Calgary, that recorded at Banff being the heaviest of the three. The sources of the Bow river and its tributaries are at much greater altitude than is the gauging station at Banff; in fact the greater part of the drainage area above Kananaskis falls lies above this altitude, so that the stations are by no means representative of the greater part of the drainage basin.

Relation of Precipitation to Runoff.

If the records of precipitation are compared with those of the run-off on the basin, it will be found that the recorded run-off exceeds the precipitation as recorded at Banff, by as much as 25 per cent. This condition is by no means uncommon for mountain districts. Mr John R. Freeman, in his report on the Hetch Hetchy Water Supply for San Francisco, says:—

> "In regard to the excess of run-off over precipitation, the fact that depth of run-off exceeded depth of rainfall at outlet simply proves that the average precipitation for the catchment as a whole was far greater than at this comparatively sheltered spot of lower altitude at the outlet of the valley."

This condition holds in the Bow basin, and emphasizes the need of more stations for the recording of precipitation.

On account of the short period over which complete run-off data are available, and the few precipitation recording stations in the catchment area, no definite relation can be established between run-off and precipitation. The only conclusion that can be arrived at from a study of these data is that for the water years from 1909 to 1911, the mean precipitation has been nearly equal to the mean yearly precipitation for the last sixteen years, as recorded at Banff. It is fair, therefore, to assume that the run-off during the same years represent approximately the mean run-off conditions during a like period.

Division of the Year.

In considering the relation of precipitation to run-off, a period known as a "water year" is made use of, instead of the calendar year. This period for the Bow Basin district may be assumed as extending from October 1 until September 30, for practically all of the water is obtained from the mountains, and from October 1 on, the precipitation in the form of snow is stored in the mountains to be held until the warm sun of the following early summer releases it, to form the summer freshets which occur during May, June and July.

TEMPERATURE.

Temperature in the Bow river drainage area is one of the great factors influencing the discharge of the river; in the upper part of the catchment area there is not a month in the year in which frost cannot be expected. The range of temperature is great, the range of mean temperature at Banff (see tables) is

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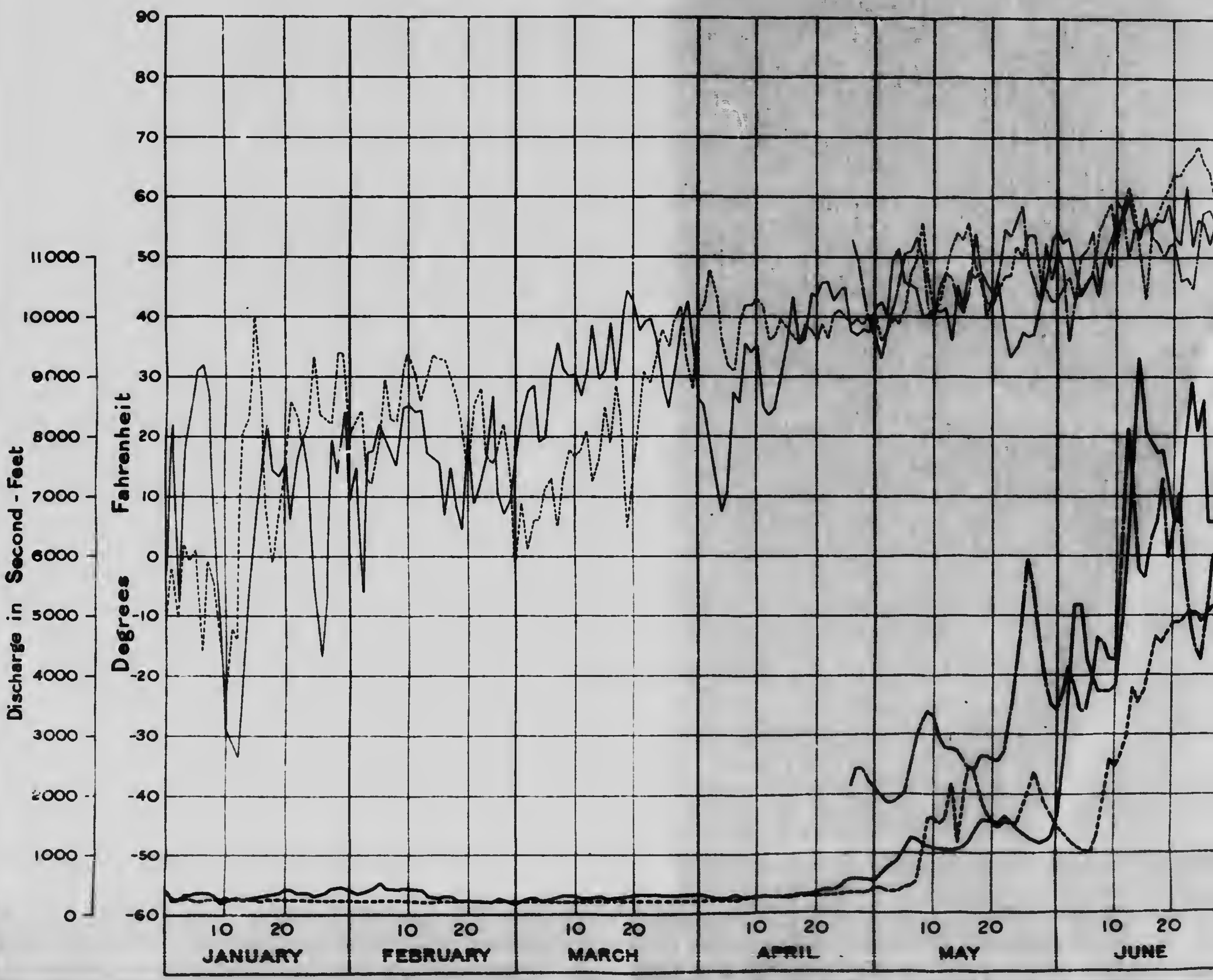

Discharge in Second - Feet
Degrees Fahrenheit
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
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JANUARY
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JUNE

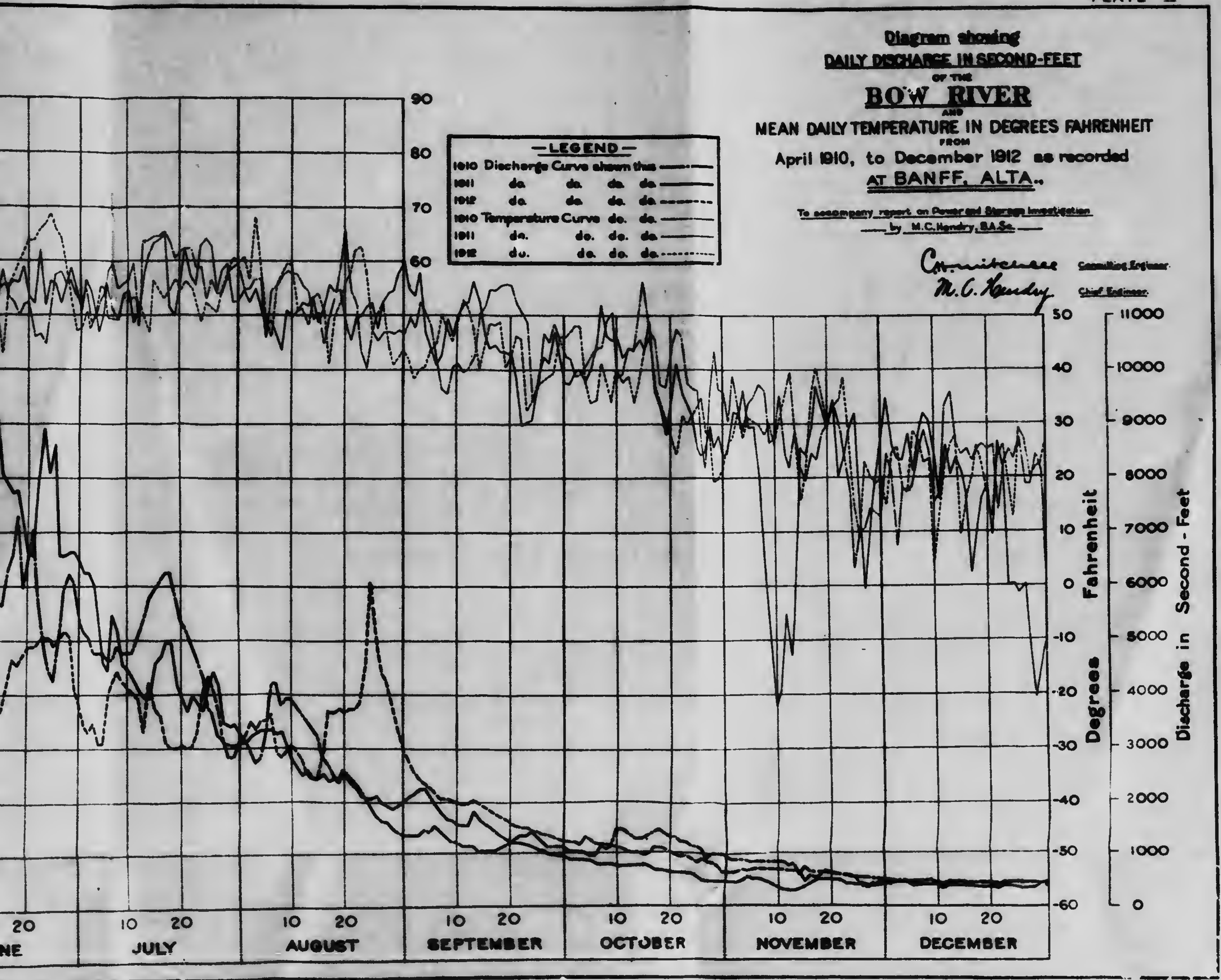
Diagram showing
DAILY DISCHARGE IN SECOND-FEET
OF THE
BOW RIVER
AND
MEAN DAILY TEMPERATURE IN DEGREES FAHRENHEIT
FROM
April 1910, to December 1912 as recorded
AT BANFF, ALTA.
To accompany report on Power and Storage Investigation
by M.C.Hendry, B.A.Sc.
Consulting Engineer.
M.C. Hendry
Chief Engineer.
—LEGEND—
1910 Discharge Curve shown thus
1911 do. do. do. do.
1912 do. do. do. do.
1910 Temperature Curve do. do.
1911 do. do. do. do.
1912 do. do. do. do.
Degrees Fahrenheit
Discharge in Second-Feet
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

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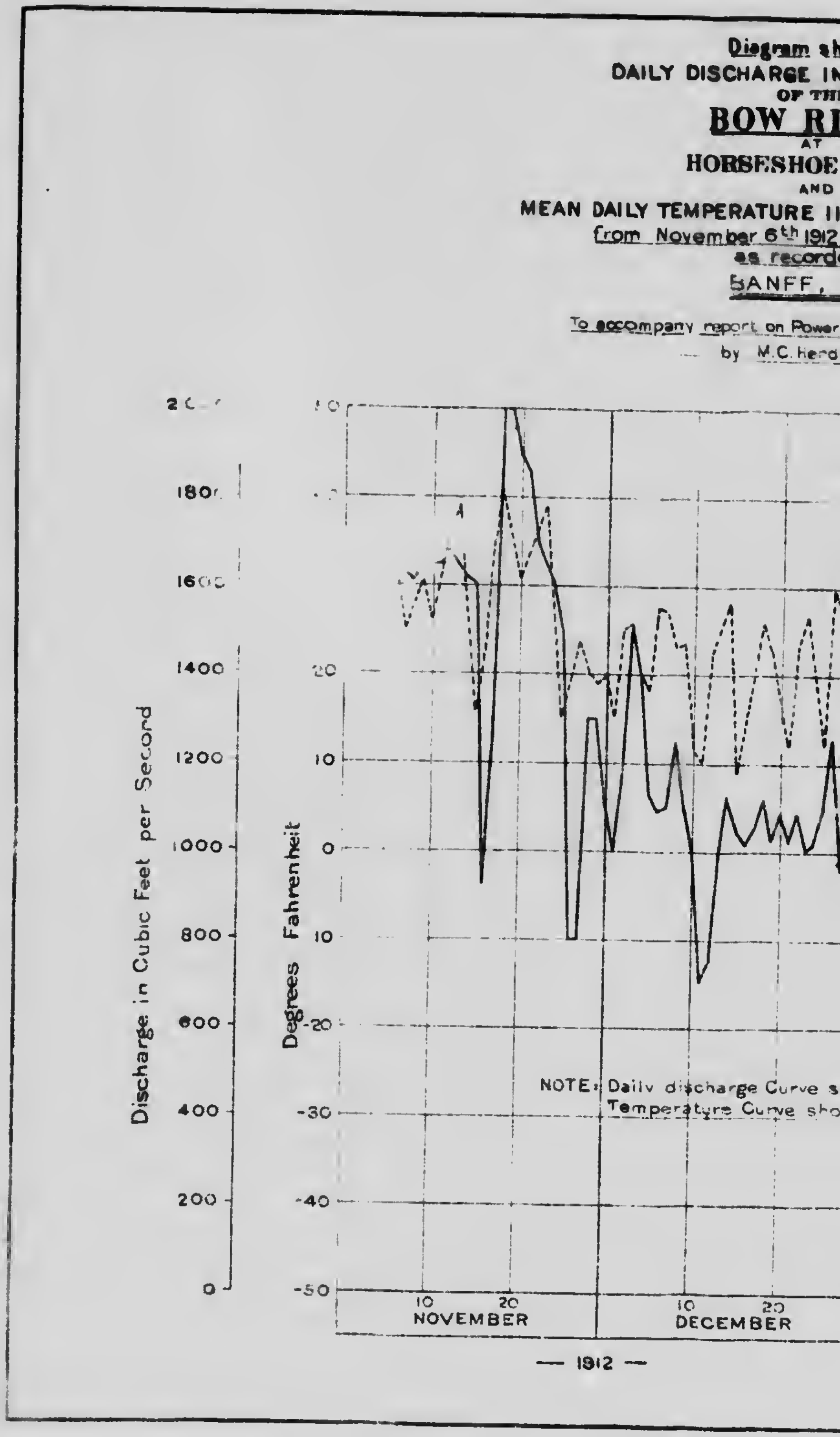
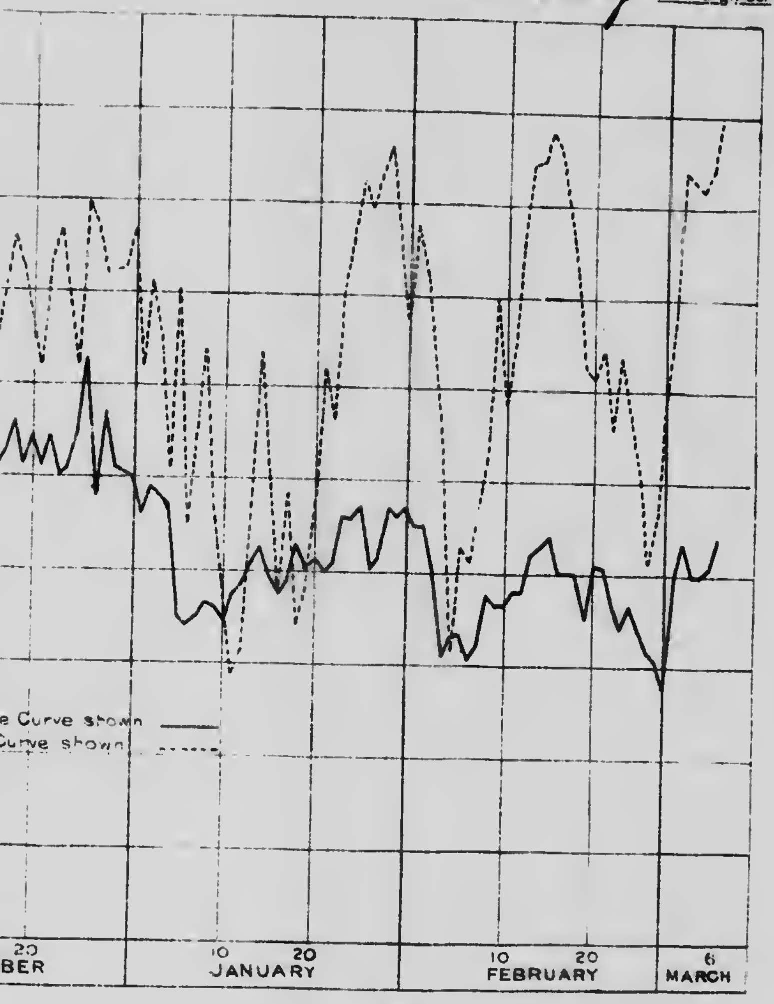


Diagram sh
DAILY DISCHARGE IN
OF THE
BOW RI
AT
HORSESHOE
AND
MEAN DAILY TEMPERATURE II
from November 6th 1912
as record
BANFF,
To accompany report on Power
by M.C. Hend
Discharge in Cubic Feet per Second
Degrees Fahrenheit
1800
1600
1400
1200
1000
800
600
400
200
0
20
10
0
10
-20
-30
-40
-50
NOTE: Daily discharge Curve s
Temperature Curve sho
10
20
NOVEMBER
10
20
DECEMBER
— 1912 —

egram showing
ARGE IN SECOND-FEET
OF THE
OW RIVER
AT
ESHOE FALLS
AND
ATURE IN DEGREES FAHRENHEIT
r 6th 1912, to March 6th 1913
s recorded at
ANFF, ALTA.

t on Power and Storage Investigation
M.C. Hendry, B.A.Sc.

C. Mitchell Consulting Engineer
M. C. Hendry Chief Engineer



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from 56°.9 in July to 13°.7 in January, or 43°.2 of difference; at Calgary, the range of mean temperature is from 70°.7 in July to 14°.2 in January, or a range of 66°.4; and the maximum and minimum temperature greatly exceed these. From these two records it will be seen that the one at the higher altitude registered the lowest temperature. At the higher altitudes it is to be expected that low temperatures will be encountered, and that the period during which conditions of low temperature obtain will be longer than at the lower levels. The records are taken at an altitude which is low, considering the drainage area of the Bow river as a whole, and hence do not represent truly conditions in the upper part of the valley of that river; they give, however, an indication of the conditions to be found and, upon study, reveal some interesting facts with regard to the bearing of temperature upon the discharge of the river.

Influence upon Evaporation.

The influence of temperature upon evaporation is one which is constant and unmistakable, but is one for which, so far, no relation has been established. Sufficient data are not available for a study of the question in the district, but in passing it seems well to note the work that has been done in this regard, and which is well summed up in a paper by Mr. Rafter, published by the United States Geological Survey. In this paper Mr. Rafter had made a careful analysis of the available data, and he reached the conclusion that no definite relation exists between evaporation and temperature, but that the influence is a constant one, and cannot be disregarded.

Influence of Temperature on Discharge.

There is no other single condition which plays such a vital part, or has such a direct influence upon the discharge of the rivers of the district as temperature. A diagram, Plate No. 2, has been prepared, showing graphically this relationship—the daily discharges of the Bow river at Banff have been plotted continuously, and on top of this has been plotted the mean daily temperature as recorded at Banff from April, 1910, to December, 1912. Another diagram, Plate No. 3, has been prepared for the period November 6, 1912, to March 6, 1913, showing the mean daily discharge for the Bow river at Horseshoe falls, and the mean daily temperature as recorded at Banff.

A study of these diagrams will reveal how direct is the influence of temperature upon the discharge of the river; during months of low temperature the discharge is shown to be low. On the other hand, high temperature corresponds to large discharge, although within the limits of the record, the highest temperatures occur in the month following the highest discharge; this can be explained by the fact that, except upon the mountains permanently covered, the snow has nearly all been melted during June and the early part of July.

The second diagram, Plate No. 3, shows clearly that the influence of low temperature on the discharge is unmistakable. The period selected is that covering the low-water stage of the river, which corresponds to the period during which extreme low temperatures are encountered throughout the interval covered by the curve. It will be noted that the mean temperature is above freezing on only eighteen days, consequently it affects not only the source of the river but also the actual flow in the river itself.

CHAPTER V.

RUN-OFF.

GENERAL.

All rivers having their source on the eastern slope of the Rocky mountains have a characteristic flow quite different from that of the rivers of Eastern Canada. Generally speaking, in the latter streams the low-water conditions exist during the summer months, normal flow occurring throughout the winter months, and high water during the spring. This condition is reversed in the case of the mountain streams. The low-water stage of the rivers extends over the winter months; the flood stage is reached during the early summer, then gradually subsides, the normal stage being reached in the late summer and early fall.

These conditions are typical of the mountain streams, and the Bow river and its tributaries are no exception to the general rule. For the section above Calgary, a hydrograph has been prepared, showing conditions at Horseshoe falls, and it may be considered as typical of the discharge conditions in regard to annual distribution of flow, at any point in the section. (See plate No. 1).

The division of the year according to the calendar does not correspond with the regulation of the river's flow, and it has been found advantageous therefore to make use of a division of the year corresponding to this annual cycle; this division has been called the "water year."

The water year in the district of which the Bow valley forms a part, extends from October 1 to September 30; it is of course an arbitrary division, but it approximates very closely to the different stages of the rivers, beginning with the low-water period. The river derives the greater part of its water from the mountains; roughly speaking, after the first of October, all precipitation of moisture in the mountains is in the form of snow, and remains in that condition until melted by the warm sun during the following summer.

The fluctuation of flow of the river during the early part of the fall and winter months, say from September 1 until November 1, is dependent almost entirely on the rainfall in the lower part of the drainage basin. (See hydrograph of Bow River, Plate No. 1.) During these months the flow is gradually diminishing, due to the storage of precipitation in the form of snow and ice in the higher altitudes. From December 1 until April 1 may be called the low-water period; the river during this period is dependent almost entirely upon the discharge of ground water, springs, and other underground sources. Extreme low water may be expected to occur during January and February; after the end of February the flow is augmented by the melting of snow in the lower parts of the valleys, and the discharge is increased gradually throughout March and April, and by May 15 the first of the floods generally appear; the discharge during May rapidly increases. In the month of June the rainfall is heavy; this, coupled with the melting snows of the mountains, produces a condition favourable to large run-off, and it is on this account that the mean monthly discharge is generally largest for that month.

The rainfall in July is also large, but the amount of snow in the mountains has been greatly depleted, so that the mean discharge is generally lower than for June; very high water may occur, however, during the month of July; in fact, two of the highest floods on record in the Bow river have been recorded in that month, but the mean discharge for the month is, as a rule, lower than for June.

In the month of August, normal stage of the river is reached, and this continues through September, completing the "water-year." The rainfall during August is frequently heavy, and no doubt has the effect of increasing the discharge of the river very materially.

Underground Flow.

The underground flow in all streams of which the beds are composed of gravel, detritus and similar loose material, must be considered when estimates of run-off or discharge are being made. The indicated surface flow of the river, where the above conditions exist, is not an evidence of the true discharge. The discrepancy between the true flow and the surface flow may be large, while on the other hand the underflow may form but a small part of the total flow of the river.

The character of the stream bottom is one of the chief influences governing underflow. If the material is composed of gravel, or disintegrated rock, such as is to be found in the mountain streams, and where there is little material of a finer nature to fill the interstices, the percentage of voids will be high and the amount of water passing through will be large, resistance to flow being small. If, on the other hand, the bed is composed of the gravel, etc., mixed with sand, the spaces will be small, the resistance to flow will be increased, and in consequence the amount of underflow will form but a very small proportion of the total flow.

The question of slope of the bed of a stream is also an influencing element. Where the bed of a stream is comparatively flat, the amount of the total flow, existing as underflow, will be large, as penetration to a considerable depth in the underlying material may be expected. Where the slope is steep, this penetration is necessarily shallow, and in consequence the underflow is smaller.

There are a number of streams in the Bow River basin where this feature of underflow is remarked, and perhaps the best example of this is on the Ghost river, though no attempt has been made to arrive at any conclusion as to the volume of underflow in any case.

The Ghost river owes its name to the fact that at certain points in its course the complete flow of the river disappears.

From a point well up in the mountains the valley of the Ghost river is, for the greater part of its length, very heavily covered with gravel. (See reproduction, page 14.) In many places the valley is quite wide, and during low water the stream is split up into a number of small rivulets, each following its own course across these wide flats; where the gravel is deep, the total low flow of the river disappears in the gravel, to reappear farther downstream.

Another example of underflow in the district is found upon the Elbow. On this river it has been noted through the comparison of practically simultaneous gaugings, that there was apparently less water flowing at one point than was recorded at another higher upstream. Such conditions have been noted in other places, but no attempt has been made to arrive at the magnitude of the underflow at any point.

The existence of this underflow means that there is a flow available for power production larger than gaugings would lead one to expect. The placing of a structure in the stream-bed has the effect of intercepting this sub-surface flow and causing it also to pass through the structures. It also has an important bearing upon the consideration of the relative discharge of different tributaries, and so should not be ignored in any scheme of regulation, or in the study of any hydrographs prepared from current meterings.

Low-Water Discharge.

In the winter months the stream flow is low, and during the period December 15 to March 1, the extreme condition is reached. Just how extreme this condition is may be realized by a study of the following figures: The maximum flood discharge recorded at Horseshoe falls during the period 1910-1911 was on July 24. 1911, when a flow of 14,770 c.f.s. was noted; on January 24, the same year, a minimum discharge of 590 c.f.s. was recorded; for the water-year 1910-11, the mean daily discharge for the period January 1 to May 1 was 851 c.f.s.; for the period October 1 to January 1 the mean daily flow was 1,983 c.f.s. During the remainder of the water-year, the flow was high.

In the above year the discharge during the latter part of December was high, the highest daily flow being December 31, when a discharge of 1,904 c.f.s., was noted; on the first of January, an abrupt change took place, the discharge being under 900 c.f.s., so that the periods for which the mean discharge are given are fairly chosen.

Flood Discharge.

The discharge of a river during flood period, is a factor in any study of power development and is of prime importance. As soon as the design of a structure to be placed in a water course is taken up, the question arises as to what volume of water it may be called upon to discharge under flood conditions, and the best method of safely taking care of the flow at such a time.

Mountain streams are noted for the great difference between their normal and their flood discharge; instances are on record where the ratio between maximum and minimum flow is as high as 1 to 40, and 1 to 50. The Bow river belongs to this class of streams; it is on record that the flood discharge at Calgary has been as high as 54,000 c.f.s. (in the flood of 1897), while the low-water discharge is known to be, at times, less than 1,000 c.f.s. at the same point.

In an interesting report, Mr. P. M. Sauder, Chief Hydrographer of the Irrigation Branch, discusses the floods on the Bow river, and estimates the flood discharge in round numbers at 60,000 c.f.s.; he also speaks of several other floods which have occurred; one in the early part of July, 1902, that followed a period of heavy rains, was very destructive, but it is estimated did not reach the discharge of that of 1897.

Several floods which have occurred are mentioned in Mr. Sauder's report, one in 1879 is stated to have been the largest of which there is any record, and another in 1884, evidence of which places it as 1 foot lower than the flood of 1897; all these floods occurred before any systematic record was kept of run-off data relating to the Bow. Since 1908, almost continuous records have been kept of the run-off, with the exception of the winter months of the first few years; in that time, only two floods of any note have occurred, one in July, 1909, when a discharge of 23,000 c.f.s. was recorded, and another in July, 1912, which is supposed to exceed that of 1909, but for which there are no figures available.

In the same report an estimate has been made of the probable flood discharge for different reaches of the river; they are as follows: From Kananaskis falls to Ghost river, 40,000 c.f.s.; from the Ghost river to the mouth of the Jumping Pound creek, 50,000 c.f.s.; between the Jumping Pound and the mouth of the Elbow river, 60,000 c.f.s.; and below the mouth of the Elbow river, 70,000 c.f.s. This discharge, it will be interesting to note, averages about 19 c.f.s. per square mile of drainage area, or a precipitation of seven-tenths of an inch per twenty-four hours.

Winter Conditions.

The factor which governs in any hydro-electric development, is the discharge of the river during the low-water period; in this district the low-water period occurs during the winter months; therefore, investigation of the winter conditions is of prime importance.

In a previous chapter, the question of temperature was dealt with, in its relation to run-off, and it was there shown that a direct relation exists between the two, especially during the winter months. A brief reference to Plates 2 and 3 is again necessary; it will be seen that a low discharge occurs simultaneous with, or immediately after, a low temperature, and that a high discharge occurs approximately at the time of high temperature. In studying Plate 3 it should be borne in mind that some discrepancy is due to the effect of storage on the natural flow of the river, but the close relationship between discharge and temperature is apparent. The inference drawn from this fact is that the decrease in discharge at times of low temperature is due to the effect of the cold weather upon the flow in the immediate section of the river studied, and not upon the source of the river.

The winter flow of the river is also dependent upon other sources which do not show the immediate effect of temperature, the decrease in flow being gradual.

Stream Measurement.

The measurement of the flow of the Bow river, and streams in the vicinity, has been carried on more or less regularly for some years; gaugings were made as early as 1894, but no continuous records were kept until 1908. From 1908 until 1911, the records are only available for what might be termed the open-water season, while during this period the records are sometimes available as late as the end of December of each year, the flow during January, February, March, and in some cases the early part of April, was not recorded; this particular interval, during which the low-water flow occurs, is the vital period from a power standpoint. This work has been carried on by the Hydrographic Survey of the Irrigation Branch.

In the early part of 1911, the work embodied in this report was instituted, and, at the beginning of the same year, the collection of records covering the low-water stage of the river was commenced on the Bow river and three of its tributaries. In order that a complete set of records might be available in the district, an arrangement was made between the Irrigation Branch and the Water Power Branch, whereby additional stations were established at points suggested by Mr. C. H. Mitchell, the expense being borne by the Water Power Branch, and the work of establishing and operating done by the Irrigation Branch; the stations established under this arrangement were; Ghost river, Kananaskis river, Pipestone creek, Bow river at Laggan, and Cascade river.

From a power standpoint, the need of continuous records of run-off in these streams, especially the low-water flow, is very pressing. Almost as often as estimates of the low-water flow are made by parties interested in power development, it is found, when records are subsequently made available, that the flow has been overestimated, frequently as much as 100 per cent. This is no doubt partly due to the rivers being investigated in the summer months, when the flow is high, or above the normal; a condition which is quite the opposite to that found in some other localities at the same period; this, together with the lack of data, is no doubt the cause of errors in estimate.

Discharge Data.

Included as an Appendix are tables giving the daily discharge of the Bow river at different points in its course; also similar tables for the different tributaries above Calgary, and including the Elbow river; these tables are compiled from information placed at the disposal of the Water Power Branch by the Irrigation Branch. In connection with this information, where gaps occur in the records, they are filled out with information obtained from the records of the Calgary Power Company; this refers particularly to the discharge of the Bow river between the Canadian Pacific Railway bridge and Morley; in this stretch of the river, the records are not continuous at any one point, so that the curves, etc., plotted for one point (generally Horseshoe falls) are a combination of information secured at different points. Up to January, 1912, the Bow was gauged at Morley bridge; between that point and Horse-shoe falls only one stream—Bow Fort creek—enters, and it is of no magnitude. Since January, 1912, the gaugings of the Bow were taken from the Canadian Pacific Railway bridge, about 1½ miles west of the Kananaskis river; between the Canadian Pacific Railway bridge and Horseshoe falls the Kananaskis river enters the Bow; this is a stream of considerable magnitude, but there is a gauging station near its mouth where records have been taken since September, 1911. The Calgary Power Company keeps records of the discharge at their plant at Horseshoe falls.

The curves for the periods are plotted from the data gathered at these several points. It is interesting to note in this connection that comparing the Calgary Power Company's records with those of the Irrigation Branch, the agreement during the period when no water is wasted, is very close for records obtained at Morley bridge, and also the combined records for the stations at the Canadian Pacific Railway bridge and Kananaskis river. During the high-water period, this agreement is not so marked; the discrepancy between the records is no doubt due in a large measure to gauging being made at different stages of the river; this could easily occur during high water, when the discharge varies from hour to hour.

Other tables are also inserted giving the maximum, minimum and mean monthly discharge; also the total monthly discharge in acre-feet, for the different streams in the district, and diagrams showing graphically the discharge of the Bow river at three points, namely, Banff, Horseshoe falls and Calgary, based upon the available data (see diagram, Plate No. 1). Also the Elbow river at Calgary (see diagram, Plate No. 4); and the Spray river at Banff (see diagram Plate No. 5).

ELBOW

Diagram shewing Mean Monthly

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To accompany report on

— By M.C.H

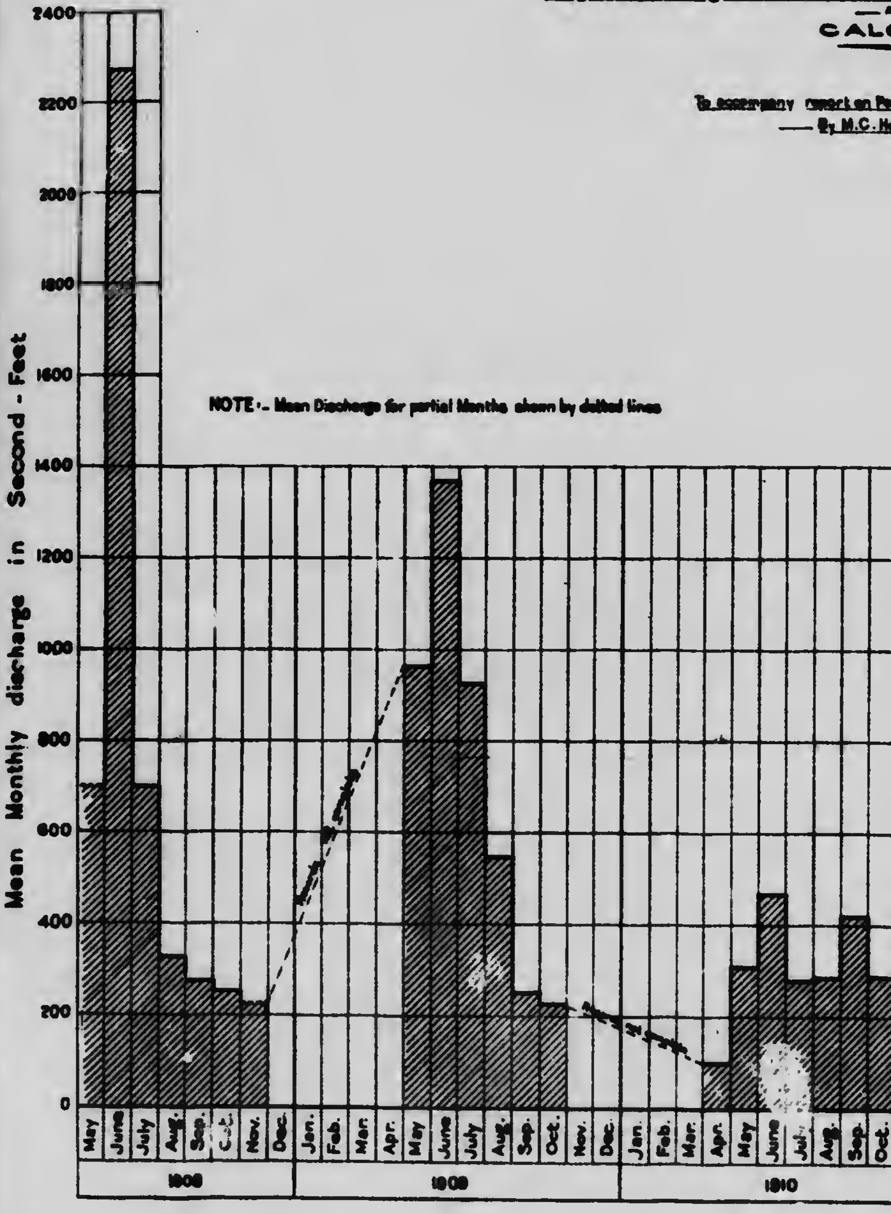
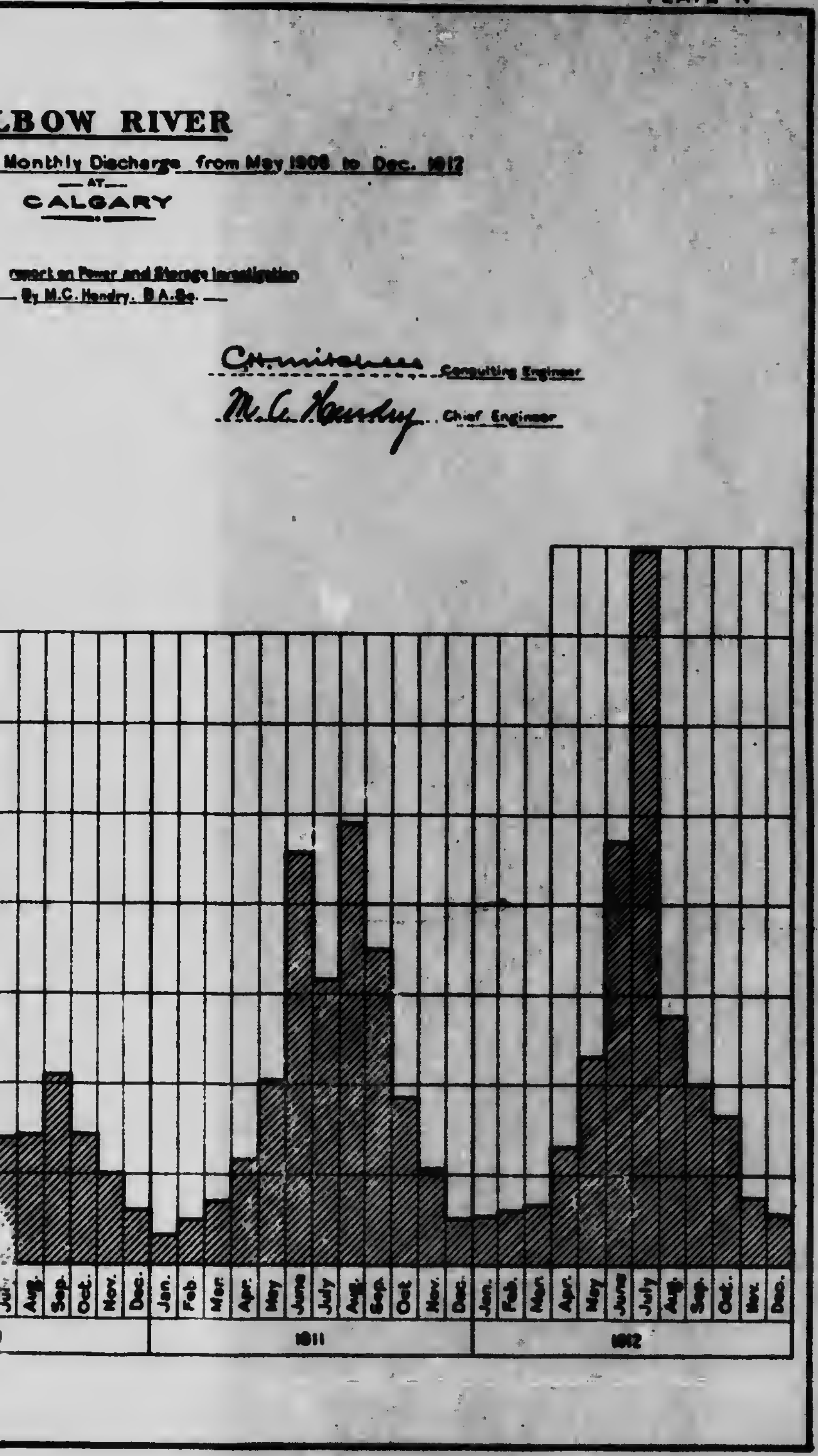


PLATE IV


LBOW RIVER
Monthly Discharge from May 1908 to Dec. 1912
AT
CALGARY
report on Power and Storage Investigation
By M.C. Hendry, B.A.Sc.
Consulting Engineer
Chief Engineer
Jul. Aug. Sep. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sep. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sep. Oct. Nov. Dec.
1911
1912

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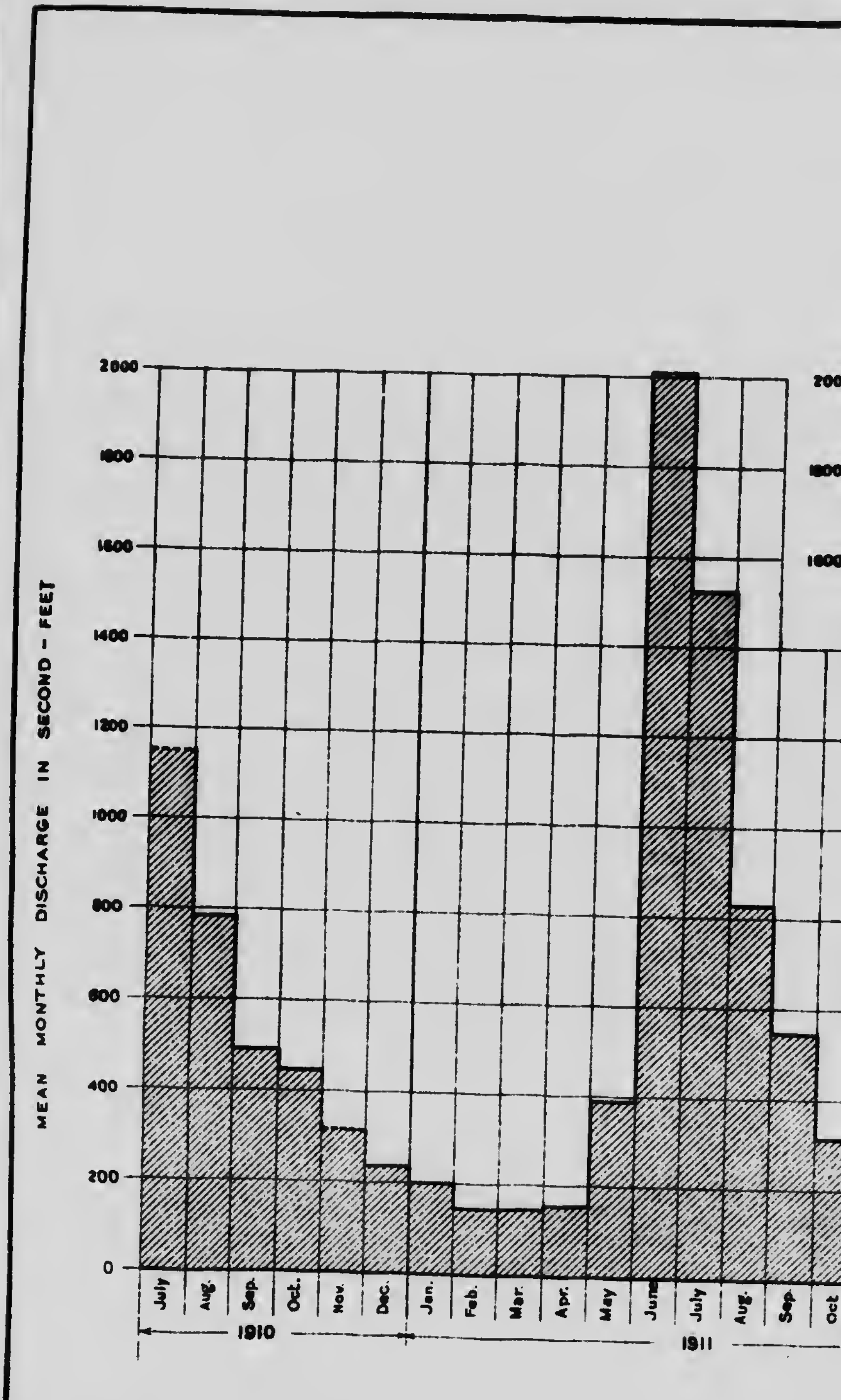

MEAN MONTHLY DISCHARGE IN SECOND - FEET
2000
1800
1600
1400
1200
1000
800
600
400
200
0
July
Aug.
Sep.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sep.
Oct
1910
1911

PLATE V

SPRAY RIVER

Diagram shewing Mean Monthly Discharge from July 1910 to Dec. 1912

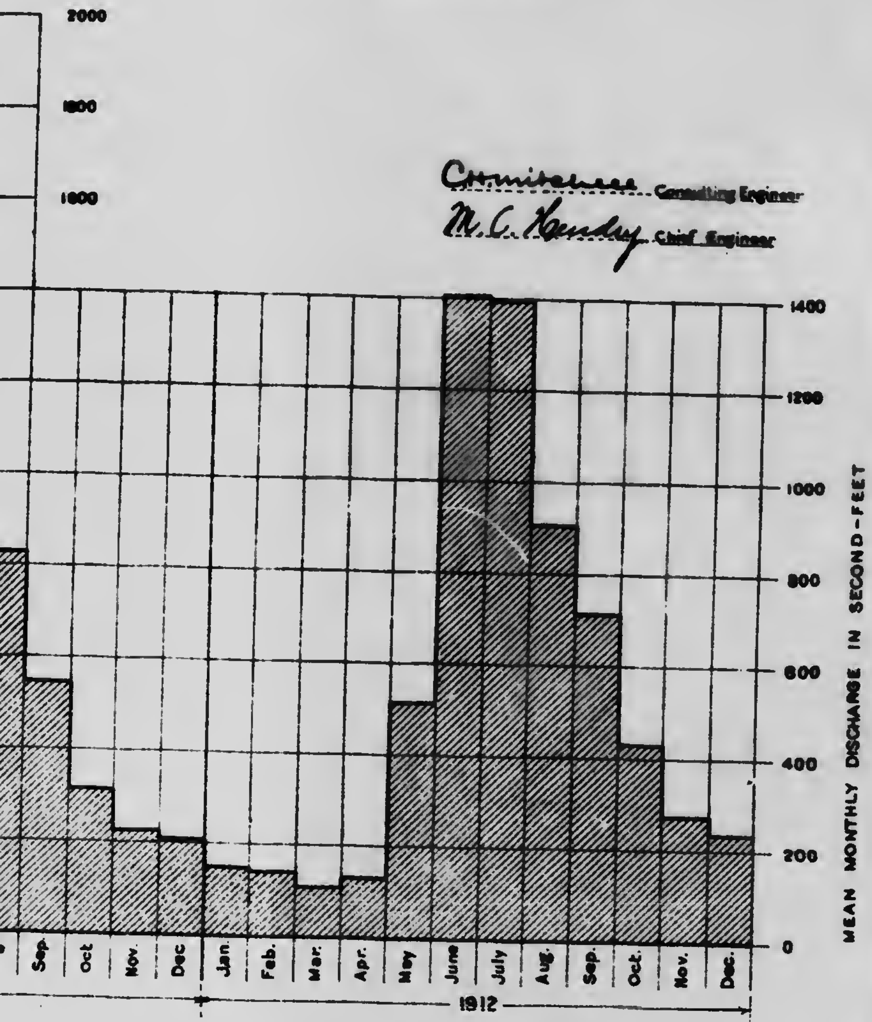
AT

BANFF, ALBERTA.

To accompany Report on Power and Storage Investigation
By M.C. Hendry, B.A.Sc.

C. H. Mitchell .... Consulting Engineer

M. C. Hendry .... Chief Engineer



NOTE:- Mean Discharge for partial Months shown by dotted lines

CHAPTER VI.

EXISTING DEVELOPMENTS.

EAU CLAIRE PLANT.

The first hydro-electric development on the Bow river, in the section from Calgary west, is that of the Eau Claire Lumber Company, situated within the city limits of Calgary. The development makes use of the natural fall in the river, by means of a diverting dam (pile and timber construction) and a canal, and the head developed is in the neighbourhood of 12 feet. The diverting dam is situated just above the bridge crossing the Bow river at Ninth Street West, and the intake and canal are on the south side, the canal following the south bank for about one-half mile. Advantage is taken of small islands or gravel bars, and these, together with timber pile structure, form the stream side of the canal. At the lower end, an island forms the north side of the canal or forebay, the original channel between it and the mainland forming the tail-race. Leffel wheels, set in an open timber wheel case, spanning the channel, are geared to two jack shafts, bolted to two generators. The installation is for 600 horsepower.

The head developed is about 12 feet, the total flow of the river at low water being utilized. The agreement between the company and the old Territorial Government, later approved by Act of Parliament, gives the company the right to the total low flow of the river at that point, and an amount equal to the low flow at high and normal stages of the river.

The development is not on a very permanent basis, and cannot be a very efficient one, though with such a small head, and the restricted flow of the river that exists, the expenditure of not very large sums of money upon its development would be wtarranted.

This plant supplies power for lighting throughout the city of Calgary, having a franchise for the distribution of power. The water-power is assisted by steam generated power, and in consequence the service is liable to very few interruptions, but it is understood that during the winter season the operation of the water-power plant is interrupted for considerable periods, owing to ice troubles.

LAKE LOUISE POWER PLANT.

General.

This plant while very small, and scarcely to be considered from a commercial standpoint, is mentioned for two reasons: first, because it lies within the territory studied; and second, because it is operated in connection with the Canadian Pacific Railway hotel at lake Louise.

Development.

The power station is situated about half a mile from the chalet. The water is conveyed from lake Louise by means of a pipeline about 2,800 feet long to the power station, which is situated on Chalet creek, the outlet of the lake; and which also forms the tail-race.

INTAKE.

A bridge leading across the outlet of the lake is so designed as to form a dam and overflow for the lake, and also part of intake structure.

PIPELINE AND HEAD.

The pipeline which conveys the water to the plant is a wood stave pipe 20 inches in diameter and approximately 2,800 feet long. It is laid on the east side of the creek for the greater part of the distance, and the gross head developed is approximately 140 feet.

EQUIPMENT.

The pipeline leads to a 24 inch S. Morgan Smith wheel which runs at 600 r.p.m. The wheel is rated at 100 horse-power, and is belted to a 75 k.w. 3-phase generator which operates at 1,200 r.p.m. and has an exciter mounted on the shaft. The current is transmitted to the chalet at 2,500 volts where it is stepped down to 125 volts for lighting and other uses.

UTILIZATION OF POWER.

The power output is disposed of at the chalet and also is used for lighting the station and grounds at Laggan. The maximum load is naturally during the tourist season which corresponds to the period of maximum discharge from the lake, so that the power demands are easily met.

The development is interesting from the standpoint of utilization of the flow, which is very limited at all seasons, during the high-water period, and illustrates the value of small hydro-electric plants to the tourist centres.

HORSESHOE FALLS PLANT.

The largest power development on the Bow river, at present completed, is that of the Calgary Power Company. This plant is located at Horseshoe falls, about 50 miles west of Calgary, and here one of the very few concentrated falls to be found upon the Bow, is utilized.

At this point the Bow river in its natural state flows through a deep gorge, the walls and bed of which are formed of a shale banded with sandstone; at the point of development a rock outcropping, which is in the nature of an anticlinal dip, occurs. This has been considerably eroded, and forms a drop in the bed of the river of approximately 25 feet. A solid concrete dam has been built across the gorge upon the lip of this outcrop, and this, with the natural fall, produces a head of 70 feet.

DAM.

The dam (see reproduction page 35) is of solid spillway type, with an inspection and drainage tunnel. In addition to the spillway there are a number of sluice-ways, provided to take care of flood discharges; these are eight in number—four being simply stoplog openings and four being supplied with sluice-gates. The former are 7 feet by 22 feet, the stoplogs being handled by means of hand winches, the other four are controlled by sluice-gates 19 feet by 14 feet of a modified "Stoney Type," operated hydraulically. The spillway section is 140 feet long and, together with the sluices, is sufficient to discharge a flood of 40,000 c.f.s. The inspection tunnel, access to which is gained by means of a well situated midway between the stoplog openings, extends under the spillway section into the rock at the west abutment of the dam.

Horseshoe Falls Plant.

Photo by M. C. Hendry.

Intake.

The intake structure is distinct from the dam and occupies a position adjacent to it, approximately parallel to the stream flow. The water, which is admitted through racks and concrete chambers to the penstocks, is controlled by means of stoplogs and butterfly valves placed in the inlet chambers.

Penstocks.

Provision has been made for four penstocks; three of these have been built and one is now under construction. These penstocks are of two sizes; the small ones, 9 feet 6 inches in diameter, and the larger, 12 feet, each delivering water to a single unit. The penstocks are approximately 250 feet in length, supported upon concrete piers, and protected from possible interference from the river at the lower end by a concrete wall. On account of the severity of the climate, it was considered necessary to house the penstocks, and a frame structure was built, inclosing them for their full length.

Power Station.

The power-house (see reproduction page 35), the main part of which measures 118 feet by 56 feet, is situated in the gorge below the dam; it is of steel, concrete and brick construction, and houses the turbines, generators, exciters, etc. At the back of the power house, and partly over the penstocks, the switch and transformer rooms are built. The tail-race is protected from back water in time of flood by means of a wing wall, which separates the tail-race from the river for some distance below the power-house.

Equipment.

The complete turbine installation consists of four turbines of the horizontal double-runner type in steel wheel cases, and two exciter turbines of the single-runner type, the latter being of 330 horse-power capacity each. Two of the main units are of 3,750 horse-power capacity and, with the governors, were supplied by the Jens Orten-Boving Company; they are of Swedish manufacture, as are also those of the exciter sets. The other two main units are of 6,000 horse-power each, built by Wellman Seaver Morgan Company, of Cleveland, Ohio, and are controlled by Lombard governors. The smaller units are directly connected to two generators, of 2,500 k.v.a. capacity, being 3 phase, 60 cycles, 300 r.p.m. machines and operating at 12,000 volts. The other two units, one of which is now installed, are direct-connected to generators of 4,000 k.v.a. capacity, operated at 12,000 volts, 3 phase and 60 cycles. The generators of the exciter sets are 175 k.w., 125 volt, and 700 r.p.m. machines. The generators were built and supplied by the Canadian General Electric.

The current is carried from the machines to two busses, one supplying the lines to Exshaw at 12,000 volts, the other supplying the step-up transformer which raises the voltage to 55,000 for the Calgary lines.

The transformer room contains two 3,000 k.v.a. 12,000 to 55,000 volt, oil-insulated, water-cooled, 3-phase transformers, and two more of the same capacity will be installed very shortly.

Transmission Lines and Substations.

The company has three transmission lines in operation, one extending to Exshaw, a distance of 8 miles, and the others forming a duplicate line to Calgary.

The Exshaw line supplies power to the cement plant at that place; it is a double circuit, 3 phase, 12,000 volt line, strung on wooden poles, the conductors being of six 00 aluminum stranded cable; in connection with the line there is a telephone line strung upon the same poles, and also a ground wire. The transformer station at Exshaw contains four 700 k.v.a. 12,000-600 volt, oil-insulated, water-cooled transformers, with lightning arrestors and switching apparatus complete. The switch apparatus in this station was installed by the Canadian General Electric Company, and the transformers by the General Electric Company of Sweden.

The transmission line to Calgary is in duplicate; each is a single circuit 3 phase 55,000 volt line, the conductors being No. 0 aluminum, with telephone line and ground wire carried on 40 foot wooden poles. The lines are parallel to one another for the first 10½ miles from the power-house, and follow the Canadian Pacific railway; they then separate, line No. 1 turns southwest and leaves the Indian reserve, just to the east of the old south road to Morley, and joins the road outside the reserve; from that point it follows the road allowance to the city of Calgary, following the Springbank road to within 8 miles of the city; the total distance is nearly 51 miles from the power-house to the substation in Calgary. The second line from the point where line No. 1 turns southeast, runs straight to the northeast corner of township 25, range 6, west of the 5th meridian; it follows the north boundary of township 25, ranges 5, 4, 3, and 2 to the northeast corner of section 35 in township 25, range 2, except for a slight jog near Cochrane, where a diversion is made to avoid a line crossing; at the point mentioned it turns south and joins the other line at the southeast corner of section 1 township 24, range 2, and from there to the substation it parallels the other line. This line crosses the Bow at two points; first, just west of Cochrane, and the second time at Shaganappi.

These lines will handle the power output of both the plant at Horseshoe falls and that at Kananaskis falls now being built.

The Calgary substation, the capacity of which is shortly to be increased, provides for delivering power to the city and the Canada Cement Company, at three voltages, 12,000, 2,400 and 600 volts. This is accomplished by means of 3,000 k.v.a., and 1250 k.v.a., oil-insulated, water-cooled, 3 phase transformers with the necessary switch apparatus.

The transformers and switch apparatus were manufactured and installed by the Canadian Westinghouse Company.

Construction.

The design and construction of the plant was carried out by the engineering firm of Smith, Kerry & Chace. The dam presented some interesting problems which required considerable thought and care in solving.

In order that the site of the foundation might be unwatered, and the discharge provided for during construction, two unwatering tunnels were driven on the intake side of the river, from the under side of the lip of the falls up to the upper level, and at such an elevation that only a low coffer-dam was necessary to keep the water out of the foundation of the dam. The rock outcrop which forms the fall, and upon which the dam was constructed, dips across the river at a considerable angle, (see reproduction page 35) and upon unwatering and exploration of the lower part (the section near the north bank) it was found that the material which is illustrated in the section shown on the plan of the development was not of a satisfactory nature for foundation purposes; an examination proved that no better material underlay it, and this material necessitated special treatment. While the section containing the sluice-ways was being built, Mr. John R. Freeman was called in by the company to advise in the matter; his report of October 10, 1910, accompanied by plans showing layout and proposed changes, was acted upon, and the plans of the plant as built, included here, embody the recommendations made.

Precaution in Construction.

The following precautions were taken, based upon the aforementioned report:

1. The hard sandstone ledge, upon which the dam was to have been built, dipped at such a considerable angle that the cost of carrying the foundations down to this rock throughout the length of the dam, would have been excessive. The northern part of the dam was therefore built upon the shaly rock, overlying the hard sandstone, which it was considered would afford a safe foundation.

In order to obviate any leakage that might develop through the underlying seams, 3-inch holes were drilled through the rock, about 2 feet in front of the face of the dam, 10 feet apart, and to a depth of about 40 feet; a casing was then placed in the upper part of the hole, and a thin cement grout forced into the holes under a pressure varying between 60 and 80 pounds per square inch until they refused to hold any more. By this means the grout would be forced into any seams in the rock, cross cut by the holes, and for a considerable distance from the holes, by first filling alternate holes and later filling the remainder, it was expected that all the seams would be completely filled for some distance from the line of holes. That considerable grout was absorbed by the seams is shown by the diagram, which shows the amount of cement grout placed in each hole, and the amount necessary to fill the hole itself. (See diagram, Plate No. 6.)

2. The possibility of leakage around the north end of the dam was met by excavating a considerable distance into the cliff, for the total height of the dam; the cliff consists of a soft shale, liable to disintegration on exposure to air, but as the excavations were completely filled with concrete, any water leaking through the seams in the shale would be forced to travel a considerable distance, and the quantity would be greatly reduced by friction, and as the seams are liable to silting, the leakage would be very nearly eliminated.

3. The inspection tunnel, before mentioned, also serves the purpose of a drainage tunnel. Drainage holes, about 16 inches square, and placed 16 feet 8 inches apart, extend from the springing line of the arch of the tunnel upward through the body of the dam, so that any leaks that may develop through cracks will be intercepted and directed into the drainage tunnel. Other holes, 3 inches in diameter, and about 12 feet 6 inches apart, have been drilled down through the base of the dam into the underlying rock for depths of from 10 feet to 18 feet; these are cased at their upper end, in order that the quantity of any water leaking through them and also the upward pressure may be measured.

4. The tunnel has been extended into the rock forming the north abutment of the dam for a distance of some 30 feet, so that most of the leakage around the end, if there is any, will be intercepted by the tunnel; this expectation has been realized by the stopping of leakage going on before the tunnel was extended; the tunnel itself is drained through an opening in the downstream side of the dam.

5. The protection of the foundation of the dam at the downstream side has required careful consideration. In order that erosion due to the water coming over the spillway section might be eliminated, Mr. Freeman recommended that the apron of the dam be extended downstream about 40 feet, heavily reinforced and anchored to the rock, and that baffle piers be built on the apron to reduce the velocity of the water and thereby prevent any possible erosion. Other recommendations were made, one was the building of a baffle wall on the crest of the old falls at the south end of the dam, and the facing of the cliff below to prevent undermining, but these recommendations, together with that of placing of a sand blanket over the bed of the river, have not yet been carried out.

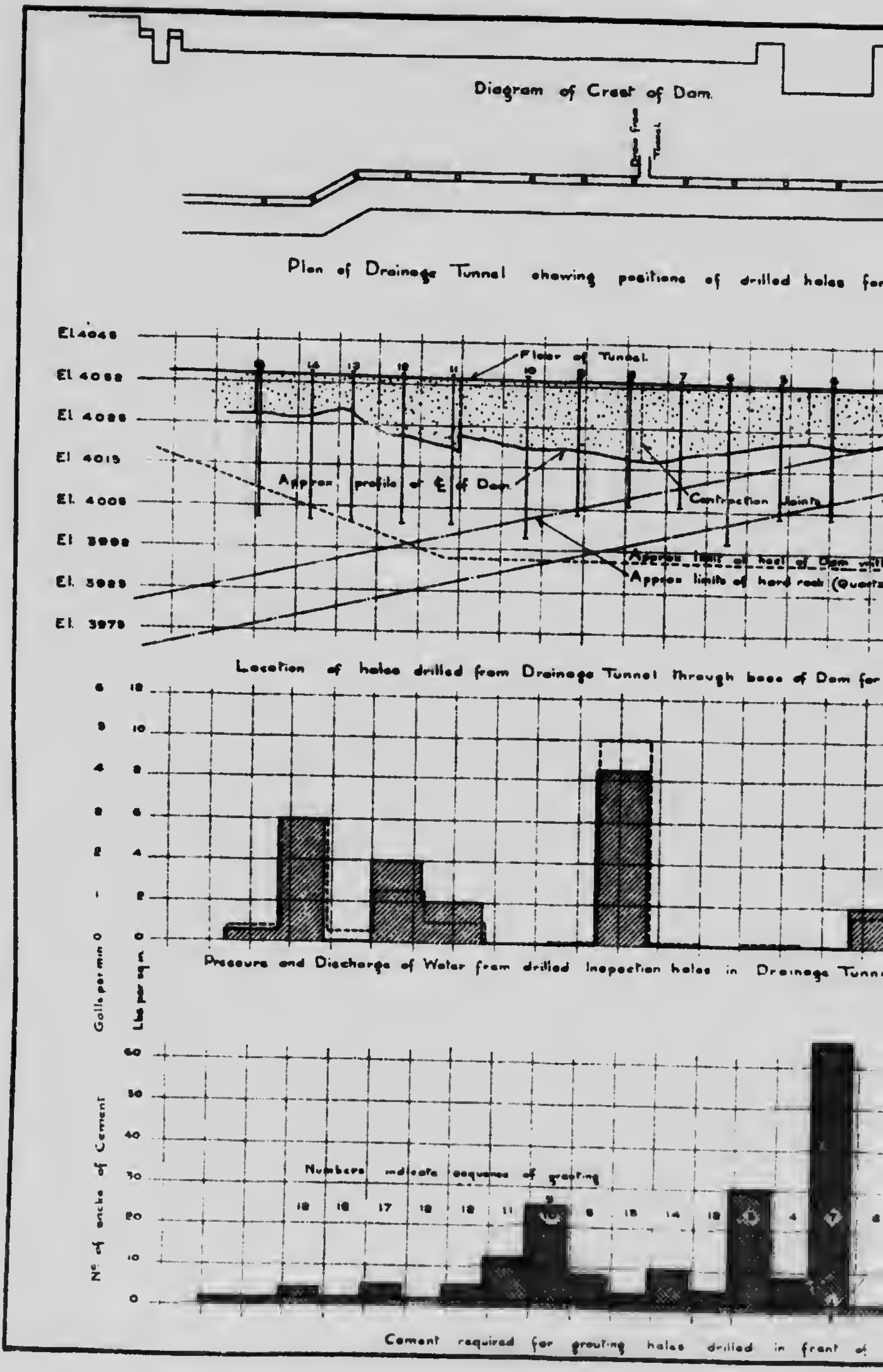
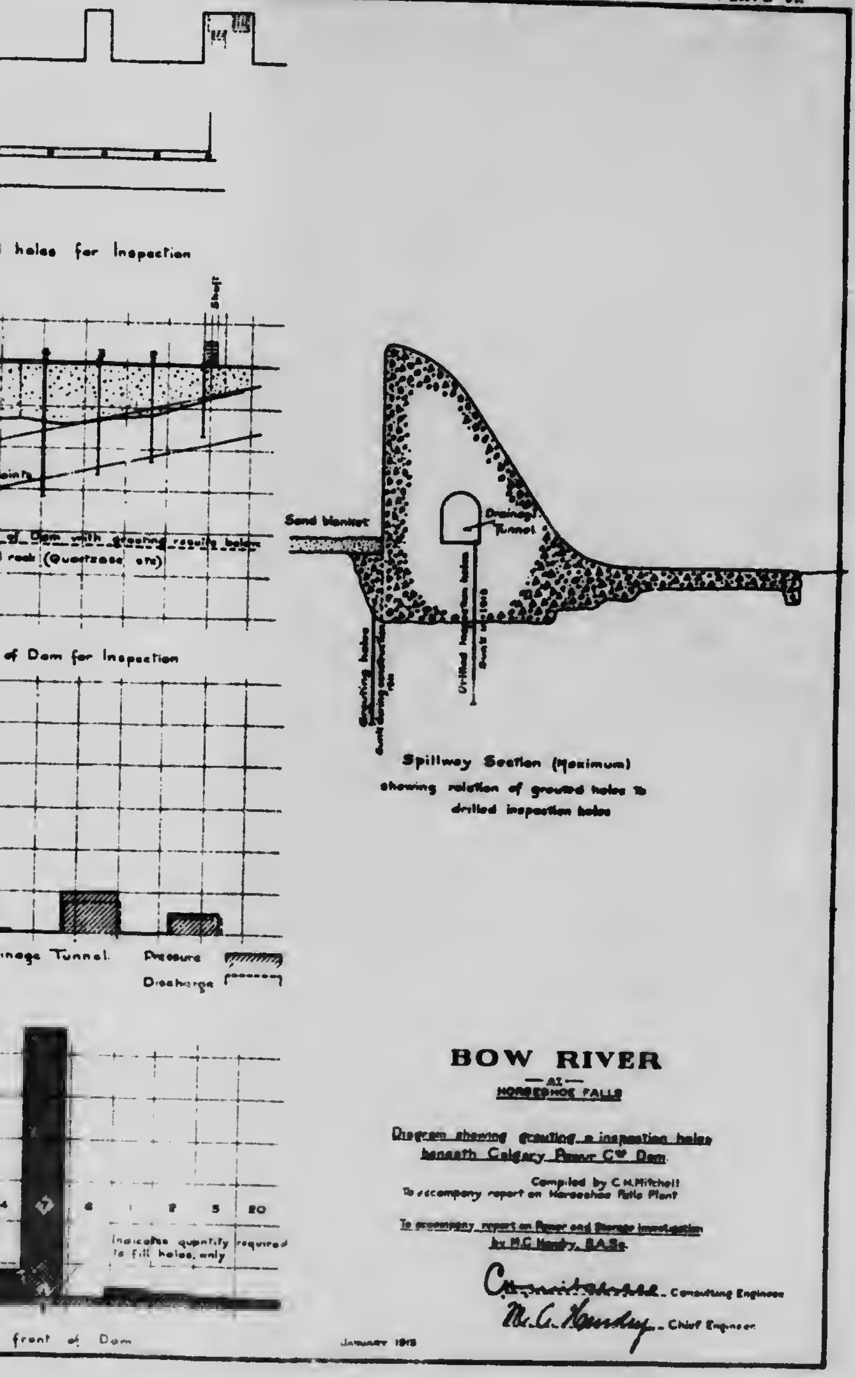


Diagram of Crest of Dam.
Plan of Drainage Tunnel showing positions of drilled holes for
El 4046
El 4032
El 4015
El 4006
El 3979
Floor of Tunnel.
Approx. profile of ℄ of Dam
Contraction Joints
Approx. limits of hard rock (Quartz
Location of holes drilled from Drainage Tunnel through base of Dam for
Pressure and Discharge of Water from drilled Inspection holes in Drainage Tunn
Galls per min
Lbs per sq. in.
No. of sacks of Cement
Numbers indicate sequence of grouting
Cement required for grouting holes drilled in front of

PLATE VI.



holes for Inspection
Shaft
Sand blanket
Drainage Tunnel
Grouting holes
Drilled inspection holes
of Dam for Inspection
Pressure
Discharge
Indicates quantity required to fill holes, only
front of Dam
Spillway Section (Maximum)
showing relation of grouted holes to
drilled inspection holes
BOW RIVER
—AT—
HORSESHOE FALLS
Diagram showing grouting & inspection holes
beneath Calgary Power Co Dam.
Compiled by C.H.Mitchell
To accompany report on Horseshoe Falls Plant
To accompany report on Power and Storage Investigation
by M.C. Hendry, B.A.Sc.
Consulting Engineer
Chief Engineer

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Inspection and Approval.

In a foregoing part of this report, the policy of the Water Power Branch in regard to the approval and inspection of any water-power development has been set out. This policy in the case of Horseshoe falls, has, with the exception of the appointment of a resident engineer, been carried out; Mr. John R. Freeman was consulted by the company with regard to the plans, and Mr. C. H. Mitchell, C.E., as consulting engineer on the Bow river work, made several inspections of the plant both during the latter part of construction, and after completion, and has submitted two reports to the branch covering the work.

KANANASKIS FALLS PLANT.

General.

The Kananaskis Falls plant is placed under the heading of plants in existence, though at the present writing it is only in the course of construction.

Site.

The site of the Kananaskis Falls plant is at the falls of that name on the Bow river. These are about 2 miles upstream from the Horseshoe Falls plant, and immediately below the junction of the Bow and Kananaskis rivers; in fact the latter stream, entering from the south, adds its waters within the limit of the rapids at the head of the falls.

The total fall at this point occurs in four sections; first, the rapids just mentioned, and then a series of three falls, giving a total drop of approximately 55 feet. Above the rapids the Bow river is wide and fairly shallow (see reproduction page 40), the banks are comparatively low, gradually increasing in height to the head of the falls. Below the falls, the banks are perpendicular, the river flowing through a rather wide canyon. The banks of the Kananaskis are high; the west bank is perpendicular, rising at least 40 feet above the surface of the stream; the slope of the east bank is more gradual for the first few hundred yards, but after that it is high and abrupt.

The Canadian Pacific railway crosses the Kananaskis river by a bridge that spans the stream about 250 yards above its mouth, and the Bow river by another bridge about 1 mile above the falls. The existence of these bridges has a very direct bearing upon the question of development at this point.

Development.

The general scheme of development adopted is that of a dam, placed across the head of the falls, by means of which the water is raised and diverted into a canal excavated on the south side of the river. The water will be conveyed by the canal to an intake structure situated on the south bank and provided with suitable racks and gates for controlling the flow. From the intake the water will be conveyed in pressure tunnels, to the wheels placed in concrete scroll chambers situated below the power station, and thence in draft tubes to discharge tunnels leading to the river below the falls. The working head for which the plant is designed is 70 feet (see plans.)

Dam.

The dam at the head of the falls will raise the water to an elevation of 4,155 feet sea level datum; this elevation was finally determined owing to the existence of the Canadian Pacific Railway bridge across the Kananaskis river, about 250 yards from the mouth. The bridge is of the inverted truss type, and the elevation of the lower chord was the controlling feature. Permission was secured from the Canadian Pacific Railway to raise the tracks at this

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)

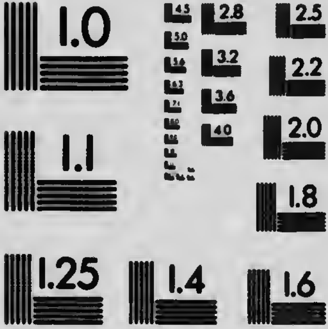

Photo by M. C. Hendry.

Kananaskis Falls. Looking upstream.

point 3 feet. The new elevation of the bottom chord became 4,161.75. The top elevation for flash-boards and stoplogs authorized by the department has been fixed at 4,155.75, or 6 feet below the bottom chord of the Canadian Pacific Railway bridge over the Kananaskis. The dam is being built upon a ledge of rock extending practically across the river (see plan), and is in three sections.

The first section, which is about 200 feet long, is nearly parallel to the centre line of the canal; the shore end of this section is in the nature of a retaining wall, while the outer 180 feet, or that portion nearest the angle, is of the spillway section, made up of nine 17 foot openings with 3 foot piers between.

The central section is 174 feet long, and is provided with eight 17-foot openings, with 3-foot piers between and one 24-foot opening in the nature of a spillway. The section is built partially upon, and partially below, the ridge of rock mentioned (see plans), and is provided with two inspection tunnels, one above and one below the ridge; drains are placed at frequent intervals leading from the face of the rock to the inspection tunnel. In addition, a line of holes is being drilled along the face of the dam down through the rock, and grouted, the idea being to close any seams that may underlie the dam. (See reproductions pages 144 and 148).

The third section, forming the connecting link between the central section and the north bank of the river, runs upstream, making an angle of about 30° with the centre portion. It is 268 feet in length between abutments, and is provided with eleven 18-foot openings, with intermediate piers 7 feet thick. It is proposed to control these 18-foot openings with stoplogs operated from a deck running the length of the dam, the bottom of the deck being at elevation 4,162. The elevation of sills of these openings has been finally determined as 4,138. Working level being 4,155, which may be raised to 4,155.75 by flash-boards. This section is also provided with an inspection tunnel extending to the north bank, and having an extension in the form of a drift leading into the rock forming the north abutment; by means of this drift it is expected to cut off possible leakage around the end of the dam and minimize danger to the structure in that respect. In addition, holes were drilled in front of this wall and then grouted under pressure. Access to the inspection tunnels is had by means of a shaft in the block, forming the junction between the second and third sections; this shaft leads to the tunnels, and also has an opening to the lower side of the dam; there is also a shaft in the north abutment of the dam, leading to the tunnels.

Discharging Capacity.

The discharging capacity of the structure under certain conditions is given below in tabular form. It should be noted that, with the exception of the roll-way and log run, the discharge is dependent upon manual operation, and is not automatic except above elevation 4,155.

Discharging Capacity of Kananaskis Dam.—Table No. 9.

Elevntion of Head-water.	Discharge through eleven 18-ft. sluices in sec.-ft. Elev. of sill 4138.	Discharge through rollway and log run in sec.-ft. (automatic.)	Discharge through sluice-ways and, with stoplogs at elev. 4155 (automatic) sec.-ft.	Total Discharge sec.-ft.
4152·0	34,600	0	0	34,600
4153·0	38,400	0	0	38,400
4154·0	42,400	0	0	42,400
4155·0	46,100	0	0	46,100
4156·0	50,300	940	660	51,240
4157·0	54,400	2,820	1,750	57,220
4158·0	58,800	5,450	3,425	64,250

Canal and Forebay.

The canal is excavated in rock, sand and clay. The formation through which it is excavated is rather peculiar, owing to the great tilting of the rock, which is to be found in all parts of the district, the rock surface appears as a series of saw teeth, the intervening spaces being filled with clay, sand and gravel; through the rock section the canal is 72 feet wide, and in the earth 40 feet wide on the bottom, and 80 feet wide on top, the bottom elevation being at 4,140; it is approximately 650 feet long.

The forebay to which the canal leads is divided into two bays, one for each pressure tube, and these are in turn divided into two openings by central piers; these openings are controlled by means of "Tainter Gates" though stoplogs, working in gains may be placed in the entrance piers. Each bay is 34 feet wide, and each opening 14 feet, the dividing pier being 6 feet wide. The method of operating is not definitely settled, but will be mechanical.

Pressure Tubes.

Easy entrance by wide passages is had from the forebay to the pressure tunnels, which are of reinforced concrete and lead to the wheels situated in wheel pits below the power house.

Power Station and Equipment.

The power station is built in excavation near the river bank. The necessity of placing the station in excavation was determined by the economical length of solid steel shafting connecting the generators and turbines.

The substructure is of concrete and the superstructure of steel and hollow tile construction.

In addition to the electrical and hydraulic equipment described below, the station is provided with a 50-ton crane, pumps, etc.

The electrical equipment will consist of two vertical shaft type, direct-connected 3,750 k.v.a., 12,000 volts, 3 phase, 60 cycle generators, together with necessary exciters and motor generator set, switch apparatus, etc.; 12,000 volt busses will be direct connected to the Exshaw line, no step-up transformers being used. With this arrangement, power may be delivered either to Exshaw or Calgary through the Horseshoe Falls plant, the two plants being connected.

The turbines are vertical shaft type, each of 5,800 h.p. capacity with scroll cases formed in the concrete, giving easy entrance to the wheels. The method of installing these wheels is similar in many respects to that used at the large plant at Keokuk on the Mississippi.

Market.

The market supplied with power from the Calgary Power Company's plants is within 50 miles of the stations, and the demand is concentrated at two points—Calgary and Exshaw. At Exshaw the load is that derived from the cement plant, which takes all the power delivered at this point; at Calgary the load is that derived from the Canada Cement Company's plant, and the city of Calgary. The latter buys power from the power company and distributes it by means of its own system.

The demand for power has been increasing rapidly; the company first installed two 3,500 k.v.a. machines; this was at once increased by the addition of a 4,000 k.v.a. machine, and the latter is being duplicated, so that the equipment will provide for a generating capacity of approximately 18,000 h.p.

In addition to the foregoing, the company has at present under construction the plant at Kananaskis falls, which when completed will have a capacity of 10,000 h.p.

The city of Calgary has recently had an investigation made of the power situation in its various phases, and the results of this work, which was carried out by Mr. R. A. Ross, C.E., of Montreal; are contained in a report by him. He estimated the amount of power that would be required in the near future, *i.e.*, by the fall of 1913, at 12,000 k.w., and also that in ten years an output of 40,000 to 45,000 k.w. will be required, assuming that the population will then be 200,000.

These figures seem large, but it is pointed out in the report:—(1) "That you anticipate bonusing industries by means of cheap power. . . . . . ". (2) that " owing to cheap rates, electric light will be universally used"; and (3) that "your output will be more readily absorbed by new industries, which are not committed to any particular method of power development as in older municipalities. . . . all of which will tend to make your demands much higher than for a similar sized municipality in the East."

Rates as Charged by City of Calgary for Power—Table No. 10.

Motor Rating.	Charge per horse-power per year.
	$
1-3 horse-power	41.89
4-9 "	37.71
10-18 "	33.52
19-54 "	27.23
55 horse-power and over	23.04

The cost for lighting is 7½ cents per k.w. hour.

1912-13 peak loads:—

Municipal system, the peak load in December, 1912, was .... 9,300 horse-power

Eau Claire plant, the peak load for the same month was .... 2,345 horse-power

Growth of Power Load Demands Investigation.

The phenomenal growth of the country at large is of necessity reflected in the growth in the demand for power, both for industrial uses and for lighting. This rapid increase in demand is illustrated in the history of the municipal plant at Calgary, which, starting with a capacity of 260 k.w. in November, 1905, has grown by leaps and bounds, practically doubling yearly, until at present approximately 6,000 k.w. is installed in the station.

The history of the Calgary Power Company, which started to operate in May, 1911, with two 2,500 k.v.a. machines is similar; the first two units were scarcely running when the installation of a third unit was commenced, and at present the fourth is being installed in their Horseshoe Falls plant. Even with this increase they are unable to keep up with the demand for power, and work is now in progress upon a second plant at Kananaskis Falls, which when completed will generate in the neighbourhood of 10,000 horse-power. These two plants combined will give a generator capacity of about 28,000 horse-power.

It is reasonable to expect, therefore, that within a very short time the present sources of power will be loaded to capacity, and development at other points will become necessary if power is to be supplied by hydro-electric plants.

Intimately connected with the question of increase in the demand for power is the question of increasing the output at the present developments, a question which is demanding the most careful consideration on the part of the companies developing, and intending to develop, power upon the Bow river, and it is therefore very fortunate that the problem has been attacked in the comprehensive manner adopted by the Water Power Branch.

The question of increasing output is that of increased flow of the river during the low-water period. As has been pointed out in an earlier part of this report, the flow during the winter months is of a very small volume, and unless some system of regulation is developed, the power output, depending as it does upon the flow as influenced by the variation in temperature, will vary very considerably from day to day. For instance, during the month of February, 1911, (which may be considered the low-water month), the mean discharge was 745 c.f.s.; the lowest for the month occurred on the 23rd and was 600 c.f.s. This is not the lowest on record, as a discharge of 550 c.f.s. has been noted at the plant at Horseshoe falls. The maximum continuous output of the plant, then, during 1911, must be based upon this flow, giving 3,818 horse-power on the shaft of the turbine at 80 per cent efficiency.

For purposes of comparison, suppose that the plant at Kananaskis was in condition to deliver power, then the water could be used twice, or with the 70-foot head to be developed at that point, a total output of the two plants of 7,636 horse-power on the shaft could be obtained.

A "HORSE-POWER . . . . . PERCENTAGE OF TIME" curve has been plotted for these two plants (see diagram, Plate No. 20); this curve will be described more fully later, but at this point it is interesting to note for what period, in percentage of time, it is possible to operate to the full capacity of the plants. From the above it will be seen that the question of regulation of the flow of the river is vital from a power standpoint. During the period of flood, the capacity of the openings in the structures is taxed to the utmost to safely pass the flow of the river, and then succeeds a period when every cubic foot of water must be conserved in order that the plants may be operated, even at a fraction of their normal output; the investigation into the possiblities of storage upon the Bow river and its tributaries as set forth in this report was undertaken to try to solve the problem of regulation.

CHAPTER VII.

POSSIBLE DEVELOPMENTS.

General.

The possibility of further development of power upon the Bow river and its tributaries is, owing to their topography, confined in a general way to particular stretches of the rivers. Upon the Elbow river the power-producing part of the river is high up in the foot-hills, where it is confined to a narrow channel by high banks, breaking through at times into wide flats which, being confined at the lower end, afford possible power and storage sites. On the Bow river itself, the power-producing portion of the river, as has been pointed out, may be described as that part lying between Kananaskis falls and Calgary. The lower part of this stretch does not offer any particular site, and only one attempt has been made at development, namely, the Eau Claire plant at Calgary, that has been already described.

Methods of Investigation.

The whole power-producing section has been investigated in a general way, while particular attention was given to the part between Kananaskis falls and Radnor, of which a complete contour survey was made. Studies were made of a number of points on the ground, and a more detailed survey made of those considered worthy of particular attention in the field. After study in the office of the detail plans of these points, it has been found that there are a number worthy of consideration as feasible developments.

The same method was adopted on the Elbow river; there the stretch of the river was studied carefully and after the consideration of several alternative schemes, a single development, covering nearly the whole of the power seetion of the river, was decided upon, and surveys were made. A storage scheme was also worked out in connection with this development.

In order that these different schemes might be studied, and their feasibility arrived at, layouts have been worked up for the different developments with some degree of detail, and estimates based upon these have been made.

It is pointed out that these layouts are for study only, and should not be considered as final designs.

The sites on the Bow river to which special attention has been given are known as:—

1. Kananaskis Falls (being built).
2. Bow Fort.
3. Mission.
4. Ghost.
5. Radnor.

On the Elbow river:—
Elbow river site near Canyon creek.

On Cascade river:—
Minnewanka Dam.

Photo by M. C. Hendry.

Bow Fort Site from Upstream.

BOW FORT SITE.

General.

The Bow river, after passing the Calgary Power Company's plant at Horseshoe falls, flows between high banks for about 3 miles, and at very few points in this distance is it possible to get down to water level, the banks for the most part being precipitous and rising to heights of from 40 to 150, and even 200 feet in places. At several places the stream is very much confined (see topographical sheets No. 4 and No. 4A and reproduction page 41), flowing through narrow gaps in the rock outcrops. A point in regard to the geology of the river is of interest here: Below the Horseshoe falls, the general dip of the rock changes twice in a distance of 3 miles; at the Calgary Power Company's plant the dip is towards the west (see reproduction page 35), about a mile below the dip is east, while below the mouth of Bow Fort creek it has changed to the west again. About a half a mile below the mouth of Bow Fort creek the character of the banks undergoes a change, and for a number of miles below this point high steep banks alternate with wide flats.

A number of rapids and swifts occur between the falls and the point just mentioned, the principal ones being about half a mile, and a mile and a half below the falls, and one about three-quarters of a mile above the mouth of Bow Fort creek. The total fall between the tail-race of the Calgary Power Company's plant and the point below Bow Fort creek where the change in the banks takes place, is approximately 70 feet.

Between the mouth of the creek and the end of the section just described the banks are high and almost perpendicular, especially immediately above the lower end; just below the section there is a wide flat which lies on the south side of the river at an elevation of a few feet above the level of the river, and it is at this point, known as Bow Fort site that a detail study has been made.

Site.

Bow Fort site lies at the extreme lower end of the section just described, about half a mile below the mouth of Bow Fort creek and three and three-quarter miles below the plant at Horseshoe falls.

Just above the flat mentioned, the river flows between perpendicular rock cliffs between 40 and 50 feet high, and from the edge of the cliffs the banks rise rather stee[illegible] slope of 40 or 50 feet in two or three hundred, to the foot of the mai[illegible]ks on the south side; on the north side the slope is much steeper; [illegible] are of solid rock, thinly overlaid with soil. From edge to edge of [illegible]e distance is only 265 feet, the general tilt of the rock is towards th[illegible] and the general characteristics of the site give the impression that there was a fall in the river here at one time, the cliff having been cut back until all that remains is a slight drop, which entirely disappears at high water. The cause of this drop is a ledge of rock extending across the river; and it is upon this ledge that it is proposed to place the dam, the intake being in the south bank and penstocks leading to the power station situated on the flat below.

Water Supply.

Under the present conditions of the river, that is without storage, the low-water discharge between Kananaskis falls and the mouth of the Ghost may be expected to go as low as 600 second-feet, though only for short periods (see discharge curves). With the storage contemplated on the upper part of the river, it is expected that a minimum flow of 1,500 second-feet will be obtained, and it is upon this basis of discharge that the schemes above the mouth of the

Ghost are worked out; the intake structures and hydraulic equipment are designed for a flow of 2,000 second-feet, such a flow being available for a great part of the year; the extra equipment would also act as a spare unit, or stand-by. The flood that the structures are expected to discharge safely is one of 50,000 second-feet. These, therefore, are the conditions of flow for which the plant has been designed:—

A minimum flow of 1,500 c.f.s., with extra equipment for a discharge of 2,000 c.f.s. to also act as a stand-by.

A maximum discharge of 50,000 c.f.s.

Development.

Several schemes of developing the power available at this point have been studied, the one here presented being finally settled upon as the most feasible. In order that these studies may be more comprehensive, designs have been prepared and are included in the report, but these are for the purpose mentioned, and are not intended as final.

The proposed scheme places a dam across the river at the point in question; here the gorge is 265 feet wide, the walls are nearly perpendicular, and the river fills the whole of the bottom of the canyon.

On the north side of the dam line the cliff rises 25 feet from the water surface, then slopes back for a distance of 50 feet, rising another 20 feet to the foot of a rock cliff some 30 feet high, the intermediate slope being formed of gravel and disintegrated rock from the cliff above. It is proposed to remove this material and place four sluice-ways at the end of the dam, using the cliff for the north abutment of the structure.

On the south side the cliff is higher, rising sheer 40 feet from the water's edge. From the top of the cliff the slope is steep, rising 25 feet in 100; this slope is formed by the dip of the rock, which at this point is overlaid with soil to a depth of only a few inches.

Head.

By placing the dam at this point a total head of 66 feet may be developed, part of which is the natural fall in the river above the site, the extra two or three feet being obtained below. To obtain this head, the water above the dam would be backed up nearly to the tail-water of the Horseshoe Falls plant and about 2 feet would intervene between the head and tail-waters of the two plants.

Dam.

The dam proposed is of the hollow reinforced concrete type, founded upon ledge rock existing in the river-bed; it would be 265 feet long between the cliffs of the river, and 350 feet long over all, including the sluice-ways; the total height of the structure would be 75 feet, from foundation to spillway crest.

The dam would be provided with four openings 20 feet by 24 feet at the north end, and controlled by stoney sluice-gates provided with proper operating mechanism and housed; these could be used for additional discharge during floods. In addition, there would be two stoplog openings, 16 feet long, and three 72 inch valves controlling additional sluice-ways in the base of the dam. These openings, together with 200 feet of spillway section, will provide for a flood discharge of 50,000 second-feet.

It may be mentioned here that, from Canadian Pacific Railway Company's data relating to the high water in the Bow river, the engineers of the Calgary Power Company have computed that the maximum flood discharge at Horseshoe falls, which occurred in June, 1902, was 43,000 c.f.s.

Intake.

The intake structure would be situated on the south side of the river at the top of the rock cliff and would necessitate some rock excavation. The whole intake would be built upon a solid rock foundation and be of concrete construction provided with the necessary trash racks; provision would also be made for handling ice under winter conditions. Behind the intake racks, the chamber would narrow down to form the gate chamber or entrance to the penstocks; this would be divided into three exactly similar bays, one for each penstock, having a cross-section of 18 feet by 20 feet at the entrance to the penstocks, and provided with stoplog gains, logs and winches by means of which the entrance to the penstocks may be closed. The whole of the gate chamber would be housed.

Penstocks.

It is proposed to have three separate penstocks from the gate chamber to the power-house in the provisional layout; these would be 10 feet 6 inches in diameter and 210 feet long, each delivering water to one main generator unit, the exciter units being mounted on the shaft of the generator.

Power Station and Equipment.

The site is an ideal one for development, with a high cliff on either side and a flat immediately below which provides a good location for a power station, and plenty of level ground for yard room.

It is proposed to place the power station on this flat immediately below the cliff and excavate the necessary tail-race to the river. By placing the station in this position the penstocks will be short, and good regulation may be secured; also the amount of excavation would be reduced.

The head of 66 feet with the regulated flow of 1,500 second-feet will give a mechanical output of 9,000 b.h.p., or 8,100 electrical h.p.

The equipment would be for three units, the turbines of 4,400 horse-power each, with governors, etc.; the electrical equipment proposed is three 2,500 k.w. generators with exciters mounted on the shaft. All the necessary switch apparatus, wiring, transformers, etc., are provided for, together with a crane of sufficient capacity to handle the station equipment.

ESTIMATE OF COST OF PLANT.

V FORT SITE.

General plans have been prepared of the layout of the plant and equipment, and the following is an estimate of the cost of the plant, based upon the foregoing plans, and without transmission line and terminals:—

Main dam and headworks	$366,000.00	
Penstock	54,600.00	
Power-house	65,500.00	
Machinery:		
Turbines and governors	52,800.00	
Generators	65,000.00	
Transformers and switch apparatus	48,000.00	
Total		$651,900.00
Engineering and contingencies	98,530.00	
		$750,430.00
Interest during construction	30,000.00	
Grand Total		$780,430.00

Storage Charges—

Total estimated cost of creating storage above Horseshoe falls................	$760,000.00
On the basis of a minimum flow of 1,500 c.f.s., the total continuous output of the river 47,300 w.h.p.	
Cost of storage per w.h.p.................	$16.00
Proportion of capital cost of storage chargeable to Bow Fort site on basis of w.h.p............................	$144,540.00

Transmission Charges.—

Proportion of capital cost of transmission lines and terminal station and equipment chargeable to Bow Fort site....	$ 86,400.00

The total capital cost of the plant, including the proportion of the cost of creating storage and transmission lines with substation and equipment to be charged against the plant, is as follows:—

Estimated total Capital Cost.—

Cost of plant..........................	$780,430.00	
Storage................................	144,540.00	
Transmission line, sub-stations, equipment, etc..............................	86,400.00	
Total capital cost........................		$1,011,370.00

Cost of plant as above, $1,011,370. The head to be developed is 66 feet. This, taken with the regulated flow of 1,500 second-feet would produce 8,100 electrical horse-power, or 7,300 horse-power on the terminals in Calgary for distribution. Under 25 per cent overload, which the machines are capable of supporting continuously, the station output would be 10,125 electrical horse-power.

Annual Charges.—

Assuming the sale of power will reach 7,300 horse-power, the probable annual cost per horse-power will be as follows:—

1.—Interest on capital invested, assuming financing is done on Bonds at 6 per cent, sold at par...........	$60,700.00
2.—Sinking fund to retire bonds in 30 years reinvested at 4 per cent, say 1¾ per cent....................	17,700.00
3.—Depreciation on plant, adjusted between general works and equipment, to provide for major repairs and renewals..	15,150.00
4.—Operation and maintenance, including management, superintendence, wages, for plant, transmission line, receiving stations, etc., proportion of storage, regulation and minor repairs, supplies, etc....	22,750.00
Total annual charges........................	$116,300.00
Annual operating and fixed charges per horse-power....	$15.93
Cost per horse-power year on 50 per cent load factor basis	31.86
Cost per k. w. year on 50 per cent load factor basis..... or 0 49 cent per k.w. hour.	42.48

MISSION SITE.

General.

Below the Bow Fort site, the river flows through a valley with banks varying from 50 to 150 feet high; the valley bottom is generally wide, and the river meanders through it, swerving from bank to bank so that the banks of the river itself are alternately high and low, a low bank facing a high one and vice versa; this is characteristic of the river from Bow Fort site to the mouth of the Ghost river. At several points there are rocky banks opposite one another, but these are low. At a point on the river, about 4 miles by the river below Morley bridge, two rocky banks occur opposite one another, and opportunity is here afforded for development; this site will be referred to as "Mission Site," owing to its proximity to the old Methodist mission on the Stoney Indian reserve.

Site.

At this point the river flows between two rock outcrops which are parallel to one another about 450 feet apart, and rise to an elevation of at least 60 feet above the river level: this stretch of the river flows almost north and south. On the west side the rock outcrop is in the nature of a long ridge, the ground behind it drops abruptly and then gradually rises to the high banks of the valley behind; here is the controlling feature of the site. On the east side of the river the outcrop forms the bank of the river and also of the valley, and the ground rises gently away from it. At its southern end the outcrop dwindles until it reaches the general level of the large flat adjacent to the river. The general course of the river in the vicinity resembles the letter "S" reversed, the rock outcrops being midway between the two loops. On the south side of the lower loop, the banks are very high while on the north side they are low, gradually rising away from the river in a series of terraces, until an elevation of some 50 feet above the river is reached; these form a bar about 2,600 feet long across the north side of the lower loop beginning at the rock outcrop and ending in a rather steep bank at a point about 6,000 feet downstream, measured along the river, from the two outcrops.

There is no direct fall in the river at this point or above it, the general characteristics being that of swifts or very flat rapids common to the greater part of the river.

The site chosen for the development is that described as above (see reproduction page 55). It is proposed to place a dam across the river between the two rock outcrops, resting against the upstream end of the one on the west side, and near the downstream end of the one on the east side. The lower end of the rock outcrop affords a good site for the intake structure, and the high land running across the loop in the river provides ground at a sufficient elevation to carry the water from the intake and deliver it to a power-house which could be placed on the banks of the river at the end of the loop.

Water Supply.

The remarks on the river flow made in connection with the Bow Fort site apply equally to this site.

Development.

A preliminary examination of the site revealed the foregoing conditions, and it was therefore decided that a detailed survey of the site in connection with the general work in the river was warranted, and from this the scheme of development here outlined has been worked up.

Briefly, the method settled upon involves placing a dam across the river at the rock outcrops, together with some necessary embankment on the west side; an intake structure with controlling devices on the east side; an open canal excavated in the top of the river terrace referred to; a forebay with racks, overflow, and entrance to the penstocks; and penstocks to deliver the water to the power station situated on the banks of the river almost 6,000 feet below the dam.

HEAD.

The water will be raised at the dam a height of 40 feet, and will back the water upstream a distance of about 4½ miles to a point above Morley bridge; between the dam and the outlet from the power-house there is a further fall in the river of 9 feet, giving a net available head of 47 feet.

DAM.

The proposed dam is similar to that for the Bow Fort site, hollow and of reinforced concrete. It will be 465 feet long, including spillway and sluice-ways, and from the crest of the spillway to the foundation it will be about 55 feet high, and will be founded upon rock. The extra discharging capacity will be provided by means of sluiceways of the same dimensions and type as those at Bow Fort site, but on account of the width of the river, no excavation will be necessary; as above, there will be four 20-foot by 24-foot sluice-ways, controlled by Stoney gates, and provided with proper operating mechanism; two 9-foot by 16-foot stoplog openings will also be provided, together with sluice-way openings, through the base of the dam, 72 inches in diameter. The structure will pass a flood of 50,000 c.f.s. with a 4-foot overtop.

The spillway is placed at elevation 3,865.00, normal water level at the site being 3,825; the bottom of the stoplog openings at elevation 3,856 and the sluice-gate sills at 3,841; an operating deck at elevation 3,871 will be provided for the sluice-way section.

This structure is different from that at Bow Fort site, and the other sites contemplated, in that there is no necessity for a bridge across the dam and the whole length of the spillway will be unobstructed.

This type of structure has many advantages over the solid spillway type, it is cheaper, the difficulties of unwatering are reduced, and the question of foundation is not as serious as with a solid masonry dam.

In connection with the dam it will be necessary to place an embankment on the west side of the rock outcrop, forming the west wing of the dam; here the ground drops about 12 feet below the contemplated spill-way level, the embankment would be 225 feet long on the crest, and at elevation 3,871 or about 16 feet high at the highest point. It is proposed to place either steel sheet piling or a concrete core wall through the centre of this embankment, depending upon the depth at which an impervious stratum of material is encountered. No test pits have been sunk, so that it is impossible to say which will be the proper course to pursue at this stage; ample provision has been made, however, for ordinary contingencies in the estimates.

INTAKE.

The intake to the canal will be situated at the east end of the dam, and will have its face approximately at right angles to the centre line. This position will secure the advantage of a current across the face of the intake which, with a sluice-way between the intake and the end of the dam, will eliminate trouble usually caused by ice and floating debris lodging against the racks over the intake. The total width of the intake is 95 feet, divided into four openings of 16 feet wide; the depth of the water at the intake will be 15 feet, and allowing for the loss of section due to trash racks, the velocity of entrance will be about 3.0 feet per second.

In addition to the trash racks it is proposed to place stoplog gains in the intake piers, and also to provide the necessary stoplogs and operating winches. As the structure will be built upon solid rock, means of shutting off the water from the canal will thus be provided, in the event of such a necessity.

The whole structure would have a top elevation of 3,871, or 6 feet above spillway elevation. That is 2 feet above the extreme flood conditions for which the dam structure is designed.

Canal.

The canal proposed is 2,600 feet long; it will have a cross-sectional area of 525 square feet. The whole length of the canal lies in gravel, and on this account the section adopted will have side slopes 1½ to 1. The working level of the water in the canal will be very nearly that of the original surface of the ground for the whole length of the canal, and it is proposed to raise the embankment to elevation 3,871 for the whole length. On account of the nature of the material, it is also proposed to line the canal with concrete for the whole prism, which will not only prevent leakage, and possible breaks, but will materially reduce the loss in head due to friction.

Forebay.

On account of the similarity of their general features it has been decided as far as possible to design the plants for the several sites along the same lines. With this in view, a standard design of forebay has been adopted, for the quantity of water to be handled is practically the same at each site; the penstocks, too, can be made of the same general dimensions.

The delivery of water to each penstock, of which there are three, is obtained by means of a bay 18 feet wide, with a depth of water of 20 feet at working level. Each bay will be provided with racks and screens to prevent the entrance of ice or trash from the canal. The water will be controlled by means of stoplogs for which gains are provided, a duplicate set of gains being also placed in each bay, as it is proposed to use a type of Stoney gate capable of being used in any one of the three bays, so as to obtain rapid control of all the water. Where the forebays are at the end of the canal as in this case, provision is made for draining canal and forebay by means of a sluice-way; this sluice will also take care of any surplus flow due to suddenly closing down of any, or all, of the machines.

The bottom of the forebay, in this case, is at elevation 3,844.5, and the working level of the water 3,864.5, providing for a loss of head in the canal of 0.5 feet.

Penstocks.

The penstocks will be three in number, 10 feet 6 inches in diameter, and 265 feet long, supported upon concrete piers, and will be similar in all respects to the ones proposed for the Bow Fort site, except that they will be slightly longer; very little excavation will be necessary to place the penstocks on a uniform grade.

Power Station and Equipment.

The general layout and size of the power-house as adopted for the Bow Fort site will be used at all the power sites, with the possible exception of the Radnor site, which will enable estimates to be made sufficiently close for the purposes of this report, as the flow is nearly the same for all plants, and the heads to be developed are nearly the same.

The equipment at this will be a slight difference in size from that at the first plant.

The power station would be situated about 100 feet back from the river, at the foot of the terrace mentioned before; the drawback at this point is the lack of evidence of rock in place underlying the heavy gravel which covers the site; on this account care will have to be exercised in securing a foundation for the station. The tail-race will be in the same material, and it may be found necessary to line it with concrete.

The head to be developed at this point is 47 feet and, with 1,500 c.f.s. expected from the regulated flow, 6,410 b.h.p. can be produced, or 5,770 e.h.p. output at the station.

The equipment provides for three units, the turbines each of 3,500 horse-power, with governors, etc.; the electrical equipment proposed is three 2,000 k.w. machines, with exciters mounted on the shaft of each, and these, together with all switch apparatus, wiring, transformers, regulators, etc., are provided for in the estimates. The power station would also be fully equipped with crane, etc. Except for the difference in the capacity of the installation, the station would be similar to that at the Bow Fort site. The size of the equipment has been adapted with the idea that under certain loading conditions two units could handle the total load on the station under minimum flow conditions, giving one unit as a stand-by.

The estimated cost of the development, based upon the layout and plans outlined in the foregoing is here given:—

Estimated Cost of Plant.

MISSION SITE.

Main dam and headworks	$313,660.00	
Canal, including lining	62,000.00	
Forebay	23,000.00	
Penstocks	35,750.00	
Power-house	61,000.00	
Machinery:		
Turbines and governors	42,000.00	
Generators and exciters	52,000.00	
Transformers and switching apparatus	36,000.00	
Total		$625,410.00
Engineering and contingencies	$94,690.00	
		$720,100.00
Interest during construction	$28,000.00	
Grand total		$748,100.00

The total capital cost of the plant, including the proportion of the cost of creation of storage, also the proportion of the cost of a duplicate transmission line to Calgary, and proportion of a transformer station and equipment is:—

Capital cost of plant	$748,100.00	
Transmission lines and station equipment	64,700.00	
Storage	103,000.00	
Total capital cost		$915,800.00

The head available is 47 feet, and the regulated flow 1,500 second-feet, resulting in a power output at the station of 6,410 b.h.p. or 5,300 horse-power at the terminals in Calgary.

ANNUAL CHARGES.

Assuming a sale of 5,300 horse-power, the probable annual cost per horse-power, based upon a capital cost of $915,800, would be:—

1.—Interest on capital invested assuming financing is done on bonds at 6 per cent sold at par	$54,900.00
2.—Sinking fund to retire bonds in 30 years reinvested at 4 per cent, say $1\frac{3}{4}$ per cent	16,050.00
3.—Depreciation on plant adjusted between general works and equipment to provide for major repairs and renewals	13,700.00
4.—Operation and maintenance including management, superintendence, wages for operators of plant, transmission line, receiving station, storage regulation, minor repairs, supplies, and upkeep, etc	20,650.00
Total annual charges	$105,300.00

Cost of power per horse-power year delivered in Calgary	$19.37
" " " " " on basis of 50 per cent load factor	39.74
" " " k.w. year on basis of 50 per cent load factor, or 0.60 cents per k.w. hour	52.98

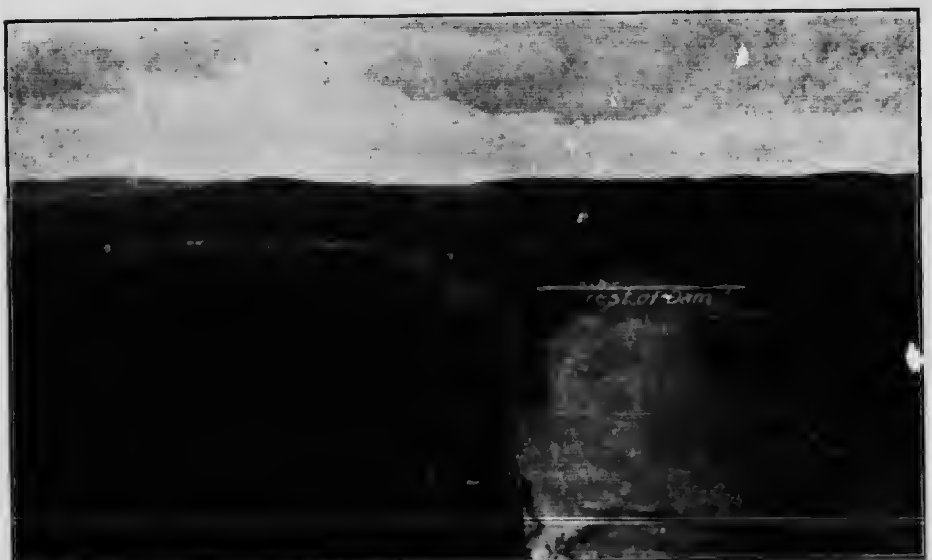

Photo by M. C. Hendry.

Mission Site.

GHOST SITE.

General.

The Ghost site (see reproduction page 56), so called on account of its situation at the mouth of the Ghost river, is about 4 miles below Mission site. The river valley between the two points is rather wide, and the banks generally low; this is especially true of the south side of the river, banks a few feet high confining the river to its bed for nearly the whole distance between the two points mentioned; on the north side there are a few low flats lying at the foot of the high banks which form the valley boundaries, these however are generally narrow. On the south side, the land lies all in the Indian reserve, while on the north it is contained in what was Morleyville settlement, of which the Ghost river formed the eastern boundary. This river enters the Bow river at right angles and directly opposite the eastern boundary of the Indian reserve, flowing from the north through a deep narrow valley; where it flows through the valley of the Bow river, before joining that stream itself, its western banks rise in a series of terraces, whilst on the east it flows along the face of a rock cliff, until it joins the main river where the latter cuts through this rock outcrop.

Ghost Site. Photo by M. C. Hendry.

Site.

The Bow river at the site immediately below the mouth of the Ghost is 300 feet wide. On the south side the river in cutting through the rock has formed a cliff which is nearly perpendicular and about 30 feet high; from the top of the cliff the ground slopes back, gently rising at least 20 feet more in about 400 feet; on the north side the banks rise higher, but are not so abrupt, the rock rises from the river to a flat at the foot of the high valley bank. This rock ridge observed on either side the river, extends right across the bed, causing quite a noticeable fall in the river at this point.

Development.

The scheme proposed is to place a dam across the river at this point, with the rock outcrops as abutments. In this position it will intercept not only the flow of the Bow river, but also that of the Ghost, and this has an important bearing on the scheme, by raising the water to the proposed level, the present road and bridge over the Ghost will be flooded out, making it necessary to relocate them; this may be done quite easily by diverting the road north before it leaves the upper level, and an easy grade down to the Ghost river above the proposed flood level may then be secured, also a good crossing point. The road will then follow the new bank of the river downstream until it joins the old road; this route, which is marked out, and may be seen on the plans, will cost very little and will not increase the length materially.

The intake will be placed upon the south side of the river, and will give entrance to a canal similar to the one proposed for the Mission site, though not as long. At the lower end will be placed a forebay and penstocks, leading to a power station and tail-race. By this means some 6 or 8 feet of fall in the river will be added to the head utilized, for an expenditure which is considered to be warranted.

Flow.

The regulated flow of the Bow river will be augmented at this point by the flow from the Ghost. The records of the discharge of the latter river do not extend over a lengthy period, only two years being available, but records at other places extending over a longer period, indicate that the winter of 1911-12 was one of low flow. and from the records it is concluded that a minimum flow during the low water period will be approximately 100 c.f.s. This will, with the storage contemplated, give an available minimum discharge at the proposed power site of 1,600 c.f.s.

Head.

The head it is proposed to develop will be secured by raising the water at the dam to an elevation of 3,812.50 and by going downstream a sufficient distance to get a tail-water elevation of 3,762, or a net available head of 50 feet. This head, together with the contemplated minimum flow of 1,600 c.f.s. will give an output of 7,275 b.h.p. an output at the station of 6,550 e.h.p.

Dam.

The dam contemplated in connection with this scheme is similar to the two already described in connection with the developments proposed at the Bow Fort and Mission sites, *i.e.*, a hollow reinforced concrete dam. The structure will be 450 feet long, including sluice-ways, and about 50 feet high, depending upon the depth of the foundation. The dam proper, will be approximately 300 feet in length, the remainder being taken up with sluice-ways, which will be placed at the north end of the dam. Some excavation will be required, in order that the sills for the large openings may be placed at the required elevations, and provide for entrance and exit for the water; the openings proposed are the same as at other sites, four 20-foot by 24-foot sluice-ways controlled by Stoney gates, and two 9-foot by 16-foot stoplog openings. Access to the north end of the dam will be by means of a passageway through the structure, leaving a clear spillway 300 feet long; in addition, sluices will be provided through the dam at the south end, controlled by 72-inch valves, giving in all a discharging capacity of 50,000 second-feet., the dam being designed for a 4-foot overtop.

At the north end of the dam an embankment 300 feet long and 8 feet high will be required, and one also at the south end of the intake, to connect it to high ground; the latter will be 400 feet long and of a maximum height of 8 feet.

Intake.

The intake to the canal will be at the south end of the dam, a sluice-way for ice and other debris intervening; the face of the intake in the proposed lay-out is at an angle of about 30° with the line of the dam, producing a cross current towards the sluice-way mentioned. The intake will be about 100 feet over all, and will be provided with five 16-foot openings, the openings to be provided with proper racks and screens to exclude ice and debris; the depth of water will be 14.5 feet to obtain which, rock excavation will be necessary, as the whole structure will have a rock foundation. With the design proposed, the entrance velocities will be low being only about 2.5 feet per second.

The piers in the intake will be provided with stoplog gains; stoplogs and operating machinery are also provided for, in order that the water may be shut off from the canal if necessary, the piers being designed with that contingency in mind.

The top of the structure will be at elevation 3,818.5, or 6 feet above working level; thus these head-works are 2 feet above extreme flood level, the dam being designed for a maximum overtop of 4 feet.

Canal.

The canal proposed will be 1,900 feet long; from the intake it will be entirely in excavation, the material being solid rock and earth in about equal quantities.

As indicated on the layout of the plant, it is assumed to be all in earth, but the estimates are based upon the assumption of rock forming 50 per cent of the excavated material.

The earth is really gravel mixed with loam, and the material being porous, a concrete lining has been provided for the whole length of the canal.

The section in the different material will be so adjusted as to obtain an area in cross-section of at least 525 square feet, giving a mean velocity in the canal, under working conditions, of from 3 to 4 feet per second.

Forebay.

From indications on the ground it is expected that a solid rock foundation may be obtained for the forebay and power station.

The forebay will be similar in every respect to that at the Mission site; it will be provided with the three penstock bays of the same size controlled by stop-logs and auxiliary stoney gate, capable of use in any one of the three bays. The overflow sluice will also be the same as for the Mission site.

Penstocks.

The penstocks will be 250 feet long, and of the same dimensions as for the other sites, *i.e.*, 10.5 feet in diameter, being under practically the same head. The other dimensions will be the same in every respect.

Power Station and Equipment.

The power station will also be similar to the one at the Mission site, both in the building itself, and the equipment. It is proposed to use three 3,500 horse-power turbines with governors, etc., and three 2,000 k.w. generators with exciters direct connected as before; also similar switch apparatus and transformer equipment.

The size of the units selected has the advantage of leaving a spare unit availabie. Two of the turbine units under capacity load are practically equal to the output of the station under low water conditions; under these conditions, the generators would be working under a 25 per cent overload, which they could maintain indefinitely; this may be said for all the developments, the stations being designed with that end in view.

Estimated Cost of Plant.

GHOST SITE.

Main dam, including embankments, excavation and unwatering and headworks	$349,800.00
Canal	71,000.00
Forebay	17,275.00
Penstocks	32,000.00
Power-house	54,000.00
Machinery:	
Turbines and governors	42,000.00
Generators and exciters	52,000.00
Transformers and switch apparatus	36,000.00
Total	$654,075.00
Engineering and contingencies	98,891.00
	$752,966.00
Interest during construction	30,000.00
Grand total	$782,966.00

The total capital cost of the plant, together with its proportion of the cost of creating storage based upon the 1,500 c.f.s. flow, also the proportion of the cost of a duplicate transmission line and terminal station with equipment, etc., is as follows:

Total cost of plant	$782,966.00
Transmission line, sub-station with equipment, etc.	70,577.00
Storage charges	109,530.00
Total capital cost	$963,073.00

The head available is 50 feet; the regulated flow is 1,500 second-feet, to which must be added 100 second-feet, which is the discharge from the Ghost to be counted upon during low-water period, giving a total of 1,600 second-feet; the power to be developed is, therefore, 7,275 b.h.p., giving an output of 5,900 horse-power on the terminals at Calgary.

Annual Charges.

Assuming a sale of 5,900 horse-power, the probable annual cost per horsepower based upon a capital cost of $963,073. would be:—

1.—Interest on capital invested assuming financing is done on bonds at 6 per cent, sold at par................	$57,825.00
2.—Sinking fund to retire bonds in 30 years, reinvested at 4 per cent, say 1¾ per cent....................	16,875.00
3.—Depreciation on plant adjusted between general works and equipment to provide for major repairs and renewals..	14,475.00
4.—Operation and maintenance, including management superintendence, wages for operation of plant, transmission line, receiving station, etc., proportion of storage regulation and minor repairs, supplies and upkeep chargeable to income..................	21,625.00
Total annual charges........................	$110,800.00
Cost of power per h.p. year, delivered in Calgary.........	18.73
" " " " " " on a basis of 50 per cent load factor..................................	37.56
" " " per k.w. year on the same basis......... or 0.57 cent per k.w. hour.	50.09

RADNOR SITE.

General.

Below the mouth of the Ghost, the Bow river flows generally between high banks; on the north side they rise to a considerable elevation above the surface of the river, while on the south side they are not so high, rising about 20 to 30 feet, and sloping back to the general valley boundaries. The next section does not contain any direct falls, but is made up of swifts, rapids and the general slope of the river, so that any development would simply mean the concentration of the natural slope in the river at one point.

Site.

The last site upon the power producing section of the river settled upon is that known as "Radnor site" (see reproductions pages 62 and 63), lying about 3½ miles below the mouth of the Ghost river. The banks of the river at the point chosen are about 300 feet apart, and are in the nature of rocky cliffs; on the south side they rise almost perpendicular to a height of about 50 feet; on the north side they are not so high, but rise about 35 feet and from that height slope back gently reaching a height of nearly 60 feet above the surface of the water. At the point chosen for building the dam, there is a ridge which extends entirely across the river causing a slight drop at that point. Directly below the site the river makes a sharp bend to the north, then swings east again and is divided into two channels by an island a few hundred yards below.

On the south side, the Canadian Pacific railway approaches very closely to the bank of the river, but is at a sufficient elevation to obviate the possibility of trouble due to placing a dam at the point mentioned. The proximity of the railway to the site facilitates the transportation, and by building an overhead cable from the railway, material could easily be transferred to the works.

Above the site the banks are generally high though the flats along the river are wide, and considerable flooding in the river bottom will occur; the total area of the pond created being 241 acres; the slope of the river is generally regular, there being only a few flat rapids or swifts between this and the mouth of the Ghost.

Development.

The method of developing the site involves placing a dam across the river at the point mentioned, and making use of the rock cliffs as abutments for the structure.

The intake which will be in the nature of a short canal, will be placed upon the north side of the river, being excavated from the side of the cliff forming the river bank and extending downstream past the dam about 300 feet. Its inshore bank will be formed of rock in excavation, and on the river side it will be confined by a concrete retaining wall designed to act as an additional spillway.

The forebay or entrance to the penstocks, will be placed at the lower end of the intake or canal and will lead to penstocks of short length, which in turn will convey the water to the power station situated on the river bank opposite the second bend in the river below the dam (see plans.)

Flow.

The flow upon which the development is based is the same as that for the Ghost site, that is, a minimum of 1,600 c.f.s. with structures designed to discharge a flood of 55,000 c.f.s., with an overtop of 4 feet.

Head.

The head it is proposed to develop will be secured by raising the water at the dam to an elevation of 3,760; the normal tail-water opposite the site of the power station is 3,716, so that the normal working head will be 44 feet; this head with the contemplated regulated flow of 1,600 c.f.s. minimum will give an output of 6,400 b.h.p. or an output at the station of 5,760 e.h.p.

Dam.

The dam upon which the estimates have been based, is the hollow reinforced concrete type similar to the structures already described in connection with the other sites. The dam will be connected to the spillway section forming the retaining wall for the intake, and as access to the south shore may be had through the dam, no deck will be necessary; this will give an unobstructed spillway of approximately 700 feet, which, together with the two 18-foot by 20-foot sluice-ways that it is proposed to place next the forebay, will give ample discharging capacity. Provision may be made for a log run at the south end of the dam.

Intake.

The intake will be on the north side of the river and will be in the nature of a canal, the entrance being in line with the upstream face of the dam; it will be 50 feet wide and excavated to a sufficient depth to provide 20 feet of water with the upper water surface at normal working level; this canal will be about 300 feet long, and at the lower end sluice-ways and an ice channel will be provided to clear any ice that may lodge against the racks, protecting the entrance to the penstocks. The entrance to the intake will be protected by a timber boom swung across from the bank to the north to deflect all logs and debris over the main spillway.

Forebay.

The forebay will be in every respect similar to those of the other sites, providing for entrance to three penstocks by means of bays 18-feet by 20-feet, the water being controlled by means of stoplogs. Duplicate stoplog gains are provided and provision made for closing the openings rapidly by means of a type of gate simiiar to the Stoney gate but mounted on a track, and capable of being used in any bay, or in the sluice openings provided in the spillway.

Penstocks.

The penstocks, three in number, and each leading to one unit, will be 10.5 feet in diameter as before, and about 75 feet long, and as the head is nearly the same as for the plants already mentioned, their other dimensions will be approximately the same.

Radnor—Power Station Site. Photo by K. H. Smith.

Power Station and Equipment.

The power station will, as already stated, be placed upon the river bank opposite the second bend below the dam, (see reproduction, page 63), and an unobstructed flow of the water from the tail-race will be thus provided for. The building will be founded upon rock and be similar in all respects as to equipment and design to the stations at Mission and Ghost sites. The equipment will consist of three 3,500 horse-power turbines direct connected to three 2,000 k.w. generators, and having exciters mounted upon their shafts, together with switch apparatus, transformers, etc.

At the north end of the station, yard room will be provided by filling in over the old gravel bar shown on the plans, up to the floor level of the station; this will provide roo[illegible]r assembling and handling the plant.

Tail-Race.

The tail-race, owing to the depth of water in front of the station, will be short, little excavation being necessary.

Estimated Cost of Plant.

RADNOR SITE

Main Dam, including excavation and unwatering	$ 295,000.00
Intake, including excavation, concrete and fixtures	64,700.00
Forebay	23,800.00
Penstocks	11,400.00
Power Station, excavation and unwatering	68,100.00
Machinery:	
Turbines, governors, etc	42,000.00
Generators and exciters	52,000.00
Transformers and switch apparatus, etc	36,000.00
Total	$ 593,000.00
Engineering and contingencies	90,750.00
	$ 683,750.00
Interest during construction	27,350.00
Grand total	$ 711,100.00

Photo by K. H. Smith.

Radnor Site (From Upstream).

Total Capital Cost.

The total capital cost of the development includes the cost of constructing the plant, the proportion of the cost of creating storage chargeable to the plant on the basis of horse-power developed (b.h.p.) from 1,500 c.f.s. and the proportion of the cost, on a basis of output e.h.p., of a duplicate transmission line to Calgary, together with substation and equipment of a capacity sufficient to serve the four lower plants. It is made up as follows:—

Cost of the plant	$ 711,100.00
Transmission line, substation, etc	62,400.00
Storage	96,360.00
Total capital cost	$ 869,860.00

ANNUAL CHARGES.

The head available is 44 feet; the regulated flow 1,500 c.f.s., to which must be added 100 c.f.s. from the Ghost river, giving a total minimum flow of 1,600 c.f.s.; the power developed would be 6,400 b.h.p., giving an output on the Calgary terminals of approximately 5,200 horse-power.

Assuming a sale of 5,200 horse-power, the probable annual cost per horse-power based upon a capital cost of $869,860 would be:—

1.—Interest on capital invested assuming financing is done on bonds at 6 per cent, sold at par	$52,200.00
2.—Sinking fund, to retire bonds in 30 years, reinvested at 4 per cent, say 1¾ per cent	15,250.00
3.—Depreciation on plant, adjusted between general works and equipment to provide for major repairs and renewals	13,050.00
4.—Operation and maintenance, including management, superintendence, wages of operators at plant, transmission line, terminal station, operation of storage, minor repairs, supplies, upkeep, etc., etc	19,600.00
Total annual charges	$ 100,100.00

Cost of power per horse-power year delivered in Calgary	$19.25
Cost per horse-power year on basis of 50 per cent load factor	38.50
Cost per k.w. year on basis of 50 per cent load factor	51.33
or 0·59 of a cent per k.w. hour.	

CASCADE POWER DEVELOPMENT.

When contemplating the creation of storage on lake Minnewanka, the question was raised as to whether it would be feasible to build a power plant in connection with the storage scheme and produce electrical power for consumption in Banff. Banff, together with the storage basin and drainage area developed, lies entirely within the boundaries of Rocky Mountains park, and as the affairs of the town are administered by the Dominion Government, through the Parks Branch, Department of the Interior, the same authorities should carry out the work; surveys were accordingly made with this end in view.

GENERAL.

The canyon of the Cascade river, in which it is proposed to develop power, lies directly below the junction between the Cascade and Devil's creek, the latter forming the outlet of lake Minnewanka. The area tributary to the river at this point is approximately 220 square miles, of which lake Minnewanka forms about 6 square miles. The greater portion of this basin lies at considerable altitudes, the entire water supply coming from mountain streams, springs, and glaciers.

At the entrance to the canyon (see reproduction, page 66), and just below the confluence of the two creeks, a dam was built last year to produce storage upon lake Minnewanka and improve the power facilities of the Bow river.

The site of the proposed power plant is about 7 miles from the town of Banff; communication with the latter place being had by means of a well-kept and travelled road; this road, which also passes through Bankhead, the nearest point on the railroad about 3 miles distant, terminates at the lake.

Water Supply.

Any development at this point will be entirely under the jurisdiction of the Government, as the whole projeet lies wholly within the Rocky Mountains park, so that all privileges such as land, water, rights of way, are vested in the Crown. The natural conditions on the river no longer apply, since the storage and regulation works are complete and in operation, but the influence of these works upon the operation of a power plant at the point contemplated will, however, be entirely beneficial.

When the agreement was entered into between the Minister of the Interior and the Calgary Power Company, it was expected that the company would not be the only beneficiaries from the storage created, but that it was possible other plants might be built upon the river and receive benefits, a clause was therefore inserted in the agreement enabling the Minister to control the operation of the dam; this clause says:—

> "The company shall after the completion of the dam, maintain and operate the same to the satisfaction of the Minister. . . ."

In connection with the necessary discharge of water from storage, subclause "*d*" of clause 17 reads:—

> "The company shall, if required by the Minister, allow a minimum amount of water of 150 cubic feet per second to pass through the dam, which the Government may use for power purposes within the Rocky Mountains park; and the release of such water through the dam shall at all times be under the full control of the Minister or person or persons duly authorized by him for that purpose."

Any development on the Cascade below the dam, will therefore be assured of a minimum flow of 150 second-feet.

During the early part of the flood season, the storage of water will take place; this will, it is expected, be completed not later than July 15 in any season, after which date water will be wasted over the dam. A flow greater than 150 second-feet is practically assured during part of July, August and September, so that the greatest power would be available during the summer months, when the tourist traffic is greatest and the consequent power load heaviest—a very fortunate combination of circumstances.

Available Power.

At the instance of the department, provision was made during the construction of the storage dam to use the structure as a head works for the contemplated power plant below; the dam produces at least half the head to be developed, the other half being due to the natural fall in the river between the dam and power site. As the pond above the dam is primarily for storage purposes, there will necessarily be fluctuation in level; this will not, however, affect the head unfavourably, for the low working head will occur during the winter months, during which period the load will be small. A study of the question of water supply has been made and the conclusions reached have been included in another portion of the report.

Devil's Canyon, before Construction. Photo by M. C Hendry.

Photo by K. H. Smith.

Devil's Canyon Dam (View from Basin).

The plant should be designed to meet the requirements during the summer by utilizing the maximum head and a flow of 200 cubic feet per second.

The available head when the storage basin is full will be 64 feet, of which 60 feet may be assumed to be the effective head; with this head, and a flow of 200 second-feet, an electrical output at the station may be secured of at least 900 horse-power, of which 825 could be delivered in Banff ready for delivery to consumers. Owing to the loading conditions imposed, this flow of 200 c.f.s. could not be utilized continuously, and hence an overdraft for peak loads would be available, say up to 330 c.f.s., and it is upon this basis of flow that the proposed development is worked out.

Under the method of development contemplated, it is proposed to construct all the general works, such as power station, tail-race, etc., for the full capacity of the plant, but only sufficient equipment will be placed in the station at the present time to develop two-thirds the proposed station capacity, the remainder to be added as the demand warrants.

Method of Development.

Dam.

The dam at the upper end of the canyon (see reproductions, page 69) to be used as an intake is of concrete masonry construction, and is provided with means for discharging water either through stoplog spillways, or through a low level sluice-way controlled by a gate valve.

At one side of the canyon, one of the stoplog openings was, on the instance of the department, modified to be used as an intake to the penstock, provision being made for screens, and a steel thimble 5 feet in diameter inserted in the opening to provide a connection to the penstock. This thimble is set at such an elevation that the water may be drawn down in the basin without breaking the water seal on the entrance to the penstocks. At this stage, it should be pointed out that the power project begins at the outside end of the thimble; the cost of the dam, thimble, etc., being charged against the cost of creating storage.

Penstock or Flume.

The penstock connecting to the thimble, will lead along the cliff for a short distance, and then enter a tunnel driven in the rock along the south side of the canyon; the tunnel will be 7 feet by 7 feet in section, concrete-lined to reduce friction losses, and will connect with a steel penstock so designed and placed as to provide an unsupported crossing of the river at this point. After crossing the river, the steel penstock will join one of wood, 7 feet in diameter, which will convey the water to a point just outside the power-house, it will be under pressure, and generally in cut, though for a length of approximately 150 feet it will be carried above the ground on concrete piers.

The lower end of the penstock, at the power-house, will be an 8-foot diameter steel pipe, from which the necessary connections to the turbines will branch. These branches will be fitted with valves to control the flow, and the steel section will terminate in a bend, leading up the bank to a steel surge tank built upon the side of the hill. The tank will be approximately 12 feet in diameter, and of such a height as to be above the highest level of lake Minnewanka, and thus prevent spilling. This tank will provide sufficient hydraulic regulations in the operation of the long pipe line.

Power Station.

The power-house, which will be placed in part of the present river bed, (see reproduction, page 71), will be of concrete construction, and will be protected on the river side by a wall both upstream and downstream from the

Photo by M. C. Hendry.
Devil's Canyon Dam (Downstream View). Summer.

Photo by M. C. Hendry.
Devil's Canyon Dam (Downstream View). Winter.

power-house. Behind the upper wall the ground will be filled in, affording yard space, and access to the Banff road will be had by a road leading by easy grades up the hill.

Equipment.

The equipment will consist of three units. The turbines being each of 600 horse-power capacity direct connected to 350 k.w. generators, the latter having exciters mounted on the outer end of the shaft. The generators will be connected through the necessary switch and protecting apparatus to the transmission line, no step up transformers being necessary.

It is proposed to install two units at first, one of which will act as a stand-by, the third will be added when the power load demands it.

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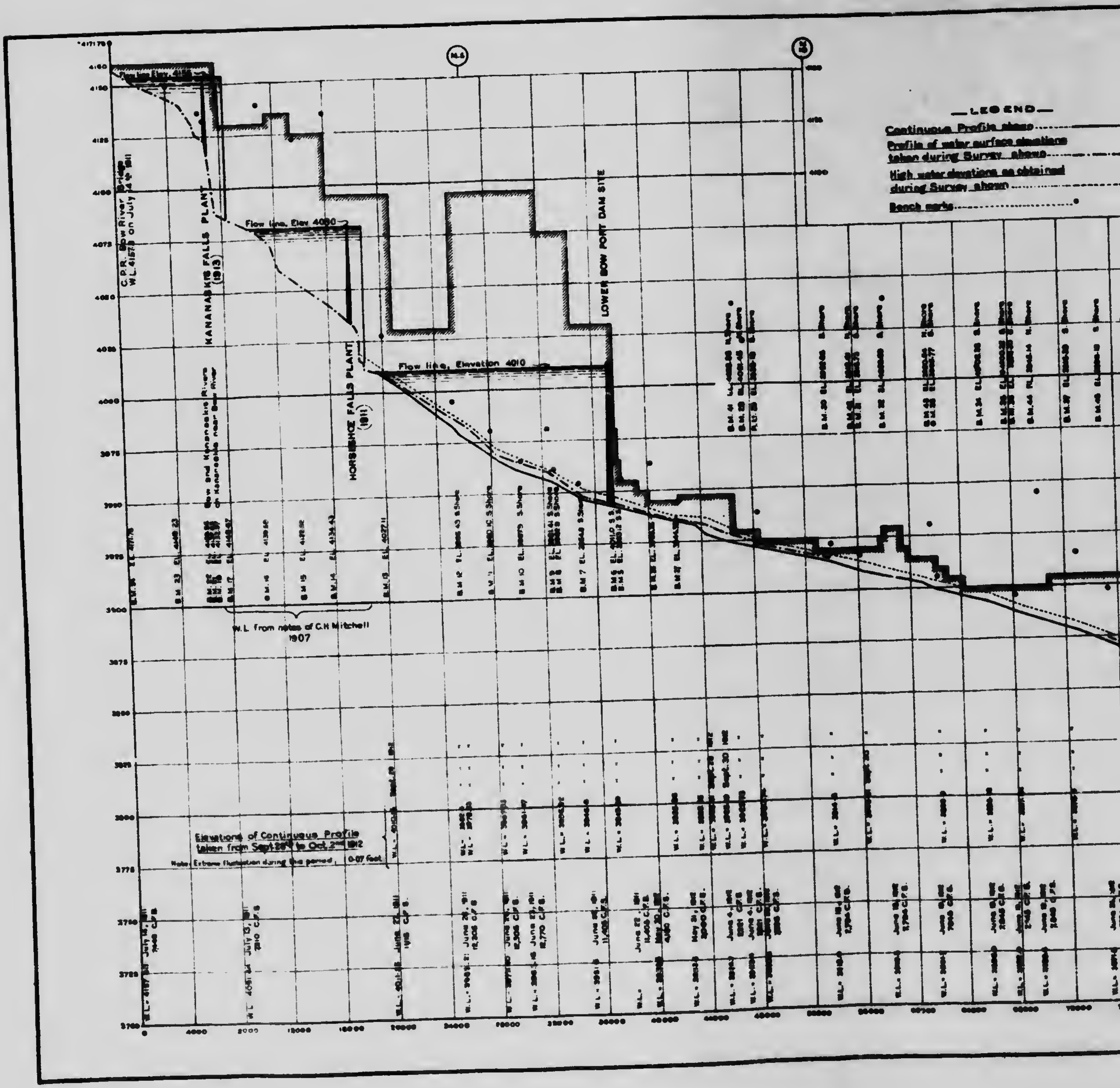
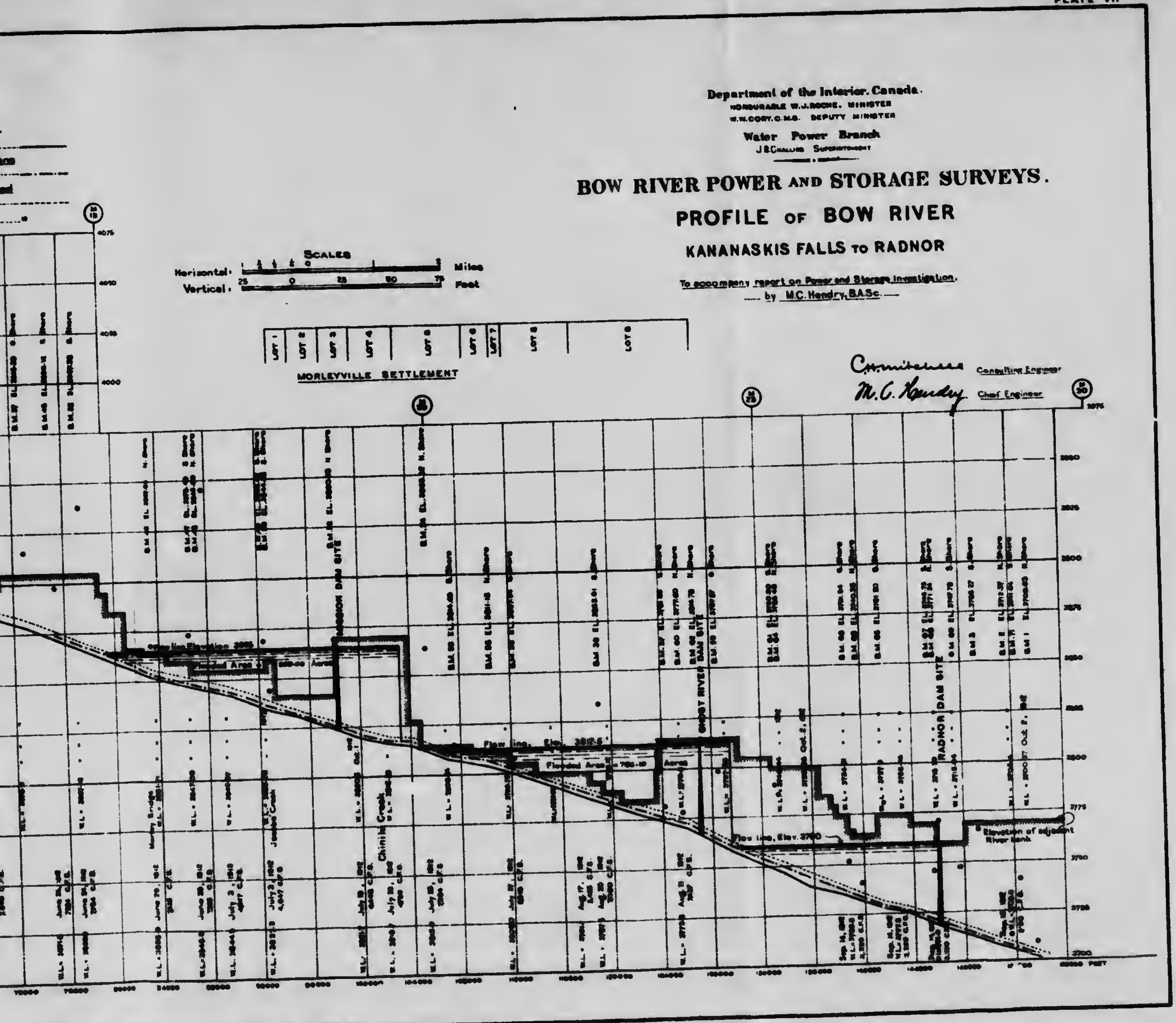


LEGEND
Continuous Profile shown
Profile of water surface elevations taken during Survey shown
High water elevations as obtained during Survey shown
Bench marks
C.P.R. Bow River Bridge
KANANASKIS FALLS PLANT (1913)
Flow line, Elev 4080
HORSESHOE FALLS PLANT (1911)
Flow line, Elevation 4010
LOWER BOW FORT DAM SITE
W.L. from notes of C.H. Mitchell 1907
Elevations of Continuous Profile taken from Sept 28th to Oct 2nd 1912

PLATE VII


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
BOW RIVER POWER AND STORAGE SURVEYS.
PROFILE OF BOW RIVER
KANANASKIS FALLS TO RADNOR
To accompany report on Power and Storage Investigation,
by M.C. Hendry, B.A.Sc.
Consulting Engineer
M. C. Hendry
Chief Engineer
SCALES
Horizontal:
Miles
Vertical:
Feet
LOT 1
LOT 2
LOT 3
LOT 4
LOT 5
LOT 6
LOT 7
LOT 8
LOT 9
MORLEYVILLE SETTLEMENT
GHOST RIVER DAM SITE
RADNOR DAM SITE
Chiniki Creek
Flow line, Elev. 3780
Flooded Area
Elevation of adjacent River Bank

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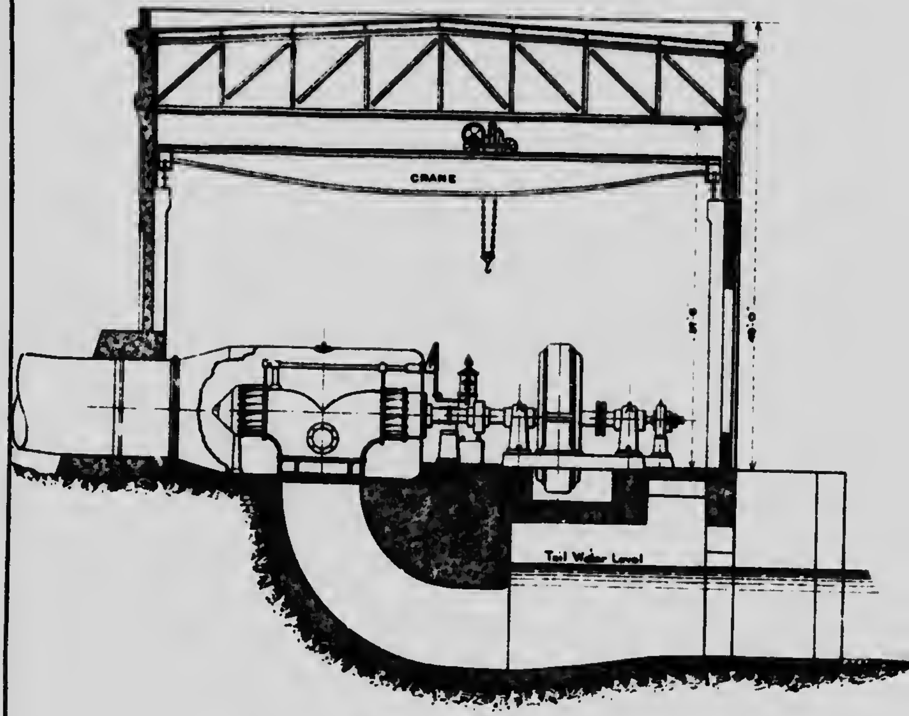


— SECTION —

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.

BOW RIVER POWER AND STORAGE SURVEYS
PLAN AND SECTION OF TYPICAL
POWER-STATION

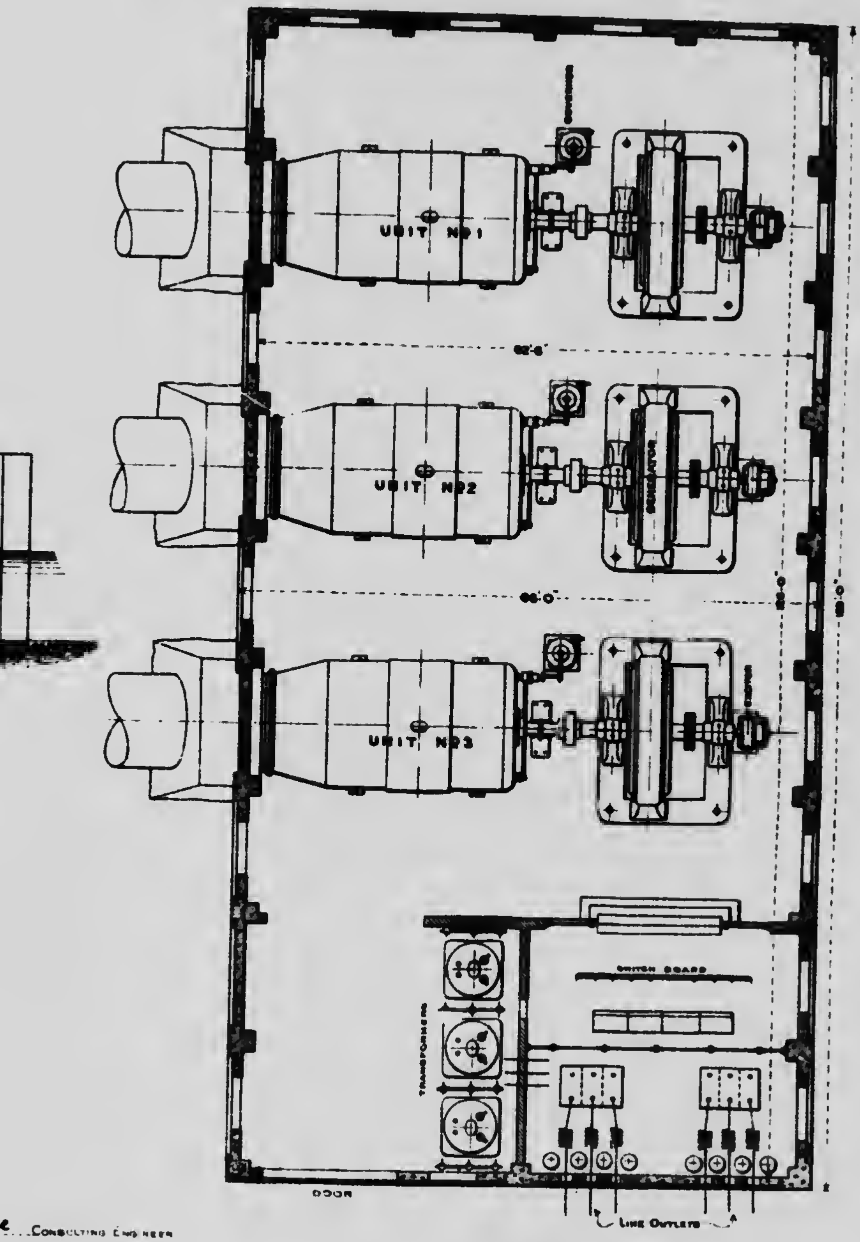
July 1913

C. H. Mitchell ..... Consultin[g]
M. C. Hendry ..... Chief E[ngineer]

FOR ESTIMATING PURPOSES ONLY

Scale of feet.
0 5 10 15 20 25

PLATE VIII



...e ... Consulting Engineer

...4. ... Chief Engineer

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CHAPTER VIII.

STORAGE.

General.

In 1909, work was cc ·enced upon the plant of the Calgary Power Company at Horseshoe Falls, though it was not until the winter of that year that actual gaugings were made of the river during the low water period, and not until the winter of 1910-11 that continuous readings were kept of the discharge.

During January and February, corresponding to the time of minimum flow, fairly complete records were kept; these corroborated the few readings made the previous winter, and revealed a state of affairs that, to say the least, was alarming. These records gave a mean minimum monthly flow of 741 second-feet r the month of February, 1911, and showed that an actual minimum discharge of less than 600 second-feet could be expected for short periods.

The plant built had a turbine installation, capable of an output of 7,500 b.h.p., with provisions to bring it up to 19,000 b.h.p. The situation was, therefore, a serious one for, under existing conditions, during six months of the year w·· was going to waste, while for the remainder of the year, owing to lack of water, a greater part of the plant would stand idle. The demand for power was meanwhile rapidly increasing, the only remedy was storage. By impounding a portion of the water wasted during the flood stage of the river, the low-water flow could be augmented and the situation very materially relieved; the loss due to idle machinery would then be prevented.

Photo by C. H. Mitchell.

Cascade River Power Station Site.

Curves have been prepared, and are embodied in the report which describes graphically the situation.

The whole basin of the Bow river was examined with a view to storage. During the first season a reconnaissance was made of the site most likely to prove satisfactory, the less likely ones being left until the next season. From the reconnaissance of 1911 it was decided that Spray lakes, lake Minnewanka and Bow lake were likely to prove suitable.

A party was sent up to Bow lake in August, and made a survey there, the results of which are given further on. After completing that work it was moved to Lake Minnewanka and made a survey of that basin.

In the summer of 1912, Spray Lake basin was also surveyed, and an examination made for storage of a number of tributaries of the Bow, these proved unsuitable.

A survey was made of the Ghost river for a distance of about 4 miles from its mouth to ascertain the extent to which the river might be used as an auxiliary storage basin. The survey proved that, while a basin might be created, the cost of development would be high and the scheme was one only to be considered as a regulating possibility in connection with plants below the mouth.

Devil's Creek (Old Dam). Photo by M. C. Hendry.

Storage Basins.

The basins that have been and may be developed are therefore:—

1. Minnewanka lake. (developed).
2. Spray lakes.
3. Bow lake.
4. Elbow river storage basin.

Lake Minnewanka.

After the general examination of the Bow drainage basin, lake Minnewanka was settled upon as affording the cheapest, most accessible and easiest developed storage basin. A survey of lake Minnewanka was made by the Calgary Power Company with this object in view.

In the meantime, a policy of conservation and investigation had been formulated by the Railway Lands Branch, Department of the Interior, which at that time handled matters relating to water-power, regarding the question of water-power and storage. This branch commenced active work in this district in the spring of 1911; after a study of the situation, and considerable work in the nature of reconnaissance, a conclusion was reached by the engineers, which, while entirely independent, was practically the same as that of the engineers employed by the Calgary Power Company, namely that storage on lake Minnewanka offered the most immediate relief to the power situation. Towards the end of the summer of 1911, a party was sent in to make surveys of the lake to determine what amount of storage could be economically obtained, the amount of land to be flooded, and, in short, all the necessary information that would enable the branch to deal with the matter; the notes were worked up in the office during the winter of 1911-12, and plans and computations made.

The power situation on the Bow river was rapidly becoming worse, though the records for 1911-12 did not show quite such low water as for the previous year; the market had increased, besides, this slight improvement was not a permanent one. Fortunately when the company asked for certain rights, the branch, owing to the work done in the field, had the situation thoroughly in hand, and was in a position to discuss the situation with the company's representatives, and make certain recommendations based upon information obtained by its own officers.

Owing to the urgency of the situation, it was desirable to obtain an increased flow for the low-water season of 1912-13, and to do this, the high-water run-off during the summer of 1912 would need to be impounded; expedition on the part of all concerned was therefore necessary, prompt action on the part of the branch in granting licence to the company to create storage and prompt action on their part in getting to work.

The policy the branch has had in mind was the control and building of any storage scheme, but this policy had not advanced to the state where the branch was prepared to take up the actual construction and control of storage; as the situation demanded speedy action, and as only the benefit for the present was to the Calgary Power Company the actual building of the necessary works was left to that Company.

Agreement of Development.

An agreement was therefore entered into between the Calgary Power Company and the department, whereby the Company was permitted to create storage upon lake Minnewanka, subject to the control of the department; the amount of storage to be created, limiting elevations, discharge, etc., were fixed and, further, a clause was placed in the agreement whereby the work might be taken over by the department at any time on paying to the company the cost of the work, as determined by the departmental engineer. These particular points are set forth in clause 17, subsections "*d*," "*e*" and "*j*" of the agreement, which reads as follows:—

> "(*d*) The company shall, if required by the Minister, allow a minimum amount of water of 150 cubic feet per second to pass through the dam, which the Government may use for power purposes within the Rocky Mountains park; and the release of such water through the dam shall at all times be under the full control of the Minister or person or persons duly authorized by him for that purpose.
>
> "(*e*) The company shall not raise or reduce the elevation of lake

Minnewanka beyond such limiting elevations as the Minister may from time to time determine are sufficient to supply forty-four thousand (44,000) acre-feet of storage.

"(j) The Government shall have the right upon giving the company sixty days' notice in writing of the intent to do so, to take over, control and operate the said dam upon the payment to the company of the actual reasonable cost to the company of the said dam and of all work required to be done in the Rocky Mountains park pursuant to said clause twelve (12)."

STORAGE BASIN.

Lake Minnewanka offered a splendid site for storage, and one capable of very economical development. Situated in the Rocky Mountains Park, and in close proximity to Banff, it required careful treatment in order that its value as a resort for tourists would be enhanced rather than damaged. The lake is the largest to be found in the Rocky Mountains Park, it is 9½ miles long, and averages over half a mile in width; the waters are very beautiful, being exceptionally clear and of a very deep blue, and surrounded as it is by high mountains, many approaching 10,000 feet, it offers great attraction to the many tourists that visit the region during the summer.

The lake has an area of 5.37 square miles. The banks are generally quite steep, and are for the most part from 15 to 20 feet high, though in places they rise gently to the slope of the surrounding mountains, having a narrow beach at the water's edge. The lake is very deep, and in consequence the shores slope off rapidly into deep water. The south shore is heavily wooded for its entire length, while the north shore is clear of timber in many places; the outlet end of the lake is low, a considerable area being but 2 or 3 feet above the original lake level. Devil's creek forms the outlet of lake Minnewanka; it is a little over a mile in length, and joins the Cascade river at the entrance to Devil's Canyon, which is a narrow gorge in the solid rock, about 500 feet long; at the entrance, this gorge was about 40 feet between rock walls, and 50 feet deep. (See reproductions, pages 66 and 75.) About a quarter of a mile from the outlet of the lake, an old dam existed, which kept the water at lake level, or 4 feet above its former natural level. From the foot of the dam to the mouth of the canyon the fall was 14 feet. A dam placed at the entrance to the canyon would have a double advantage—the natural run-off of the lake would be stored, and also the discharge of the Cascade river, the lake being used as a storage basin for both.

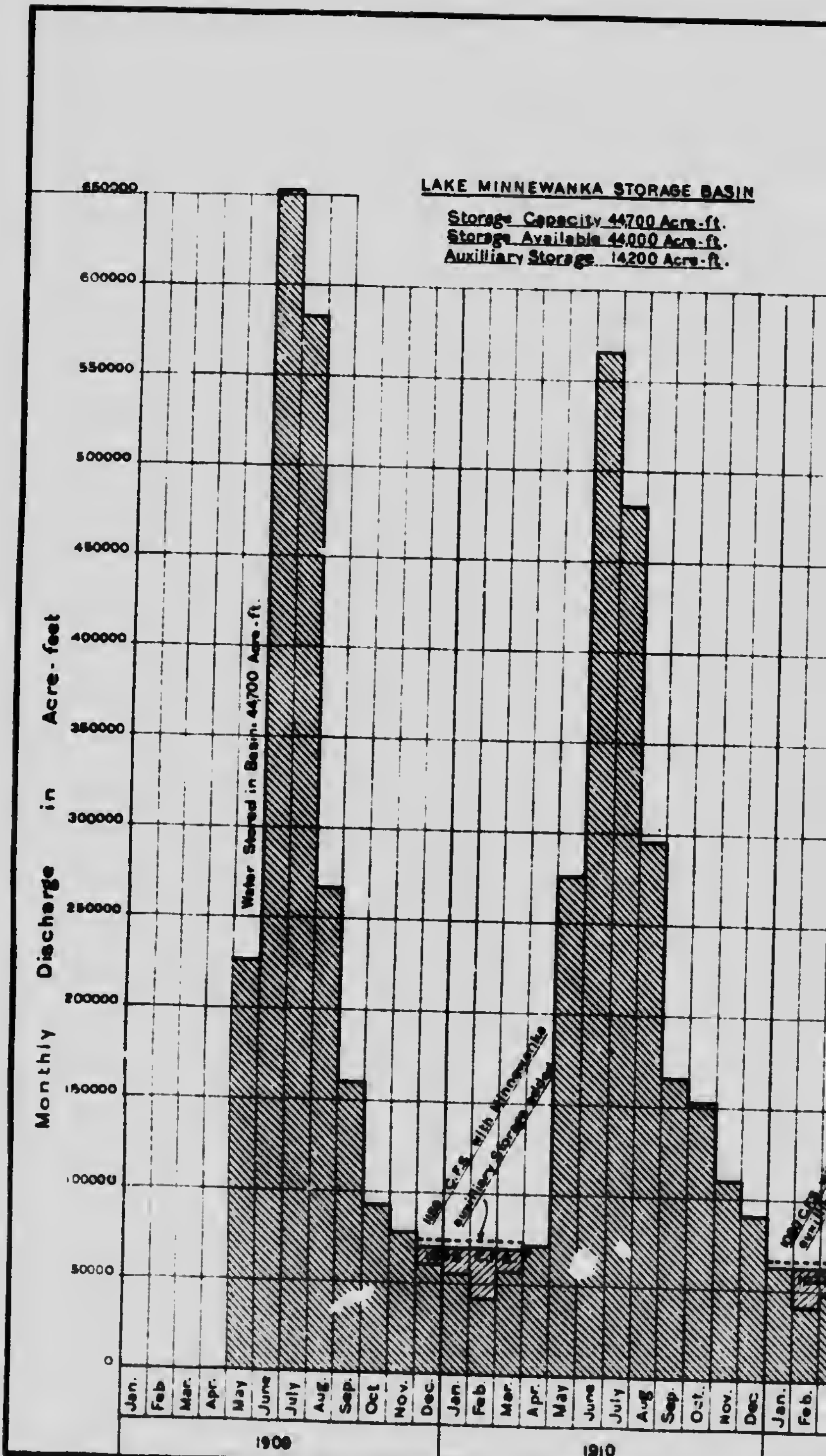
CAPACITY.

After a study of the plans made, it was considered that storage to a depth of 12 feet upon the lake was feasible, this depth meant the flooding of a considerable area at the lower end of the lake and in the Cascade valley, rendering necessary the diversion of the roa[illegible] the replacing of a bridge, the moving of some houses to higher ground an[illegible]so the building of a new dock, with slips for the boats on the lake, all of [illegible]h could be done at comparatively small expense.

The area of the lake at normal level is 3,449.8 acres, and the area within the 12-foot flood line is 4,009.9, thus the area flooded at the lower end of the lake is approximately 600 acres. The storage in round numbers is 44,000 acre-feet. (See diagram, Plate No. 9 for effect upon flow at Horseshoe falls.)

DISCHARGE.

Records of the discharge of Devil's creek and the Cascade river have been taken more or less continuously since 1910. A gauging station was established



LAKE MINNEWANKA STORAGE BASIN
Storage Capacity 44700 Acre-ft.
Storage Available 44000 Acre-ft.
Auxilliary Storage 14200 Acre-ft.
Monthly Discharge in Acre-feet
650000
600000
550000
500000
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Water Stored in Basin 44700 Acre-ft.
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sep.
Oct.
Nov.
Dec.
1909
1910

PLATE IX

BOW RIVER

AT

HORSESHOE FALLS

Diagram shewing Discharge in Acre-Feet. from May 1909 to Feb. 1913

also

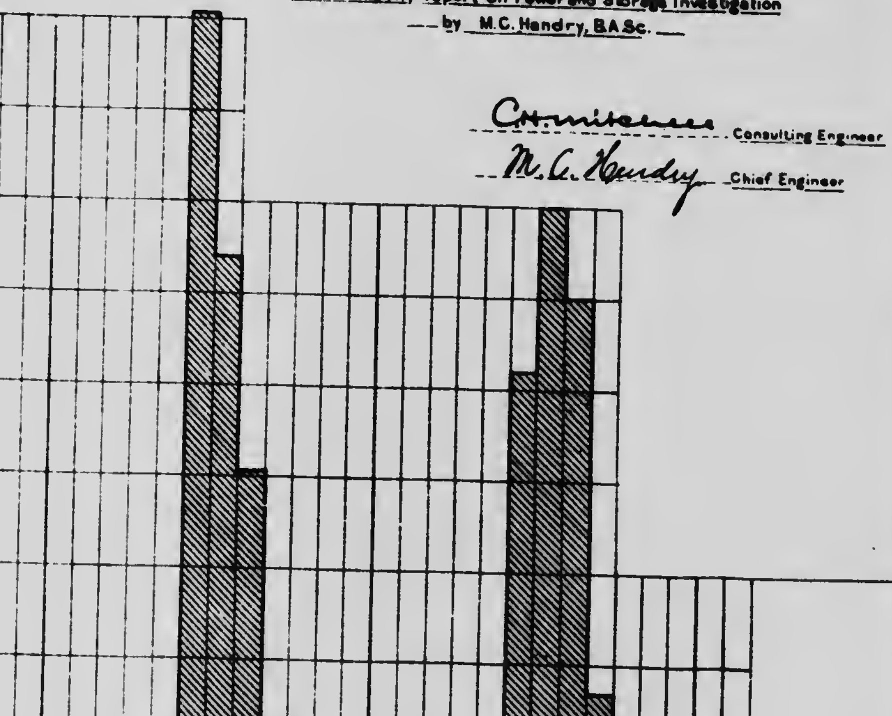
Effect of Lake Minnewanka Storage over low water periods.

To accompany report on Power and Storage Investigation

by M.C. Hendry, B.A.Sc.

C.H. Mitchell . Consulting Engineer

M.C. Hendry Chief Engineer



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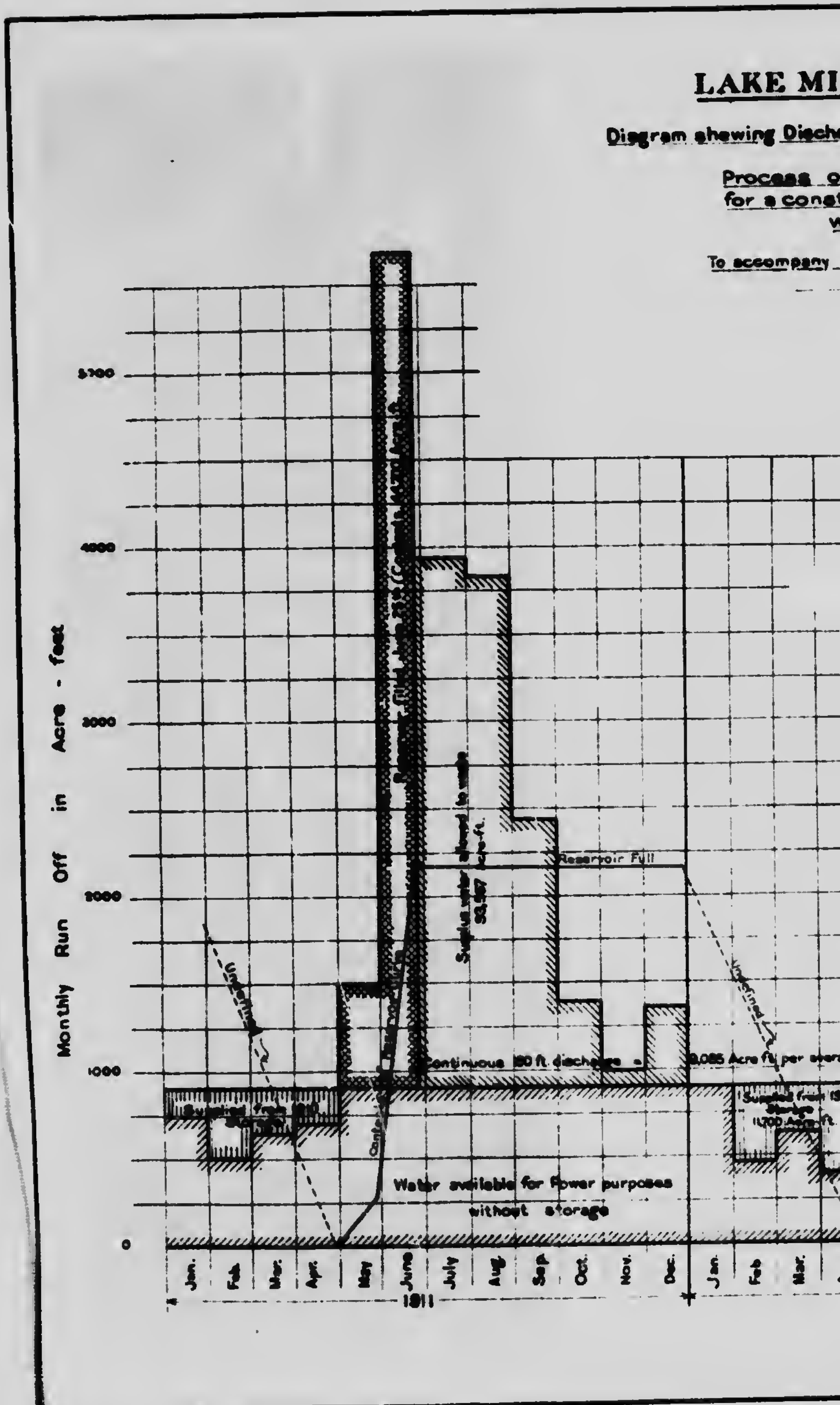

LAKE MI
Diagram shewing Disch
Process o
for a const
To accompany
Monthly Run Off in Acre - feet
5000
4000
3000
2000
1000
0
Reservoir Full
Continuous 150 ft. discharge
Supplied from 1910 Storage
Water available for Power purposes
without storage
Jan. Feb. Mar. Apr. May June July Aug. Sep. Oct. Nov. Dec. Jan. Feb. Mar.
1911

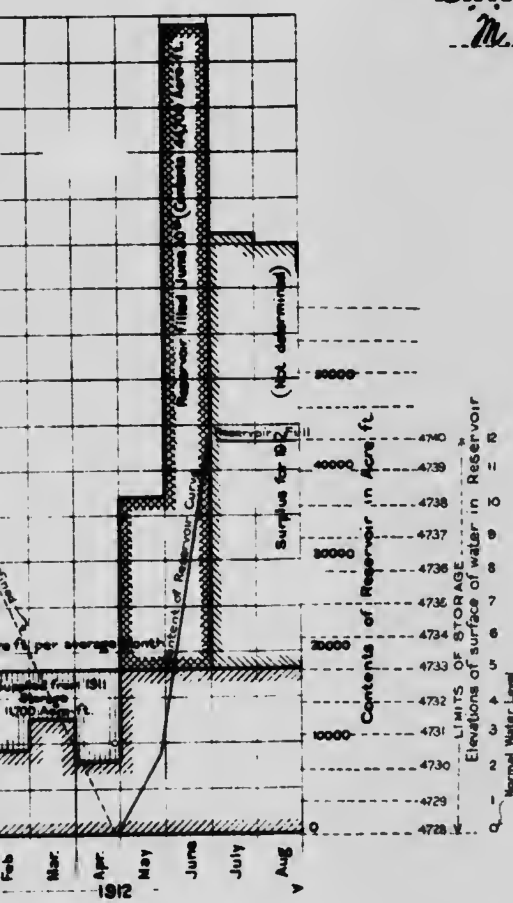
PLATE X

KE MINNEWANKA STORAGE

ing Discharge in Acre-Feet, from Jan. 1911 to Aug. 1912
also
ocess of Filling Basin, and providing
r a constant Discharge of 150 Sec-Ft.
with 12 ft. of Storage

ccompany report on Power and Storage Investigation
— by M.C. Hendry, B.A.Sc. —

C. H. Mitchell Consulting Engineer
M. C. Hendry. Chief Engineer



Wall of Devil's Canyon, Centre line of Dam before Construction.

Photo by M. C. Hendry.

on Devil's creek by the Irrigation branch in June, 1910, and from that date until May 31, 1912, continuous records were kept. Isolated meterings were made of the Cascade during the first part of this period; then in August, 1911, a gauging station was established upon it below the mouth of Devil's creek, from which records are available up to June, 1912. All these records are included in the report.

Diagrams.

From the available records, two curves (see diagrams, Plates Nos. 10 and 13) have been prepared by Mr. J. T. Johnston for the department, and these, supplemented by others, are here made use of. Owing to the lack of continuity in the data for the Cascade during 1910, that period is not included. Diagram, Plate No. 10, is compiled from the mean monthly discharges in sec.-feet for the period January, 1911, to January, 1913, and shows the relation of the reserved flow of 150 c.f.s. to the monthly discharges. Tables have also been compiled in connection with these diagrams. Table No. 11 compiled from the available data shows when the basin could be filled.

In 1911, allowing for a continuous flow of 150 sec.-feet, and commencing to fill the reservoir on May 1, providing for a storage of 44,000 acre-feet, the basin would have been filled by June 24. The surplus run-off (over and above the 150 c.f.s. provided for) up to December 31, would amount to 84,530 acre-feet. During the period, January 1 to May 1, the storage is discharged; no attempt is made to show how this would be done, as it depends upon the stage of the Bow river and the necessity of storage.

In 1912, assuming that the filling of the reservoir was started May 1, 1912, the total amount of 44,000 acre-feet would have been in the basin by July 1, allowing, as before, for a continuous flow of 150 sec.-feet; the surplus discharge that could have been used as storage would amount to 47,700 acre-feet up to September 1, 1912.

From the above it will be seen that there is evidently ample discharge from the lake and Cascade river to fill the basin. Owing to the influx of tourists after July 1, the mere fact of filling is not the sole requisite, and it is desirable that the basin be filled as early after June 15 as possible, so that unsightly flats may not be exposed to view; it is certain, however, that the basin can be so nearly filled by July 1 of any year that no apprehension need be occasioned that the lake will suffer from the scenic standpoint.

TABLE No. 11.

LAKE MINNEWANKA STORAGE, RECORD OF FLOW AND STORAGE WITH 150 SECOND-FEET DRAW-OFF. CAPACITY, 44,700 ACRE-FEET.

Month.	Mean Flow.	Allowing 150 Second-feet Continuous Flow.					Remarks.
		Flow past Power-house.	To fill reservoir.		Surplus Flow.	Surplus Flow in acre-feet.	
			Flow.	Quantity in acre-feet.			
1911.							
January	122						
February	101						
March	104						
April	118						Started filling May 1st.
May	245	150	95	5,841·3			
June 25	956	150	806	38,859			Reservoir filled June 25.
				44,700·3			
June 25-30	956	956			806	9,101	
July	642	642			492	30,252	
August	624	624			474	29,144	
September	411	411			261	15,530	
October	226	226			76	4,673	
November	166	166			16	952	
December	221	221			71	4,366	
						94,018	
1912.							
January	149	150					
February	85	150					
March	102	150					
April	67	150					
May	301	150	151	9,285			Started filling May 1st.
June 30	748	150	598	35,583			Reservoir filled June 30th.
				44,868			
July	538	150			388	23,855	
August	538	150			388	23,855	

(NOTE.—The actual capacity of the basin is 44,700 acre-feet; of this amount 44,000 acre-feet has been granted as storage, and it is upon this basis that the following tables Nos. 11, 12 and 13 are worked out.)

STORAGE CAPACITY.

The limiting levels for storage created on lake Minnewanka were fixed from the surveys made. The existing normal level of the lake was elevation 4,728.00, though this was not the natural level of the lake, which was some 4 feet lower, but had been raised to the existing elevation by a small wooden dam placed in Devil's creek about one-quarter of a mile below the outlet of the lake. (See reproduction, page 72.) This dam was still in place, and during the winter 1911-12, it was cut and a stoplog opening made; stoplogs were put in place, but could be removed with little labour.

The upper limiting level of the lake was placed at 4,740; 12 feet above the existing normal level, giving 16 feet between former normal lake level and the proposed top elevation.

The amount of storage available between elevations 4,728 and 4,740 is 44,700 acre-feet, an excess of 700 acre-feet over the amount of storage granted.

A depth of 0.2 feet in the lake would account for the 700 acre-feet, and as this difference in elevation may easily occur between the lake and the dam, due to storing or drawing down, the limiting elevations were fixed as above. (The effect of this amount of storage upon the Bow river at Horseshoe falls may be seen by a reference to diagram, Plate No. 3.) Between elevation 4,728 and 4,724, 14,200 acre-feet of storage is available, and this may be made use of in connection with a contemplated Government power proposition on the Cascade river.

Construction.

An agreement was entered into between the Water Power Branch and the Calgary Power Company, and the construction of a dam in Devil's canyon to provide for the impounding of water in lake Minnewanka commenced early in the spring of 1912. Plans were submitted by the Company, and after examination by Mr. C. H. Mitchell, Consulting Engineer to the Water Power Branch, certain modifications and additions were required.

Dam.

The plans submitted provided for a concrete dam to be placed at the entrance of the canyon. The dam consisted of a spillway section with four spillways and a sluice-way for unwatering, and a deck to act as a bridge, spanning the canyon, and also to be used to carry the winch for operating the stoplogs in the sluice-ways; provision was also made for a fishway, if required. The changes recommended by Mr. Mitchell were made partly from a study of the plans, and partly as a result of an inspection of the conditions existing in the ground, these are embodied in the accompanying plans and are as follows: In place of the deep sluice-way on the left of the dam, a penstock opening was provided with the necessary racks, intake piers, stoplog openings, etc. A steel thimble to form the intake end of a penstock 5 feet in diameter was placed, this was 12 feet in length, 5 feet diameter at the lower end, and flared to an oval-shaped opening, 5 feet 8 inches by 8 feet 0 inches, so as to give the necessary easy entrance; I-beams were also provided for holding racks. Certain precautions were also recommended and carried out in building.

The construction of the dam was an interesting piece of work. The place is very restricted, and in addition to that, it was necessary to take care of the discharge of lake Minnewanka and Cascade river during construction. To do this, a cofferdam was placed at the entrance to the canyon. A concrete block (see plan No. 17) was first placed at one side of the river bed, the cofferdam extending from the block to the opposite canyon wall; behind this a concrete wall was placed and a flume built with the concrete block as the controlling works, the downstream end being kept at an elevation sufficient to allow the river bottom under the flume to be cleared. The flume was built to provide for a discharge of 300 c.f.s. with a depth of 18 inches (see reproduction page 79). Excavation was carried on behind the cofferdam, and below the flume; the conditions revealed were interesting; the bottom was covered with heavy gravel and boulders to a depth of 8 or 10 feet, and the bedrock was worn into numerous pot holes (see reproductions, page 79). The section containing the sluice and valve was placed first, the flume was then removed and the water diverted through the sluice-way, the other side then built to the level of the first section; after which the whole was carried to the top elevation at the same time.

Large seams existed in the wall rock (see reproduction, page 75). Leakage through these was provided against by facing up with concrete and allowing free discharge on the downstream side; possibility of erosion was insured against by the same method (see plan No. 17). The Cascade is a turbulent stream and carries much silt and gravel in high water; to prevent any possibility of the valve clogging, the concrete cofferdam was left in, and a wall from the cofferdam to the entrance of the sluice-way was built, thus any material carried by the water would be prevented from passing into the sluice-way.

Unwatering Flume. Photo by M. C. Hendry.

Potholes in Canyon Bottom. Photo by M. C. Hendry.

The dam was completed in May, 1912. The construction was carried on by the Foundation Company of Montreal under contract with the Calgary Power Company, and both companies are to be congratulated for the expedition with which the work was carried out and the general appearance of the structure on completion.

Clearing Basin.

Simultaneous with the construction of the dam, the work of clearing the margins of the lake and the area within the flood line at the lower end of the lake, and on the Cascade river was carried on; also such additional work as, removal of buildings, clearing up the new townsite, building necessary road diversions and improving the old road, changing the telephone line and building a new wharf with slips for the boats on the lake. The clearing amounted to nearly 600 acres, a great proportion of the flooded area being very densely wooded, and as the department required careful clearing and low cutting of the stumps, considerable work was involved.

A resurvey of the area devoted to summer cottages, and a change in the layout was made, and some additional lots surveyed; the plot was then cleared up, one or two of the streets were graded and the whole was left in good shape.

Bridge.

The road diversion necessitated a new bridge over Devil's creek; the n bridge was considerably longer than the old one and was built entirely of ti ber, with the exception of the concrete foundation put in to carry the two ma cribs. In order that the west end of the lake and the flooded portion of the Ca cade river might be used for small pleasure crafts, the under side of the string ers of the bridge were placed 4 feet above high-water level, giving ample room for boats to pass under.

The improvements made, such as new wharf, roads, bridge, etc., are illustrated in the accompanying illustrations. The work of creating storage on lake Minnewanka was carried out very expeditiously; work was commenced in March, 1912, a dam built in the canyon, over 600 acres of clearing done, a road diversion of 1 mile made and regraded, a new bridge built, a new townsite surveyed, and buildings moved out of the flooded area and in some cases rebuilt, 1 mile of telephone line rebuilt, a new wharf built and two slips provided, together with a marine railway for each, all of which was completed by the 1st of July. The storage of water was commenced on June 1, 1912, and the level was raised to 4,740 by August 12; the storage could have been completed much earlier, but was held back by the progress of the clearing, so that flooding did not begin until the date given.

Power in Connection with Storage.

Lake Minnewanka is 8 miles by road from the well-known mountain resort, Banff, the visitors to which are rapidly increasing in numbers. This town is the principal place in the Rocky Mountains park, and from here many camping parties enter the mountains. As a place where people may spend the summer either at the hotels or in summer cottages, it offers many attractions, and in passing it might be mentioned that three times as many people visited Banff during the summer of 1911 as visited the famed Yellowstone park. With this increased population, the necessity of power for lighting streets and houses has also increased; at present the power is supplied from the Bankhead mines, which is 5 miles from Banff, on the road to Minnewanka; no franchise has been given, the street lighting being done by yearly contract.

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Diagram shewing Disc

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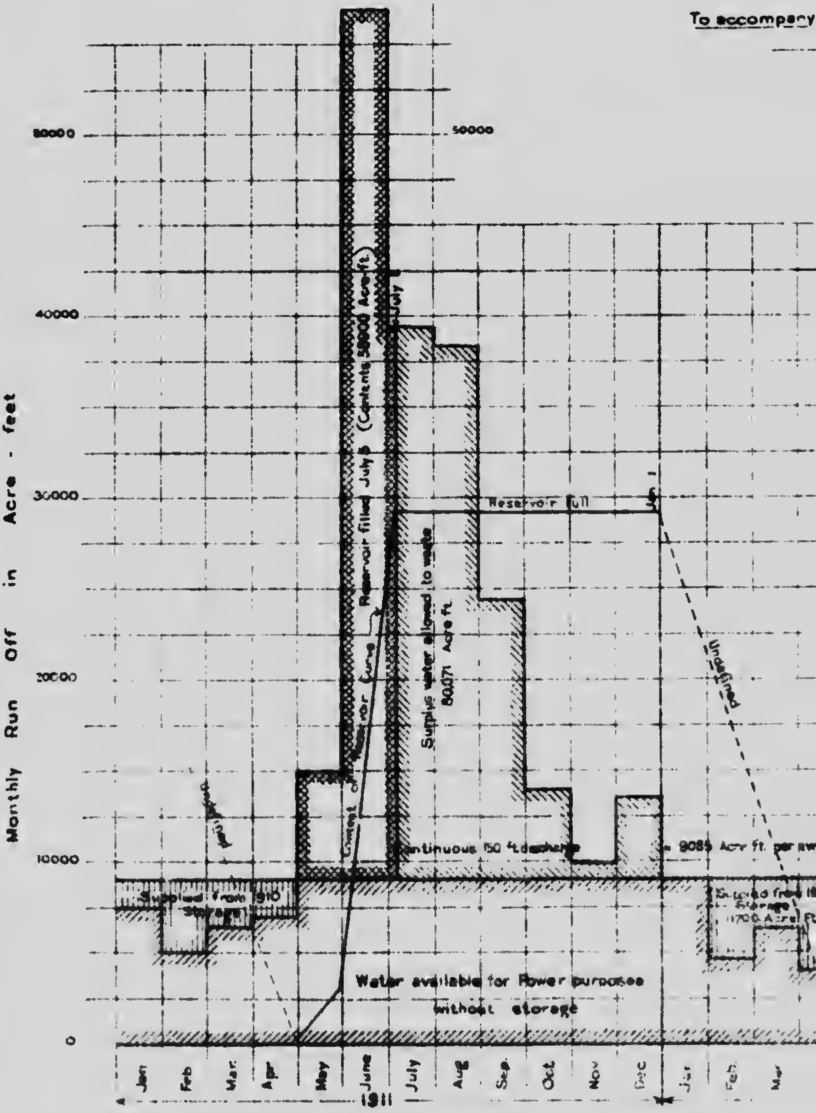


PLATE XI

[L]AKE MINNEWANKA STORAGE

[Sho]wing Discharge in Acre-Feet, from Jan. 1911 to Aug 1912

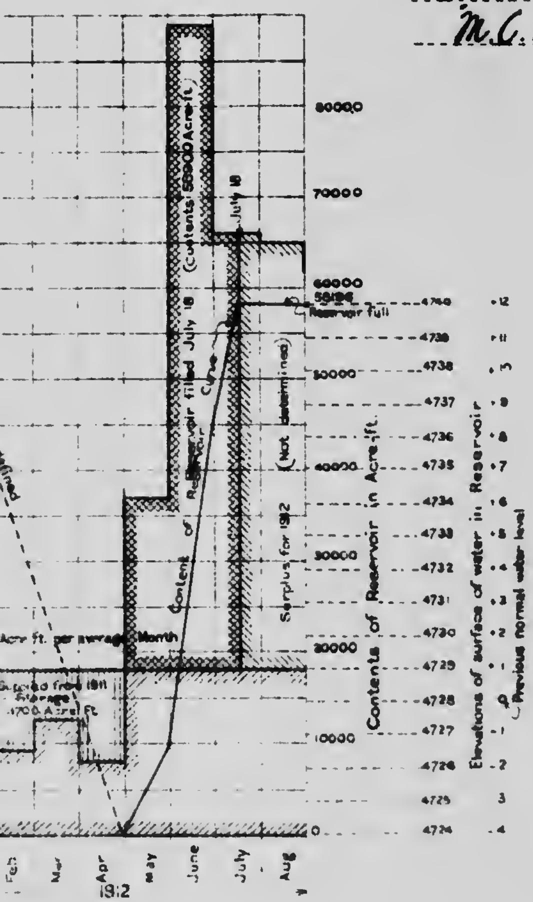
— also —

[P]rocess of Filling Basin, and providing [f]or a constant Discharge of 150 Sec-Ft. with 16 ft. of Storage

[To] accompany report on Power and Storage Investigation by M. C. Hendry, BA.Sc.

C. H. Mitchell .... Consulting Engineer

M. C. Hendry .... Chief Engineer.



Compiled from data on hand to date by

J. T. Johnston
Hydraulic Engineer

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The park and town are under the Dominion Government control through the Parks Branch, Department of the Interior. Under the conditions existing, it was considered that a power plant operated by the park authorities would be a good thing; the feasibility of producing power in connection with the storage in lake Minnewanka was looked into, and the conclusion was reached that such was possible. Provision for the utilization of the storage dam as head-works of the power scheme was therefore secured, and the plans show the method of making use of the storage dam as an intake for the plant.

Utilization of Flow for Power from Extra Storage.

In connection with the storage of water in lake Minnewanka, when the agreement was made with the Calgary Power Company, granting them the right to store water in the lake, a clause was inserted whereby the department reserved the right to a continuous flow of 150 second-feet, to be used for development of power or other purposes; in addition, the company was required to so modify the design of the structure as to permit of it being made use of as head-works for a power plant, the construction of which the department had in mind. The discharge data in this connection is interesting, and some of the diagrams included are to illustrate the utilization of the water discharged from storage for that purpose. In making use of the water in such a manner, a continuous flow is necessary, and in making provision for 150 c.f.s. continuous flow it was not the intention to work a hardship to the company, as there might be occasions when it would be advantageous to conserve the storage as much as possible. Having in mind this point, an investigation was made as to the effect of the department making use of 4 feet extra storage, not by raising the lake an extra 4 feet, but by drawing it down to a lower level; by this method, 14,200 acre-feet could be made available. The diagram shown on Plate No. 11, together with Table No. 12, compiled by Mr. Johnston, was plotted with this object in view; these are self-explanatory. The basin, as in the other case, is assumed empty May 1, 1911, but at the lower elevation 4 feet below normal lake level; deducting the 150 c.f.s. reserved from the mean monthly flow, it is found that the reservoir could have been filled by July 1, 1911, or 58,900 acre-feet could be stored. From then until December 31, 1911, 80,071 acre-feet would be wasted, over and above the 150 c.f.s. discharge. During the interval of low water, *i.e.*, with less than 150 c.f.s. discharge, from January 1 to May 1, 11,699 acre-feet would be required from storage, to make up the flow to 150 c.f.s., or less than the extra storage secured by lowering the basin 4 feet below normal lake level. So that, had it been necessary to utilize the storage at other than the time it was required by the Calgary Power Company, it would still be possible to pay them back out of the department's reserve. The method of emptying the basin is indeterminate, but filling is again commenced (at the low level) on May 1, 1912, from which date to August 30, the limit of the data, some 33,850 acre-feet, was wasted, after allowing for the 150 c.f.s. discharge called for. In this scheme, as in the other, no detrimental effects are to be expected from the slight delay in filling the basin, as by July 1 only the top rim of the lake would be exposed.

It will be noted in examining the tables that the total storage capacity of the basin is given as 44,700 acre-feet for the 12-foot storage and 58,900 feet for the 16-foot storage, and that only a run-off of 44,000 acre-feet has been granted; this is to provide for some leeway in regulation.

Utilization of Flow of 200 Second-feet with Extra Storage.

The scheme was then extended a little further, and diagrams and a table prepared on the assumption of 200 c.f.s. continuous run-off. The diagram, Plate

No. 12 and Table No. 13 cover this case. Beginning at the same time, and assuming as before the lake level 4 feet below normal level, the reservoir could be filled by July 12; 58,180 acre-feet being stored from then until October 31,

TABLE No. 12.

LAKE MINNEWANKA STORAGE. RECORD OF FLOW AND STORAGE WITH A 150 SECOND-FEET DRAW-OFF. CAPACITY 58,900 ACRE-FEET.

Month.	Mean flow c.f.s.	Flow past Power-station.	Allowing 150 Second-feet continuous flow.						Remarks.
			To fill reservoir.		Surplus flow, c.f.s.	Surplus flow, in ac.-ft.	Deficit flow, c.f.s.	Deficit flow, acre-feet.	
			Flow c.f.s.	Flow ac.-ft.					
1911.									
January	122	.....	.....	.....	.....	.....	.....	.....	
February	101	.....	.....	.....	.....	.....	.....	.....	
March	104	.....	.....	.....	.....	.....	.....	.....	
April	118	.....	.....	.....	.....	.....	.....	.....	
May	245	150	95	5,850	.....	.....	.....	.....	Started filling May 1.
June	956	150	806	47,980	.....	.....	.....	.....	
July 1-5	642	150	492	4,870	.....	.....	.....	.....	
				58,700					
July 6-31	642	542	.....	.....	492	25,370	.....	.....	Reservoir filled July 5.
August	624	624	.....	.....	474	29,160	.....	.....	
September	411	411	.....	.....	261	15,550	.....	.....	
October	226	226	.....	.....	76	4,672	.....	.....	
November	166	166	.....	.....	16	953	.....	.....	
December	221	221	.....	.....	71	4,366	.....	.....	
						80,071			
1912.									
January	149	150	.....	.....	.....	.....	1	60	
February	85	150	.....	.....	.....	.....	65	3,743	
March	102	150	.....	.....	.....	.....	48	2,953	
April	67	150	.....	.....	.....	.....	83	4,943	
								11,699	
May	301	150	151	9,285	.....	.....	.....	.....	Started filling May 1.
June	748	150	598	35,600	.....	.....	.....	.....	
July 1-18	538	150	388	13,850	.....	.....	.....	.....	Reservoir filled July 18.
				58,735					
July 19-31	538	538	.....	.....	388	10,000	.....	.....	
August	538	538	.....	.....	388	23,850	.....	.....	

55,990 acre-feet would be wasted, after providing for a continuous flow of 200 c.f.s. Through the low-water period, 26,130 acre-feet would have to be released from storage to ensure a continuous flow of 200 second-feet. While this is in excess of the amount of storage in the lower 4 feet, it is reasonable to suppose that part would be provided by water released for the Calgary Power Company's own purposes. Beginning to store on May 1, 1912, that basin would be filled by July 29. This is assurance that, should the department find it necessary to increase the output of the contemplated plant at any future time, a flow of 200 c.f.s. can be obtained by making use of the additional storage. Further, the possibility of any difficulty arising from the regulation of discharge from storage for power purposes in the Bow river is practically eliminated, the department being in a position to offer return for any overdraft on the storage

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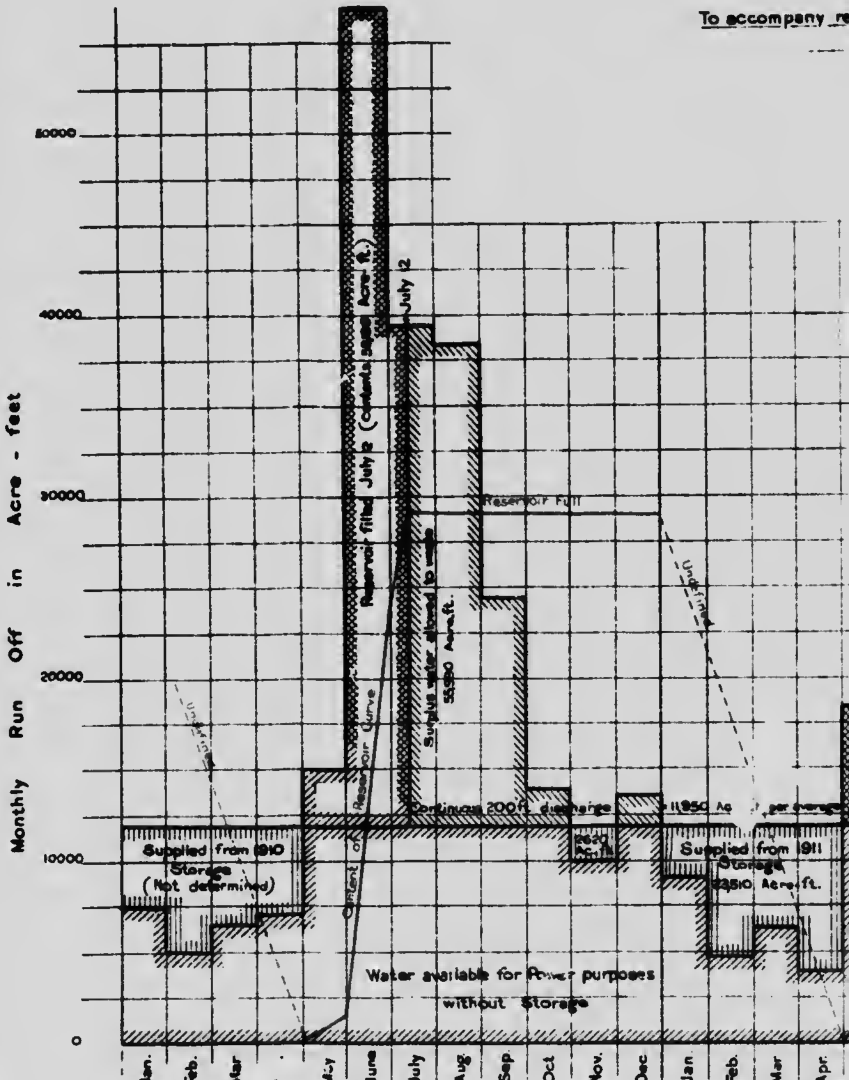
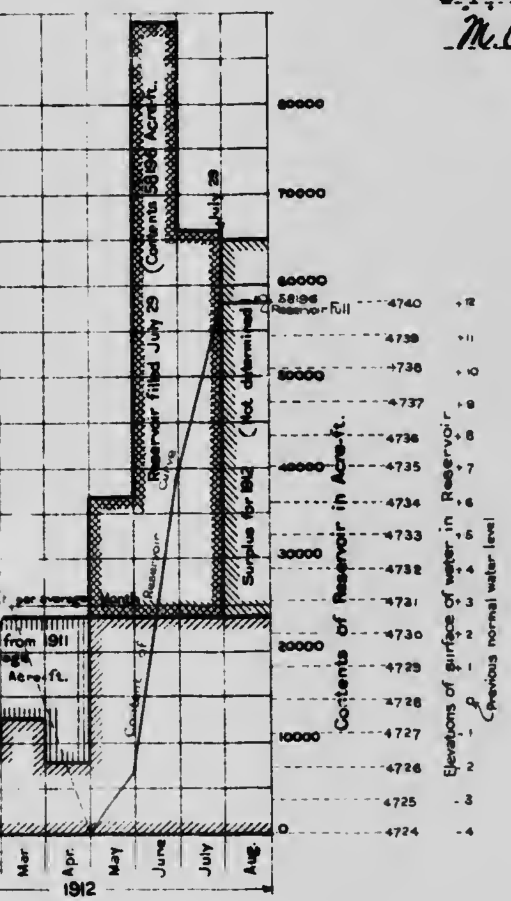


KE MINNEWANKA STORAGE

g Discharge in Acre-Feet, from Jan. 1911 to Aug. 1912
— also —
cess of Filling Basin, and providing
a constant Discharge of 200 Sec.-Ft.
with 16 ft. of Storage

company report on Power and Storage Investigation
by M.C. Hendry, B.A.Sc.

C. H. Mitchell Consulting Engineer
M. C. Hendry Chief Engineer



Compiled from data
on hand to date by

J. T. Johnston
Hydraulic Engineer

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LAKE MINNEWANKA STORAGE

Hydrograph of Mean Monthly Flow, from January 1911 to August 1912

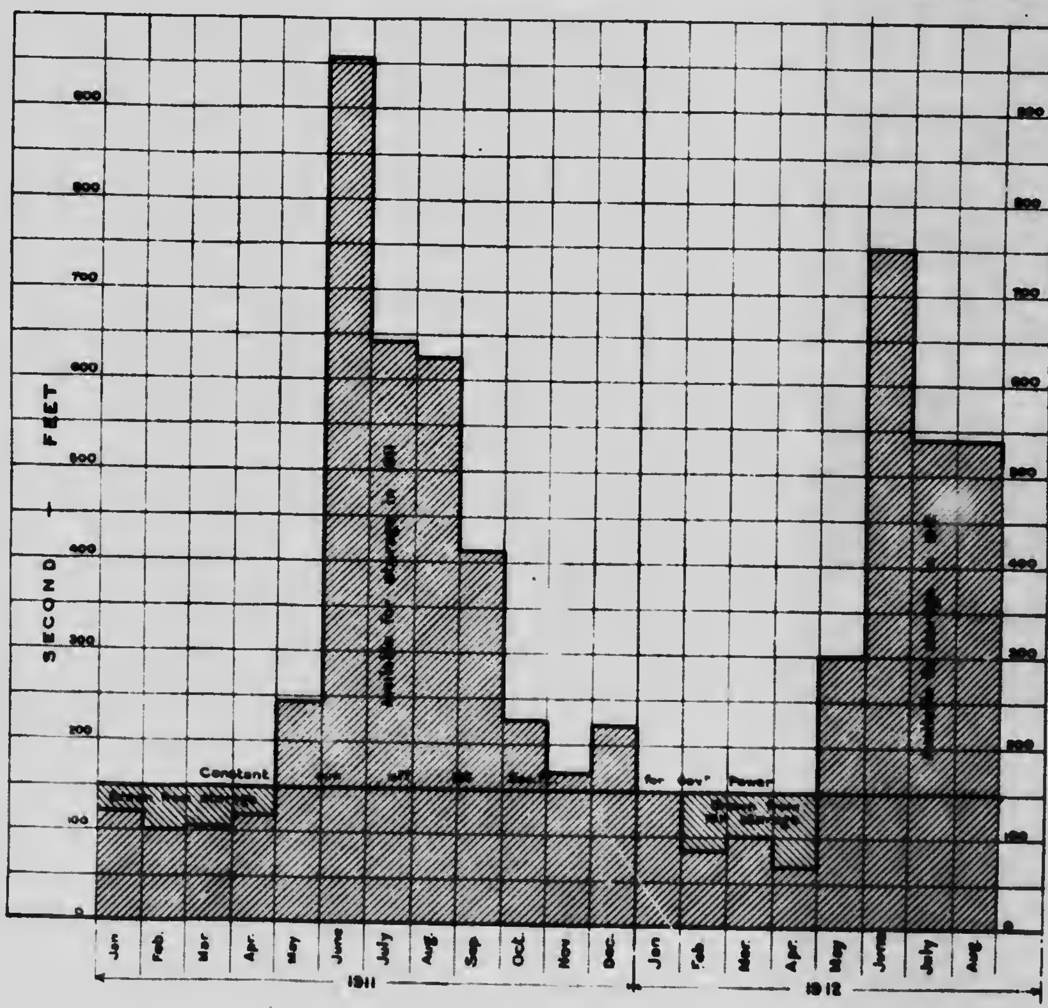
— showing —

Conditions imposed by a constant Run Off of 150 Sec.Ft.

To accompany report on Power and Storage Investigation
— By M.C. Hendry, B.A.Sc. —

C.H. Mitchell .... Consulting Engineer

M.C. Hendry .... Chief Engineer



basin at the beginning of the low-water season, and in this way each water user may aid the other, and the discharge may be so adjusted as to be of the greatest mutual benefit.

The storage of 44,000 acre-feet in lake Minnewanka provides for a continuous flow for five months of 150 c.f.s. (see diagram, Plate No. 13), nearly all of this will become available for use in the power section of the Bow river; any loss due to evaporation may be neglected, for after the basin is once filled there is more than enough flow to keep it full, and when the lake freezes, this loss is practically stopped.

Under the general head of evaporation, all losses are included; that due to ice is the largest and the most difficult of determination. The storage in the lake, which is held in the form of ice, is not all available until the latter end of April, or even later, though doubtless the greater part of it will become available before the general flood takes place on the river.

TABLE NO. 13.

LAKE MINNEWANKA STORAGE. RECORDS OF FLOW AND STORAGE WITH A 200 SECOND-FEET DRAW-OFF CAPACITY 58,900 ACRE-FEET.

Month.	Mean Flow c.f.s.	Flow past Power-station.	Allowing 200 c.f.s. Continuous Flow.						Remarks.
			To fill reservoir.						
			Flow c.f.s.	Quantity in ac.-feet.	Surplus flow in c.f.s.	Surplus flow in ac.-ft.	Deficit flow c.f.s.	Deficit flow acre-feet.	
1911.									
January	122								
February	101								
March	104								
April	118								
May	245	200	45	2,680					Started filling May 1.
June	956	200	756	44,970					
July 1-12	642	200	442	10,530					Reservoir filled July 12.
				58,180					
July 13-31	642	642			442	15,780			
August	624	624			424	26,050			
September	411	411			211	12,560			
October	226	226			26	1,600			
November	166	200					44	2,620	
December	221	221			21	1,290			
1912.						57,280			
January	149	200					51	3,180	
February	85	200					115	6,390	
March	102	200					08	6,030	
April	67	200					133	7,910	
								26,130	
May	301	200	101	6,130					Started filling May
June	748	200	548	32,630					
July 1-29	538	200	338	19,450					Reservoir filled July 29.
				58,210					
July 30-31	538	538			338	1,340			
August	538				338	20,780			

INFLUENCE OF WINTER CONDITIONS ON DISCHARGE FROM STORAGE.

The dissipation of storage through the formation of ice, and the extent of its influence has required considerable attention. During the winter 1912-1913, a study was made of the situation. The release of water from lake Minnewanka the last winter was not attended with unmixed success from the power standpoint. One reason for this was the distance between the storage basin and the point of utilization, approximately twenty-four hours being required for water from the lake to reach the power station, thus close regulation was prevented; a scheme is now on foot to remedy this. Another adverse influence was the formation of ice in the bed of the Cascade river, and overflow of the valley. This condition existed to a very marked degree between Bankhead and the junction with the Bow, for as is the case with all rapidly flowing open streams during extreme cold weather, large quantities of frazil ice was formed in the Cascade; this ice formed blockades, dammed back the river, flooding the flats where the water was turned into ice. Nearly the whole of the section referred to was covered with a sheet of ice, extending across the valley. In places this ice field was two or three hundred yards across and of a depth of 3 feet. Where the valley was more confined, the sheet was not so wide, but was as much as 7 feet thick (see reproductions, pages 19 and 25). No doubt, the formation of anchor ice had something to do with the flooding, but frazil appears to have been the greatest cause, coupled with other conditions.

From a study of the discharge curve of lake Minnewanka during the winter, together with the temperature curve for the same period, the following conclusions have been drawn. During the periods of comparatively mild weather, little water was flowing in the river, the channel became very much restricted and clogged with the ice margins and hard snow. Directly a cold snap came, a considerable quantity of water was released, frazil formed, and blocked up the restricted channels, the flats, overflowed and froze, causing ice fields.

From an examination of the other streams in the vicinity, this explanation is apparently confirmed, because little evidence of overflow and ice formation existed at the end of the season. The normal flow apparently did not have the same effect as that of a regulated stream where little water flowed during normal, and large quantities during severe weather.

It is expected, in view of this, that with a plant in Cascade below the dam, and a consequent continuous flow of considerable volume, little difficulty will be experienced from ice after the plant is installed.

The loss of water due to ice formation in the stream is rather a loss of regulation than actual loss of water, as nearly all eventually becomes available during the latter end of the low-water period, the ice in the streams disappearing long before the high-water period.

SPRAY LAKE AND RIVER.

General.

The Spray river, one of the largest tributaries of the Bow west of Calgary, joins that stream in the Rocky Mountains park, at Banff, just below the Spray falls on the Bow. Flowing from the south, it enters the Bow valley between mount Rundle and Sulphur mountain; it is between 40 and 50 miles long from source to mouth, and has a drainage area of 310 square miles. About 8 miles above the mouth, the river branches, one branch, the east and smallest, flows from the valley between mount Rundle and Goat mountain.

The west branch comes down the valley on the other side of the Goat range. The fall in the river is fairly regular, about 40 feet per mile, the valley is very narrow and the banks are very high and precipitous. From the junction upstream for about 17 miles, this branch flows through a narrow valley between the Goat range and the range to the west, and the total drop in the distance is 750 feet. In this stretch there are very few creeks of any size coming in; the possibility of power has not been investigated, but it is quite possible that a limited amount, such as that to be developed on the Cascade in connection with the storage at lake Minnewanka, might be developed.

At the end of this stretch of the river, it breaks up into three branches, the main branch from the south, one which forms the outlet of the Spray lakes and Hogarth creek. (See reproduction, page 95).

The principal branch is from the south. About 5 miles above the lakes it divides into two branches, one to the east heading on the main continental divide in a small lake, and the other from the west having its source in a small lake under mount Assiniboine. The fall in these two branches is considerable, but no records are available as to the slope.

Hogarth creek is rather small, and flows between the Spray and Kananaskis ranges, heading on the divide between the Spray and Kananaskis rivers.

Photo by K. H. Smith.
Spray River Canyon (Looking Upstream).

LAKES.

The Spray lakes, three in number, lie to the north of the river. They are connected with it by a stream about half-a-mile in length, which enters just below the mouth of Hogarth creek. The lakes lie in the main valley between high mountains, and are connected by small streams. The lower and largest lake is 301 acres in extent, and lies at an elevation of over 5,000 feet, given on the maps as 5,396, but assumed for purposes of survey at 5,200 feet. The second lake, which is 37 feet higher than the first, is 143 acres in extent, and the third has an area of 17 acres, and is 3 feet higher than the second lake. The total area of the lakes is 461 acres.

Photo by K. H. Smith.
Spray River Canyon (looking down stream).

Reconnaisance.

A reconnaisance was made of these lakes in July, 1911, but it was not until July, 1912, that any work was done there. At that time a small party was put in the field, consisting of an engineer and two assistants, a cook, and a packer with a pack train. The surrounding country, while wooded to a considerable extent, is fairly open, the timber being generally dry, and standing, permitting the use of a plane table, by which method the whole valley was developed.

The reconnaissance revealed the fact that the general topography of the country surrounding the lakes lent itself to the creation of storage. The main branch of the Spray at this point comes from the south, is joined by Hogarth creek from the east and the outlet of the lakes from the north; and at the junction of these creeks a wide valley is formed. About one-quarter-of-a-mile from the lower lake, just below the junction of the branch from the lakes and the main stream, the river leaves the valley through a narrow canyon, the walls of which are of rock formation, covered, to a greater or less extent, by soil and detritus, and are wooded. These walls rise on a slope of not less than 60°, to a height of at least 300 feet, the rock outcrops being nearly perpendicular for a great portion of their height. (See reproductions, pages 85 and 86). This canyon extends downstream about a mile, the stream falling rapidly; the width at the water level is from 60 to 150 feet, and at an elevation of 150 feet above the water, between 400 and 450 feet.

There is evidence of rock above this point, and on the south side an outcrop appears at an elevation of over 160 feet above water level, and extends up and down stream as far as was examined.

The rock on the south is of limestone formation, and appears to dip towards the south, and is overlaid to a considerable depth with a glacier deposit. On the north side the rock resembles a sandstone formation, the valley having been formed apparently in the fault between the two formations as on the north side the dip is practically vertical; the rock rises higher, and is overlaid to a greater depth than on the south side, the outcrop appearing at least 200 feet above the level of the water.

The conclusion reached from the reconnaissance was that, by placing a dam in this canyon, as near the mouth as practicable, considerable storage could be developed in the basin behind.

SURVEY.

The survey made of the basin in the summer of 1912 was made with the object of verifying the conclusions reached in reconnaissance. The work was done as rapidly as possible by plane table, and with a degree of accuracy commensurate with the object in view. Special attention was paid to the canyon, which was contoured with care, with the object of locating several dam sites, all rock outcrops, etc., were located in order that fairly close estimates might be made of the probable cost of control structures.

A careful study was made of the canyon at the time the survey was commenced, and it was decided to make the 5,300 feet contour (lake level, 5,200), the limiting elevation, as far as the structure in the canyon was concerned, though it was not certain at the time that this would not lead to difficulties in other parts of the valley. With this in mind, the contours were developed by the plane table, particular attention being given to the 5,250, 5,275 and 5,300 contours, though sufficient information was taken to develop the intermediate ones at 10 foot intervals.

The method pursued was to run traverses with the plane table, making use of two rod men, sometimes the packer was pressed into service. Vertical angles were read.

No attempt was made to follow out a contour by horizontal shots, but by controlling all the changes in the ground, and sketching, on the ground, the country was developed. Frequent checks were made to eliminate errors. When the sheets were finally assembled, it was found that the traverses closed well within the permissible error for such work, and frequent checking for elevation exhibited the same condition.

In referring to this basin it seems well to draw attention to this method of survey. Where the country is of such a nature that control of the ground may be had, there is no doubt that the plane table will give results quite accurate enough for preliminary work and if extra care is taken, results may be obtained upon which final estimates for the creation of storage may be based. The personnel of the party has been given before, but is repeated: one plane table man (engineer in charge), two rodmen, one handy man, one packer, and eight pack horses; on moving days the handyman acted as packer, and at odd times he cooked and, when the party was working in timber, he acted as axeman. This party operated 30 miles from the base of supplies. Including the time of moving in and out, and actual work in the field, but excluding the cost of the work of the chief engineer, the work was done at a cost of 25 cents per acre, which, considering the value of the data secured, is very reasonable.

Area and Capacity.

The area contoured was roughly eight and one half miles long and three-quarters of a mile wide, giving inside the 5,300 contour, an area of 3,024 acres. This includes the three lakes in the valley and also the falls on the main branch of the river. The area inside the 5,275 contour is 2,429 acres; inside the 5,250 contour, the area is 1,755 acres; and inside the 5,220-foot contour the area is 729 acres. The quantity of water that could be stored below each contour is 171,129, 102,829, 49,986 and 11,880 acre-feet, respectively. A curve giving the contents of the basin at each foot of elevation shows that the storage capacity increases much more rapidly at the top of the reservoir than at the bottom. This curve, which is remarkably regular, emphasizes the advantage in storage capacity to be gained by raising the control works as high as possible. The assumption has been made in this report that the basin will have its upper level at 5,300, giving, in round numbers, a total storage of 171,000 acre-feet; of this amount, 160,000 acre-feet has been made the basis of all calculations, the remainder it is assumed being dissipated as evaporation or otherwise.

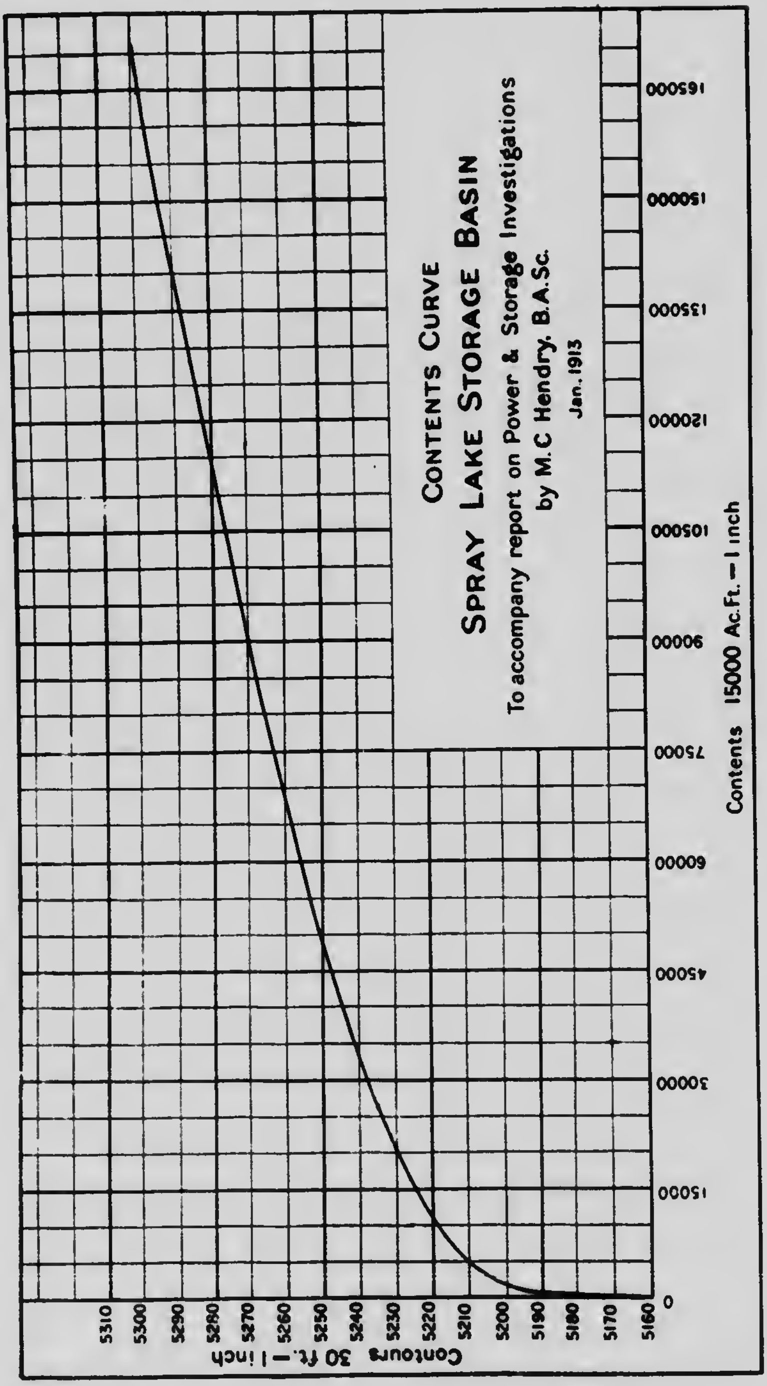
Discharge.

The gauging station on the Spray river, established in July, 1910, is located about 100 yards above the junction with the Bow, and in consequence the total discharge of the river is measured at that point. The records have been kept continuously since the establishment of the station, except for the month of November, 1910.

The only stream of consequence entering the Spray between the gauging station and the lakes, is the branch coming in at the end of Goat mountain; the discharge from this stream forms, however, but a small proportion of the total flow. The river heads for the most part in the glaciers and snow fields of the summit range, so that it is safe to assume that fully three-fifths of its discharge comes from above the entrance to the canyon, near the Spray lakes.

The results of the gaugings are tabulated and included with data of a like nature. A diagram (see plate No. 5) shows graphically the mean monthly discharge of the river over the period recorded. The discharge for the period, October 1, 1910, to October 1, 1911, excluding November, 1910, is 398,687 acre-feet; it may therefore be assumed that the discharge was well over 400,000 acre-feet for the whole period. The records do not extend over a sufficient period to enable any definite conclusions to be drawn, but the amount of water available for storage during the high-water period is estimated to be about twice that of the capacity of the storage basin.

From the discharge tables it will be seen that the minimum mean monthly discharge for the period recorded was 108 c.f.s. in March, 1912. The maximum mean monthly flow was 2,011 c.f.s. in June, 1911. The absolute minimum daily flow recorded was 75 c.f.s. on March 29, 1912, and the maximum daily discharge was 2,640, June 18, 1911. It is interesting to note that the period of minimum flow is apparently during the month of March rather than February, as in the other streams, but whether this will always hold true, and the reason for it, is not apparent.



CONTENTS CURVE
SPRAY LAKE STORAGE BASIN
To accompany report on Power & Storage Investigations
by M.C Hendry. B.A.Sc.
Jan. 1913
Contents 15000 Ac.Ft. — 1 inch
0
15000
30000
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60000
75000
90000
105000
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Storage Operation.

Another diagram, Plate No. 14, has been prepared showing certain conditions of filling and emptying the storage basin based upon the recorded discharge of the river. In this connection it was necessary to make some assumptions as to the amount of water to be discharged during the operation of filling the reservoir, a discharge of 316 c.f.s. was therefore provided for, and the length of time necessary to fill the reservoir, and the amount of water wasted in excess of this flow was computed. It has been assumed that during the high-water period of 1910, the reservoir was filled; at the beginning of November, water was first released from storage and added to the mean monthly flow.

The distance of the basin from any point, other than one on the Spray river at which the water could be used for power purposes, is great, so any attempt at close regulation would be futile. It would only be possible to regulate upon the basis of a continuous flow of the Spray river itself, and it is upon this basis that the diagram for the stream has been compiled. Assuming that the intention is to augment the flow of the Bow river during the months in which low water occurs, would mean a flow from storage during six months of the year or from November 1 to May 1. With 160,000 acre-feet of available storage, a continuous flow of 446 c.f.s. could be maintained, adding the mean monthly flow of the river during these same months, and assuming that a continuous uniform flow is maintained, it would be possible to secure a discharge of 635 c.f.s.; making the same assumptions, and using the same reasoning, during the low-water period, 1911-12, 607 c.f.s. would be the continuous uniform flow for the period.

On the assumption that a flow of 316 c.f.s. is being provided during the storing period, and that filling the basin commences on May 1, it is found that for the year 1911 the basin could have been filled by July 23, 171,000 acre-feet being stored. From the time of filling to the time of commencing to discharge from storage, 64,937 acre-feet would be wasted in excess of the flow of 316 c.f.s. provided. From the year 1912, sufficient data are not to hand to compute the time of filling and the amount of waste.

Creation of Storage.

The best storage scheme in the Bow basin is undoubtedly that at the Spray lakes, though the proposition is not an easy one. The amount of additional water that could be made available would form a considerable percentage of the present low flow.

The size of the structure involved is great so that considerable care and thought will have to be exercised in the final design and construction; it is quite possible that if the proposition is undertaken, the general scheme as advanced now will require modification in many ways. With the information that is now available it is, however, considered that the creation of the amount of storage assumed is feasible, from both an engineering and economic stand-point.

Type of Structure.

The estimates for the cost of creating this storage basin are based upon the design of a hydraulic-fill type of dam.

Hydraulic-Fill Dams.

The hydraulic-fill type of dam belongs essentially to the western mining districts, especially California. It was in connection with the mining operations carried on there by means of sluices and hydraulic giants, or "monitors" that n

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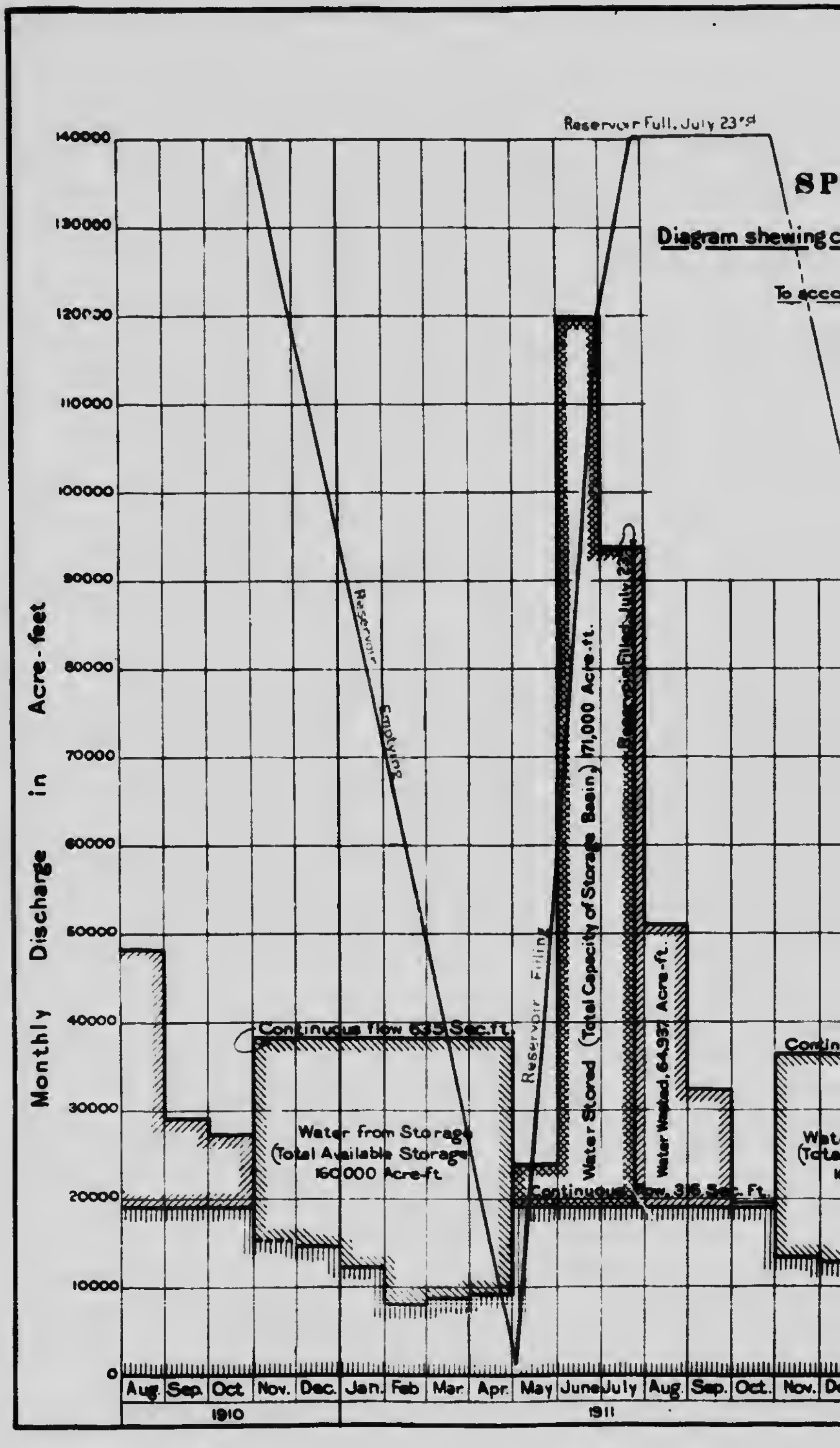

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Reservoir Full, July 23rd
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Reservoir Emptying
Reservoir Filling
Continuous flow 635 Sec. ft.
Water from Storage (Total Available Storage 160000 Acre-ft.
Water Stored (Total Capacity of Storage Basin,) 171,000 Acre-ft.
Reservoir Filled July 23
Water Wasted, 64,937 Acre-ft.
Continuous flow 316 Sec. Ft.
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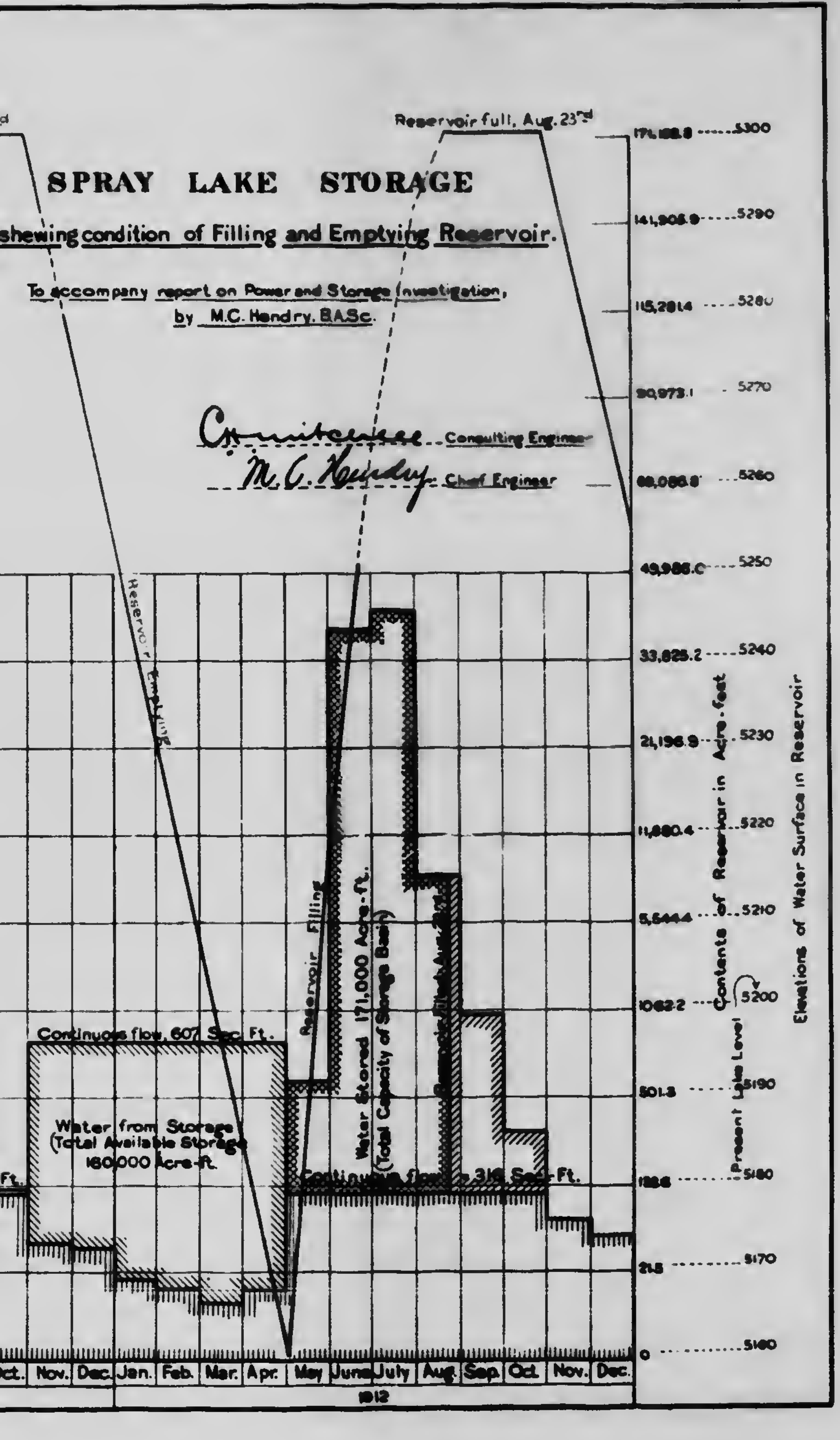
1911

PLATE XIV


SPRAY LAKE STORAGE
shewing condition of Filling and Emptying Reservoir.
To accompany report on Power and Storage Investigation,
by M.C. Hendry. B.A.Sc.
Consulting Engineer
M. C. Hendry Chief Engineer
Reservoir full, Aug. 23rd
Reservoir Emptying
Reservoir Filling
Water Stored 171,000 Acre-Ft.
(Total Capacity of Storage Basin)
Continuous flow, 607 Sec. Ft.
Water from Storage
(Total Available Storage
160,000 Acre-Ft.
Continuous flow 316 Sec-Ft.
Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sep. Oct. Nov. Dec.
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115,281.4 5280
90,973.1 5270
68,086.8 5260
49,986.0 5250
33,825.2 5240
21,196.9 5230
11,880.4 5220
5,544.4 5210
1062.2 5200
501.3 5190
188.6 5180
21.5 5170
0 5160
Contents of Reservoir in Acre-feet
Present Lake Level
Elevations of Water Surface in Reservoir

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the methods of excavating, transporting, and placing material to form a dam was originated, and it might be said that to the engineers of that section of the country belongs the credit of raising the method to its present high plane.

This type of dam is not confined to structures of low height, there being examples in existence of dams, built by this method, of heights varying from 77 feet to over 200 feet. Dams of this type are built of clay, gravel, rock and sand, which has been excavated and placed in position in the structure by means of water conveyed in pipes or sluices. Generally speaking, the material is excavated by the same agent, streams of water at a high velocity being directed against the material in its natural bed.

Mr. J. D. Schuyler, an authority on the subject, has, in a paper before the American Society of Civil Engineers, gone into the subject thoroughly. He has described in detail a number of dams of this type, amongst which are the following (Trans. Am. Soc. C.E., vol. LVIII):—

1. Crane Valley dam.
2. Terrace dam.
3. Lake Francis dam.
4. Tyler dam.
5. Como Lake dam.
6. Necaxa dam.

To this list may be added the Coquitlam dam in British Columbia, which is of particular interest, being a Canadian example.

SITE.

The site of the proposed dam at Spray lakes, as has been mentioned before, lies in a narrow canyon near the outlet of the lake. The banks or walls of the canyon are composed of rock (limestone), which rises at an angle of about 60° to a height of approximately 170 feet. Above that elevation the banks are of a glacial deposit, composed of clay, gravel, sand and boulders, overlying the rock on the south side to a depth of from 50 to 100 feet, and on the north side to a much greater height, the slope being almost as steep as the lower part. The rock at the lower level of the canyon is completely buried in places by material from above, and only appears as an outcrop on the south side. On the north side it presents a rock face for 100 feet in the height, here the rock is rather badly decomposed. At elevation 5,300 or 140 feet above the water level, the width of the canyon is 380 feet.

The above conditions may be considered ideal from the standpoint of a hydraulic-fill dam. The surroundings are such that good borrow pits could be had near the site, and at such a height above the work, that no difficulty would be experienced in regard to grades in the sluices; an ample water supply exists in the river, which would of course need to be pumped.

The matter of unwatering the site during construction is comparatively easy. The proximity of rock to the surface would permit of the construction of a tunnel of comparatively short length, which could be built with the ultimate object of discharging the storage.

HYDRAULIC-FILL MATERIALS

Regarding what constitutes a good material for this class of construction, the following extracts are taken from Mr. Schuyler's paper, Transaction Am. Soc. C.E., vol. LVIII, quoted before. He says:—

"As far as the writer's experience has gone, it is his opinion that the best material for hydraulic-fill dams is rounded gravel, sand and boulders, intermixed with about 25 to 35 per cent. of clay. The rounded rocks roll more readily than broken angular chips, and clay acts as a lubricant to assist in transporting the heavier materials.

"The most difficult material with which to build such a dam is pure clay unmixed with sand, because it is unstable until the water is drained from the mass, and drainage is slow. The shrinkage, therefore, is much greater than in other materials, and there is greater likelihood of the opening of shrinkage cracks, months after the work is finished, through which leakage could start if the dam were put in service too soon after completion. When clay is finally consolidated, however, it makes a dam which can have no superior for water-tightness.

"As a core for coarser and more stable materials, clay is extremely desirable, and its presence with sand, gravel, and rock in sufficient proportion to form one-fourth to one-third of the volume of the dam to be segregated by water and placed in the centre of the mass, makes it more easily worked, more useful, and more valuable for safe dam construction than in any greater proportions.

"While clay is doubtless the most impervious of all earth, it is not indispensable in the building of water-tight dams. The volcanic ash soil of the Snake River Valley has none of the characteristics of clay, and yet it is so finely divided as to make a water-tight embankment when properly moistened and compacted. Glacial flour, which has no resemblance to clay, will also make an equally good dam."

The creating of storage at Spray lakes, with whatever type of structure that may ultimately be decided upon, involves the question of transportation. Situated as the site is, up in the mountains, and at a distance of 30 miles by trail from Banff, the expense of transporting materials such a distance over mountain roads would be great, and there is the initial expense of building at least 20 miles of new road; any scheme of construction therefore which reduces the amount of materials to be transported is worthy of consideration. It has been estimated that the cost of cement landed at the site of the work would be at least $6 per barrel by the cheapest method of transportation, *i.e.*, in winter, when the roads would be good and the loads hauled large: concrete construction, with cement at such a figure, would be very expensive. A hydraulic-fill dam would reduce the amount of material to be transported to a minimum. The amount of material to be placed in the structure is greatly in excess of that for a concrete dam, but there is no comparison between the unit cost for the methods, there being contracts on record where the price for this kind of work has been 18 cents per cubic yard.

Mr. Schuyler, in his paper (vol. LVIII, Trans. Am. Soc. C.E.) quoted before, says regarding this method:—

> "While economy in first cost is certainly a most potent factor in governing the choice of methods of doing any work, it is by no means the only reason which has led the writer to advocate a widespread and general use of the hydraulic-fill method of dam construction. He regards its superiority as consisting largely in the ability afforded to utilize materials which would be otherwise unfit or unsuitable due to the assorting, grading and separation of different classes of material, by reason of the dissolving action of moving water and its varying velocities, which are entirely controllable, and which permit the deposition of the several grades in making a stable dam. By this means, the course, friction-bearing stable materials may be placed on the exterior slopes, and the finer particles may be assembled in the centre of the mass to serve as a puddle core, and the ease and simplicity with which this may be done constitutes one of the strongest possible reasons aside from that of economy in cost, for using this method. In fact, by this process it becomes practic-

able, with care and skill, to build a safe and stable dam of materials which would otherwise be considered valueless. As nature does not always mingle her materials in the proper proportions to make them fit for forming a water-tight embankment without proper segregation; this selection and separation cannot usually be made by the ordinary process at practicable cost."

Construction.

The first consideration in construction of this kind, is the question of water supply under pressure. This is obtained in one of two methods—either by means of a gravity supply at an elevation above the work sufficient to insure a good working pressure, or by pumping; the former method is the cheaper. The pressure is, of course, of prime importance, and as a rule at least 100 pounds per square inch is required with a discharge up to 20 cubic feet per second. Where the supply of water and the pressure is secured by pumping, power has to be secured.

At this site, so far as is known, there is no adequate gravity supply of water available; it is therefore proposed to obtain the required supply of pumping, a method for which the site is well adapted.

Power for Construction Purposes.

At the upper end of the basin, and in the main branch of the river, there is a fall with an available head of 50 feet. The flow varies, but during the season when sluicing could be done, the amount available would be between 150 and 200 second-feet. When the basin is filled, the fall will be drowned out, but during construction it would be available for power. It is proposed to install a temporary power plant at this fall. This could be done very economically, and such a plant would supply all the power necessary for the construction of the dam; the fall is about a mile and a half from the site of the proposed work, so the transmission lines would be short. Altogether, the site seems peculiarly adapted to this type of construction.

Dam.

The dam would occupy the same position as of that proposed for a masonry dam, *i.e.*, about 2,500 feet from the mouth of the canyon. It would be 380 feet long on top and 30 feet wide, and from foundation to crest, the total height would be 160 feet. A design has been prepared of the structure, and quantities estimated.

The upstream slope is 3 to 1, and the downstream 2 to 1. Riprapping is also included for each slope, but owing to the material this may be found to be unnecessary. A rock toe is proposed at the up and down stream side of the dam.

The necessity for a core wall in the heart of the dam cannot be definitely decided until the foundation is uncovered. Regarding the advisability of the use of a core wall in connection with hydraulic-fill dams there seems to be a wide difference of opinion; there is no lack of examples of both the use and omission of core walls. The Terrace dam and Necaxa dam No. 2 are good examples of the use of core walls; in the former case the wall fills the lower part of the canyon and rises to a height of 70 feet, and in the latter case the core wall extends down through the underlying material to an impervious stratum and rises to within a short distance of the original surface of the ground. On the other hand, a notable example where the core wall is omitted though not entirely is the Coquitlam dam in British Columbia, at the outlet of Coquitlam lake. The core wall being only built on the side of the confining valley where rock is in place.

In connection with the need of core walls, in a discussion of the paper before quoted, Mr. Schuyler says:—

"The fixed objection which the writer has to a core wall of masonry or concrete in the centre of an earth dam, especially of large dimensions, is that it introduces an element entirely foreign to the nature of the body of the earth structure, acting as a huge knife to sever it in half, destroying its homogeneity, and preventing the complete knitting of the mass as a whole in a manner that must best subserve the purpose for which it was built. A core wall must necessarily be built comparatively thin to be reasonable in cost, and must be subject to the minor defects of construction incident to all such work, and subject also to rupture from the possible uneven settlement of the earth on either side of it."

The placing of a core wall in the dam depends upon the nature of the material upon which it is founded. If based upon an impervious stratum of clay, or material to which a good bond may be secured, its introduction seems unnecessary. On the other hand, where the dam is placed upon rock, it would appear that some method should be used to prevent possible percolation along the line of contact, either by trenches filled with material bonded to the dam, and homogeneous with it, or by a low core wall. Mr. Schuyler gives it as his opinion that: "A core wall of moderate height in an earth dam founded on bedrock, is a most useful and necessary element to form a bond between the earth embankment and the bedrock on which it rests, but for this purpose it does not need to be carried higher above the rock surface than is reasonably necessary to form such a bond."

It is proposed to make the unwatering tunnel serve the double purpose of taking care of the flow of the river during construction, and of serving as a means of discharging the water from storage when complete. This tunnel will be placed in the solid rock at the north end of the dam, the entrance at the upper end being constructed with proper intake structure, and the tunnel lined throughout with concrete. The discharge will be controlled by suitable valves placed in a chamber excavated in the rock, and situated above the tunnel, access to which will be by means of a shaft sunk from the surface at some distance from the dam. This tunnel will be of ample size to take care of any flood discharge that may occur.

Spillway.

A spillway to supplement the sluice tunnel at times of excessive flood may be provided at either end of the dam, depending upon the nature of the material encountered.

Dimensions.

The dimensions, on which the estimate of cost given later is based, are here given:—

Length on crest	380 feet.
Top width	30 "
Height	160 "
Upstream slope	3:1
Downstream slope	2:1
Contents	550,000 cubic yards.
Tunnel:—	
Length	900 feet.
Section	1,548 square feet.
Maximum estimated flood, 20 c.f.s., per square mile	4,000 c.f.s.

The cost of the dam itself has been based upon the above figures.

Clearing.

The total area to be flooded is 3,024 acres. Of this amount, 464 acres is water surface, the remainder being covered to a greater or less extent with timber, etc.

Spray River (above Canyon). Taken by K. H. Smith.

A large part of the country in the basin has been burned over (see reproduction page 95), but not completely, leaving the trunks standing. The heaviest stand of dry timber occurs between the lakes and the south end of the basin; here the timber is mostly jackpine, running from 16 inches to 20 inches in diameter, and fairly straight; a second growth of jackpine has appeared, but it is for the most part small, though thick in places. The part lying above the junction with Hogarth creek is fairly clear: the part between the mouth of the canyon and the proposed dam site has been well covered with jackpine, but a considerable quantity has been cut for mine props within the last year. In the district surrounding the lakes, the standing growth is generally green and of small size, though scattered clumps of jackpine and spruce ranging from 10 inches to 20 inches are to be found. The location and kind of trees is indicated upon the plans of the area, and in estimating the cost [illegible] storage, the cost of clearing has been included. No attempt has been made to separate the open areas from the timbered, estimates being made on the basis that the total area not under water, *i.e.*, an area of 2,560 acres, is to be cleared.

Trails.

Upon the creation of storage at Spray lakes, it will be necessary to relocate some of the trails. For the most part, the trail along the west side of the lower lake will be undisturbed, but a change of location of the trail coming from White Man's pass at the upper end of the valley will be necessary, also of the trail leading from the lakes to mount Assiniboine. It will be necessary to locate a new trail around the east side of the basin leading to Kananaskis lakes and up Hogarth creek, also around the south end of the basin, branching off from the mount Assiniboine trail. These changes will involve little work, and may be done at small cost.

Spray Lake. Photo by K. H. Smith.

Temporary Power Plant.

The Spray falls, which will be flooded out when the storage basin is created, has a direct drop of 40 feet; immediately above the main fall are a series of cascades of from 1 to 3 feet each, so that by going upstream a few hundred feet the available head could be increased to 50 feet. There are a number of points where the stream flows over the exposed rock and at one of these places, the river can be easily intercepted by a temporary dam across the stream, a structure about 100 feet long being necessary. In order that this head may be obtained, a conduit 1,000 feet long would be necessary; this could be an open flume.

In order that difficulties of transportation may be reduced as much as possible, it is proposed to use two units of about 400 b.h.p. each. An estimate has been made of the probable cost of this plant, and included in the cost of the dam.

The gross available head for the plant is 50 feet, and the estimated discharge during the working season 200 c.f.s.; this is taken in place of the low flow because with the exception of work on the sluice tunnel, little work could be done during the winter months.

Head	50 feet.
Discharge	200 "
E.h.p.	800
Proposed installation	2—400 h.p. turbines. 2—225 k.w. generators

Construction Road.

Besides the construction of the dam and other preliminary construction required, it will be necessary to build in the neighbourhood of 20 miles of wagon road; of this, about 7 or 8 miles will involve considerable grading, the remainder being comparatively easy of construction. At present there exists a good road from Banff to the junction of the two branches at the end of the Goat mountain; from there the best route for a road to the lake follows up the north branch, and into the valley by the north end of the lakes. The part from the end of Banff road to about a mile east of White Man's pass would be the most difficult of construction.

Estimated Cost of Creating Storage.

1. Roads, camps and telephone	$25,000.00
2. Temporary power plant (800 h.p.)	30,000.00
3. Excavations and preparation of foundations, etc.	40,000.00
4. Sluice tunnel and control works	117,000.00
5. Dam, 550,000 cubic yards, complete	165,000.00
6. Clearing of basin, 2,560 acres	38,000.00
7. Contingencies of construction	41,500.00
8. Engineering and Inspection	28,000.00
9. Interest during construction, etc.	29,500.00
Total	$514,000.00

Cost.... ....$3 per acre-foot.

BOW LAKE STORAGE.

General.

Bow lake at the head of Bow river is at an altitude of nearly 6,500 feet above sea-level, and may be considered the source of the river. On the south side of the lake the mountains rise from the water's edge from 2,500 to 3,000 feet, but on the north and east sides the slope is gentle, the valley wide, and the mountains not so high. About 3 miles to the north west of the lake, is Bow pass at an elevation of 6,870 feet, forming the upper limit of the Bow basin.

The mountains to the south and west of the lake are for the most part perpetually snow-capped, immense fields of snow lie upon the top of Bow peak, mount St. Nicholas, and others in the vicinity; these feed the two glaciers that discharge into the lake. These two glaciers are the famous Crowfoot and Bow glaciers. (See reproduction page 99.) The former is the smallest and very beautiful, deriving its name from the form it takes; it enters from the south, the foot of the glacier being within a hundred yards of the lake shore. Bow glacier lying at the west end of the lake is much larger; the foot is one mile from the shore, the intervening distance being filled up with the debris from the glacier or moraine; over this the creeks from the forefoot find their way.

Area.

The lake is approximately 3 miles long, from east to west, and varies from a quarter of a mile to nearly a mile in width. (See reproduction page 98.) The lower portion about 100 acres in extent being 3 feet lower than the upper part, and connected with it by a creek of considerable width, from 100 to 200 yards wide. The total area of the lake is 800 acres and the area tributary to it roughly 30 square miles; lying as it does at a comparatively high altitude, the drainage area is peculiar. The surrounding mountains are classed among the high peaks, Bow peak being slightly over 9,000 and the majority over 10,000 feet. Under these circumstances, it is to be expected that the run-off will occur to a great extent during the warmer part of the summer. Information as to the time of ice formation on the lake in the fall is not available, nor the approximate date on which the ice leaves the lake.

Photo by M. C. Hendry.

Bow Lake—Looking East.

INVESTIGATION.

In the summer of 1911, when a general reconnaissance was made of the Bow basin, in the search for possible storage sites, Bow lake was included. After a general investigation of the lake and its surroundings and a rather careful examination of the outlet, it was decided that a survey in greater detail was justified. Accordingly a party was sent up to the lake in August, 1911. Owing to the difficulty of transportation, and distance from the nearest base of supplies, Banff, it was decided not to survey the lake in any great detail but to work up thoroughly the outlet end of the lake.

Photo by M. C. Hendry.
Bow Lake—Looking East and showing Ice Field above Crow Foot Glacier.

A stadia traverse was run around the lower part of the lake, also around the upper part for part of the distance; the traverse was confined to one side only, points being located at frequent intervals on the opposite side by stadia and triangulation.

Cross sections were taken of the banks of the lake at every station, with hand level and tape, and the shores of the lake contoured for a height of thirty feet. The outlet end of the lake was worked up in greater detail, a complete stadia survey being made and two dam lines located. In addition a couple of test pits were dug, revealing a very compact boulder clay overlying the rock in the vicinity of the dam site.

STORAGE CAPACITY.

The accompanying plans were plotted from the surveys made. A study of them revealed the fact that the height to which the water in the lake might be raised was governed by the height of the ridge of land to the north of the lower lake; this is at an elevation above 6,530, but in places drops below that elevation; by building a short embankment, however, the water might be raised to 6,530. This was therefore fixed upon as the upper level of the storage, the lower level being the present normal lake level.

The amount of storage secured by raising the water to elevation 6,530 is 27,411 acre-feet, equivalent to a discharge of 466 c.f.s. for one month of thirty-one days.

Sources of Water Supply.

The lake is fed from a number of sources, the two principal ones being the Bow and Crowfoot glaciers. The former discharges into the upper lake at the west end; the stream flowing from the glacier varies in size with the temperature; where it enters the lake it breaks up into a number of small streams, which at time of examination would aggregate about 50 c.f.s.; this was visible discharge, but owing to the nature of the underlying material the underflow must bear a large ratio to the surface flow. At the northwest corner of the lake, a stream, which is the actual source of the Bow river, enters (see reproduction page 102); this rises about 3 miles west of the lake upon the Bow summit, and is for the most part spring fed; it has drainage area for several square miles and at the time of examination had a discharge of from 10 to 20 c.f.s. Along the north side of the lake there are a number of small creeks with a flow of from 2 or 3 c.f.s. to 8 or 10 c.f.s. discharging into the lake; on the south side there are only two or three streams entering the lake, the principal one coming from the Crowfoot glacier; this had a discharge of 10 to 12 c.f.s. when examined. There is no doubt that springs discharging considerable quantities of water exist, as a number of pot holes of from 10 to 15 feet in depth are filled with water; these stand with the water about 10 feet above the lake level, and from the appearance of the water must receive their supply from an underground source. During the time the surveys of the lake were made in the latter part of August, the discharge from the lake was between 125 and 150 c.f.s.; earlier in the season this is, no doubt, very much exceeded.

Process of Filling.

Measurement of the discharge from the Bow lake have not been made owing to the difficulty of access, and the foregoing figures are based upon estimates made of the different discharges; it is thus impossible to draw up diagrams showing the process of filling and emptying the proposed reservoir though certain conclusions have been arrived at.

On the assumption of 27,411 acre-feet of storage, if the process of filling was commenced May 1 and continued during June, July and August, with a constant inflow into the basin, it would require 112 c.f.s. to fill the basin. There is therefore no reason to doubt that there is sufficient run-off into the lake to provide this amount of storage, and make up the loss due to evaporation.

Manipulation of Storage.

One objection to this storage basin, is its distance from the point of utilization, and in view of what has occurred during the winter of 1912-13, the objection appears to be a good one.

There is also the question of attendance in connection with regulation and some method of communication; the objection to placing an attendant at the lake, during the winter, is the difficulty of securing a man who would be both suitable and willing to remain at the lake during the entire winter, for at this season it would be difficult to get out and in. If a telephone was placed at the lake, a line would have to be built from Laggan, a distance of nearly 30 miles.

It is proposed, however, to make special use of this storage; during the season just mentioned it was necessary to draw on the storage during November and December, and the water would be badly needed during the early spring months; the idea is, therefore, to release the water from Bow lake during November and December, or March and April, depending upon the season, the latter period being preferable as conditions are improving and the loss due to ice troubles would be reduced to a minimum. No attempt at regulation would be made, but a uniform discharge over a period of one month could be maintained. Any necessary regulation could then be made more easily by means of storage in closer proximity to the point of use. By operating in this way, the services of an attendant at the dam could be dispensed with, and the loss due to the formation of ice could to a large extent be overcome.

Assuming that all the water would be released in one month, a continuous discharge of 466 c.f.s. would be secured at the lake. In arriving at the benefits to be derived from storage in the lower river, only a discharge of 400 c.f.s. has been used, it being assumed that the rest is lost between the point of storage and the point used.

Dam.

The site of the proposed structure is 400 feet downstream from the outlet of the lake. About that distance downstream the river makes a sharp bend to the left, and then again to the right, forming the letter "S." On the right hand side the bank rises steeply for a height of 15 feet, then slopes more gently, rising to an elevation of 35 feet above the water in a distance of 150 feet, where the solid rock is exposed, forming the banks of the river. On the left side the slope is more gentle, rising gradually from the surface of the stream to a height of 35 feet in about 400; the rock is overlaid as on the other side by a glacial deposit of boulder clay; a short distance upstream, on the left side, the rock is exposed, but not at the dam line. The stream at this point is fifty feet wide, and flows over boulders and gravel overlying the solid rock.

The bedrock, where exposed on the left side, is a thinly-bedded limestone, and is badly disintegrated (see reproduction page 104). On the right hand side this is not the case, the rock exposed being in good condition.

The structure involved in creating the storage will be a dam 650 feet long, the centre portion of which will be a hollow-type spillway section of concrete provided with sluiceways for discharging the water, and also providing for extra discharge if necessary.

Spillway.

The spill section would be placed in the bed of the stream, and from foundation to spillway elevation would be between 35 and 40 feet, depending upon the depth at which the solid rock lies. The spillway section will be provided with concrete wing walls at each end, and with either a concrete core-wall or steel sheet piling extending through the earth fill section.

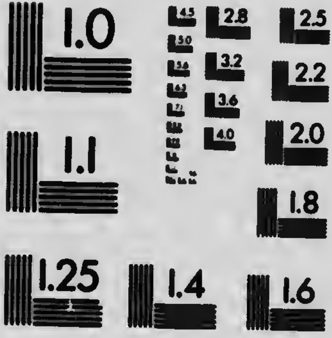
A provisional section has been prepared for estimating purposes, and is shown in the accompanying drawings. It is proposed to place three 4-foot by 4-foot sluices in the dam to provide for discharging the storage; these will be provided with suitable gates and operating mechanism and will provide for additional discharge should the 100 feet of spillway prove inadequate at flood time. This, however, is only a remote possibility as a run-off of 25 c.f.s. per square mile would only give a discharge of 750 c.f.s., while with an overtop of 1 foot the spillway would discharge 334 c.f.s. and with 2 feet overtop, 945 c.f.s.

Embankment.

At either end of the spillway section, the dam will be made up of an earth embankment carefully built of boulder clay found in the immediate vicinity, that on the right hand side 130 feet and on the left 400 feet long. The embankments will rise to elevation 6,535, or 5 feet above the upper level of the basin.

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



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The slopes of the embankments will be 2 : 1, the upstream sides will be rip-rapped to a depth of 1 foot for the whole of the surface, and washed over with a cement grout, and they will be 10 feet wide on top. A concrete core wall or sheet-piling would be placed through the centre of the embankments, and joined to the wing walls of the spillway.

Creek entering upper end of Bow Lake. Photo by M. C. Hendry.

Bow Lake—Looking towards outlet. Photo by M. C. Hendry.

In addition to these, it will be necessary to build an embankment opposite the outlet of the upper part of the lake at the point indicated on the plan; this will be 450 feet long and 8 feet high at the highest point. By placing the embankment at this point, water will be prevented from escaping down what is apparently an old bed of the river, lying to the north of the present one, and joining it about a mile-and-a-half downstream.

Construction Difficulties.

The creation of the storage at this point does not present any engineering difficulties. The greatest difficulty to be overcome is transportation; at present the only means of communication is by pack trail, and though a considerable length of new trail has recently been constructed, the cost to convert it into a wagon road would be prohibitive. Winter transportation seems to be the solution of the difficulty; during the summer all the Bow valley flats below Hector lake are soft, but in the winter, for little outlay, a first-class road could be built. Above Hector lake there are no difficulties to be encountered either in the way of hills or soft spots. Once the bottom was secured, heavy loads could be transported with ease, and the cost should not exceed $8,000 to $10,000 at the outside.

Transportation being secured, the cost of undertaking would be small, supplies being placed on the ground during the winter and the work prosecuted during the summer. It would be possible, if proper precautions were taken, to place the central portion of the dam during the winter or low-water period.

Estimated Cost.

The estimated cost of construction is as follows:

Clearing	$5,500·00
Dam—Earth section	11,000·00
Rip-rap	4,300·00
Spill section	30,000·00
Wing walls	15,000·00
Core walls	8,000·00
Valves and installation	6,000·00
Excavation	1,200·00
Miscellaneous:	
Winter road	10,000·00
Engineering and contingencies, etc	14,000·00
	$ 105,000·00
Available storage	27,400 acre-feet.
Cost, per acre-foot	$3 83

Bow Lake rock at Dam site. Photo by M. C. Hendry.

CHAPTER IX.

ELBOW RIVER.

General.

The Elbow river is one of the chief tributaries of the Bow, to which it adds its waters within the limits of the City of Calgary; from source to mouth it is over 60 miles in length. It rises in the eastern slope of the Rockies, the source being near the main continental divide, and it has all the features of a mountain stream.

The total drainage area of the Elbow river is 482 square miles, about 255 square miles of which lie above what may be termed the power-producing section. Near the head of the river, the drainage area is al[illegible]t a considerable altitude, and, in consequence, the discharge is very susceptible to changes in temperature. The flood period occurs toward the latter end of May and during the month of June, when the flow of the stream is augmented by the water from the melting snow in the mountains. Owing to the steep slope, the run-off is very rapid and the variations in the stream flow very great, due not only to hot weather, but to the sudden heavy rains which occur in the region.

The river-bed is composed for its entire length of gravel and detritus, especially in the mountain portion, where the gravel overlies the bed rock to considerable depths, the latter being exposed only at isolated points.

These conditions are ideal for underflow, the flattening out of the slope of the stream allowing the water under the slower velocity to sink into the loose material composing the bed.

Discharge.

Gaugings have been kept of the Elbow river for a considerable period, and with very few omissions since May, 1908. The station is just above the junction with the Bow river and gives the total discharge of the river; no other gauging station has been established, but miscellaneous meterings have been made at other points on the river. These have, with few exceptions, been made at other than the low water period, consequently it is nearly impossible to arrive at any definite conclusion as to the discharge of the upper part of the river.

Isolated gaugings were made in the vicinity of Canyon creek during the winter of 1910-11, and may be used as an indication of the probable discharge at that time, though the discharge, due to ice conditions, may vary greatly from day to day or even from hour to hour. The fact that under-flow occurs has a very material bearing on the discharge. This portion of the run-off is not recorded, but is, nevertheless, available, for the erection of a structure in the stream bed on a solid foundation would intercept all the flow, thus any recorded surface flow must be increased to arrive at the true discharge of the stream.

Tables are included giving the discharge of the Elbow river at Calgary, also a curve giving the mean monthly discharges has been plotted and is included. (See diagram, Plate No. 4.) The table reveals the fact that the surface flow is at times as low as 100 c.f.s., and may be even lower, though what amount should be added to this to give the combined surface and underflow discharge is rather hard to determine. In March 14, 1911, gaugings were made above and below Canyon creek which was practically dry; the results were 92 and 113 c.f.s.

respectively, or a difference of 21 c.f.s. in two sections 200 feet apart, which may be taken as rather conclusive evidence of the presence of underflow. In February, 1911, gaugings were made at the same two points, and gave 138 c.f.s. above and 135 c.f.s. below. Mr. Mitchell, in a report upon the possibilities of power on the Elbow, states that, in his opinion, the underflow may be taken as forming 25 per cent. of the total discharge of the river in the vicinity of Canyon creek; no attempt has been made to verify this opinion by actual measurement, as the construction of a tight weir would be involved, but there seems little reason for disputing it, in fact, quite possibly this figure might be exceeded.

From the tables and the foregoing estimate of underflow it is concluded that the total mean discharge of the river at Canyon creek will not be less than say 120 c.f.s. This low flow would extend over the period from December 15 to March 15.

Power Section of River.

In May, 1911, a reconnaisance of the Elbow river was made and from the examination of the river it was decided that the possibility of producing power was confined to the section lying between the 20-foot falls in section 17, township 22. range 6, west 5th, and the east boundary of section 14, township 22, range 6, west 5th. Below Canyon creek for a distance of about 2 miles the river is confined in a narrow valley by banks from 150 to 200 feet high; below this section the fall in the river is less, so nothing would be gained by going below the point indicated.

Between the 20 foot falls and the Canyon creek the river flows through what is practically a continuous canyon. Above the falls the valley is wide and flat and it was hoped that advantage might be taken of the natural fall and the wide valley above for a power site but no feasible dam site exists in the vicinity with banks of sufficient height. There are several possible locations below the falls to which the same applies, but the only one found is at a point a few hundred yards above the mouth of Canyon creek. One site lying above this was examined in detail, which in itself was suitable in every way, but the existence below it of a very high cliff and rock slide on the north side precluded the building of a necessary flume, so that point had to be abandoned.

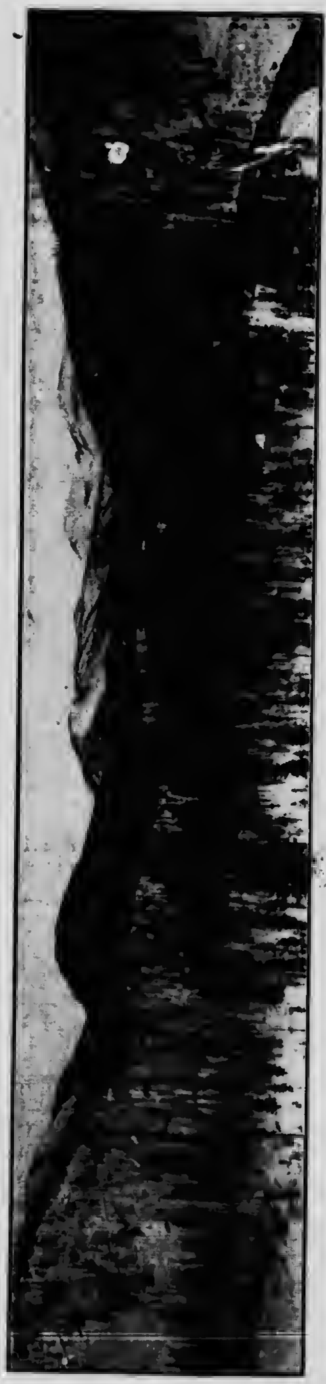
The height of the cliffs and adjacent benches determine the height to which the dam, necessary in connection with a flume line, may be built. In any scheme that has been evolved for the development of power on the Elbow, a flume line has been an essential part; the comparatively low discharge necessitates a high head development to insure economical development. The general idea of the development has therefore been, to develop part of the head by a dam and to secure the remainder by carrying the water along the benches to some convenient point and there convey it to the valley, thus utilizing the natural fall in the river below the dam.

Storage.

The flat above the 20-foot falls narrows rapidly about 2 miles up the valley, and is confined by the high mountains. The river is very steep and rough and at the extreme end issues through a narrow gap between two mountains; here the walls are formed of limestone.

Just above the gap there is a very wide valley (see reproduction page 107), the whole bottom of which is covered with gravel, and the stream finds its way through this by a number of small channels. The valley is about 3 miles long and varies from 1,200 to 1,500 feet in width, and with the gap at the lower end forms an ideal site for storage; this question will be dealt with later.

SESSIONAL PAPER No. 25e



Elbow River Storage Basin.

Elbow River Storage Dam site.

Power Development.

The study of the situation during reconnaissance leads to the conclusion that there is only one scheme worthy of full consideration. This involves a dam above the Canyon creek, a flume line following the bench lands on the north side of the river, and a power house placed in the river valley about a mile and a half below Canyon creek. In May, 1911, a party was placed in the field and this general scheme was developed in detail; a survey was made of the dam site in sufficient detail to admit of preliminary plans and estimates for the structure being made, care being taken to locate all evidence of rock in place and obtain such additional information as might be necessary. The flood line was defined in a general way, the upper limit being located at all vital points. The flume line was located and a contour survey made of the country adjacent to the line including the site of the proposed head-works, penstock line and power-house. This information is all embodied in the accompanying plans.

Power Dam.

The site of the dam is a few hundred yards above the mouth of Canyon creek where the river flows between two high rock cliffs (see reproduction page 107). The south bank rises to a height of 80 feet above the surface of the river, while on the north side it rises to 90 feet. The bank on the south side slopes back gradually from the top of the cliff, rising to an elevation of several hundred feet, while on the north the height of the banks is about 175 feet, 125 to 150 feet of which is rock cliff, a dam at this point would raise the water to a sufficient height to allow it being carried on the bench in a flume. It would also back the water upstream to a point about a quarter of a mile above the 20 foot falls, flooding an area of about 80 acres.

The lower hundred feet of the dam is not over 250 feet in length. An approximate estimate of the cost of the dam has been made and is given.

Flume and Penstock.

It is proposed to construct the conduit between the power dam and the forebay or standpipe above the power station of wooden staves, banded with steel, having a circular section 84 inches in diameter. Such a flume when well built of good timber is tight and efficient and has a life of from fifteen to twenty years, depending on earth and water conditions; it is elastic, easy of transport and construction, offers a minimum frictional loss to flowing water and is above all, economical in first cost and repairs. The total length of flume is about 7,500 feet, most of which will be laid in shallow earth cut on the sides of the gravel benches, and would be subjected to but a few pounds pressure.

The flume line as located was assumed at an elevation of 4,820, the water surface being 4,840. On this assumption it was run as nearly as possible to grade. It follows along the top of the first bench on the north side of the river, crossing Canyon creek about 150 yards from the mouth, on a trestle. It then keeps up on the second bench at a distance from the river, varying between two hundred feet and a quarter of a mile. At the lower end of the flume a regulation chamber or forebay is proposed, and leading from it to the power house a penstock (wooden stave pipe) 84 inches diameter and 1,600 feet long, will be necessary. The larger diameter is designed to reduce the velocity and avoid dangerous water hammer in so long a pipe, which would also be fitted with relief valves at the lower end. The penstock would be laid in a trench conforming to the general grades of the hillsides and benches and be amply provided with concrete anchorages.

F[illegible]AY.

The flume will terminate at the lower end in a concrete chamber surmounted by a large steel standpipe so arranged and of such dimensions that it will form an intermediate reservoir of small capacity into which the water will flow from the flume before commencing its flow down the penstock. This chamber will have its bottom well below the bottom level of the inlet at the dam and the top of the standpipe well above the level of the dam crest and will thus also act as a surge tank or species of safety valve for the large flume as well as for hydraulic regulating purposes.

POWER STATION.

The site of the power house is just west of the eastern boundary of section 14, township 22, range 6, west 5th, and at the lower end of an island to be found in the river at that point (see reproduction page 114), a dry channel of the river would be utilized for the tail-race. The elevation of the water in the tail-race will be 4,618, and the total fall intercepted 222 feet, of which approximately 215 feet would be available for power production, giving a continuous output of 3,900 b.h.p.

EQUIPMENT.

The power station proposed would have three power units and two exciter units, the power turbines being 1,600 horse-power and the generators 1,000 k.w. capacity, the latter would be 3-phase, 60-cycles and capable of an overload for temporary peak loading. If the power is used locally it will not be necessary to transform to high tension for transmission, in which case the generators would be wound for 6,600 or 10,000 volts.

The power station would be fireproof and built of concrete and so situated as to be protected from high water by means of fills and a dyke at the head of the adjacent island.

STORAGE DEVELOPMENT.

As the governing factor of this development is the water supply already discussed, the scheme of development has been worked out having in view the fact that, for the winter months, a portion of the water must be supplied from a storage reservoir. For the initial development this storage basin is not essential, but for the ultimate scheme, wherein the development is carried to the utmost capacity of the river, the fullest storage available must be employed. The only storage basin proposed under this project is that formed by the proposed storage dam in section 4, township 22, range 6, already referred to (see reproduction page 107); this basin of 23,000 acre-feet capacity will afford storage sufficient to bring the minimum water supply up to about 200 cubic feet per second (see diagram, plate No. 18). Two other basins have been considered, viz., Fisher's brook (3,500 acre-feet) and Canyon creek (4,000 acre-feet); these are, however, of small capacity in relation to their cost; they would require dams 100 feet in height and would only enter into the development at a date when increased storage facilities might be sought under urgent power demands.

STORAGE DAM.

The type of dam suggested for this storage basin is the same as that proposed for the power site, that is a hydraulic-fill dam, for which type the site is favourable.

Elbow River—Power Dam site.

Photo by M. C. Hendry.

Elbow River—Power Dam site. Photo by M. C. Hendry.

Owing to the possibility of a rock foundation throughout, it may be necessary, in order to secure a good bond between the foundation and the dam, and to prevent possible leakage along the rock surfaces, to build a core wall across the dam site extending 10 to 12 feet up into the dam.

The accompanying plans illustrate the layout of the site; an estimate of the probable cost of the work has been prepared and appears in the report.

Benefits of Storage.

The available water stored will after due allowance for evaporation and other losses provide for a continuous flow for three months and a half of 80 cubic feet per second, which should ensure a continuous flow of about 200 c.f.s. throughout the year; there is little doubt that the surplus flood water in any season will fill this reservoir.

Power Developed.

With a water supply of 200 cubic feet per second and effective working head of 215 feet, about 3,900 horse-power in mechanical energy would be developed after electric generation and transmission, say within a radius of 10 miles, it would produce an effective commercial power of 3,600 horse-power in electrical energy. The foregoing is based throughout on 24-hour service and is assumed to be the minimum power of the year, which occurs during the three winter months; for the remaining nine months, the electrical output of the plant would be increased from 3,800 to 4,200 horse-power on peak load by the use of more water, and it is proposed to arrange the equipment of the plant so as to produce a maximum of 4,200 horse-power in electrical power delivered within a radius of 10 miles of the plant.

Estimated Cost of Elbow River Development.

Transportation		$ 30,000.00
Storage Dam:—		
Sluice tunnel and control		
Dam and core wall		
Concrete spillway, etc		193,000.00
Power Dam:—		
Sluice tunnel and control		
Dam and core walls		
Intake, spillway, etc		145,000.00
Flume Line:—		
Pipe and excavation	$110,000.00	
Bridge, etc	20,000.00	130,000.00
Forebay:—		
Surge tank, etc	$ 22,000.00	
Penstocks, etc	23,000.00	45,000.00
Power House and Equipment:—		
Turbines	$ 20,000.00	
Generators	30,000.00	
Switch apparatus	12,000.00	
Building, etc	25,000.00	87,000.00

Tail race	$ 10,000.00
Transmission line	15,000.00
Engineering and contingencies, 15 per cent	98,800.00
Total	$753,800.00
Interest during construction, 5 per cent	37,700.00
Total estimated cost	$791,500.00

$200 per wheel horse-power.

Conclusions.

The scheme of developing power on the Elbow river is not an attractive one from an economic standpoint; there have been a number of applications filed respecting the development of power upon the river, and in order that these have might be dealt with the investigations were instituted with the above results.

The market for such power must, owing to the high cost per horse-power, be in the immediate vicinity of the plant. It cannot be expected to compete with power in other districts, and it is even doubtful whether the development would be warranted, as it is quite possible that power produced by a steam plant would be much cheaper; this can only be settled when the quality of the coal in the locality is known. The one thing in favour of the water power is its capacity to take care of peak loads. This plant, while nominally of 4,000 horse-power capacity could be commercially operated so as to sell from 4,500 to 5,000 horse-power on a 24-hour basis, as is quite frequently done, owing to overlapping in the loads.

Photo by M. C. Hendry.

Elbow River Power Station Site from head of Island.

CHAPTER X.

ADDITION STORAGE INSPECTIONS.

In the investigation for storage, a general reconnaissance of the whole basin was made, and certain areas or sections were proven to be economically unsuitable for storage purposes; as these formed the largest part of the district investigated they are worthy of description.

To this particular division belong the following, which are named in the order of investigation:—

- (a) Kananaskis river and lakes.
- (b) Hector lake.
- (c) Pipestone creek.
- (d) Baker creek.
- (e) Johnson creek.
- (f) Redearth creek.
- (g) Brewster creek.
- (h) Ghost river.

The question of storage on the first two was looked into in 1911, the rest being investigated in 1912.

KANANASKIS RIVER AND LAKES.

The Kananaskis river, which flows from the south, is one of the main tributaries of the Bow, joining the latter at the head of Kananaskis falls; the western limit of its watershed forms the boundary of the Rocky Mountains park.

Source.

The Kananaskis river has its source in two lakes of the same name which are about 40 miles due south of the Canadian Pacific railway at Kananaskis; these lakes lie at an elevation of about 5,500 feet above sea-level and are situated close to the main continental divide, which here forms a barrier of snow-capped mountains. To the west of the lakes is Kananaskis pass, with an elevation of 6,200 feet, over which the trail leads, following the Palliser river down to the Kootenay. From the south, there is a small stream flowing into the lower lake; this rises near the summit of Elk pass, at an elevation of 6,500 feet.

Tributaries.

Just below the outlet of the lower lake, a small stream, which rises on the summit between the Spray and Kananaskis basins and drains the area between the Kananaskis and Spray ranges, comes in from the west. About 3 miles below the outlet we come to the forks, where from the east, flows a stream rising between Misty and Elk ranges, and draining the territory lying to the east of the lake, and west of the Misty range.

These streams and branches of the Kananaskis form its principal tributaries. Below the junction with the east fork, the streams flowing in are all short and of negligible size, the largest one being that coming in from the east a short distance south of the Indian Reserve boundary. Between these two points the river is confined between the Opal and Kananaskis ranges, and the valley is comparatively narrow. (See contour map.)

Kananaskis Lakes.

The Kananaskis lakes are spoken of as the Upper and Lower lakes, on account of a difference in level of about 90 feet, the Upper lake being at elevation 5,550 and the Lower at elevation 5,460. The Upper lake is about 2¾ miles long and 1½ miles wide. The lower is 3 miles long and half-a-mile wide.

The Upper lake is worthy of special mention from a scenic point of view—it is studded with islands and has snow-capped mountains to form a background, the addition of well-timbered shores and islands forms a picture which rivals in beauty any of the better-known lakes which are to be found in the Rockies. (See reproduction page 117). The stream which joins the Upper and Lower lakes is about 1 mile in length and, as has been noted, drops 90 feet in that distance, the fall being composed of rapids and one abrupt fall of about 40 feet.

The Lower lake, being surrounded by lower-lying hills, and having no islands, presents a less fine appearance than the Upper lake, though it is not without beauty. The fishing in these two lakes is excellent, and will be an added attraction to the locality when it becomes, as no doubt it will, a resort for tourists. (See reproduction page 118.)

As far as storage is concerned, the lakes do not offer any desirable site, the outlet of the Upper lake—the only possible point at which the water could be controlled—would require such a long structure placed in water of considerable depth (from inspection estimated at at least 40 feet) at a cost which, in view of the advantages obtained, is beyond consideration.

Further, in considering any scheme of storage on this lake, the beauty of the lake in its natural state and the extreme probability of its becoming a summer resort in the near future should not be lost sight of.

Below the Lower lake for a considerable distance the banks of the valley are far apart, and except at one point about a mile and a half below the outlet of the lake, do not offer a site for control. At this point there is a possible site for a dam, but the fall of the stream is so rapid that at the extreme height of the dam only about 2 feet of storage would be obtainable on the lake, and the structure involved would be six or seven hundred feet long on the crest.

After careful consideration of the physical peculiarities of the locality, it was not thought that a detail survey of the different points in the vicinity was justified, and the possibility of storage at this point was therefore not further considered.

Kananaskis River.

The Kananaskis river has a drainage area of 406 square miles between the lakes and the Bow river. It flows through a narrow valley confined by high mountains—the Kananaskis range forming the west boundary, and the Opal range the east. The tributaries are all small and on account of the topography are mountain torrents, being short and steep and carry down large quantities of gravel and detritus. The valley bottom through which the river flows is, on the whole, wide and flat. Where this is not the case, the river flows between alternating high rocky cliff and gravel and clay banks, the latter being moraines composed of the material transported by the mountain torrent and ancient glaciers. The valley floor is deeply covered with this transported material, through which the river has cut its way and, where the valley is wide and flat, the river is continually changing its course, especially during the high-water season. At one point about 4 miles below the Lower lake, a fall about 25 feet high occurs; for the rest of its length, no abrupt drops occur, but the fall is considerable.

Storage Possibilities.

One scheme which has been put forward for the storage of water from the Kananaskis river. From a point south of the Indian reserve, the water was to be conveyed across the summit by canal or flume into lake Chiniki on the Indian reserve; this would involve a dam in the river at a point about 2 miles south of the mouth of the first creek which flows into the river from the east, and south of the Indian reserve (the only important creek in some miles).

It would be necessary to build a structure about 50 feet high in order that the water might be raised over the low summit between the lake and the river, and a flume about half a mile long would be necessary to carry the water across the low valley of the creek mentioned above. At the lower end of the lake, a structure approximately 4,000 feet long would be required to maintain the water at the necessary level so that it could be returned to the river when required at the Kananaskis falls and Horseshoe falls on the Bow river.

The elevation of the river at the point where a dam would be necessary is 200 feet above the water level under the Canadian Pacific Railway bridge or elevation 4,328; lake Chiniki level reduced to the same elevation is 4,300, the summit referred to between the lake and river is long and flat, rising to an elevation of 4,370, precluding the possibility of a canal through in place of going over.

A careful survey of the river has revealed the fact that there are several sites where small storage basins may be developed. They must, however, be considered mainly as regulating basins, being used for the creation of auxiliary power and providing small amounts of water to carry the peak loads on the plants on the Bow river below the junction of the Kananaskis and Bow rivers. The sites of this description are three in number, as follows:—

Upper Site, No. 1.—The upper site situated about 9 miles upstream from the mouth of the river at a point where two spurs of the mountains approach one another, producing a short canyon through which the river flows. The valley

Upper Kananaskis Lake. Photo by M. C. Hendry.

above this canyon is wide and provides for considerable storage at this point. (See reproduction page 122.) Surveys were made in more detail by the Calgary Power Company and the figures in relation to the size of the structures and capacity of the basins are quoted from the report by their engineers. The length of river flooded would be approximately 12,000 feet. The size of the structure involved is as follows:—

Height of dam	110 feet.
Length on crest	1,250 "
Depth of water	100 "
Average head (for power purposes)	70 "
Capacity of basin	14,900 acre-feet.
Estimated cost	$304,000

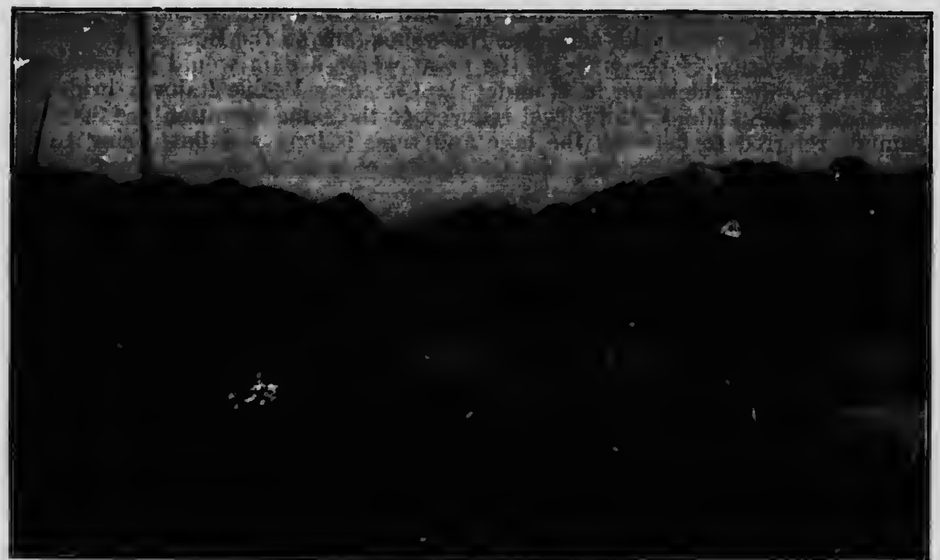


Photo by M. C. Hendry.

Lower Kananaskis Lake.

Central Site, No. 2.—The middle site lies about 6 miles upstream from the mouth of the river. The site of the dam is in a narrow rock canyon (see reproduction page 123), the walls of which rise abruptly to a height of about 100 feet above the level of the river.

The flooded length of the river at this site would be approximately 9,500 feet. The size of the dam involved is as follows:—

Length on the crest	1,000 feet.
Height of water	100 "
Height of dam	110 "
Average head (for power purposes)	70 "
Capacity of basin	10,750 acre-feet.
Estimated cost	$213,000

Lower Site, No. 3.—The lower site is the one of particular interest. It lies about three-quarters of a mile above the mouth of the river, at which point the water is raised about 12 feet by the Kananaskis Falls plant. That is, the impounding structure is actually situated in the pond of the plant below so that any water released from storage is at once available for producing power at the plant. In addition it is proposed to install equipment at the storage dam capable of an output of 1,000 horse-power.

The size and capacity of the structure is as follows:—

Length of flooded river	8,000 feet.
Length of dam on crest	670 "
Height of dam	85 "
Depth of water	80 "
Average head (for power purposes)	45 "
Capacity of basin	8,040 acre-feet.
Estimated cost	$150,000.00

Water Supply.

The stream has been gauged since September, 1911. The latest records available are for the year 1912. Those of November and December, 1911, are not complete, so the records for 1912 are used. The mean monthly flows and also the maximum and minimum flows are as follows:—

Discharge Kananaskis River.

Month.	Maximum.	Minimum.	Mean.
	c.f.s.	c.f.s.	c.f.s.
January	160	123	136
February	132	118	129
March	132	113	129
April	149	108	128
May	866	120	477
June	3,006	478	1,582
July	3,258	1,262	1,996
August	3,222	1,014	1,424
September	898	424	653
October	414	314	376
November	314	120	252
December	440	72	204

These discharges are only for one year so are not truly representative, but must be used as a basis to work out the benefits of creating a storage and regulating basin.

Effect of Storage.

Two tables have been prepared showing the effect of the storage allowing for a continuous discharge through the basin and in addition a discharge which will help to carry the peak loads upon tho plants situated upon the Bov [illegible]iver.

Table No. 14 is based upon certain assumptions made by Mr. [illegible] S. Johnston, of the Calgary Power Company, in his preliminary report on a[illegible]ary storage on the Kananaskis river.

A continuous flow of 140 c.f.s. has been provided for, and in addition to this a discharge of 81 c.f.s. for eight hours each day, it being assumed that that length of time would cover the peak-load hours. Under these conditions the storage would be exhausted by May 1, that is, there would be no power derived from the continuous discharge through the dam or from the additional intermittent discharge owing to the head being eliminated.

TABLE No. 14.

STORAGE BASIN 8,040 ACRE-FEET, ALLOWING FOR 140 SECOND-FEET CONTINUOUS FLOW; ALSO A FLOW OF 81 SECOND-FEET FOR EIGHT HOURS PER DAY.

Month.	Mean Flow.	Continuous Flow.	Intermittent Flow Ac.-ft. in 8 hours per day.	Surplus Flow Ac.-ft.	Deficit Flow Ac.-ft.	Quantity in Basin Ac.-ft.	Remarks.
November......	252	140	1,605·	5,055·	....	8,040·	Basin full.
December......	204	140	1,658·5	2,831·7	....	8,040·	"
January........	136	140	1,658·5	....	1,880·6	6,159·4	Basin drawn on.
February.......	129	140	1,488·	....	2,098·7	4,060·7	" "
March..........	129	140	1,658·5	....	2,269·2	1,791·5	" "
April...........	128	140	1,605·	....	2,198·	....	Basin empty.
May............	477	140					

TABLE No. 15.

STORAGE BASIN 8,040 ACRE-FEET, ALLOWING 130 SECOND-FEET CONTINUOUS FLOW; ALSO ALLOWING 80 SECOND-FEET FLOW FOR EIGHT HOURS PER DAY.

Month.	Mean Flow	Continuous Flow	Intermittent Flow Ac.-ft. 8 hours per day.	Surplus Flow Ac.-ft.	Deficit Flow Ac.-ft.	Quantity in Basin Ac.-ft.	Remarks.
November......	252	130	1,586·4	6,262·6	....	8,040·	Basin full.
December......	204	130	1,639·	2,763·2	....	8,040·	"
January........	136	130	1,639·	....	1,270·	6,770·	Basin drawn on.
February.......	129	130	1,480·6	....	1,536·	5,234·	" "
March..........	129	130	1,639·	....	1,700·5	3,534·5	" "
April...........	128	130	1,586·4	....	1,700·5	1,825·0	" "
May............	477	130					

FIRST ASSUMPTION.

The only benefit obtained during the last month of storage being that due to the effect of the eight-hour discharge upon the plants below. The continuous discharge cannot be included since it represents the natural flow of the river and would be utilized under ordinary conditions. This effect may be stated as follows:—

During the first five months of storage the average head at the storage dam may be taken as 45 feet, giving a continuous output of 572 b.h.p. due to a discharge of 140 c.f.s. In addition to this there will be an output for eight hours each day of 330 b.h.p., due to a discharge of 81 c.f.s.

The effect of releasing 81 second-feet from the basin would be to make it at once available for power production at the three points below the basin at Kananaskis falls, Horseshoe falls and the Bow Fort site since the tail-water of one plant is nearly at the same elevation as the head-water of the plant next below.

The effect upon the fourth site would not be noticed for at least two hours after water was released, as there is a stretch of about 8 miles of river between the tail-water of the Bow Fort site and the Mission site; at the next two sites, Ghost and Radnor, the effect would be noticed about the same time or approximately two hours and a half after water was released. If the power from these plants could be sold so that the peaks could lag behind the pe[illegible]n the plants above from two to two-and-a-half hours the water could be utilized, otherwise no benefit would be realized. Assuming that such an arrangement could be consummated, the peak loads on the different plants could be increased by releasing water from the auxiliary storage to the following extent:—

TABLE No. 16.

EFFECT OF KANANASKIS AUXILIARY STORAGE.

Plant.	Head.	Peak Load Power.
		b.h.p.
Kananaskis Falls	70	515
Horseshoe Falls	70	515
Bow Fort	66	490
Mission Site	47	350
Ghost Site	50	370
Radnor Site	44	325
Total on 6 plants		2,565

In addition, there is the continuous output for five months at the storage dam of 572 b.h.p. due to 140 c.f.s. flow; also the peak output of 330 b.h.p., or a total peak output, due to 81 c.f.s. on all the plants, of 2,895 b.h.p. for five months. For the whole period the peak load output would be increased by 2,565 b.h.p.

SECOND ASSUMPTION.

TABLE No. 15 provides for a continuous flow of 130 second-feet, which corresponds nearly to the mean low-water discharge of the river, also an intermittent discharge of 80 c.f.s. for eight hours per day. Under this arrangement there is in the basin at the end of the season 1,825 acre-feet, or an average head of 45 feet can be maintained at the dam throughout the low-water season.

Under the same assumptions as to distribution of peak loads as before we obtain the following:—

TABLE No. 17.

EFFECT OF KANANASKIS AUXILIARY STORAGE.

Plant.	Head.	Peak Load Power.
		b.h.p.
Kananaskis Falls	70	510
Horseshoe Falls	70	510
Bow Fort Site	66	480
Mission Site	47	342
Ghost Site	50	363
Radnor Site	44	320
Storage Site	45	327
Total: Peak load output from storage		2,852

Or, comparing the two methods on the basis of horse-power hours, the auxiliary output on peak load by the first method of regulation would be 4,623,120 horse-power hours.

By the second method of regulation the output on peak load from auxiliary storage would be 4,700,096 horse-power hours.

By the first method the continuous output of power would be reduced by 907,200 horse-power hours and by the second increased about one-half of that amount, or 383,000 horse-power hours. If the peak loads are high, then the second method of regulation would be the most advantageous. If the load is nearly uniform, then the reverse is the case.

No definite conclusions can be drawn with regard to the economic side of the question without knowing the load conditions on the plants. An attempt has been made, however, to arrive at the probable cost of the power produced by the use of this basin. The cost deduced is in terms of kilowatt hours, to conform to the other costs in this report.

Photo by M. C. Hendry.

Kananaskis River—Looking South from shoulder of Mt. McDougall.

Capital Cost.

The estimated cost of creating this storage also building and equipping the auxiliary plant is, approximately, $150,000.

Annual Charges.

Taking the capital cost at $150,000, the probable annual cost of maintaining and operating the plant would be:—

1. Interest on capital invested assuming financing done on bonds at 6 per cent, sold at par...........	$9,000·00
2. Sinking fund to return bonds in 30 years, reinvested at 4 per cent, say 1¾ per cent....................	2,625·00
3. Depreciation, adjusted between general works and equipment, to provide for major repairs and renewals	2,250·00
4. Operation and maintenance, including management, superintendence, wages, minor repairs, etc.........	3,375·00
Total annual charges........................	$17,250·00

Assuming that the output of the plant is continuous the year round, that is, to the capacity of the plant for six months and for the remainder of the year, having an output due to the continuous flow of 130 second-feet, plus the peak load discharge; then the output would be 6,078,840 k.w. hours; to this may be added the peak output on the plants below due to this auxiliary storage, that is, 2,726,584 k.w. hours.

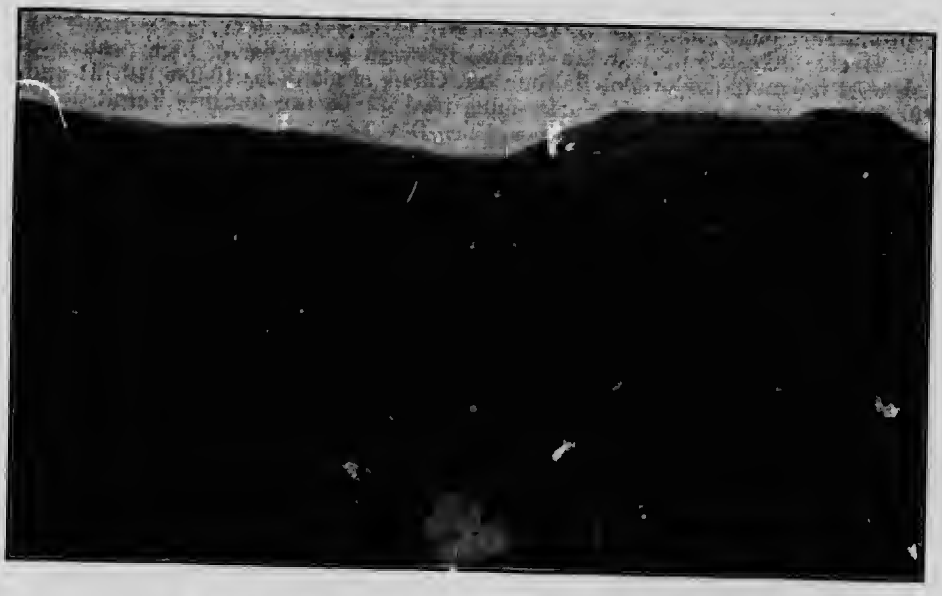


Photo by M. C. Hendry.
Kananaskis River—Looking North from shoulder of Mt. McDougall.

Cost of Power.

That is the total output from storage is 8,805,400 k.w. hours.

On this basis, assuming the annual charges at $17,250, the cost per k.w. hour would be 0·20·cents.

Owing to the possibility that some time may elapse before the three lower plants are built, the following costs have been arrived at, basing the output on the auxiliary plant and the three plants at Kananaskis falls, Horseshoe falls and Bow Fort site.

As before, the capital cost of the undertaking would be $150,000 and the probable annual charges $17,250. With the same assumptions as before, a capacity load on the auxiliary plant for six months and the remaining six months a load carried by the discharge of 130 c.f.s, plus the load carried by the discharge of 80 c.f.s. per day, and added to this the peak load on the upper three plants carried by the discharge of 80 c.f.s. from storage. The output of power from the storage created would be:—

From auxiliary	plant..........	6,078,840	k.w. hours per year.
" Kananaskis	"	550,906	" " " "
" Horseshoe Falls	"	550,906	" " " "
" Bow Fort Site	"	518,499	" " " "
Total	....	7,699,151	k.w. hours per year.

With an annual cost of $17,250 the cost would be 0·22 cents per k.w. hour.

HECTOR LAKE.

In July, 1911, a reconnaissance was made of the upper part of the Bow river, to determine the possibilities of storage in that section of the river. The expectation was that either or both the lakes, Hector and Bow, forming the source of the Bow river, might be utilized. Bow lake at the source was proved to be suitable, and is dealt with in another part of the report; on the other hand, Hector lake was found to be unsuitable for storage purposes. (See reproduction page 127).

Hector lake lies in a hollow formed between a number of high peaks; to the west lie mounts Gordon, Balfour and Olive, of altitudes 10,336, 10,731 and 10,260 feet, respectively, all glacier-hung peaks. To the south is Pulpit peak, of an elevation 6,930, and to the north lies Bow peak.

Hector lake is fed from the glaciers to the west, and also from two small lakes to the south that lie at high altitudes—the upper one, Turquoise lake, at an elevation of 5,975 feet, and Margaret lake at an elevation of 5,926; the upper lake empties into the lower, and this in turn into Hector lake; to the north is a stream coming down on the south side of Bow peak.

The lake is about 3½ miles long, and three-quarters of a mile wide, it lies about 15 miles by the river above Laggan and at an elevation of 5,700 feet above sea-level, or upwards of 600 feet higher than Laggan. The lake is to the west of the river, about three-quarters of a mile, and is connected with it by two streams which form the outlet; the intervening land had the appearance of having been deposited there in past ages by the river in the form of a bar. Apparently the lake at one time formed a great enlargement of the river and was probably, at the same time, to a great extent covered by the ice from the glacier to the west. This glacier is known as Balfour glacier and is formed by the immense snow fields which cap the summit of the main divide at this point, and which also feed the Bow glacier. As the glacier receded, the bed of the present lake was left, the east end being separated from the river by the material deposited, as has been said.

This barrier, as it may be called, is about three-quarters of a mile wide, and about the same length, parallel to the river, rising to an elevation of several feet above the level of the lake, and any structure to impound water in the lake would have to be of great length in order to raise the lake level any considerable height; the material is loose and in places very swampy. The lake could not be considered, therefore, as a storage basin either from the engineering or economic standpoint.

PIPESTONE CREEK.

The Pipestone creek is one of the largest tributaries of the Bow river, entering above Banff. It has a drainage area of about 160 square miles, which is comparable with that of the main river above their junction, their confluence is about half a mile below Laggan station on the Canadian Pacific railway.

DISCHARGE.

At the junction point with the main river a gauging station has been established at the instance of the Water Power Branch.

The discharge of the Pipestone, as measured at the entrance of the Bow, [illegible] a considerable portion of the discharge of the Bow at that point. From records available the discharge of the Pipestone may be taken as forming one-third of the discharge of the Bow below their junction during high water; during the normal period the proportion is greater; while at the low-water period, it forms nearly one-half of the total discharge.

The records extend over only a very brief period (since September, 1911), so that no definite conclusion can be drawn as to the relative discharges of the two streams, but the available records are, however, included and may prove of interest.

Drainage Area.

The drainage area of the Pipestone is very similar in character to that of the Bow above Laggan, the same mountains forming a considerable proportion of the drainage area of each. Their sources lie at considerable altitude, the great difference between the two being that while the Bow has two lakes as its source the Pipestone has no lake to act as a regulator of run-off. Strangely enough, this difference has apparently the opposite effect to that to be expected, for the variation between high and low water on the Pipestone is, from the records available, apparently less than upon the Bow.

The Pipestone from source to mouth is about 22 miles long. It rises at an altitude of 8,364, and is fed by numerous small streams coming down the mountains, such as Molar creek from mount Molar and from Cataract peak. The descent of this creek is very rapid, reaching an altitude at the junction with the Little Pipestone of 5,860, a fall of 2,500 feet in about 11 miles, or 257 feet per mile. For the next 6 miles the fall is 360 feet, or 60 feet per mile, and for the remainder of its length, about 110 feet per mile. The largest creek entering the Pipestone is that known as the Little Pipestone, which enters from the east, and is about 8 miles long, having as its source several small lakes, which lie at between 6,500 and 7,000 feet above sea-level. It drains the northern slope of mounts Richardson and Ptarmigan, which are both over 10,000 feet high and glacier hung.

Possibility of Storage.

A reconnaissance of the Pipestone with a view to storage was made in July, 1912, and at the same time the head-waters of Corral creek and Baker creek were examined.

On the Pipestone it was found that for the first few miles the river was very rapid, the fall of 110 feet per mile being exceeded in places. The stream is confined to a comparatively narrow valley by high steep banks of what might be termed glacial drift, which overlies the rock to a considerable depth; this, in conjunction with the rapidity of fall, is not favourable for the storage of any considerable volume—such as would warrant construction. Higher up, the valley widens into a large flat, which on examination showed that no suitable site for a dam offered itself, and that the slope of the valley was so great that in any event a high structure would be required to flood the valley for any distance upstream.

Above the junction of the Little Pipestone the character of the valley changes, becoming narrower and much steeper; after careful examination it proved as disappointing as the lower portion of the river, and in consequence the only possible conclusion was that storage on the Pipestone is not possible, and no further work upon it was warranted.

BAKER CREEK.

At the same time as the reconnaissance of Pipestone creek the trip was made to include Baker creek, which is the next important stream to enter the Bow below Laggan.

Drainage Area.

This creek enters the Bow from the north about 8 miles from the mouth of the Pipestone; it is about 15 miles long and has a drainage area of 52.8 square miles, about one-third the area of the Pipestone drainage basin. Unlike the

Pipestone, it has two lakes at the source of the main branch, whilst another lake forms the source of the second branch; these lakes are among the highest in the country, the lower of the two first—Baker lake—being at an elevation 7,230 feet above sea-level, and the higher—Ptarmigan lake—at an elevation of 7,561 feet; and lake Redoubt, which forms the source of one of the branches, is the highest, at an elevation of 8,000 feet. The elevation at the mouth of the river is 4,859, so it will be seen that the fall is very rapid; from Ptarmigan lake to Baker lake the fall is 331 feet in less than a mile, and from Baker lake to the mouth of that river the fall is 2,371 feet, being 1,230 feet in the first 3 miles below Baker lake, or 410 feet per mile, and from there to the mouth the fall averages 142 feet per mile.

Discharge.

The discharge of Baker creek has not been measured systematically, no gauging station has been established upon it and any records of its discharge that may exist are not available. An estimate of the discharge might be made from a comparison of the size of the drainage area and a study on the ground of the Pipestone and Baker creeks, assuming a run-off one-half that of the Pipestone. The existence of three lakes at the source of Baker creek would be expected to have some influence upon the regulation of the flow, but this regulation cannot be very marked on account of the formation of the outlets of the lakes.

Storage Possibilities.

After a study of the maps, and a consideration of the evidence gathered from men familiar with the country as to the physical features of the valley of Baker creek, it was considered that any possibility of storage lay in one or all of the lakes which were to be found at the head of the creek and that any study should be made at the upper part; this was done.

Baker lake was the first one visited. As before stated, it lies in a rocky basin at an elevation of 7,230, is about three-quarters of a mile long from east to west, and about one-fifth of a mile wide. On the north side the shoulder of Fossil mountain slopes down to the water's edge, while to the south is Fallen mountain. The lake is confined in its bed by a long, low rock ridge, which extends across the east or outlet end, this ridge is very low, rising only a few feet above the lake level for the greater part of its length, and falling away very rapidly on the downstream side. The situation is not favourable for storage. the area that might be developed by a structure at the lower end being small, and, owing to the topography, any structure would be of great length. (See reproduction, page 128.)

The upper, or Ptarmigan lake, about a mile to the west, is somewhat smaller than Baker lake, into which it empties, and is very similarly situated. From the outlet, the descent is very rapid, falling in a series of cascades; the outlet is over a low ridge, and presents the same difficulties to storage as does Baker lake.

Redoubt lake lies to the south of the west end of Ptarmigan lake, and as has been pointed out, is about 500 feet higher. The waters from Redoubt lake do not enter Baker creek through Ptarmigan and Baker lakes, but through a valley extending to the east from the shore of the lake. The descent of this creek is extremely rapid, it is less than 3 miles in length, yet in that distance it has a total fall of over 2,100 feet, from three to five hundred feet of this fall occurs at, or near, the outlet, and in this respect the lake is the most peculiar of the three. This lake is situated on a shelf of rock, on the shoulder of mount Redoubt, and on account of its situation (resembling a saucer upon a shelf) very little variation in level can occur. A rise of less than 2 feet would give a spillway of at least 300 feet in length, while any reduction below that level prevents run-off, as apparently the only outlet is over the ridge rock. This peculiarity, taken in conjunction with its size, about one-half-a-mile by one eighth of a mile, places it out of the question for storage.

In addition to the physical features of the lakes, their extreme altitude militates their use as storage basins unless they could be utilized during the early fall to augment the flow; in the spring they would be useless, because by the time their waters, stored from the previous year, were available, the floods would have set in and discharge from storage would be unnecessary.

The idea of using the lakes and Baker creek for storage purposes had therefore to be abandoned.

JOHNSON CREEK.

Johnson creek, a stream of considerable size entering from the north, adds its waters to the Bow river about 3½ miles below Castle station on the Canadian Pacific railway. It is about the same length as Baker creek. The head-waters are at considerable altitude, one branch rising at 8,000 feet, and the area drained is 49 square miles. The mountains to be found in the basin, however, are not generally so high as those to be found in the Baker basin; in the matter of glaciers, too, it resembles Baker creek, there being none in either area. Given, then, the same general characteristics in the matter of altitude, area, etc., the run-off should be expected to be nearly the same, their drainage areas being so close to one another. In the matter of lakes, the resemblance is not so marked, only one occurring on Johnson creek.

For the upper 6 miles of the creek, the fall is 2,000 feet, or 333 feet per mile, below this the fall averages about 170 feet per mile down to the mouth, the total fall being 3,367 feet. About 8 miles from the mouth a small lake empties its waters into the main creek; this lake is about one-quarter of a mile to the west and almost 500 feet above the bed of the stream.

Photo by M. C. Hendry.

Hector Lake—Looking towards outlet.

Discharge.

No data are available regarding the discharge of Johnson creek, though it is understood that some isolated gaugings were made of the creek during the last season, it might, however, be assumed that it would bear the same relation to the discharge of the Pipestone as Baker creek does, approximately one-half to one-third that of the former stream might be a fair estimate.

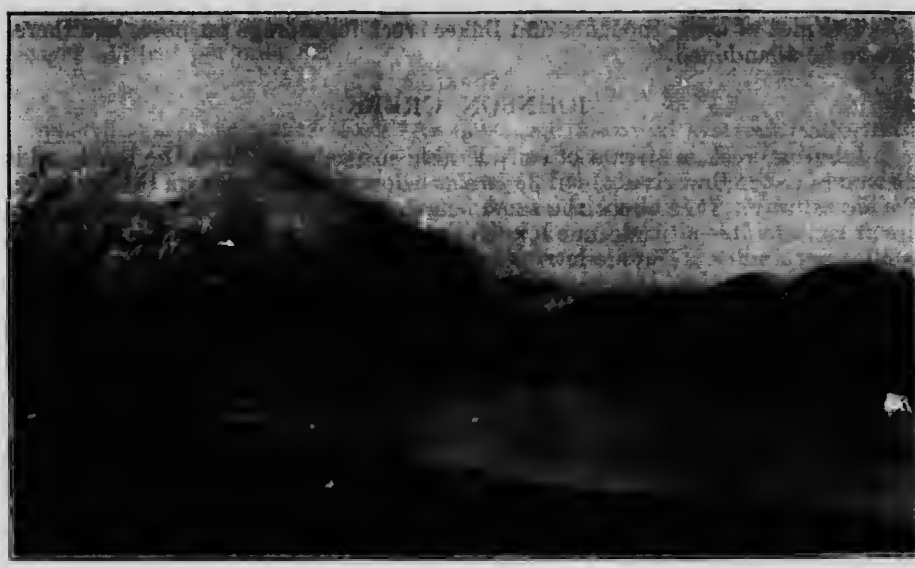


Photo by M. C. Hendry.

Ptarmigan Lake.

Storage Possibilities.

In August, 1912, an investigation of this creek was made, in order to determine whether storage of any extent might be developed upon it. It was known that a deep and narrow canyon existed where the stream made its exit between the shoulder of Castle mountain and the Sawback range (see reproduction, page 131), and that a valley of some considerable extent lay at the upper end of the canyon. An examination proved this to be so. Access to the valley is gained by means of a trail which leads up the west side of the creek, and lies well up on the outlying shoulder of Castle mountain. On account of the depth and narrowness of the canyon, the trail swings up, as the latter is neared, then following parallel to it, it finally turns abruptly down until it strikes the rim of the canyon proper, along which it lies for nearly one-half mile until the latter widens out when the trail drops down into the valley so formed. This canyon is the deepest encountered in the area covered by the investigations, it is approximately three-quarters of a mile long, and at one point must be from 600 to 700 feet deep and at the top not over that in width at the narrowest point; the accompanying reproductions illustrate the nature of this canyon fairly well. The valley behind the canyon is rather limited in extent, and does not widen out suddenly at the mouth of the canyon, but extends for nearly one-quarter of a mile before the widest point is reached where it is not over one-third of a mile wide. The valley floor is narrow, rising in a series of benches on either side; it is about one mile long, and then narrows, the stream having banks from ten to twenty feet high, back of which are a series of terraces. As was shown earlier, the valley slope is very steep, especially where the stream enters the canyon, and in order to flood the valley even for one mile upstream a structure at least 200 feet in height would be required; this in the light of the restricted area that would be flooded would involve a cost that could not be considered.

VERMILION AND REDEARTH CREEKS.

These two creeks enter the Bow river from the south, Vermilion about 1 mile west of Castle, where the new motor road, which will eventually cross the Rockies, crosses the Bow river from the north to the south side. The Redearth enters about 5½ miles below the Vermilion, and from the same side.

Both these creeks are very short and their slopes abrupt, the former falls 1,550 feet in 7 miles, or 220 feet per mile, and the latter averages 200 feet per mile.

A careful inquiry was made into the natural conditions and considerable information gathered from men thoroughly familiar with the country. Owing to the inaccessibility of the streams, especially Redearth, it was not considered that an examination was necessary, the conclusion being reached that they were not adapted to storage.

BREWSTER CREEK.

The waters of Brewster creek and Healey creek combined enter the Bow river about 3½ miles west of Banff; the flow is of fair magnitude, though no gauging has been made of the stream.

Just above the mouth where it issues into the bottom of Bow valley, it spreads itself over a gravel flat and is divided into a number of small streams, each of which finds its way to the main river, and on this account cannot have any marked effect upon the winter flow of that river. Brewster creek, like all the other creeks that have been examined, has an excessive slope from source to mouth; it is not as steep, however, as the others, having an average fall of 100 feet per mile.

Drainage Area.

The drainage area is 92 square miles, rather larger than that of Baker creek. There are three main branches, all of which rise on the northeastern slope of the main divide, the chief of these rises in the mountains lying between the Spray river and mount Assiniboine, Fatigue creek, fed from the slopes of the mountain of the same name, and Douglas, west of Fatigue creek; Healey creek lies farther to the west, near the summit of Simpson pass.

Above the junction of Healey creek and Brewster creek, and on the main stream, occurs the only possible site suitable for a storage dam. This is a canyon of about 70 to 80 feet wide, and 60 to 70 feet deep. In passing through it, the course of the stream is similar to the letter "S," the point suitable for the dam being midway between the two loops. The canyon is only a few hundred feet long; above it the valley opens out and in places is about 1 mile wide. The stream flows very rapidly, however, and the slope is steep at this point, the immediate utilization of the dam is therefore unlikely.

Examination of the creek did not reveal any other suitable dam site with a sufficient storage area behind it.

These examinations exhausted the possible sites for storage in the mountains on streams tributary to the Bow.

GHOST RIVER.

The Ghost river, which enters the Bow on the north side at a point about 35 miles west of Calgary, is 40 miles long from source to mouth, and has a drainage area of 367 square miles. Eight miles from the mouth, the stream divides into two branches, known as the Main branch and the North Fork. At a point 7 miles farther the main stream divides again, one branch retaining the name Ghost river, and the other being known as the South Fork.

The sources of these three branches are at about the same altitude, 8,000 feet above the sea-level. The South Fork rises on the east slope of the Fairholm range, and issues through the gap formed by End mountain and Saddle peak into the foot-hill country, and in a distance of 8 miles falls 2,000 feet, or 250 feet per mile. The main branch of the Ghost rises on the north side of the Palliser range, of which Cascade mountain is the easterly end, it flows around to the north of mount Aylmer, to the south side of Devil's Head, and out into the foot-hills. The fall of this part of the Main branch is not as steep as that of the South Fork, being approximately 133 feet per mile; the valley through which it flows is wide, and covered with gravel and the debris carried down by the mountain torrents which are tributary to it. The North Fork rises on the eastern slope of Castle Rock; it has a less steep slope than the others, and is for the most part in the foot-hills; it has numerous tributaries, which rise in the swamps and sloughs to be found in the territory through which it flows.

Discharge.

Discharge records of the Ghost river have been kept since August, 1911 The gauging station, which was established at the instance of the Water Power Branch, is at the highway bridge which crosses the river about 200 yards from the mouth, and the gauge rod is placed about 1 mile upstream. The available records cover only one year, the readings were unfortunately interrupted for a period during November and December, no data being available for a month during the low-water; good records were obtained, however, for January, February, March and April. The mean flow for that part of November available shows a flow of 219 c.f.s., with 191 c.f.s. as the minimum, so that it may be assumed that a flow of approximately 100 c.f.s. is available during the period of low-water. The available records of run-off will be found elsewhere in the report.

The greater part of the area drained by the Ghost river lies in the foothills; it is reasonable to expect, therefore, that the discharge will be more susceptible to the direct influence of rain and snowfall. An examination of the data reveals the fact that the flood period is earlier than on the other streams, making its appearance in April and May, and that the precipitation during the fall, instead of being stored as it would be in the higher altitudes, is apparently discharged to a great extent at once, or being at a lower altitude is melted and runs off. The run-off during September and October is comparable to that of May and June, while from the records the run-off during August appears to be even greater.

Storage Possibilities.

The slope of the stream is so steep in the mountain portion that the development of any storage in that section was at once discarded as improbable, and attention was given to the section to be found in the foot-hills. The South Fork and the Main branch both, particularly the portion between the junction with the South Fork and the junction with the North Fork, flow through valleys that are comparatively wide, varying from a couple of hundred to a thousand feet in width. During low and normal periods, the river spreads all over the

Photo by M. C. Hendry.

Johnstons Creek Canyon.

valley; in many places the river is split up into a number of small streams, which flow all over the gravel bed of the river. The whole floor of the valley is covered to a considerable depth with the gravel and detritus carried down by the river during high water, at which time the river covers the whole valley. (See reproduction, page 12).

The banks are for the most part high, rising from 50 to between 100 and 200 feet, the rise for the first hundred feet being rather abrupt, after which it is more gradual. In the part between the two banks very little bottom land exists, the river occupying the whole of the valley bottom. The south side of the valley is mostly formed of rocky cliffs, overlaid with gravel and glacial drift, and affording very few points of access to the river valley, from the north side the river may be reached in many places. The first point encountered where storage might be developed, was just west of the junction of the Main branch and the North Fork; here the banks of the valley approach each other, and the river flows through a narrow canyon, the south bank of which rises to a considerable height, but the north does not rise more than 50 feet above the water level. The rock forms a cliff on either side and extends across the river forming a bar, on the upstream side a considerable quantity of gravel has been deposited, the water drops about 2 feet in 50 at this point, a drop of nearly a foot occurring where it passes over the bar. The limiting feature of any storage scheme at this point is the height of the rock on the north side; approximately 45 feet above the present water level would be the limiting height to which the water could be raised. Considerable fall in the water level exists at the entrance to this canyon, so that 40 feet would probably be the depth that could be obtained in the valley at the mouth, and the rise in the river would not admit of backing the water up for more than a mile, with a structure of this height. The storage provided under these circumstances would be of little use from a power standpoint, except as an auxiliary storage to take care of fluctuations due to changes of temperature. Any storage created on the Ghost would only affect the plants below the junction with the Bow, and these would be benefited within a few hours of the release of the water from the storage.

As the necessity for such storage is somewhat remote, nothing more than a reconnaissance was made of the site. A detail survey might prove the scheme to be out of the question.

On the North Fork, the Eau Claire Lumber Company have built a small timber dam near section 29, township 27, range 7, to store water for driving purposes when the river is low, but just how large this storage is, is not known. It is also understood that they are contemplating changing the site for one higher up stream where more water may be impounded. It is not likely that these basins will store any large amount of water; besides which, they are rather remote for close regulation. It is understood that the basin now used may be filled in a few hours when the flow is normal.

Below the junction of the North Fork with the Main river, the valley is not nearly so wide as above, the banks are steeper, especially on the south side. From a point in section 5, township 27, range 6, to the mouth of the river, the river winds from side to side on the valley and the banks alternate as high rocky cliffs and steep gravel banks, and the valley becomes deeper and narrower as the mouth is approached; the slope of the river for the last 5 miles from the mouth averaging a little under 40 feet per mile.

Regulation Storage Basin.

Two miles from the mouth, the river passes through a narrow gap in the rock formation, the banks are nearly 300 feet high, while the width at water level is not more than 125 feet, and at an elevation of 80 feet above water level the width is only 200 feet. While working on the Bow river the work of necessity extended nearly to this point, and a very rapid plane-table survey of the river valley upstream for a distance of 3 miles was made and tied into the Bow river work. This survey has not developed anything attractive, but it illustrates the nature of this stretch of the Ghost river. Rough computations were made of the storage capacity at this point, based upon different-sized structures, and even with a structure 100 feet high the amount of water impounded is only 4,300 acre-feet, while the cost of securing this places it out of the question.

From the foregoing it will be seen that storage upon the Ghost is not a very attractive proposition, though it might be considered advisable at some future time to create a basin capable of storing say 4,000 acre-feet for purposes of close regulation of power plants on the Bow (say at the mouth of the Ghost, and at Radnor), similar to that proposed for the Kananaskis river; any greater storage on the Ghost could not be considered.

CHAPTER XI.

BENEFITS OF STORAGE.

GENERAL.

In the foregoing part of this report, the estimates of the capacities of the different reservoirs based upon the surveys made and run-off data available have been given. Also they are considered to be an economical development of each basin, and are briefly as follows:—

TABLE No. 18.

CAPACITY OF STORAGE BASINS.

Basin.	Capacity.
	Acre-feet.
Spray Lakes basin	171,000
Lake Minnewanka between elevations 4728-4740	44,700
Lake Minnewanka between elevations 4724-4740	58,900
Bow lake between elevations 6400-6430	27,400
Elbow river (Approx.)	23,000
Total storage capacity (Minnewanka 12 feet)	266,100
Total storage capacity (Minnewanka 16 feet)	280,300

The estimated costs of creating the different basins have been given, but are here recapitulated.

TABLE No. 19.

COST OF STORAGE.

Basin.	Quantity of storage. Acre-feet.	Cost.	Per Cost Acre-foot.
Bow lake	27,400	$105,000	$3·88
Spray lake	171,000	514,000	3·00
Minnewanka	44,700	140,000	3·00 (approx.)
Elbow	23,000	190,000	8·30

The cost of creating these storage basins with the exception of that on the Elbow, compare favourably with similar work in other places. For comparison purposes the following table, taken from a report by J. D. Schuyler, is included, giving the capacity of basin, cost of creating storage and type of structure:—

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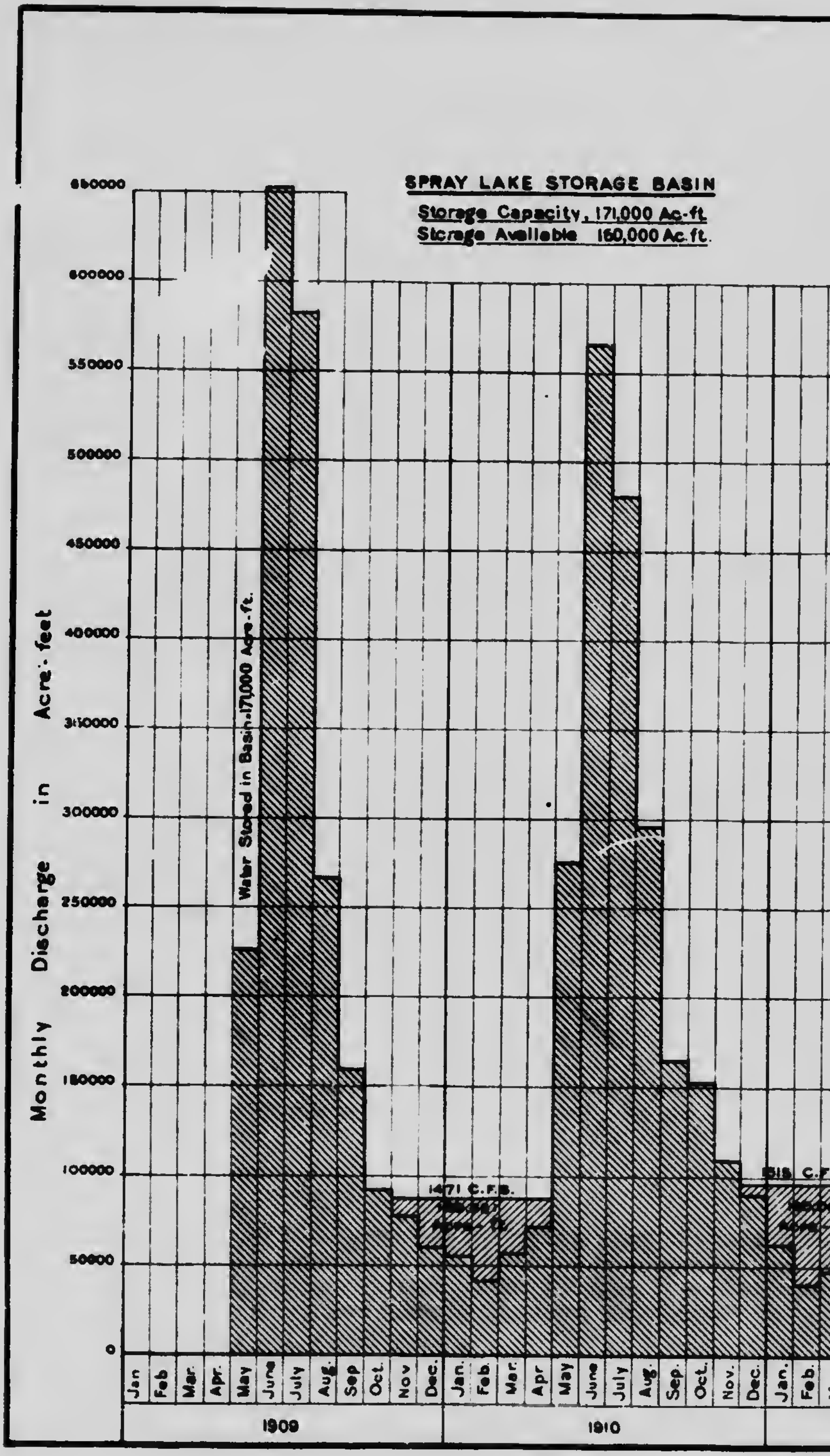
SPRAY LAKE STORAGE BASIN
Storage Capacity, 171,000 Ac.-ft.
Storage Available 160,000 Ac.ft.
Monthly Discharge in Acre-feet
Water Stored in Basin-171,000 Acre-ft.
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500000
450000
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300000
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200000
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Jan Feb Mar. Apr. May June July Aug. Sep Oct. Nov Dec.
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Jan. Feb.
1909
1910

PLATE XV

BOW RIVER

— AT —

HORSESHOE FALLS

Diagram shewing Discharge in Acre-Feet, from May 1909 to Feb. 1913

— ALSO —

Effect of Spray Lake Storage over low water periods.

To accompany report on Power and Storage Investigation,

by M.C. Hendry, B.A.Sc.

C. H. Mitchell .... Consulting Engineer

M. C. Hendry .... Chief Engineer

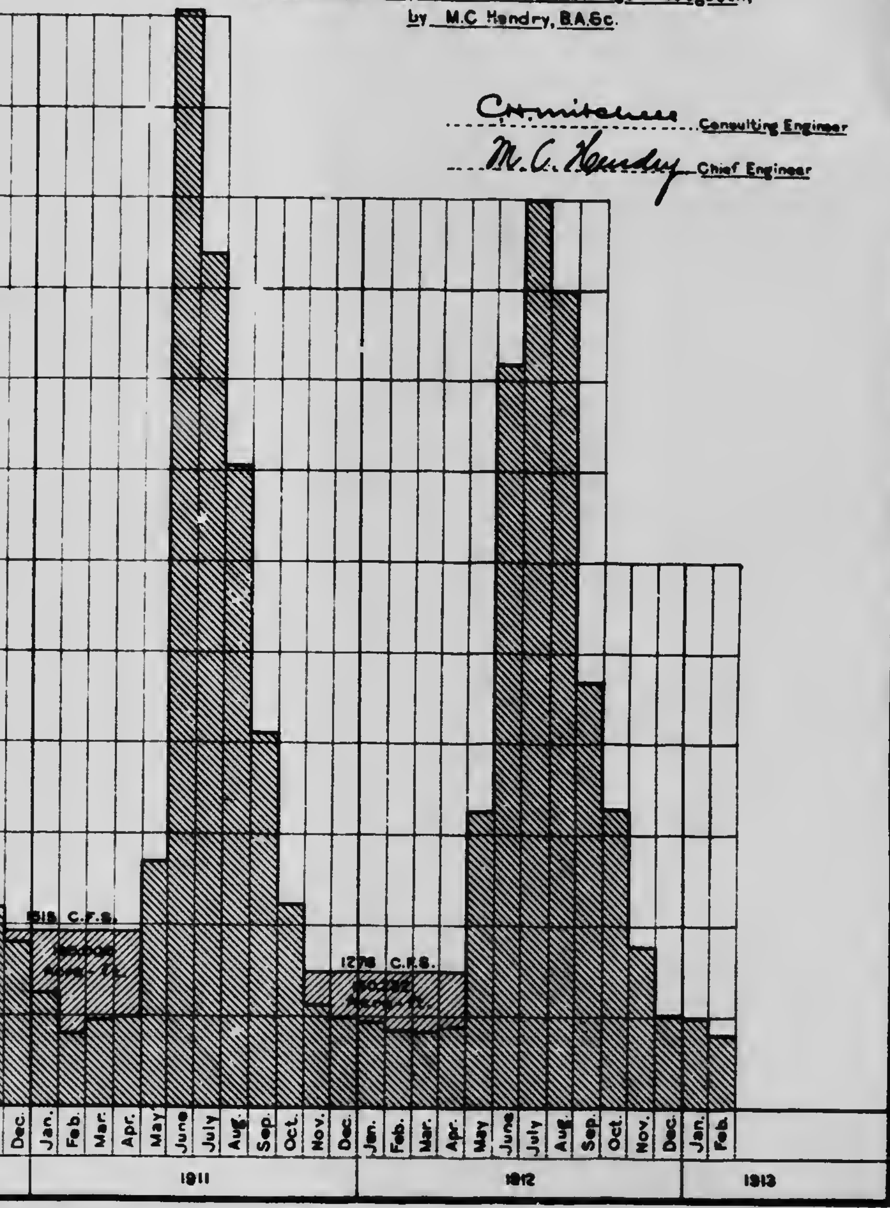

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TABLE No. 20.

STORAGE BASINS.

Name.	Location.	Character of structure.	Total cost.	Storage capacity in million cu. ft.	Cost per ac.-ft.
Belle Fourche dam	S.D.	Earth	$897,164	9,360	$4·16
Buena Vista lake	Cal.	"	150,000	7,400	0·88
Laramie R. Dam	Wy.	"	117,200	5,230	0·98
Bear Valley Dam	Cal.	Masonry	68,000	1,740	1·70
Windsor	Cal.	Earth	75,000	1,000	3·27
Sweetwater	Cal.	Masonry	264,500	980	11·76
Eureka Lake	Cal.	Rock-fill	35,000	660	2·31
Hemet	Cal	Masonry	150,000	460	14·20
Tyler	Texas.	Hydraulic-fill	1,140	[illegible]	0·64
La Mesa	Cal.	Hydraulic-fill	17,000	[illegible]	13·00
Yuba	Cal.	Hydraulic-fill	38,000	51	32·46

The comparison of costs is comparatively favourable to the Bow river storage; the ultimate basis upon which the whole project must be judged, however, is the actual benefit to be reaped by the power producers upon the part of the river affected by storage, and the increased amount of power which may be produced at the undeveloped sites.

REVIEW OF SITUATION.

Before going into these benefits, the general question of storage will be reviewed. As has been emphasized before, the lack of continuous records of run-off over any considerable period renders positive conclusions impossible, but it is considered that those reached, regarding discharge under low-water conditions, are reasonably correct. After a careful investigation and a study of the run-off and meteorological data available, together with a knowledge of the physical conditions obtaining throughout the year, it has been found that the mean monthly flow at Horseshoe falls during the period recorded does not fall below 720 c.f.s.; during short periods, perhaps a single day, the flow has dropped below 600 c.f.s.; but the mean monthly flow upon which the storage scheme must be worked out is as above. The lowest average mean monthly flow for the period 1909-12 was 833 c.f.s, and occurred in the low-water season 1911-12. The benefits to be derived from storage has been worked out upon the basis of mean monthly flow, and what is felt to be a fair allowance has been made for loss due to evaporation and wastage between the point of storage and the point of utilization.

DIAGRAMS.

Diagrams have been prepared showing the effect of storage upon the flow at Horseshoe falls. The effect of storage from Minnewanka lake, for the low-water period 1909-13, may be seen on the diagram, Plate No. 9; the effect of storage from Spray and Bow lakes for the same periods is shown by diagrams, Plates Nos. 15 and 16 respectively.

On the Minnewanka diagram are two lines, the lower shows the effect of the 44,000 ac.-feet available at 12 foot storage (the odd 700 feet is deducted to allow for waste), while the upper shows the effect of the 16-foot storage obtained by drawing the lake down to its original level, which was raised 4 feet some years ago by a dam at the outlet of the lake. A diagram showing the continued effect of the storage upon the flow of the river at Horseshoe falls (see diagram, Plate No. 17) has also been prepared. This is based upon a storage capacity of 257,300 acre-feet, and after allowing for losses it is considered that 245,200 acre-feet will be available for augmenting the minimum flow; the diagram is based upon the mean monthly flows and is for the period 1909-12, and was compiled from tables Nos. 21, 22 and 23, which are based upon the run-off data for the low water seasons of 1909-10, 1910-11, 1911-12, and show the effect of storage upon the discharge of the Bow river at Kananaskis falls. It will be seen that at the lowest season a discharge of 1,500 second-feet can be secured.

Operation of Storage Season, 1909-1910.

Table No. 21.

Month.	Mean Monthly Flow.	Quantity to raise Natural Flow to													
		800 sec.-ft.		850 sec.-ft.		900 sec.-ft.		950 sec.-ft.		1,000 sec.-ft.		1,200 sec.-ft.		1,500 sec.-ft.	
	c.f.s.	c.f.s.	Ac.-ft.	c.f.s.	Ac.-ft.	c.f.s.	Ac.-ft.	c.f.s.	Ac.-ft.	c.f.s.	Ac.-ft.	c.f.s.	Ac.-ft.	c.f.s.	Ac.-ft.
1909.															
November	1,320													180	10,710·7
December	990									10	614·87	210	12,495·8	510	31,358·7
1910.															
January	910							40	2,459·5	90	5,533·8	290	17,831·4	590	36,277·7
February	790	10	555·37	60	3,332·2	110	6,109·1	160	8,885·9	210	11,662·8	410	22,770·1	710	39,431·4
March	940							10	614·87	60	3,689·2	260	15,986·8	560	34,433·06
April U	1,200											0		300	17,851·2
Mean Flow	1,025	Total	555·37		3,332·2		6,109·1		11,960·27		21,500·67		69,084·1		170,062·76

Minnewanka storage = 44,000 acre-feet.
Bow Lake " 27,000 "
Spray Lake " = 160,000 "

Total = 231,000 "
Auxiliary to Minnewanka = 14,200 "

Grand total = 245,200 acre-feet (Maximum storage).

Storage required during low-water period of 1909-10 for continuous flow of 1,500 sec.-ft. is 170,062·7 acre-feet.
*Therefore surplus water in storage is
231,000 — 170,062 = 60,938 acre-feet.
or 245,200 — 170,062 = 75,138 "

Mean flow for low-water period 1909 and 1910 is 1,025 second-feet.
The regulated flow with Minnewanka storage... 1,148 "
and auxiliary... 1,187 "
Bow lake storage... 1,130 "
Spray lake storage... 1,468 "
Bow and Minnewanka storage combined... 1,223 "
Spray and Minnewanka storage combined... 1,591 "
Spray lake and Bow lake storage combined... 1,543 "
The regulated flow with maximum storage
Spray, Bow, Minnewanka and auxiliary... 1,705 "

*Therefore maximum storage for 1909-10 for a continuous flow of 1,500 second-feet gives a surplus flow of 205 second-feet.

Operation of Storage Season, 1910-1911.

Table No. 22.

Month.	Mean Monthly Flow.	Quantity to raise Natural Flow to 800 sec.-ft.		850 sec.-ft.		900 sec.-ft.		950 sec.-ft.		1,000 sec.-ft.		1,200 sec.-ft.		1,500 sec.-ft.	
	c.f.s.	c.f.s.	Ac.-ft.	c.f.s.	Ac.-ft.	c.f.s.	Ac.-ft.	c.f.s.	Ac.-ft.	c.f.s.	Ac.-ft.	c.f.s.	Ac.-ft.	c.f.s.	Ac.-ft.
1910.															
November	1,866	.....	.....	.....		.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
December	1,483	.....	.....	.....		.....	.....	.....	.....	.....	.....	.....	.....	17	1,045·3
1911.															
January	1,027	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	173	10,637·35	473	29,084·6
February	745	55	3,054·54	105	5,831·40	155	8,608·25	205	11,385·10	255	14,161·96	455	25,260·33	755	41,930·56
March	795	5	307·43	55	3,381·81	105	6,456·19	155	9,530·57	205	12,604·92	405	24,902·47	705	43,348·75
April	827	.....	.....	23	1,368·50	73	4,343·8	123	7,319·0	173	10,294·2	373	22,195·04	673	40,046·3
Mean Flow	1,124	Total	3,361·97	.....	10,581·76	.....	19,407·24	.....	28,234·67	.....	37,061·0	.....	83,004·2	.....	155,455·5

Minnewanka storage .... 44,000 acre-feet.
Bow Lake storage .... 27,000 "
Spray Lake storage .... 160,000 "

Grand total .... 231,000 acre-feet.
Auxiliary to Minnewanka 114,200

Grand total .... 245,200 acre-feet (Maximum storage).

Storage required during low-water period of 1910 and 1911 for a continuous flow of 1,500 section-feet is 155,455 acre-feet.

Therefore Surplus water in storage =
231,000 — 155,455 = 75,545 acrefeet.
or 245,200 — 155,455 = 89,745 "

Mean flow for low-water period 1910 and 1911 is .... 1,124 second-feet.
The regulated flow with Minnewanka storage is .... 1,247 "
The regulated flow with Minnewanka storage and auxiliary storage is .... 1,286 "
The regulated flow with Bow lake storage .... 1,199 "
The regulated flow with Spray lake storage .... 1,576 "
The regulated flow with Bow and Minnewanka storage combined .... 1,322 "
The regulated flow with Spray and Minnewanka storage combined .... 1,690 "
The regulated flow with Spray lake, Bow lake and Minnewanka combined .... 1,765 "
The regulated flow with Spray lake and Bow lake combined 1,642 "
The regulated flow with (maximum storage) Spray, Bow, Minnewanka and auxiliary combined .... 1,804 "

*Therefore maximum storage for 1910 and 1911 for a continuous flow of 1,500 second-feet gives a surplus flow of 304 second-feet over low-water period.

OPERATION OF STORAGE SEASON 1911-1912.

TABLE NO. 23.

Month.	Mean Monthly Flow.	Quantity to raise Natural Flow to													
		800 sec.-ft.		850 sec.-ft.		900 sec.-ft.		950 sec.-ft.		1,000 sec.-ft.		1,200 sec.-ft.		1,500 sec.-ft.	
	c.f.s.	c.f.s.	Ac.-ft.	c.f.s.	Ac.-ft.	c.f.s.	Ac.-ft.	c.f.s.	Ac.-ft.	c.f.s.	Ac.-ft.	c.f.s.	Ac.-ft.	c.f.s.	Ac.-ft.
1911.															
November	1,056	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	144	8,568·6	444	26,419·8
December	836	.....	.....	14	860·8	64	3,935·2	114	7,009·5	164	10,083·9	364	22,381·4	664	40,826·7
1912.															
January	786	14	860·8	64	3,935·2	114	7,009·5	164	10,083·9	214	13,158·3	414	25,455·8	714	43,902·1
February	766	34	1,955·7	84	4,831·7	134	7,707·7	184	10,583·7	234	13,459·7	434	24,936·7	734	42,219·7
March	720	80	4,919·0	130	7,993·4	180	11,067·7	230	14,142·2	280	17,216·5	480	29,514·0	780	47,960·3
April	835	.....	.....	15	892·5	65	3,867·7	115	6,843·0	165	9,817·6	365	21,719·0	665	39,570·2
Mean Flow	833	Total	7,735·5	.....	18,513·6	.....	35,587·8	.....	48,662·3	.....	63,736·0	.....	132,574·5	.....	240,898·8

Minnewanka storage	=	44,000	acre-feet.
Bow lake storage	=	27,000	"
Spray lake storage	=	160,000	"
*Total	=	231,000	
Auxiliary to Minnewanka	=	14,200	"
†Grand total	=	245,200	"

*Would give a regulated flow over low-water period 1911 and 1912, 1,473·0 section-feet.

†Would give a regulated flow over low-water period 1911 and 1912, 1,512·0 section-feet.

Mean flow low-water period 1911 and 1912 is	833	second-feet.
The regulated flow with Minnewanka storage is (833+122)	955	"
The regulated flow with auxiliary storage from Minnewanka is (955+39)	994	"
The regulated flow with Bow lake storage (833+75)	908	"
The regulated flow with Spray lake storage (833+443)	1,276	"
The regulated flow with Bow lake added to Minnewanka	1,030	"
The regulated flow with Bow lake added to Minnewanka with auxiliary	1,069	"
The regulated flow with Spray and Bow lake combined	1,351	
The regulated flow with Spray added to Bow, Minnewanka and auxiliary (Maximum storage)	1,512	"
The regulated flow with Spray lake and Minnewanka combined	1,398	"
The maximum storage for 1911 and 1912 will give a continuous flow over the low-water period of	1,512	"

Tables

In preparing the tables Nos. 21, 22, 23, the effect to be obtained from storage is taken as that due to a discharge of 160,000 acre-feet from the proposed Spray basin, 27,000 acre-feet from the Bow lake basin and 44,000 acre-feet from lake Minnewanka. In addition to this, there can be made available at lake Minnewanka, a storage of 14,200 acre-feet between the present normal lake level, 4,728 and 4,724.

Explanation.

The tables give the necessary quantity in cubic feet per second, and in acre-feet, required to raise the mean monthly flow from that recorded to discharges, ranging from 800 c.f.s. to 1,500 c.f.s. At the bottom of each column is given the mean flow for the low-water period, together with the total in acre-feet necessary to produce the given discharge for the period. Below the table is given the effect in concise form, of the flow from each storage basin upon the discharge and finally the combined effect of all the storage basins upon the flow.

For the low-water period 1909-10, the mean discharge for the period for an average month is 1,025 c.f.s. With this as a basis, from the table we find that providing for a flow of 1,500 c.f.s. over the low-water period, November to April, inclusive, there will be a surplus of 60,938 acre-feet, without making use of the extra storage available in Minnewanka, or including 14,200 acre-feet auxiliary storage, a total of 75,138 acre-feet, sufficient to provide for a flow of 1705 c.f.s. over the whole period.

For the low-water period 1910-11, the mean discharge is 1,124 c.f.s., over the whole period. As before, providing for a continuous flow of 1,500 c.f.s. over this period, there is a surplus (omitting as before the auxiliary storage) of 75,545 acre-feet, or including the 14,200 acre-feet auxiliary storage a total of 89,745 acre-feet, which would give a continuous flow from October to April, of 1804 c.f.s.

During the period 1911-12, the mean flow is only 833 c.f.s., and to secure a flow of 1,500 c.f.s., the entire storage capacity, including the auxiliary 14,200 acre-feet, a total of 245,200 acre-feet would have to be utilized.

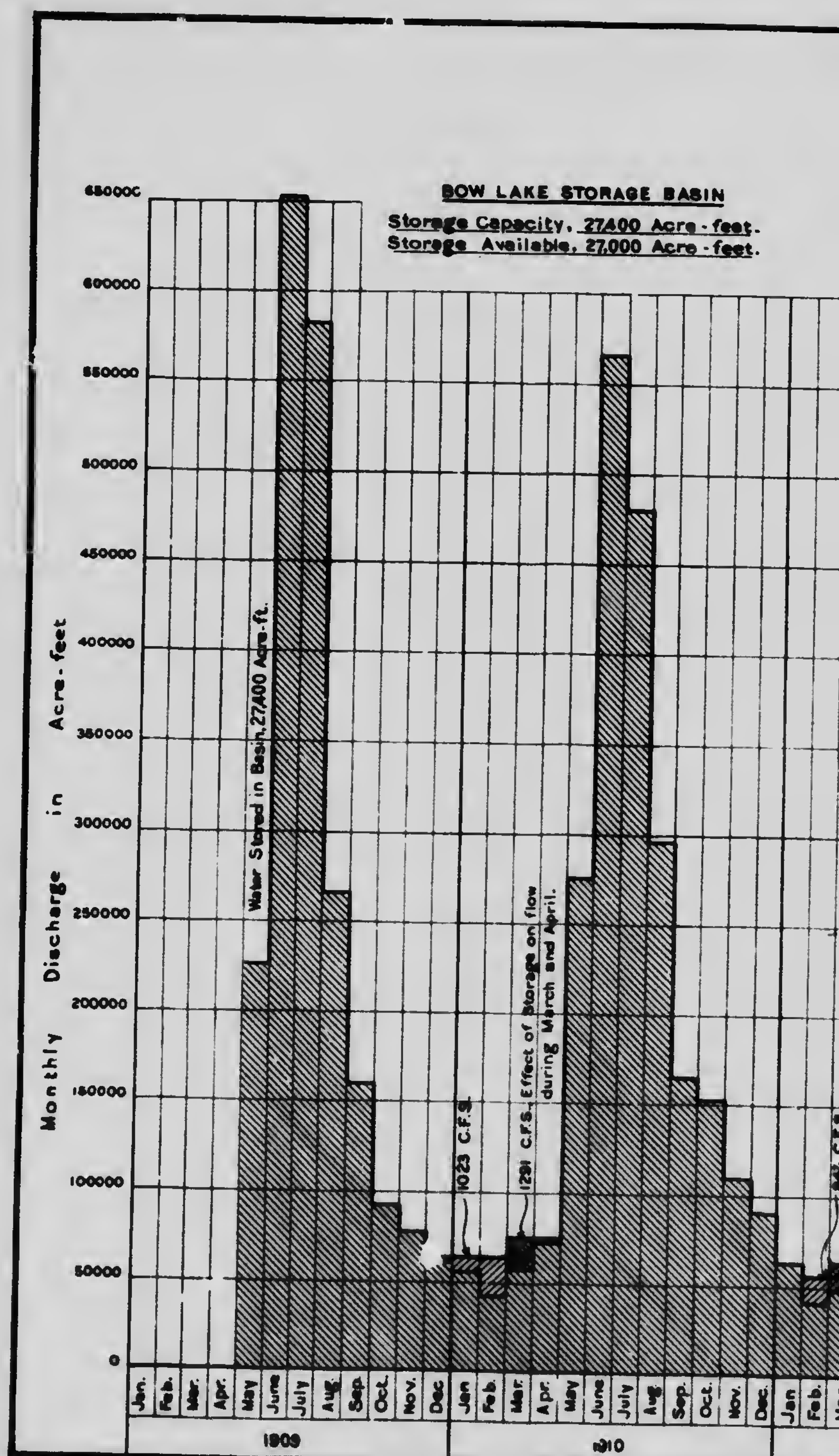
From these figures it seems reasonably certain therefore that a flow of 1,500 second-feet can be maintained; during seasons of unusually low water, this may possibly not be realized, and records over a longer period would give the conclusions drawn, more weight, but in the absence of more complete information this flow has been accepted as reasonably certain and it is the discharge upon which the developments between Horseshoe falls and Ghost river have been based.

Below the mouth of the Ghost these figures are increased; from the data available it seems reasonable to expect a minimum flow of 100 cubic feet per second during the low-water period, from this river, so that the minimum regulated flow should be increased to 1,600 c.f.s. for points below the mouth of that river.

For the low-water season, October 1st to March 31, 1911-12, from the precipitation data it is found that the precipitation was less than for any season during the last eight years, and the total precipitation for the water year 1911-12 was just 0.38 inch higher than the mean flow over a period of sixteen years. The above assumption regarding discharge in view of this seems reasonable.

Effect below Calgary.

Below Calgary, the effect of storage on the Elbow would be apparent. The amount of storage on this river is taken at 23,000 acre-feet, giving a total available storage for points below Calgary of 268,200 acre-feet. Diagram Plate No. 18 has been plotted: it gives the mean monthly discharge in acre-feet of the



BOW LAKE STORAGE BASIN

Storage Capacity, 27,400 Acre-feet.

Storage Available, 27,000 Acre-feet.

PLATE XVI

BOW RIVER

AT

HORSESHOE FALLS

Diagram shewing Discharge in Acre-Feet, from May 1909 to Feb. 1913

ALSO

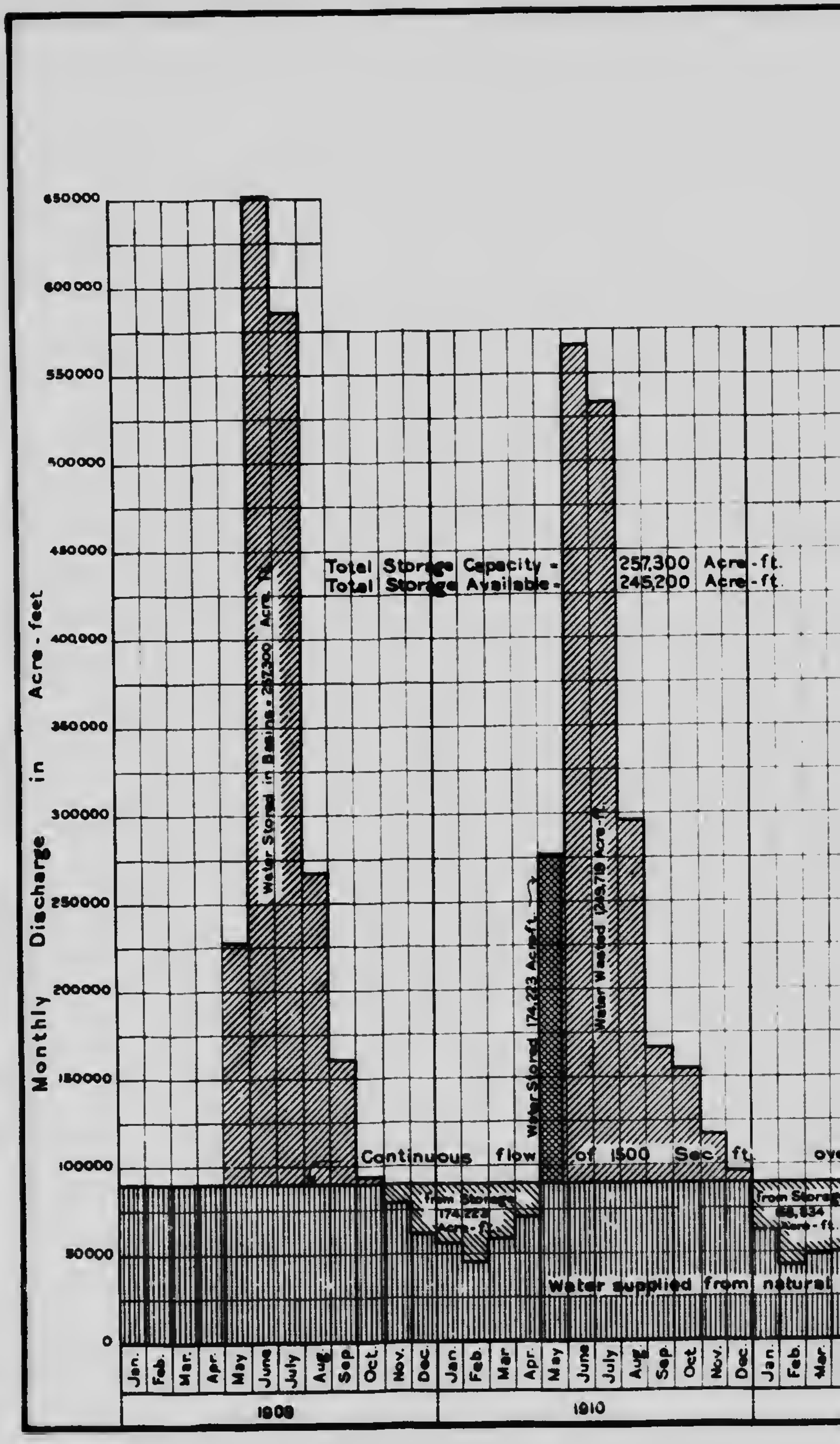
Effect of Bow Lake Storage over low water periods

To accompany report on Power and Storage Investigation,

by M.C. Hendry, B.A.Sc.

C.H. Mitchell .... Consulting Engineer

M.C. Hendry .... Chief Engineer



Monthly Discharge in Acre-feet
650000
600000
550000
500000
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Total Storage Capacity = 257,300 Acre-ft.
Total Storage Available - 245,200 Acre-ft.
Water Stored in Basins = 257,300 Acre ft.
Water Stored 174,223 Acre-ft.
Water Wasted 1249,719 Acre-ft.
Continuous flow of 1500 Sec. ft.
From Storage 174,223 Acre-ft.
From Storage 68,834 Acre-ft.
Water supplied from natural
Jan. Feb. Mar. Apr. May June July Aug. Sep. Oct. Nov. Dec.
1909
Jan. Feb. Mar. Apr. May June July Aug. Sep. Oct. Nov. Dec.
1910
Jan. Feb. Mar.

PLATE XVII

BOW RIVER

—AT—

HORSESHOE FALLS

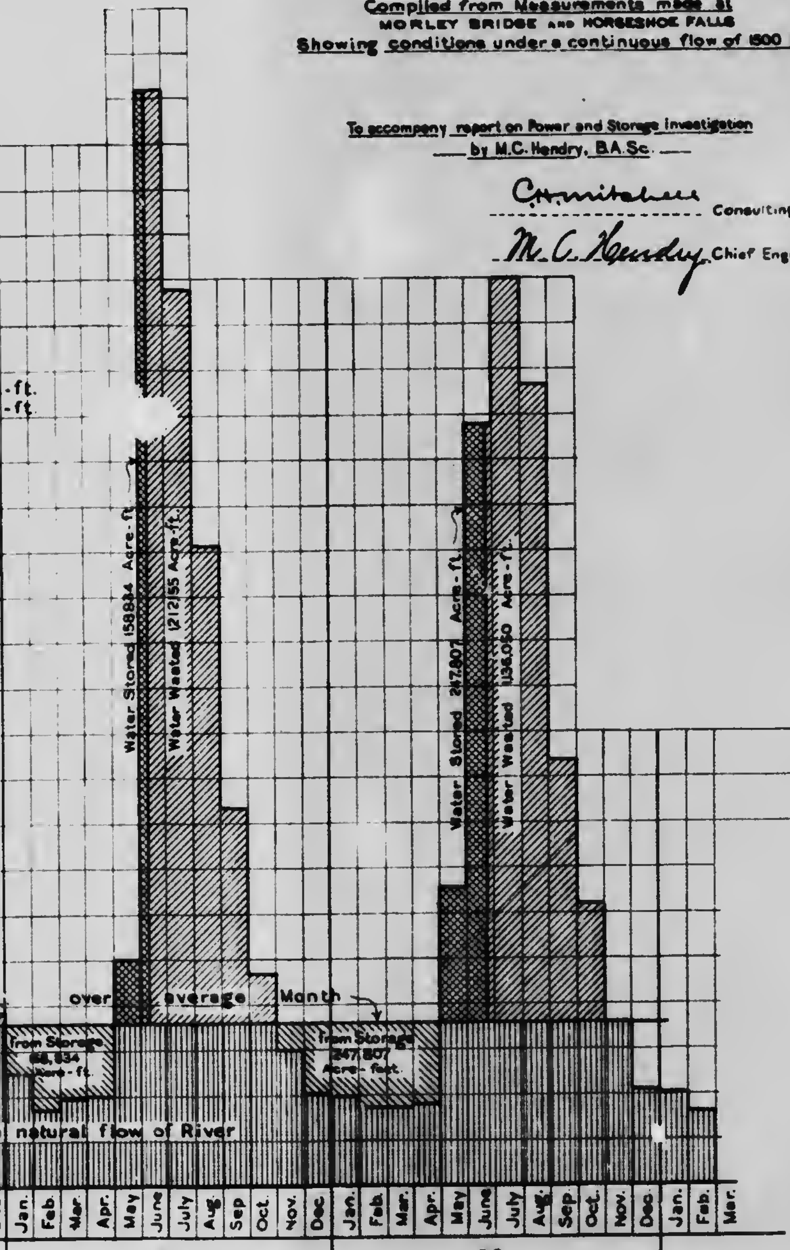
Diagram of Discharge in Acre-ft. from Jan. 1909 to Feb. 1913

Compiled from Measurements made at
MORLEY BRIDGE AND HORSESHOE FALLS
Showing conditions under a continuous flow of 1500 Sec. ft.

To accompany report on Power and Storage Investigation
by M.C. Hendry, B.A.Sc.

C.H. Mitchell .... Consulting Engineer

M. C. Hendry Chief Engineer



ELBOW RIVER STORAGE

Diagram shewing Discharge in Acre-Feet, from Apr. 1910 to Dec. 1912

also

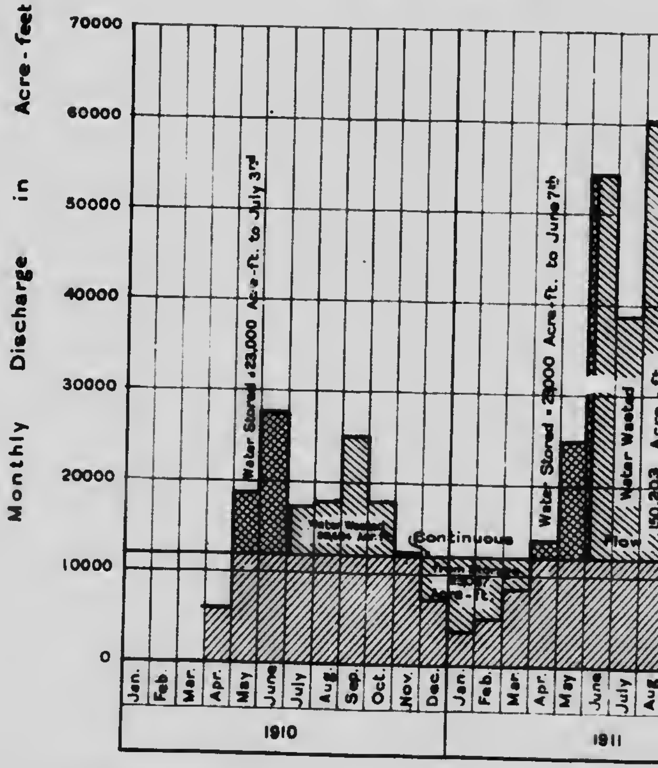
Process of Filling Basin, and providing for a constant Discharge of 200 Sec.-Ft.

To accompany report on Power and Storage Investigation

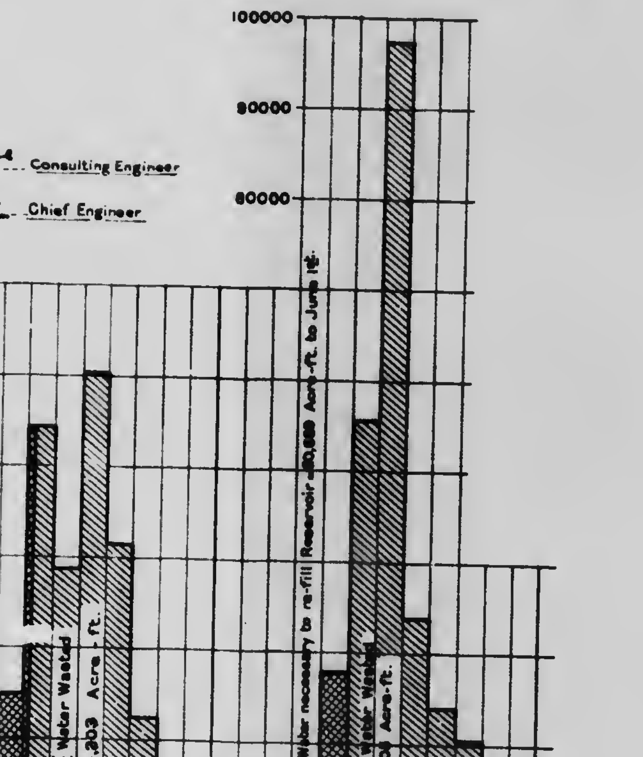
by M.C. Hendry, B.A.Sc.

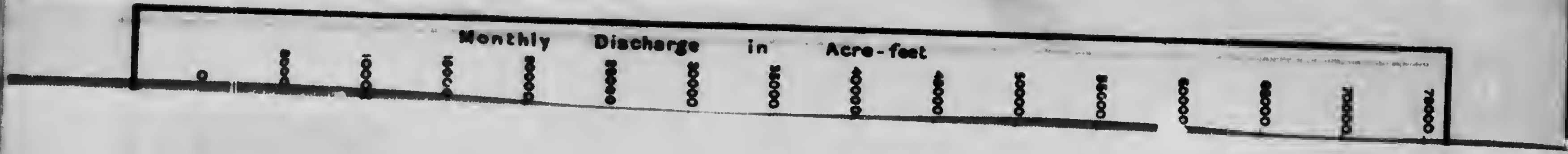
C.H. Mitchell .... Consulti

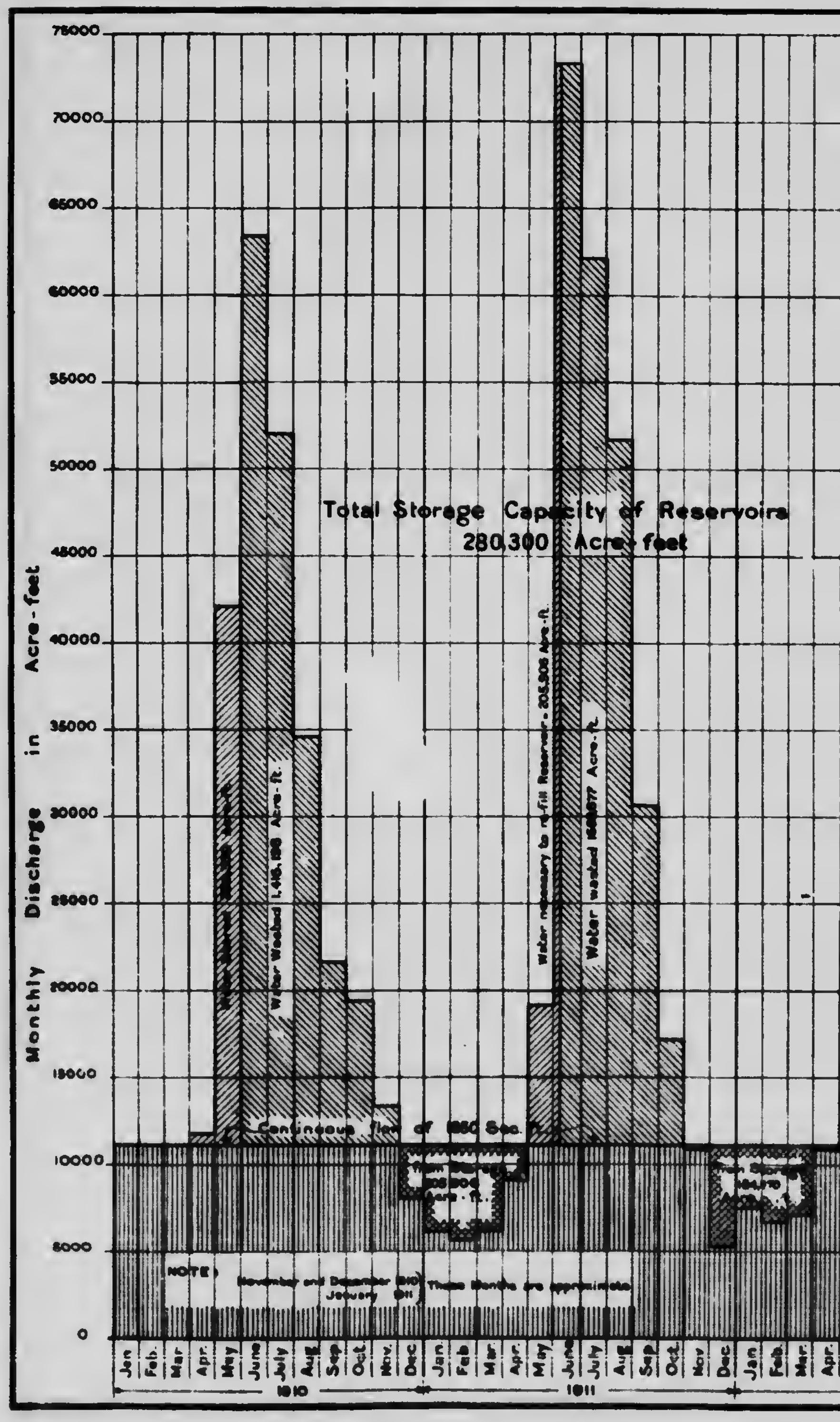
M.C. Hendry ..... Chief En



Dec. 1912

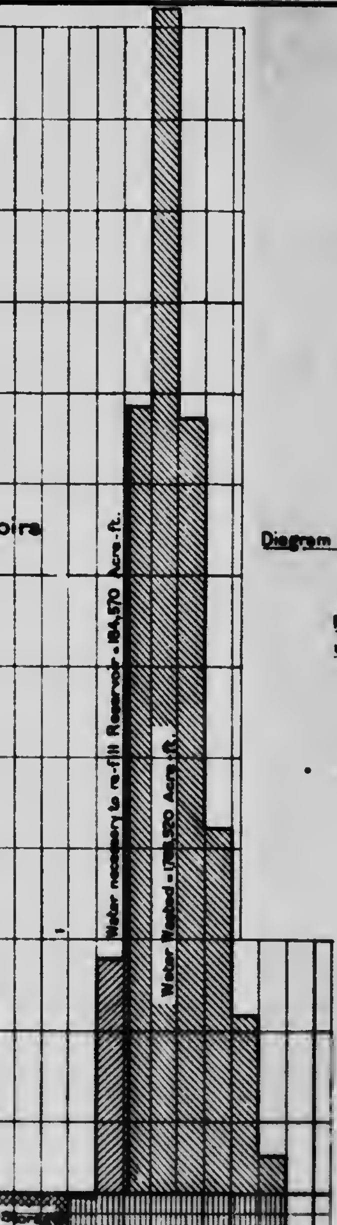

Consulting Engineer
Chief Engineer
100000
90000
80000
Water Wasted
150,303 Acre-ft.
Water Wasted
170,404 Acre-ft.
Flow of 200 Sec-Ft
May
June
July
Aug.
Sep.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sep.
Oct.
Nov.
Dec.
1911
1912


Monthly Discharge in Acre-feet
0
35000
40000
50000
55000
60000
70000
75000



Total Storage Capacity of Reservoirs
280,300 Acre-feet
Monthly Discharge in Acre-feet
75000
70000
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
Water Wasted 1,416,198 Acre-ft.
Water necessary to re-fill Reservoir - 205,908 Acre-ft.
Water wasted Acre-ft.
Continuous flow of Sec. ft.
NOTE:
November and December 1910
January 1911
These Months are approximate
Jan
Feb.
Mar
Apr.
May
June
July
Aug
Sep
Oct
Nov.
Dec
1910
1911

PLATE XIX



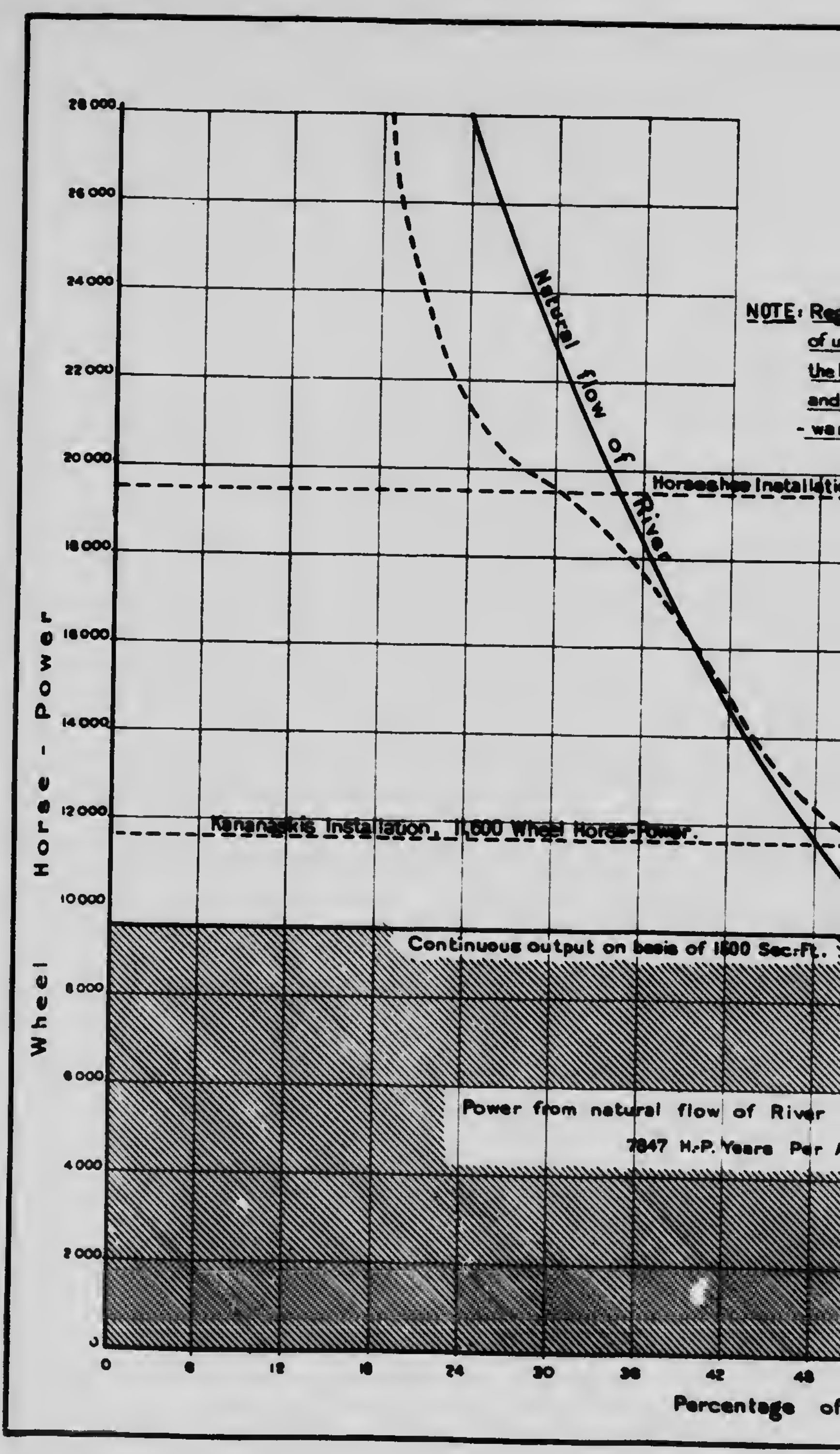
BOW RIVER

Diagram shewing Discharge in Acre-ft. from Jan. 1910 to Dec. 1912
below
CALGARY
— ALSO —
Record of filling Storage Basins and water wasted
under a continuous flow of 1850 Cubic Ft. per Sec.

To accompany report on Power and Storage Investigation
By M.C. Hendry, B.A.Sc.

C.H. Mitchell — Consulting Engineer

M.C. Hendry — Chief Engineer



28 000
26 000
24 000
22 000
20 000
18 000
16 000
14 000
12 000
10 000
8 000
6 000
4 000
2 000
0
Wheel Horse - Power
Natural flow of River
Kananaskis Installation, 11,600 Wheel Horse-Power.
Continuous output on basis of 1500 Sec.-Ft.
Power from natural flow of River
7847 H.P. Years Per
0
6
12
18
24
30
36
42
48
Percentage of

PLATE XX

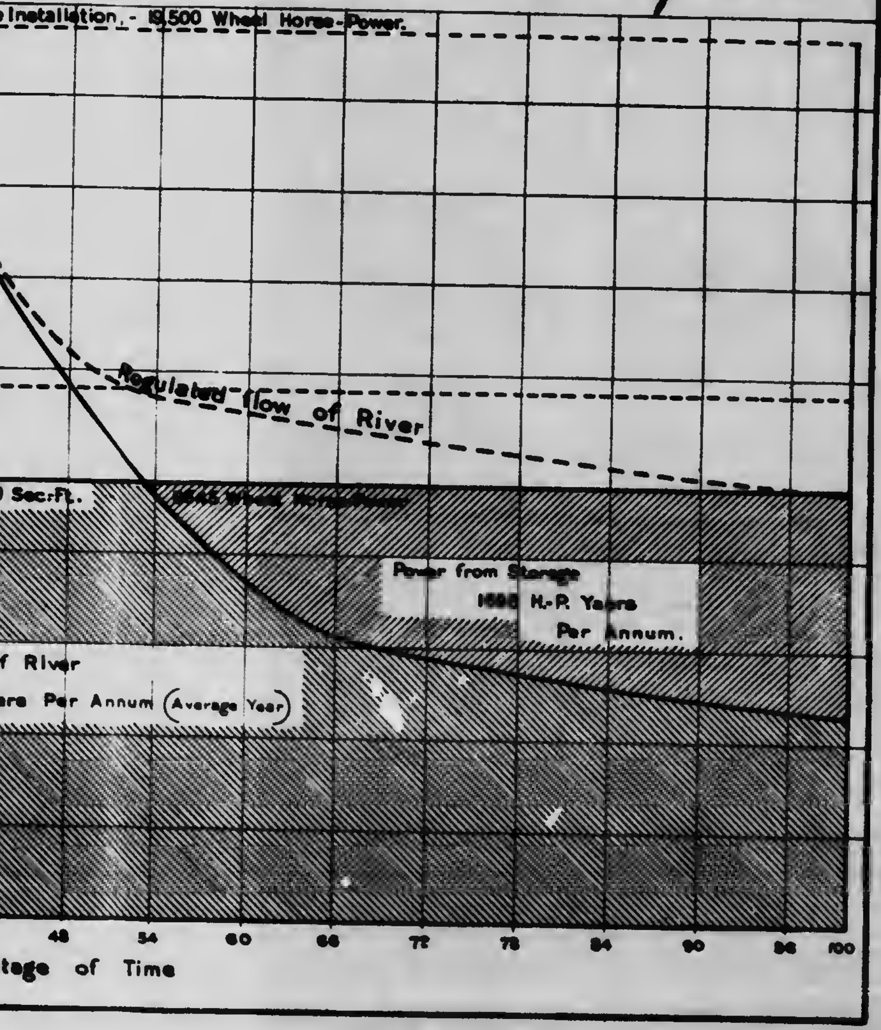
Power - Percentage of Time Curves
— of the —
Bow River at Horseshoe and Kananaskis
Period: May 1909 to April 1912.
Head - 70 ft. - 80 % Efficiency

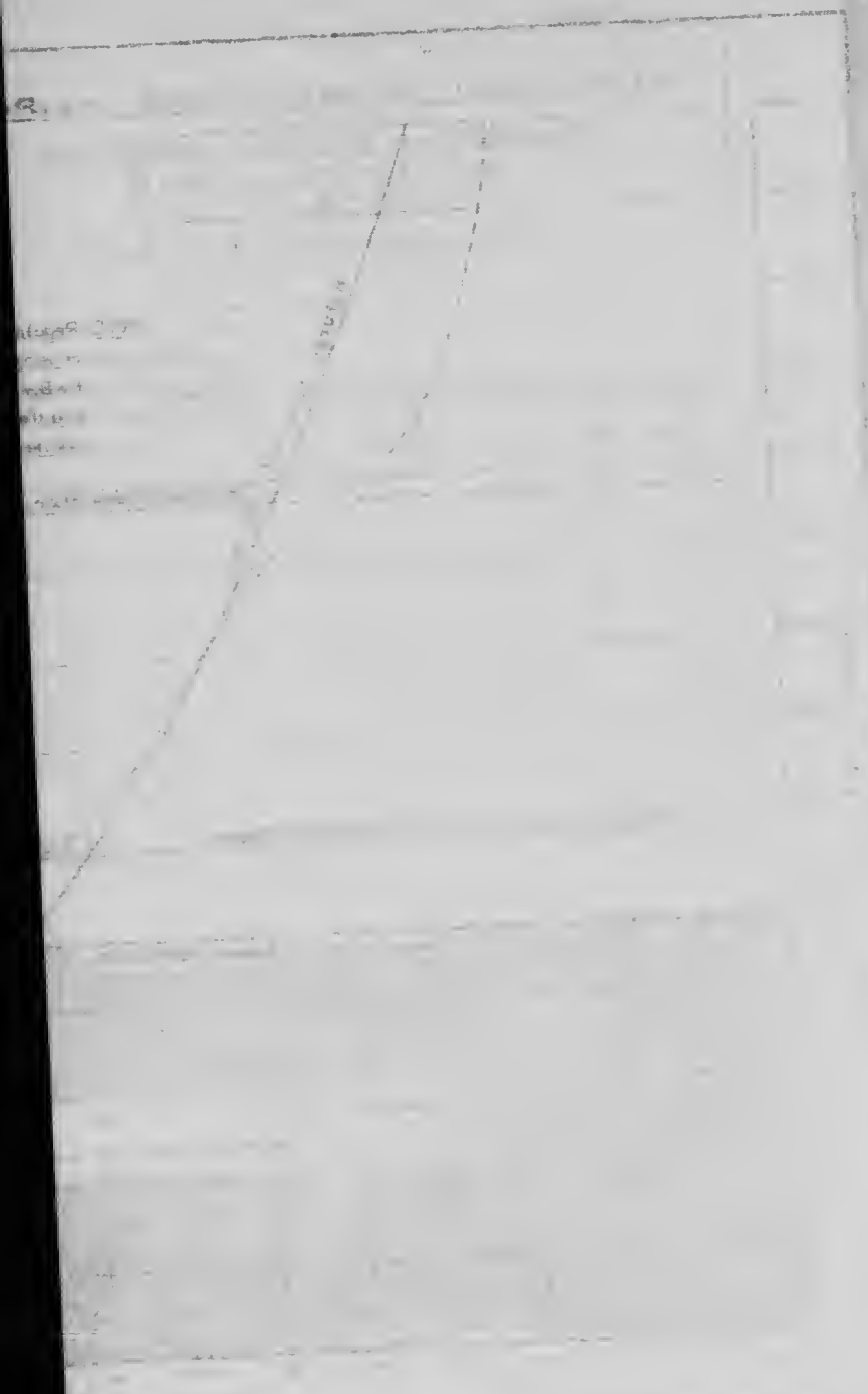
To accompany report on Power and Storage Investigation
— by M.C. Hendry, B.A.Sc. —

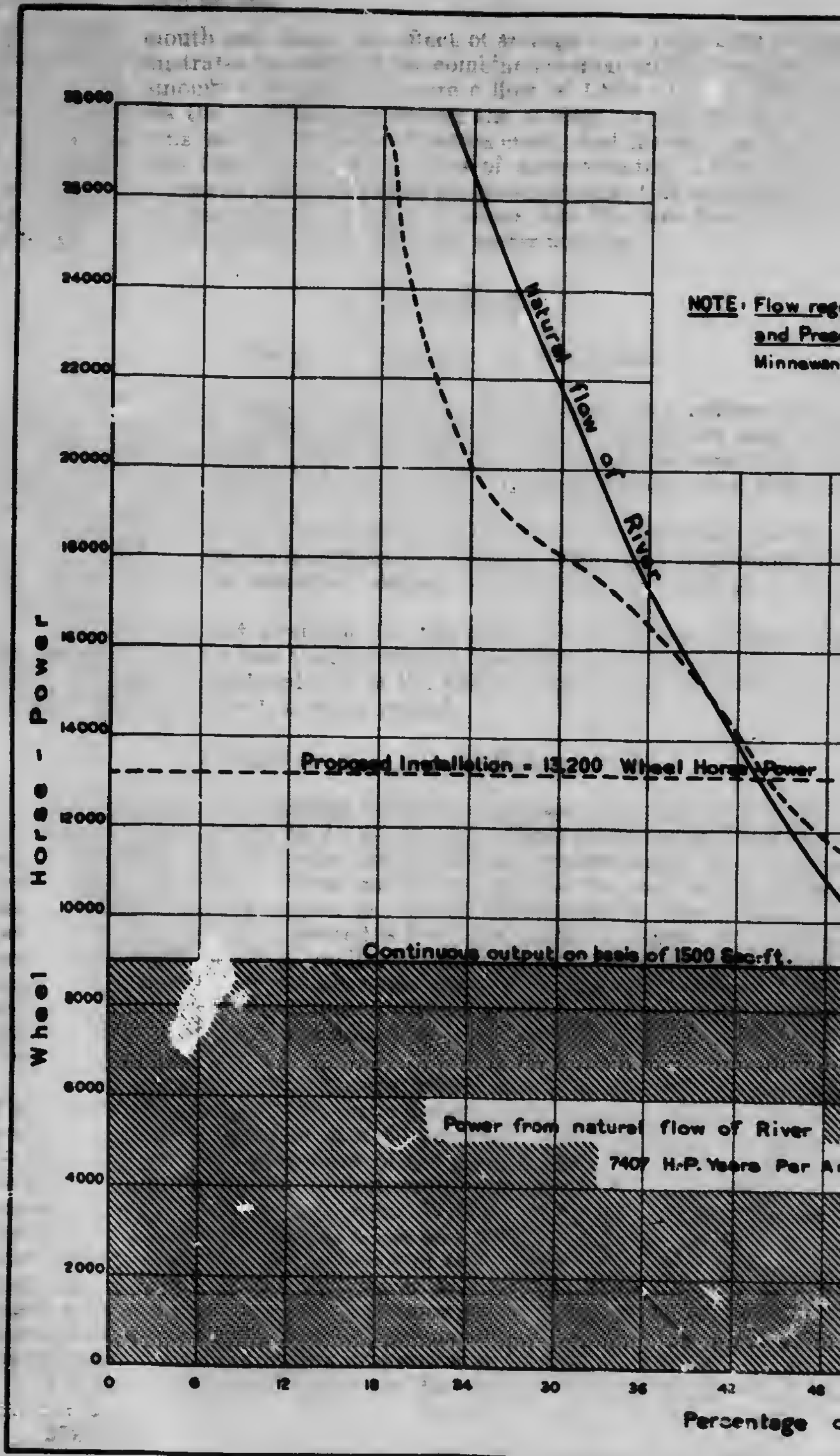
NOTE: Regulated flow of River is result of using the proposed Reservoirs of the Bow Lakes and the Spray Lakes. and the Reservoir at Lake Minne- - wanka, with auxiliary.

C. H. Mitchell — Consulting Engineer.

M. C. Hendry — Chief Engineer.







Wheel Horse - Power
28000
26000
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
6
12
18
24
30
36
42
48
Natural flow of River
NOTE:
Proposed Installation = 13,200 Wheel Horse Power
Continuous output on basis of 1500 Sec-ft.
Power from natural flow of River
Percentage

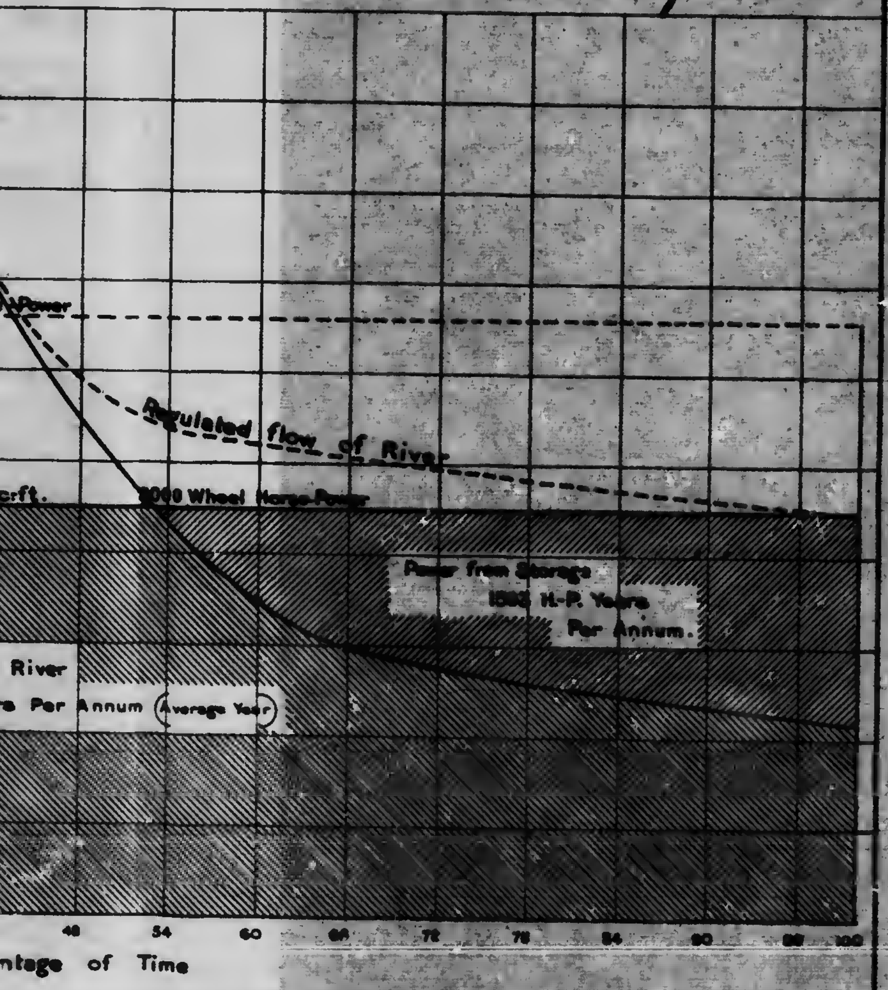
PLATE XXI

POWER - PERCENTAGE OF TIME CURVES
OF THE
BOW RIVER AT BOW-FORT POWER SITE
Period: May 1909 to April 1912.
Head - 66 ft. - 80% Efficiency

To accompany report on Power and Storage Investigation
by M.C. Hendry, B.A.Sc.

Flow regulated from Proposed and Present Reservoirs, with Minnewanka auxiliary.

C.H. Mitchell . Consulting Engineer.
M.C. Hendry . Chief Engineer.



S

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Pl
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Ca
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of

lak
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mo
as l

by
1,60
1,80

Bow
and
be e

prep
avai
prod
and
perio
pract
whee
equal
that
from
I
Falls
under
be de
be 28
would
natur
derive
duce
9,545
horse-
power
F
natura
25

Elbow at its mouth and shows the effect of storage from 1910-1912. Diagram Plate No. 19 illustrates the effect of the combined storage on the Bow river below Calgary and amount necessary to secure a flow of 1,850 c.f.s.; a study of this diagram reveals the fact that regulating the storage on the Elbow to secure a flow of 200 c.f.s. at the site below Canyon creek, and the storage on the Bow from Kananaskis falls would give a flow of approximately 1,850 c.f.s. below Calgary. It is apparent from the diagram, however, that this would be exceeded by at least 200 c.f.s., due to the flow of water into the Bow below the Ghost, of which there is no record during the low water months.

CONCLUSION.

Effect of Storage on Discharge.

Using a storage capacity of 243,100 acre-feet and an auxiliary storage at lake Minnewanka of 14,200 acre-feet, a flow of 1,500 second-feet may be maintained over the low-water period of any year, between Kananaskis falls and the mouth of the Ghost river; during years of ordinary precipitation, this may go as high as 1,700 c.f.s.

Below the mouth of the Ghost river, the regulated flow may be increased by at least 100 c.f.s., or say from the Ghost to Radnor a continuous flow of 1,600 c.f.s. would be available; during some seasons it might go as high as 1,800 c.f.s.

The data are not available for the discharge of creeks tributary to the Bow between Radnor and Calgary during low-water months, but below Calgary and including the regulated flow of the Elbow, a flow of nearly 2,000 c.f.s. may be expected during the low water period.

Effect of Storage on Power Output.

In addition to the foregoing tables and hydrographs, some curves have been prepared (see Plates Nos. 20, 21, 22, 23, 24). These show the effect of the total available storage in the basin (developed and undeveloped) upon the power producing of the river. These curves are plotted for each of the plants built and proposed and are known as "Power-percentage of time curves." The period for which they are plotted is from May, 1909, to April, 1912, embracing practically all the records available. The ordinates of the curves represent wheel horse-power, and the abscissae time, in percentages, 100 per cent being equal to the period given above. Two curves are plotted, one in a full line being that derived from the natural flow during the period, and the broken line that from the regulated flow.

Diagram, Plate No. 20 has curves for both the Horseshoe Falls and Kananaskis Falls plants; referring to the curve derived from the natural flow of the river, under a head of 70 feet and with 80 per cent efficiency, the power that could be derived from the natural flow of the river, 24 per cent of the period, would be 28,000 wheel horse-power; that due to the regulated flow for the same time would be 21,400 wheel horse-power. Where the regulated flow is less than the natural flow, the power derived is less and where the former is greater the power derived is greater; for 100 per cent of the period the natural flow would produce about 4,580 wheel horse-power and the regulated flow would produce 9,545 wheel horse-power; that is 24-hour power, 365 days a year. Of this, 7,847 horse-power years would be due to the natural flow of the river and 1,698 horse-power years due to the release of water from storage.

For the Kananaskis Falls plant the output in an average year from the natural flow of the river would be, for the turbine installation, 8,101 horse-power years. With the proposed regulated flow this could be increased by 1,863 horse-power years, giving a total annual output of 9,964 horse-power years.

For the Horseshoe Falls plant the same curve applies, the head and regulated flow being the same. Here, however, the turbine installation is greater, being 19,500 horse-power from the curve, it will be seen that the total annual output due to the natural flow would be 12,087 horse-power years, to which may be added, due to stream regulation, 2,171 horse-power years, giving the total annual output of 14,258 horse-power years.

The other curves for the undeveloped sites are worked out on the same basis and the results are tabulated in table No. 5 so that further explanation is hardly necessary.

Auxiliary Storage.

Where the main storage basins are so remote from the point of utilization as in the Bow basin, some auxiliary storage of sufficient capacity to tide the plant over a sudden drop in the flow is necessary. The amount of storage that may be developed in connection with each plant is rather limited, the river is confined mainly between high banks so that any increase in level produces a very small increase in area; this is especially the case at the present plant at Horseshoe falls; from the dam to the foot of Kananaskis falls the banks are high and the present flooded area is but little in excess of the former area of the river.

At Horseshoe falls the area of the pond above the plant is 98.5 acres which, with a draw down of 4 feet, has a capacity of 394 acre-feet, capable of supporting a discharge of 200 second-feet for twenty-four hours; this might be sufficient over a short period, but is of little value when a reduction of flow takes place. At such a time it becomes necessary to sustain the flow for the eighteen to twenty-four hours which must elapse before the effect of storage above can be felt.

The Horseshoe Falls plant is, of all the developments built or proposed, the least favourably situated in this regard. The plant at present building at Kananaskis, though better situated, has very little advantage in respect to storage area. When the elevations of the structure are finally settled, the depth of storage possible may be found to be in excess of that at the Horseshoe Falls plant, but with a draw down of 4 feet as before, and a pond area above the dam of 122.25 acres, a total of 489 acre-feet would be available; this would provide a flow of 258 second-feet for twenty-four hours.

The drawing down of the head-water, however, makes a serious inroad upon the output of the plant; the storage propositions looked into on the Kananaskis river within a radius of 8 or 10 miles of Kananaskis falls have been made with a view to eliminating this trouble as much as possible.

An examination was made of the Kananaskis river during the summer of 1912, to investigate the possibility of creating storage in lake Chiniki by damming the river and raising the water to a sufficient height to flow into the lake, to be there stored until needed. It was found that it would be necessary to go a long way upstream to raise the water to the desired height, and also that to return the water to the river it would be necessary to re-traverse or cut through a height of land between the lake and the river; this would involve considerable work, as the summit, though not high, is long.

There are several possible dam sites within a distance of 8 miles from the mouth of the river, at which the water might be raised 40 or 50 feet; the amount of storage these would create would be small, and only a survey in detail would reveal the value of the several basins so created; these were dealt with before.

The other proposed developments are rather better situated than the present two, the area of the ponds at these several sites are as follows:—

TABLE No. 24.

PONDAGE AREA ABOVE EACH PLANT.

Site.	Pond Area.
Bow Fort	205 acres.
Mission	353 "
Ghost	786 "
Radnor	241 "

In connection with the Ghost and Radnor sites, the question of storage on the Ghost river was looked into. A possible storage basin of small area near the mouth of the river, and of which plans accompany this report, was developed in some detail; the site, however, is not considered attractive as the capacity for storage is limited and the structure involved large.

ICE CONDITIONS BELOW STORAGE BASINS.

At the end of last winter an examination was made of the river between Banff and Kananaskis falls; also of the Cascade river between lake Minnewanka and the mouth, and the Spray river for about 8 miles from the mouth. A number of photographs were taken to illustrate ice conditions found at different points on the rivers, some of these are reproduced here.

Between Kananaskis falls and the mouth of the Cascade the Bow, when examined, was for the most part open, and in a few places only was there evidence of overflow. Below the Spray falls on the Bow, where the formation of frazil would be excessive, there was little evidence of clogging and overflow, the river being entirely confined to the channels. On the Spray river, as far as examined, the same conditions obtained; for the first 4 miles above the mouth, the river was entirely ice bound, above that point the river was open in many places, and, although some overflow had occurred, the amount was so small that it was practically negligible.

On the Cascade, the conditions encountered were somewhat different. Between the storage dam and Bankhead, the river was practically clear of ice, and there was no evidence of the formation of any large quantity. This condition showed a reversal of the conditions found in March, 1912, for, after a certain amount of water had been discharged from the lake in 1913, large quantities of ice were found upon the flats below Bankhead, and these extended nearly to the mouth. In many places this ice was in fields, 4 and 5 feet thick, and 400 to 500 feet wide; below the Canadian Pacific Railway bridge the ice was in even greater quantities and much thicker.

These conditions were due largely to the nature of the river bed, and also the method of releasing the water from storage. During the early part of any cold spell (as evidenced by the records), the flow in the stream was small and the channel narrow and easily blocked during severe weather by frazil and anchor ice; when water was released, the choking of the channels increased, and flooding and consequent ice formation took place. Reproductions, pages 19, 20, 24 and 25 illustrate the resulting conditions.

STORAGE MANIPULATION.

The question of regulation of discharge from the different storage basins is one requiring care and experience. During the first few years of operation it is not expected that they can be operated to secure the maximum efficiency though regulation should improve as the amount of data is increased.

Photo by K. H. Smith.

Kananaskis Falls after Construction.

The comparative remoteness of the several storage basins from the power-producing sections of the river, prevents any close regulation of the flow at the plants, for it is estimated that it will take at least 18 hours before water released from Minnewanka will reach Kananaskis Falls.

During the last winter, owing to the difficulty of anticipating temperature changes (the controlling factor), water released from Minnewanka did not reach the plant until the extreme conditions due to the weather had partially adjusted themselves; also, a large percentage of the water was wasted in transit, especially in the upper part of the river near the basin, in the form of ice. It is scarcely fair, however, to use the first season of regulation as a basis for reaching definite conclusions as to the benefits to be secured, for it must be remembered that, besides lack of experience in handling the storage, other things militated against maximum efficiency; for instance, between Bankhead and the mouth of the Cascade, no improvement to the river bed has been made, thus much of the water released spreads over the flats, freezes and is wasted.

Diagram, Plate No. 3 shows not only the marked influence of temperature upon discharge, but also shows when and to what extent storage was supplied, for the recorded levels indicate the discharge indirectly; it may safely be assumed that when the surface level remains constant there is no discharge, and when the lake level falls, water is being discharged from storage; also the rate of decrease in the lake level indicates the rate of discharge.

The wasting of water by ice formation on the flats, as mentioned above, is due, in a very great measure, to the method of storage manipulation.

A study of other rivers in the vicinity during the past season has led to the conclusion that if the channel is kept open, little clogging and overflow occur.

It will be noted in nearly every case, that for a varying length of time, immediately preceding a period of low temperature, and during the first part of that period, the flow from storage was that of the normal flow of the river. Later, the water released from storage met with a condition in the river, a channel restricted and clogged with ice, the result being an overflow and excessive ice formation in the river valley.

The opinion is advanced that, under the normal conditions of the river, or where the normal discharge is fairly large and constant the ice troubles will be very appreciably reduced.

It is therefore expected that, with the building of a power plant upon the Cascade, immediately below the storage dam, and the consequent nearly constant discharge, the channel will be kept in fair condition, which will go far to eliminate the trouble.

The discharge from Spray Lake basins will take even longer to reach the plants, so that any attempt at regulation would be of little benefit; it is therefore proposed in regard to that basin to keep the flow fairly constant during the low water period, and do any necessary regulation near the plants.

A fairly large flow or discharge from Spray lakes will, it is expected, eliminate, to a very great extent, the trouble and losses due to ice. During the last winter season, the river was examined for a distance of about 8 miles, and while the flow was fairly large, the amount of ice formed was comparatively small, only at two or three points in the section examined was there evidence of blocking and overflow; these were of very small extent.

The manipulation of the proposed Bow lake storage presents further difficulties, but by special treatment these may be overcome.

To attempt to secure a continuous discharge from that source throughout the winter months, would mean practically the entire loss of the value of the storage, the nature of the channel through which the water flows being very similar to that of the Cascade for nearly the entire length above Laggan. In order that the maximum benefit may be secured from this basin, it is proposed to release the water during one or two months only and hold it through the sever weather, say from December to March. In some years it may be found ad vantageous not to release any water during November, but hold the whol amount for use during March and April; this would probably secure the greates efficiency, for the release of water during November might mean a loss of considerable amount owing to cold weather towards the end of the month, whil in March and April the conditions for discharging are improving.

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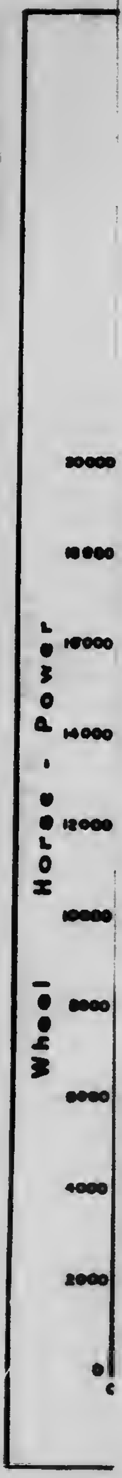

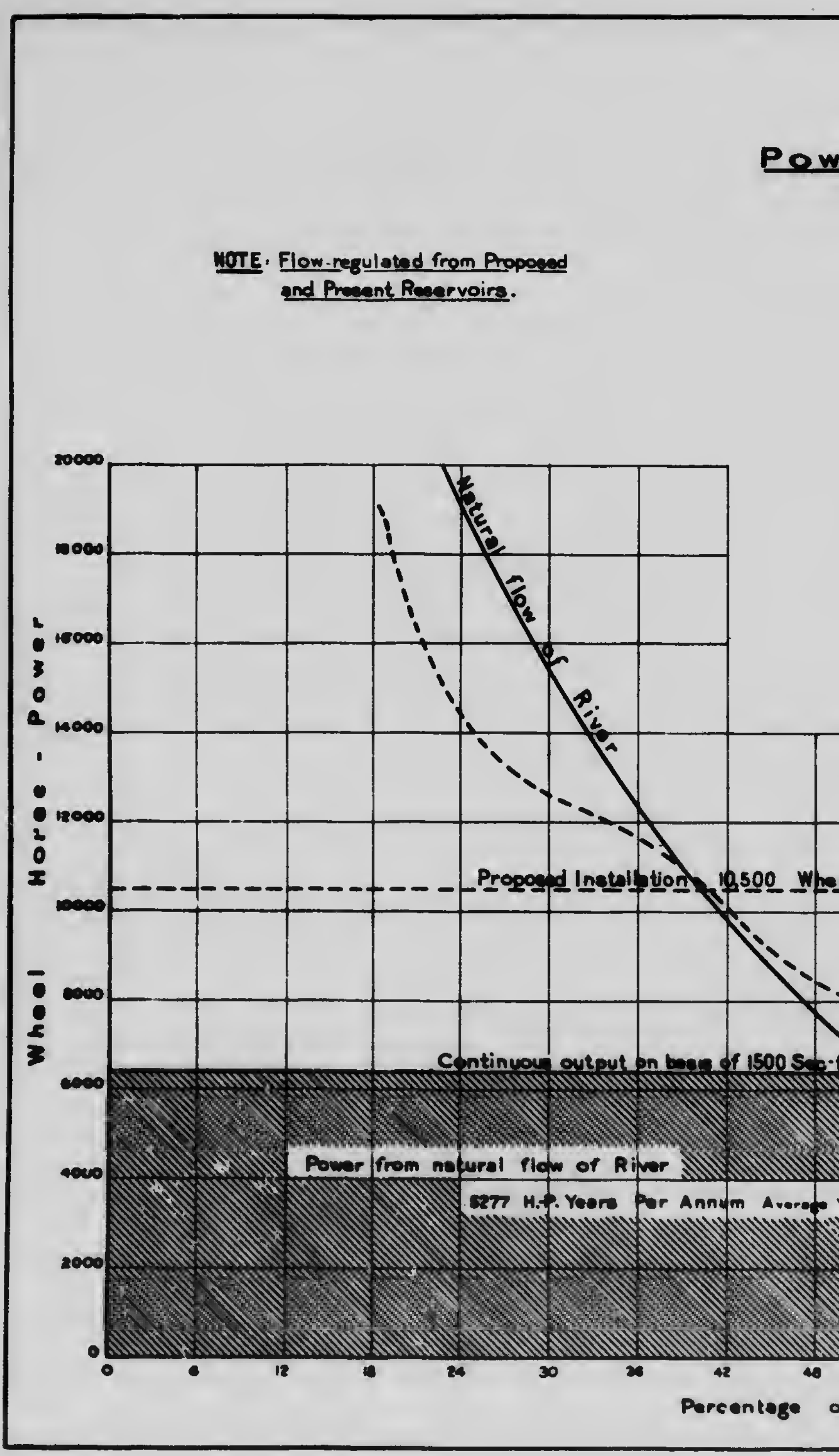

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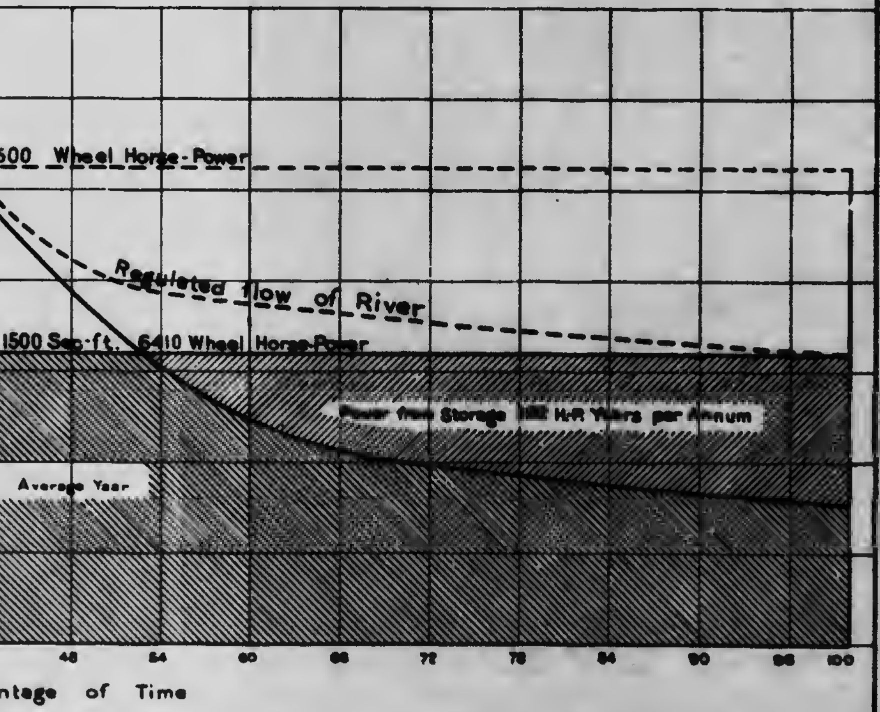
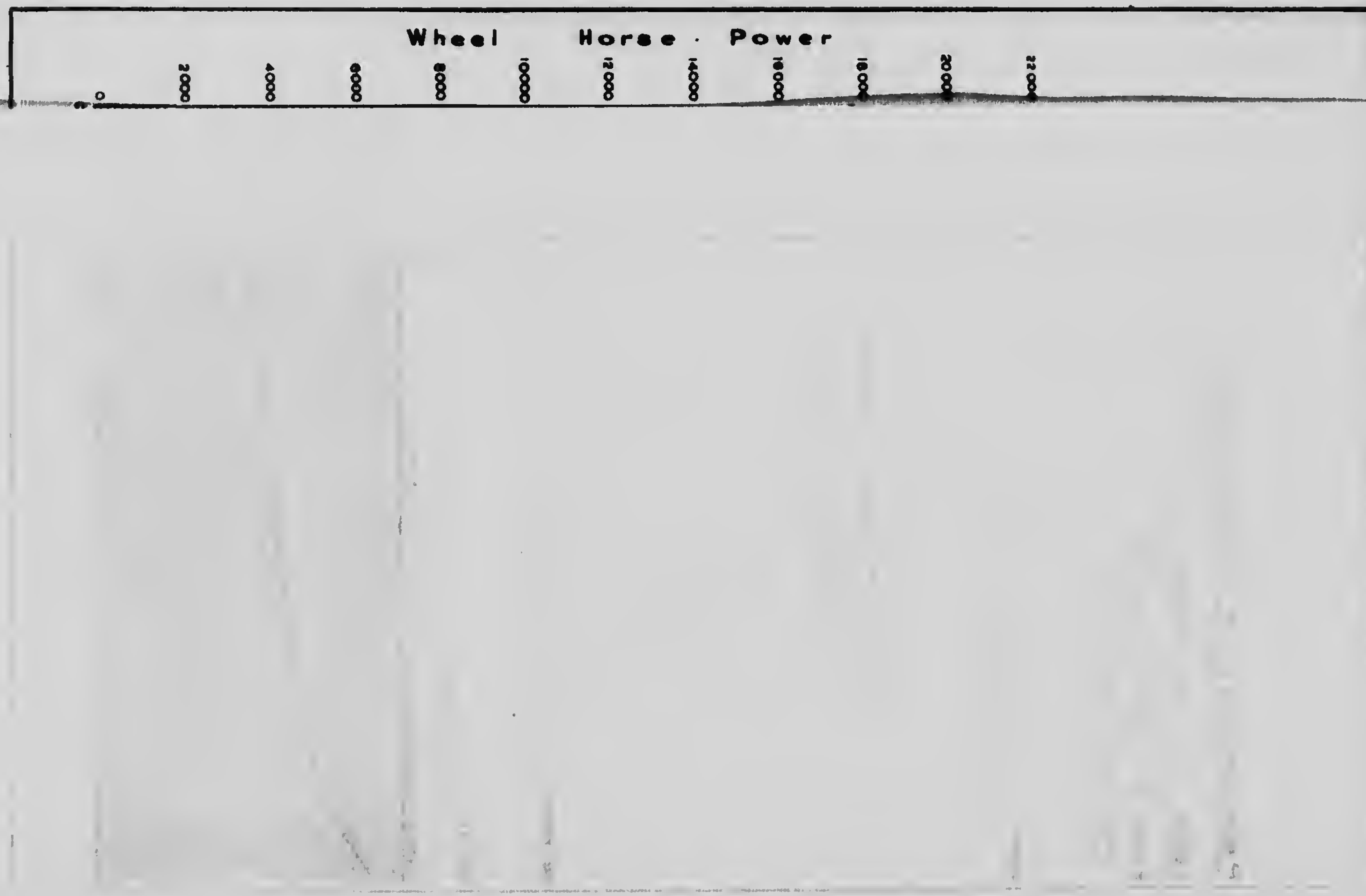
Percentage

Power - Percentage of Time Curves
— of the —
Bow River at Mission Power Site
Period: May 1909 to April 1912.
Head - 47 ft., 80% Efficiency

To accompany report on Power and Storage Investigation
—— by M.C. Hendry, B.A.Sc. ——

C.H. Mitchell Consulting Engineer
M.C. Hendry Chief Engineer

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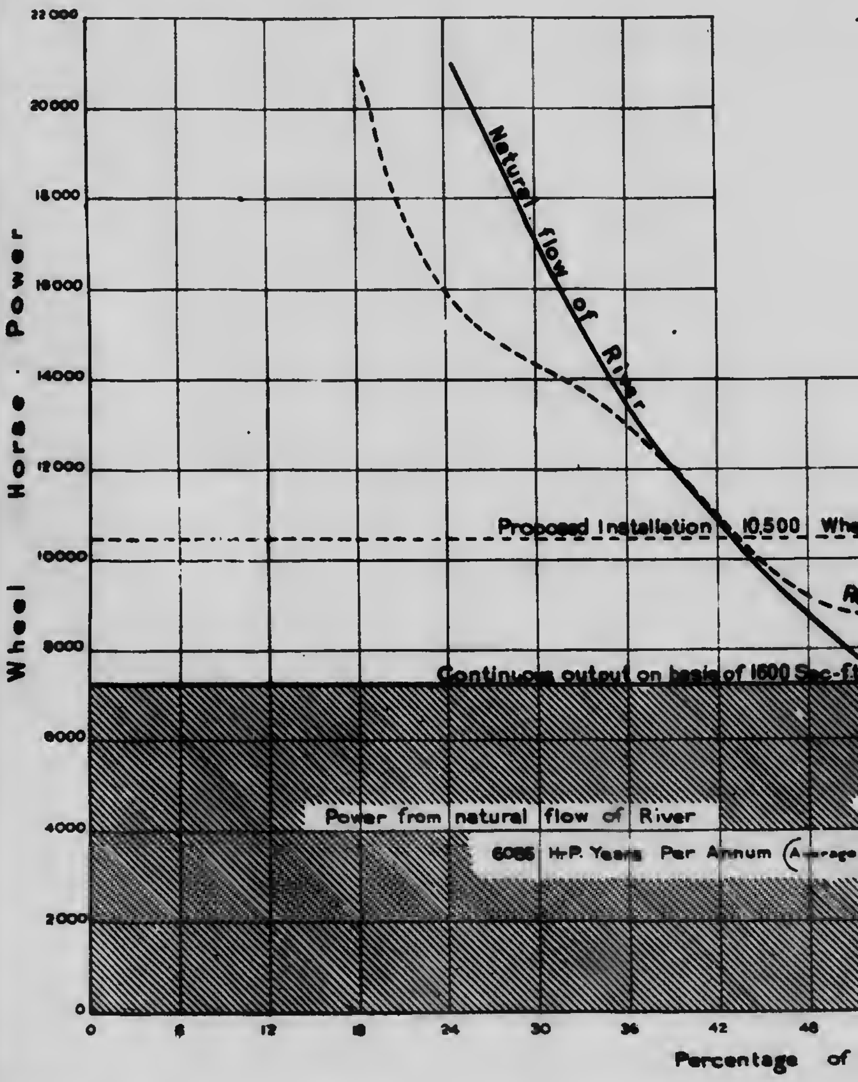
NOTE: Regulated flow of River is result of using Present and Proposed Storage



…OWER - PERCENTAGE OF TIME CURVES

OF THE

BOW RIVER AT GHOST POWER SITE

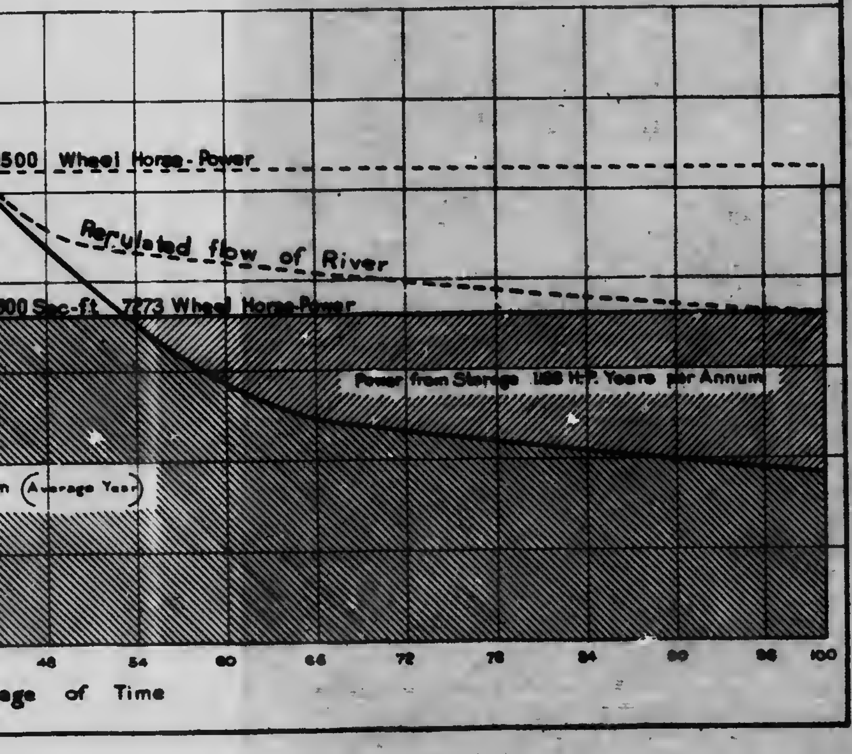
Period: May 1909 to April 1912.

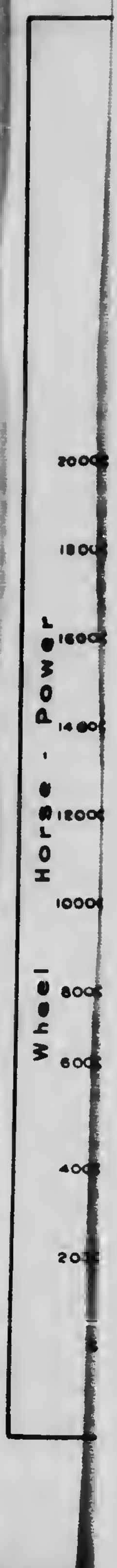
Head - 50 ft.. 80% Efficiency

To accompany report on Power and Storage Investigation
by M.C. Hendry, B.A.Sc.

C H Mitchell — Consulting Engineer

M. C. Hendry — Chief Engineer





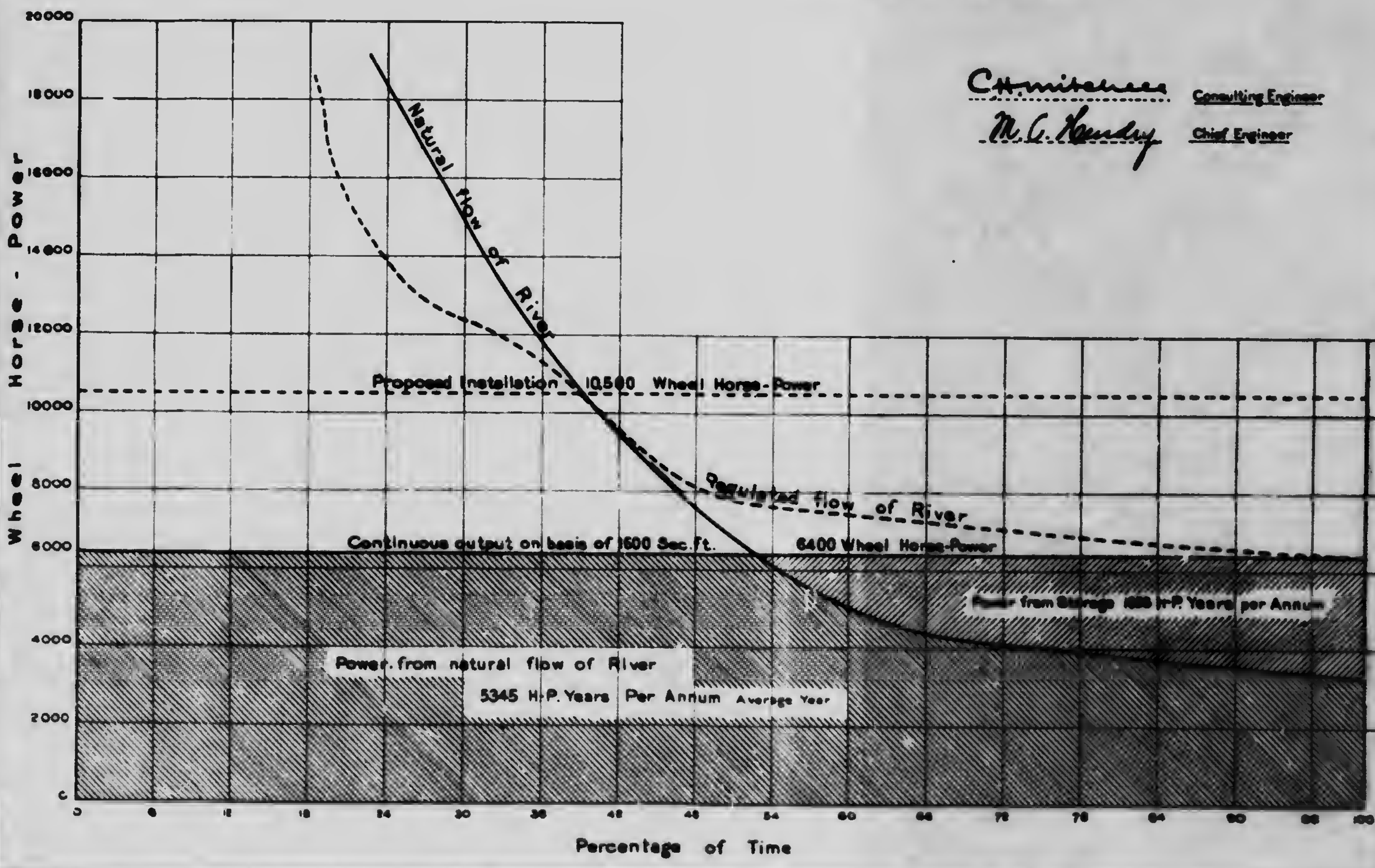
Wheel Horse - Power

POWER - PERCENTAGE OF TIME CURVES
OF THE
BOW RIVER AT RADNOR POWER SITE
Period: May 1909 to April 1912.
Head - 44 ft., 80% Efficiency

NOTE: Regulated flow of River is result of using Present and Proposed Storage

To accompany report on Power and Storage Investigation
— by M.C. Hendry B.A.Sc. —

C. H. Mitchell .... Consulting Engineer
M. C. Hendry .... Chief Engineer



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CHAPTER XII.

IRRIGATION.

General.

The question of the effect of the creation of storage upon irrigation requirements is one which must be considered at the same time as that of its effect on the power interests.

Calgary lies on the western and Regina on the eastern limit of a dry belt, in which the soil is, for the most part, very fertile.

From time to time irrigation has been attempted in this district, the first scheme being on Fish creek as early as 1879. Numerous other small schemes were instituted, but it was not until 1893 that an undertaking of any magnitude was begun. The two largest undertakings were those of the Calgary Hydraulic Company, with head-works on the Elbow river west of Calgary, and the Calgary Irrigation Company, whose head-works were also on the Elbow river; by the end of 1894 there were projects of all sizes in operation to the total number of seventy.

The increase in irrigation undertakings was continuous until, by the year 1902, the number of ditches in operation was 169, capable of irrigating 614,684 acres. Recently some of the schemes have been abandoned; one of these is that of the Calgary Hydraulic Company.

About 1905 the Canadian Pacific Railway Company became an active advocate of irrigation, and instituted the scheme which, at present, is the largest and most comprehensive reclamation undertaking in the Canadian West; a main channel with head-works just below the junction of the Bow and Elbow rivers carries water to irrigate land to the north and east of Calgary, while the principal undertaking is farther to the east, and it has recently constructed a large dam near Bassano to serve 513,000 acres of irrigable land.

Relation of Power and Irrigation Requirements.

It is well to recognize that the agricultural industry, with its accompanying irrigation requirements, is pre-eminent in this locality, and must consequently take precedence of all power requirements as regards the use of water.

When this investigation of the Bow river water supply was first undertaken there was some apprehension that possibly there might be a conflict of interests in the adjustment of water supply. As, however, the investigations were proceeded with and broadened it was rapidly discovered that instead of any interference there was, on the other hand, rather a co-operative effect. On the broad principle that any storage project will equally assist both power production and irrigation in supplying ample water for their requirements, it is obvious that there can be no interference of rights if the river discharge is equitably controlled so as to be uniform throughout the spring and autumn.

Fortunately the requirements for irrigation exist only throughout what may be termed high and normal water periods of the river, commencing not earlier than April 7 and extending not later than September 30. Of these summer months at least three have high flood discharge on this river, whilst the other two, viz., May and September, produce discharges larger than the proposed new regulated flow of 1,500 second-feet at, say, Morley. The effect of the withdrawal of water by storage on the high summer flood, cannot be such as to interfere with efficient irrigation; on the contrary, provision is made for the future, because such a large supply cannot be maintained throughout the entire irrigable season, and the month of April is much improved by storage while September remains as before.

Under any circumstances, during the operations of water control and supply from storage reservoirs, the requirements of irrigation should be kept clearly in mind, and in the face of a threatened shortage, the reasonable demands of irrigation must be given precedence.

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Kananask

Kananaskis Falls Dam. Photo by K. H. Smith.

APPENDIX I.

RECOMMENDATIONS *RE* A POLICY OF STORAGE AND REGULATION ON THE BOW RIVER.

BY

C. H. MITCHELL, C.E.

RECOMMENDATIONS RE POLICY OF STORAGE AND REGULATION ON THE BOW RIVER.

(By C. H. Mitchell, C.E.)

March 31, 1914.

J. B. Challies, Esq.,
Superintendent of Water Power Branch,
Department of the Interior,
Ottawa.

Dear Sir,—In concluding my investigations and study of the Bow river and its basin with respect to water supply, storage and regulation of discharge, I have the following to bring to your attention. This report embraces recommendations and suggestions for giving practical effect to the conclusions which we have reached.

Scope.

The conclusions herein contained have reference to the water supply question solely with respect to the regulation and control of the river so as to equalize the discharge in the most advantageous manner for power purposes keeping in mind the requirements of irrigation.

General.

If the country in the foot-hills east of the Rockies and within transmission radius of the Bow river is to be encouraged as an industrial region, the utilization of its natural resources is an economic necessity and the utmost development of the water power of the Bow river is a logical outcome. In this region there are already rapidly-growing industrial communities and their steady growth is dependent on probably no more important factor than an ample supply of power.

The Bow river is peculiar in that, in its natural condition, its high summer-flood discharge is upwards of seventy times its low-water winter discharge, a condition which obviously renders its use, in its present state, unsuitable, inefficient and commercially unfeasible for power purposes.

The investigations which have been carried on during the past two years, the results of which have been embodied in the general report of Mr. Hendry and in which I have collaborated, indicate that if the Bow river is to be an efficient commercial source of power and at the same time to afford all ample water supply for irrigation purposes it is absolutely necessary that the river be regulated and controlled so as to ensure a fixed and useful supply of water continuously throughout the year.

Conditions to be Met.

If the improvement of Bow river is undertaken for the advantage of the power and irrigation industries it is obvious that it should be done by, and remain under the control of, the Government because of the many conflicting interests of water demand which would be involved. In addition to the irri-

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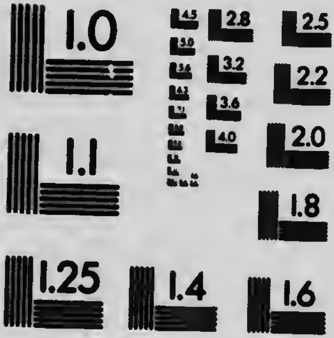


gation interests, there are, or are likely to be, several power companies all requiring water in some degree of uniformity throughout the year. Such being the case, it is evident that once the storage system is constructed, its satisfactory operation, impartial and efficient, can be secured only through the medium of some central official body, exercising an absolute control over the water supply so as to obtain the greatest advantage and efficiency to the largest proportion of public users. All users must be made parties to the arrangement so as to make it completely co-operative.

Policy to be Framed.

If this water supply project is undertaken as a work of public benefit by the Dominion Government, it would naturally be the function of the Water Power Branch of the Department of the Interior to carry it out and subsequently administer its operation. To carry this to a successful issue, looking to the distant as well as the immediate future, it appears to me that a definite departmental policy will require to be framed with respect to:—

A.—Investigations as to: (1) the requirements and the possibilities, and as to (2) the betterment of the conditions under which the project is to be administered and operated.

B.—Construction of storage reservoirs and regulating works on the river and its head-waters.

C.—Operation of the storage, and regulating works for the benefit of all concerned.

There need be no alteration in the policy of the department with respect to power sites, leases and operative conditions thereof except in so far as they may be affected by the supply of the additional water furnished under the storage and regulating project.

A.—Investigation.—The work which has been carried on by the Water Power Branch on the Bow river during the past two years, the results of which are now being published, constitutes practically the whole of the investigation preliminary to the undertaking of this project. So far as it has been possible to carry this investigation up to the present, it is reasonably complete, pending the development of a definite policy to be laid down.

Some of the data upon which the general project is based, being obtained from various sources, have by necessity been meagre because of the short period over which the investigations have been made. It has been necessary to employ data which were originally made for other purposes and with another viewpoint, whilst on the other hand, if data obtained especially for this purpose were to be secured, a long term of years would elapse and the project be delayed in its consummation.

On account of the foregoing, it appears now to be necessary to continue the periodic collection of data and to further investigate the performance of the river and its tributaries so that as time goes on, whether actual construction is entered upon or not, a continuous cycle of records becomes available. This applies more particularly to: (1) River gaugings, more especially on the separate tributaries; (2) precipitation records, especially in new stations nearer the head-waters and at a higher altitude; (3) temperature records at the same stations; (4) observations on the diminution of glaciers; (5) observations regarding water elevations along Bow river; (6) effect of winter conditions on the flow in the Bow river tributaries; and (7) observations regarding seepage.

It is also of the greatest importance that, after operation of the storage works is commenced, a careful study and analysis be made of the performance of the various storage basins, their sources, water supplied by the various tributaries of the river and their performance during regulating operations in the winter months and the other controlling factors entering into the regulation of water supply so as to secure the best results.

B.—Construction.—The construction work involved in this project in its entirety, in accordance with the report, comprises storage and regulating dams on:—

1. Lake Minnewanka.
2. Bow lake
3. Spray River canyon (Spray lakes).

In order to carry this whole project to its logical conclusion, it is evident that the construction of these reservoirs should be undertaken as a Government work in the same manner as the Government constructs other public improvements for the benefit of the locality or the country at large. This undertaking has a strong point in its favour, in that the Government can very rightly recover the whole or a portion of the cost of the work in the form of annual rentals charged to the various users for the additional water thus supplied. These rentals can be adjusted amongst the various power companies or power sites in the leases given by the department, and be recoverable with the annual power rentals. The basis of water charge can be adjusted either according to quantity of water used or to power produced, arranged on some equitable scale.

The first of the foregoing works has already been constructed and was finished in time to catch the 1912 summer flood; the performance of this reservoir and its regulation during the past winter has been made the subject of considerable study and will form the basis of the further investigations which I have suggested above. This reservoir with its accessory works was constructed at the expense of the Calgary Power Company with an arrangement whereby the Government may take it over at cost at any time in the future, and on this account the work was done under the supervision of the Government's engineers and accepted by them with a view to its ultimately becoming a part of the proposed storage and regulation system. In this respect, therefore, the way is already prepared for carrying out the Governmental policy outlined above.

Co-operation.

As has already been stated, it is necessary to the success of the project that the operation of the storage and regulation be solely under the control of the Government. The authority could best be vested in an engineer located on the ground, say at Banff, who would apportion the water and adjudicate between the users and he, through his several assistants, would actually carry out this process from day to day or week to week as the occasion might arise. These operations would apply to water for irrigation purposes as well as for power.

In addition to these duties of regulation, this Engineer would also be charged with continuing and collecting the various data and information already outlined consequent upon operation.

The cost of up-keep and maintenance of the works, as well as the expense of the actual operation of the regulation by the Government, can be apportioned yearly amongst the various users in the same manner as already outlined for repayment of the construction cost.

Recommendations.

In conclusion, and in accordance with the foregoing I have the following recommendations to offer as being designed to meet the general conditions:—

1. That the investigations on the Bow River basin be continued for the purpose of making the data more complete and useful in the subsequent operation of the project.

2. That the Government undertake the further construction of storage reservoirs and regulating works and provide for the repayment of their cost by means of annual rentals charged to users of water.

3. That a scheme for operating these storage reservoirs and for regulating and controlling the discharge of the river be adopted and put into practical working effect by the Government, and that the annual cost of same be charged to the users in the same manner as the original cost.

4. That as soon as the project is put into working effect (or sooner), the existing storage works at lake Minnewanka be acquired and its regulation and operation be taken over by the Government according to the terms of the existing agreement with the Power Company.

Yours very truly,

C. H. MITCHELL.

APPENDIX II

PROPOSED DAM AT SPRAY LAKES

REPORT BY

G. R. G. CONWAY, C.E.

REPORT PROPOSED DAM AT SPRAY RIVER, B.C.

(By G. R. G. Conway, C.E.)

Vancouver, B.C., April 6, 1914.

To J. B. Challies, Esq.,
Superintendent, Water Power Branch,
Department of the Interior,
Ottawa.

Proposed Dam at Spray River, British Columbia.

Sir,—In accordance with your request, I have reviewed the available data that you have obtained with regard to the possibilities of constructing a storage dam at the Spray River canyon in Alberta. The construction of a dam with a proposed maximum height of 160 feet in a place so remote from rail transportation involves the consideration of several points that are of extreme importance when considering the subject from the economical standpoint. The difficulties of access to the site and high cost of materials that may require to be transported to that site, makes it imperative to select a type of dam that while absolutely safe shall be constructed at the lowest cost. From careful consideration of the data available with regard to the proposed location, I believe, subject to further investigation as to the foundation conditions, that a dam can be safely constructed there either of concrete masonry, rock-fill, or of earth work, the latter either of the ordinary type or constructed by the hydraulic-fill method.

To determine the approximate cost of a concrete dam designed either as a gravity dam or one of the arch type, much careful exploration work by means of test pits and diamond drill borings is absolutely necessary; but after taking into consideration the high cost of cement and materials, and the difficulty of transporting the large amount of plant necessary for its construction a distance of 30 miles from the Canadian Pacific Railway, it is obvious that an approximate estimate, based upon reasonable assumptions with regard to foundation conditions makes it necessary to dismiss a proposal for a concrete dam from practical consideration. I have, though, made an approximate estimate of the cost of a typical gravity dam for the purpose of comparison with other types. From the general geological character of the canyon, the type of dam most suitable for the location is either one of a rock-fill type or an earthen dam, preferably of the hydraulic-fill type.

Rock-fill Dam.—A dam of the best rock-fill type, such, for example, as the Morena dam in California, is quite feasible and entirely suitable for the site, and satisfactory rock could be quarried at a convenient elevation so that the material could be handled by gravity at an economical figure. This type, however, involves the use of large quantities of concrete for obtaining a watertight upstream face, and considerable plant to handle the rock economically, and, in addition, its construction would be prolonged over several seasons. An approximate estimate shows, too, that its cost is prohibitive.

Earth Dam.—From a consideration of the materials available at the site at a suitable elevation so as to be economically placed in the dam, I am of the opinion that a dam of the hydraulic-fill type which has been proposed is the most suitable and economical one to adopt.

This type has already been adopted in building two large dams in British Columbia, one a dam 1,000 feet long and 60 feet high at Bear creek, Vancouver island, for the Vancouver Island Power Company, where the construction of the dam had to be carried on in a very inaccessible region and under severe winter conditions, and the other a dam at the outlet of Coquitlam lake, for the Vancouver Power Company. The latter dam is 99 feet high and contains nearly 600,000 cubic yards of material. Both of these dams have been built of glacial drift, and in the case of Coquitlam a homogeneous dam of clay concrete of an excellent character was obtained. In my opinion the glacial clays of British Columbia afford the very finest material for constructing a satisfactory dam if the materials are graded with skill, and are infinitely superior to clays of a purer and richer character. From a consideration of the samples that were examined by Mr. G. L. Albert, it appears that a satisfactory grading of materials could be obtained for forming an impervious core. The chief difficulty, in my opinion, however, is in the apparent scarcity of heavy boulders for the outer slopes, a scarcity which may, however, be overcome by quarrying quantities of rock near the site for incorporation with the sluiced material.

In constructing a dam of the height proposed, which is well below the limit of the height of a number of other similar dams that have been successfully completed, great care must be taken to ensure the provision of ample rock toes of cyclopean rubble, and at the same time to limit the amount of fine impervious material in the centre of the dam only to what is necessary to ensure water tightness. In the construction of the Necaxa dam No. 2 in Mexico, a dam 190 feet in height, the preponderance of rich clays and fine impervious material was the cause of serious disaster, and in the reconstruction of that dam, as actually built, the rock toes were so heavy and massive that the proportion of impervious material was reduced considerably beyond that called for in the original design; in fact, the revised design differs in very many important essentials from that as originally published.[1] The lessons learned from the partial failure of the Necaxa dam are very instructive, and must be borne in mind in designing dams of the hydraulic-fill type.

The available materials for the hydraulic-fill at the Spray canyon appear to me to be eminently satisfactory for obtaining a properly graded fill throughout the major portion of the dam. The proportions of sand and gravel are such that a proper drainage of the interior mass can be obtained so that the stability of the whole can be secured. The material appears to be lacking in large boulders of rock, but the proximity to the dam location of an excellent site for quarrying limestone rock will enable large quantities to be secured if necessary at an economical cost for the outer or more porous section of the dam so as to increase its stability. From the general character of the rock, it would appear possible to break it up with black powder into comparatively small fragments and convey it by sluicing to the dam.

After carefully studying the available information, I have proposed in the sketch attached herewith the main outline of a suitable maximum cross-section of the dam. Further information should be available before the exact foundation conditions are settled, and I would recommend that a series of test pits be sunk along the centre line of the proposed dam.

The base of the dam for a distance of 400 feet along the river bed should be thoroughly cleaned to expose bedrock, and the whole of the site should be thoroughly cleared of all roots, stumps, and loose material, and a core wall of concrete, carried well into the bedrock across the river-bed and stepped up the side slopes, is, in my judgment, necessary to obtain a perfectly water-tight seal between the joint rock and the impervious material; but there is no necessity for this core wall being carried more than 4 to 6 feet high above the rock level.

[1] See page 243, Trans. Am. Soc. C.E., vol. lviii.

The provision of a centre core wall of the full height of the dam would not only involve a heavy expenditure, but would be unnecessary, and, in fact, dangerous, because of its interference with the proper drainage of the glacial material in a dam of the character proposed.

The only justification for core walls in hydraulic-fill dams is where there is a danger from burrowing rodents, and even in such cases reliance upon properly riprapped slopes would be more satisfactory, but I believe the danger of damage from burrowing animals at the Spray canyon site is not present.

In the Bear Creek dam, Jordan river, a satisfactory cut-off wall was obtained where the rock lay 30 to 40 feet below the surface, by the use of interlocking steel piles. In the Coquitlam dam a core wall about 4 feet high was constructed on the east bank, founded on the rock ledge, but this wall was not carried across the clay foundation. In the design which I have indicated, allowance has been made for heavy cyclopean rock toes, upstream and downstream, and if it was found economical to quarry rock, these toes could be increased considerably beyond the dimensions shown, with advantage.

In constructing the dam, two seasons will be required for the sluicing. In the construction of the Coquitlam dam 77,700 yards of material were sluiced into place during one month in a run of 528 hours, with a monitor pressure of 80 pounds per square inch, representing with a twenty hours' daily run, an average of 2,800 yards daily. The special conditions, however, existing at this dam permitted that quantity to be safely sluiced into the work owing to the massive proportions of the heavy cyclopean rock-fill toes and broad bases, but in the case of the dam at the Spray canyon, to obtain proper drainage of the materials, this speed should not be attempted, owing to the rapid increase of height which would be obtained in so short a dam. If the total quantity of material to be placed in the dam, amounting to approximately 500,000 cubic yards, excluding the rock toes, two shifts daily of ten hours each, at an average of 1,500 cubic yards, will mean eleven months' work distributed over two working seasons. It is advisable during the winter months to close down the work entirely, otherwise the cost would be excessive. I have proposed that the upstream slope should be heavily riprapped, and near the crest the riprapping should be grouted or laid in cement so as to prevent wave action (which will probably be considerable), from damaging the dam at high-water line. In addition to the [illegible]nnel, I believe a spillway having a capacity of not less than 12,000 cu. [illegible] second should be provided on the west bank, as this quantity migh[illegible] discharged under flood conditions with a full reservoir, and a possible [illegible]t the intake tower at the same time. This spillway should be excav[illegible]own to the level of the rock, and if necessary a concrete wall carried across so as to bring it to the required level, and a channel excavated, or a retaining wall built, so as to prevent the water overflowing on to the downstream face of the dam. The exact location of the spillway and channel can be determined when locating the borrow pits so as to reduce the excavation as much as possible.

The design of the intake tower and the construction of the tunnel presents no difficulties. Duplicate sets of valves of the Stoney pattern similar to those in use at the Coquitlan-Buntzen tunnel can be easily adapted for control purposes.

I have given careful consideration to the cost of building this dam, and believe the hydraulic-fill type can be constructed at a considerably less cost than any other type. One of the principal items involved, viz., that of sluicing the hydraulic-fill, varies considerably in different dams. At Bear creek, Jordan river, where 160,000 cubic yards were placed in position by the hydraulic method, the cost, including plant, etc., amounted to 49½ cents per cubic yard; at the Coquitlam dam the labour cost varied in different months between ten cents and twenty-two cents a cubic yard; the average labour cost, including the construction of flumes, their removal, etc., during the whole period of sluicing 450,000 cubic yards was 17 cents; the average cost, including plant, pumping, power (electric energy charged ½ cent per k.w.h.) and superintendence was 29 cents per cubic yard.

The convenient position of the borrow pits at the Spray Canyon site and the class of material, together with an available water power for a temporary hydro-electric installation, should make an estimate of 30 cents a cubic yard a sufficient one. This figure, however, may be a little low if it is found necessary to quarry rock to incorporate in the hydraulic fill at the outer slopes of the dam. I estimate that not less than 15 per cent of the quantities of material in the dam (exclusive of the rock toes) will require to be of large boulders or rock, say about 75,000 cubic yards.

For the cyclopean rock toes, the loose rock obtained in stripping the foundations in the centre of the dam and the excavations from the tunnel may be utilized to advantage. To the estimate in Mr. Hendry's report, I should prefer, to be on the conservative side, to add the sum of $44,000 to item No. 5 for heavy cyclopean rock toes, and with the available information which you have already obtained, I believe the sum of $558,000 as the cost of constructing the dam to be a reasonably approximate one, although the estimates may require revision upon fuller investigation and exploration work.

From estimates which I have prepared, the following is a comparative estimate of the cost of different types of dams:—

Concrete Dam..................	$1,350,000.00	$8.00	per acre-foot.
Rock Fill Dam (288,000 cu. yds.).	810,000.00	4.75	" " "
Hydraulic Fill Dam.............	558,000.00	3.25	" " "

Even if the above estimate for an hydraulic-fill dam is slightly exceeded, its cost will be very economical and reasonable, and will compare most favourably with that obtained by the construction of other high dams, and the available water storage will have been obtained at a much lower cost than has been obtained by the building of other storage dams in British Columbia and on the Pacific coast.

I recommend further explorations of the foundations, and believe it to be important to obtain a report from a competent geologist dealing with the stratigraphical features of the site and basin.

The proposal to build a dam at this site appears to be an excellent one, and from the information already available would appear to present no special engineering difficulties.

Yours faithfully,

G. R. G. CONWAY.

COMMENT ON MR. CONWAY'S REPORT BY MR. HENDRY.

In order that the effect of the increased cost of the Spray Canyon dam, as estimated by Mr. Conway, upon the cost of power from the several developments, may be seen, the following has been prepared:—

ESTIMATED COST OF DAM.

Roads, etc.	$ 25,000.00
Temporary power plant	30,000.00
Preliminary, foundations, etc.	40,000.00
Sluice tunnel and control	117,000.00
Dam, core wall, spillway, etc.	165,000.00
Clearing	38,000.00
Engineering, contingencies and interest	99,000.00
Rock toes (as per Mr. Conway's report)	44,000.00
Giving a total of	$558,000.00

To the above should be added the charges due to engineering, contingencies and interest on $44,000, which amount to, say $12,000, giving a grand total of $570,000 as the cost of creating storage at Spray lakes.

The total estimated cost of creating storage on the Bow river sufficient to ensure a minimum flow of 1,500 c.f.s. would be as follows:—

Estimated cost Spray Lake storage	$570,000.00
" " Bow Lake "	105,000.00
" " Lake Minnewanka "	140,000.00
Total	$815,000.00

On the basis of a minimum flow of 1,500 c.f.s. the total continuous output of the river would be 47,300 w.h.p. Therefore cost of storage per w.h.p. is $17.23, in place of $16.03 per w.h.p. as per estimate in the report. The cost of power from the several plants under this increase is set forth in the following table:—

Plant.	Bow Fort.	Mission.	Ghost.	Radnor.
Cost of plant	$ 780,430.00	$748,100.00	$782,966.00	$711,100.00
Storage charges	155,070 00	110,445.00	117,500.00	103,400.00
Transmission, etc	86,400.00	64,700.00	70,577.00	62,400.00
Total capital cost	$1,021,900.00	$923,245.00	$971,043.00	$876,900.00
Annual charges	$ 117,518 00	$106,173.00	$111,670.00	$100,843.00
Annual charges per h.-p.	16 09	20.03	18.92	19.39
Annual charges per h.-p. on 50 per cent load factor	32.18	40.06	37.84	38.78
Annual charges per k.w. on 50 per cent load factor	42.91	53.41	50.45	51.71
Annual charges per k.w. on 50 per cent load factor under former estimate	42 48	52.98	50.09	51.33

From the above it will be seen that the increased estimated cost has very little effect upon the actual cost of producing power from the several plants.

APPENDIX III

PROPOSED DAM AT SPRAY LAKES

REPORT BY

GEO. L. ALBERT.

PROPOSED DAM AT SPRAY LAKES

(By Geo. L. Albert).

Banff, Alta., July 19, 1913.

Mr. M. C. Hendry, B.A.Sc.,
Chief Engineer, Bow River Survey.

Dear Sir,—According to the agreement made with you at Coquitlam dam, I beg to hand you herewith report upon the investigation made by me, during the past few days, into the feasibility of placing a hydraulic-fill dam in the canyon on Spray river below Spray lakes; also the suitability of the adjacent material to that form of construction.

Canyon and Formation.

The canyon is a deep, narrow gorge, formed in limestone, and evidently following the course of an old fault. I found that the bedding planes of the limestone on the west wall of canyon were lying nearly horizontal, east and west, and with a slight dip, or strike, south; the canyon wall on this west side rising to an elevation of about 160 feet above river-bed, and is very precipitous but not so nearly vertical as on the east side.

On east wall the bedding planes have been turned up nearly vertical, running north and south with, or paralleling, the river, and rising to an elevation of about 200 feet or more above the river-bed.

Dam Sites.

I first made a general examination of the canyon and selected three points for study and comparison, which I will distinguish by numbering as follows:—

Site No. 1, or Lower,
Site No. 2, or Middle,
Site No. 3, or Upper.

Site No. 1 is at the narrowest part of gorge, 1,000 or 1,200 feet downstream from the beginning of the canyon, with the center line of the proposed dam falling across the river through the center of the cliff. At this point it approximated very nearly to the site pointed out by you as the one having been selected. This site would require less material, likely, than either site No. 2 or site No. 3; but after a careful study and examination of the walls, I found that the west wall is shattered and seamy for some depth into the side of wall from top to bottom, necessitating expensive cleaning. The east wall is very clean on the face; but back in the wall from about 25 to 40 feet, the strata are badly seamed and parted, plainly showing the effects of the milling in the faulting: and the seams being partly refilled with hydrated fragments, and very porous, would make a good seal doubtful without a great deal of special work. Both rock walls rise to a sufficient height to admit of a dam of the proposed elevation, which is, I understand, approximately 160 feet.

Site No. 2 is 150 or 200 feet upstream from site No. 1, with all conditions as at site No. 1, except that all of the shattered material on the west side, and all of the seamed and hydrated materials on the east side have been torn off, and worked and slid away; so that little or no work would be necessary to secure an absolutely safe seal to a good bonding surface.

It is possible that the yardage may be slightly greater at this point than it would be at site No. 1; but this could be ascertained later on by measurements which I could not make at this time.

The problem of spillway involved would be the same at both sites, Nos. 1 and 2. They are simple, as you know, and very natural. The cleaning of the river-bed also would be about the same; and with the surface indications, and what examination I was able to make at this time, I have no doubt that a good tight bottom could be easily reached. Also, the diversion of river water, etc., would be equal.

Site No. 3 is still further upstream, being at the upper end of the canyon. A good foundation can no doubt be had there, and the height of dam would be reduced some 15 or 20 feet. On account of the dip of the rock formation to the south on the west side, the solid rock would not be high enough for spillway floor; also, there would likely be a porous stratum between the surface of the rock formation and the overlying glacial material on this side. As it necessitated more exploration work than I was able to give it at this time, I accordingly abandoned it for the present.

After careful consideration and comparison of the best points along the canyon, I have selected site No. 2 for recommendation, the reasons being as follows:—

First.—The problem of foundation in the present river-bed would be equal at all points along the gorge, no doubt.

Second.—The preparation and cleaning for foundation and bond along the entire centre line above the present river-bed involves very much less expense at site No. 2 than at any of the other points, and this site indicates a very much more perfectly solid foundation free of all seams.

Third.—Considering the profile along the centre line, across a deep, narrow gorge, as this gorge is, it would be the flatter at site No. 2, which is of considerable value to the poise, or rest, of the hydraulic material; for the reason that there is much less tendency of the material in the final drying out and shrinking, to curl or break the bond with the solid formation at or near the top of fill, on the flatter profile, than there would be with the nearly vertical walls, as at site No. 1.

Fourth.—The work involved in creating a spillway and providing for river diversion would be the same at sites 1 and 2.

Material for Sluicing.

The solid limestone formation on both sides of the canyon is covered by a glacial material, principally of disintegrated limestone hydraulically deposited to varying depths, and over an extensive area. On the east side, at sites 1 and 2, the bedrock rises to a much greater elevation than on the west side. The deposited material is much thinner here, but ample and available.

On the west side, the deposit of material is from 80 to 100 feet deep; is easily available and ample; and apparently contains clay, sand, fine and coarse gravel, cobbles and boulders, in very desirable proportions to meet the requirements of an hydraulic-fill. It is composed of disintegrated limestone, its natural gravity corresponding to the limestone, which has a very heavy gravity—about 2.7.

Therefore it is my opinion that a dam with slopes of 2 : 1 on back side, and 3 : 1 on water side, with a 35-foot or 40-foot crest, would make an absolutely safe, stable, impermeable fill, safely and economically adapted to this particular location.

Classification, location, and explanation of samples of materials taken at various points in the basin below the lakes and on down to the sites:—

The samples were taken from excavations I made into the materials at many points; the samples being panned or washed in water in such a manner as to separate and grade the material, showing approximately the percentage of the fine and coarse material combine.

Commencing at the lake on both sides, I made a very careful examination of all material from river level to the top of the hills, and on below sides, by making many test holes, and only taking samples where a marked difference in class would show. As generally taken, the material was sufficiently uniform to be judged, as a whole, as almost ideal material for the work proposed. As previously stated herein, the deposits being much deeper on the west side than on the east side, and consequently being at a lower level on the west side, the percentages of clay and fine sand are greater than on the east side; more particularly so near bedrock, the coarser materials lying nearer the top. The great depth of the deposit and very convenient location suggests the west side for the choice of borrow pits.

The percentages given below of the various samples do not show accurately the proportions as found in each small sample of about one-half cubic foot of the material washed; but gives very closely the proportions of the aggregate at the place of taking, considered as deposited in an hydraulic-fill.

I have delivered to you two samples of the best clay and sand deposit, which I would suggest that you have tested. The sample of the pulverized material is from an exposed bank of clay on west side, and about 300 feet upstream from site No. 2. It is off the surface, and is principally clay and fine sand. The solid sample is from an excavation made in an old slide near the upper end of canyon on west side. I estimated that it contained about 15 per cent of moisture when first taken out, and about 60 per cent of clay and fine sand, and about 25 per cent of coarse sand and gravel.

This material alone would give more puddle material than would be necessary; but estimating the whole deposit as taken in the construction, there is sufficient of all grades to make it especially good.

The tests of all samples on west side, taken near bedrock, showed about as these samples:—

Moisture	.15
Clay and fine sand	.60
Coarse sand and gravel	.25
	1.00

The samples taken at from 25 to 40 feet above bedrock were much coarser, and, not considering moisture, showed as follows:—

Clay	.30	
Fine sand	.10	
Coarse sand	.15	
Gravel	.25	West Side.
Cobbles and boulders	.20	
	1.00	

The samples taken at and near the top of deposit showed:—

Clay	.10	
Fine sand	.10	
Coarse sand	.20	
Gravel	.25	West Side.
Cobbles and boulders	.35	
	1.00	

Of the samples tested on east side along the top wall of canyon, above sites 1 and 2, the material near bedrock was of about the same uniformity, averaging about:—

Clay	.20	
Fine sand	.10	
Coarse sand	.20	
Gravel	.25	East Side.
Cobblestones	.25	
	1.00	

Samples taken at slide just below lake showed very little clay and fine sand, or about:—

Clay	.03
Fine sand	.05
Coarse sand	.10
Fine gravel	.25
Coarse gravel	.50
Cobbles	.07
	1.00

CONCLUSION.

Examination and tests of all materials show them to be of very first-class quality for building a first-class hydraulic-fill dam of height required.

Dam site location No. 2 is absolutely beyond question.

There is timber available for trestles, and most other necessities.

There is water under sufficient head to provide ample power, and very handily.

Construction of road for transportation not excessive.

In my opinion it is altogether a first-class scheme, and I can very readily recommend it.

Awaiting your acknowledgments, I beg to remain,

Yours faithfully,

GEO. L. ALBERT,
Supt. of Construction, Lake Coquitlam dam, also Canyon Creek dam, Lake Francis dam, Acatlan dam, Laguna dam, Los Reyes dam, and others.

APPENDIX IV

RESULTS OF ANALYSIS OF SLUICING MATERIAL

REPORT BY

FRANK T. SHUTT, M. A., F. I. C., D. S.c., *Dominion Chemist.*

RESULTS OF ANALYSIS OF SLUICING MATERIALS.

(Frank T. Shutt, M. A., F. I. C., D. Sc., *Dominion Chemist.*)

Central Experimental Farm,

Ottawa, August 21, 1913.

J. T. Johnston, Esq.,
Hydraulic Engineer, Water Power Branch,
Department of the Interior,
Ottawa, Ont.
Re "Hydraulic Fill," Laby. Nos. 15364-5.

Dear Sir,—The two samples of "fill" forwarded with your letter of recent date, have been submitted to mechanical analysis and the following results obtained:

Sample A.—A hard conglomerate of gravel, sand and clay, in large lumps. Readily disintegrates in water.

Sample B.—Chiefly in small lumps and consisting of sand and clay with small stones.

Analysis of Fills.

No.	Type.	Obtained by.	Size of Particles.	Percentage A.	Percentage B.
			Mms.		
I.	Coarse gravel and stones	2 mm. sieve	2 to 200	23·80	18·64
II.	Fine gravel	1 mm. sieve	1 to 2	4·71	3·57
III.	Coarse sand	·5 mm. sieve	·5 to 1	3·27	2·53
IV.	Fine sand	Rapid settlement	·05 to ·5	19·07	15·33
V.	Silt, with fine sand	Slower sedimentation	·005 to ·05	9·75	7·64
VI.	Clay	By difference	·0005 and finer to ·005	39·40	52·29

Under separate cover we send specimens of the types mentioned in this table (with the exception of VI), as obtained from "A." These will probably enable you the better to comprehend the character of the various components into which we separated the material.

Yours faithfully,

FRANK T. SHUTT,
Dominion Chemist.

APPENDIX V

THE GEOLOGY OF THE BOW RIVER BASIN

BY

CHARLES CAMSELL, B. Sc., Ph. D.

THE GEOLOGY OF THE BOW RIVER BASIN

(By Charles Camsell, B.Sc., Ph. D.)

INTRODUCTORY STATEMENT.

The information contained in this portion of the report is compiled wholly from reports of officers of the Geological Survey, and mainly from those of Dawson, McConnell, Cairnes, Dowling, and Allan. Much of it is copied verbatim from the Guide Books prepared by J. A. Allan and D. B. Dowling for the International Geological Congress in 1913.

The following reports deal more fully with the geology of certain portions of the Bow River basin:—

Dawson, G. M.—Preliminary report on the Physical and Geological Features of that portion of the Rocky mountains between latitude 49° and 51° 30′. Geol. Surv. of Can., vol. 1, part B, 1885.

McConnell, R. G.—On the Geological Structure of a portion of the Rocky mountains, Geol. Surv. of Can., vol. 2, part D, 1886.

Dowling, D. B.—Report on the Cascade Coal Basin. Geol. Surv., Can., No. 949.

Cairnes, D. B.—Report on the Moose Mountain District, Geol. Surv., Can., No. 968, 1907.

Allan, J. A.—Rocky Mountains—Guide Book No. 8, part 2, page 167.

Dowling, D. B.—Winnipeg to Bankhead, Guide Book No. 8, part 1, page 77.

General Physical Features.

The basin of Bow river west of Calgary lies on the eastern slope of the Rocky Mountain system, between latitude 50° 30′ and latitude 51° 45′. In this basin are three distinct types of topographic form, the western, including the rugged alpine region of the eastern ranges of the Rocky Mountain system, the middle covering the more rolling foothills region, and the eastern the level plains region about Calgary.

The Rocky mountains here, as elsewhere, are made up of a series of parallel ranges striking about N. 30° W., and coinciding more or less closely with the general trend of the main mountain system. Between the ranges are deep longitudinal valleys whose positions have been determined by the presence of belts of softer rocks. Crossing the ranges here and there at right angles are a number of transverse gaps through which the larger streams break on their way eastward to the plains. The pattern produced by this system of drainage is that of a series of oblong, rectangular blocks, the longer directions of which are parallel to the trend of the mountain axis, while the shorter are at right angles to it.

The origin of the longitudinal valleys is directly connected with the origin of the mountains themselves. The transverse valleys, however, may represent portions of very old drainage systems which existed previous to the elevation of the mountains, or they are due to erosion of the streams along lines of weakness or fracturing developed during the period of mountain building.

Bow river is in some places longitudinal and in others transverse. For example, from Laggan down to Sawback it occupies a longitudinal valley that has been cut out by the stream along the crest of a fold in the strata. From Sawback it turns eastward and as far as Bankhead occupies a transverse break across the strike of the bedrock and across the trend of the ranges. It then reaches a belt of soft rocks which deflects its course again southeastward down a longitudinal valley until below Canmore it again turns at right angles and breaks through the outer ranges into the foothills region.

The loftiest summits of these ranges are those about the main divide, where several individual peaks are more than 11,000 feet above sea-level. A number of mountains exceed 10,000 feet and whole ranges and groups of peaks surpass 8,000 feet.

The type of mountain most commonly developed in the Bow River basin is that with a steep escarpment on the east side and a longer easy slope on the west side. This feature, like that of the longitudinal valleys, can be attributed to elevation of the mountains by thrust from the west, the strata having been folded and overturned, or broken and overthrust on each other. Erosion then produces the steep eastern slope, while the easy western slope represents the original dip of the strata. Where the summits are composed of horizontal beds of massive limestones the easy breaking of the beds along joint planes at right angles to the bedding produces mountains of which the upper parts are sheer cliffs. A later stage in decay of these mountains results in chimney or spire-like peaks. Where the limestone beds have been turned completely on edge as in the Sawback range the massive character is replaced by straight narrow crests and saw-like outlines.

The break between the mountains and the foothills is sharp and distinct and marked by the abrupt escarpment-like front of the Rocky mountains.

The foothills region is characterized by a group of long ridges or hills arranged in linear series, the positions of which have been determined by zones of harder rocks. The trend of the ridges is the same as in the main ranges, and to a certain extent the same general drainage pattern holds.

The summits of the ridges are generally rounded and flowing, except where crested with ledges of sandstone. While the disturbance of the bedrock in the foothills is not less than that found in the mountains the more subdued topographic outlines of the former are due to their being composed of much younger and softer rocks which are less resistant to the action of erosion and denudation.

Topographically the foot-hills region merges gradually into prairie region on the east, the open rolling character of which is due primarily to the almost undisturbed attitude of its underlying bed rock.

Stratigraphy.

The rocks of the Bow River basin above Calgary contain representatives of almost every age from Pre-Cambrian to Recent, or from the oldest to the youngest. They are all stratified rocks and the sequence is exposed in descending order from east to west, the strata about the main divide being the oldest. The missing formations are those of the upper part of the Tertiary, the Silurian and the Ordovician. The last two mentioned, however, appear on the western slope of the Rocky mountains.

The following table, mainly after Allan, presents the geological formations in summarized form with the approximate thicknesses and lithological character of each:—

TABLE OF FORMATIONS.

System.	Formation.	Approx. Thickness.	Lithology.
		Feet.	
Recent and Pleistocene	Fluviatile		Gravel, sand.
	Lacustrine		Gravel, sand, clay, silt and conglomerate. Till.
	Glacial. (Erosion surface).		
Tertiary	Paskapoo	5,700	Yellowish sandstones and bluish gray and olive sandy shales.
Cretaceous	Edmonton	700	Light coloured, soft sand-stones, shales and clays.
	Pierre	1,000	Dark gray or black shales (Bear paw shales); light coloured sandstones, shales and clays (Belly River beds); and dark shales (Claggett shales).
	Niobrara	200	Sandstones and shales (Cardium).
	Benton	725	Dark gray or black shales
	Dakota	950	Sandstones and conglomerates.
	Kootenay	3,700	Massive and thin bedded sandstones, shales and coal seams
Jurassic	Fernie shale	1,500	Dark brown to black arenaceous shale; weathers into lens-like fragments.
Permian	Upper Banff shale	1,400	Dark brown arenaceous shale weathering reddish and yellowish.
Mississippian	Rocky Mountain quartzite	800	White to gray quartzite and arenaceous siliceous limestone
	Upper Banff limestone	2,300	Thick-bedded dark gray limestones with numerous thin cherty layers underlain by thin-bedded limestone and shale weathering gray.
Pennsylvanian	Lower Banff shale	1,200	Black to dark gray shale, argillaceous and calcareous; weathering light brown.
	Lower Banff limestone	1,500	Thick-bedded gray limestones with numerous dolomitic segregations.
Devonian	Intermediate limestone	1,800	Thin-bedded limestones with alternating more massive layers of gray dolomitic and siliceous limestone.
Contact relations not known.	Sawback limestone (age?)	3,700	Thin-bedded limestone inter-bedded with less resistant layers and brownish and yellowish shale.
Upper Cambrian	Ottertail limestone	1,725	Massive blue limestones with cherty and shaly bands.
	Chancellor	4,500	Thinly laminated gray argillaceous and calcareous metaargillites and shales; weathering reddish, yellowish and fawn; underlain by highly sheared gray shales, slates, argillites and phyllites in Ottertail valley.
	Sherbrooke	1,375	Thin-bedded oolitic arenaceous or dolomitic limestones.
	Paget	360	Massive bluish gray limestones, with oolitic bands of dolomitic limestone.
	Bosworth	1,855	Massive gray arenaceous and dolomitic limestone; weathering yellowish buff; inter-bedded with greenish siliceous shale; weathering red, yellow, purple.

TABLE OF FORMATIONS.—*Concluded.*

System.	Formation.	Approx. Thickness.	Lithology.
		Feet.	
Middle Cambrian	Eldon	2,728	Massive-bedded arenaceous limestones forming cliffs and castellated crags.
	Stephen	640	Thin-bedded limestone, and shale; includes "Ogygopsis shale" in Mt. Stephen and "Burgess shale" in Mt. Field.
	Cathedral	1,595	Thin-bedded arenaceous and dolomitic limestones.
Lower Cambrian	Mt. Whyte	390	Siliceous shale, sandstone and thin-bedded limestone.
	St. Piran	2,705	Ferruginous quartzitic sandstone.
	Lake Louise	105	Compact grayish siliceous shale.
	Fairview	600	Ferruginous quartzitic sandstone. Local basal conglomerate and coarse-grained sandstone.
Conformable in some places.			
Pre-Cambrian	Hector	4,590	Gray, green and purple siliceous shale with conglomerate interbedded.
	Corral Creek	1,320	Quartzitic and coarse-grained sandstone with shale interbedded.

PRE-CAMBRIAN.

The Pre-Cambrian rocks are distributed along the floor and sides of Bow River valley from the base of Castle mountain to the head-waters of the stream. The lower part, known as the Corral Creek formation, consists of grey sandstone underlain by a coarser quartzitic sandstone which in turn rests on a conglomerate. The upper part, or Hector formation, consists mainly of grey, purplish and greenish shale, with which are interbedded bands of conglomerate.

LOWER CAMBRIAN.

The Lower Cambrian rocks form the base of Castle mountain and are exposed above the Pre-Cambrian on the western slope of Bow Valley from Vermilion creek to the head-waters of Bow river.

The Fairview formation consists of brown and white quartzitic sandstone. Locally there is a basal conglomerate on the Pre-Cambrian shales containing rounded pebbles of white quartz in a cement of quartz, feldspar and mica. The basal rock is more frequently a coarse sandstone with rounded and angular grains of quartz and feldspar. Some of the quartz grains have a glassy, almost opalescent, colour.

The Lake Louise formation, as the name suggests, is best exposed at lake Louise. The formation has a total thickness of 105 feet and consists of a ferruginous siliceous shale. It weathers more readily than the beds below or above, so that the slopes in it are more gradual.

The St. Piran formation consists of massive-bedded, ferruginous quartzitic sandstone, with a total measured thickness of 2,705 feet. These beds form steep escarpments wherever they are exposed. On the west side of mount Victoria the cliffs composed of these beds are over 2,500 feet high. The brown colour of the rock is due to smoky quartz and small particles of mica in the cement.

In sharp contrast with the underlying massive quartzites, there is a thin series of siliceous and calcareous shales grouped as the Mount Whyte formation. These shales are less resistant than the quartzite and form gradual slopes. Some of the layers contain numerous annelid borings and trails.

Middle Cambrian.

The Middle Cambrian consists of massive limestones and some shaly limestone and calcareous shale. It forms the steep escarpment of the upper part of the Castle mountain and occurs again on the summit of the main divide in the Bow range and the Waputik mountains.

The Cathedral formation consists of massive and thin-bedded dolomitic limestone, which on the weathered surface becomes buff and grey. The more massive beds are arenaceous in their composition. The Monarch mine, in mount Stephen, and other small mineral prospects in the Kicking Horse valley, are in this formation.

Some of the limestone has become metamorphosed into marble. One of the best exposures of this rock is in Cathedral mountain, 4 miles east of Field.

The Stephen formation is only 640 feet thick, but it is important for the number and variety of fossils which it contains. It consists of shaly limestone and calcareous shale. These beds include the "Ogygopsis shale" in mount Stephen, and the "Burgess shale" in mount Field, on the opposite side of the valley. The former includes the widely known trilobite-bearing "fossil bed," while the latter includes the new "fossil bed" discovered by Dr. C. D. Walcott in 1910.

The Eldon formation has a thickness of 2,728 feet in Castle mountain. It consists essentially of massive-bedded, arenaceous limestones, which form steep castellated crags on the erosion surface, thus making the formation readily recognizable wherever exposed. It is this formation which forms the steep escarpment about the upper part of Castle mountain.

Upper Cambrian.

The Bosworth formation of the Upper Cambrian is exposed in the mountain of the same name on the continental divide. It consists largely of thin-bedded limestone with a few more thick-bedded layers, interbedded with siliceous and arenaceous shale. One band of shale makes a good horizon-marker because it weathers greenish, yellowish, deep red and purplish.

The Paget formation is a band of greyish oolitic limestone, typically exposed in Paget peak, on the west slope of mount Bosworth. These beds can not be readily distinguished from the underlying limestone.

The Sherbrooke formation consists of arenaceous limestone at the base, overlain by thin-bedded limestone, including some oolitic and shaly layers. This formation includes the highest beds exposed in the Bow range in the vicinity of Hector pass.

The remaining Cambrian formations, the Ordovician, and the Silurian, are all exposed in the western portion of the Rocky mountains between the Bow range and Columbia valley, and are not present in the basin of Bow river.

Devonian.

The Devonian occurs in a number of bands which trend in a direction parallel to the axis of the mountains. One band crosses the Bow Valley at the Gap, and another at the western end of Lac des Arcs. A third band overlies the Cretaceous shales on the west side of Bow valley from Canmore to Bankhead. Other bands occur in the Vermilion lake and Sawback ranges.

The Intermediate Limestone consists of thin-bedded limestones alternating with harder layers of grey dolomitic and siliceous limestone, which on the weathered surface becomes banded. In the Sawback, Vermilion lake, and Cascade ranges it is exposed where reversed faulting has caused repetition.

The thermal sulphur springs at Banff occur in the intermediate limestone. The rock is high in sulphur, derived by decomposition from the pyrite which the limestone contains; a strong odour of sulphide of hydrogen is given off when the rock is struck with a hammer.

The upper limit of this formation is not clearly defined as it is transitional into the Lower Banff shale.

Sawback formation, underlying and conformable with the Intermediate limestone is a series of massive and thin-bedded dolomitic limestone and shale, which McConnell has placed in the Cambrian. These beds form a wedge-shaped band in the Sawback range and lie between mount Hole-in-the-wall and mount Edith, with a broader exposure along the north side of the Bow valley. It has been possible to measure and estimate a thickness of about 3,700 feet, but the actual thickness is believed to be much greater. The beds differ lithologically from the Cambrian beds in Castle mountain, which are largely Middle Cambrian, and from the Cambrian in the Bow range and to the west of this range. The age of the formation is still in doubt, but it is older than the Intermediate limestone, which is definitely known to be Devonian in age. These beds are lithologically closely related to some of the Silurian beds in the Beaverfoot range to the west.

Mississippian.

The Lower Banff limestone has been mapped as Mississippian, but it grades into the Devonian below, and has recently been proved to be largely of that age. The beds consist of massive-bedded grey limestone which forms steep escarpments wherever exposed on the slopes of a mountain.

This limestone forms the eastern cliffs of Cascade mountain and mount Rundle, and the steeper eastern slopes of Sulphur mountain. Some beds are fossiliferous, and the formation is characterized by numerous fossil-like dolomitic segregations.

The Lower Banff Shale consists of about 1,200 feet of shales. These shales are black to dark grey in colour, and weather brown. They are usually calcareous in composition, but certain layers are argillaceous and arenaceous. The lower contact of this series is sharply defined but at the top of the series the beds change to a shaly limestone difficult to distinguish from the overlying limestone. The shales weather out more easily than the limestone, so that a depression is always formed where these shales cut across a ridge.

Pennsylvanian.

The Upper Banff limestone contains over 2,300 feet of beds, which are well exposed in Sawback and Cascade ranges. The series is shaly at the bottom, but more massive towards the top. Cherty lenses and cherty shale interbedded with the lower shaly limestone help to distinguish this formation from the shales below.

The Rocky Mountain quartzite lies directly on the Upper Banff limestone. It represents a very sudden shallowing of the water, which, however, was not rendered muddy. The section in the Sawback range gives 800 feet as a maximum thickness. There is a rapid thickening of this formation to the east so that at lake Minnewanka, 12 miles to the east, there are 1,600 feet of quartzite exposed.

This is the uppermost formation in the Carboniferous.

Permian.

The Upper Banff Shale lies conformably upon the Rocky Mountain quartzite and consists of a series of brown, calcareous and arenaceous, often sun-cracked shales, interbedded with thin layers of sandstone. The shales weather out more easily than the underlying formations, forming valleys such as those between the Cascade, Vermilion lake, and Sawback ranges. More than 1,400 feet of strata are represented in this section, but it is difficult to get an accurate measurement on account of the foldings and contortions within the beds.

Jurassic.

Fernie Shale.—No sharp line can be drawn between the Upper Banff shale and the Fernie shale, except where fossils are found. The Fernie formation consists of black and dark brown, siliceous, very thinly laminated shales which break up into small fragments on the weathered surface. On the Cascade river it contains some gray sandstone beds and an occasional limestone layer. West of Banff it has a limited distribution, lying on the Upper Banff shale. East of Banff and on the north side of the Cascade trough, it forms a band about 1,500 feet thick. The Fernie shale occurs near Exshaw 6 miles east of the Gap.

Cretaceous.

The Cretaceous formations occur mainly in the foot-hills region from Kananaskis to Cochrane. A narrow band occupies what is known as the Cascade trough and extends from the head-waters of Cascade river down the Cascade and Bow valleys to Canmore and southward in that same direction across the upper part of Kananaskis river. In the foothills the rocks are of the same character and are so soft compared to the older rocks that they either floor the valleys or produce a type of country that is more subdued in form than that of the mountains.

Kootenay.—The lowest member of this formation rests upon the Jurassic in the Rocky mountains, and forms the bottom of the Cascade trough. The base of the formation consists of alternating beds of sandstone and shale, which are succeeded by sandstones and shales and many coal seams.

The upper part of the formation consists of thin-bedded sandstones and shales exposed in the eastern base of Cascade mountain. Near Banff the total thickness of this formation is over 4,000 feet.

Dakota.—In the mountains the coal-bearing Kootenay formation is overlaid by a series of sandstones and conglomerates containing thin seams of coal. In the foot-hills the sandstones are finer grained and are associated with some clays and shales. The thickness in the foot-hills is about 950 feet.

Benton.—This is a series of dark marine shales so soft and pliable as to be easily folded and distorted. They weather easily so that the outcrop is usually masked or marked by a depression.

Niobrara.—This formation is correlated with the Cardium sandstone, a formation which is important as forming the series of falls and rapids on the Bow river below Kananaskis. It consists of three sandstone beds, each capped by a conglomerate and separated by shales. A detailed diagrammatic section of this formation is given under the heading of "Bow Fort," in a later section of this report.

Pierre.—Marine deposits containing some calcareous matter overlie the Niobrara. They consist mainly of dark shales with some sandy beds in the middle. They occur in the foot-hills region and are exposed in the valley of Bow river below Bow Fort, where they have been folded into a series of anticlines and synclines and faulted.

Edmonton.—The Edmonton formation consists of light coloured, soft sandstones, shales and clays, well bedded and frequently alternating. The sandstones predominate and usually weather to a yellow colour. The shales are of various dark shades of colour. Some coal seams are present. The formation is not as highly disturbed as the older Cretaceous beds, and is the bed rock formation of Bow valley from Radnor to Mitford.

Tertiary.

Tertiary rocks under the name of the Paskapoo formation overlap the Cretaceous at Cochrane and extend from there eastward to Calgary. They consist of yellowish sandstones and bluish grey and olive shales. They have not been greatly disturbed since they were laid down and still lie in almost horizontal attitudes in contrast to the older rocks which have in general been tilted at high angles.

Pleistocene.

A thin veneer of unconsolidated material covers the surface of the solid rocks nearly everywhere except on the higher levels of the region. This unconsolidated material includes river deposits of gravel and sand, which appear as terraces about the sides of the larger streams, clays which were laid down in post-Glacial lakes, and glacial debris such as moraines and boulder clay.

Geological Structure.

There are four different types of geological structure developed in the rocks of the Bow river basin. The first is that of the almost flat lying rocks of the region east of Cochrane where the beds have been very slightly disturbed from their original attitude. In the foot-hills pressure from the west has thrown the beds into a series of irregular major folds and minor crumples which have their axis parallel to the general trend of the mountains. In many cases the beds are broken and faulted along lines parallel to the folds.

The eastern ranges of the Rocky mountains are characterized by a series of great longitudinal fractures along which the strata have been broken, tilted and shoved one over the other towards the east. The result is a series of fault blocks having a steep face to the east and a more gentle slope to the west. The western slope of these fault blocks represents the dip of the beds. In the ranges about the head waters of Bow river the disturbance is not as great and the strata are not as closely folded and are traversed by fewer faults. The beds in consequence have lower dips and horizontal attitudes are not rare.

Geological History.

The Rocky Mountain region in the neighbourhood of Bow river was a region in which sediments were being laid down almost without interruption from Pre-Cambrian times to the close of the Cretaceous. The region formed part of a great interior sea whose shore line fluctuated from time to time, but which was gradually pushed eastward towards the plains. By the close of Cretaceous times a great thickness of sediments had been laid down, the materials for which had been derived from a land area to the west. Sedimentation continued even into the Tertiary, but after the Paskapoo sandstones had been laid down, movements in the earth's crust which had already been felt along the line of the continental divide, culminated in a revolutionary period of mountain building during which the Rocky mountains were formed. The force which caused the elevation of the Rocky mountains was directed from the Pacific, and in the course of mountain building the strata were arched upward, compressed and overturned on each other, and up-folded portions were pushed miles to the eastward over the level plains region.

The subsequent history of the region was in general one of erosion, that is to say, the carving out of its valleys by the streams and the development of its drainage system and a general wearing down of the mountain ranges.

GLACIATION.

During the Glacial period the Canadian Cordillera is believed to have been covered by an ice cap much as that which covers Greenland or the Antarctic continent to-day. This ice cap extended from the 48th to the 63rd parallels of latitude, or a distance of about 1,200 miles. During the maximum period of glaciation, the interior ice cap was fed by a double row of valley glaciers, one flowing eastward from the Coast range and another westward from the Rockies; the united stream then moved southward and northward over the interior of British Columbia. The eastern slope of the Rockies was also drained by eastward-moving valley glaciers which became confluent as piedmont sheets on the plains of Alberta.

In the basin of Bow river all the valleys were occupied during the glacial period by valley glaciers moving slowly down grade toward the east. These valley glaciers, by the aid of rock fragments along the bottom of the glaciers, deepened and broadened the valleys and gave them the general outlines that they have to-day. As the glaciers dwindled and retreated up the valleys they left large quantities of loose materials in their train. At certain points glacial lakes, dammed by ice tongues, were formed which received sediments in the form of clays and sands. Towards the heads of the valleys basin-shaped cirques were gouged out of the solid rock by means of mountain glaciers, the remnants of larger valley glaciers.

SPRAY LAKES.

Spray lakes lie in a transverse valley, which cuts across the general trend of the mountain axis and which separates the Goat range from Kananaskis range. The valley was probably at one time the main course of Spray river, but having been filled with glacial material the stream became diverted and the valley is only now occupied by a tributary of the main river. The lakes are stated by Dawson to be due to damming of the outlet by glacial materials or débris washed down from the bordering mountains.

The part of the valley which it is proposed to utilize as a storage basin is underlain by rocks of Palæozoic age Devonian and Carboniferous—consisting mainly of limestones with some quartzite and possibly shale. The strata have been tilted, and on the northeast side of Goat range dip at angles of about 45° to the southwest. On the west side of the Goat range the dips average about 60° in the same direction. The strike of the outcropping edges of the strata coincides roughly with the trend of the mountain axis, so that on the transverse portion of the valley at Spray lakes the strike is directly across the valley, while in the main valley of Spray river below Spray lakes the strike is parallel to the valley. At the point then where it is suggested the site of the dam should be the strike of the rocks is in general parallel to the course of the stream, and the rocks themselves consist of limestone and quartzite.

At Spray falls a ledge of pale grey limestone crosses the river, making a drop of 40 feet. The remainder of the proposed storage basin is covered with unconsolidated glacial and stream deposits which rest with a variable thickness on the upturned edges of the solid rocks.

KANANASKIS FALLS.

Kananaskis falls are caused by outcropping ledges of Cretaceous sandstone, known as the Cardium sandstone. The sandstone beds are from 50 to 150 feet in thickness and are overlain and underlain by shales. Cairnes describes the Cardium sandstone at this point as follows: "The lowest bed is a very hard sandstone, weathering to a reddish colour and is fairly well bedded. The bed next above is grey in colour on a freshly-fractured surface, is very massive, hard, and even quartzitic. There is a conglomerate bed 1 foot thick on top of each of these two lower sandstones. The upper sandstone is here also quite hard and weathers to a reddish colour."

The sandstone beds dip westward or upstream about 20°, and strike across the course of the stream.

HORSESHOE FALLS.

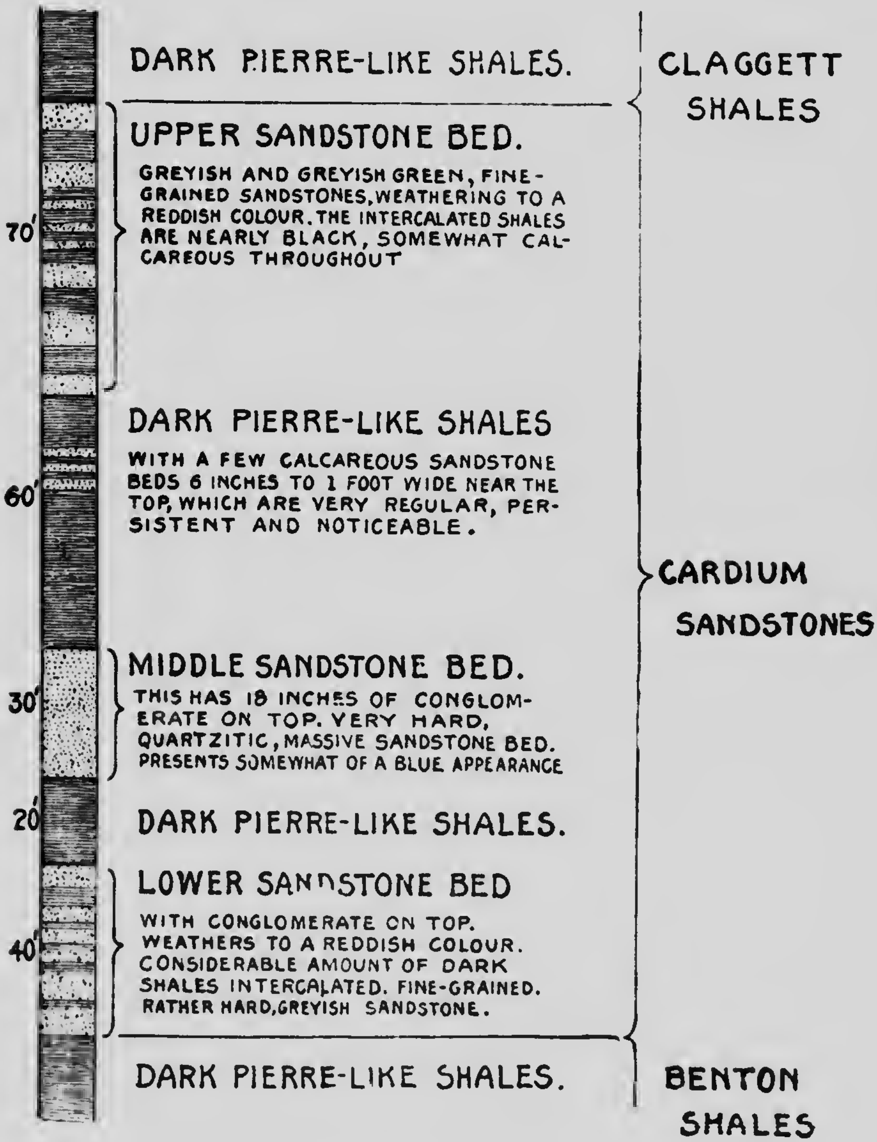
Horseshoe falls are caused by an outcropping ledge of sandstone of the Cardium sandstone formation, the character and structure of which has been described under Kananaskis falls.

BOW FORT.

For ten miles below the site of Bow Fort the Cardium sandstone formation is exposed in the banks of the river. The attitude of the beds is almost horizontal. Above Bow Fort the shales below the Cardium sandstone are brought up to the surface in a low anticline, the western limb of which is just below the Horseshoe falls. The shales are of Benton age, dark in colour, and soft. They weather down readily and are easily folded and distorted.

The Cardium sandstone formation near Bow Fort was carefully measured by Cairnes who gives the following section:—

SECTION OF THE CARDIUM SANDSTONES MEASURED NEAR OLD BOW FORT, ON THE BOW RIVER.



APPENDIX VI

WATER-POWER REGULATIONS UNDER THE DOMINION LANDS ACT, SEC. 36, S.S. 2.

WATER-POWER REGULATIONS UNDER THE DOMINION LANDS ACT, SEC. 36, S.S. 2.

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, as amended by Section 6 of Chapter 27, 4-5 George V, to govern the mode of granting water-power rights in the provinces of Manitoba, Saskatchewan and Alberta, and the Northwest Territories.

SECTION 35.—DOMINION LANDS ACT.—WATER-POWER.

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 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 within which 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 lar which may be taken by any person without the consent of the owner for · purpose in connection with any water-power undertaking.

Regulatior Governing the Granting of Water-power Rights in the Provinces of Manitoba, Saskatch wan and Alberta, and the Northwest Territories.

(*Established by Orders in Council dated June 2, 1909; June 8, 1909; April 20, 1910; and January 24, 1911.*)

1. Under these regulations the word "works" shall be held to mean and include all sluices, races, dams, weirs, tunnels, pits, slides, flumes, machines 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 head water and tail water 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 neecessary, and the same shall be furnished by and at the expense of the applicant.

The Agreement for a License.

6. Upon receipt and consideration of the application, and information accompanying same, the Minister of the Interior may, if he approve 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*.

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.

8. Upon fulfilment by the applicant of all 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 there from.

(*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 or 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, 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.

(i) 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

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, and 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.

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 lessee.

(c) A detail plan in duplicate on tracing linen, showing all dams and other works proposed to be constructed in connection with such storage.

11. When the plans for 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.

APPENDIX VII

RUN-OFF DATA.

RUN-OFF DATA.

NOTE.—The data contained in the following 96 pages were collected and published by the Irrigation Branch of the Department of the Interior under the title of Progress of Streams Measurements for the years 1909, 1910, 1911 and 1912.

DISCHARGE MEASUREMENTS of Bow River near Laggan in 1910.

Date.	Hydrographer.	Width.	Area of section.	Mean velocity.	Gauge height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
July 18	J. C. Keith	112·3	300·45	5·832	3·43	1752·30
Aug. 12	do	111·3	243·50	4·974	3·02	1202·24
Sept. 2	do	73·2	99·70	3·328	2·12	331·79
Sept. 24	do	97·8	127·22	3·142	2·285	399·75
Oct. 20	H. R. Carscallen	85·6	104·74	3·25	2·14	340·63
Nov. 8	do	42·0	66·43	2·68	1·66	178·02
Dec. 5	do	42·0	57·88	2·084	1·33	120·62
Dec. 29	do	42·0	50·33	1·814	1·26	91·31

DISCHARGE MEASUREMENTS of Bow River at Laggan, Alta., in 1911.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
Jan 30	H. R. Carscallen	40·5	55·9	1·49	2·68	83·2x
Feb. 13	do	35·5	45·1	1·10	1·94	49·4x
Mar. 6	do	35·5	36·8	1·48	1·30	51·4x
Mar. 23	do	42	45·2	1·41	1·02	63·7x
Apr. 7	H. C. Ritchie	43·5	53·4	1·52	1·04	81·1x
Apr. 27	do	43·5	58·8	1·88	1·25	110·7x
May 11	do	62·5	93·4	2·85	1·85	265·9x
June 1	B. Russell	103·8	184·6	3·50	2·47	647·6x
June 16	do	111·8	310·6	5·77	3·32	1793·0x
July 1	do	110·0	277·6	5·71	3·17	1585·0x
July 14	do	86·3	232·8	4·54	2·84	1058·0x
July 27	H. C. Ritchie	111·5	259·6	5·24	3·11	1360·0x
Aug. 18	H. Brown	108·3	200·0	3·99	2·59	798·7x
Sept. 5	do	69·5	157·9	4·90	6·38	774·2*
Sept 21	do	61·5	98·3	3·43	5·48	336·7*
Oct. 17	V. A. Newhall	47·7	46·1	2·79	4·64	128·5*
Nov. 2	do	34·5	29·0	1·95	4·37	56·8*
Nov. 20	do	61·5	289·5	0·23	†	65·5*‡
Dec. 4	do	61	196·0	0·62	†	121·7***
Dec. 6	do	42	38·2	1·65	†	63·2**
Dec. 18	do	45	42·2	1·43	†	60·2*

xDischarge measured at old station. *Discharge measured at new station.
†Gauge not read owing to backwater caused by ice jam. ‡May be slightly inaccurate owing to slush ice.
*Accuracy affected by great amount of frozen slush ice causing cross-currents.
**Gauging made at an open water section west of Laggan. Probable error small.

Daily Gauge Height and Discharge of Bow River at Laggan, Alta., for 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	1·65	114	2·65	80	1·85	53	1·10	90	1·33	125	2·42	617
2	1·90	130	2·65	80	1·80	53	1·08	87·6	1·35	129	2·66	850
3	2·80	210	2·75	90	1·40	46	1·05	84	1·53	167	2·82	1,035
4	2·90	216	2·70	85	1·38	48	1·05	84	1·60	185	2·80	1,010
5	3·00	216	2·65	80	1·30	48	1·05	84	1·75	230	2·63	818
6	2·85	195	2·65	80	1·25	48	1·05	84	1·85	266	2·64	828
7	2·35	140	2·40	65	1·15	48	1·10	90	1·80	247	2·65	839
8	2·35	135	2·20	57	1·10	48	1·20	103	1·78	240	2·60	786
9	2·50	140	2·10	53	1·03	47	1·30	120	1·80	247	2·60	786
10	2·50	130	2·00	49	1·03	48	1·40	139	1·80	247	2·70	894
11	2·60	130	2·00	49	1·03	49	1·45	149	1·85	266	2·76	963
12	2·60	121	1·98	48·2	1·03	51	1·15	96	1·85	266	3·05	1,349
13	2·40	95	1·96	47·4	1·00	51	1·10	90	1·85	266	3·12	1,456
14	2·20	72	1·95	47	0·95	50	1·05	84	1·76	233	3·27	1,697
15	2·20	66	1·95	47	0·95	52	1·05	84	1·89	283	3·35	1,832
16	2·10	59	1·98	48·2	0·95	53	1·03	81·6	2·07	371	3·32	1,781
17	2·05	51	2·00	49	0·95	54	1·05	84	2·25	484	3·33	1,798
18	2·05	51	2·05	51	0·95	55	1·05	84	2·20	450	3·34	1,815
19	2·05	51	2·05	51	0·95	56	1·05	84	2·25	484	3·30	1,747
20	2·05	51	2·10	53	0·95	57	1·03	81·6	2·25	484	3·16	1,519
21	2·10	53	2·00	49	0·95	58	1·08	87·6	2·30	520	3·12	1,456
22	2·00	49	2·03	50·2	0·95	59	1·08	87·6	2·28	506	3·45	2,008
23	2·10	53	2·05	51	1·00	62	1·12	92·4	2·16	424	3·40	1,919
24	2·10	53	2·05	51	1·02	66	1·15	96	2·09	382	3·48	2,063
25	†2·05	51	2·08	52·2	1·05	70	1·20	103	2·03	350	3·40	1,919
26	2·00	49	2·10	53	1·05	71	1·20	103	1·95	310	3·32	1,781
27	2·20	57	2·05	51	1·05	74	1·25	111	1·86	270	3·25	1,664
28	2·20	57	1·90	51	1·05	77	1·30	120	1·91	292	3·24	1,648
29	2·10	53	....	....	1·06	89	1·40	139	1·96	315	3·20	1,583
30	2·68	83	....	....	1·06	82	1·45	149	2·06	366	3·22	1,615
31	2·65	80	....	....	1·06	85	....	....	2·18	437	....	....

Note.—Gauge height observations were made at the old gauging station until the end of August. After that they were taken at the cable station. An ice jam a short distance below the station caused backwater on the gauge and made it impossible to compute daily discharges after November 9.

Daily Gauge Height and Discharge of Bow River at Laggan, Alta., for 1911.—*Continued.*

Day.	July.		August.		September.		October.		November.	
	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
1	3·19	1567	2·98	1248	6·56	870	4·95	169	4·31	50·2
2	3·18	1551	2·93	1178	6·65	919	4·92	162	4·47	71·2
3	3·17	1535	2·96	1219	6·67	930	4·90	157	4·53	81·4
4	3·09	1410	3·00	[illegible]	6·55	865	4·87	150	4·53	81·4
5	3·06	1364	3·01	[illegible]	6·38	773	4·85	145	4·55	85
6	3·05	1349	2·9[illegible]	[illegible]	6·25	703	4·82	138	4·56	86·9
7	3·03	1320	2·93	[illegible]	6·08	613	4·79	132	4·53	81·4
8	3·00	1276	2·82	[illegible]	5·99	568	4·76	125	4·37	57·4
9	2·92	1164	2·75	951	5·90	523	4·76	125	4·30	49·0
10	2·89	1124	2·68	872	5·90	523	4·75	123	....	....
11	2·85	1072	2·63	818	5·94	543	4·75	123	....	....
12	2·80	1010	2·65	839	6·01	578	4·75	123	....	....
13	2·81	1022	2·65	839	6·11	628	4·75	123	....	....
14	2·82	1035	2·63	818	6·05	598	4·75	123	....	....
15	2·82	1035	2·60	786	5·95	548	4·73	119	....	....
16	·03	1320	2·58	766	5·80	475	4·66	105	—........	....
17	3·02	1305	2·62	807	5·70	430	4·66	105	....	....
18	3·02	1305	2·65	839	5·60	386	4·67	107	....	....
19	3·00	1276	2·65	839	5·50	345	4·64	101	....	....
20	2·96	1219	2·65	839	5·50	345	4·57	88·6	....	....
21	2·98	1248	2·63	818	5·48	337	4·70	113	....	....
22	3·02	1305	2·59	776	5·40	307	4·58	90·4	....	....
23	3·03	1320	2·57	756	5·32	279	4·54	83·2	....	....
24	3·10	1425	2·57	756	5·22	246	4·52	79·6	....	....
25	3·20	1583	2·58	766	5·18	234	4·53	81·4	....	....
26	3·19	1567	2·57	756	5·14	222	4·35	55	....	....
27	3·11	1441	2·47	661	5·08	204	4·33	52·6	....	....
28	3·09	1410	2·45	643	5·04	193	4·41	62·4	....	....
29	3·08	1395	2·50	688	5·00	182	4·28	46·6	....	....
30	3·05	1349	2·55	736	4·97	174	4·40	61	....	....
31	3·01	1291	2·55	736	....	....	4·42	63·8	....	....

Drainage area, 166 square miles.

Monthly Discharge of Bow River at Laggan, Alta., for 1911.

Month.	Discharge in Second-Feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on Drainage area.	Total in acre-feet.
January	216	49	97·1	0·585	0·67	5,970
February	90	47	57·8	0·348	0·36	3,210
March	89	46	58·3	0·351	0·40	3,585
April	149	81·6	99·1	0·597	0·67	5,897
May	520	125	317	1·91	2·20	19,492
June	2,063	617	1,403	8·45	9·43	83,484
July	1,583	1,010	1,309	7·89	9·10	80,488
August	1,291	643	897	5·40	6·23	55,154
September	930	174	485	2·92	3·26	28,860
October	169	46·6	108	0·651	0·75	6,641
November (1-9)	86·8	49	71·5	0·431	0·14	1,276
The period					33·21	294,057

Discharge Measurements of Bow River at Laggan, in 1912.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
Jan. 23	V. A. Newhall	10·00	15·35	2·18	....	33·43
Feb. 5	do	11·00	14·90	1·78	4·76	26·55
Feb. 16	do	39·60	60·87	2·33	....	141.73
Feb. 28	do	16·00	36·60	2·00	7·45	73·06
Mar. 8	H. C. Ritchie	15·00	28·80	1·66	5·30	48·60
Mar. 18	do	15·00	22·80	1·50	4·73	37·50
Mar. 28	do	14·00	22·60	1·95	4·78	40·50
April 9	do	40·00	31·00	1·28	4·38	39·66
April 24	do	45·00	44·00	1·63	4·64	71·95
May 9	do	51·00	75·90	2·36	5·41	178·90
May 22	do	65·00	118·75	3·05	6·05	362·17
June 5	do	59·00	79·80	2·70	5·45	215·46
June 19	do	72·00	216·35	5·25	7·59	1,136·12
July 4	do	71·00	196·95	5·01	7·07	985·13
July 18	do	71·00	176·40	4·79	6·88	844·29
Aug. 1	do	72·00	210·15	5·30	7·30	113·72
Aug. 13	do	70·00	190·15	4·66	6·87	885·16
Aug. 29	do	72·50	227·40	4·86	7·34	1,104·40
Sept. 12	do	65·00	125·70	3·21	6·08	404·00
Oct. 4	H. R. Cram	58·00	84·90	2·48	5·40	210·50
Oct. 17	H. C. Ritchie	52·50	83·50	2·54	5·30	212·70
Nov. 1	do	46·00	53·40	1·58	4·68	84·69
Nov. 14	do	46·50	66·50	1·76	4·95	117·20
Nov. 28	do	45·00	71·25	1·11	5·03	79·20

Daily Gauge Height and Discharge of Bow River at Laggan, for 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	....	(1)......	5·54	46·76	6·46	59·64	4·75	35·70	4·65	71·00	5·81	313·35
2	....	....	5·37	44·38	6·43	59·22	4·72	35·28	4·62	67·40	5·74	292·35
3	....	....	5·34	43·96	6·25	56·70	4·68	34·72	4·73	81·70	5·61	255·95
4	....	....	5·14	41·16	6·22	56·28	4·66	34·44	4·75	84·50	5·55	240·25
5	....	....	4·76	35·84	5·98	52·92	4·72	35·28	4·85	100·00	5·45	215·75
6	....	....	4·94	38·36	5·80	50·41	4·38	(2) 34·72	4·86	101·65	5·45	215·75
7	....	....	4·86	37·24	5·53	46·62	4·60	65·00	5·17	156·65	5·60	253·25
8	....	....	4·84	36·96	5·43	45·22	4·50	54·50	5·26	174·55	6·14	427·25
9	....	....	4·84	36·96	5·24	42·56	4·38	42·40	5·41	206·55	6·59	665·75
10	....	....	4·84	36·96	4·96	38·64	4·40	44·00	5·31	184·85	6·65	702·25
11	....	....	4·86	37·24	5·11	40·74	4·44	47·20	5·26	174·55	6·76	770·20
12	....	....	4·86	37·24	4·94	38·36	4·44	47·20	5·35	193·25	6·98	906·60
13	....	....	4·94	38·36	4·94	38·36	4·44	47·20	5·52	232·75	7·50	1,229·00
14	....	....	5·33	43·82	4·92	38·08	4·45	48·00	5·85	325·75	7·16	1,018·20
15	....	....	9·56	101·00	4·92	38·08	4·46	48·90	6·25	475·75	7·51	1,235·20
16	....	....	9·95	107·00	4·90	37·80	4·50	54·50	6·45	582·25	7·20	1,043·00
17	....	....	9·99	107·50	4·75	35·70	4·55	59·50	6·25	475·75	7·29	1,098·80
18	....	....	9·95	107·00	4·74	35·56	4·57	61·70	6·24	471·15	7·41	1,173·20
19	....	....	9·50	100·50	4·86	37·24	4·59	63·90	6·09	407·55	7·59	1,284·80
20	....	....	8·72	90·00	5·02	39·48	4·58	62·80	6·05	392·75	7·71	1,359·20
21	....	....	8·55	87·00	5·05	39·90	4·51	55·50	5·85	325·75	7·86	1,452·20
22	....	....	8·76	91·00	4·92	38·08	4·58	62·80	6·06	396·45	7·87	1,458·40
23	....	....	8·47	86·00	4·78	36·12	4·61	66·20	5·96	361·65	8·10	1,601·00
24	(1)	....	7·39	72·00	4·76	35·84	4·65	71·00	6·06	396·45	8·18	1,650·00
25	5·74	(2)49·56	7·60	74·00	4·78	36·12	4·71	78·90	6·20	452·75	8·20	1,663·00
26	5·74	49·56	6·40	58·80	4·80	36·40	4·64	69·80	6·45	582·25	8·39	1,780·80
27	5·73	49·42	6·35	58·10	4·88	37·52	4·65	71·00	6·65	702·25	8·51	1,855·20
28	5·73	49·42	7·42	72·10	4·80	36·40	4·63	68·60	6·50	611·25	8.15	1,632·00
29	5·73	49·42	6·26	56·84	4·78	36·12	4·64	69·80	6·28	490·45	7·70	1,353·00
30	5·73	49·42	....	....	4·78	36·12	4·74	83·10	6·14	427·25	7·60	1,291·00
31	5·64	48·16	....	....	4·73	35·42	....	....	5·96	361·65	....	....

(1) Ice jams rendered gauge heights useless Jan. 1 to 24. (2) Ice conditiond Jan. 25 to April 6.

Daily Gauge Height and Discharge of Bow River at Laggan, for 1912 — *Concluded.*

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	7·33	1123·6	7·27	1086·4	6·59	665·8	5·31	184·8	4·75	84·5	5·96	76·0
2	7·30	1105·0	7·35	1136·0	6·49	606·4	5·28	178·6	4·81	93·6	6·17	76·0
3	7·19	1036·8	7·35	1136·0	6·44	576·6	5·37	197·6	4·86	101·6	6·46	76·0
4	7·08	968·6	7·57	1272·4	6·30	500·2	5·37	197·6	4·89	106·6	6·60	75·0
5	7·08	968·6	7·65	1322·0	6·25	475·8	5·34	191·2	4·94	115·0	6·98	75·0
6	7·44	1191·8	7·31	1111·2	6·15	431·2	5·29	180·7	4·94	115·0	7·25	74·0
7	7·31	111·2	7·13	999·6	6·10	411·2	5·25	172·5	4·95	116·8	7·28	74·0
8	7·18	1030·6	7·10	981·0	6·09	407·6	5·25	172·5	4·98	121·5	7·16	74·0
9	7·15	1012·0	7·35	1136·0	6·00	375·2	5·18	158·6	4·98	121·5	6·99	74·0
10	7·16	1018·2	7·31	1111·2	5·98	368·4	5·16	154·7	5·12	147·0	6·74	75·0
11	7·20	1043·0	7·25	1074·0	5·98	368·4	5·14	150·8	5·01	126·8	6·64	76·0
12	7·15	1012·0	7·03	937·6	6·08	403·8	5·06	135·8	4·99	123·8	6·76	75·0
13	7·33	1123·6	6·85	826·0	6·09	407·8	5·06	135·8	4·96	118·5	6·65	76·0
14	7·00	919·0	6·78	782·6	6·02	382·2	5·06	135·8	4·95	116·8	6·35	76·0
15	6·95	888·0	6·84	819·8	5·94	354·9	5·04	132·2	4·74	83·1	6·27	76·0
16	6·88	844·6	7·24	1067·8	5·89	338·6	5·11	145·2	4·90	102·0	6·27	76·0
17	6·84	819·8	7·48	1216·6	5·87	332·2	5·28	178·6	4·96	107·0	6·27	76·0
18	6·86	832·2	7·26	1080·2	5·85	325·8	5·21	164·5	4·90	96·0	6·12	76·0
19	6·99	912·8	7·24	1067·8	5·78	304·2	5·16	154·7	4·75	78·0	6·09	76·0
20	7·06	956·2	7·24	1067·8	5·69	278·0	5·12	147·0	4·72	75·0	6·05	76·0
21	7·14	1005·8	7·30	1105·0	5·63	261·4	5·09	141·4	4·74	73·0	6·13	76·0
22	7·16	1018·2	7·48	1216·6	5·58	248·0	5·00	125·0	4·74	70·0	6·22	76·0
23	7·15	1012·0	7·65	1322·0	5·57	245·4	4·97	120·2	4·79	68·0	6·16	76·0
24	7·44	1191·8	8·44	1811·8	5·51	230·2	4·99	123·8	4·74	67·0	6·06	76·0
25	7·36	1142·2	8·56	1886·2	5·54	237·8	4·96	118·5	4·76	61·0	5·84	76·0
26	7·25	1074·0	8·09	1594·8	5·46	218·2	4·95	116·8	4·53	62·0	6·06	76·0
27	7·09	974·8	7·74	1377·8	5·44	213·4	4·95	116·8	4·76	68·0	6·00	76·0
28	6·94	881·8	7·56	1266·2	5·40	204·2	4·90	108·2	5·03	79·0	5·90	76·0
29	6·93	875·6	7·28	1092·6	5·30	182·8	4·76	86·0	5·33	78·0	5·80	76·0
30	7·04	943·8	6·97	900·4	5·31	184·8	4·69	76·2	5·59	77·0	5·90	76·0
31	7·19	1036·8	6·75	764·0	....	....	4·70	77·5	....	....	5·86	76·0

Monthly Discharge of Bow River at Laggan, for 1912.

(Drainage area. 166 square miles.)

Month.	Discharge in Second-Feet				Run-Off.	
	Maximum.	Minimum.	Mean.	Per Square Mile.	Depth in inches on Drainage Area.	Total in Acre-feet.
January	49·56	48·16	49·28	0·30	0·08	684
February	107·50	35·84	62·90	0·38	0·41	3,618
March	59·64	35·42	41·67	0·25	0·29	2,562
April	83·10	34·44	55·12	0·33	0·37	3,280
May	702·25	67·40	324·79	1·96	2·26	19,970
June	1,855·20	215·75	1,014·58	6·11	6·83	60,385
July	1,191·80	819·80	1,002·40	6·04	6·96	61,634
August	1,886·20	764·00	1,147·40	6·91	7·97	70,551
September	665·8	182·8	351·34	2·11	2·35	20,906
October	197·6	76·2	144·59	·87	1·00	8,885
November	147·0	61·0	95·10	·57	·63	5,659
December	76·0	74·0	88·12	·53	·61	5,418
The year					29·76	263,552

DISCHARGE MEASUREMENTS of Pipestone River, near Laggan, Alta., in 1911.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq.-ft.	Ft. per sec.	Feet.	Sec.-ft.
Sept. 5	H. Brown	64·5	99·1	2·71	4·95	268·5
Sept. 21	do	58·5	74·9	2·13	4·54	159 8
Oct. 17	V. A. Newhall	52·2	50·2	1·74	4·24	87·2
Nov. 2	do	27·5	36·0	0·98	4·19	35·4
Dec. 19	do	14·2	31·3	1·38	....	43·3

DAILY GAUGE HEIGHT AND DISCHARGE of Pipestone River, near Laggan, Alta, for 1911

DAY.	September.		October.	
	Gauge Height.	Discharge.	Gauge Height.	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	5·12	316	4·40	123
2	5·15	324	4·40	123
3	5·17	330	4·40	123
4	5·08	304	4·39	121
5	4·95	268	4·38	118
6	4·90	254	4·37	116
7	4·80	227	4·36	113
8	4·75	214	4·35	111
9	4·70	201	4·35	111
10	4·70	201	4·34	109
11	4·72	206	4·33	106
12	4·80	227	4·33	106
13	4·90	254	4·33	106
14	4·76	217	4·33	106
15	4·75	214	4·33	106
16	4·68	196	4·30	99
17	4·65	188	4·33	106
18	4·60	175	4·33	106
19	4·56	165	4·27	92·4
20	4·55	162	4·15	69
21	4·55	162	4·10	60
22	4·52	154	4·10	60
23	4·52	154	4·26	90·2
24	4·40	123	4·15	69
25	4·40	123	4·00	46
26	4·45	136	3·98	43·6
27	4·47	128	4·05	52
28	4·42	128	4·00	46
29	4·42	128	3·98	43·6
30	4·41	126	4·10	60
31	....	....	3·98	43·6

NOTE.—An ice jam formed below the station during the cold spell in the early part of November and caused the banks of the stream to overflow. Gauge height observations could not be applied and were therefore discontinued.

SESSIONAL PAPER No. 25e

Monthly Discharge of Pipestone River near Laggan, Alta , for 1911.

(Drainage area, 122 square miles)

Month.	Discharge in Second-Feet.				Run-off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on Drainage area.	Total acre-feet.
September	330	123	200	1·639	1·83	11,901
October	123	43·6	89·8	0·739	0·85	5,522
The period					2·68	17,423

Discharge Measurements of Pipestone River, near Laggan, in 1912.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
Jan. 23	V. A. Newhall	17·0	13·0	2·42	4·67	31·43
Feb. 5	do	21·0	28·6	1·17	4·25	33·37
Feb. 15	do	35·0	32·5	0·75	4·975	24·5
Feb. 28	do	35·0	26·5	0·68	4·40	17·91
Mar. 8	H. C. Ritchie	33·0	17·1	1·00	4·20	17·06
Mar. 19	do	33·0	9·8	1·26	4·16	12·41
Mar. 29	do	33·0	25·7	1·03	4·00	26·52
April 10	do	35·0	26·0	0·846	3·85	22·02
April 24	do	40·0	36·1	1·01	4·12	36·59
May 10	do	59·0	70·3	2·34	4·69	164·76
May 22	do	73·0	98·9	3·21	5·20	317·67
June 5	do	59·0	65·1	2·33	4·65	151·5
June 19	do	75·0	152·5	5·12	5·85	780·21
July 4	do	74·0	106·9	3·65	5·29	389·65
July 18	do	73·0	107·30	3·71	5·29	398·07
Aug. 1	do	74·0	120·30	3·93	5·42	472·81
Aug. 13	do	68·0	94·25	3·36	5·12	316·34
Aug. 29	do	74·0	126·80	4·21	5·50	533·30
Sept. 12	do	65·0	91·00	3·14	5·08	286·00
Oct. 4	H. R. Cram	60·5	68·20	2·38	4·68	182·00
Oct. 17	H. C. Ritchie	58·5	66·80	2·43	4·57	162·10
Nov 1	do	53·5	47·50	1·24	4·26	58·90
Nov. 14	do	58·0	58·10	1·32	4·60	76·50
Nov. 28	do		Ice jammed.			
Dec. 14	do	52·0	52·05	0·89	5·47	46·52

Daily Gauge Height and Discharge of Pipestone River, near Laggan, for 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	....	(1.)	4·17	34·6	4·11	13·2	3·95	11·0	4·08	32·0	4·75	180·0
2	....	....	4·20	34·0	4·15	14·0	3·92	10·4	4·04	30·2	4·80	196·0
3	....	....	4·17	34·5	4·15	14·0	3·88	10·0	4·12	38·4	4·70	165·0
4	....	....	4·17	34·[illegible]	4·17	14·0	3·85	10·0	4·06	32·0	4·70	165·0
5	....	....	4·20	[illegible]	4·17	14·0	3·84	19·8	4·09	35·0	4·60	136·0
6	....	....	4·18	34·4	4·15	14·0	3·76	18·2	4·14	40·8	4·66	153·0
7	....	....	4·15	35·0	4·17	14·0	3·88	20·5	3·41	89·2	4·98	260·0
8	....	....	4·12	35·0	4·20	14·0	3·86	20·2	4·65	150·0	5·35	441·0
9	....	....	4·15	35·0	4·20	14·0	3·85	20·0	4·80	196·0	5·51	535·0
10	....	....	4·10	35·0	4·23	14·5	3·87	20·4	4·69	162·0	5·47	509·0
11	....	....	4·15	35·0	4·25	15·0	3·92	22·2	4·65	150·0	5·50	528·0
12	....	....	4·20	34·0	4·22	14·4	3·90	21·0	4·85	212·0	5·58	583·0
13	....	....	4·20	34·0	4·20	14·0	3·95	24·0	4·99	264·0	5·54	555·0
14	....	....	4·22	33·6	4·20	14·0	3·86	20·2	5·26	385·0	5·50	528·0
15	....	....	4·98	24·5	4·20	14·0	3·91	21·5	5·53	548·0	5·86	788·0
16	....	....	4·98	24·5	4·20	14·0	3·90	21·0	5·53	648·0	5·57	645·0
17	....	....	4·80	22·0	4·17	14·0	3·85	20·0	5·36	441·0	5·70	668·0
18	....	....	4·60	20·0	4·15	14·0	3·95	24·0	5·18	334·0	5·71	675·0
19	....	....	4·70	21·0	4·15	14·0	3·96	24·5	5·14	[illegible]	5·79	735·0
20	....	....	4·38	15·5	4·14	13·8	3·95	24·0	5·10	[illegible]	5·79	735·0
21	....	....	4·60	20·0	4·15	14·0	3·95	24·0	5·00	268·0	5·85	780·0
22	....	....	4·80	22·0	3·65	7·0	4·05	31·0	5·20	354·0	5·78	727·0
23	....	....	4·60	20·0	4·15	14·0	4·03	29·4	5·04	284·0	5·95	860·0
24	4·63	28·4	4·55	19·0	3·92	10·4	4·06	32·0	5·15	330·0	5·91	828·0
25	4·54	30·0	4·28	15·6	4·44	17·8	4·06	32·0	5·24	374·0	5·86	788·0
26	4·60	29·0	4·15	14·0	4·45	18·0	4·04	30·2	5·43	484·0	6·00	900·0
27	4·48	30·4	4·10	13·0	4·46	18·0	4·04	30·2	5·54	555·0	6·10	980·0
28	4·38	31·4	4·20	14·0	4·46	18·0	4·05	31·0	5·34	429·0	5·75	705·0
29	4·33	32·0	4·08	12·5	4·00	12·0	4·03	29·4	5·09	304·0	5·45	502·0
30	4·27	32·6	....	....	3·97	11·4	4·12	38·4	5·00	268·0	5·42	477·0
31	4·17	34·5	....	....	3·92	10·4	....	....	4·88	223·0	....	....

(1) No records Jan. 1 to 23.

Daily Gauge Height and Discharge of Pipestone River near Laggan, for 1912.—*Concluded.*

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	5·30	407	5·38	453	5·22	364	4·64	147	4·26	59	6·14	410
2	5·35	435	5·42	471	5·14	326	4·60	136	4·31	64	6·11	380
3	5·31	413	6·37	447	5·13	321	4·55	123	4·46	92	6·01	310
4	5·25	379	5·50	628	5·09	30[illegible]	4·55	123	4·55	108	5·91	262
5	5·30	407	5·57	576	5·14	[illegible]	4·61	139	4·58	110	5·80	210
6	5·71	675	5·35	435	5·04	284	4·60	136	4·56	102	5·85	212
7	5·59	590	5·23	369	5·00	268	4·57	12[illegible]	4·56	98	5·84	197
8	5·56	569	5·23	369	5·02	276	4·58	131	4·58	98	6·68	140
9	5·54	555	5·36	441	4·96	252	4·55	123	4·58	94	5·60	108
10	5·54	555	5·30	407	4·94	244	4·55	123	4·66	106	5·53	88
11	5·52	542	5·26	385	4·97	256	4·50	110	4·66	102	5·35	48
12	5·46	502	5·13	321	5·04	284	4·41	89	4·65	98	5·46	58
13	5·58	583	6·06	292	5·01	272	4·48	105	4·61	82	5·55	66
14	5·40	465	5·05	288	5·01	272	4·48	105	4·58	76	5·45	46
15	5·34	429	5·07	296	4·87	219	4·48	105	4·35	32	5·30	36
16	5·32	418	5·39	459	4·84	209	4·52	115	5·21	227	5·30	36
17	5·25	379	5·59	590	4·83	206	4·57	128	4·72	80	5·30	36
18	5·25	379	5·48	515	4·83	206	4·54	120	4·85	100	5·14	28
19	5·27	390	5·54	555	4·78	190	4·50	110	4·68	58	5·12	28
20	5·34	429	5·58	583	4·71	168	4·48	106	4·63	46	5·04	25
21	5·31	413	5·61	604	4·64	147	4·41	89	4·66	44	4·98	24
22	5·35	435	5·59	590	4·72	171	4·40	87	4·65	40	5·05	26
23	5·35	435	5·64	625	4·71	168	4·38	83	4·74	46	5·05	26
24	5·65	632	6·17	1,036	4·63	144	4·44	96	4·75	44	5·00	24
25	5·51	535	6·15	1,020	4·69	162	4·41	89	5·33	168	4·89	23
26	5·45	496	5·77	720	4·64	147	4·41	89	5·72	202	4·95	24
27	5·36	441	5·60	597	4·64	147	4·20	49	6·05	440	4·91	23
28	5·28	396	5·53	548	4·61	139	4·14	41	6·21	520	4·87	23
29	5·28	396	5·45	496	4·59	133	4·10	36	6·17	478	4·86	22
30	5·30	407	5·34	429	4·59	133	4·06	32	6·15	440	4·89	23
31	5·33	424	5·26	385	...	.....	4·06	32	...	....	4·86	22

Notes:—Changing conditions, Nov. 1 to Dec. 14.
Ice conditions, Dec. 15 to 31.

Monthly Discharge of Pipestone River near Laggan, for 1912.

(Drainage area, 122 square miles.)

Month.	Discharge in Second-Feet.				Run-Off.	
	Maximum	Minimum.	Mean.	Per Square Mile.	Depth in inches on Drainage Area.	Total in Acre-feet.
January (24-31)	34·6	28·4	31·0	0·25	0·07	493
February	35·0	12·6	26·3	0·22	0·24	1,513
March	18·0	7·0	13·9	0·11	0·13	855
April	38·4	10·0	23·0	0·19	0·21	1,369
May	555·0	30·2	264·7	2·17	2·50	16,276
June	980·0	136·0	557·6	4·57	5·10	33,179
July	675·0	379·0	468·1	3·84	4·43	28,782
August	1,036·0	288·0	510·7	4·18	4·82	31,401
September	364·0	133·0	224·6	1·84	2·05	13,364
October	147·0	32·0	100·8	0·83	0·96	6,198
November	520·0	32·0	145·0	1·19	1·33	8,628
December	410·0	22·0	96·2	0·788	0·91	6,915
The period					22·75	147,978

DISCHARGE MEASUREMENTS of Fortymile Creek, near Banff, in 1912.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
July 31	H. C. Ritchie	32	74·2	1·36	3·90	100·95
Aug. 19	do	32	96·7	1·95	4·55	188·6
Aug. 31	do	32	85·1	1·86	4·30	158·0
Sept. 14	do	32·5	76·4	1·61	3·89	123·0
Oct. 1	H. R. Cram	28·5	57·0	1·39	3·43	78·9
Oct. 15	do	28	53·5	1·28	3·25	68·2
Sept. 30	H. C. Ritchie	26	41·7	0·97	2·92	40·5
Nov. 12	do	27·5	46·0	1·20	3·04	55·2
Nov. 26	do	28·5	48·1	0·34	2·59	16·5
Dec. 10	do	28·5	53·8	0·42	3·30	22·8
Dec. 28	do	25·5	44·8	0·93	2·85	42·6

DAILY GAUGE HEIGHT AND DISCHARGE of Fortymile Creek, near Banff, for 1912.

DAY.	August.		September.		October.		November.		December.	
	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.
1	3·93	120	4·20	147	3·43	80	3·12	59	2·75	17·50
2	3·95	122	4·17	144	3·42	79	3·12	59	2·97	21·0
3	3·90	116	4·12	138	3·40	78	3·10	58	3·10	24·0
4	3·90	116	4·05	132	3·43	80	3·08	57	3·05	21·0
5	3·90	116	4·00	126	3·40	78	3·08	57	3·02	19·5
6	3·85	112	3·97	124	3·37	76	3·06	56	2·96	18·0
7	3·83	110	3·95	122	3·35	74	3·06	56	2·93	16·5
8	3·80	108	3·95	122	3·35	74	3·06	56	2·90	15·0
9	3·70	100	3·93	120	3·35	74	3·06	56	2·90	15·5
10	3·70	100	3·95	122	3·34	74	3·04	55	2·94	15·0
11	3·70	100	3·95	122	3·32	72	3·04	55	3·04	17·5
12	3·65	96	3·93	120	3·30	71	3·04	55	2·60	12·0
13	3·63	94	3·90	116	3·29	70	3·04*	53	2·65	13·0
14	3·60	92	3·85	112	3·27	69	3·10	56	2·78	16·0
15	3·60	92	3·83	110	3·24	67	3·15	59	2·85	19·0
16	3·75	104	3·77	106	3·24	67	3·15	58	2·70	17·50
17	4·35	164	3·72	101	3·26	68	3·13	55	2·70	18·0
18	4·50	182	3·70	100	3·24	67	3·12	53	2·72	20·0
19	4·50	182	3·70	100	3·25	68	3·10	50	2·75	22·0
20	4·60	194	3·68	98	3·23	66	3·06	46	2·74	23·0
21	4·57	190	3·65	96	3·20	64	3·04	43	3·45	59·0
22	4·50	182	3·62	94	3·18	63	3·00	39	2·73	26·0
23	4·37	166	3·58	91	3·18	63	2·98	36	2·95	37·0
24	4·52	184	3·55	88	3·16	82	2·98	34	2·90	37·0
25	5·[illegible]	254	3·54	87	3·16	62	2·70	31	2·87	38·0
26	4·82	220	3·50	85	3·16	62	2·59	16	2·85	40·0
27	4·57	190	3·48	83	3·15	61	2·59	16	2·83	41·0
28	4·50	182	3·44	80	3·15	61	2·58	15	2·85	44·0
29	4·45	176	3·44	80	3·14	60	2·70	17	2·85	44·0
30	4·37	166	3·43	80	3·14	60	2·75	17·50	2·83	43·0
31	4·27	155	.....	....	3·14	60	....	.....	2·83	43·0

*Shifting conditions Nov. 12 to Dec. 28, due to ice.

MONTHLY DISCHARGE of Fortymile Creek, near Banff, for 1912.

(Drainage area, 58 square miles.)

Month.	Discharge in Second-Feet.				Run-Off.	
	Maximum.	Minimum.	Mean.	Per Square Mile.	Depth in inches on Drainage Area.	Total in Acre-feet.
August	254	92	145	2·50	2·88	8,916
September	147	80	108	1·86	2·08	6,426
October	80	60	69	1·19	1·37	4,243
November	59	15	45	·786	·874	2,678
December	59	12	26	·448	·516	1,599
The period					7·720	23,862

NOTE.—Gauge readings started Aug. 1, 1912.

DISCHARGE MEASUREMENT of Bow River at Banff, Alta., in 1909.

Date.	Hydrographer.	Width.	Area of section.	Mean velocity	Gauge height.	Dis-charge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
June 9	P. M. Sauder	316·5	1,228	3·05	2·69	3,737
June 23	J. C. Keith	319·5	1,513	4·09	3·55	6,184
July 8	do	320·5	1,931	5·48	4·86	10,586
July 22	do	312·5	1,260	3·20	2·875	4,033
August 9	do	298·0	1,045	2·27	2·38	2,379
September 3	do	294·0	994	2·12	2·20	2,104
September 23	do	257·0	774	1·43	1·50	1,122

DAILY GAUGE HEIGHT AND DISCHARGE of Bow River at Banff, for 1909.

DAY.	May.		June.		July.	
	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	....	....	2·80	4,015	3·50	6,020
2	....	....	3·70	6,680	3·50	6,020
3	....	....	4·10	8,020	3·60	6,350
4	....	....	3·70	6,680	3·70	6,680
5	....	....	3·40	5,715	3·90	7,345
6	....	....	3·00	4,560	4·20	8,360
7	....	....	2·80	4,015	5·00	11,060
8	....	....	2·60	3,510	5·00	11,060
9	....	....	2·70	3,760	4·50	9,380
10	....	....	3·00	4,560	4·10	8,020
11	....	....	3·50	6,020	4·00	7,680
12	....	....	3·80	7,010	3·70	6,680
13	....	....	4·00	7,680	3·50	6,020
14	....	....	4·00	7,680	3·30	5,415
15	....	....	4·00	7,680	3·20	5,120
16	....	....	4·00	7,680	3·20	5,120
17	....	....	4·40	9,040	3·20	5,120
18	....	....	4·30	8,700	3·10	4,830
19	....	....	4·30	8,700	2·95	4,390
20	....	....	4·10	8,020	2·85	4,090
21	....	....	4·10	8,020	2·80	3,920
22	....	....	3·90	7,345	2·90	4,090
23	....	....	3·50	6,020	3·00	4,200
24	....	....	3·30	5,415	3·10	4,330
25	1·60	1,400	3·10	4,840	3·00	4,100
26	1·80	1,770	3·10	4,840	3·00	4,060
27	2·00	2,170	3·10	4,840	3·10	4,190
28	2·30	2,800	3·20	5,125	3·10	4,130
29	2·60	3,510	3·10	4,840	3·00	3,920
30	2·50	3,260	3·20	5,125	3·00	3,880
31	2·50	3,260	....	....	3·00	3,820

Daily Gauge Height and Discharge of Bow River at Banff, for 1909. —*Concluded.*

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	3·00	3,780	2·10	1,955	1·75	1,460	0·90	475
2	2·90	3,560	2·10	1,955	1·60	1,250	0·90	475
3	2·80	3,350	2·20	2,100	1·60	1,250	0·95	525
4	2·70	3,140	2·20	2,100	1·50	1,120	0·95	525
5	2·70	3,080	2·10	1,955	1·50	1,120	0·90	475
6	2·55	2,800	2·10	1,955	1·40	1,000	0·90	475
7	2·40	2,500	2·10	1,955	1·50	1,120	0·80	375
8	2·40	2,450	2·20	2,100	1·40	1,000	0·80	375
9	2·40	2,400	2·10	1,955	1·30	890	0·90	475
10	2·30	2,250	2·10	1,955	1·40	1,000	0·90	475
11	2·40	2,400	2·10	1,955	1·40	1,000	0·90	475
12	2·40	2,400	2·00	1,810	1·30	890	....	....
13	2·40	2,400	1·90	1,670	1·30	890	....	....
14	2·40	2,400	1·90	1,670	1·30	890	....	....
15	2·40	2,400	1·80	1,530	1·20	785	....	....
16	2·40	2,400	1·80	1,530	1·20	785	....	....
17	2·40	2,400	1·80	1,530	1·20	785	....	....
18	2·30	2,250	1·90	1,670	1·10	680	....	....
19	2·40	2,400	1·80	1,530	1·10	680	....	....
20	2·40	2,400	1·70	1,390	1·10	680	....	....
21	2·40	2,400	1·60	1,250	1·10	680	....	....
22	2·30	2,250	1·60	1,250	1·10	680	....	....
23	2·20	2,100	1·50	1,120	1·10	680	....	....
24	2·10	1,955	1·40	1,000	1·10	680	....	....
25	2·10	1,955	1·40	1,000	1·00	575	....	....
26	2·30	2,250	1·40	1,000	1·00	575	....	....
27	2·50	2,560	1·40	1,000	1·00	575	....	....
28	2·25	2,175	1·40	1,000	0·95	525	....	....
29	2·10	1,955	1·40	1,000	0·95	525	....	....
30	2·10	1,955	1·75	1,460	1·00	575	....	....
31	2·10	1,955	....	....	0·95	525	....	....

NOTE.—On September 23rd the gauge was lowered 1 foot and all previous observations were increased 1 foot to apply to the present position of the gauge.

Monthly Drainage of Bow River at Banff, Alta., for 1909.

(Drainage area, 876 square miles.)

Month.	Discharge in Second-Feet.				Run-Off	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on drainage area.	Total in acre-feet.
May (25-31)	3,510	1,400	2,595·7	2·963	0·771	36,039
June	9,040	3,510	6,204·5	7·082	7·901	369,193
July	11,000	3,920	5,787·1	6·606	7·616	355,833
August	3,780	1,955	2,473·2	2·823	3·255	152,068
September	2,100	1,000	1,578·3	1·801	2·009	93,918
October	1,460	525	834·5	0·952	1·097	51,311
November (1-11)	[illegible]	375	465·9	0·532	0·218	10,165
The period	....	....	....	....	....	1,068,527

DISCHARGE MEASUREMENTS of Bow River at Banff, in 1910.

Date.	Hydrographer.	Width.	Area of section.	Mean velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
May 13	C. Keith	304	1107·59	2·553	2·375	2827·20
June 3	do	317	1255·45	2·99	2·865	3745·43
June 17	do	322	1595·86	4·205	3·94	6710·95
July 15	do	320	1528·68	3·927	3·72	6003·60
Aug. 11	do	315	1265·85	2·94	2·925	3727·37
Aug. 31	do	274	864·19	1·62	1·83	1403·57
Sept. 22	do	278	867·97	1·58	1·81	1378·02
Oct. 19	R. Cascallen	283	884·98	1·61	1·90	1428·02
Nov. 5	do	239·5	729·80	1·16	1·22	844·26
Dec. 1	do	119	517·85	0·86	*0·82	496·63
Dec 13	do	59	182·80	2·23	*0·52	406·85

*Ice conditions.

DAILY GAUGE HEIGHT AND DISCHARGE of Bow River at Banff, for 1910.

DAY.	April.		May.		June.		July.	
	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	......	......	1·75	1,978	2·85	3,708	3·45	5,190
2	......	......	1·65	1,865	3·05	4,165	3·4	5,045
3	......	......	1·65	1,865	2·9	3,815	3·3	4,760
4	......	......	1·7	1,920	2·7	3,400	3·3	4,760
5	......	......	1·8	2,035	2·7	3,400	3·3	4,760
6	......	......	2·15	2,490	2·9	3,815	3·25	4,620
7	......	......	2·4	2,865	3·25	4,657	3·25	4,620
8	......	......	2·6	3,210	3·2	4,530	3·35	4,902
9	......	......	2·7	3,400	3·1	4,285	3·3	4,760
10	·3	460	2·65	3,305	3·1	4,285	3·3	4,760
11	·3	460	2·45	2,947	3·7	5,980	3·3	4,760
12	·35	470	2·35	2,788	4·35	8,120	3·4	5,045
13	·5	518	2·35	2,787	4·05	7,100	3·5	5,335
14	·4	485	2·3	2,710	3·65	5,782	3·65	5,783
15	·35	470	2·2	2,560	3·6	5,630	3·7	5,933
16	·4	485	2·1	2,420	3·8	6,250	3·75	6,092
17	·4	485	2·1	2,420	3·9	6,575	3·8	6,250
18	·4	485	2·25	2,635	4·1	7,265	3·8	6,250
19	·5	518	2·25	2,635	3·7	5,935	3·65	5,783
20	·75	610	2·2	2,560	3·85	6,413	3·5	5,335
21	·8	630	2·2	2,560	4·05	7,088	3·45	5,190
22	·8	630	2·3	2,710	3·65	5,782	3·35	4,902
23	·85	650	2·7	3,400	3·35	4,903	3·25	4,620
24	1·15	810	3·0	4,045	3·2	4,480	3·15	4,343
25	1·55	1,092	3·35	4,915	3·1	4,205	2·95	3,792
26	1·9	2,185	3·7	5,940	3·4	5,045	2·9	3,635
27	2·1	2,420	3·55	5,475	3·7	5,935	2·75	3,243
28	2·1	2,420	3·2	4,530	3·8	6,250	2·7	3,105
29	1·95	2,220	2·95	3,930	3·75	6,092	2·6	2,855
30	1·85	2,095	2·75	3,500	3·55	5,483	2·6	2,855
31	......	......	2·7	3,400	...	......	2·7	3,105

From April 10 to 25, curve not sufficiently defined to read discharge.

Daily Gauge Height and Discharge of Bow River at Banff, for 1910.—*Continued.*

Day.	August. Gauge Height.	August. Dis-charge.	September. Gauge Height.	September. Dis-charge.	October. Gauge Height.	October. Dis-charge.	November. Gauge Height.	November. Dis-charge.	December. Gauge Height.*	December. Dis-charge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	2·7	3,105	1·8	1,370	1·5	1,055	1·3	905	0·82	496
2	2·65	2,980	1·8	1,370	1·5	1,055	1·3	905	....	....
3	2·55	2,732	1·8	1,370	1·5	1,055	1·3	905	....	....
4	2·6	2,855	1·9	1,500	1·45	1,015	1·25	872	0·75	475
5	2·75	3,243	1·85	1,435	1·4	975	1·2	840	....	....
6	3·1	4,205	1·95	1,573	1·4	975	1·2	840	0·79	487
7	3·1	4,205	1·85	1,435	1·6	1,150	1·2	840	0·77	481
8	2·95	3,792	1·8	1,370	1·55	1,102	1·2	840	0·8	490
9	3·0	3,930	1·7	1,255	1·6	1,150	1·2	840	0·79	487
10	3·0	3,930	1·7	1,255	1·9	1,500	1·2	840	0·68	454
11	2·95	3,793	1·6	1,150	1·9	1,500	1·2	840	0·6	430
12	2·9	3,655	1·6	1,150	1·85	1,435	1·1	780	0·73	469
13	2·85	3,517	1·6	1,150	1·8	1,370	1·15	810	0·75	475
14	2·8	3,380	1·5	1,055	1·75	1,313	0·8	630	0·70	460
15	2·75	3,243	1·5	1,055	1·75	1,312	1·05	753	0·64	442
16	2·6	2,855	1·5	1,055	1·8	1,370	0·9	675	0·67	451
17	2·55	2,732	1·5	1,055	1·85	1,435	†	....	0·71	463
18	2·45	2,498	1·55	1,102	1·9	1,500	....	....	0·66	448
19	2·4	2,385	1·6	1,150	1·85	1,435	....	....	0·64	442
20	2·5	2,610	1·65	1,203	1·8	1,370	....	....	0·60	430
21	2·45	2,497	1·75	1,312	1·8	1,370	....	....	0·66	448
22	2·4	2,385	1·8	1,370	1·7	1,255	....	....	0·50	404
23	2·35	2,283	1·8	1,370	1·7	1,255	....	....	0·57	421
24	2·25	2,085	1·85	1,435	1·6	1,150	....	....	0·68	454
25	2·15	1,900	1·75	1,313	1·6	1,150	....	....	0·65	445
26	2·05	1,727	1·7	1,255	1·55	1,103	....	....	0·65	445
27	2·0	1,645	1·6	1,150	1·35	940	....	....	0·64	442
28	2·0	1,645	1·6	1,150	1·45	1,015	....	....	0·60	430
29	1·9	1,500	1·6	1,150	1·45	1,015	....	....	0·59	427
30	1·85	1,435	1·6	1,150	1·45	1,015	....	....	0·63	439
31	1·8	1,370	....	....	1·4	975	....	....	0·44	392

*Ice conditions during all the month of December. †No gauge height observations from Nov. 17 to Dec. 1.

Monthly Discharge of Bow River at Banff, for 1910.

(Drainage area, 845 square miles).

Month.	Discharge in Second-Feet. Maximum.	Minimum.	Mean.	Per square mile.	Run-Off. Depth in inches on Drainage area.	Total in acre-feet.
April 26-30	2,420	2,095	2,262	2·68	·498	22,433
May	5,940	1,865	3,090	3·66	4·22	190,018
June	8,120	3,400	5,345·8	6·32	7·05	318,098
July	6,250	2,855	4,722·9	5·59	6·445	290,400
August	4,205	1,370	2,778	3·29	3·79	170,816
September	1,573	1,055	1,257	1·49	1·66	74,806
October	1,500	940	1,203·7	1·42	·637	74,010
November 1-16	905	630	819	·97	·577	26,014
December, 28 days	496	392	451	·53	·55	25,047
The period						1,391,642

DISCHARGE MEASUREMENTS of Bow River a. Banff, Alta., in 1911.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
Jan. 23	H. R. Carscallen	50	151·6	2·58	0·84	390·6x
Feb. 15	do	51	140·6	2·17	0·71	305·5x
Mar. 8	do	52	151·4	2·26	0·06	341·4x
Mar. 24	do	82·5	172·5	1·97	0·16	340·2†
Apr. 6	H. C. Ritchie	58	148·8	1·89	*0·04	281·3†
Apr. 26	do	161·5	586·9	1·01	0·65	592·7
May 10	do	240	739·6	1·51	1·24	1,114
May 31	B. Russell	284·5	957·5	1·93	1·90	1,852
June 15	do	320	1709	4·62	4·35	7,908
June 29	do	322	1566	4·03	3·90	6,309
July 13	do	320	1305	3·01	2·98	3,928
July 26	H. C. Ritchie	319	1376	3·25	3·30	4,465
Aug. 17	H. Brown	305	1092	2·25	2·49	2,456
Aug. 31	do	297	1042	1·98	2·26	2·066
Sept. 18	do	279	872·1	1·56	1·73	1,365
Oct. 18	V. A. Newhall	199·5	655·8	1·03	1·09	373·8
Nov. 4	do	130·5	556·3	0·99	0·85	553·0
Nov. 24	do	114	473·7	1·00	0 76	474·0†
Dec. 21	do	54·5	173·0	1·89	0·41	327·4†

* Negative gauge height. x Ice conditions. † Partly frozen over.

DAILY GAUGE HEIGHTS AND DISCHARGE of Bow River at Banff, Alta., for 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	0·25	280	0·76	336	0·40	240	0·06	313	0·76	669	2·35	2.595
2	0·23	260	0·81	367	0·44	270	†*0·01	292	0·90	795	3·10	4,210
3	0·44	345	0·88	416	0·41	285	*0·08	274	0·94	831	3·50	5,200
4	0·47	345	0·92	444	0·20	255	*0·11	268	1·04	921	3·50	5,200
5	0·54	375	1·04	537	†0·16	265	*0·04	283	1·23	1,100	3·15	4,330
6	0·58	375	0·92	444	0·11	280	0·04	307	1·42	1,290	3·00	3,970
7	0·59	375	0·91	437	0·10	300	*0·01	292	1·38	1,250	2·90	3,735
8	0·55	320	0·89	423	0·04	307	*0·02	289	1·31	1,180	2·90	3,735
9	0·29	210	0·91	437	0·04	307	†0·00	295	1·27	1,140	2·90	3,735
10	0·41	240	0·91	437	0·02	301	0·01	298	1·23	1,100	2·95	3,850
11	0·48	265	0·89	423	*0·02	289	*0·01	292	1·22	1,090	3·35	4,815
12	0·60	300	0·87	409	†*0·02	289	*0·05	280	1·21	1,080	3·98	6,572
13	0·59	280	0·73	318	*0·03	286	*0·05	280	1·20	1,070	4·35	7,900
14	0·65	295	0·71	306	0·03	304	*0·04	283	1·20	1,070	4·70	9,310
15	0·70	300	0·67	285	*0·02	289	*0·04	283	1·25	1,120	4·40	8,095
16	0·72	312	0·71	306	*0·01	292	†0·00	295	1·35	1,220	4·35	7,900
17	0·76	336	0·71	306	*0·01	292	0·04	307	1·57	1,452	4·30	7,710
18	0·78	348	0·59	251	*0·01	292	0·03	304	1 70	1,595	4·32	7,786
19	0·82	374	†0·58	247	†0·06	313	0·07	316	1·67	1,562	4·15	7,155
20	0·90	430	0·57	243	0·13	334	0·13	334	1·66	1,551	4·00	6,640
21	0·88	416	0·49	211	0·16	344	0·30	400	1·65	1,540	3·98	6,572
22	0·84	388	0·49	211	0·13	334	0·30	400	1·72	1,619	4·38	8,017
23	0·82	374	0·50	215	0·16	344	0·30	400	1·64	1,529	4·60	8,900
24	0·82	374	0·52	223	0·13	334	0·42	460	1·55	1,430	4·40	8,095
25	0·74	324	0·62	263	0·06	313	0·60	555	1·48	1,353	4·53	8,613
26	0·76	336	†0·55	235	†0·06	313	0·65	590	1·41	1,286	3·98	6,572
27	0·85	395	0·47	203	0·06	313	0·64	583	1·36	1,230	3·98	6,572
28	0·93	451	0·41	210	0·05	310	0·64	583	1·32	1,190	4·00	6,640
29	0·95	465			0·09	322	0·62	569	1·36	1,230	4·00	6,640
30	0·92	444	....	...	0·12	331	0·64	583	1·44	1,310	3·95	6,470
31	0·68	416	....	...	0·09	322	....	.....	1·73	1,631	..	.. ..

†No observations, gauge height interpolated. *Negative gauge height. NOTE.—Very good winter Station.

Daily Gauge Heights and Discharge of Bow River at Banff, Alta., for 1911. —*Continued.*

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	3·88	6,252	2·78	3,079	2·30	2,120	1·32	885	0·65	425	0·69	445
2	3·88	6,252	2·84	3,225	2·32	2,154	1·32	885	0·67	435	0·72	460
3	3·80	6,025	2·86	3,275	2·38	2,259	1·32	885	0·76	480	0·67	435
4	3·55	5,330	2·88	3,325	2·38	2,259	1·28	845	0·83	518	0·63	415
5	3·27	4,618	2·88	3,325	2·28	2,088	1·27	835	0·80	500	0·58	392
6	3·20	4,450	2·88	3,325	2·18	1,930	1·22	788	0·80	500	0·58	392
7	3·61	5,493	2·85	3,250	2·07	1,773	1·20	770	†0·71	455	0·60	400
8	3·50	5,200	2·86	3,275	2·00	1,675	1·21	779	†0·62	410	0·60	400
9	3·25	4,570	2·75	3,010	1·98	1,649	1·19	761	†0·51	364	0·60	400
10	3·20	4,450	2·65	2,790	1·92	1,574	1·18	752	†0·38	319	0·59	396
11	3·12	4,258	2·58	2,643	1·91	1,562	1·18	752	0·23	276	0·51	364
12	3·05	4,090	2·50	2,480	1·91	1,562	1·18	752	0·20	270	0·57	388
13	2·98	3,922	2·55	2,580	2·10	1,815	1·17	743	0·24	278	0·55	380
14	3·00	3,945	2·48	2,442	1·99	1,662	1·18	752	0·39	322	0·55	380
15	3·22	4,545	2·48	2,442	1·93	1,586	1·18	752	0·56	384	0·51	364
16	3·28	4,700	2·52	2,520	1·89	1,538	1·13	709	0·66	430	0·51	364
17	3·38	4,965	2·45	2,385	1·81	1,442	1·08	671	0·74	470	†0·47	348
18	3·38	4,940	2·48	2,442	1·73	1,348	1·08	671	0·81	506	0·44	337
19	3·14	4,200	2·48	2,442	1·69	1,298	1·04	644	0·80	500	0·49	356
20	3·05	3,915	2·52	2,520	1·62	1,214	1·02	632	0·79	495	0·51	364
21	2·97	3,660	2·44	2,367	1·62	1,214	1·00	620	0·79	495	0·41	328
22	3·10	3,990	2·39	2,277	1·61	1,202	0·99	614	0·63	415	0·51	364
23	3·05	3,840	2·30	2,120	1·59	1,178	0·97	602	0·62	410	0·52	368
24	3·00	3,670	2·27	2,072	1·54	1,119	0·98	608	0·60	400	†0·50	360
25	3·17	4,095	2·28	2,088	1·48	1,053	0·87	542	0·65	425	0·48	352
26	3·29	4,436	2·30	2,120	1·46	1,031	0·75	475	0·62	410	0·41	328
27	3·20	4,180	2·21	1,976	1·41	976	0·79	495	0·52	368	0·40	325
28	2·94	3,475	2·17	1,915	1·40	965	0·76	480	0·53	372	0·41	328
29	2·92	3,425	2·14	1,871	1·38	945	0·72	460	0·55	380	0·61	405
30	2·93	3,450	2·18	1,930	1·37	935	0·72	460	0·67	435	0·66	430
31	2·85	3,250	2·23	2,008	......	......	0·70	450	......	......	†0·64	420

Monthly Discharge of Bow River at Banff, Alta., for 1911.

(Drainage area, 857 square miles.)

Month.	Discharge in Second-Feet.				Run-Off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on Drainage area.	Total in acre-feet.
January	465	210	347	0·405	0·47	21,336
February	537	203	327	0·382	0·40	18,161
March	344	240	302	0·352	0·41	18,569
April	590	268	367	0·428	0·48	21,838
May	1,631	669	1,240	1·45	1·67	76,240
June	9,310	2,595	6,251	7·30	8·14	371,960
July	6,252	3,250	4,438	5·18	5·97	272,878
August	3,325	1,871	2,565	2·99	3·45	157,715
September	2,259	935	1,504	1·75	1·95	89,494
October	885	450	680	0·794	0·92	41,812
November	518	270	415	0·484	0·54	24,694
December	460	325	380	0·443	0·51	23,365
The year	....	....	....	....	24·91	1,138,062

Discharge Measurements of Bow River at Banff, in 1912.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
Jan. 1	V. A. Newhall	53·0	176·5	1·62	1·78	286·0
Jan. 15	do	50·0	164·0	1 92	2·03	314·8
Jan. 26	do	56·0	200·0	1·41	2·08	284·0
Feb. 3	do	61·5	156·4	1·72	1·18	268·4
Feb. 10	do	50·0	150·6	1·83	1·15	275·0
Feb. 17	do	50·0	153·0	1·84	1·24	282·2
Feb. 24	do	50·0	148·0	1·71	1·25	252·6
Mar. 5	do	50·0	145·2	1·60	1·00	230·8
Mar. 14	H. C. Ritchie	52·0	153·8	1·32	0·90	202·7
Mar. 25	do	61·0	139·95	1·65	0·97	230·6
Apr. 8	do	67·6	150·63	1·72	0·90	258·6
Apr. 13	do	60·0	163·0	1·83	1·15	298·1
Apr. 22	do	120·0	475·7	0·64	1·15	307·3
May 7	do	126·0	642·4	0·897	1·44	486·98
May 20	do	284·0	931·0	1·83	1·93	1,702·02
June 4	do	276·5	808·1	1·61	1·53	1,220·45
June 17	do	320·5	1,377·5	3·42	3·40	4,708·92
July 3	do	312·5	1,214·38	2·78	3·00	3,381·25
July 16	do	313·5	1,268·65	2·89	3·00	3,665·88
July 29	do	314·5	1,209·67	2·67	2·80	3,230·90
Aug. 12	do	309·5	1,151·10	2·49	2·20	2,864·87
Aug. 26	do	319·5	1,442·80	3·44	3·60	4,966·10
Sept. 9	do	302·0	1,016·0	2·05	2·25	2,079·00
Sept. 30	H. R. Cram	276·0	820·0	1·42	1·65	1,167·00
Oct. 19	H. C. Ritchie	263·5	760·0	1·25	1·50	951·00
Oct. 31	do	188·0	583·0	0·92	0·90	537·60
Nov. 11	do	195·0	621·8	1·15	1·05	713·00
Nov. 25	do	126·0	534·5	0·88	0·68	472·40
Dec. 9	do	119·0	477·6	0·90	0·63	431·47
Dec. 23	do	115·0	458·2	0·86	0·64	392·59

Daily Gauge Height and Discharge of Bow River, near Banff, for 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	*1·72	284	1·26	268	1·01	238	1·01	246	1·34	398	1·73	1,336
2	1·76	285	1·21	267	1·00	235	1·06	249	1·31	379	1·66	1,252
3	2·31	286	1·15	265	1·00	233	1·07	251	1·31	379	1·58	1,156
4	2·15	282	1·15	266	1·03	233	1·05	254	1·31	379	1·51	1,080
5	1·75	280	1·12	267	1·01	231	1·00	252	1·38	428	1·44	1,010
6	1·95	282	1·60	283	1·03	228	0·94	252	1·42	456	1·43	1,000
7	1·96	283	1·14	270	1·01	226	0·97	255	1·50	570	1·60	1,238
8	1·96	284	1·14	271	1·00	224	0·99	261	1·84	1,010	2·16	1,904
9	2·20	286	1·12	270	1·00	221	1·01	270	2·08	1,620	2·56	2,590
10	2·42	290	1·15	275	1·00	219	1·04	274	1·05	1,600	2·49	2,452
11	2·20	294	1·15	276	1·00	216	1·15	302	1·98	1,500	2·57	2,610
12	1·99	292	1·12	273	0·98	212	1·11	291	2·02	1,620	2·75	2,990
13	2·00	307	1·12	274	0·98	209	1·13	297	2·27	2,170	3·09	3,832
14	2·00	313	1·10	274	0·98	205	1·13	297	2·25	2,150	2·98	3,528
15	2·03	314	1·12	275	0·98	208	1·13	297	2·20	2,100	3·05	3,720
16	1·75	303	1·16	278	0·86	206	1·14	299	2·37	2,470	3·30	4,140
17	2·12	312	1·22	280	0·90	210	1·14	299	2·30	2,340	3·39	4,680
18	2·35	317	1·22	277	0·94	213	1·13	297	2·12	1,950	3·35	4,560
19	2·12	309	1·25	278	0·86	214	1·15	302	2·00	1,700	3·40	4,710
20	2·12	303	1·14	270	0·86	216	1·15	302	1·92	1,570	3·46	4,890
21	2·00	298	1·24	271	0·87	219	1·15	302	1·80	1,420	3·46	4,890
22	1·96	295	1·21	265	0·88	220	·15	307	1·89	1,528	3·48	4,950
23	1·94	291	1·29	260	0·86	221	·15	302	1·88	1,516	3·52	5,070
24	1·78	286	1·25	252	0·86	224	1·20	321	1·86	1,492	3·52	5,070
25	1·71	280	1·20	248	0·97	230	1·22	329	2·04	1,726	3·46	4,890
26	2·02	282	1·18	246	0·91	232	1·22	329	2·24	2,024	3·50	5,010
27	1·95	280	1·10	245	0·95	234	1·22	329	2·49	2,452	3·56	5,192
28	1·75	278	1·00	244	1·00	237	1·21	325	2·32	2,152	3·53	5,100
29	1·55	273	0·97	241	1·00	241	1·26	348	2·10	1,820	3·20	4,140
30	1·40	270	....	....	0·96	242	1·34	398	1·98	1,640	3·10	3,860
31	1·34	270	....	....	0·96	244	....	....	1·84	1,468	....	....

*Gauge heights during 1912 are taken from a rod 1·09 lower than that used during 1911.

Daily Gauge Height and Discharge of Bow River, near Banff, for 1912.—*Concluded.*

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	2·95	3,450	2·85	3,210	2·66	2,792	1·64	1,228	1·03	648	0·65	435
2	2·88	3,282	2·97	3,502	2·56	2,590	1·63	1,216	1·03	648	0·64	432
3	2·96	3,476	2·90	3,330	2·49	2,452	1·60	1,180	1·10	700	0·77	492
4	2·79	3,078	2·97	3,502	2·45	2,380	1·73	1,336	1·04	654	0·73	468
5	2·81	3,122	2·97	3,502	2·40	2,290	1·66	1,252	1·06	668	0·65	435
6	3·13	3,944	3·01	3,608	2·34	2,184	1·61	1,192	1·08	684	0·64	432
7	3·24	4,252	2·72	2,924	2·27	2,072	1·59	1,168	1·06	668	0·65	435
8	3·30	4,420	2·67	2,814	2·28	2,088	1·59	1,168	1·04	654	0·70	450
9	3·24	4,252	2·73	2,946	2·25	2,040	1·57	1,144	1·07	676	0·74	474
10	3·21	4,168	2·78	3,056	2·23	2,008	1·54	1,110	1·08	684	0·52	396
11	3·17	4,056	2·73	2,946	2·21	1,976	1·51	1,080	1·04	654	0·34	315
12	3·12	3,916	2·67	2,814	2·22	1,992	1·46	1,030	1·03	648	0·51	393
13	3·26	3,308	2·53	2,530	2·25	2,040	1·44	1·010	1·02	642	0·57	411
14	3·25	4,280	2·48	2,434	2·22	1,992	1·43	1,000	1·02	642	0·73	468
15	3·07	3,776	2·48	2,434	2·16	1,904	1·40	970	0·72	465	0·65	435
16	3·02	3,636	2·69	2,858	2·12	1,848	1·42	990	0·93	588	0·55	405
17	2·82	3,144	3·06	3,748	2·07	1,778	1·54	1,100	0·82	522	0·65	435
18	2·76	3,012	3·04	3,692	2·04	1,726	1·53	1,100	0·93	588	0·71	456
19	2·76	3,012	3·06	3,748	2·01	1,684	1·49	1,060	1·04	654	0·70	450
20	2·78	3,056	3·03	3,664	1·95	1,600	1·42	990	0·95	600	0·61	423
21	2·76	3,012	3·06	3,748	1·90	1,540	1·38	950	0·95	600	0·53	399
22	2·77	3,034	3·06	3,748	1·88	1,516	1·34	910	0·94	594	0·58	414
23	2·89	3,306	3·11	3,888	1·88	1,516	1·36	930	0·93	588	0·63	429
24	3·17	4,056	3·37	4.620	1·82	1,444	1·32	890	0·93	588	0·66	438
25	3·28	4,364	3·85	6,140	1·80	1,420	1·28	850	0·66	435	0·56	408
26	3·20	4,140	3·53	5,100	1·77	1,384	1·33	900	0·44	345	0·63	429
27	3·05	3,720	3·30	4,420	1·74	1,348	1·28	850	0·45	360	0·66	438
28	2·80	3,100	3·24	4,252	1·72	1,324	1·26	830	0·60	418	0·63	429
29	2·79	3,078	3·10	3,860	1·66	1,252	1·21	788	0·65	435	0·65	435
30	2·77	3,034	2·93	3,402	1·64	1,228	1·04	654	0·73	468	0·63	429
31	2·79	3,078	2·75	2,990	....	....	1·01	636	.....	.....	0·64	432

Monthly Discharge of Bow River at Banff, for 1912.

(Drainage area, 857 square miles.)

Month.	Discharge in Second-Feet.				Run-Off.	
	Maximum.	Minimum.	Mean.	Per Square Mile.	Depth in inches on Drainage Area.	Total in Acre-feet.
January	317	270	291	0·34	0·39	17,868
February	283	241	266	0·31	0·34	15,312
March	244	205	224	0·26	0·30	13,767
April	398	246	295	0·34	0·38	17,530
May	2,470	379	1,485	1·73	1·99	91,291
June	5,192	1,000	3,430	4·00	4·46	204,100
July	4,420	3,012	3,566	4·16	4·79	219,260
August	6,140	2,434	3,530	4·12	4·75	217,050
September	2,792	1,228	1,847	2·16	2·41	109,903
October	1,336	636	1,017	1·19	1·37	62,534
November	700	345	584	0·68	0·76	34,750
December	492	315	429	0·50	0·58	26,378
The year					22·52	1,029,743

Discharge Measurements of Spray River, near Banff, in 1910.

Date.	Hydrographer.	Width.	Area of section.	Mean velocity.	Gauge height.	Discharge.
1910.		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
July 15	J. C. Keith	108·5	233·82	6·22	1·95	1,452·45
Aug. 10	do	82·5	181·87	[illegible]	1·45	952·00
Aug. 31	do	77·5	[illegible]	[illegible]	·86	490·03
Sept. 22	do	74·5	[illegible]	4·14	·95	557·16
Oct. 19	H. R. Carscallen	73·0	[illegible]	[illegible]	·83	454·59
Nov. 5	do	72·5	[illegible]	[illegible]	·54	312·81
Dec. 2	do	57·0	[illegible]	[illegible]	·63	231·93
Dec. 24	do	52·0	[illegible]	2·43	·59	221·69

Daily Gauge Height and Discharge of Spray River, near Banff, for 1910.

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			1·35	862	·85	480	·80	450				
2			1·30	820	·85	480	·80	450				
3			1·25	777	·80	450	·80	450				
4			1·35	862	·80	450	·80	450			1·92	350
5			1·35	862	·80	450	·75	422				
6			1·45	950	·90	510	75	422			1·99	390
7			1·55	1,042	·90	510	·85	480			1·98	380
8			1·45	950	·85	480	·85	480			1·72	260
9			1·45	950	·85	480	·80	450			1·66	235
10			1·45	950	·85	480	·90	510			1·66	235
11			1·50	995	·80	450	·95	545			1·62	220
12			1·45	950	·80	450	·90	510			1·71	255
13			1·45	950	·80	450	·90	510			1·56	200
14			1·40	905	·80	450	·85	480			1·47	170
15	1·95	1,455	1·40	905	·80	450	·85	480			1·52	185
16	1·95	1,455	1·35	862	·85	480	·85	480			1·52	185
17	1·95	1,455	1·30	820	·85	480	·85	480			1·51	180
18	2·00	1,510	1·25	777	·90	510	·85	480			1·54	190
19	1·80	1,290	1·25	777	·90	510	·85	480			1·38	150
20	1·75	1,240	1·25	777	·95	545	·85	480			1·49	175
21	1·75	1,240	1·20	735	·95	545	·80	450			1·52	185
22	1·75	1,240	1·20	735	·95	545	·75	422			1·44	165
23	1·70	1,190	1·15	695	·95	545	·75	422			1·67	240
24	1·60	1,090	1·20	735	·95	545	·70	395			1·62	220
25	1·50	995	1·05	617	·95	545	·75	422			1·77	280
26	1·50	995	·95	545	·90	510	·70	395			1·75	275
27	1·45	950	·95	545	·85	480	·60	345			1·72	260
28	1·40	905	·90	510	·85	480	·60	345			1·80	290
29	1·35	862	·90	510	·85	480	·60	345			1·76	275
30	1·35	862	·85	480	·85	480	·60	345			1·58	210
31	1·35	862	·80	450			·60	345			1·64	230

No observations taken for November.
Ice conditions during December.
Auxiliary Gauge used during month of December.

Monthly Discharge of Spray River, near Banff, for 1910.

(Drainage area, 310 square miles.)

Month.	Discharge in Second-Feet.				Run-Off.	
	Maximum	Minimum.	Mean.	Per square mile.	Depth in inches on Drainage Area.	Total in acre-feet.
July (15-31)	1,510	862	1,153	3·72	2·35	38,876
August	1,042	450	784	2·53	2·92	48,198
September	545	450	490	1·58	1·76	29,157
October	545	345	443	1·43	1·65	27,213
November†						
December (4-31)	390	150	237	·764	·767	12,486
The period						155,930

†No observations taken for November.

Discharge Measurements of Spray River, near Banff, Alta., in 1911.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
Jan. 25	H. R. Carscallen	33·5	104·8	1·62	*3·30	170·3
Feb. 15	do	22·5	1·2	2·34	*2·05	143·4
Mar. 8	do	27·5	50·8	2·76	*1·89	140·2
Apr. 8	do	37·5	59·5	1·99	*0·75	118·6
Apr. 28	H. C. Ritchie	60·5	83·7	2·68	*1·02	224·5
May 12	do	74·5	109·8	3·51	*1·35	385·0
June 17	B. Russell	120	356·3	7·05	2·70	2,511
July 3	do	119	315·1	6·98	2·22	2,200
July 15	do	118·5	255·3	5·85	1·80	1,494
July 28	H. C. Ritchie	117·5	303·6	3·48	1·60	1,058
Aug. 19	H. Brown	111	168·7	4·42	1·36	745·8
Sep. 2	do	92·5	148·7	4·45	1·18	661·3
Sept. 22	do	74·5	119·0	3·91	0·89	466·3
Oct. 14	V. A. Newhall	62·5	86·0	3·61	0·70	310·5
Oct. 31	do	41	83·6	3·07	0·36	256·7
Nov. 22	do	35·5	87·4	2·19	0·58	191·1
Dec. 7	do	32·5	85·6	2·40	0·75	201·4

*Auxiliary gauge.

DAILY GAUGE HEIGHT AND DISCHARGE of Spray River, near Banff, for 1911.

Day.	January.		February.		March.		April.		May.		June.	
	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	1·58	200	2·47	152	1·94	140	0·85	158	1·07	246	1·90	815
2	1·29	195	2·48	152	1·98	141	†0·80	140	1·10	260	2·20	1,190
2	1·75	198	2·50	153	1·72	135	0·75	122	1·14	278	2·56	1,852
4	2·11	200	2·44	151	1·82	127	0·73	115	1·17	292	2·55	1,830
5	2·07	195	2·45	152	†1·92	140	0·74	119	1·25	335	2·38	1,484
6	2·02	192	2·36	149	2·03	143	0·75	122	1·35	388	2·40	1,520
7	1·78	188	2·25	147	1·93	140	0·77	130	†1·35	382	*1·64	1,520
8	1·82	186	2·30	148	1·99	142	0·77	130	1·35	382	1·53	1,502
9	2·10	188	2·46	152	1·88	139	†0·77	130	1·37	394	1·48	1,412
10	3·92	228	2·36	149	1·88	139	0·78	133	1·36	388	1·52	1,484
11	5·22	255	2·23	147	1·89	129	0·77	130	1·36	388	1·88	1,475
12	4·63	240	2·20	146	†1·94	140	0·77	130	1·35	382	2·26	1,920
13	5·10	246	2·14	145	2·00	142	0·77	130	1·35	382	2·65	2,390
14	5·12	245	2·16	145	1·77	136	0·78	133	†1·35	382	2·45	1,920
15	5·04	240	2·05	143	2·33	149	0·77	130	1·35	382	2·70	2,510
15	4·83	232	2·13	145	2·11	144	*0·76	126	1·38	399	2·65	2,390
17	4·68	226	2·00	142	2·72	157	0·76	126	1·44	436	2·65	2,290
18	4·38	215	1·87	138	2·27	147	0·77	130	1·46	449	2·75	2,640
19	4·23	206	2·10	144	†2·02	142	0·79	136	1·48	462	2·68	2,460
20	4·08	202	2·03	143	1·82	137	0·81	144	1·46	449	2·58	2,220
21	3·99	198	1·99	142	1·49	140	0·87	164	1·45	442	2·52	2,090
22	4·12	198	1·98	141	1·33	140	0·89	172	1·46	449	2·62	2,320
23	3·68	180	2·10	144	1·36	142	†0·92	183	1·46	449	2·70	2,510
24	3·49	175	1·97	141	1·25	148	0·96	199	1·44	436	2·55	2,160
25	3·27	169	†1·98	141	1·12	150	1·01	220	1·38	399	2·65	2,390
26	3·20	168	†1·99	142	†0·98	150	1·02	224	1·37	394	2·35	2,500
27	3·16	167	2·00	142	0·84	154	1·02	224	1·34	377	2·35	2,500
28	3·12	166	1·97	141	0·80	140	1·02	224	1·32	266	2·25	2,200
29	3·00	163	....	....	0·82	147	1·01	220	1·33	372	2·25	2,200
30	2·29	161	....	....	0·61	144	†1·04	233	1·37	394	2·32	2,428
31	2·64	156	....	....	0·79	135	....	....	1·55	512	....	....

*Readings made at regular gauge after June 7.
†No observations, gauge height interpolated.

DAILY GAUGE HEIGHT AND DISCHARGE of Spray River, near Banff, for 1911.—*Continued.*

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	2·28	2,332	1·55	995	1·22	690	0·79	395	0·24	225	0·67	198
2	2·25	2,260	1·56	1,000	1·18	664	0·79	390	0·20	215	0·60	191
3	2·25	2,260	1·58	1,020	1·22	696	0·77	380	0·50	300	0·63	194
4	2·15	2,050	1·58	1,020	1·29	752	0·76	370	0·35	255	0·65	196
5	2·02	1,780	1·56	995	1·22	696	0·76	370	0·36	258	0·69	199
6	1·95	1,660	1·55	980	1·19	672	0·73	355	0·34	252	0·78	201
7	2·20	2,240	1·55	980	1·17	656	0·70	340	†0·36	250	0·72	200
8	1·95	1,690	1·56	985	1·13	624	0·70	335	†0·38	235	0·72	200
9	†1·88	1,580	1·56	985	1·09	593	0·69	330	†0·40	235	0·63	194
10	1·82	1,480	1·54	955	1·07	579	0·69	325	†0·42	230	0·52	188
11	1·82	1,490	1·53	945	1·06	572	0·69	320	0·45	225	0·53	189
12	1·75	1,390	1·50	910	1·06	572	0·70	320	0·54	235	0·68	198
13	1·75	1,400	1·48	880	†1·05	565	0·69	315	0·68	238	0·74	200
14	1·75	1,410	1·47	870	1·05	565	0·69	305	0·62	230	0·75	201
15	1·85	1,690	1·46	850	1·02	544	0·69	310	1·11	258	0·72	200
16	1·85	1,580	1·45	830	0·99	524	0·67	305	1·13	255	0·62	192
17	1·90	1,670	†1·41	795	0·98	518	0·65	305	1·14	250	†0·68	198
18	1·85	1,560	1·37	755	0·96	506	0·64	305	0·95	232	0·74	200
19	1·78	1,430	1·36	745	0·92	482	0·62	300	0·89	225	0·96	218
20	1·70	1,300	1·38	770	0·92	482	0·64	310	0·86	215	0·99	218
21	1·72	1,310	1·36	755	0·91	476	0·61	305	0·72	200	1·02	220
22	1·75	1,350	1·32	725	0·89	465	0·61	310	0·79	202	1·07	222
23	1·72	1,300	1·27	690	0·88	455	0·59	305	0·84	207	0·92	211
24	1·68	1,220	1·24	670	0·88	455	0·59	310	0·78	202	†0·95	213
25	1·72	1,270	1·22	660	0·84	430	0·55	300	0·59	190	0·99	218
26	1·76	1,310	1·27	705	0·84	430	0·54	300	0·52	188	1·45	245
27	1·68	1,180	1·22	670	0·83	425	0·44	27[illegible]	0·42	180	1·78	260
28	1·62	1,085	1·18	640	0·83	420	0·39	260	0·57	190	1·68	250
29	1·60	1,050	1·17	635	0·82	410	0·37	260	0·68	198	1·10	200
30	1·55	1,000	1·17	640	0·80	400	0·32	240	0·75	201	1·42	220
31	1·54	990	1·18	650	...	...	2·07	232	....	....	†1·68	235

† No observations, gauge height, interpolated.

MONTHLY DISCHARGE of Spray River, near Banff, for 1911.

(Drainage area, 310 square miles.)

Month.	Discharge in Second-Feet.				Run-Off	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on Drainage area.	Total in acre-feet.
January	255	156	199	0·642	0·74	12,236
February	153	138	146	0·471	0·49	8,108
March	157	135	143	0·461	0·53	8,793
April	233	116	156	0·503	0·56	9,283
May	512	246	389	1·255	1·45	23,919
June	2,640	815	2,011	6·49	7·24	119,660
July	2,332	990	1,523	4·91	5·66	93,646
August	1,020	635	829	2·67	3·08	50,973
September	752	400	544	1·755	1·96	32,370
October	395	232	315	1·016	1·17	19,380
November	300	180	226	0·729	0·81	14,446
December	260	188	209	0·674	0·78	12,851
The year	....	....	....	....	24·47	404,666

Discharge Measurements of Spray River, near Banff, in 1912.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
Jan. 11	V. A. Newhall	26·0	75·40	1·99	5·975	150·0
Jan. 24	do	29·0	78·45	1·92	5·53	150·5
Jan. 30	do	29·0	74·10	1·92	5·66	141·91
Feb. 9	do	28·5	68·60	2·18	5·225	149·50
Feb. 14	do	28·5	58·45	2·44	5·085	142·80
Feb. 26	W. Turnbull	28·5	66·55	1·89	4·995	125·90
Mar. 4	V. A. Newhall	28·5	68·02	1·24	5·00	84·37
Mar. 16	H. C. Ritchie	32·0	81·70	1·44	5·27	117·64
Mar. 30	do	28·5	73·00	1·54	5·10	112·35
April 6	do	30·0	62·87	1·97	4·73	123·80
April 23	do	35·5	62·45	2·41	4·69	150·38
May 6	do	37·5	65·50	2·85	4·79	186·45
May 25	do	116·5	163·25	3·92	5·86	640·28
June 3	do	106·5	139·07	3·72	5·65	517·06
July 17	do	119·5	261·35	5·95	6·85	1,556·28
July 30	do	117·5	214·75	5·21	6·50	1,118·40
Aug. 15	do	116·5	169·80	4·45	6·08	754·70
Aug. 27	do	117·5	187·12	4·65	6·20	871·0
Sept. 10	do	116·5	172·60	4·38	6·00	757·0
Oct. 1	H. R. Cram	115·0	128·0	3·93	5·60	504·0
Oct. 14	do	110·0	113·0	3·73	5·48	420·0
Oct. 30	H. C. Ritchie	47·5	92·9	3·67	5·27	341·0
Nov. 12	do	62·5	95·5	3·34	5·18	319·0
Nov. 27	do	38·5	71·48	2·52	4·94	180·39
Dec. 11	do	33·0	86·95	1·66	5·25	144·20
Dec. 24	do	35·0	108·0	2·09	5·77	225·72

Daily Gauge Height and Discharge of Spray River, near Banff, for 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	6·53	155·0	5·34	144·0	5·08	138·0	4·92	108·0	4·70	152·0	5·79	590·0
2	5·98	150·0	5·36	144·0	4·98	135·0	4·85	108·0	4·72	158·0	*5·70	540·0
3	6·10	151·0	5·75	150·0	*4·98	135·0	4·79	110·0	4·72	158·0	5·69	535·0
4	6·08	151·0	*5·61	149·0	5·34	129·0	4·73	110·0	4·72	158·0	5·63	504·0
5	5·97	150·0	5·61	149·0	5·43	138·0	4·69	110·0	4·73	160·0	5·57	474·0
6	5·87	150·0	5·48	147·0	5·31	126·0	4·79	128·0	4·76	169·0	5·56	469·0
7	*5·80	150·0	5·28	143·0	5·30	125·0	*4·79	128·0	4·82	186·0	5·62	499·0
8	5·71	149·0	5·21	141·0	5·46	141·0	4·63	120·0	4·88	204·0	5·95	690·0
9	6·72	149·0	5·21	141·0	5·25	120·0	4·66	124·0	5·07	267·0	*6·00	724·0
10	6·10	151·0	5·21	141·0	*5·20	115·0	4·68	125·0	5·07	267·0	6·30	943·0
11	5·97	150·0	*5·21	141·0	5·08	103·0	4·65	126·0	5·07	267·0	6·34	877·0
12	6·00	150·0	5·23	142·0	5·10	105·0	4·65	128·0	*5·35	374·0	6·44	1,065·0
13	5·90	150·0	5·16	140·0	5·02	97·0	4·65	130·0	5·42	403·0	6·66	1,306·0
14	*5·90	150·0	5·06	137·0	4·97	92·0	*4·65	132·0	5·66	519·0	6·66	1,306·0
15	5·95	150·0	5·04	137·0	5·04	99·0	4·66	134·0	6·02	738·0	6·75	1,420·0
16	6·25	152·0	5·57	148·0	5·24	119·0	4·66	135·0	6·26	912·0	*6·80	1,485·0
17	5·75	150·0	5·19	141·0	*5·20	115·0	4·65	135·0	6·22	881·0	7·55	2,530·0
18	5·60	149·0	*5·19	141·0	5·05	100·0	4·66	136·0	6·06	765·0	7·45	2,390·0
19	5·60	149·0	5·25	142·0	5·02	97·0	*4·66	136·0	*6·05	758·0	7·41	2,348·0
20	5·61	149·0	5·08	138·0	5·01	96·0	4·67	136·0	5·96	710·0	7·43	2,362·0
21	*5·61	149·0	5·16	140·0	4·96	91·0	4·67	141·0	5·94	683·0	7·40	2,320·0
22	5·63	149·0	5·15	140·0	4·96	91·0	4·66	141·0	5·83	614·0	7·29	2,166·0
23	5·57	148·0	5·16	140·0	4·88	83·0	†4·67	150·0	5·83	614·0	*7·29	2,166·0
24	5·52	147·0	5·06	137·0	*4·88	83·0	4·69	149·0	5·82	608·0	7·29	2,166·0
25	5·61	149·0	*5·05	137·0	4·91	86·0	4·72	158·0	5·84	620·0	7·08	1,872·0
26	5·55	148·0	5·03	136·0	4·89	89·0	4·72	158·0	*6·20	865·0	7·15	1,970·0
27	6·40	155·0	4·97	135·0	4·89	89·0	4·71	155·0	6·23	885·0	7·12	1,928·0
28	*6·20	152·0	4·90	132·0	4·84	79·0	4·70	152·0	6·17	842·0	6·99	1,748·0
29	5·93	150·0	4·90	132·0	†4·80	75·0	4·71	155·0	6·05	758·0	6·75	1,420·0
30	5·64	149·0			*5·24	124·0	4·70	152·0	5·95	690·0	*6·60	1,234·0
31	5·47	146·0			*5·24	135·0			5·87	638·0		

* Gauge Heights interpolated.
† Shifting conditions from March 30 to April 23

Daily Gauge Height and Discharge of Spray River, near Banff, for 1912 —*Concluded.*

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	6·64	1,282	6·43	1,056	*6·05	758	5·59	484	5·24	330	5·35	260
2	6·56	1,188	*6·40	1,028	6·01	731	5·61	494	5·21	318	5·49	395
3	6·68	1,331	*6·38	1,011	5·98	710	5·59	484	*5·22	322	5·49	395
4	6·57	1,200	*6·36	994	5·95	690	5·67	524	5·23	326	5·56	394
5	6·58	1,211	6·35	985	*5·93	676	5·62	499	5·21	318	5·85	318
6	6·60	1,234	6·33	968	5·91	663	*5·60	489	5·22	322	6·07	256
7	*6·75	1,420	6·20	865	5·90	656	5·58	479	5·20	314	5·72	209
8	6·91	1,634	6·20	865	*5·95	690	5·59	484	5·19	310	5·65	180
9	7·03	1,802	6·18	857	6·01	731	5·58	479	5·22	322	5·55	160
10	7·00	1,760	6·16	834	6·02	738	5·56	460	*5·20	314	5·45	152
11	7·00	1,760	*6·18	857	6·02	738	5·53	454	5·19	310	5·25	144
12	6·99	1,746	6·20	865	6·06	765	5·50	439	5·19	310	5·86	184
13	7·00	1,760	6·15	826	6·15	826	*5·50	439	5·20	311	5·87	190
14	*7·00	1,760	6·10	792	6·13	812	5·49	434	5·20	308	5·75	206
15	*7·00	1,760	6·06	765	*6·06	765	5·46	421	5·10	267	5·65	184
16	7·05	1,830	6·15	826	6·00	724	5·47	425	5·11	267	5·56	223
17	6·86	1,564	6·34	977	5·98	710	5·40	395	5·15	278	5·80	218
18	6·73	1,394	*6·34	977	5·93	676	5·52	449	5·13	267	5·84	215
19	6·68	1,331	6·34	977	5·93	676	5·51	444	5·11	257	5·72	179
20	6·62	1,258	6·31	951	5·86	632	*5·45	416	5·12	260	5·84	164
21	*6·55	1,176	6·32	960	5·83	614	5·41	399	5·11	257	5·76	148
22	6·51	1,135	6·31	951	*5·82	608	5·41	399	5·09	243	5·80	194
23	6·48	1,105	6·30	943	5·80	596	5·41	399	5·10	248	5·88	250
24	6·50	1,125	6·32	960	5·76	572	5·41	399	5·00	210	5·77	226
25	6·72	1,382	*6·30	943	5·75	566	5·40	395	4·92	180	5·63	210
26	6·67	1,319	6·25	904	5·71	545	5·36	378	4·80	144	6·03	334
27	6·68	1,331	6·20	865	5·69	535	*5·35	374	5·02	188	5·92	324
28	*6·60	1,234	6·21	873	5·66	519	5·33	366	4·98	174	5·81	278
29	6·53	1,156	6·20	865	*5·64	509	5·25	334	5·18	229	5·78	284
30	6·47	1,094	6·[illegible]	806	5·62	499	5·22	322	5·27	243	5·75	260
31	6·44	1,065	6·08	778	....		5·21	318	.	.	5·70	243

* Gauge heights interpolated.

Monthly Discharge of Spray River, near Banff, for 1912.

(Drainage area, 310 square miles.)

Month.	Discharge in Second-Feet.				Run-Off.	
	Maximum.	Minimum.	Mean.	Per Square Mile	Depth in inches on Drainage Area.	Total in Acre-feet.
January	155	146	150	0·48	0·55	9,217
February	150	132	141	0·45	0·48	8,104
March	141	75	108	0·35	0·40	6,641
April	158	108	134	0·43	0·48	7,950
May	912	152	517	1·67	1·92	31,780
June	2,530	469	1,405	4·05	4·52	85,590
July	1,830	1,065	1,398	4·51	5·20	85,900
August	1,056	778	907	2·93	3·38	55,781
September	826	499	664	2·14	2·39	39,520
October	524	318	428	1·38	1·59	26,248
November	330	144	272	0·88	0·98	16,161
December	395	144	237	0·76	0·88	14,554
The year					22·77	385,624

Discharge Measurements of Cascade River at Bankhead, Alta., in 1911.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
Jan. 27	H. R. Carscallen	27	45·0	2·72	....	122·0
Feb. 14	do	27	35·6	2·82	....	101·0
Mar. 7	do	27	34·1	2·84	....	97·1
Mar. 24	do	42	53·2	2·10	....	111·8
Apr. 26	H. C. Ritchie	49	55·5	2·09	....	116·2
Aug. 16	H. Brown	45·1	144·3	4·95	1·58	714·2
Aug. 21	do	45·1	141·3	4·38	1·46	618·7
Sept. 1	do	44·6	127·8	3·89	1·36	496·4
Sept. 19	do	44·8	123·7	3·84	1·19	381·5
Oct. 16	V. A. Newhall	44·8	126·0	1·97	1·04	248·6
Nov. 6	do	45	100·1	1·79	0·89	178·8
Nov. 23	do	43·5	99·4	1·55	....	154·1*
Dec. 8	do	38	89·0	1·56	0·73	139·3
Dec. 22	do	43·3	114·1	0·90	1·73	103·0

*No gauge.

Daily Gauge Height and Discharge of Cascade River at Bankhead, Alta., for 1911.

Day.	August.		September.		October.		November.		December.	
	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.
1	....	....	1·35	486	1·06	296	0·84	160	....	....
2	....	....	1·34	480	1·07	287	0·85	163	....	....
3	....	....	1·36	500	1·06	280	0·85	163	....	....
4	....	....	1·35	493	1·05	274	0·86	167	....	....
5	....	....	1·35	496	1·04	267	0·67	171	....	....
6	....	....	1·35	499	1·04	264	0·88	175	....	....
7	....	....	1·35	501	1·03	258	0·90	....	....	....
8	....	....	1·33	484	1·03	257	0·93	....	‡0·73	....
9	....	....	1·32	478	1·03	256	0·98	....	0·75	....
10	....	....	1.30	461	1·02	247	1·08	....	0.92	....
11	....	....	1·30	464	1·02	246	1·26	....	1·22	....
12	....	....	1·28	447	1·02	244	1·50	....	1·42	....
13	....	....	1·27	440	1·03	250	1·68	....	1·62	....
14	....	....	1·26	434	1·01	238	1·75	....	1·97	....
15	....	....	1·26	436	1·01	236	1·75	....	2·27	....
16	1·58	714	1·25	428	1·00	228	1·73	....	2·52	....
17	†1·56	701	1·34	420	0·99	223	1·45	....	2·72	....
18	†1·53	675	1·22	405	0·98	216		....	3·02	....
19	1·50	649	1·20	390	0·97	214		....	2·97	....
20	†1·48	634	1·18	374	0·96	209	....	....	2·57	....
21	1·46	619	1·16	360	0·96	209	....	....	2·27	....
22	1·50	659	1·14	343	0·94	200	....	....	1·87	....
23	1·50	656	1·12	328	0·93	196	....	....	1·52	....
24	1·48	633	1·12	328	0·92	191	....	....	1·52	....
25	1·50	651	1·11	320	0·91	167	....	....	1·77	....
26	1·50	648	1·10	313	0·90	183	....	....	1·77	....
27	1·46	606	1·10	313	0·69	179	....	....	1·77	....
28	1·44	583	1·09	304	0·67	171	....	....	1·82	....
29	1·40	541	1·08	304	0·56	167	....	....	1·52	....
30	1·38	520	1·06	298	0·85	163	....	....	1·67	....
31	1·36	499	....	....	0·83	156	....	....	1·57	....

†No observation, gauge height interpolated.
‡Gauge carried away by ice on Nov. 18. Replaced Dec. 9.
Note.—Not sufficient data to compute daily discharges after Nov. 6.

MONTHLY DISCHARGE of Cascade River at Bankhead, Alta., for 1911.

(Drainage area, 248 square miles.)

Month.	Discharge in Second-Feet.				Run-Off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on Drainage area.	Total in acre-feet.
August (16-31)	714	499	624	2·516	1·50	19,803
September	501	298	411	1·657	1·85	24,456
October	296	156	226	0·911	1·05	13,896
November (1-6)	175	160	166	0·669	0·15	1,976
The period					4·55	60,131

DISCHARGE MEASUREMENTS of Cascade River at Bankhead, in 1912.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
Jan. 29	V. A. Newhall	45·5	164·2	0·66	3·03	108·4
Feb. 8	do	43·0	163·7	0·75	3·21	122·3
Feb. 20	do	24·5	22·6	1·83	2·91	41·4
Feb. 27	do	18·5	19·1	3·37	1·78	64·5
Mar. 27	H. C. Ritchie	46·0	81·1	0·86	1·36	69·6
April 12	do	46·0	76·3	0·76	1·32	57·7
April 26	do	44·0	74·6	0·77	1·34	57·3
May 8	do	46·0	100·9	1·73	1·81	174·2
May 21	do	49·0	104·3	2·52	1·97	262·6
June 7	do	44·0	66·6	0·71	1·24	47·3
June 18	do	53·3	182·8	7·92	3·30	1,446·0
July 17	do	39·5	42·4	0·39	0·84	16·4
July 30	do	35·0	44·5	0·34	0·84	15·4
Aug. 17	do	49·0	158·2	7·35	2·96	1,162·1
Aug. 28	do	57·3	192·3	7·48	3·65	1,439·0
Sept. 11	do	59·1	187·0	6·23	3·30	1,164·6
Oct. 2	H. R. Cram	55·2	124·0	2·39	2·48	296·0
Oct. 21	H. C. Ritchie	51·0	121·6	2·01	2·35	244·8
Oct. 29	do	52·0	126·2	2·08	2·35	262·6
Nov. 15	do	51·4	109·8	1·37	2·08	150·6
Nov. 29	do	56·0	146·1	3·02	2·66	447·9
Dec. 12	do	57·0	142·0	2·70	2·58	383·4
Dec. 31	do	52·0	118·4	1·84	2·25	218·0

Daily Gauge Height and Discharge of Cascade River at Bankhead, for 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	2·32	80·8	2·82	101·0	2·42	84·8	1·23	42·6	1·37	61·2	(3)	Nil.
2	2·17	74·8	2·77	99·8	2·52	88·8	1·70	135·0	1·39	64·4	1·45	75·0
3	2·07	70·8	2·72	96·8	2·62	92·8	1·98	261·0	1·43	71·4	1·45	75·0
4	2·27	78·8	2·67	94·8	2·67	194·8	1·58	102·0	1·45	75·0	1·43	71·4
6	(1)	......	2·62	92·8	3·04	110·0	1·25	45·0	1·55	95·0	(3)	Nil.
6	......	......	2·67	90·8	3·05	110·0	1·25	45·0	1·55	95·0	1·10	29·0
7	(5)	......	3·28	119·0	3·77	139·0	1·26	45·2	1·62	111·6	1·24	43·8
8	6·21	196·0	3·22	117·0	3·67	131·0	1·24	43·8	1·82	181·2	2·00	272·0
9	6·42	205·0	3·15	114·0	3·55	130·0	1·33	55·2	1·90	220·0	1·20	39·0
10	5·45	206·0	2·77	98·8	3·07	111·0	1·35	58·0	1·29	230·0	1·55	95·0
11	5·45	206·0	2·60	92·0	2·72	96·8	1·35	58·0	1·96	250·0	1·75	152·0
12	5·42	205·0	2·47	86·8	2·42	84·8	1·32	53·8	1·99	267·0	1·90	220·0
13	4·77	179·0	2·32	80·8	2·72	96·8	1·33	55·2	2·10	235·0	2·20	405·0
14	4·47	167·0	2·25	78·0	2·67	94·8	1·34	56·6	2·22	421·0	2·65	792·0
15	4·27	159·0	2·30	80·0	3·07	111·0	1·35	58·0	2·28	467·0	2·47	626·0
16	3·87	143·0	2·22	76·8	2·67	94·8	1·41	67·8	2·36	532·0	3·15	1287·0
17	3·62	133·0	2·17	74·8	2·37	82·8	1·41	67·8	2·28	467·0	3·33	1478·0
18	3·72	137·0	2·12	72·8	1·79	61·6	1·42	69·6	2·20	405·0	3·35	1500·0
19	3·77	139·0	2·07	70·8	1·97	66·8	1·38	62·8	2·25	444·0	3·31	1456·0
20	4·37	163·0	2·02	68·8	1·87	63·8	1·35	58·0	2·07	316·0	3·29	1434·0
21	5·01	188·0	2·41	84·4	(2)	......	1·31	62·4	2·10	335·0	3·25	1390·0
22	5·32	201·0	2·14	73·4	......	......	1·28	48·6	2·13	355·0	3·25	1390·0
23	5·35	202·0	2·10	72·0	......	......	1·35	58·0	2·12	349·0	3·22	1359·0
24	5·17	195·0	2·07	70·8	......	......	1·35	58·0	2·15	369·0	3·20	1338·0
25	3·67	135·0	1·77	60·8	......	......	1·35	58·0	2·20	405·0	3·15	1287·0
26	3·62	133·0	1·82	62·8	......	......	1·35	58·0	2·25	444·0	3·10	1230·0
27	3·47	127·0	1·78	61·2	1·36	69·6	1·34	56·6	2·33	508·0	3·00	1135·0
28	3·27	119·0	2·62	88·8	2·05	303·0	1·34	56·6	2·28	467·0	2·00	272·0
29	3·11	112·0	2·67	90·8	1·53	91·0	1·32	58·8	2·20	405·0	(4)	......
30	2·92	105·0	......	......	1·48	81·0	1·33	55·2	2·10	335·0	......	......
31	2·87	103·0	......	......	1·35	58·0	......	......	1·98	261·0	......	......

(1)—Ice flooded.
(2)—Rod carried out by ice.
(3)—Dam closed.—River dry.
(4)—River practically dry.
(5)—Extreme fluctuations caused by dam above station.

Daily Gauge Height and Discharge of Cascade River at Bankhead, for 1912. —*Concluded.*

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	†	15·00	0·78	13	2·15	174	2·46	308	2·65	437	2·60	398
2	†	14·80	0·79	14	2·15	174	2·46	308	2·66	445	2·53	350
3	†	14·80	0·75	10	2·14	171	2·46	308	2·64	429	2·49	326
4	†	14·80	0·77	12	2·13	168	2·46	308	2·45	302	2·45	302
5	†	14·70	0·78	13	2·15	174	2·47	314	2·25	212	2·30	232
6	†	14·60	0·78	10	2·15	174	2·47	314	2·28	224	2·15	174
7	1·15	34·	0·75	10	......	Nil.	2·46	308	2·25	212	2·20	193
8	3·15	1,287	0·78	13	......	Nil.	2·46	308	2·25	212	2·18	186
9	3·25	1,390	1·65	120	3·35	1,132	2·45	302	2·28	224	2·17	182
10	2·75	888	2·03	291	3·28	1,061	2·45	302	2·27	220	2·15	174
11	3·35	1,500	2·08	322	2·02	135	2·43	292	2·27	220	2·75	522
12	3·22	1,359	2·06	309	2·10	157	2·42	237	2·27	220	2·60	398
13	3·12	1,256	2·20	405	2·22	201	2·38	267	2·28	224	2·58	384
14	3·08	1,216	2·50	654	2·48	320	2·33	245	2·11	160	2·50	332
15	3·09	1,205	2·55	700	2·50	332	2·32	240	2·07	149	2·45	302
16	†	17·0	2·93	1,065	2·60	398	2·30	232	2·12	164	2·42	286
17	†	16·44	*2·97	1,105	2·62	414	2·31	236	2·30	232	2·45	302
18	†	16·32	3·47	1,695	2·65	437	2·35	253	2·70	479	2·70	479
19	†	16·12	3·55	1,650	1·30	29	2·36	258	1·95	117	2·68	461
20	†	16·00	3·55	1,625	1·35	32	2·37	262	1·93	113	2·64	429
21	†	15·90	3·53	1,560	2·45	302	2·36	258	1·90	107	2·60	398
22	†	15·90	3·53	1,525	2·37	262	2·36	258	1·90	107	2·55	362
23	†	15·80	3·50	1,450	2·43	292	2·35	253	1·95	117	2·50	332
24	†	15·70	3·42	1,330	2·45	302	2·35	253	1·97	122	2·43	292
25	†	15·60	3·44	1,325	2·46	308	2·35	253	2·30	232	2·75	522
26	†	15·60	3·54	1,395	2·45	302	2·35	253	2·95	724	2·40	276
27	†	15·45	3·73	1,570	2·46	308	2·35	253	2·95	724	2·35	253
28	†	15·40	*3·65	1,443	2·45	302	2·35	253	2·95	724	2·31	236
29	†	15·38	3·55	1,336	2·46	308	2·35	253	2·66	445	2·25	212
30	0·84	15·39	3·50	1,285	2·46	308	2·47	314	2·62	414	2·27	220
31	0·72	8·50	2·15	174	......	......	2·55	362	......	......	2·25	212

* Changing conditions from Aug. 17 to Aug. 28
† Gauge not read. Discharge estimated.
? Irregularities in July Discharge due to operation of dam above.

Monthly Discharge of Cascade River at Bankhead, for 1912.

(Drainage area, 248 square miles.)

Month	Discharge in Second-Feet.				Run-Off.	
	Maximum.	Minimum.	Mean.	Per Square Mile.	Depth in inches on Drainage Area.	Total in Acre-feet.
January (1-4, 8-31)	206·0	70·8	148·7	0·61	0·62	8,258
February	119·0	69·8	85·2	0·34	0·37	4,901
March (1-21, 27-31)	303·0	58·0	101·6	0·41	0·38	5,038
April	261·0	42·6	66·6	0·27	0·30	3,963
May	532·0	62·1	301·4	1·22	1·41	18,532
June	1,500·0	Nil.	648·4	2·61	2·91	38,583
July	1,500·0	8·5	337·8	1·36	1·57	20,767
August	1,695·0	10·0	788·0	3·18	3·67	48,452
September	437·0	Nil	289·2	1·17	1·31	17,209
October	1,362·0	232·0	278·0	1·12	1·29	17,09[illegible]
November	724·0	107·0	290·4	1·17	1·31	17,280
December	522·0	74·0	313·8	1·27	1·46	19,295
The period					16·60	219,372

Discharge Measurements of Devil's Creek, near Bankhead, in 1910.

Date.	Hydrographer.	Width.	Area of section.	Mean velocity.	Gauge height.	Discharge
1910.		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
June 4	J. C. Keith	23	35·25	3·65	....	128·65
" 18	do	25	44·10	4·25	1·96	187·23
July 18	do	24	33·25	3·43	1·73	113·96
Aug. 10	do	25	41·16	3·93	1·86	161·92
Sept. 1	do	24	29·30	2·77	1·58	84·89
" 23	do	24	31·60	3·034	1·63	95·90
Oct. 18	H. R. Carscallen	24	30·75	2·78	1·52	85·54
Nov. 7	do	24	26·92	2·579	1·42	69·53
Dec. 3	do	24	25·80	2·403	1·34	61·99
" 28	do	24	27·12	2·179	1·15	59·10

Daily Gauge Height and Discharge of Devil's Creek, near Bankhead, for 1910.

Day.	June.		July.		August.		September.	
	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	....	....	1·90	163	1·57	87·3	1·58	88·7
2	....	....	1·89	160	1·57	87·3	1·56	85·9
3	....	....	1·84	143	1·57	87·3	1·56	85·9
4	....	....	1·85	145	1·56	85·9	1·56	85·9
5	....	....	1·85	146	1·65	99·5	1·59	90·1
6	....	....	1·80	131	1·81	134	1·60	91·5
7	....	....	1·78	126	1·86	149	1·60	91·5
8	....	....	1·78	126	1·86	149	1·62	94·7
9	....	....	1·78	126	1·87	153	1·60	91·5
10	....	....	1·78	126	1·86	149	1·58	88·7
11	....	....	1·75	121	1·85	146	1·59	90·1
12	....	....	1·76	121	1·84	143	1·58	88·7
13	....	....	1·75	118·5	1·81	134	1·58	88·7
14	....	....	1·74	115·4	1·81	134	1·57	87·3
15	....	....	1·72	112·2	1·80	131	1·57	87·3
16	....	....	1·72	112·2	1·81	134	1·56	85·9
17	....	....	1·72	112·2	1·81	134	1·56	85·9
18	....	....	1·70	108	1·76	121	1·59	90·1
19	1·95	183	1·69	106·3	1·73	114·3	1·52	94·7
20	2·00	204	1·69	106·3	1·71	110·1	1·64	97·9
21	2·02	213	1·68	104·5	1·69	106·3	1·64	97·9
22	2·00	204	1·65	99·5	1·66	101·2	1·64	97·9
23	1·97	191	1·64	97·9	1·68	104·6	1·64	97·9
24	1·96	187	1·62	94·7	1·65	99·5	1·64	97·9
25	1·96	187	1·59	90·1	1·64	97·9	1·62	94·7
26	1·94	170	1·59	90·1	1·52	94·7	1·60	91·5
27	1·95	183	1·59	90·1	1·60	91·5	1·60	91·5
28	1·95	183	1·59	90·1	1·58	88·7	1·63	96·3
29	1·94	179	1·59	90·1	1·58	88·7	1·58	88·7
30	1·92	171	1·59	90·1	1·60	91·5	1·55	84·5
31	....	....	1·59	90·1	1·60	91·5	....	....

Daily Gauge Height and Discharge of Devil's Creek, near Bankhead, for 1910.—*Continued.*

Day.	October.		November.		December.	
	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	1·58	88·7	1·39	66·5	1·28	56·4
2	1·57	87·3	1·36	63·5	1·32	59·8
3	1·56	85·9	1·38	65·5	1·30	58
4	1·56	85·9	1·39	66·5	1·25	54
5	1·52	80·9	1·36	63·5	1·24	53
6	1·53	82·1	1·40	67·5	1·25	54
7	1·57	87·3	1·40	67·5	1·24	53
8	1·53	82·1	1·38	65·5	1·20	50
9	1·55	84·5	1·38	65·5	1·33	60·7
10	1·56	85·9	1·37	64·5	1·25	54
11	1·56	85·9	1·37	64·5	1·19	49
12	1·53	82·1	1·38	65·5	1·15	46
13	1·51	79·7	1·36	63·5	1·12	44
14	1·47	74·9	1·37	64·5	1·20	50
15	1·48	76·1	1·37	64·5	1·25	54
16	1·48	76·1	1·37	64·5	1·18	49
17	1·49	77·3	1·36	63·5	1·20	51
18	1·51	79·7	1·36	63·5	1·20	52
19	1·48	76·1	1·36	63·5	1·18	51
20	1·46	73·7	1·33	60·7	1·20	54
21	1·45	72·5	1·37	64·5	1·16	52
22	1·45	72·5	1·37	64·5	1·15	52
23	1·42	69·5	1·35	62·5	1·14	52
24	1·41	68·5	1·36	63·5	1·18	58
25	1·46	73·7	1·35	62·5	1·18	59
26	1·42	69·5	1·35	62·5	1·20	61
27	1·41	68·5	1·33	60·7	1·13	56
28	1·38	65·5	1·30	58·0	1·11	55
29	1·37	64·5	1·30	58·0	1·12	56
30	1·39	66·5	1·30	58·0	1·11	55
31	1·37	64·5	....	....	1·10	54

Ice conditions from Dec. 16th to Dec. 31st.

Monthly Discharge of Devil's Creek, near Bankhead, for 1910.

(Drainage area, 58 square miles.)

Month.	Discharge in Second-Feet				Run-Off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on Drainage area.	Total in acre-feet.
June (19-30)	213	171	88·7	3·26	1·45	4,490
July	163	90·1	114·7	1·98	2·28	7,052
August	153	87·3	114·1	1·96	2·26	7,017
September	97·9	84·5	90·66	1·56	1·74	5,394
October	88·7	64·5	77·03	1·33	1·53	4,736
November	67·5	58·0	63·63	1·09	1·22	3,786
December	61	44·	53·64	·925	1·06	3,298
The period	....	....	....	....	....	35,773

DISCHARGE MEASUREMENTS of Devil's Creek, near Bankhead, Alta., in 1911.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
Jan. 27—	H. R. Carscallen	24	26·9	2·41	1·11	64·9
Feb. 14	do	24	24·4	1·59	1·07	38·8
Mar. 7	do	24	22·2	1·85	1·01	41·0
Mar. 24	do	24	19·4	1·76	0·94	34·2
Apr. 26	H. C. Ritchie	24	20·1	1·93	1·03	38·9
May 10	do	24	22·2	2·10	1·15	46·5
June 2	B. Russell	24	35·8	3·15	1·53	112·9
June 17	do	24	55·0	4·33	1·96	238·4
July 15	do	25	49·4	4·13	1·87	204·0
Aug. 16	H. Brown	25	50·4	4·20	1·88	211·8
Sept. 1	do	25	46·6	3·84	1·79	179·0
Sept. 19	do	25	46·5	3·64	1·78	171·1
Oct. 16	V. A. Newhall	25	40·1	3·05	1·56	122·1
Nov. 6	do	24	33·4	2·78	1·42	92·9
Nov. 23	do	24	30·8	2·38	1·26	73·3
Dec. 8	do	24	28·6	2·37	1·26	67·7
Dec. 22	do	22	20·4	1·76	1·22	36·0
Dec. 27	do	20·5	21·9	1·77	1·27	38·8

DAILY GAUGE HEIGHT AND DISCHARGE of Devil's Creek, near Bankhead, for 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	1·02	49	1·13	60	1·09	44	1·02	38	1·06	41	1·45	98
2	0·96	45	1·13	56	1·06	43	1·02	38	1·06	41	1·54	116
3	0·91	42	1·12	56	1·07	43	1·01	38	1·07	41	1·66	144
4	0·88	40	1·10	53	1·05	43	1·02	38	1·07	41	1·66	144
5	0·88	40	1·11	53	1·16	44	1·03	39	1·07	41	1·67	146
6	0·91	42	1·12	53	1·02	41	1·02	38	1·10	43	1·68	149
7	0·93	44	1·10	50	1·03	42	1·01	38	1·10	43	1·70	154
8	0·92	44	1·11	49	1·05	43	1·00	37	1·11	44	1·68	149
9	0·91	43	1·12	49	1·05	43	1·01	38	1·09	42	1·66	144
10	0·97	47	1·08	44	1·00	39	1·01	38	1·10	43	1·68	149
11	1·01	50	1·08	43	1·00	39	1·01	38	1·12	47	1·71	157
12	1·06	55	1·06	41	1·00	39	1·01	38	1·14	49	1·77	174
13	1·09	58	1·08	40	1·00	39	1·01	38	1·18	52	1·86	201
14	1·08	57	1·07	39	1·02	40	1·01	38	1·20	55	1·92	223
15	1·10	59	1·08	40	1·00	39	1·00	37	1·20	56	1·96	238
16	1·11	61	1·07	39	1·00	39	0·80	28	1·23	59	1·99	251
17	1·11	61	1·07	40	0·96	37	0·90	32	1·24	61	1·99	251
18	1·10	60	1·08	40	0·95	36	1·00	37	1·23	61	1·99	251
19	1·10	60	1·08	41	1·00	38	1·00	37	1·25	65	2·01	259
20	1·12	62	1·08	41	0·96	36	1·00	37	1·24	65	1·99	251
21	1·16	67	1·06	40	0·96	36	1·00	37	1·24	66	1·98	247
22	1·18	69	1·09	42	0·95	35	1·00	37	1·25	67	1·97	247
23	1·17	68	1·08	41	0·97	36	1·01	38	1·33	76	1·97	242
24	1·17	68	1·07	42	1·00	37	1·00	37	1·32	76	2·06	281
25	1·10	62	1·09	43	1·03	37	1·00	37	1·33	78	2·07	286
26	1·10	63	1·07	42	0·90	32	1·02	38	1·34	80	2·06	251
27	1·12	65	1·10	44	0·60	21	1·05	40	1·33	80	2·06	281
28	1·20	72	1·07	43	0·50	19	1·04	39	1·34	81	2·08	290
29	1·15	65	....	....	0·80	28	1·05	40	1·30	77	2·08	290
30	1·15	64	....	....	1·00	37	1·05	40	1·33	81	2·09	295
31	1·13	61	....	....	1·02	38	....	....	1·39	89	....	....

Daily Gauge Height and Discharge of Devil's Creek, near Bankhead, for 1911.—*Continued.*

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	2·02	264	1·70	154	1·79	179	1·68	149	1·47	102	1·31	76
2	2·00	255	1·72	160	1·77	174	1·68	149	1·46	100	1·33	78
3	2·01	259	1·75	168	1·80	182	1·66	144	1·45	98	1·33	78
4	1·99	251	1·78	176	1·68	208	1·65	141	1·46	100	1·29	73
5	1·99	251	1·79	179	1·90	215	1·61	131	1·46	100	1·31	74
6	1·98	247	1·83	191	1·89	211	1·61	131	1·45	98	1·21	64
7	1·98	247	1·88	208	1·88	208	1·61	131	1·45	98	1·34	76
8	1·97	242	1·90	215	1·88	208	1·60	129	1·47	102	1·28	69
9	1·93	226	1·92	223	1·88	208	1·60	129	1·47	102	1·29	69
10	1·91	219	1·93	226	1·86	201	1·61	131	1·45	98	1·26	64
11	1·89	211	1·90	215	1·86	201	1·59	127	1·42	93	1·25	61
12	1·88	208	1·88	208	1·85	197	1·59	127	1·40	90	1·29	63
13	1·88	208	1·90	215	1·81	185	1·59	127	1·39	89	1·22	54
14	1·87	204	1·89	211	1·80	182	1·57	122	1·40	90	1·25	54
15	1·85	197	1·91	219	1·80	182	1·55	118	1·35	83	1·11	42
16	1·83	191	1·89	211	1·78	176	1·56	120	1·37	86	1·25	50
17	1·83	191	1·87	204	1·78	176	1·54	116	1·36	84	1·22	46
18	1·83	191	1·88	208	1·78	176	1·55	118	1·39	89	1·21	43
19	1·82	188	1·89	211	1·78	176	1·55	118	1·39	89	1·22	42
20	1·79	179	1·88	208	1·78	176	1·54	116	†1·39	89	1·10	34
21	1·79	179	1·87	204	1·78	176	1·53	114	1·36	84	1·08	31
22	1·79	179	1·89	211	1·77	174	1·54	116	1·35	83	1·22	36
23	1·78	176	1·86	201	1·77	174	1·54	116	1·30	77	1·22	36
24	1·78	176	1·84	194	1·73	162	1·52	112	1·33	81	1·28	40
25	1·77	174	1·88	208	1·70	154	1·52	112	1·33	81	1·28	40
26	1·73	162	1·89	211	1·69	151	1·50	108	1·36	84	1·28	40
27	1·71	157	1·87	204	1·69	151	1·50	108	1·38	86	1·27	39
28	1·71	157	1·85	197	1·68	149	1·47	102	1·37	84	1·22	36
29	1·69	151	1·80	182	1·66	144	1·47	102	1·38	85	1·21	36
30	1·69	151	1·79	179	1·67	146	1·47	102	1·29	74	1·21	36
31	1·68	149	1·78	176	....	....	1·47	102	....	....	†1·21	36

† No observation, gauge height interpolated.

Monthly Discharge of Devil's Creek, near Bankhead, Alta., for 1911.

(Drainage area, 58 square miles.)

Month.	Discharge in Second-Feet.				Run-Off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on Drainage area.	Total in acre-feet.
January	72	40	56·2	0·969	1·12	3,456
February	60	39	45·2	0·779	0·81	2,510
March	41	19	37·5	0·647	0·75	2,306
April	40	28	37·4	0·615	0·72	2,226
May	89	41	59·4	1·024	1·18	3,652
June	295	98	213	3·672	4·10	12,674
July	264	149	201	3·466	4·00	12,359
August	226	154	199	3·431	3·96	12,236
September	215	144	180	3·103	3·46	10,711
October	149	102	122	2·103	2·42	7,501
November	102	74	90·0	1·551	1·73	5,355
December	78	31	52·1	0·898	1·04	3,204
The year	....	....	....	....	25·29	73,190

DISCHARGE MEASUREMENTS of Kananaskis River, near Kananaskis, Alta., for 1911.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
Feb. 11	H. R. Carscallen	35	66·8	1·97	...	131·7
Mar. 4	do	32	58·4	1·87	...	109·4
Mar. 22	do	32	56·1	2·19	...	122·8
Sept. 6	H. Brown	63·6	178·6	5·68	7·03	1,014·7
Sept. 16	do	62·1	143·5	6·04	6·46	724·0
Oct. 13	V. A. Newhall	60·5	101·3	3·77	5·76	371·9
Nov. 29	do	55	74·0	2·88	5·62	212·1
Dec. 11	do	59	90·7	2·38	5·62	215·9

DAILY GAUGE HEIGHT AND DISCHARGE of Kananaskis River, near Kananaskis, Alta., for 1911.

DAY.	September.		October.		November.		December.	
	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	6·73	860	5·83	404	5·37	172	...	...
2	6·72	855	5·85	415	5·40	187	5·16	...
3	6·74	865	5·81	394	6·38	177	5·15	...
4	7·34	1,168	5·80	389	6·35	162	5·14	...
5	7·10	1,047	5·76	369	5·34	157	5·15	...
6	7·00	996	5·75	364	5·36	167	5·16	...
7	6·88	936	6·71	344	5·38	177	5·13	...
8	6·76	875	5·69	334	5·30	136	5·12	...
9	6·71	850	5·70	330	5·25	111	5·10	...
10	6·63	809	5·68	329	6·25	111	5·11	...
11	6·61	799	5·67	324	5·25	111	...	...
12	6·58	784	5·66	318	...	...	...	...
13	6·54	764	5·65	313	...	...	...	...
14	6·53	759	5·66	318	...	...	...	...
15	6·48	733	5·64	308	...	...	...	...
16	6·43	708	5·63	303	...	...	...	...
17	6·36	673	6·64	308	...	...	5·25	...
18	6·30	642	5·62	298	...	...	5·35	...
19	6·30	642	5·61	293	...	...	5·35	...
20	6·23	607	6·59	283	...	...	5·33	...
21	6·15	566	5·58	278	...	...	3·31	...
22	6·17	577	5·57	273	...	...	5·30	...
23	6·12	551	5·56	268	...	...	5·29	...
24	6·08	531	5·55	263	...	...	5·28	...
25	6·05	516	5·54	258	5·24	...	5·26	...
26	6·01	496	5·52	248	5·27	...	5·23	...
27	5·99	485	5·51	243	5·28	...	5·20	...
28	5·98	480	5·45	212	...	...	5·18	...
29	6·90	440	5·44	207	...	...	5·17	...
30	5·88	430	5·43	202	...	...	5·15	...
31	...	...	5·40	187	...	...	5·14	...

NOTE.—Stream frozen over on Nov. 12, observer did not read the gauge from Nov. 12 to 24, Nov. 29 to Dec. 1, and Dec. 11 to 15. The gauge height readings from Nov. 25 to end of year are of . ttle value. It was difficult to read the gauge and the observer did not cut a large enough hole. His readings do not agree with those of the hydrographer. As the observer was away from home at the time of the visit of the hydrographer it was not until after the end of the year that he was shown the correct method of making observations.

SESSIONAL PAPER No. 25e

MONTHLY DISCHARGE of Kananaskis River, near Kananaskis, Alta., for 1911.

(Drainage area, 406 square miles.)

Month.	Discharge in Second-Feet.				Run-Off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on Drainage area.	Total in acre-feet.
September	1,168	430	715	1·761	1·96	42,545
October	415	187	300	0·739	0·85	18,446
November (1-11)	187	111	152	0·374	0·15	3,316
The period					2·96	64,307

DISCHARGE MEASUREMENTS of Kananaskis River, near Kananaskis, in 1912.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec. ft.
Jan. 3	V. A. Newhall	57·0	160·1	0·98	8·34	141·15
Jan. 20	do	30·0	43·25	2·88	5·98	124·70
Feb. 1	do	60·0	70·80	2·26	6·23	160·20
Feb. 13	do	58·0	60·50	2·24	6·35	135·80
Feb. 21	do	60·0	64·50	2·19	6·52	141·15
Mar. 1	do	60·0	58·50	1·79	6·04	104·65
Mar. 12	H. C. Ritchie	60·0	69·00	1·87	6·47	128·00
Mar. 21	do		Slush ice to bottom.			
April 3	do	59·0	58·40	2·20	5·10	128·71
April 16	do	60·0	64·50	2·20	5·08	143·44
April 30	do	58·0	64·38	2·29	5·12	147·89
May 14	do	60·0	108·70	4·02	5·98	427·23
May 27	do	63·5	151·93	5·68	6·75	863·33
June 12	do	62·0	141·55	5·47	6·62	774·09
June 26	do	65·0	271·86	6·11	8·37	1,661·56
July 10	do	66·0	321·30	8·43	8·92	2,707·95
July 25	do	65·0	245·49	7·14	7·87	1,715·28
Aug. 7	do	63·5	205·35	6·39	7·10	1,312·59
Aug. 21	do	64·0	204·70	5·89	7·20	1,205·00
Sept. 6	do	65·1	144·40	5·11	6·34	738·30
Sept. 25	do	60·0	116·00	4·80	6·05	558·00
Oct. 8	do	60·0	96·80	3·77	5·60	365·00
Oct. 22	do	59·0	96·20	4·07	5·49	391·50
Nov. 5	do	58·0	84·70	3·55	5·24	301·00
Nov. 19	do	57·5	82·53	3·48	5·16	287·00
Dec. 4	do	60·0	130·00	2·30	5·94	299·14
Dec. 17	do	56·0	121·00	1·58	5·90	190·40

DAILY GAUGE HEIGHT AND DISCHARGE of Kananaskis River, near Kananaskis, for 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	7·00	138·00	6·50	131·75	6·17	127·63	5·00	120·00	5·14	154·40	6·32	626·40
2	7·30	141·75	6·53	132·13	6·16	127·50	5·02	124·80	5·15	157·00	6·22	574·40
3	7·50	144·25	5·50	131·75	6·14	127·25	4·97	112·80	5·15	157·00	6·17	548·40
4	6·80	160·50	6·53	132·13	6·08	126·50	4·98	115·20	5·16	159·60	6·14	532·80
5	8·30	154·25	6·52	132·00	6·10	126·75	4·98	115·20	5·17	162·20	6·08	502·40
6	8·30	154·25	6·50	131·75	6·09	126·63	4·95	108·00	5·19	167·40	6·03	478·40
7	8·30	154·25	6·49	131·63	6·05	126·13	5·00	120·00	5·21	173·00	6·09	507·20
8	7·80	148·00	6·47	131·37	6·03	125·88	5·03	127·20	5·40	230·00	6·18	553·60
9	7·30	141·75	6·20	128·00	6·04	126·00	5·01	122·40	5·58	292·80	6·47	707·20
10	7·40	143·00	6·10	126·75	6·18	127·75	5·01	122·40	5·00	120·00	6·56	757·60
11	7·50	144·25	5·45	118·62	6·25	128·63	5·03	127·20	5·49	260·60	6·62	791·20
12	7·50	144·25	5·43	118·38	6·49	131·63	5·02	124·80	5·48	257·20	6·76	872·00
13	7·30	141·75	6·35	129·63	6·50	131·75	5·04	129·6	5·64	314·40	6·99	101·00
14	7·20	140·50	6·34	129·75	6·49	131·63	5·03	127·20	5·98	455·20	7·10	1,060·00
15	7·10	139·25	6·29	129·13	6·50	131·75	5·04	129·60	6·35	642·00	7·97	1,740·00
16	6·50	151·75	6·27	128·87	6·53	132·13	5·06	134·40	6·71	842·00	9·21	2,877·20
17	6·40	[illegible]	6·28	129·00	6·37	130·13	5·03	127·20	6·36	647·20	9·35	3,006·00
18	6·30	[illegible]	6·29	129·13	6·38	130·25	5·05	132·00	6·42	670·20	9·15	2,822·00
19	6·00	[illegible]25·50	6·28	129·00	6·37	130·13	5·00	120·00	6·45	696·00	9·12	2,794·40
20	5·98	125·25	6·29	129·13	6·39	130·37	5·01	122·40	6·32	626·40	9·04	2,720·80
21	5·95	124·88	6·26	128·75	6·38	130·25	5·06	134·40	6·24	584·80	8·78	2,481·60
22	5·93	124·63	6·22	128·25	6·40	130·50	5·05	132·00	6·15	538·00	8·73	2,435·60
23	5·90	124·25	6·24	128·50	6·39	130·37	5·04	129·60	6·20	564·00	8·54	2,260·80
24	5·87	123·88	6·23	128·37	6·40	130·50	5·06	134·40	6·25	590·00	8·48	2,205·60
25	5·85	123·63	6·25	128·63	6·40	130·50	5·10	144·00	6·30	616·00	8·44	2,168·80
26	5·85	123·63	6·23	128·37	6·43	130·87	5·11	146·60	6·54	746·40	8·40	2,132·00
27	5·83	123·38	6·23	128·37	6·45	131·13	5·09	141·60	6·75	866·00	8·30	2,048·00
28	5·83	123·38	6·21	128·12	6·43	130·87	5·06	134·40	6·67	819·20	8·15	1,920·00
29	5·80	123·00	6·18	127·75	6·43	130·87	5·09	141·60	6·60	780·00	8·01	1,800·00
30	6·00	125·50	......	......	6·45	131·13	5·12	149·20	6·55	752·00	8·78	2,520·00
31	6·20	128·00	......	......	5·02	113·25	......	......	6·52	735·20	......	......

Daily Gauge Height and Discharge of Kananaskis River, near Kananaskis, for 1912.—*Concluded.*

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	7·62	*1,488	7·20	1,248	6·65	898	5·67	414	5·28	311	5·32	148
2	7·58	1,464	7·17	1,228	6·51	818	5·63	402	5·27	309	5·41	175
3	9·52	3,210	7·13	1,202	6·34	722	5·60	392	5·29	314	5·90	298
4	7·43	1,360	7·15	1,215	5·27	684	5·63	402	5·27	309	5·94	296
5	7·36	1,320	7·24	1,277	6·35	728	5·66	411	5·24	302	5·30	440
6	7·46	1,406	7·17	1,228	6·36	734	5·52	398	5·23	299	5·31	435
7	7·72	1,608	7·08	1,169	6·29	695	5·60	392	5·23	299	5·71	204
8	8·63	2,520	7·03	1,137	5·30	700	5·59	389	5·21	294	5·64	175
9	8·84	2,632	5·98	1,105	6·32	711	5·61	395	5·23	299	5·96	272
10	8·90	*2,688	6·90	1,052	5·30	700	5·57	384	5·22	297	5·49	120
11	8·89	2,680	7·05	1,150	6·32	711	5·60	392	5·20	292	5·28	72
12	8·69	2,495	7·03	1,137	6·35	728	5·62	398	5·23	299	5·30	72
13	8·70	2,504	6·92	1,065	6·40	756	5·57	384	5·21	294	5·42	88
14	9·12	2,890	6·84	1,014	6·38	745	5·56	381	5·19	290	5·64	136
15	8·82	2,614	6·87	1,033	6·33	717	5·53	372	5·16	284	†5·70	148
16	8·49	2,311	6·90	1,052	6·31	706	5·54	375	5·09	270	5·91	208
17	8·50	2,320	7·26	1,292	6·26	679	5·58	386	5·10	272	5·90	192
18	7·86	1,744	7·32	1,334	6·19	643	5·57	384	5·17	286	5·86	190
19	7·58	1,525	7·35	1,356	6·19	643	5·55	378	5·16	284	5·84	188
20	7·55	1,503	7·24	1,277	6·08	588	5·56	381	5·12	256	5·96	193
21	9·53	3,258	7·20	1,248	6·00	548	5·54	375	5·13	244	5·93	192
22	9·24	3,001	7·18	1,235	5·98	538	5·49	362	5·10	216	5·60	178
23	7·32	1,331	7·15	1,215	6·01	553	5·48	359	5·09	200	6·08	198
24	7·53	1,488	7·20	1,248	6·07	583	5·46	354	5·11	192	5·91	191
25	7·84	1,728	7·63	1,563	6·12	608	5·45	352	5·06	156	†6·00	196
26	7·78	1,680	8·00	1,860	6·03	663	5·44	350	5·05	144	6·64	216
27	7·71	1,624	9·69	3,115	5·84	476	5·42	345	5·10	144	6·30	200
28	7·54	1,496	9·48	3,222	5·77	449	5·44	350	5·08	120	6·52	208
29	7·40	1,392	9·34	3,093	5·73	435	5·44	350	5·20	136	6·75	224
30	7·31	1,327	7·12	1,195	5·70	424	5·38	335	5·30	152	6·89	232
31	7·22	1,262	6·93	1,572			5·29	314			7·10	248

* Shifting conditions July 1 to July 10.
† Gauge heights interpolated.

Monthly Discharge of Kananaskis River, near Kananaskis, for 1912.

(Drainage area, 406 square miles.)

Month.	Discharge in Second-Feet				Run-Off	
	Maximum.	Minimum.	Mean.	Per Square Mile.	Depth in inches on Drainage Area	Total in Acre-feet.
January	160	123	136	0·33	0·38	8,332
February	132	118	129	0·32	0·34	7,400
March	132	113	129	0·32	0·37	7,926
April	149	108	128	0·32	0·36	7,635
May	866	120	477	1·17	1·35	29,305
June	3,006	478	1,582	3·90	4·35	94,138
July	3,258	1,262	1,996	4·91	5·66	122,729
August	3,222	1,014	1,424	3·51	4·05	87,558
September	898	424	653	1·61	1·80	38,856
October	414	314	376	0·926	1·07	23,119
November	314	120	252	0·621	0·69	14,995
December	440	72	204	0·502	0·58	12,543
The year					21·00	454,545

DISCHARGE MEASUREMENTS of Bow River, near Morley, in 1910.

Date.	Hydrographer.	Width.	Area of section.	Mean velocity.	Gauge height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
May 26	J. C. Keith	222·7	1,466·59	6·44	4·90	9,443·54
June 21	do	235·7	1,610·50	7·49	5·55	12,066·97
July 14	do	217·7	1,422·58	5·96	4·74	8,476·01
Aug. 9	do	207·4	1,207·23	4·96	3·80	5,990·30
Aug. 30	do	182·2	933·94	3·26	2·37	3,047·86
*Sept. 21	do	182·2	926·86	3·22	2·38	2,987·93
†Sept. 21	do	182·2	926·86	3·23	2·38	2,989·38
Oct. 17	H. R. Carscallen	179·5	903·80	3·06	2·30	2,767·68
Nov. 4	do	175·5	799·30	2·29	1·63	1,829·87
Nov. 30	do	155·5	733·35	1·61	1·22	1,177·06
Dec. 22	do	154·0	463·81	1·83	1·16	847·19

* One point method used.
† Two point method used.

DAILY GAUGE HEIGHT AND DISCHARGE of Bow River, near Morley, for 1910

DAY.	May.		June.		July.		August.	
	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			4·15	6·910	4·85	[illegible]	3·45	5,185
2			4·4	7,660	4·9	[illegible]	3·4	5,070
3			4·25	7,195	4·6	8,350	3·3	4,850
4			4·05	6,635	4·55	8,175	3·25	4,740
5			3·85	6,115	4·5	8,000	3·55	5,415
6			4·0	6,500	4·5	8,000	4·0	6,500
7			4·45	7,830	4·45	7,830	4·05	6,635
8			4·55	8,175	4·5	8,000	4·0	6,500
9			4·4	7,660	[illegible]	8,175	3·85	6,115
10			4·4	7,660	4·45	7,830	3·85	6,115
11			4·8	9,070	4·45	7,830	3·75	5,875
12			5·65	12,475	4·55	8,175	3·75	5,875
13			5·7	12,680	4·7	8,700	3·7	5,760
14			5·2	10,640	4·85	9,255	3·65	5,645
15			5·05	10,040	4·85	9,255	3·6	5,530
16			5·35	11,245	4·95	9,640	3·5	5,300
17			5·5	11,860	4·8	9,070	3·35	4,960
18			5·8	13,090	4·9	9,440	3·25	4,740
19			5·35	11,245	4·75	8,885	3·2	4,630
20			5·35	11,245	4·55	8,175	3·1	4,410
21			5·7	12,680	4·45	7,830	3·1	4,410
22			5·4	11,450	4·4	7,660	3·05	4,305
23			5·0	9,840	4·3	7,340	3·0	4,200
24			4·65	8,525	4·2	7,050	2·95	4,095
25	4·6	8,350	4·45	7,830	3·9	6,240	2·75	3,685
26	5·1	10,240	4·7	8,700	3·95	6,370	2·63	3,485
27	5·15	10,440	5·0	9,840	3·8	5,990	2·55	3,305
28	4·8	9,070	5·25	10,840	3·7	5,760	2·55	3,305
29	4·4	7,660	5·25	10,840	3·8	5,990	2·45	3,115
30	4·2	7,050	5·0	9,840	3·77	5,921	2·38	2,986
31	4·0	6,500		..	3·8	5,990	2·36	2,952

DAILY GAUGE HEIGHT AND DISCHARGE of Bow River, near Morley, for 1910.—*Continued.*

Day.	September.		October.		November.		December.	
	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	2·33	2,901	2·1	2,520	1·67	1,888	1·2	*1,150
2	2·28	2,816	2·08	2,490	1·7	1,930	1·4	*1,380
3	2·18	2,648	2·0	2,370	1·65	1,860	1·38	*1,340
4	2·27	2,799	2·0	2,370	1·7	1,930	1·28	*1,210
5	2·35	2,935	1·95	2,295	1·64	1,846	1·47	*1,430
6	2·45	3,115	1·9	2,220	1·66	1,874	1·49	*1,440
7	2·5	3,210	2·0	2,370	1·6	1,790	1·55	*1,510
8	2·43	3,077	2·1	2,520	1·5	1,660	1·46	*1,380
9	2·25	2,765	2·05	2,445	1·53	1,699	1·45	*1,350
10	2·2	2,680	2·2	2,680	1·55	1,725	1·53	*1,440
11	2·23	2,731	2·3	2,850	1·52	1,686	1·5	*1,400
12	2·13	2,568	2·35	2,935	1·53	1,699	1·25	*1,080
13	2·12	2,552	2·25	2,765	1·45	1,595	1·45	*1,300
14	2·07	2,475	2·27	2,799	1·5	1,660	1·4	*1,220
15	2·07	2,475	2·15	2,600	1·45	*1,595	1·25	*1,030
16	2·1	2,520	2·15	2,600	1·4	*1,530	1·23	*1,000
17	2·23	2,731	2·3	2,850	1·34	*1,440	1·27	*1,020
18	2·25	2,765	2·38	2,986	1·25	*1,320	1·3	*1,050
19	2·3	2,850	2·32	2,884	1·37	*1,470	1·2	* 920
20	2·35	2,935	2·24	2,748	1·37	*1,460	1·2	* 920
21	2·33	2,901	2·2	2,680	1·36	*1,440	1·19	* 890
22	2·4	3,020	2·15	2,600	1·33	*1,390	1·15	* 840
23	2·44	3,096	2·1	2,520	1·34	*1,400	1·25	* 870
24	2·33	2,901	2·04	2,430	1·45	*1,520	1·25	* 800
25	2·4	3,020	2·05	2,445	1·0	* 970	1·3	* 770
26	2·37	2,969	2·0	2,370	1·0	* 960	1·47	* 900
27	2·25	2,765	1·93	2,265	1·0	* 950	1·6	* 990
28	2·15	2,600	1·86	2,160	1·03	* 980	1·55	* 800
29	2·11	2,536	1·8	2,070	1·15	*1,100	1·7	* 970
30	2·06	2,460	1·75	2,000	1·23	*1,190	2·35	* 900
31	....		1·73	1,972	....		2·25	* 990

* Changing conditions due to ice: Nov. 15th to Dec. 31st.

MONTHLY DISCHARGE of Bow River, near Morley, for 1910.

Drainage area, 2,000 square miles.

Month.	Discharge in Second-Feet.				Run-Off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on Drainage area.	Total in acre-feet.
May (25-31)	10,440	6,500	8,472·8	4·08	1·04	117,039
June	13,090	6,115	9,543·8	4·54	5·06	567,894
July	9,640	5,760	7,858·7	3·74	4·31	483,211
August	6,635	2,952	4,828·8	2·30	2·65	297,916
September	3,210	2,460	2,793·8	1·33	1·48	166,244
October	2,986	1,972	2,509·9	1·20	1·38	154,324
November	1,930	950	1,518·6	·72	·80	90,366
December	1,510	770	1,110·6	·53	·61	65,287
The period						1,945,881

DISCHARGE MEASUREMENTS of Bow River near Morley, Alta., in 1911.

Date.	Hydrographer.	Width	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
Jan. 21	H. R. Carscallen	143	328.1	2.06	2.83	675.0†
Feb. 10	do	89	302.5	2.22	2.95	671.3†
Mar. 3	do	114	369.6	1.66	2.85	613.5x
Mar. 21	do	114	412.0	1.77	2.53	730.6x
Apr. 5	H. C. Ritchie	107	406.6	1.80	0.80	733.2?
Apr. 25	H. C. Ritchie	162.5	668.1	1.41	0.89	941.6
May 9	do	179	866.3	2.53	1.85	2,190
May 30	B. Russell	196.5	865.9	2.74	2.04	2,377
June 14	do	241.2	1,748	7.07	6.08	12,375
July. 12	do	217.6	1,350	5.71	4.42	7,702
Aug. 14	H. Brown	198.4	1,200	4.94	3.69	5,930
Sept. 23	do	198	932.1	2.95	2.26	2,746
Oct. 12	V. A. Newhall	174.4	804.3	2.26	1.73	1,821
Nov. 17	do	174.6	915.5	1.50	3.50	1,374 *
Nov. 27	do	177.6	952.8	0.85	3.24	807.2*
Dec. 14	do	187.6	841.8	1.30	2.74	1,091**

† Stream frozen over, conditions bad, results approximate.
x Stream frozen over.
? Stream partly frozen over, results may be slightly inaccurate.
|| May be slight error due to inaccuracy of soundings.
* Large amount of slush ice, results only approximate.
**Large amount of slush ice. Compared with the records at Banff and Calgary the discharge appears to be too high.

DAILY GAUGE HEIGHT AND DISCHARGE of Bow River near Morley, Alta., for 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	1·85	....	2·75	590	2·85	614	0·74	694	1·20	1,240	3·35	6,040
2	2·30	....	2·75	586	2·85	614	0·70	670	1·27	1,317	4·40	7,700
3	†2·40	....	2·80	610	2·83	604	0·70	670	1·36	1,422	4·80	8,740
4	†2·45	....	2·75	582	2·75	564	0·70	670	1·40	1,470	4·90	9,000
5	†2·50	....	2·85	630	2·80	588	0·76	708	1·60	1,720	†4·62	8,272
6	2·60	....	2·85	626	2·75	564	0·88	808	1·90	2,160	4·35	7,570
7	†2·60	....	2·90	652	2·85	614	0·65	674	1·80	2,010	4·05	6,790
8	2·60	....	2·85	620	2·80	588	0·68	708	1·80	2,010	3·95	6,530
9	2·15	....	2·90	646	2·80	588	0·75	768	1·82	2,040	3·85	6,275
10	1·95	....	2·90	642	2·70	564	0·72	768,	1·80	2,010	3·90	6,400
11	2·15	.	2·95	672	2·65	562	0·70	774	1·75	1,935	4·40	7,700
12	2·25	...	3·00	704	2·60	560	0·65	755	1·80	2,010	5·15	9,690
13	2·45	....	2·95	672	2·60	580	*0·35	340	1·85	2,085	5·80	11,550
14	2·50	.	2·90	642	2·55	576	0·65	755	1·90	2,010	6·10	12,460
15	2·70	.	2·85	614	2·65	652	0·70	790	1·75	1,935	6·20	12,770
16	2·75	...	2·75	564	2·60	648	0·68	776	1·95	2,240	6·15	12,615
17	2·95	...	2·80	588	2·60	672	0·70	790	2·10	2,480	6·10	12,460
18	2·95	.	2·85	614	2·63	720	0·74	822	2·20	2,640	6·05	12,305
19	2·80	.	2·80	588	2·60	724	0·70	790	2·18	2,608	6·00	12,150
20	2·85	.	2·80	588	2·56	726	0·75	830	2·25	2,725	5·75	11,405
21	2·80	654	2·75	564	2·55	746	0·80	870	2·27	2,759	5·65	11,115
22	2·83	680	2·85	614	2·50	790	*0·35	340	2·26	2,742	5·75	11,405
23	2·80	646	2·85	614	2·47	856	0·90	950	2·37	2,943	6·20	12,770
24	2·70	500	2·83	604	2·30	814	1·22	1,262	2·27	2,759	6·35	13,235
25	2·70	586	2·85	614	2·25	862	0·98	1,022	2·17	2,592	6·45	13,545
26	2·60	536	2·80	588	2·15	878	†1·06	1,100	2·10	2,480	6·05	12,305
27	2·55	512	2·85	614	2·07	904	1·15	1,190	2·05	2,400	5·65	11,115
28	2·65	554	2·80	588	1·05	920	1·10	1,140	1·95	2,240	5·60	10,970
29	2·75	598			0·85	766	1·17	1,210	1·98	2,288	5·55	10,825
30	2·70	570	.	..	0·80	732	1·12	1,160	2·06	2,416	5·55	10,825
31	2·75	592			0·76	708			2·60	3,400	....	....

Daily Gauge Height and Discharge of Bow River near Morley, Alta., for 1911.—*Continued.*

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	5·50	10,680	3·86	6,300	†3·05	4,345	1·95	2,240	1·48	1,566	3·30	....
2	5·55	10,825	†3·90	6,400	3·10	4,460	1·97	2,272	†1·48	1,566	3·26	....
3	6·40	10,390	3·95	6,530	3·16	4,675	1·95	2,240	†1·48	1,566	3·31	....
4	6·20	9,830	4·00	6,660	3·40	5,160	1·90	2,160	1·48	1,566	3·19	....
5	†4·95	9,135	4·05	6,790	3·30	4,920	1·85	2,085	1·35	1,410	3 26	....
6	4·70	8,480	4·15	7,050	†3·21	4,713	1·80	2,010	1·61	1,734	3·14	....
7	4·90	9,000	4·25	7,310	3·12	4,506	1·70	1,860	1·45	1,530	3·03	....
8	5·00	9,270	4·30	7,440	3·00	4,230	1·78	1,980	1·53	1,629	3·10	....
9	4·75	8,610	4·15	7,050	2·95	4,120	1·70	1,860	....	....	3·31	....
10	4·55	8,090	4·03	6,738	3·20	4,690	1·56	1,668	....	....	3·03	....
11	4·40	7,700	†3·91	6,426	2·75	3,700	1·65	1,790	....	....	2·82	....
12	4·40	7,700	3·80	6,150	2·75	3,700	1·70	1,860	1·73	....	2·85	....
13	4·25	7,310	3·70	5,900	2·70	3,600	†1·70	1,860	3·05	....	2·75	....
14	4·30	7,440	3·65	6,775	2·70	3,600	1·70	1,860	3·03	....	2·74	....
15	4·35	7,570	3·60	5,650	2·65	3,500	1·69	1,846	3·24	....	2·73	....
16	4·55	8,090	3·60	5,650	2·60	3,400	1·77	1,965	3·28	....	2·74	....
17	4·80	8,740	†3·54	5,500	2·55	3,300	1·69	1,846	3·25	....	2·68	....
18	4·70	8,480	†3·47	5,328	2·50	3,200	1·68	1,832	†3·56	....	2·27	....
19	†4·47	7,882	3·40	5,160	2·45	3,100	1·66	1,804	3·88	....	2·32	....
20	4·23	7,310	3·43	5,232	2·35	2,905	1·59	1,707	3·98	....	2·74	....
21	4·18	7,128	3·45	5,280	2·30	2,810	1·69	1,846	3·99	....	2·59	....
22	4·22	7,232	3·40	5,160	2·30	2,810	1·68	1,832	3·96	....	2·63	....
23	4·25	7,310	3·35	5,040	2·27	2,759	1·71	1,875	4·02	....	2·73	....
24	4·15	7,050	†3·27	4,851	2·18	2,608	†1·70	1,860	†3·83	....	2·76	....
25	4·15	7,050	3·20	4,690	2·15	2,560	1·69	1,846	†3·63	....	2·62	....
26	4·35	7,670	†3·50	5,400	2·10	2,480	1·59	1,707	†3·44	....	2·69	....
27	4·30	7,440	3·80	6,150	2·05	2,400	1·48	1,566	3·24	807	2·74	....
28	4·15	7,050	3·05	4,345	2·00	2,320	†1·42	1,494	3·07	724	2·72	....
29	4·05	6,790	3·03	4,299	2·00	2,320	†1·36	1,422	3·13	800	2·69	....
30	3·95	6,530	2·93	4,076	1·95	2,240	1·30	1,350	3·07	798	2·68	....
31	3·80	6,150	†2·99	4,208	.		1·39	1,458	...	....	2·74	....

During January, February, March and November. Daily discharge for these months are only approximate.
†No observation, gauge height interpolated.
*Negative gauge height. Low water caused by Calgary Power and Transmission Co. holding back the water.
Note—Data insufficient to compute the daily discharge from Jan. 1 to 20, Nov. 9 to 26 and Dec. 1 to 31. Ice conditions

Monthly Discharge of Bow River near Morley, Alta., for 1911.

(Drainage area, 2,111 square miles.)

Month.	Discharge in Second-Feet.				Run-Off.	
	Maximum	Minimum.	Mean.	Per square mile.	Depth in inches on Drainage area.	Total in acre-feet.
January (21-31)	680	512	593	0·281	0·11	12,938
February	704	564	615	0·291	0·30	34,155
March	920	560	687	0·325	0·37	42,242
April	1,262	340	827	0·392	0·44	49,210
May	3,400	1,210	2,229	1·06	1·22	137,058
June	13,545	5,040	10,184	4·82	5·38	605,990
July	10,825	6,150	8,059	3·82	4·40	495,529
August	7,440	4,076	5,759	2·73	3·15	354,108
September	5,160	2,240	3,501	1·66	1·85	208,324
October	2,272	1,350	1,840	0·872	1·00	113,140
November (1-8 27-30)	1,734	724	1,308	0·620	0·28	31,131
The period	....	....	....	....	18·50	2,[illegible]

Discharge Measurements of Bow River near Kananaskis, in 1912.

Date.	Hydrographer.	Width.	Area of section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
*Feb. 29	V. A. Newhall	270·00	303·25	1·94		587·18
*Mar. 10	H. C. Ritchie	255·00	267·00	2·174	2·00	580·45
*Mar. 20	do	272·00	244·55	2·27	1·97	555·30
*April 2	do	338·00	271·25	2·09	1·84	567·99
April 15	do	346·50	287·90	2·14	1·83	617·22
April 29	do	349·00	300·50	2·27	1·85	681·88
May 13	do	367·00	423·70	3·26	2·23	1,388·39
May 28	do	403·00	783·55	6·78	3·03	4,628·61
June 11	do	402·00	731·00	5·51	2·94	4,027·07
June 25	do	422·00	1,042·98	7·35	3·70	7,672·14
July 9	do	416·00	1,033·85	7·34	3·70	7,591·62
July 25	do	412·00	986·40	6·47	3·60	6,403·36
Aug. 6	do	406·5	827·48	6·21	3·20	6,139·39
Aug. 20	do	409·00	980·20	6·61	3·60	6,477·10
Sept. 6	do	399·00	698·60	5·41	2·87	3,780·00
Sept. 24	H. R. Cram	397·00	606·00	4·59	2·54	2,784·00
Oct. 9	do	381·00	556·00	3·97	2·50	2,207·00
Oct. 23	H. C. Ritchie	372·00	488·00	3·41	2·40	1,662·00
Nov. 6	do	359·00	412·00	3·61	2·22	1,4[illegible]8·00
*Nov. 19	do	373·00	422·7	3·23	2·23	1,366·70
*Dec. 3	do	319·00	500·00	2·82	3·16	1,212·40
*Dec. 17	do	180·00	555·4	1·57	4·32	871·00

*Ice conditions.
NOTE.—This station established in 1912 to replace the station at Morley.

Daily Gauge Height and Discharge of Bow River, near Kananaskis, for 1912.

Day.	March.		April.		May.		June.	
	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			1·98	678	1·87	665	2·53	2,428
2			1·97	677	1·85	635	2·51	2,356
3			1·86	650	1·88	680	2·50	2,320
4			1·87	665	1·87	695	2·47	2,221
5			1·86	650	1·88	680	2·45	2,155
6			1·85	635	1·67	665	2·41	2,023
7			1·83	605	1·89	695	2·37	1,894
8			1·85	635	1·93	764	2·62	2,392
9			1·85	635	2·09	1,097	2·71	3,100
10	2·00	580	1·88	680	2·08	1,074	2·96	4,100
11	1·99	579	1·90	710	2·10	1,120	2·98	4,180
12	1·98	578	1·88	680	2·16	1,255	3·04	4,432
13	1·92	672	1·89	695	2·23	1,474	3·06	4,518
14	1·65	676	1·86	650	2·36	1,662	3·57	6,927
15	1·78	586	1·87	665	2·54	2,464	3·61	7,131
16	1·97	677	1·88	680	2·86	3,700	3·74	7,794
17	1·95	676	1·80	560	2·89	3,820	3·80	8,100
18	1·96	676	1·82	590	2·86	3,700	3·74	7,794
19	1·99	579	1·79	546	2·85	3,660	3·75	7,845
20	1·97	677	1·83	605	2·63	2,794	3·73	7,743
21	1·97	577	1·82	690	2·50	2,320	3·76	7,896
22	1·94	574	1·83	605	2·49	2,287	3·72	7,692
23	1·95	575	1·84	620	2·46	2,188	3·63	7,233
24	1·92	572	1·83	605	2·43	2,089	3·64	7,284
25	1·90	670	1·80	560	2·61	2,718	3·70	7,690
26	1·89	571	1·84	620	2·79	3,420	3·66	7,386
27	1·88	572	1·85	635	2·88	3,780	3·62	7,192
28	1·87	673	1·84	620	3·03	4,399	3·64	7,284
29	2·20	640	1·85	635	3·00	4,260	3·65	7,335
30	2·10	600	1·85	635	2·98	4,190	3·37	5,919
31	2·10	600			2·70	3,060		

Daily Gauge Height and Discharge of Bow River, near Kananaskis, for 1912.—*Concluded.*

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	3·26	5,410	3·18	5,050	3·08	4,604	2·54	2,464	2·39	1,958	3·34	710
2	3·17	5,005	3·21	5,185	3·01	4,303	2·52	2,392	2·47	2,221	3·32	746
3	3·09	4,647	3·19	5,095	2·97	4,140	2·50	2,320	2·40	1,991	3·39	890
4	3·06	4,518	3·22	5,230	2·95	4,060	2·49	2,287	2·33	1,766	3·33	854
5	3·04	4,432	3·25	5,365	2·99	4,220	2·53	2·428	2·27	1,586	3·26	800
6	3·05	4,475	3·20	5,140	2·89	3,820	2·50	2,320	2·21	1,418	3·04	635
7	3·42	6,162	3·16	4,960	2·80	3,460	2·52	2,392	2·19	1,363	2·93	490
8	3·56	6,876	3·11	4,735	2·80	3,460	2·53	2,428	2·18	1,336	2·74	420
9	3·70	7,590	3·07	4,561	2·79	3,420	2·52	2,392	2·15	1,255	2·47	360
10	3·72	7,692	3·15	4,915	2·81	3,500	2·49	2,287	2·16	1,282	2·49	300
11	3·69	7,539	3·09	4,647	3·06	4,518	2·47	2,221	2·15	1,253	2·97	324
12	3·67	7,437	3·05	4,475	3·07	4,561	2·45	2,155	2·16	1,282	3·51	360
13	3·74	7,794	3·00	4,260	3·04	4,432	2·44	2,122	2·18	1,336	3·53	420
14	3·84	8,308	2·96	4,100	2·74	3,220	2·45	2,155	2·15	1,255	3·32	300
15	3·66	7,386	2·97	4,140	2·71	3,100	2·43	2,089	2·10	1,120	3·70	360
16	3·62	7,182	2·99	4,220	2·73	3,180	2·44	2,122	1·99	872	4·16	420
17	3·54	6,774	3·27	5,455	2·69	3,022	2·48	2,254	2·48	*1,390	4·32	710
18	3·43	6,213	3·52	6,72	2·672	2,946	2·46	2,188	2·31	1,228	5·00	890
19	3·48	6,468	3·61	7,131	2·63	2,794	2·47	2,221	2·24	1,255	5·68	1,120
20	3·37	5,919	3·69	7,080	2·60	2,680	2·45	2,155	2·22	1,250	6·33	1,390
21	3·31	5,637	3·67	7,437	2·58	2,608	2·43	2,089	2·19	1,174	6·06	1,120
22	3·06	4,518	3·63	7,233	2·56	2,536	2·42	2,056	2·15	1,120	6·10	1,120
23	3·12	4,780	3·60	7,080	2·53	2,428	2·45	2,155	2·12	872	5·72	890
24	3·37	5,919	3·69	7,539	2·58	2,608	2·43	2,089	2·14	1,170	5·60	710
25	3·64	7,284	3·77	7,947	2·60	2,680	2·32	1,734	2·32	1,070	5·37	560
26	3·72	7,692	3·71	7,641	2·57	2,572	2·39	1,958	2·35	800	5·37	560
27	3·37	5,919	3·73	7,743	2·59	2,644	2·39	1,958	2·94	854	4·94	560
28	3·25	5,365	3·70	7,590	2·57	2,572	2·35	1,830	2·95	836	4·56	590
29	3·18	5,050	3·69	7,539	2·53	2,428	2·32	1,734	3·04	710	4·63	560
30	3·19	5,095	3·65	7,335	2·50	2,320	2·38	1,926	2·98	746	4·42	632
31	3·16	4,960	3·41	6,111	...	...	2·40	1,990	...	...	4·44	532

*Ice conditions.

Monthly Discharge of Bow River near Kananaskis, for 1912.

(Drainage area, 1304 square miles.)

Month	Discharge in Second Feet.				Run-Off.	
	Maximum.	Minimum.	Mean.	Per Square Mile	Depth in inches on Drainage Area.	Total in Acre-feet.
March (10–31)	640	570	580·50	0·45	0·37	34,542
April	710	546	627·00	0·48	0·54	37,321
May	4,389	635	2,199·68	1·69	1·95	135,240
June	8,100	1,894	5,475·13	4·20	4·48	325,753
July	8,308	4,432	6,130·0	4·70	5·42	376,920
August	7,947	4,100	5,923·0	4·54	5·23	364,193
September	4,604	2,320	3,294·0	2·53	2·82	196,006
October	2,461	1,734	2,158	1·65	1·90	132,688
November	2,221	710	1,259	0·966	1·08	74,920
December	1,390	300	656	0·503	0·58	40,336
The period			...	...	24·37	1,717,919

Discharge Measurements of Ghost River at Gillies' Ranch, Alta., in 1911.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
May 3	H. C. Ritchie	58·0	81·2	1·60	....	130·0
June 9	R. T. Sailman	67·0	155·5	1·97	....	305·9
July 13	L. R. Brereton	89·0	164·4	2·79	....	457·9
Aug. 15	do	91·0	193·1	3·97	2·46	768·0
Sept. 19	do	70·0	143·4	2·80	1·95	401·1
Oct. 20	do	68·0	124·4	2·46	1·72	305·6
Nov. 9	V. A. Newhall	52·5	68·5	2·92	1·30	200·0
Nov. 28	do	48·0	75·3	2·94	*	221·6†
Dec. 15	do	51·0	71·6	2·68	*	192·1†

*No gauge.
†Gauging made near the site of gauge. Ice conditions but the probable error small.

Daily Gauge Height and Discharge of Ghost River at Gillies' Ranch, Alta., for 1911.

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	....	....	2·11	498	1·85	355	1·44	228
2	....	....	2·06	465	1·86	359	1·44	228
3	....	....	2·43	740	1·86	359	1·49	240
4	....	....	3·03	1235	1·85	355	1·52	247
5	....	....	2·60	879	1·84	351	1·45	230
6	....	....	2·55	838	1·77	324	1·44	228
7	....	....	2·31	644	1·77	324	1·45	230
8	....	....	2·26	606	1·80	335	1·34	207
9	....	....	2·16	532	1·80	335	1·25	191
10	....	....	2·15	525	1·80	335	1·25	191
11	....	....	2·13	511	1·80	335	1·25	191
12	....	....	2·07	472	1·78	328	....	....
13	....	....	2·06	465	1·70	300	....	....
14	....	....	2·00	429	1·69	297	1·55	....
15	....	....	1·99	423	1·69	297	1·55	....
16	....	....	2·00	429	1·67	290	1·45	....
17	2·56	846	2·00	429	1·60	269	1·47	....
18	2·44	748	1·95	401	1·57	261	1·66	....
19	2·44	748	1·95	401	1·55	255	1·66	....
20	2·56	846	1·93	391	1·56	258	1·62	....
21	2,46	764	1,93	391	1,56	258	....	....
22	2·67	936	1·94	396	1·56	258	....	....
23	2·52	813	1·90	377	1·56	258	....	....
24	2·33	659	1·89	373	1·56	258	....	....
25	2·89	1118	1·90	377	1·56	258	....	....
26	2·67	936	1·94	396	1·56	258	....	....
27	2·45	756	1·96	407	1·45	230	....	....
28	2·37	691	1·93	391	1·44	228	....	....
29	2·31	644	1·89	373	1·44	228	....	....
30	2·20	561	1·86	359	1·44	228	....	....
31	2·16	532	....	....	1·45	230	....	....

Note.—On Nov. 12, the river was frozen to the bottom of the gauge and the height of water could no be read. A thaw on Nov. 14 caused the water to overflow the ice and on Nov. 20 the gauge was carried out by the ice which broke up. Satisfactory arrangements regarding remuneration could not be made and no observations were therefore reported after Nov. 21. Not sufficient data to compute daily discharge from Nov. 14 to 20.

Monthly Discharge of Ghost River at Gillies' Ranch, Alta., for 1911.

(Drainage area, 367 square miles.)

Month.	Discharge in Second-Feet.				Run-Off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on Drainage area.	Total in acre-feet.
August (17-31)	1,118	532	773	2·106	1·18	22,998
September	1,235	359	595	1·376	1·54	30,050
October	359	228	291	0·793	0·91	17,893
November (1-11)	247	191	219	0·597	0·24	4,778
The period					3·87	75,719

Discharge Measurements of Ghost River at Gillies' Ranch, in 1912.

Date	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
Feb. 2	V. A. Newhall	31·0	50·20	2·64	2·00	132·60*
Feb. 12	do	27·0	39·40	2·62	1·53	103·27
Feb. 22	do	29·0	45·25	2·10	1·80	95·01
Mar. 2	do	26·0	38·80	1·82	1·36	70·75
Mar. 13	H. C. Ritchie	30·0	38·00	2·88	1·06	109·60
Mar. 23	do	25·0	43·00	2·44	1·76	104·90*
April 17	do	47·0	58·10	2·61	0·99	152·02
May 16	do	68·0	145·00	2·35	1·51	340·64
June 14	do	63·0	113·05	1·24	1·00	140·15
June 27	do	62·5	116·57	1·79	1·02	207·91
July 11	do	93·5	246·4	5·41	4·00	1,332·7
July 26	do	86·0	269·8	5·42	4·10	1,460·4
Aug. 8	do	81·5	156·5	4·06	3·05	634·4
Aug. 23	do	81·0	183·1	3·44	3·15	630·0
Sept. 4	do	79·0	184·0	3·24	3·12	598·0
Sept. 26	H. R. Cram	78·5	155·0	3·01	2·87	466·0
Oct. 11	do	77·0	146·0	2·85	2·70	417·0
Oct. 24	H. C. Ritchie	73·0	130·0	2·48	2·44	322·0
Nov. 8	do	69·0	121·2	2·27	2·35	276·0
Nov. 21	do	70·0	114·5	2·26	2·30	258·4
Dec. 5	do	50·9	75·2	2·57	2·22	193·3*
Dec. 19	do	50·3	80·4	2·18	2·30	176·0†

*Ice conditions, Feb. 2 to Mar. 23.
† do Dec. 5 to Dec. 31.

DAILY GAUGE HEIGHT AND DISCHARGE of Ghost River at Gillies' Ranch, for 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	3·85	142·00*	1·61	97·20	2·02	105·40	3·22	129·40	1·55	362·50	1·04	[illegible]
2	3·85	142·00†	1·56	96·40	1·12	104·80	3·06	126·20	1·40	301·00	1·04	153·40
3	3·85	142·00	1·56	96·40	1·61	97·20	3·01	125·20	1·03	149·30	0·95	116·50
4	3·85	142·00	1·56	96·40	1·52	95·80	2·81	121·20	1·40	301·00	1·30	200·00
5	3·85	142·00†	1·54	96·10	1·61	97·20	2·56	116·20	2·00	547·00	0·95	116·50
6	3·56	136·20	2·11	107·20	3·41	**98·00	1·56	96·40	1·95	526·50	0·94	112·40
7	3·81	141·20	1·89	102·80	1·21	99·70	1·86	102·20	2·39	706·90	0·93	[illegible]
8	3·90	143·20	1·61	97·20	2·56	116·20	1·90	103·00	2·49	747·90	0·90	[illegible]
9	3·87	142·40	1·59	96·85	3·51	135·20	2·16	106·20	2·30	670·00	1·30	260·00
10	3·91	143·20	1·58	96·70	2·76	120·20	1·56	96·40	1·69	419·90	0·93	108·30
11	3·96	144·20	1·59	96·85	2·77	120·40	1·46	95·70	1·35	280·50	0·92	104·20
12	3·86	142·20	1·56	96·40	2·90	123·00	1·51	95·65*	1·40	301·00	0·90	96·00
13	3·94	143·8	1·61	97·20	0·90	124·00	1·20	120·00†	1·45	321·50	1·02	145·20
14	3·95	144·00	1·58	96·70	0·86	126·20	1·10	150·00‡	1·54	358·40	1·00	137·00
15	3·62	137·40	1·56	96·40	3·11	127·20	1·10	178·00	1·66	407·60	2·80	875·00
16	3·44	133·80	1·56	96·40	2·76	120·20	1·05	157·50†	1·60	383·00	3·30	1080·00
17	3·25	130·00	1·86	102·20	1·36	96·40	1·00	137·00	1·65	403·50	4·01	1371·10
18	2·95	124·00	1·43	95·85	1·41	95·95	1·00	137·00	1·50	342·00	2·85	895·50
19	3·09	126·80	1·60	97·00	0·89	124·90	0·95	116·50	1·59	378·90	1·80	465·00
20	3·15	128·00	1·11	105·40	0·91	123·10	0·89	91·50	1·52	350·20	1·96	530·60
21	3·05	126·00	2·03	105·60	2·76	120·20	0·86	79·60	1·80	465·00	1·45	321·50
22	2·70	119·00	1·72	99·40	2·51	115·20	0·85	75·50	1·35	280·50	1·02	145·20
23	2·36	112·20	1·11	105·40	1·44	95·80	0·95	116·50	1·20	219·00	1·01	141·10
24	2·25	110·00	1·81	101·20	2·42	113·40	0·99	132·90	1·50	342·00	1·02	145·20
25	2·15	108·00	1·71	99·20	3·06	126·20	1·05	157·50	1·40	301·00	1·02	145·20
26	1·95	104·00	1·12	104·80	2·36	112·20	1·05	157·50	1·25	239·50	1·02	145·20
27	1·90	103·00	1·51	95·65	2·54	115·80	1·03	149·30	1·30	260·00	1·01	141·10
28	1·80	101·00	1·61	97·20	3·46	134·20	1·00	137·00	1·35	280·50	1·01	141·10
29	1·74	99·80	1·01	112·10	3·61	137·20	1·00	137·00	1·10	178·00	1·20	219·00
30	1·76	100·20	....	....	3·16	128·20	·50	342·00	1·00	137·00	1·30	200·00
31	1·75	100·00	....	....	3·21	129·20	....	....	0·99	132·90	....	....

*Ice conditions Jan. 1 to Apr. 12.
†Gauge heights interpolated Jan. 1 to 5 and Apr. 13 to 1[illegible]
‡Shifting conditions Apr. 13 and 14.
**Gauge height raised by ice jam.

DAILY GAUGE HEIGHT AND DISCHARGE of Ghost River at Gillies' Ranch, for 1912.—*Concluded.*

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	2·35	690	2·45	732	2·15	609	1·85	486	1·39	297	1·40	276
2	1·20	219	2·40	711	2·10	588	1·84	482	1·44	317	1·45	294
3	1 80	465	2·30	670	2·10	588	1·80	465	1·49	338	1·50	312
4	2·80	875	2·30	670	2·08	580	1·75	445	1·39	297	1·35	248
5	2·85	895	2·25	650	2·14	604	1·74	441	1·40	301	1·22	194
6	3·80	1,285	2·20	629	2·15	608	1·65	404	1·38	293	1·25	186
7	4·20	1,449	2·15	609	2·08	580	1·70	424	1·34	276	1·22	186
8	4·80	1,695	2·05	568	2·28	662	1·75	445	1·34	276	1·22	186
9	4·60	1,613	2·05	568	2·30	670	1·74	441	1·39	297	1·22	186
10	4·20	1,449	2·00	547	2·14	604	1 74	441	1·40	301	1·22	186
11	4·00	1,367	2·02	555	2·10	588	1·73	436	1·45	322	1·21	186
12	3·80	1,285	2·05	568	2·05	568	1·70	424	1·45	322	1·20	186
13	3·80	1,285	1·05	527	2·04	564	1·70	424	1·40	301	1·21	186
14	3·75	1,264	1·90	506	2·00	547	1·70	424	1·39	297	1·20	186
15	3·70	1,244	1·88	498	1·95	527	1·70	424	1·30	260	1·20	186
16	3·50	1,162	1·88	498	1·95	527	1·66	408	1·34	276	1·19	186
17	3·50	1,162	3·35	1,101	1·94	522	1·68	416	1·40	301	1·12	180
18	3·25	1,060	2·95	527	1·90	506	1·66	408	1·39	297	1·10	170
19	3·30	1,080	2·3[illegible]	691	1·88	498	1·65	404	1·40	301	1·30	184
20	3·00	957	2·60	793	1·84	481	1·65	404	1·35	281	1·35	184
21	3·00	957	2·20	629	1·84	481	1·50	342	1·32	268	1·36	184
22	3·00	957	2·20	629	1·95	527	1·55	362	1·30	256	1·49	182
23	3·15	1,019	2·00	547	1·95	527	1·56	367	1·30	252	1·58	180
24	3·00	1,367	2·15	609	1·90	506	1·46	326	1·30	250	1·47	182
25	4·50	1,572	3·00	957	1·90	506	1·54	358	1·20	208	1·58	180
26	3·00	957	2·59	752	1·86	490	1·50	342	1·14	180	1·60	178
27	2·95	937	2·33	682	1·85	486	1·44	317	1·25	228	1·55	181
28	2·70	834	2·50	752	1·83	477	1·44	317	1·30	240	1·60	178
29	2·55	773	2·35	691	1·76	449	1·44	317	1·35	260	1·60	178
30	2·45	732	2·35	691	1·85	486	1·35	281	1·35	256	1·60	178
31	2·30	670	2·32	678	.....		1·34	277		.....	1·70	176

*Shifting conditions Nov. 21 to Dec. 5.
†Ice conditions Dec. 5 to Dec. 31.

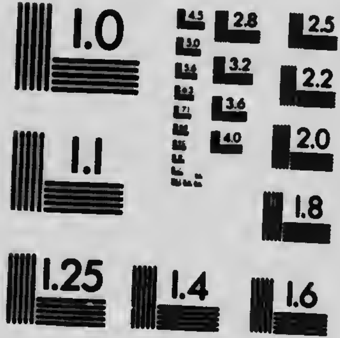
MONTHLY DISCHARGE of Ghost River at Gillies' Ranch, for 1912.

(Drainage area, 367 square miles.)

MONTH.	Discharge in Second-Feet.				Run-Off.	
	Maximum.	Minimum.	Mean.	Per Square Mile.	Depth in inches on Drainage. Area.	Total in Acre-feet.
January	144	100	128	0·35	0·40	7,841
February	112	96	99	0·27	0·29	5,721
March	137	96	115	0·32	0·37	7,098
April	342	76	134	0·36	0·40	7,950
May	748	133	358	0·98	1·13	22,005
June	1,371	96	300	0·82	0·92	17,826
July	1,695	219	1,073	2·92	3·37	65,976
August	1,101	498	653	1·78	2·05	40·151
September	670	449	545	1·48	1·65	32,430
October	486	277	395	1·07	1·23	24,288
November	338	180	278	0·757	0·845	16,542
December	294	176	196	0·534	0·615	12,052
The year	.....	.....	.....	.....	13·270	259·880

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



Discharge Measurements of Jumpingpound Creek near Jumping Pound, Alta., in 1906-8-9.

Date.	Hydrographer.	Width.	Area of section.	Mean velocity.	Gauge height.	Discharge.
1906.		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
June 15	J. F. Hamilton	103	289	0·60	2·70	162
June 16*	do				2·75	169
1908.						
May 6	P. M. Sauder	99·3	250	0·22	2·30	55
May 6*	do	49·4	65	0·88	2·30	57
July 25*	H. R. Carscallen	57·0	74	0·96	2·36	71
September 4	do	89·0	187	0·17	2·05	32
1909.						
June 28	J. C. Keith	93·0	212	0·53	2·48	113
July 20	do	87·0	195	0·33	2·24	64
September 7*	do	28·5	34	0·70	1·96	24

* Measurements taken at wading sections.

Daily Gauge Height and Discharge of Jumpingpound Creek near Jumping Pound, Alta., for 1908.

Day.	April.		May.		June.	
	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1			2·40		5·00	751
2			2·30		5·30	829
3			2·30		4·70	673
4			2·30		5·00	751
5			2·30		5·30	829
6			2·30		5·00	751
7			2·30		4·70	673
8			2·50		4·00	491
9			2·80		3·90	465
10			2·70		3·60	387
11			2·60		3·50	361
12			2·50		3·50	361
13			2·70		3·40	336
14			2·80		3·40	336
15			3·00		3·30	311
16			3·30		3·30	311
17			3·30		3·20	286
18			3·10		3·20	286
19	2·50		3·20		3·10	261
20	2·45		3·30		3·30	311
21	2·40		3·30		3·30	311
22	2·40		3·20		3·20	286
23	2·35		3·20		3·20	286
24	2·30		3·10		3·10	261
25	2·30		3·10		3·00	236
26	2·30		3·20		3·00	236
27	2·30		3·30		3·30	311
28	2·40		3·20		3·20	286
29	2·40		3·20		3·00	236
30	2·40		3·50		3·00	236
31			3·70			

Daily Gauge Height and Discharge of Jumpingpound Creek, near Jumping Pound Alta., for 1908.—*Continued.*

Day.	July.		August.		September.		October.	
	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	2·80	186	2·20	57	2·20	57	2·00	27
2	2·70	162	2·20	57	2·10	40	2·10	40
3	2·60	139	2·20	57	2·10	40	2·10	40
4	2·60	139	2·20	57	2·10	40	2·10	40
5	2·60	139	2·10	40	2·00	27	2·10	40
6	2·60	139	2·10	40	2·00	27	2·10	40
7	2·60	139	2·10	40	2·00	27	2·10	40
8	2·50	117	2·10	40	2·00	27	2·10	40
9	2·50	117	2·10	40	2·00	27	2·10	40
10	2·50	117	2·10	40	2·00	27	2·10	40
11	2·40	96	2·20	57	2·00	27	2·10	40
12	2·40	96	2·30	76	2·00	27	2·10	40
13	2·40	96	2·30	76	2·00	27	2·10	40
14	2·40	96	2·20	57	2·00	27	2·10	40
15	2·40	96	2·20	57	2·00	27	2·10	40
16	2·50	117	2·20	57	2·00	27	2·10	40
17	2·50	117	2·20	57	1·90	20	2·10	40
18	2·40	96	2·10	40	1·90	20	2·10	40
19	2·40	96	2·10	40	1·90	20	2·10	40
20	2·40	96	2·10	40	1·90	20	2·10	40
21	2·40	96	2·10	40	1·90	20	2·10	40
22	2·40	96	2·00	27	1·90	20	2·10	40
23	2·30	76	2·00	27	1·90	20	2·10	40
24	2·30	76	2·10	40	1·90	20	2·10	40
25	2·30	76	2·20	57	2·00	27	2·10	40
26	2·20	57	2·20	57	2·10	40	2·10	40
27	2·20	57	2·20	57	2·10	40		
28	2·20	57	2·20	57	2·10	40		
29	2·20	57	2·10	40	2·00	27		
30	2·20	57	2·20	57	2·00	27		
31	2·20	57	2·20	57				

Note.—Rating table does not apply to gauge heights previous to June 1st.

Daily Gauge Height and Discharge of Jumpingpound Creek near Jumping Pound, Alta., for 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	2·60	139	3·30	311	2·30	76	2·50	117	2·00	27	1·90	20
2	2·60	139	3·20	286	2·30	76	2·40	96	2·00	27	1·90	20
3	2·70	162	3·10	261	2·30	76	2·40	96	2·00	27	1·90	20
4	2·70	162	3·10	261	2·30	76	2·40	96	2·00	27	1·90	20
5	2·60	139	3·20	286	2·30	76	2·40	96	2·00	27	1·90	20
6	2·50	117	3·20	286	2·40	96	2·40	96	2·00	27	1·90	20
7	2·50	117	3·20	286	3·00	236	2·30	76	2·00	27	1·90	20
8	2·40	96	3·10	261	2·80	186	2·30	76	2·00	27	1·90	20
9	2·40	96	3·10	261	2·70	162	2·30	76	2·00	27	1·90	20
10	2·30	76	3·00	236	2·70	162	2·30	76	2·00	27	1·90	20
11	2·40	96	3·00	236	2·60	139	2·40	96	2·00	27	1·90	20
12	2·60	139	2·90	211	2·60	139	2·30	76	2·00	27	1·90	20
13	2·80	186	2·90	211	2·70	162	2·30	76	2·00	27	1·90	20
14	2·80	186	2·80	186	2·70	162	2·20	57	2·00	27	1·00	20
15	2·70	162	2·80	186	2·60	139	2·20	57	2·00	27	1·90	20
16	2·70	162	2·70	162	2·50	117	2·20	57	2·00	27	1·90	20
17	2·80	186	2·70	162	2·50	117	2·20	57	2·00	27	1·90	20
18	2·80	186	2·60	139	2·40	96	2·20	57	2·00	27	1·90	20
19	2·60	139	2·60	139	2·40	96	2·20	57	2·00	27	1·90	20
20	2·90	211	2·50	117	2·30	76	2·10	40	2·00	27	1·90	20
21	3·10	261	2·50	117	2·30	76	2·10	40	1·90	20	1·90	20
22	3·30	311	2·50	117	2·30	76	2·10	40	1·90	20	1·90	20
23	3·30	311	2·50	117	2·30	76	2·10	40	1·90	20	1·90	20
24	4·00	491	2·60	139	2·20	57	2·10	40	1·90	20	1·90	20
25	4·00	491	2·60	139	2·20	57	2·10	40	1·90	20	1·90	20
26	3·80	439	2·60	139	2·60	139	2·10	40	1·90	20	1·90	20
27	3·60	387	2·50	117	2·60	139	2·10	40	1·90	20	1·90	20
28	3·50	361	2·40	96	2·90	211	2·00	27	1·90	20	1·90	20
29	3·40	336	2·40	96	2·80	186	2·00	27	1·90	20	1·90	20
30	3·30	311	2·40	96	2·70	162	2·00	27	1·90	20	1·90	20
31	3·30	311	....	....	2·50	117	2·00	27	....	....	1·90	20

Monthly Discharge of Jumpingpound Creek near Jumping Pound, Alta., for 1908–9.

(Drainage area, 178 square miles.)

Month.	Discharge in Second-Feet.				Run-Off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on drainage area.	Total in acre-feet.
1908.						
June	829	236	414·8	2·330	2·600	24,684
July	186	57	101·9	0·572	0·659	6,264
August	57	27	49·7	0·279	0·322	3,056
September	57	20	28·7	0·161	0·180	1,710
October (1-26)	40	27	39·5	0·222	0·215	2,037
The period	....	....	....	....	....	37,751
1909						
May	491	76	222·8	1·251	1·442	13,698
June	311	96	188·6	1·059	1·182	11,221
July	236	57	121·3	0·681	0·785	7,459
August	117	27	61·9	0·347	0·400	3,806
September	27	20	24·7	0·138	0·154	1,468
October	20	20	20·0	0·112	0·129	1,230
The period	....	....	....	....	....	38,882

Discharge Measurements of Jumpingpound Creek at Sec. 30, Tp. 24, Rge. 4, W. 5th M., near Jumping Pound for 1910.

Date.	Hydrographer.	Width.	Area of section.	Mean velocity.	Gauge height	Discharge
1910		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
May 23	J. C. Keith	54	32·50	1·11	2·08	36·19†
June 28	do	54	166·53	0·16	1·97	26·38†
July 21	do	68	148·54	0·05	1·78	7·42
Aug. 16	do	77·8	163·67	0·156	1·98	25·53†
Sept. 7	do	90	177·03	0·214	2·10	38·02†
Sept. 30	H. R. Carscallen	101	215·14	0·22	2·12	47·22

† At wading stations near regular station.

Daily Gauge Height and Discharge of Jumpingpound Creek near Jumping Pound, for 1910.

Day.	April.		May.		June.	
	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1			2·00	27	1·90	16
2			2·00	27	1·90	9
3			2·00	27	2·10	40
4			2·00	27	2·10	40
5			2·00	27	2·00	27
6			2·00	27	2·00	27
7			2·00	27	2·00	27
8			2·00	27	2·00	27
9	1·80	9	2·00	27	2·10	40
10	1·80	9	2·00	27	2·10	40
11	1·80	9	2·00	27	2·10	40
12	1·80	9	2·00	27	2·10	40
13	1·80	9	2,00	27	2·10	40
14	1·80	9	2·00	27	2·10	40
15	1·80	9	1·90	16	2·10	40
16	1·80	9	1·90	16	2·10	40
17	1·80	9	1·90	16	2·20	57
18	1·80	9	1·90	16	2·20	57
19	1·90	16	2·00	27	2·20	57
20	1·90	16	2·00	27	2·30	76
21	1·90	16	2·00	27	2·30	76
22	·90	16	2·00	27	2·30	76
23	1·90	16	1·90	16	2·30	76
24	1·90	16	1·90	16	2·20	57
25	1·90	16	1·99	16	2·10	40
26	1·90	16	1·90	16	2·00	27
27	1·90	16	1·90	16	2·00	27
28	·90	16	1·90	16	2·00	27
29	·90	16	1·90	16	1·90	16
30	1·90	16	1·90	16	1·90	16
31			1·90	16		...

DAILY GAUGE HEIGHT AND DISCHARGE of Jumpingpound Creek near Jumping Pound, for 1910.—*Continued.*

Day.	July.		August.		September.		October.	
	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	1·90	16	1·60	3·5	1·80	9	2·10	40
2	1·80	9	1·60	3·5	1·80	9	2·10	40
3	1·80	9	[illegible]	3·5	1·80	9	2·10	40
4	1·80	9	[illegible]	3·5	1·80	9	2·10	40
5	1·80	9	9·70	5	1·90	16	2·10	40
6	1·80	9	1·80	9	1·95	21	2·10	40
7	1·80	9	1·90	16	2·12	43	2·00	27
8	1·80	9	1·70	5	2·20	57	2·00	27
9	[illegible]	9	1·70	5	2·20	57	2·00	27
10	[illegible]	9	1·70	5	2·20	57	1·90	16
11	1·80	9	1·70	5	2·20	57	1·90	16
12	1·80	9	1·80	9	2·20	57	1·90	16
13	1·80	9	1·90	16	2·20	57	1·90	16
14	1·70	5	2·00	27	2·30	76	1·80	9
15	[illegible]	5	2·00	27	2·30	76	1·80	9
16	1·70	5	2·00	27	2·30	76	1·80	9
17	1·70	5	1·90	16	2·40	96	1·80	9
18	1·70	5	1·70	5	2·40	96	1·80	9
19	1·70	5	1·70	5	2·50	117	1·80	9
20	1·70	5	1·70	5	2·50	117	1·80	9
21	1·70	[illegible]	1·70	5	2·50	117	1·80	9
22	1·70	5	1·70	5	2·50	117	1·80	9
23	1·70	5	1·80	9	2·40	96	1·70	5
24	1·70	5	1·80	9	2·40	96	1·70	5
25	1·60	3·5	1·70	5	2·30	76	1·70	5
26	1·60	3·5	1·70	5	2·30	76	1·70	5
27	1·60	3·5	1·70	5	2·30	76	1·70	5
28	1·60	3·5	1·70	5	2·20	57	1·70	5
29	1·60	3·5	1·80	9	2·20	57	1·70	5
30	1·60	3·5	1·80	9	2·10	40	1·70	5
31	1·60	3·5	1·80	9	....	....	1·70	5

MONTHLY DISCHARGE of Jumpingpound Creek near Jumping Pound, for 1910.

(Drainage area, 187 square miles.)

Month.	Discharge in Second-Feet.				Run-Off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on Drainage area.	Total in acre-feet.
April (9-30)	16	9	12·8	·063	·052	560
May	27	16	22·4	·119	·137	1,377
June	76	9	40·6	·216	·241	2,416
July	16	3·5	6·56	·035	·040	403
August	27	3·5	8·9	·042	·048	547
September	117	9	64·0	·342	·282	3,808
October	40	5	16·5	·088	·101	1,014
The period	.....	.....	.....	.....	.....	10,125

Discharge Measurements of Jumpingpound Creek at Jumping Pound, Alta., in 1911.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
May 2	H. C. Ritchie	77	168·3	0·21	2·02	35·2
June 8	R. T. Sailman	99·8	215·7	0·83	2·56	178·2
July 12	L. R. Brereton	98	209·2	0·62	2·39	130·6
Aug. 16	do	109	268·5	1·30	2·92	350·7
Sept. 14	do	98	208·6	0·66	2·44	137·9
Oct. 19	do	75	169·7	0·36	2·23	60·2

Daily Gauge Height and Discharge of Jumpingpound Creek at Jumping Pound, Alta., for 1911.

Day.	May.		June.		July.		August.		September.		October.	
	Gauge Height.	Discharge.	Gauge Heigth.	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	†2·02	30·8	3·30	548	2·98	382	2·35	106	2·56	184	2·47	149
2	2·02	30·8	3·20	496	2·99	387	2·53	172	2·54	176	2·49	156
3	†2·02	30·8	3·00	392	2·81	297	2·65	223	2·95	366	2·49	156
4	2·02	30·8	2·80	292	2·80	292	2·70	246	2·95	366	2·48	152
5	2·02	30·8	2·60	201	2·75	269	2·75	269	2·90	341	2·49	156
6	2·02	30·8	2·60	201	2·65	223	2·75	269	2·82	302	2·45	141
7	2·02	30·8	2·60	201	2·60	201	4·35	1,116	2·72	255	2·43	134
8	2·02	30·8	2·56	184	2·55	180	4·50	1,200	2·70	246	2·39	120
9	2·02	30·8	2·49	156	2·51	164	4·00	921	2·63	214	2·37	113
10	2·02	30·8	2·49	156	2·50	160	3·50	652	2·63	214	2·36	109
11	2·02	30·8	2·49	156	2·50	160	3·25	522	2·55	180	2·33	100
12	2·02	30·8	2·48	152	2·39	120	3·00	392	2·55	180	2·32	96·4
13	2·03	32·2	2·48	152	2·35	106	2·95	366	2·50	160	2·30	90
14	2·30	90	2·47	149	2·30	90	2·85	316	2·45	141	2·29	87·2
15	2·40	123	2·47	149	2·30	90	3·01	397	2·42	130	2·30	90
16	3·00	392	2·45	141	2·28	84·4	2·92	351	2·40	123	2·29	87·2
17	2·90	341	2·44	137	2·25	76	2·85	316	2·38	116	2·28	84·4
18	2·70	246	2·42	130	2·25	76	2·73	260	2·37	113	2·29	87·2
19	2·60	201	2·40	123	2·24	73·4	2·70	246	2·36	109	2·23	70·8
20	2·50	160	2·30	90	2·24	73·4	2·60	201	2·36	109		
21	2·40	123	2·21	65·6	2·24	73·4	2·70	246	2·38	116		
22	2·50	160	2·15	52	3·30	548	2·70	246	2·40	123		
23	2·40	123	2·15	52	3·25	522	2·65	223	2·46	145		
24	2·40	123	2·55	180	3·00	392	2·60	201	2·48	152		
25	2·40	123	2·91	346	2·78	283	2·73	260	2·49	156		
26	2·50	160	2·70	246	2·75	269	2·73	260	2·50	260		
27	2·50	160	2·65	223	2·65	223	2·70	246	2·50	160		
28	2·49	123	2·95	366	2·56	184	2·68	237	2·52	168		
29	2·50	160	2·95	306	2·45	141	2·62	210	2·49	156		
30	2·90	341	2·99	387	2·39	120	2·60	201	2·47	149		
31	3·00	392	......		2·35	106	1·58	193	.....	.....		

†No observations, gauge height interpolated.

MONTHLY DISCHARGE of Jumpingpound Creek near Jumping Pound, for 1911.

(Drainage area, 187 square miles.)

Month.	Discharge in Second-Feet.				Run-Off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on Drainage area.	Total in acre-feet.
May	392	30·8	127	0·679	0·78	7,809
June	548	52·0	216	1·155	1·29	12,853
July	548	73·4	205	1·096	1·26	12,605
August	1,200	106·0	357	1·909	2·20	21,951
September	366	109·0	184	0·984	1·10	10,949
October (1-19)	156	70·8	115	0·615	0·43	4,334
The period					7·06	70,501

DISCHARGE MEASUREMENTS of Jumpingpound Creek at Jumping Pound, Alta., in 1912.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
April 18	H. C. Ritchie	70·0	189·00	0·42	2·43	80·06
May 17	do	99·5	208·70	0·57	2·40	118·63
May 31	do	97·5	198·00	0·594	2·35	117·59
June [illegible]	do	90·5	176·75	0·24	2·17	43·17
June [illegible]	do	97·5	189·85	0·64	2·37	121·14
July 12	do	110·5	314·75	2·58	3·44	800·92
July 2[illegible]	do	110·0	285·63	2·50	3·32	715·50
Aug. 9	do	97·5	190·35	0·92	2·42	174·74
Aug. 23	do	94·5	178·00	0·70	2·35	122·80
Sept. 3	H. R. Cram	97·5	196·70	0·78	2·37	152·60
Sept. 27	do	97·5	179·00	0·71	2·36	127·00
Oct. 10	do	96·5	189·00	0·71	2·37	134·00
Oct. 25	H. C. Ritchie	94·0	167·40	0·48	2·30	80·40
Nov. 7	do				2·54	114·30

Daily Gauge Height and Discharge of Jumpingpound Creek near Jumping Pound, Alta., for 1912.

Day.	April.		May.		June.	
	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	......	......	2·82	308·00	2·34	112·60
2	......	......	2·55	165·00	2·36	121·80
3	......	......	2·50	140·00	2·40	141·00
4	......	......	2·76	280·00	2·32	103·80
5	......	......	2·68	234·00	2·30	95·00
6	......	......	2·58	182·00	2·27	82·40
7	......	......	2·55	174·00	2·25	74·00
8	......	......	2·53	166·00	2·29	90·80
9	......	......	2·55	177·00	2·28	84·60
10	......	......	2·43	120·00	2·25	74·00
11	......	......	2·39	104·00	2·20	56·00
12	......	......	2·35	89·00	2·18	50·00
13	......	......	2·35	90·00	2·15	41·00
14	......	......	2·35	90·50	2·25	74·00
15	......	......	2·40	115·00	3·35	736·00
16	......	......	2·41	118·50	3·40	772·00
17	......	......	2·40	118·00	3·03	512·40
18	*2·43	80·06	2·45	144·00	3·01	498·80
19	2·40	70·00	2·55	198·00	2·90	425·00
20	2·25	28·00	2·55	200·00	2·80	363·00
21	2·25	29·00	2·70	286·60	2·60	248·00
22	2·23	25·00	2·59	226·00	2·50	194·00
23	2·20	20·00	2·65	262·00	2·48	182·60
24	2·20	20·50	2·60	237·00	2·45	167·00
25	2·20	21·00	2·55	210·00	2·50	194·00
26	2·20	21·50	2·60	238·00	2·45	167·00
27	2·18	19·00	2·60	240·00	2·45	167·00
28	2·18	19·50	2·45	160·00	2·43	156·60
29	2·15	17·00	2·40	138·00	2·40	141·00
30	2·64	220·00	2·38	126·00	2·55	220·00
31	......	......	2·35	117·50		....

*Shifting conditions from April 18 to May 3'

Daily Gauge Height and Discharge of Jumpingpound Creek, near Jumping Pound, for 1912.—*Concluded.*

Day.	July.		August.		September.		October.		November.	
	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.
1	2·50	194·00	2·75	333·00	2·38	131·40	2·30	95·00	2·30	95·00
2	2·70	304·00	2·70	304·00	2·35	117·00	2·28	86·60	2·30	95·00
3	2·90	425·00	2·65	276·00	2·38	131·40	2·28	86·60	2·30	95·00
4	2·95	458·00	2·60	248·00	2·38	131·40	2·29	90·80	2·30	95·00
5	3·00	492·00	2·55	255·00	2·50	194·00	2·30	95·00	2·30	95·00
6	3·10	560·00	2·60	248·00	2·60	248·00	2·30	95·00	2·30	95·00
7	3·25	664·00	2·50	194·00	2·61	253·60	2·29	90·80	2·30	95·00
8	3·60	916·00	2·45	167·00	2·65	276·00	2·30	95·00	2·30	95·00
9	3·90	1,132·00	2·40	141·00	2·60	248·00	2·29	90·80	2·30	95·00
10	4·25	1,384·00	2·35	117·00	2·60	248·00	2·30	95·00	2·30	95·00
11	4·00	1,204·00	2·45	167·00	2·60	248·00	2·35	117·00	2·30	95·00
12	3·60	916·00	2·55	220·00	2·50	194·00	2·38	131·40	2·30	95·00
13	3·80	1,060·00	2·50	194·00	2·40	141·00	2·40	141·00	2·30	95·00
14	3·60	916·00	2·50	194·00	2·35	117·00	2·38	131·40	2·30	95·00
15	3·40	772·00	2·47	177·80	2·30	95·00	2·37	126·60	2·30	95·00
16	3·30	700·00	2·43	156·60	2·25	74·00	2·36	121·80	....	....
17	3·20	628·00	2·95	458·00	2·40	141·00	2·36	121·80	....	....
18	3·00	492·00	2·90	425·00	2·40	141·00	2·35	117·00	....	....
19	2·80	363·00	2·70	304·00	2·35	117·00	2·35	117·00	....	....
20	3·10	560·00	2·60	248·00	2·30	95·00	2·35	117·00	....	....
21	3·00	492·00	2·55	220·00	2·25	74·00	2·35	117·00	....	....
22	3·00	492·00	2·50	194·00	2·30	95·00	2·34	112·60	....	....
23	3·40	772·00	2·35	117·00	2·30	95·00	2·35	117·00	....	....
24	4·00	1,204·00	2·30	95·00	2·35	117·00	2·35	117·00	....	....
25	4·00	1,204·00	2·56	225·60	2·30	95·00	2·32	103·80	....	....
26	3·80	1,060·00	2·50	194·00	2·36	121·80	2·30	95·00	....	....
27	3·30	700·00	2·65	276·00	2·34	112·60	2·29	90·80	....	....
28	3·15	594·00	2·60	248·00	2·30	95·00	2·28	86·60	....	....
29	3·00	492·00	2·60	194·00	2·31	99·40	2·27	82·40	....	....
30	2·92	438·20	2·45	167·00	2·30	95·00	2·26	78·20	....	....
31	2·80	363·00	2·40	141·00	....	....	2·26	78·20	....	....

Note.—Gauge was not read after Nov. 15.

Monthly Discharge of Jumpingpound Creek near Jumping Pound, for 1912.

(Drainage area, 187 square miles.)

Month.	Discharge in Second-Feet.				Run-Off.	
	Maximum.	Minimum.	Mean.	Per Square Mile.	Depth in inches on Drainage Area.	Total in Acre-feet.
April	220	19·0	45·4	0·24	0·116	1,171
May	308	89·0	175·9	0·94	1·084	10,816
June	772	41·0	211·5	1·13	1·261	12,585
July	1,384	194·0	708·1	3·78	4·358	43,539
August	333	95·0	222·6	1·19	1·372	13,685
September	276	74·0	144·7	0·77	0·859	8,611
October	131	78·2	104·6	0·56	0·646	6,429
November (1-15)	950	95·0	95·0	0·51	0·284	2,826
The period	....	....	....	....	9·980	99,662

Note.—No gauge readings after Nov. 15.

DISCHARGE MEASUREMENTS of Bow River at Calgary, Alta., in 1908-9.

Date.	Hydrographer.	Width.	Area of section	Mean velocity.	Gauge height.	Discharge.
1908.		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
April 29	P. M. Sauder	192·5	730	2·73	3·35	1,996
May 11	do	210·0	1,059	4·72	5·00	4,994
May 16	H. R. Carscallen	218·0	1,150	5·22	5·38	6,053
June 3	P. M. Sauder	298·6	1,893	·92	8·03	13,099
July 20	H. R. Carscallen	287·9	2,234	·82	6·99	10,779
Sept. 1	do	211·5	1,607	2·56	4·50	4,109
Oct. 9	P. M. Sauder	201·5	1,404	1·63	3·52	2,284
1909.						
April 23	P. M. Sauder	174·0	1,169	1·07	2·69	1,248
May 21	do	205·5	1,742	2·52	3·98	3,713
June 7	do	284·5	2,244	5·71	7·05	12,807
June 26	J. C. Keith	274·0	2,159	5·21	6·73	11,242
June 30	do	277·5	2,074	4·91	6·43	10,179
July 7	do	334·2	2,863	7·67	8·99	21,952
July 16	do	278·5	2,095	4·90	6·46	10,272
Aug. 6	do	228·5	1,821	3·85	5·46	7,019
Aug. 26	do	209·0	1,564	2·71	4·40	4,252
Sept. 17	do	203·5	1,425	2·18	3·785	3,0[illegible]
Oct. 26	P. M. Sauder	196·5	1,306	1·50	3·30	1,958

DAILY GAUGE HEIGHT AND DISCHARGE of Bow River, at Calgary, Alta., for 1908.

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	....	....	6·70	9,090	6·70	9,490	5·50	6,400	4·60	4,300	3·80	2,790
2	....	....	8·95	16,325	6·60	9,210	5·60	6,660	4·40	3,900	3·80	2,790
3	....	....	8·25	13,820	7·20	11,070	5·50	6,400	4·30	3,700	3·80	2,790
4	....	....	8·45	14,550	7·70	12,720	5 50	6,400	4·30	3,700	3·80	2,790
5		....	9·50	18,450	7·50	12,090		5,900	4·30	3,700	3·80	2,790
6	....	....	9·63	18,880	7·00	10,500		5,900	4·30	3,700	3·70	2,620
7	....	....	0·45	18,330	7·00	10,520	[illegible]	5,900	4·20	3,510	3·70	2,620
8	....	....	9·20	17,390	7·00	10,540	5·40	6,150	4·20	3,510	3·70	2,620
9	....	....	8·9	16,280	6·90	10,260	5 30	5,900	4·20	3,510	3·60	2,450
10	5·00	4,990	9·50	18,570	7·60	12,530	5·30	5,900	4·20	3,510	3·40	2,110
11	5·00	4,990	9·10	17,080	7·60	12,550	5·30	5,900	4·20	3,510	3·40	2,110
12	5·10	5,200	9·	16,740	7·50	12,230	5·30	5,900	4·20	3,510	3·40	2,110
13	5·30	5,640	8·8	15,990	7·40	12,250	5·30	5,900	4·10	3,330	3·40	2,110
14	5·30	5,640	8·2	13,890	7·50	12,270	5·20	5,650	4·20	3,510	3·40	2,110
15	5·35	5,750	7·90	12,800	7·50	12,290	5·00	5,160	4·30	3,700	3·40	2,110
16	5·40	5,860	8·00	13,160	7·50	12,310	4·00	4,930	4·30	3,700	3·40	2,110
17	5·75	6,660	8·30	14,300	7·50	12,330	4·90	4,930	4·30	3,700	3·40	2,110
18	5·65	6,425	7·80	12,660	7·40	12,030	4·90	4,930	4·50	4,100	3·30	1,940
19	5·55	6,195	7·40	11,420	7·30	11,720	4·90	4,930	4·50	4,100	3·40	2 110
20	5·50	6,080	7·40	11,460	7·00	10,780	4·90	4,930	4·40	3,900	3·50	2,280
21	5·45	5,970	7·20	10,860	6·90	10,470	4·90	4,930	4·30	3,700	3·30	1,940
22	5·30	5,640	7·00	10,260	6·90	10,470	4·90	4,[illegible]	4·20	3,510	3·30	1,940
23	5 30	5,640	6·70	0,430	6·70	9,850	4·90	4,[illegible]	4·20	3,510	3·30	1,940
24	5·20	5,420	6·50	8,890	6·70	9,850	4·90	4,[illegible]	4·20	3,510	3·30	1,940
25	5·30	5,640	6·70	9,450	6·70	9,850	5·10	[illegible],400	4·20	3,510	3·40	2,110
26	5·50	6,080	7·60	12,180	6·50	9,240	5·10	5,400	4·20	3,510	3·40	2,110
27	5·50	6,080	8·10	13,960	6·30	8,640	5·10	5,400	4·20	3,510	3·40	2,110
28	5·50	6,080	7·60	12,300	6·20	8,340	4·80	4,710	3·90	2,970	3·40	2,110
29	5·50	6,080	7·30	11,320	6·00	7,760	4·80	4,710	3·90	2,970	....	....
30	5·60	6,310	6·70	9,470	5·90	7,480	4·70	4,500	3·80	2,790	....	....
31	5·90	7,020	....	....	5·50	6,400	4·60	4,300	....	....	....	....

Daily Gauge Height and Discharge of Bow River, at Calgary, Alta., for 1909.

Day.	April.		May.		June		July.	
	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	....	....	2·70	1,280	6·60	11,100	6·70	11,130
2	....	....	2·90	1,620	7·60	15,230	6·90	11,910
3	....	....	3·30	2,370	8·60	20,220	7·00	12,330
4	....	....	3·70	3,130	8·30	18,660	7·30	13,610
5	....	....	3·00	1,800	7·90	16,670	7·50	14,480
6	....	....	2·90	1,620	7·60	15,230	7·50	14,480
7	....	....	2·80	1,440	7·00	12,600	9·00	22,020
8	....	....	2·80	1,440	6·60	10,971	8·90	21,490
9	....	....	2·70	1,280	6·30	9,884	8·50	19,380
10	....	....	2·80	1,440	6·30	9,873	8·30	18,340
11	....	....	3·30	2,370	6·60	10,936	7·80	15,860
12	....	....	3·10	1,990	7·50	14,684	7·60	14,940
13	....	....	3·50	2,750	7·80	16,054	7·30	13,610
14	....	....	3·50	2,750	8·20	18,024	7·10	12,750
15	....	....	3·70	3,130	8·10	17,504	6·70	11,130
16	....	....	3·50	2,750	8·00	16,988	6·50	10,400
17	....	....	3·30	2,370	8·20	17,974	6·50	10,400
18	....	....	3·30	2,370	8·30	18,470	6·40	10,040
19	....	....	3·70	3,130	8·20	17,941	6·20	9,360
20	2·70	1,280	4·00	3,760	8·20	17,925	6·00	8,690
21	2·70	1,280	4·00	3,760	8·00	16,910	5·80	8,040
22	2·70	1,280	4·20	4,200	7·90	16,391	5·80	8,040
23	2·70	1,280	4·30	4,430	7·70	15,[illegible]41	5·70	7,740
24	2·70	1,280	4·80	5,640	7·10	12,776	5·80	8,040
25	2·80	1,440	5·50	7,520	6·90	11,922	5·90	8.360
26	2·80	1,440	5·90	8,740	6·80	11,510	6·00	8,690
27	2·80	1,440	5·70	8,120	6·50	10,400	6·80	11,510
28	2·90	1,620	6·00	9,050	6·50	10,400	6·70	11,130
29	2·70	1,280	6·20	9,700	6·50	10,400	6·30	9,700
30	2·70	1,280	6·30	10,040	6·40	10,040	6·10	9,020
31	....	....	6·20	9,700	....	....	6·00	8,690

Daily Gauge Height and Discharge of Bow River, at Calgary, Alta., for 1909.—*Continued.*

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	5·90	8,360	4·40	4,290	3·60	2,640	3·20	1,88
2	5·80	8,040	4·30	4,070	3·70	2,830	3·20	1,880
3	5·70	7,740	4·30	4,070	3·70	2,830	3·20	1,880
4	5·70	7,740	4·30	4,070	3·80	3,020	3·20	1,880
5	5·60	7,440	4·40	4,290	3·70	2,830	3·20	1,880
6	5·40	6,850	4·40	4,290	3·70	2,830	3·20	1,880
7	5·30	6,570	4·40	4,290	3·60	2,640		
8	5·10	6,010	4·40	4,290	3·60	2,640		
9	5·00	5,730	4·30	4,070	3·60	2,640		
10	5·00	5,730	4·30	4,070	3·50	2,450		
11	4·90	5,470	4·30	4,070	3·50	2,450		
12	4·90	5,470	4·30	4,070	3·60	2,640		
13	4·80	5,220	4·20	3,850	3·60	2,640		
14	4·80	5,220	4·10	3,630	3·50	2,450		
15	4·80	5,220	4·00	3,410	3·50	2,450		
16	4·80	5,220	3·90	3,210	3·50	2,450		
17	4·70	4,980	3·80	3,020	3·40	2,260		
18	4·70	4,980	3·90	3,210	3·40	2,260		
19	4·70	4,980	3·90	3,210	3·40	2,260		
20	4·70	4,980	3·90	3,210	3·40	2,260		
21	4·70	4,980	3·90	3,210	3·40	2,260		
22	4·70	4,980	3·80	3,020	3·40	2,260		
23	4·70	4,980	3·80	3,020	3·30	2,070		
24	4·70	4,980	3·70	2,830	3·30	2,070		
25	4·60	4,740	3·60	2,640	3·30	2,070		
26	4·40	4,290	3·60	2,640	3·30	2,070		
27	4·50	4,510	3·60	2,640	3·20	1,880		
28	4·60	4,740	3·60	2,640	3·20	1,880		
29	4·50	4,510	3·50	2,450	3·20	1,880		
30	4·40	4,290	3·50	2,450	3·20	1,880		
31	4·40	4,290			3·20	1,880		

Monthly Discharge of Bow River at Calgary, Alta., for 1908-1909.

(Drainage area, 3,828 square miles.)

Month.	Discharge in Second-Feet.				Run-Off.	
	Maximum.	Minimum.	Mean.	Per Square Mile.	Depth in inches on Drainage area.	Total in acre-feet.
1908.						
May (10-31)	7,093	5,063	5,954·9	1·556	1·273	259,850
June	18,880	9,050	13,701·5	3·579	3·993	815,290
July	13,134	6,631	10,801·1	2·822	3·253	664,167
August	6,873	4,496	5,652·2	1·476	1·702	347,536
September	4,496	2,904	3,648·2	0·953	1·063	217,084
October (1-28)	2,904	1,940	2,400·2	0·627	0·653	133,300
The period						2,437,227
1909.						
April (20-30)	1,620	1,280	1,354·5	0·354	0·145	29,553
May	10,126	1,280	4,176·2	1·091	1·258	256,784
June	20,306	10,069	14,527·4	3·795	4·234	864,444
July	22,051	8,060	12,263·2	3·204	3·694	754,018
August	8,680	4,314	5,878·9	1·536	1·771	361,482
September	4,758	2,490	3,703·0	0·967	1·064	220,343
October	3,106	1,880	2,422·9	0·633	0·729	148,977
November (1-6)	1,880	1,880	1,880·0	0·491	0·109	22,373
The period						2,657,974

Note.—The discharges of the Canadian Pacific Railway Company's canal have been added to those of Bow River at Cushing Bridge, in this table.

Discharge Measurements of Bow River at Calgary, in 1910.

Date.	Hydrographer.	Width.	Area of section.	Mean velocity.	Gauge height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
May 12	J. C. Keith	224·5	1,739·00	3·90	5·31	6,774·50
May 28	do	282·5	2,082·38	5·77	6·58	12,020·62
June 16	do	281·5	2,093·18	5·38	5·585	11,265·10
June 22	do	296·0	2,120·70	5·87	7·145	12,455·85
July 12	do	255·5	1,819·72	4·45	5·895	8,100·98
Aug. 6	do	227·0	1,733·50	3·90	5·475	6,755·10
Aug. 18	do	220·5	1,599·68	3·18	4·95	5,081·93
Sept. 20	do	207·0	1,451·90	2·50	4·20	3,640·74
Oct. 14	H. R. Carscallen	200·0	1,434·11	2·41	4·17	3,457·45

Daily Gauge Height and Discharge of Bow River, at Calgary, for 1910.

Day.	April.		May.		June.	
	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1			4·6	4,860	5·8	8,380
2			4·5	4,620	6·0	9,070
3			4·2	3,930	6·1	9,430
4			4·2	3,930	5·8	8,380
5			4·2	3,930	5·6	7,710
6			4·1	3,700	5·9	8,720
7	2·7	760	4·6	4,860	5·9	8,720
8	2·9	1,160	5·1	6,190	6·3	10,170
9	2·9	1,160	5·2	6,480	6·1	9,430
10	2·9	1,160	5·5	7,390	6·0	9,070
11	2·9	1,160	5·6	7,710	6·2	9,800
12	2·9	1,160	5·4	7,080	7·1	13,240
13	2·9	1,160	5·2	6,480	7·3	14,020
14	2·9	1,160	5·1	6,190	6·8	12,070
15	2·9	1,160	5·0	5,910	6·7	11,680
16	2·9	1,160	4·9	5,640	6·7	11,680
17	2·9	1,160	4·9	5,640	*6·7	11,560
18	2·9	1,160	4·8	5,360	*7·3	13,640
19	2·9	1,160	4·9	5,640	*7·1	12,760
20	3·0	1,360	4·9	5,640	*6·9	11,800
21	3·0	1,360	4·9	5,640	*6·9	11,680
22	3·1	1,560	4·8	5,360	7·0	11,880
23	3·2	1,760	5·0	5,910	6·6	10,430
24	3·2	1,760	5·6	7,710	6·3	9,390
25	3·5	2,380	5·9	8,720	6·1	8,710
26	4·0	3,470	6·5	10,920	6·1	8,710
27	4·2	3,930	6·8	12,070	6·4	9,730
28	4·5	4,620	6·6	11,300	6·6	10,430
29	4·7	5,110	6·5	10,920	6·6	10,430
30	4·6	4,860	6·0	9,070	6·5	10,080
31			5·8	8,380		

*Changing conditions

Daily Gauge Height and Discharge of Bow River, at Calgary, for 1910.—*Continued.*

Day.	July.		August.		September.		October.	
	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	6·5	10,080	4·8	4,910	4·1	3·310	3·9	2,900
2	6·3	9,390	4·8	4,910	4·0	3,100	3·9	2,900
3	6·1	8,710	4·8	4,910	4·0	3·100	3,9	2,900
4	6·1	8,710	4·8	4,910	4·0	3,100	3·9	2,900
5	6·0	8,380	4·9	5,160	4·1	3,310	3·8	2,710
6	5·9	8,060	5·475	6,745	4·3	3,740	3·8	2,710
7	5·9	8,060	5·7	7,430	3·3	3,740	3·9	2,900
8	5·9	8,060	5·6	7,120	4·3	3,740	4·0	3,100
9	5·9	8,060	5·4	6,520	4·2	3,520	4·0	3,100
10	5·9	8,060	5·4	6,520	4·1	3,310	4·0	3,100
11	5·9	8,060	5·4	6,520	4·0	3,100	4·2	3,520
12	5·9	8,060	5·4	6,520	4·0	3,100	4·2	3,520
13	5·9	8,060	5·4	6,520	4·0	3·100	4·3	3,740
14	6·0	8,380	5·4	6,520	4·0	3,100	4·2	3,520
15	6·1	8,710	5·4	6,520	4·1	3,310	4·2	3,520
16	6·3	9,390	5·3	6,230	4·1	3,310	4·1	3,310
17	6·3	9,390	5·2	5,950	4·3	3,740	4·2	3,520
18	6·3	9,390	5·0	5,420	4·3	3,740	4·2	3,520
19	6·3	9·390	4·8	4,910	4·3	3,740	4·3	3,740
20	6·3	9,390	4·8	4,910	4·3	3,740	4·2	3,520
21	6·3	9,390	4·8	4,910	4·3	3,740	4·2	3,520
22	6·1	8,710	4·8	4,910	4·3	3,740	4·1	3,310
23	5·9	8,060	4·7	4,660	4·3	3,740	4·0	3,100
24	5·7	7,430	4·7	4,660	4·3	3,740	4·0	3,100
25	5·5	6,820	4·5	4,190	4·3	3,740	4·0	3,100
26	5·3	6,230	4·4	3,960	4·3	3,740	3·9	2,900
27	5·2	5,950	4·3	3,740	4·2	3,520	3·8	2,710
28	5·0	5,420	4·2	3,520	4·1	3,310	3·7	2,520
29	4·9	5,160	4·1	3,310	4·0	3,100	3·6	2,330
30	4·8	4,910	4·1	3,310	3·9	2,900	3·6	2,330
31	4·8	4,910	4·1	3,310		..	3·6	2,330

Monthly Discharge of Bow River at Calgary, for 1910.

(Drainage area, 3,900 square miles.)

Month.	Discharge in Second-Feet.				Run-Off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on Drainage area.	Total in acre-feet.
April 6-30	5,110	760	1,952	0·500	0·446	92,925
May	12,070	3,700	6,683	1·710	1·970	410,935
June	11,020	7,710	10,427	2·670	2·980	620,429
July	10,080	4,910	7,961	2·040	2·350	489,480
August	7,430	3,310	5,279	1·350	1·560	324,094
September	3,740	2,900	3,441	0·882	0·984	204,730
October	3,740	2,330	3,094	0·793	0·914	190,216
The period	....	....	....	....	......	2,332,809

Discharge Measurements of Bow River at Calgary, Alta., in 1910*-1911.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
1910		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
Nov. 25	H. R. Carscallen	170·6	491·8	3·22	1·71	1,583†x
Dec. 13	do	244·8	738·4	1·76	1·67	1,302x
1911						
Jan. 4	H. R. Carscallen				1·87	600·8‖x
Feb. 3	do	212	311·4	3·02	3·60	942·x
Feb. 22	do	212	286·3	2·88	3·34	823·4x
Mar. 11	do	212	370·6	2·65	3·30	832·x
Apr. 24	H. C. Ritchie	284	755·4	1·90	1·57	1,438
May 8	do	290·5	901·4	2·66	2·37	2,394
May 15	do	290·5	881·1	2·63	2·36	2,317
May 26	do	294	964·8	3·02	2·70	2,916
June 9	B. Russell	397	1,428	4·85	4·15	6,936
June 19	do	320	1,962	6·85	5·68	13,438
July 6	do	315·8	1,808	5·58	4·82	10,093
Aug. 12	H. Brown	312	1,658	4·96	4·44	8,224
Aug. 28	do	293	1,451	3·89	3·76	5,643
Sept. 12	do	298·8	1,295	3,38	3·30	4,371
Sept. 26	do	295	1,194	2·79	2·87	3,330
Nov. 23	N. M. Sutherland	242	795·4	1·95	2·19	1,551x
Dec. 7	do	293	851·7	0·89	4·44	5,754·7x
Dec. 22	do	277	795·3	0·91	4·30	722·9x

* Other gaugings at the old gauging station in 1910 were published in the Second Annual Report. Data are insufficient to compute daily discharges in November and December of 1910.

† Gauging made at Centre St. bridge.

‖ Gauging was made at traffic bridge on sec. 14 and the discharge of Elbow river was deducted to obtain the discharge of Bow river at the regular station.

x Ice conditions.

Daily Gauge Height and Discharge of Bow River at Calgary, Alta., for 1910.

Day.	November.		December.	
	Gauge Height.	Discharge.	Gauge Height.	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1			1·45	1,270
2			1·60	1,380
3			1·65	1,410
4			1·55	1,310
5			1·62	1,350
6			1·75	1,450
7			1·79	1,470
8			1·97	1,620
9			1·97	1,600
10			1·97	1,580
11			2·05	1,660
12			1·67	1,300
13			2·04	1,590
14			2·05	1,560
15			1·97	1,470
16			1·78	1,240
17			1·85	1,250
18			1·73	1,130
19			1·89	1,190
20			1·80	1,100
21			1·78	1,050
22			1·69	970
23			1·78	960
24			1·44	810
25			1·70	880
26			1·74	860
27			1·75	820
28			1·80	810
29	1·30	1,108	1·80	770
30	1·40	1,230	1·64	700
31			1·97	760

Note.—Ice conditions during the whole period and daily discharges are therefore only approximate.

Daily Gauge Height and Discharge of Bow River at Calgary, Alta., for 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	1·83	690	3·74	963	3·35	840	2·64	890	1·64	1,495	3·87	5,970
2	1·70	640	3·65	940	3·30	820	2·47	860	1·70	1,550	4·05	6,690
3	1·42	600	3·57	928	3·42	868	2·57	940	1·83	1,670	4·17	7,032
4	1·90	600	3·73	1,005	3·40	860	2·44	930	1·84	1,680	4·96	10,144
5	2·38	*	3·67	975	3·40	860	2·45	980	1·98	1,836	4·75	9,240
6	2·87	....	3·68	980	3·35	840	2·67	1,120	2·25	2,170	4·55	8,450
7	3·02	....	3·66	970	3·35	840	2·75	1,200	2·33	2,288	4·32	7,576
8	3·73	....	3·67	975	3·37	848	2·57	1,170	2·35	2,320	4·30	7,500
9	3·85	....	3·67	975	3·36	844	2·70	1,270	2·37	2,352	4·27	7,392
10	3·44	....	3·65	965	3·35	840	2·73	1,330	2·34	2,304	4·12	6,852
11	2·95	....	3·65	965	3·35	840	2·64	1,340	2·27	2,198	4·10	6,780
12	3·12	....	3·70	990	3·35	840	2·50	1,320	2·24	2,156	4·22	7,212
13	3·45	....	3·63	955	3·35	840	2·45	1,340	2·34	2,304	4·57	8,526
14	3·80	....	3·55	920	3·40	860	1·84	1,040	2·37	2,352	5·85	14,290
15	4·10	....	3·54	916	3·45	880	1·97	1,180	2·37	2,352	5·97	14,890
16	4·85	....	3·50	900	3·37	848	2·05	1,300	2·40	2,400	6·05	15,300
17	4·86	....	3·37	848	3·37	848	1·87	1,220	2·97	3,534	6·00	15,040
18	4·75	....	3·45	880	3·33	832	2·07	1,450	2·94	3,468	5·84	14,240
19	4·55	....	3·43	872	3·46	884	1·67	1,190	2·90	3,380	5·75	13,800
20	4·46	*	3·24	796	3·60	940	1·70	1,270	2·85	3,270	5·60	13,320
21	4·37	1,000	3·43	872	3·56	024	1·76	1,390	2·85	3,270	5·52	13,180
22	4·30	990	3·35	840	3·56	924	1·88	1,560	3·00	3,600	5·47	13,150
23	4·27	1,000	3·42	868	3·56	924	1·15	1,069	3·05	3,720	5·77	14,340
24	4·27	1,020	3·24	796	3·35	840	1·56	1,428	2·97	3,534	6·10	15,740
25	4·05	950	3·44	876	3·15	810	2·33	2,288	2·90	3,380	6·25	16,460
26	3·93	910	3·44	876	3·08	820	1·73	1,577	2·77	3,094	6·05	15,840
27	3·67	830	3·45	880	2·95	810	1·70	1,550	2·69	2,920	5·56	14,080
28	3·93	960	3·43	872	2·95	850	1·66	1,514	2·65	2,840	5·47	13,330
29	3·94	980	....	....	2·80	830	1·68	1,532	2·59	2,722	5·47	13,330
30	3·90	990	....	....	2·82	880	1·67	1,523	2·82	3,204	5·49	13,430
31	3·97	1,040	....	....	2·70	870	....	....	3·00	3,600	....	....

* Not sufficient data to compute discharge from Jan. 5 to Jan. 20.

Daily Gauge Height and Discharge of Bow River at Calgary, Alta., for 1911.—*Continued.*

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	5·55	13,730	4·15	7,000	3·65	5,310	2·78	3,116	1·93	1,775	4·30	1,070
2	5·45	13,230	4·16	7,040	3·67	5,370	2·75	3,050	1·92	1,754	4·30	980
3	5·40	12,980	4·18	7,120	3·70	5,460	2·75	3,050	1·92	1,764	4·52	1,050
4	5·30	12,480	4·37	7,908	4·00	5,420	2·73	3,006	1·93	1,776	4·55	990
5	5·06	11,280	4·45	8,280	3·97	5,312	2·68	2,900	1·95	1,800	4·53	880
5	4·74	9,680	4·45	8,280	3·85	5,910	2·65	2,840	1·95	1,800	4·50	770
7	4·77	9,830	5·05	11,230	3·77	5,670	2·75	3,050	1·85	1,690	4·45	744
8	5·05	11,230	5·83	15,130	3·65	5,310	2·85	3,270	1·45	1,34	4·40	748
9	4·95	10,730	4·97	10,830	3·55	5,020	2·75	3,050	1·43	1,324	4·50	740
10	4·75	9,730	4·73	9,630	3·48	4,828	2·42	2,432	1·40	1,300	4·43	746
11	4·85	10,230	4·55	8,760	3·40	4,750	2·45	2,480	1·25	1,185	4·51	739
12	4·54	8,712	4·45	8,280	3·40	4,620	2·40	2,400	1·20	1,150	4·37	750
13	4·42	8,136	4·30	7,600	3·37	4,542	2·42	2,432	0·90	960	4·45	743
14	4·40	8,040	4·25	7,400	3·35	4,490	2·40	2,400	1·32	1,200	4·47	742
15	4·58	8,904	4·23	7,320	3·32	4,412	2·23	2,142	1·50	1,295	4·25	760
16	4·53	8,664	4·20	7,200	3·32	4,412	2·18	2,076	2·00	1,700	4·47	742
17	4·60	9,000	4·15	7,00	3·25	4,230	2·43	2,448	2·35	2,060	4·37	750
18	4·65	9,240	4·00	5,420	3·23	4,178	2·40	2,400	2·47	2,200	4·32	754
19	4·57	9,336	4·00	5,420	3·20	4,100	2·30	2,240	2·48	2,160	4·25	760
20	4·57	8,856	3·97	6,312	3·05	3,720	2·17	2,064	2·48	2,120	4·32	754
21	4·52	8,515	3·95	5,240	3·10	3,840	2·25	2,170	2·45	2,010	4·37	750
22	4·53	8,664	3·95	5,240	3·05	3,720	2·15	2,040	2·37	1,840	4·34	753
23	4·55	8,760	3·90	5,060	3·00	3,600	2·17	2,064	2·35	1,720	4·35	752
24	4·45	8,280	3·85	5,910	2·97	3,534	2·20	2,100	2·35	1,740	4·55	736
25	4·40	8,040	3·85	5,910	2·95	3,490	2·23	2,142	2·30	1,660	4·57	726
26	4·45	8,328	3·90	6,060	2·90	3,380	2·25	2,170	2·25	1,510	4·75	720
27	4·55	8,760	3·85	5,910	2·88	3,336	2·13	2,015	2·23	1,590	5·51	659
28	4·40	8,040	3·75	5,510	2·85	3,270	2·10	1,980	4·28	1,360	5·35	572
29	4·25	7,400	3·70	5,460	2·80	3,160	2·10	1,980	4·27	1,230	5·15	688
30	4·23	7,320	3·63	5,250	2·80	3,160	1·97	1,824	4·25	1,120	5·35	572
31	4·15	7,000	3·70	5,460	....	....	1·95	1,800	....	....	5·62	650

Note.—Ice conditions during January, February, March, November and December. Daily discharges for those months are only approximate, particularly December which may be a little low.

MONTHLY DISCHARGE of Bow River near Calgary, Alta., for 1910-1911

(Drainage area, 3,138 square miles.)

Month.	Discharge in Second-Feet.				Run-Off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on Drainage area.	Total in acre-feet.
1910						
November 29-30	1,230	1,180	1,205	0·348	0·03	4,780
December	1,660	700	1,205	0·384	0·44	74,093
The period					0·47	78,873
1911						
January (1-4) (21-30)	1,040	600	880	0·280	0·16	26·182
February	1,005	796	914	0·291	0·30	50,671
March	940	810	857	0,273	0·31	52,695
April	2,288	860	1,292	0·412	0·46	76,879
May	3,720	1,496	2,676	0·852	0·98	164,541
June	16,460	5,970	11,434	3·640	4·06	680,370
July	13,730	7,000	9,459	3·010	3·47	581,611
August	15,130	5,250	7,396	2·360	2·72	454,762
September	6,420	3,160	4,452	1·420	1·58	264,912
October	3,270	1,800	2,424	0·772	0·89	149,046
November	2,200	960	1,609	0·513	0·57	95,740
December	1,070	650	774	0·247	0·28	47,591
The period					15·78	2,645,090

DISCHARGE MEASUREMENTS of Bow River at Calgary, in 1912.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq ft.	Ft. per sec.	Feet.	Sec.-ft.
*Jan. 15	N. McL. Sutherland	286	1,004·4	1·23	6·38	1,236·2
*Jan. 30	do	286	862·3	1·35	6·49	1,166·6
*Feb. 10	do	315	961·7	1·25	6·25	1,204·0
*Feb. 23	do	287	807·0	1·24	5·99	999·0
*Mar. 7	do	287	755·2	1·15	5·74	869·4
*Mar. 22	do	287	722·7	1·07	5·62	824·6
May 2	H. C. Ritchie	285·5	950·6	1·84	4·185	1,752·7
May 7	F. R. Burfield	287	1,053·8	2·22	4·41	2,338·5
May 21	do	299	1,329·4	3·34	5·35	4,434·2
June 8	do	291·5	1,142·4	2·56	4·66	2,919·0
June 21	do	321	1,975·0	6·10	7·36	12,047·5
July 9	do	323	2,107·5	6·71	7·78	14,149·0
July 15	do	324	2,063·0	6·61	7·60	13,618·1
July 29	do	313·5	1,713·8	5·18	6·60	8,872·9
Aug. 8	do	306·5	1,450·6	4·45	6·11	6,459·7
Aug. 22	do	313·5	1,596·4	5·36	6·56	8,552·7
Sept. 4	do	303·5	1,298·6	4·31	5·79	5,599·6
Sept. 20	do	300·5	1,235·4	3·84	5·51	4,741·7
Oct. 4	do	294·5	1,056·3	3·04	4·91	3,209·0
Oct. 21	do	292·5	1,025	2·82	4·73	2,806·0
Oct. 31	do	292	938	2·37	4·48	2,226·0
Nov. 14	do	287·5	927	2·50	4·39	2,313·0

*Ice conditions.

DAILY GAUGE HEIGHT AND DISCHARGE of Bow River at Calgary, for 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	5·65	680	6·35	1,190	5·94	974	5·00	1,740	4·40	2,420	5·15	3,805
2	5·65	680	6·30	1,070	5·95	980	4·9[illegible]	1,850	4·18	1,748	5·10	3,680
3	5·77	720	6·30	1,080	5·97	992	4·93	1,990	4·10	1,620	4·97	3,358
4	5·75	720	6·25	1,080	5·98	998	4·95	2,160	4·30	1,950	4·97	3,358
5	6·06	880	6·1[illegible]	1,060	5·97	992	4·80	2,170	4·32	1,984	4·95	3,310
6	5·76	720	6·15	1,070	5·95	980	4·40	2,020	4·32	1,984	4·73	2,796
7	6·25	1,000	6·20	1,110	5·[illegible]1	855	4·20	1,780	4·31	1,967	4·55	2,420
8	5·95	830	6·25	1,160	5·68	840	4·10	1,620	4·40	2,120	4·75	2,840
9	6·25	1,000	6·23	,160	5·65	825	4·40	2,120	4·42	2,160	5·00	3,430
10	6·21	980	6·20	1,160	5·85	925	4·27	1,899	4·39	2,103	5·52	4,780
11	6·05	870	6·15	1,100	5·90	950	4·15	1,700	4·38	2,086	5·52	4,780
12	6·07	990	6·13	1,088	5·90	950	4·05	1,540	4·43	2,180	5·72	5,392
13	6·35	1,070	6·12	1,082	5·68	840	4·03	1,508	4·42	2,160	5·98	6,258
14	6·35	1,070	6·12	1,082	5·90	950	4·03	1,508	4·53	2,380	6·42	7,629
15	6·31	1,197	6·10	1,070	5·80	900	4·05	1,540	5·03	3,505	6·99	10,474
16	6·50	1,330	6·10	1,070	5·75	875	4·30	1,950	5·37	4,262	7·45	12,625
17	6·95	1,670	6·05	1,040	5·80	900	4·23	1,831	5·63	5,113	7·72	13,894
18	6·65	1,410	6·05	1,040	5·40	710	4·15	1,700	5·55	4,870	7·70	13,800
19	6·65	1,410	6·03	1,028	5·75	875	4·08	1,588	5·53	4,810	7·62	13,424
20	6·11	1,040	5·92	962	5·75	875	3·92	1,332	5·45	4,580	7·50	12,860
21	6·37	1,210	5·92	962	5·80	900	3·81	1,183	5·33	4,258	7·38	12,296
22	6·65	1,370	5·93	968	5·65	825	3·70	1,040	5·33	4,258	7·35	12,155
23	6·65	1,370	5·94	974	5·45	850	3·72	1,066	5·30	4,180	7·26	11,732
24	6·60	1,310	5·94	974	5·69	1,110	3·75	1,105	5·27	4,105	7·20	11,450
25	6·65	1,350	5·95	[illegible]80	5·69	1,240	3·75	1,105	5·25	4,055	7·13	11,121
26	6·65	1,320	5·95	980	5·50	1,260	3·77	1,131	5·43	4,524	7·07	10,842
27	6·65	1,320	5·97	992	5·50	1,400	3·75	1,105	5·75	5,485	7·00	10,520
28	6·65	1,300	5·97	992	5·40	1,450	3·77	1,131	5·75	5,485	7·02	10,612
29	6·65	1,300	5·95	980	5·25	1,490	3·93	1,348	5·63	5,113	6·95	10,290
30	6·65	1,270	....	....	5·25	1,640	3·87	1,261	5·53	4,810	6·73	9,295
31	6·35	1,080	....	....	5·00	1,590	....	....	5·35	4,310	....	....

NOTES.—Ice conditions from Jan. 1 to Apr. 6.
From Jan. 1 to Jan. 14 extremely cold.

DAILY GAUGE HEIGHT AND DISCHARGE of Bow River at Calgary, for 1912.—*Concluded.*

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	6·51	8,333	6·38	7,800	6·22	7,160	5·00	3,430	4·45	2,220	4·01	1,420
2	6·23	7,200	6·34	7,640	6·13	6,814	5·00	3,430	4·60	2,520	4·03	1,400
3	6·40	7,880	6·37	7,760	5·93	6,078	4·99	3,406	4·62	2,562	3·96	1,230
4	6·23	7,200	6·35	7,680	5·61	5,051	4·98	3,382	4·62	2,562	4·30	1,720
5	6·15	6,890	6·37	7,760	5·47	4,636	4·97	3,358	4·60	2,520	4·28	1,640
6	6·21	7,12[illegible]	6·30	7,480	5·58	4,960	4·95	3,310	4·55	2,420	4·16	1,400
7	6·77	9,47[illegible]	6·26	7,320	5·69	5,299	4·94	3,286	4·48	2,280	4·14	1,300
8	7·19	11,403	6·19	7,042	5·77	5,547	4·97	3,358	4·45	2,220	4·18	1,320
9	7·77	14,129	6·12	6,776	5·74	5,454	4·99	3,406	4·51	2,380	4·16	1,230
10	8·00	15,210	6·02	6,404	5·68	5,268	5·03	3,505	4·50	2,320	4·10	1,120
11	7·72	13,894	6·08	6,626	5·73	5,423	5·01	3,455	4·45	2,220	3·95	900
12	7·67	13,659	6·13	6,814	5·81	5,673	4·99	3,496	4·43	2,180	3·64	580
13	7·49	12,813	6·13	6,814	5·69	5,299	4·96	3,334	4·40	2,120	3·78	670
14	7·93	14,881	5·95	6,150	5·60	5,020	4·93	3,262	4·41	2,140	3·98	820
15	7·70	13,860	5·91	6,006	5·58	4,960	4·84	3,046	4·29	1,933	3·95	760
16	7·15	12,625	6·30	7,480	5·55	4,870	4·83	3,022	4·21	1,797	4·07	840
17	7·25	11,685	5·29	7,440	5·49	4,692	4·80	2,959	4·25	1,865	4·14	880
18	6·90	10,060	6·57	8,591	5·48	4,664	4·82	2,998	4·29	1,933	4·09	800
19	6·70	9,160	6·73	9,295	5·46	4,608	4·84	3,046	4·45	2,220	4·30	980
20	6·83	9,745	6·70	9,160	5·38	4,388	4·86	3,094	4·40	2,120	4·21	850
21	6·67	9,028	6·68	9,072	5·30	4,180	4·83	3,022	4·38	2,086	4·33	940
22	6·50	8,290	6·67	0,028	5·31	4,206	4·80	2,959	4·35	2,035	4·34	920
23	7·15	11,215	6·65	8,940	5·33	4,258	4·65	2,625	4·30	1,950	4·33	860
24	7·88	14,646	6·60	8,720	5·31	4,206	4·68	2,688	4·31	2,001	4·32	810
25	7·92	14,834	6·92	10,152	5·27	4,105	4·70	2,730	4·36	2,052	4·29	760
26	7·45	12,625	7·13	11,121	5·24	4,030	4·59	2,709	4·29	1,933	4·23	680
27	7·05	10,750	7·06	10,796	5·20	3,930	4·65	2,625	3·88	1,274	4·16	580
28	6·91	10,106	7·03	10,658	5·13	3,755	4·67	2,687	3·93	1,348	4·38	760
29	6·62	8,808	6·72	9,259	5·06	3,530	4·70	2,730	4·05	1,540	4·42	760
30	6·53	8,419	6·73	9,295	4·95	3,310	4·60	2,520	4·04	1,524	4·45	750
31	6·44	8,044	6·47	8,167	.....	...	4·46	2,210	...	......	4·61	870

MONTHLY DISCHARGE of Bow River at Calgary, for 1912.

(Drainage area, 3,138 square miles.)

Month.	Discharge in Second-Feet.				Run-Off.	
	Maximum.	Minimum.	Mean.	Per Square Mile.	Depth in inches on Drainage Area.	Total in Acre-feet.
January	1,670	689	1,109	0·35	0·40	68,189
February	1,160	980	1,048	0·33	0·36	60,284
March	1,640	825	1,030	0·33	0·38	63,330
April	2,170	1,049	1,571	0·50	0·56	93,480
May	5,485	1,620	3,432	1·09	1·26	211,024
June	11,894	2,420	8,185	2·61	2·91	487,040
July	15,210	6,890	10,772	3·43	3·96	662,400
August	11,121	6,006	8,169	2·60	3·00	502,290
September	7,160	3,310	4,847	1·54	1·72	288,420
October	3,505	2,240	3,064	0·98	1·12	188,400
November	2,562	1,274	2,076	0·66	0·74	123,590
December	1,720	580	985	0·31	0·36	60,565
The year	....	....	....	....	16·77	2,809,012

Discharge Measurements of Elbow River at Calgary, Alta., in 1908-1909.

Date.	Hydrographer.	Width.	Area of section.	Mean velocity.	Gauge height.	Discharge.
1908.		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
May 8	P. M. Sauder	132·5	280	0·76	1·00	212
May 16	H. R. Carscallen	137·6	369	1·49	1·655	550
June 6	P. M. Sauder	158·6	922	5·34	6·30	4,925
July 21	H. R. Carscallen	139·5	370	1·43	1·67	529
July 25	do	139·0	350	1·27	1·625	445
Sept. 3	do	138·0	303	0·95	1·116	287
Oct. 7	P. M. Sauder	135·0	288	0·87	1·05	252
1909.						
May 7	H. R. Carscallen	133·0	278	0·83	0·755	230
May 18	P. M. Sauder	138·0	355	1·35	1·326	478
May 26	do	167·0	667	3·72	3·43	2,487
June 8	J. C. Keith	141·0	467	2·09	2·11	976
June 24	do	140·0	444	1·94	1·94	860
July 2	do	140·0	425	1·82	1·82	775
July 15	do	139·0	415	1·80	1·76	749
Aug. 7	do	138·0	359	1·37	1·40	493
Aug. 30	do	135·0	294	0·92	0·975	270

Daily Gauge Height and Discharge of Elbow River, at Calgary, Alta., for 1908.

Day.	May.		June.		July.	
	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1			3·35	2,022	2·15	882
2			5·70	6,615	2·30	1,000
3			4·40	3,435	2·30	1,000
4			5·00	4,400	2·30	1,000
5			5·60	5,440	2·30	1,000
6			5·60	5,440	2·20	920
7			4·85	4,152	2·15	882
8	1·00	212	4·15	3,062	2·10	845
9	1·50	460	3·85	2,637	2·10	845
10	1·40	410	3·70	2,440	2·10	845
11	1·30	360	3·70	2,440	2·05	810
12	1·45	435	3·50	2,195	2·00	775
13	1·55	490	3·25	1,910	2·00	775
14	1·65	550	3·00	1,640	1·90	705
15	1·70	580	3·00	1,640	1·90	705
16	1·76	610	3·00	1,640	1·80	640
17	2·35	1,040	2·70	1,340	1·80	640
18	2·16	882	2·50	1,165	1·90	705
19	2·00	775	2·50	1,165	1·00	705
20	2·05	810	2·65	1,295	1·80	640
21	2·05	810	2·70	1,340	1·80	640
22	2·00	775	2·55	1,207	1·75	610
23	1·90	705	2·50	1,165	1·70	580
24	1·90	705	2·55	1,207	1·70	580
25	1·95	740	2·80	1,435	1·60	520
26	2·05	810	2·95	1,587	1·50	460
27	2·10	845	2·95	1,587	1·50	460
28	2·10	845	2·70	1,340	1·40	410
29	2·10	845	2·40	1,060	1·40	410
30	2·05	810	2·25	960	1·30	360
31	2·50	1,165			1·30	360

DAILY GAUGE HEIGHT AND DISCHARGE of Elbow River, at Calgary, Alta., for 1908.—*Continued.*

Day.	August.		September.		October.		November.	
	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	1·30	360	1·20	310	1·10	260	1·30	360
2	1·30	360	1·20	310	1·10	260	1·20	310
3	1·30	360	1·20	310	1·10	260	1·10	260
4	1·30	360	1·20	310	1·10	260	1·00	212
5	1·30	360	1·20	310	1·10	260	1·00	212
6	1·20	310	1·20	310	1·10	260	1·00	212
7	1·20	310	1·20	310	1·10	260	1·00	212
8	1·20	310	1·20	310	1·10	260	1·00	212
9	1·20	310	1·10	260	1·10	260	1·00	212
10	1·20	310	1·10	260	1·10	260	1·00	212
11	1·25	335	1·10	260	1·10	260	1·00	212
12	1·30	360	1·10	260	1·10	260	1·00	212
13	1·30	360	1·10	260	1·00	212	....	....
14	1·30	360	1·10	260	1·00	212	....	....
15	1·30	360	1·10	260	1·00	212	....	....
16	1·30	360	1·10	260	1·00	212	....	....
17	1·20	310	1·10	260	1·00	212	....	....
18	1·20	310	1·10	260	1·00	212	....	....
19	1·20	310	1·10	260	1·00	212	....	....
20	1·20	310	1·10	260	1·00	212	....	....
21	1·10	260	1·10	260	1·00	212	....	....
22	1·10	260	1·10	260	1·00	212	....	....
23	1·10	260	1·10	260	1·00	212	....	....
24	1·40	410	1·15	285	1·00	212	....	....
25	1·40	410	1·20	310	1·00	212	....	....
26	1·35	385	1·20	310	1·00	212	....	....
27	1·30	360	1·20	310	1·05	236	....	....
28	1·20	310	1·20	310	1·10	260	....	....
29	1·20	310	1·10	260	1·20	310	....	....
30	1·20	310	1·10	260	1·25	335	....	....
31	1·20	310	....	....	1·30	360	....	....

DAILY GAUGE HEIGHT AND DISCHARGE of Elbow River, at Calgary, Alta., for 1909.

DAY.	May.		June.		July.		August.		September.		October.	
	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	0·60	220	3·34	2,370	1·89	823	1·72	695	0·97	271	0·84	240
2	0·90	250	3·32	2,345	1·82	[illegible]	1·65	645	0·95	265	0·84	240
3	1·23	391	4·10	3,320	1·88	815	1·64	[illegible]	0·96	268	0·83	238
4	1·42	502	2·85	1,765	2·02	927	1·57	592	0·95	265	0·82	236
5	1·03	293	2·87	1,789	2·19	1,076	1·62	624	0·95	265	0·82	236
6	0·82	236	2·71	1,601	2·30	1,180	1·50	604	0·94	262	0·82	236
7	0·86	243	2·45	1,325	3·27	2,282	1·40	490	0·94	262	0·81	235
8	0·85	241	2·10	1,095	2·77	1,670	1·43	508	0·93	259	0·80	233
9	0·91	253	2·06	961	2·40	1,275	1·42	502	0·93	259	0·79	232
10	1·06	307	2·07	969	2·35	1,227	1·35	460	0·92	256	0·79	232
11	1·29	425	2·37	1,246	2·25	1,132	1·33	448	0·94	262	0·79	232
12	1·50	550	2·66	1,546	2·06	961	1·32	442	0·93	259	0·78	231
13	1·66	652	2·61	1,491	2·15	1,040	1·31	436	0·92	256	0·78	231
14	1·49	544	2·65	1,535	2·01	918	1·29	425	0·91	253	0·77	230
15	1·70	680	2·59	1,470	1·95	870	1·28	419	0·92	256	0·76	230
16	1·56	586	2·69	1,679	1·76	725	1·25	402	0·91	253	0·79	232
17	1·43	508	2·75	1,647	1·69	673	1·24	397	0·90	250	0·78	231
18	1·32	442	2·68	1,568	1·66	652	1·23	391	0·92	256	0·78	231
19	1·79	748	2·51	1,385	1·65	645	1·20	375	0·92	256	0·77	230
20	2·04	944	2·40	1,275	1·65	645	1·19	370	0·91	253	0·77	230
21	2·03	935	2·29	1,171	1·58	598	1·19	370	0·91	253	0·77	230
22	2·06	961	2·26	1,142	1·65	580	1·17	360	0·91	253	0·76	230
23	2·34	1,218	2·16	1,040	1·45	520	1·16	355	0·91	253	0·76	230
24	2·81	1,717	1·94	862	1·43	508	1·12	335	0·90	250	0·75	229
25	3·06	2,020	1·91	838	1·42	502	1·09	320	0·90	250	0·75	229
26	3·65	2,757	2·00	910	1·44	514	1·07	311	0·91	253	0·74	228
27	3·28	2,295	1·87	807	1·65	645	1·04	298	0·89	248	0·73	227
28	3·40	2,445	1·86	800	2·66	1,546	1·05	302	0·85	241	0·73	227
29	3·39	2,433	1·79	748	2·42	1,295	1·02	289	0·83	238	0·73	227
30	3·25	2,257	1·75	717	2·01	918	0·98	274	0·85	241	0·72	226
31	3·01	1,957	......	......	1·98	894	[illegible]	271	......	......	0·72	226

MONTHLY DISCHARGE of Elbow River at Calgary, Alta., for 1908-1909.

(Drainage area, 466 square miles.)

MONTH.	DISCHARGE IN SECOND-FEET.				RUN-OFF.	
	Maximum.	Minimum.	Mean.	Per Square Mile.	Depth in inches on Drainage Area.	Total in Acre-feet.
1908.						
May (8-31)	1,165	212	694·5	1·49	1·330	33,060
June	5,615	960	2,266·0	4·86	5·422	134,834
July	1,000	360	700·3	1·50	1·729	43,060
August	410	260	332·6	0·71	0·819	20,450
September	310	260	280·8	0·60	0·669	16,709
October	360	212	244·8	0·52	0·600	15,052
November (1-12)	360	.12	236·5	0·50	0·223	6,629
The period	......	......	......	......	......	268,794
1909.						
May	2,757	220	968·0	2·070	2·386	59,520
June	3,320	717	1,377·2	2·950	3·291	81,952
	2,282	502	929·9	1·995	2·300	67,177
August	695	271	[illegible]	0·920	1·061	26,476
September	271	238	255·5	0·548	0·612	15,203
October	240	226	231·4	0·490	0·565	14,228
The period	......	......	......	......	......	254,556

DISCHARGE MEASUREMENTS of Elbow River at Calgary, for 1910.

Date.	Hydrographer.	Width.	Area of section.	Mean velocity.	Gauge height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
May 11	J. C. Keith	135	306·6	1·06	1·04	325·39
May 27	do	139	371·05	1·48	1·50	548·04
June 16	do	136	350·95	1·28	1·33	450·55
July 11	do	135	298·70	0·925	0·965	276·27
Aug. 6	do	135	298·75	0·93	0·97	278·74
Aug. 26	do	134	284·25	0·825	0·86	234·87
Sept. 19	do	140	395·46	1·64	1·655	647·00
Oct. 6	H. R. Carscallen	106	316·05	1·03	1·0[illegible]	326·97
Nov. 3	do	133	278·20	0·81	0·8	225·58
Nov. 24	do	104	25[illegible]·25	0·385	0·84	98·29*†
Dec. 14	do	126	221·70	0·57	1·10	126·43*
Dec. 31	do	120	210·95	0·333	1·00	70·32*

*Ice conditions.
†Measurement taken at Bridge 400 yards down stream.

DAILY GAUGE HEIGHT AND DISCHARGE of Elbow River at Calgary, for 1910.

Day.	April.		May.		June.		July.	
	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	·00	76	·55	160	1·10	336	1·21	387
2	·00	76	·54	158	1·36	468	1·20	382
3	·00	76	·53	156	1·30	434	1·18	372
4	·00	76	·53	156	1·25	407	1·15	358
5	·00	76	·59	170	1·18	372	1·08	328
6	·00	76	·61	174	1·15	358	1·05	315
7	·00	76	·70	196	1·13	349	1·03	307
8	·00	76	·82	230	1·35	462	1·02	302
9	·00	76	1·15	358	1·32	445	1·00	294
10	·00	76	1·17	368	1·35	462	·99	290
11	·00	76	1·13	349	1·34	456	·98	286
12	·00	76	1·12	345	1·65	650	·94	270
13	·00	76	1·07	323	1·55	582	·92	263
14	·00	76	1·05	315	1·46	526	·95	274
15	·01	77	1·01	298	1·35	462	·99	290
16	·09	87	·99	290	1·41	496	·99	290
17	·24	108	·98	286	1·57	596	·97	282
18	·26	110	·97	282	1·58	602	·97	282
19	·30	116	1·03	307	1·46	526	·98	286
20	·31	118	1·04	311	1·57	596	·96	278
21	·33	121	1·03	307	1·58	602	·93	267
22	·34	122	1·01	298	1·56	589	·92	263
23	·34	122	1·00	294	1·34	456	·90	256
24	·34	122	·99	290	1·28	423	·86	243
25	·35	124	1·21	387	1·20	382	·84	237
26	·39	130	1·58	602	1·17	368	·83	233
27	·43	137	1·51	576	1·23	397	·82	230
28	·47	144	1·35	462	1·22	392	·85	240
29	·56	162	1·26	412	1·22	392	·79	221
30	·57	165	1·15	358	1·22	392	·76	213
31	....	..	1·12	345	....	....	·73	204

Daily Gauge Height and Discharge of Elbow River at Calgary, for 1910. *Continued.*

Day.	August.		September.		October.		November.		December.	
	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.
1	·72	202	·90	256	1·16	363	·82	230	1·24	161
2	·72	202	·86	243	1·13	349	·81	227	1·10	151
3	·71	199	·84	237	1·10	336	·80	224	1·21	154
4	·69	194	·89	253	1·12	345	·78	218	1·08	129
5	·79	221	·94	270	1·09	332	·76	213	1·06	126
6	·76	213	1·06	320	1·07	323	·75	210	1·01	117
7	1·01	298	1·22	392	1·03	307	·74	207	1·13	136
8	1·16	363	1·18	372	1·04	311	·73	204	1·07	126
9	1·13	349	1·12	345	1·04	311	·72	202	1·11	132
10	1·15	358	1·06	320	1·06	320	·71	199	1·05	120
11	1·26	412	1·15	358	1·05	315	1·07	323	·99	112
12	1·24	402	1·20	382	1·05	315	·85	240	1·01	114
13	1·18	372	1·25	407	1·04	311	·79	221	·97	107
14	1·17	368	1·25	407	1·03	307	·86	243	1·12	130
15	1·19	377	1·33	451	1·01	298	·85	240	1·16	134
16	1·13	349	1·46	526	·99	290	·84	237	1·32	160
17	1·10	336	[illegible]	576	·97	282	·78	218	1·17	130
18	1·05	315	1·65	650	1·01	299	*·75	210	1·14	123
19	1·00	294	1·66	657	·97	282	·94	240	1·21	132
20	·96	286	1·58	602	·95	274	·94	212	1·23	132
21	·95	274	1·54	576	·94	270	1·12	238	1·225	128
22	·94	270	1·45	520	·92	263	1·15	212	·90	80
23	·93	267	1·43	508	·91	260	1·00	146	·84	72
24	·93	267	1·41	496	·89	253	·97	116	1·145	110
25	·92	263	1·36	467	·88	250	·79	90	1·195	114
26	·87	246	1·31	440	·90	256	1·06	130	1·18	108
27	·84	237	1·28	423	·88	250	1·22	157	1·235	115
28	·79	221	1·27	418	·87	246	1·26	166	1·095	90
29	·85	240	1·24	402	·86	243	1·41	204	1·06	84
30	·86	243	1·20	382	·85	240	1·35	188	1·04	80
31	·95	274	....	....	·84	237	....	....	*1·095	82

*Ice conditions from November 18 to December 31.

Monthly Discharge of Elbow River at Calgary, for 1910.

(Drainage area, 482 square miles.)

Month.	Discharge in Second-Feet.				Run-Off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on Drainage area.	Total in Acre-Feet.
April	165	76	101	0·209	0·233	6,009
May	602	156	308·5	0·640	0·738	18,970
June	650	336	466	0·967	1·08	27,727
July	387	204	282	0·585	0·675	17,34[illegible]
August	412	194	287·5	0·596	0·687	17,678
September	657	237	421·9	0·875	0·976	25,103
October	363	237	291·6	0·605	0·698	17,930
November	323	90	205·5	0·426	0·475	12,228
December	161	72	119	0·247	0·285	7,317
The period	....	....	....	....	....	150,302

Discharge Measurements of Elbow River at Calgary, Alta., for 1911.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq ft.	Ft. per sec.	Feet.	Sec.-ft.
Jan. 5	H. R. Carscallen	120·0	193·1	0·33	1·10	64·0†
Jan. 16	"	120·0	181·1	0·25	0·90	45·1†
Feb. 6	"	120·0	215·8	0·40	1·97	85·4†
Feb. 18	"	100·0	204·0	0·54	2·22	111·0†
Mar. 14	"	100·0	178·3	0·58	2·05	103·6†
Apr. 6	"	85·0	143·0	0·64	0·33	90·9†
Apr. 15	"	123·0	249·5	0·66	0·57	165·3
May 1	H. C. Ritchie	133·0	269·2	0·79	0·68	211·5
May 25	"	137·5	346·2	1·22	1·21	422·5
June 5	B. Russell	148·0	457·3	2·06	2·01	942·4
June 21	"	144·0	395·6	1·65	1·59	654·5
July 5	"	142·5	441·6	1·93	1·90	852·6
Aug. 3	H. T. Thomas	140·0	394·3	1·56	1·56	629·6
Aug. 9	H. Brown	150·5	675·1	3·63	3·46	2,385·0
Aug. 23	"	139·0	410·8	1·67	1·66	686·4
Sept. 8	"	142·5	461·6	2·10	2·01	967·6
Sept. 25	"	135·5	347·8	1·30	1·33	453·1
Oct. 18	B. Russell	132·0	331·8	1·04	1·08	344·5
Nov. 21	N. McL. Sutherland	127·0	279·1	0·82	2·24*	229·1†
Dec. 6	"	115·0	241·2	0·40	2·30*	95·8†
Dec. 23	"	105·0	206·2	0·73	2·10*	151·1†

*New chain gauge. †Ice conditions.

Daily Gauge Height and Discharge of Elbow River at Calgary, Alta., for 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	1·06	71	1·78	73	2·30	128	0·55	80	0·71	209	2·61	1,466
2	0·99	65	1·79	74	2·26	123	0·45	79	0·78	201	2·51	1,370
3	0·90	60	1·86	78	2·25	122	†0·42	82	0·66	196	2·37	1,244
4	0·87	55	1·89	79	2·25	123	0·38	81	0·64	190	2·25	1,139
5	1·09	64		85	2·26	125	0·51	102	0·73	215	2·09	1,006
6	1·12	64	2·[illegible]	88	2·23	121	0·47	105	0·73	215	1·83	807
7	1·25	69	1·95	84	2·26	126	0·60	147	0·74	218	1·74	743
8	1·34	71	2·03	91	2·25	125	0·49	143	0·78	230	1·69	708
9	1·19	63	1·99	87	2·21	121	0·47	152	0·76	224	1·65	682
10	†1·05	57	1·96	85	2·22	122	0·67	198	0·71	209	1·61	655
11	†0·90	51	1·98	86	2·17	116	0·63	188	0·71	209	1·78	771
12	0·76	48	2·02	90	2·09	107	0·89	267	0·68	201	1·90	926
13	0·79	47	2·03	91	2·13	114	0·80	236	0·78	230	2·21	1,105
14	0·74	45	2·00	88	2·08	107	0·67	198	1·02	319	2·17	1,071
15	0·99	48	2·07	95	2·08	116	0·69	203	0·98	302	2·09	1,006
16	0·90	45	2·03	91	2·09	128	0·79	233	1·18	392	2·02	950
17	1·01	47	2·10	98	1·96	118	0·92	278	1·97	911	1·97	911
18	1·59	64	2·21	110	1·92	123	0·87	269	1·75	750	1·85	821
19	1·59	64	2·16	104	1·86	124	0·84	250	1·59	641	1·70	715
20	1·69	64	2·10	98	1·82	128	0·98	302	1·40	520	1·65	682
21	1·68	68	2·12	101	2·26	255	1·30	458	1·36	495	1·59	641
22	1·69	68	2·23	115	1·97	191	1·43	539	1·32	470	1·58	635
23	1·72	70	2·27	120	1·92	199	1·17	388	1·33	477	1·67	695
24	1·69	68	2·19	111	1·84	192	1·16	383	1·29	452	1·76	757
25	1·68	68	2·16	108	1·81	203	1·10	354	1·28	447	2·40	1,270
26	1·75	72	2·20	113	1·70	193	1·06	336	1·25	430	1·09	926
27	1·64	66	2·23	119	1·60	185	0·99	306	1·22	413	1·95	896
28	1·74	71	2·27	123	1·55	189	0·89	267	1·22	413	2·00	934
29	1·75	72	....	....	1·40	170	0·80	236	1·43	539	2·02	950
30	1·76	72	....	....	0·90	90	0·73	215	1·86	829	2·06	974
31	1·78	73	....	....	0·69	86			2·16	1,063		....

Daily Gauge Height and Discharge of Elbow River at Calgary, Alta., for 1911.—*Continued.*

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	2·33	1,208	1·25	430	1·50	583	1·30	458	0·95	290	2·08	87
2	2·31	1,191	1·55	615	1·47	564	1·29	452	0·93	282	2·07	70
3	2·10	1,014	1·60	648	1·45	552	1·32	470	0·92	278	2·15	91
4	1·99	926	1·80	785	2·69	1,546	1·30	458	0·92	278	2·10	75
5	1·88	843	1·89	851	2·40	1,270	1·29	452	0·90	270	2·11	70
6	1·75	750	1·90	858	2·25	1,139	1·28	447	0·84	250	2·28	92
7	1·70	715	2·31	1,191	2·16	1,063	1·26	436	0·80	236	2·16	76
8	1·64	675	4·05	3,159	2·08	998	1·24	424	0·49	157	2·07	75
9	1·61	655	3·35	2,252	1·99	926	1·21	408	0·14	103	2·05	64
10	1·55	615	2·91	1,769	1·93	881	1·18	3[illegible]	‡	85	2·16	90
11	1·48	570	2·69	1,546	1·89	851	1·14	373	‡	75	2·28	129
12	1·42	533	2·41	1,279	1·84	814	1·13	368	‡	80	2·35	146
13	1·35	489	2·30	1,182	1·77	764	1·12	364	‡	100	2·20	114
14	1·31	464	2·15	1,055	1·68	702	1·11	359	2·02*	120	2·06	85
15	1·33	477	2·00	934	1·61	655	1·10	354	2·15	183	2·05	89
16	1·38	508	2·18	1,080	1·56	622	1·10	354	2·46	377	2·07	97
17	1·35	489	1·93	881	1·55	615	1·08	345	2·34	293	2·35	196
18	1·33	477	1·78	771	1·48	570	1·06	336	2·35	300	2·20	150
19	1·51	590	1·67	695	1·43	539	1·05	332	2·36	307	1·91	61
20	1·47	564	1·91	866	1·41	526	1·05	332	2·37	314	2·10	130
21	1·41	526	1·75	7[illegible]0	1·38	508	1·03	323	2·24	231	2·27	207
22	1·39	514	1·73	[illegible]	1·37	501	1·03	323	2·44	340	1·99	100
23	1·65	682	1·69	708	1·37	501	1·04	328	2·18	180	2·08	143
24	1·59	641	1·64	675	1·35	489	1·04	328	2·19	175	2·23	225
25	1·48	570	1·61	655	1·33	477	1·03	323	2·25	192	1·99	107
26	1·41	526	1·75	750	1·33	477	1·02	319	2·26	185	1·76	31
27	1·45	552	1·70	715	1·32	470	1·02	319	2·49	270	1·79	38
28	1·39	514	1·67	695	1·32	470	1·01	314	2·20	144	1·79	38
29	1·31	464	1·62	661	1·32	470	0·99	306	2·28	162	1·76	31
30	1·28	447	1·59	641	1·31	464	0·98	302	2·12	105	1·76	31
31	1·26	436	1·54	609	....	....	0·95	290	....	....	2·08	149

† No observation, gauge height interpolated. ‡ Water below zero of gauge. Chain gauge installed.

Note.—Ice conditions during January, February, March, November and December. Daily discharges for those months are only approximate.

Monthly Discharge of Elbow River at Calgary, Alta., for 1911.

(Drainage area, 482 square miles.)

Month.	Discharge in Second-Feet.				Run-Off.	
	Maximum.	Minimum.	Mean.	Per Square Mile.	Depth in inches on Drainage Area.	Total in Acre-feet.
January	73	45	62·2	0·129	0·15	3,824
February	123	73	95·9	0·199	0·21	5,326
March	255	86	141·0	0·293	0·34	8,670
April	539	79	236·0	0·490	0·55	14,043
May	1,063	190	407·0	0·844	0·97	25,025
June	1,466	635	915·0	1·898	2·12	54,446
July	1,208	436	633·0	1·313	1·51	38,922
August	3,159	430	982·0	2·037	2·35	60,381
September	1,546	464	700·0	1·452	1·62	41,653
October	470	290	367·0	0·761	0·88	22,566
November	377	75	212·0	0·440	0·49	12,615
December	225	31	100·0	0·207	0·24	6,1[illegible]
The year						293,62[illegible]

Discharge Measurements of Elbow River at Calgary, for 1912.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
Jan. 12	N. McL. Sutherland	125	180·75	0·51	1·96	92·3
Jan. 29	"	120	209·01	0·66	2·04	138·98
Feb. 12	"	118	194·7	0·66	2·00	129·4
Feb. 24	"	120	197·5	0·59	1·95	116·13
Mar. 8	"	105	171·2	0·51	1·84	88·0
Mar. 23	"	104	192·1	0·56	1·865	107·5
Apr. 4	"	130	315·5	1·14	2·40	351·47
May 2	H. C. Ritchie	135	347·8	1·38	2·47	481·14
May 5	F. R. Burfield	134	312·35	1·17	2·28	365·99
May 20	"	138·5	356·4	1·48	2·52	527·83
June 11	"	133	303·25	1·11	2·22	357·64
June 24	"	139	421·8	2·09	2·84	881·4
July 8	"	147	602·5	3·70	4·15	2,227·41
July 15	"	146	547·5	3·16	3·76	1,721·83
July 25	H. O. Brown	149	651·4	3·79	4·305	2,470·59
July 31	F. R. Burfield	143	435·4	2·23	3·00	972·72
Aug. 10	"	137	353·35	1·60	2·51	564·86
Aug. 24	"	143	334·2	1·44	2·35	480·41
Sept. 7	"	136	320·15	1·32	2·32	421·32
Sept. 24	"	137	320·4	1·25	2·32	400·30
Oct. 7	"	135·5	286·57	1·05	2·15	300·18
Oct. 22	"	135	298·0	1·10	2·13	326·00
Nov. 2	"	133·5	295·0	0·98	2·10	290·50
Nov. 15	"	129	251·0	0·72	1·91	180·40
Dec. 16	"	127	208·4	0·59	1·97	123·00

Daily Gauge Height and Discharge of Elbow River at Calgary, for 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	1·99	125	2·01	132	1·94	113	2·28	305	2·70	540	2·[illegible]	412
2	1·95	115	2·00	129	1·76	67	2·33	330	†2·47	480	2·26	377
3	1·69	51	2·10	155	1·95	116	2·45	370	2·44	460	2·17	317
4	1·52	34	*2·46	150	1·75	65	2·38	365	2·41	440	2·19	329
5	1·66	43	2·03	137	1·84	87	2·64	300	2·38	420	2·15	305
6	1·75	65	1·97	121	1·92	108	2·05	190	2·20	335	2·14	299
7	1·72	58	1·96	119	1·83	85	2·03	180	2·25	370	2·14	299
8	1·68	48	1·97	121	1·86	93	2·13	230	2·29	398	2·15	305
9	1·74	53	1·96	119	1·94	113	2·15	245	2·34	433	2·14	299
10	1·79	75	1·98	124	1·95	116	2·19	265	2·25	370	2·14	299
11	1·88	108	1·98	124	1·95	116	2·14	245	2·20	335	2·21	342
12	1·96	119	1·97	121	1·95	116	2·01	185	2·11	281	2·21	342
13	1·96	119	1·97	[illegible]	1·97	121	2·04	205	2·06	255	2·17	317
14	1·96	119	1·97	[illegible]	1·93	111	2·05	210	2·15	311	2·46	520
15	1·99	126	*2·25	120	1·94	113	2·40	400	2·20	335	3·26	1,207
16	2·02	134	1·96	119	1·99	126	2·37	390	2·47	528	5·36	4,312
17	1·99	126	1·96	119	2·16	171	2·35	375	2·50	550	4·88	3,460
18	2·00	129	*2·73	121	2·03	137	2·30	350	2·50	550	4·55	2,918
19	2·04	139	1·98	124	1·91	106	2·20	295	2·49	542	4·01	2,024
20	1·99	126	1·93	111	1·91	106	2·09	230	2·49	542	3·59	1,535
21	1·95	116	1·94	113	1·86	93	2·08	225	2·45	512	3·36	1,306
22	1·96	119	1·94	113	1·86	93	2·06	220	2·49	542	3·10	1,060
23	1·95	115	1·95	116	†1·95	116	2·05	215	2·54	582	2·94	916
24	1·98	124	1·94	113	1·96	130	2·06	220	2·53	574	2·79	786
25	1·98	124	*2·42	110	1·96	150	2·05	215	2·44	505	2·72	727
26	2·00	129	1·90	103	1·96	165	2·04	210	2·39	468	2·70	710
27	2·01	132	1·91	106	1·97	175	2·04	210	2·53	574	2·59	622
28	2·01	132	1·91	106	2·00	190	2·01	200	2·55	590	2·51	558
29	2·01	132	1·89	100	2·02	210	2·06	222	2·45	520	2·47	528
30	2·00	129	....	....	1·98	205	2·18	287	2·44	505	2·68	694
31	2·00	129	....	....	2·29	300	....	....	2·36	447	....	....

*Gauge heights were taken at a different time of day. Mean daily discharge is about that given. †Changing conditions.

DAILY GAUGE HEIGHT AND DISCHARGE of Elbow River at Calgary, for 1912.—*Concluded.*

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	2·60	630	2·85	838	2·35	440	2·18	323	2·15	*168	1·88	98
2	2·58	614	2·75	752	2·33	426	2·17	317	2·14	165	1·85	90
3	2·61	638	2·74	744	2·32	419	2·16	311	2·13	163	1·94	113
4	2·76	761	2·64	662	2·36	447	2·15	305	2·13	163	1·96	119
5	2·68	694	2·61	638	2·44	505	2·14	299	2·12	160	1·93	110
6	3·01	979	2·57	606	2·29	398	2·17	317	2·11	158	1·94	113
7	3·36	1,305	2·54	582	2·32	419	2·16	311	2·10	155	1·98	124
8	3·66	1,611	2·54	582	2·40	475	2·16	311	2·11	158	2·06	144
9	4·61	3,008	2·49	542	2·41	482	2·26	377	2·12	160	2·03	136
10	4·46	2,742	2·45	512	2·48	535	2·23	356	2·12	160	2·06	144
11	4·28	2,437	2·57	606	2·34	433	2·20	335	2·11	158	2·03	136
12	4·16	2,245	2·50	550	2·30	405	2·19	329	2·11	158	2·00	129
13	4·20	2,305	2·46	520	2·26	377	2·24	363	2·10	155	1·99	126
14	4·56	2,918	2·41	482	2·27	384	2·25	370	2·12	160	2·01	132
15	4·17	2,260	2·33	426	2·28	391	2·27	384	2·10	155	2·24	191
16	3·75	1,710	2·38	461	2·25	370	2·27	387	2·10	155	1·97	121
17	3·48	1,425	2·54	582	2·25	370	2·30	405	2·07	147	1·82	82
18	3·26	1,207	2·57	606	2·24	363	2·33	426	2·06	144	1·80	77
19	3·10	1,060	2·52	566	2·21	342	2·26	377	2·13	163	1·79	74
20	3·12	1,078	2·46	520	2·20	335	2·23	356	2·05	142	1·81	80
21	3·17	1,123	2·44	505	2·19	329	2·25	370	2·04	139	1·80	77
22	3·04	1,006	2·37	454	2·31	412	2·11	281	2·06	144	2·10	155
23	3·32	1,265	2·33	426	2·33	426	2·15	305	2·05	142	2·06	146
24	4·10	2,155	2·31	412	2·31	412	2·14	239	2·05	142	2·11	158
25	5·01	3,690	2·41	482	2·30	405	2·14	299	2·02	134	2·14	165
26	4·28	2,437	2·45	512	2·29	398	2·16	311	2·02	134	2·09	152
27	3·73	1,688	2·40	475	2·26	377	2·14	299	2·04	139	2·01	132
28	3·32	1,265	2·53	574	2·23	356	2·14	299	2·03	137	1·95	116
29	3·15	1,105	2·58	614	2·21	342	2·12	287	1·99	126	1·91	106
30	3·01	979	2·46	520	2·18	323	2·14	299	1·94	113	1·71	56
31	2·94	916	2·35	440	......	......	2·13	293	......	......	1·68	48

* Ice conditions after Nov. 1.

MONTHLY DISCHARGE of Elbow River at Calgary, for 1912.

(Drainage area, 482 square miles.)

MONTH	DISCHARGE IN SECOND-FEET.				RUN-OFF.	
	Maximum.	Minimum.	Mean.	Per Square Mile.	Depth in inches on Drainage Area.	Total in Acre-feet.
January	139·0	34·0	106·3	0·22	0·25	6,536
February	155·0	100·0	120·2	0·25	0·27	6,914
March	300·0	65·0	129·4	0·27	0·31	7,956
April	400·0	180·0	263·0	0·54	0·60	15,650
May	590·0	255·0	461·0	0·96	1·11	28,346
June	4,312·0	299·0	937·0	1·94	2·16	55,755
July	3,690·0	614·0	1,588·9	3·30	3·81	97,202
August	838·0	412·0	554·5	1·15	1·33	34,095
September	535·0	323·0	403·2	0·84	0·93	23,992
October	426·0	281·0	332·2	0·69	0·79	20,426
November	168·0	113·0	149·9	0·31	0·35	8,920
December	191·0	48·0	117·7	0·24	0·28	7,237
The year	......	......	......	......	12·19	312,929

Miscellaneous Discharge Measurements of tributaries of Bow River, by J. C. Keith, in 1909.

Date.	Stream.	Locality.	Width.	Area of section.	Discharge.
			Feet.	Sq.-ft.	Sec.-ft.
September 9	Bighill Creek	Sec. 10-26-4-5	10	5·75	6·4
September 9	Horse Creek	Sec. 8-26-4-5			Dry.
September 9	Grand Valley Creek	Sec. 24-26-5-5	7·8	3·04	0·80
September 9	Beaupre Creek	Sec. 15-26-5-5			Dry.
September 9	Spencer Creek	Sec. 17-26-5-5	8·	2·17	1·88
September 9	Ghost River	Sec. 24-26-6-5	70·	153·	303·
September 9	Jacob Creek	On Stony Indian Reserve, near mouth			Dry.
September 10	Cripple Creek	On Stony Indian Reserve, near mouth	4	1·29	0·73
September 10	Oldfort Creek	On Stony Indian Reserve, near mouth	11·6	6·06	10·57

MISCELLANEOUS MEASUREMENTS.

Miscellaneous Discharge Measurements of Nose Creek, near Calgary, Alta., in 1909.

Date.	Hydrographer.	Locality.	Width.	Area of section.	Discharge.
			Feet.	Sq.-ft.	Sec.-ft.
July 19	J. C. Keith	N. W. 13-24-1-5	19	15·8	23·4
September 2	do	do	9	4·0	5·8
September 18	do	do	9·3	4·2	5·7

Miscellaneous Discharge Measurements of Bow River, in 1909.

Date.	Hydrographer.	Locality.	Width.	Area of section.	Discharge.
			Feet.	Sq.-ft.	Sec.-ft.
September 5	J. C. Keith	Road allowance E. of sec. 34-25-4-5	305	813	4,017
September 10	do	Morley bridge on Stony Indian Reserve	178·5	966	3,390
October 20	P. M. Sauder	Intake S.A.L.Co., S.E. 31-21-25-4	336	887	2,874

Discharge Measurements of Nose Creek, near Calgary, in 1911.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
May 5	H. C. Ritchie	16·0	5·8	1·06	1·59	6·2
May 17	do	24·5	31·9	1·65	2·00	52·9
May 29	do	23·5	25·2	1·32	1·85	33·2
June 8	B. Russell	22·5	21·7	0·80	1·75	17·4
July 5	do	15·9	14·6	0·44	1·65	6·4
Aug. 2	H. T. Thomas	14·6	7·9	0·66	1·56	5·2
Aug. 24	H. Brown	16·1	9·7	0·91	1·66	8·8
Sept. 13	do	16·3	10·7	0·63	1·65	6·7
Sept. 27	do	16·9	44·5	0·21	1·67	9·3

DAILY GAUGE HEIGHT AND DISCHARGE of Nose Creek, near Calgary, Alta., for 1911.

Day.	April.		May.		June.		July.	
	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	....	....	1·62	7·2	1·74	16·2	1·75	17·4
2	....	....	1·64	7·9	1·70	11·5	1·73	15·0
3	....	....	1·60	6·5	1·75	17·4	1·65	8·3
4	....	....	1·62	7·2	1·76	18·6	1·65	8·3
5	....	....	1·60	6·5	1·70	11·5	1·60	6·5
6	....	....	1·70	11·5	1·68	10·2	1·62	7·2
7	....	....	1·71	12·7	1·70	11·5	1·60	6·5
8	....	....	1·65	8·3	1·76	18·6	1·58	5·9
9	....	....	1·68	10·2	1·75	17·4	1·63	7·6
10	....	....	1·63	7·6	1·73	15·0	1·67	9·6
11	....	....	1·63	7·6	1·69	10·9	1·70	11·5
12	....	....	1·65	8·3	1·65	8·3	1·66	8·9
13	....	....	1·76	18·6	1·68	10·2	1·70	11·5
14	....	....	1·80	23·6	2·35	110·0	1·68	10·2
15	....	....	1·75	17·4	2·30	102·0	1·63	7·6
16	....	....	1·80	23·6	2·15	77·2	1·57	5·7
17	....	....	2·20	85·3	1·89	36·2	1·59	6·2
18	....	....	2·10	69·1	1·90	37·6	1·63	7·6
19	....	....	1·90	37·6	1·75	17·4	1·68	10·2
20	....	....	1·80	23·6	1·65	8·3	1·71	12·7
21	....	....	1·82	26·3	1·63	7·6	1·68	10·2
22	....	....	1·73	15·0	1·60	6·5	1·65	8·3
23	....	....	1·80	23·6	1·63	7·6	1·70	11·5
24	1·75	17·4	1·85	30·4	2·00	52·9	1·67	9·6
25	1·78	21·1	1·70	11·5	2·32	105	1·65	8·3
26	1·73	15·0	1·68	10·2	2·25	93·5	1·63	7·6
27	1·68	10·2	1·79	22·4	1·80	23·6	[illegible]	6·5
28	1·65	8·3	1·88	34·7	1·73	15·0	[illegible]	6·5
29	1·65	8·3	1·83	27·7	[illegible]	15·0	1·59	6·2
30	1·60	6·5	1·77	19·9	[illegible]	17·4	1·58	5·9
31	....	....	1·75	17	....	....	1·58	5·9

Daily Gauge Height and Discharge of Nose Creek, near Calgary, Alta., for 1911.—*Continued.*

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	1·60	6·5	1·65	8·3	1·65	8·3	1·58	6·9
2	1·60	6·5	1·65	8·3	1·66	8·9	1·58	6·9
3	1·60	6·5	1·66	8·9	1·66	8·9	1·69	6·2
4	1·64	7·9	1·75	17·4	1·67	9·6	1·60	6·6
5	1·70	11·5	1·75	17·4	1·66	8·9	1·58	5·9
6	1·68	10·2	1·70	11·5	1·66	8·9	1·58	5·9
7	1·72	13·9	1·69	10·9	1·65	8·3	1·67	6·7
8	1·85	30·4	1·67	9·6	1·65	8·3	1·67	5·7
9	1·93	42·1	1·65	8·3	1·65	8·3	1·67	6·7
10	1·79	22·4	1·67	9·6	1·65	8·3	1·57	6·7
11	1·78	21·1	1·67	9·6	1·65	8·3	1·67	6·7
12	1·75	17·4	1·68	10·2	1·64	7·9	1·67	5·7
13	1·66	8·9	1·68	10·2	1·63	7·6	1·57	6·7
14	1·65	8·3	1·67	9·6	1·62	7·2	1·57	6·7
15	1·70	11·5	1·68	10·2	1·61	6·[illegible]	1·57	6·7
16	1·75	17·4	1·65	8·3	1·60	6·6	....	....
17	1·80	23·6	1·64	7·9	1·60	6·6	....	....
18	1·75	17·4	1·65	8·3	1·59	6·2	....	....
19	1·75	17·4	1·65	8·3	1·58	6·9	....	....
20	1·71	12·7	1·65	8·3	1·69	6·2	....	....
21	1·68	10·2	1·66	8·9	1·59	6·2	....	....
22	1·68	10·2	1·68	10·2	1·60	6·6	....	....
23	1·67	9·6	1·70	11·5	1·62	7·2	....	....
24	1·69	10·9	1·69	10·9	1·63	7·6	....	....
25	1·71	12·7	1·68	10·2	1·63	7·6	....	....
26	1·75	17·4	1·65	8·3	1·61	5·9	....	....
27	1·73	15·0	1·65	8·3	1·61	6·9	....	....
28	1·75	17·4	1·65	8·3	1·60	6·5	....	....
29	1·70	11·6	1·66	8·9	1·59	6·2	....	....
30	1·68	10·2	1·66	8·9	1·59	6·2	....	....
31	1·65	8·3	....	....	1·58	5·9	....	....

Monthly Discharge of Nose Creek, near Calgary, Alta., for 1911.

(Drainage area, 294 square miles.)

Month.	Discharge in Second-Feet.				Run-Off.	
	Maximum.	Minimum.	Mean.	Per square mile.	Depth in inches on Drainage	Total in acre-feet.
April 24-30	21·1	6·5	12·4	0·042	0·01	172
May	85·3	6·5	20·6	0·070	0·08	1,[illegible]
June	110·0	6·5	30·3	0·103	0·12	1,[illegible]
July	17·4	5·7	8·7	0·030	0·03	5[illegible]
August	42·1	6·5	14·4	0·049	0·06	88[illegible]
September	17·4	7·9	9·8	0·033	0·04	583
October	9·6	5·9	7·4	0·025	0·03	455
November 1-15	6·5	5·7	5·8	0·020	0·01	173
The period	....	....	....	....	0·38	5,873

Discharge Measurements of Nose Creek, near Calgary, in 1912.

Date.	Hydrographer.	Width.	Area of section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
May 4	H. C. Ritchie	23·5	28·95	1·98	2·04	57·25
Mry 5	F. R. Burfield	24	25·12	2·15	1·90	54·34
May 27	do	22·1	18·88	0·98	1·60	18·44
June 10	do	20	15·80	0·23	1·40	3·62
June 20	do	50·1	16·51	1·35	1·74	22·23
July 17	do	31·5	38·57	1·23	1·91	47·72
July 30	do	25	26·9	0·81	1·75	21·72
Aug. 9	do	21	15·95	0·64	1·66	10·25
Aug. 23	do	25	26·95	0·58	1·72	15·65
Sept. 7	do	25	31·65	2·12	2·04	66·97
Sept. 21	do	24	24·35	1·30	1·84	31·58
Oct. 5	do	23	23 20	1·11	1·87	25·57
Oct. 19	do	25	29·0	1·55	2·01	47·90
Oct. 30—	do	24·5	25·6	1·19	1·92	30·50
Nov. 16	do	23	23·4	0·84	1·81	19·68

Note.—These gaugings were made at wading sections below gauge. Width, area, and mean ve locity refer to actual gauging section.

Daily Gauge Height and Discharge of Nose Creek, near Calgary, for 1912.

Day.	March.		April.		May.		June.		July.	
	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.
1			2·10	69	1·95	45	1·58	15·1	1·70	15·5
2			2·00	53	1·95	45	1·58	14·9	1·74	19·9
3			2·15	77	2·00	53	1·59	15·7	1·78	25
4			2·10	69	2·02	56	1·58	14·5	1·75	22
5			2·00	53	2·02	60	1·58	14·2	1·73	18·8
6			1·90	38	2·03	66	1·57	13·0	1·80	28
7			1·90	38	2·00	65	1·57	12·6	1·83	32
8			1·95	45	1·95	62	1·55	10·7	1·83	32
9			1·97	48	1·82	43	1·52	8·5	1·95	45*
10			1·95	45	1·85	47	1·50	8·0	2·09	65*
11			1·93	42	1·73	32	1·50	7·1	2·00	58*
12			1·85	30	1·70	28	1·52	7·4	1·93	49
13			1·90	38	1·67	25	1·52	7·0	2·13	82
14			1·85	30	1·52	19·7	1·60	10·5	2·20	82*
15			1·80	24	1·58	16·1	1·73	22	2·13	82
16			1·77	20	1·57	15·2	1 95	43*	2·00	60
17			1·75	17·4	1·58	15·1	2·23	75*	1·93	49
18			1·79	22	1·60	17·8	2·05	70	1·90	44
19			1·75	17·4	1·81	42	1·81	30	1·87	39
20			1·73	15·0	1·85	47	1·73	18·8	2·06	70
21			1·73	15·0	1·92	57	1·70	15·5	2·05	68
22			1·70	11·5	1·83	44	1·68	13·9	1·95	52
23			1·70	11·5	1·80	40	1·64	10·9	1·94	50
24			1·68	10·1	1·75	35	1·51	9·1	1·90	44
25			1·68	10·1	1·78	38	1·60	8·5	2·22	80*
26	2·20	85	1·65	8·3	1·70	28	1·58	7·5	1·92	46
27	2·25	94	1·63	7·5	1·68	26	1·63	10·3	1·84	34
28	2·20	85	1·63	7·5	1·68	25	1·60	8·5	1·82	31
29	2·00	63	1·00	6·5	1·66	23	1·62	9·7	1·80	28
30	2·12	72	1·73	15·0	1·63	20	1·65	11·5	1·75	21
31	2·15	77			1·60	17			1·74	19 9

Note.—Shifting conditions May 4 to May 8, and May 27 to June 20.
*Bow River backing up to gauge. Discharge estimated.

Daily Gauge Height and Discharge of Nose Creek, near Calgary, for 1912.

Day.	August.		September.		October.		November.	
	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge Height.	Discharge.
	Feet.	Sec.-ft.	Feet.	Feet.	Gauge	Sec.-ft.	Feet.	Sec.-ft.
1	1·72	17·7	2·10	77	1·87	30	1·78	17·4
2	1·70	15·5	2·10	77	1·87	29	1·73	13·8
3	1·68	13·9	2·12	80	1·86	27	1·70	12·0
4	1·66	12·3	2·09	75	1·86	25	1·63	8·7
5	1·70	15·5	2·05	68	1·86	25	1·68	11·0
6	1·70	15·5	2·02	64	1·85	24	1·74	14·4
7	1·69	14·7	2·05	68	1·85	24	1·86	25
8	1·68	13·9	2·11	78	1·90	30	1·89	28
9	1·67	13·1	2·14	83	1·94	35	1·83	22
10	1·67	13·1	2·13	82	1·95	37	1·79	18·2
11	1·72	17·7	2·09	75	1·99	43	1·73	13·8
12	1·70	15·5	2·03	65	2·01	45	1·75	15·0
13	1·70	15·5	2·02	64	2·02	48	1·80	19·0
14	1·70	15·5	1·98	57	2·04	51	1·83	22
15	1·70	15·5	1·95	52	2·03	52	1·83	22
16	1·74	19·9	1·93	49	2·04	51	....	....
17	1·85	35	1·89	42	2·02	48	....	....
18	1·90	44	1·86	37	2·04	51	....	....
19	1·88	40	1·86	37	2·00	44	....	....
20	1·85	35	1·85	36	1·96	38	....	....
21	1·75	21	1·85	35	1·93	34	....	....
22	1·72	17·7	1·86	37	1·90	30	....	....
23	1·74	19·9	1·88	39	1·85	24	....	....
24	1·77	24	1·94	48	1·82	21	....	....
25	1·85	35	1·93	45	1·80	19·0	....	....
26	1·83	32	1·92	43	1·78	17·4	....	....
27	1·88	40	1·91	40	1·78	17·4	....	....
28	1·89	42	1·90	38	1·79	18·2	....	....
29	2·31	62	1·88	34	1·81	19·9	....	....
30	2·13	82	1·87	31	1·80	19·0	....	....
31	2·11	78	....	....	1·78	17·4	....	....

Note.—Shifting conditions Sept. 21 to Oct. 5.

Monthly Discharge of Nose Creek, near Calgary, for 1912.

(Drainage area, 284 square miles).

Month.	Discharge in Second-Feet.				Run-Off.	
	Maximum.	Minimum.	Mean.	Per Square Mile.	Depth in inches on Drainage Area.	Total in Acre-feet.
March (26-31)	94	53	77·7	0·264	0·06	925
April	77	5·5	29·8	0·101	0·11	1,773
May	66	15·2	37·3	0·127	0·15	2,204
June	75	7·0	17·5	0·060	0·07	1,041
July	82	15·5	44·9	0·153	0·18	2,761
August	52	12·3	27·5	0·094	0·11	1,607
September	83	31	55·2	0·188	0·21	3,285
October	52	17·4	32·1	0·109	0·13	1,974
November (1-15)	28	8·7	17·5	0·060	0·03	521
The period	....	....	....	....	1·05	16,271

Daily Gauge Height and Discharge of Canadian Pacific Railway Company's Canal near Calgary, Alta., for 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	....	....	2·10	86	2·90	73	3·50	320	1·50	24	3·20	266
2	....	....	2·10	86	2·00	73	3·50	320	3·50	320	3·20	266
3	0·90	00	2·10	86	1·50	24	3·50	320	3·50	320	3·20	266
4	1·80	50	2·10	86	1·50	24	3·40	302	4·10	430	2·10	86
5	1·90	61	2·10	86	1·40	17	3·40	302	4·30	468	2·10	86
6	2·70	179	2·10	86	1·30	12	3·40	302	4·10	430	2·10	86
7	2·70	179	2·10	86	1·50	31	3·40	302	1·90	61	2·10	86
8	2·80	196	2·70	179	1·90	61	3·40	302	1·10	3	2·10	86
9	2·80	196	2·80	196	1·90	61	3·50	320	3·20	266	2·10	86
10	2·90	213	2·80	196	1·90	61	3·60	338	3·20	266	1·80	50
11	3·10	248	2·50	146	1·90	61	3·60	338	3·50	320	1·40	17
12	3·10	248	2·40	130	1·80	50	3·60	338	3·90	230	1·30	12
13	3·20	266	2·00	73	1·80	50	3·60	338	2·80	196	1·20	7
14	3·40	302	1·80	50	1·80	50	3·60	338	3·10	248	1·20	7
15	2·40	130	1·60	31	1·80	50	3·50	338	3·20	266	1·20	7
16	2·30	114	1·50	24	2·10	86	3·60	338	3·00	230	1·20	7
17	2·20	99	1·50	24	2·10	86	3·60	338	3·20	266	1·20	7
18	2·10	86	1·50	24	2·00	73	3·50	320	3·00	230	1·20	7
19	2·20	99	1·50	24	2·20	99	3·50	320	3·20	266	1·00	1
20	2·30	114	1·50	24	2·70	179	3·20	266	3·20	266	1·00	1
21	2·30	114	1·50	24	3·50	320	3·20	266	3·20	266	1·90	1
22	2·30	114	1·50	24	3·50	320	2·90	213	2·90	213	1·90	1
23	2·30	114	1·50	24	3·50	320	3·20	266	1·60	31	0·90	0
24	2·00	73	1·50	24	3·50	320	3·50	320	2·30	114	0·90	0
25	2·00	73	2·10	86	3·50	320	3·50	320	3·20	266	0·90	0
26	2·90	73	3·30	284	3·50	320	3·50	320	3·20	266	0·90	0
27	2·10	86	3·20	266	3·50	320	3·50	320	3·20	266	0·80	0
28	2·10	86	1·90	61	3·50	338	3·50	320	2·50	162	0·80	0
29	2·10	86	1·70	40	3·70	356	2·90	213	2·40	130	0·80	0
30	2·10	86	1·70	40	3·80	374	1·50	24	1·70	40	0·80	0
31	2·10	86	....	....	3·50	320	1·50	24	....	....	0·80	0

Discharge Measurements of Canadian Pacific Railway Company's Canal near Calgary, Alta., in 1908-1909.

Date.	Hydrographer.	Width.	Area of section.	Mean velocity.	Gauge height.	Discharge.
1908.		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
May 12	H. R. Carscallen	49·5	84	0·74	2·19	63
July 22	do	46·5	60	0·27	1·625	16
September 2	do	46·5	62	0·26	1·64	15·8
October 1	H. C. Ritchie	52·0	103	0·95	2·45	98
1909.						
June 11	P. M. Sauder	51·5	111	1·27	2·47	141
June 25	J. C. Keith	45·0	62	0·36	1·47	22
July 3	do	48·0	84	0·82	1·975	69
July 17	do	50·0	97	0·98	2·20	96
August 6	do	56·0	159	1·89	3·40	301
August 30	do	56·5	165	1·92	3·48	318
September 18	do	55·5	175	1·94	3·70	341

Daily Gauge Height and Discharge of Canadian Pacific Railway Company's Canal near Calgary, Alta., for 1908.

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	....	....	2·30	86	4·00	376	3·10	213	3·00	196	2·50	114
2	....	....	2·30	86	4·10	395	3·10	213	1·70	23	1·40	5
3	....	....	1·40	5	4·20	414	3·10	213	1·60	16	2·50	114
4	....	....	1·10	0	4·20	414	3·10	213	1·60	16	2·50	114
5	....	....	0·90	0	4·20	414	3·10	213	1·60	16	2·50	114
6	....	....	0·90	0	4·10	395	3·10	213	2·60	129	1·40	5
7	....	....	0·90	0	4·10	395	3·10	213	2·60	129	1·00	0
8	2·50	114	0·90	0	4·10	395	3·10	213	2·70	144	2·50	114
9	2·50	114	0·90	0	4·10	395	3·10	213	2·40	100	3·60	302
10	2·20	73	0·90	0	2·90	178	3·10	213	1·50	10	3·40	266
11	2·20	73	0·90	0	1·70	23	3·10	213	1·50	10	3·40	...
12	2·20	73	0·80	0	1·40	5	3·10	213	1·80	31	3·40	266
13	2·20	73	0·80	0	1·40	5	3·10	213	1·90	40	3·40	266
14	2·20	73	0·90	0	1·30	2	3·10	213	2·10	61	3·40	266
15	2·20	73	0·90	0	1·20	1	3·10	213	2·80	161	3·50	284
16	2·20	73	0·90	0	1·20	1	3·10	213	2·00	50	3·60	302
17	2·20	73	0·90	0	1·10	0	3·10	213	1·40	5	3·60	302
18	2·20	73	0·90	0	1·10	0	3·10	213	1·00	0	3·60	302
19	2·20	73	0·90	0	2·60	129	3·00	196	1·50	10	2·50	114
20	2·30	86	0·90	0	2·60	129	3·00	196	1·40	5	1·50	10
21	2·20	73	0·90	0	2·60	129	3·00	196	1·60	16	1·50	10
22	2·20	73	0·90	0	2·20	73	2·90	178	1·60	16	1·00	0
23	2·20	73	2·20	73	3·90	357	3·00	196	1·80	31	0·90	0
24	2·20	73	2·80	161	3·90	357	3·00	196	1·80	31	0·80	0
25	2·20	73	2·90	178	3·90	357	3·10	213	1·90	40	0·80	0
26	2·20	73	3·00	196	3·40	266	3·10	213	2·50	114	0·80	0
27	2·20	73	3·00	196	3·30	248	3·00	196	2·50	114	0·80	0
28	2·20	73	3·00	196	3·30	248	3·00	196	2·50	114	0·80	0
29	2·20	73	3·00	196	3·20	231	3·00	196	2·50	114	0·80	0
30	2·20	73	3·90	357	3·20	231	3·00	196	2·50	114	0·80	0
31	2·20	73	....	....	3·20	231	3·00	196	....	....	0·80	0

Discharge Measurements of Canadian Pacific Railway Company's Canal near Calgary, in 1910.

Date.	Hydrographer.	Width.	Area of section.	Mean velocity.	Gauge height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
May 9	J. C. Keith	54·5	156·9	1·78	2·4	279·46
May 21	do	63·5	70·02	2·2	1·55	154·18
June 15	do	55·0	133·27	1·51	2·0	205·25
June 27	do	55·5	200·98	2·15	3·3	432·28
July 13	do	56·0	226·46	2·15	3·64	486·75
Aug. 8	do	56·0	220·78	2·226	3·6	491·7
Aug. 27	do	56·0	184·73	1·87	2·7	343·45
Sept. 10	do	55·5	150·32	1·54	2·245	231·7
Oct. 3	H. R. Carscallen	60·7	206·79	1·9	3·01	391·94
Oct. 14	do	11·0	5·48	0·651	0·45	3·67

Daily Gauge Height and Discharge of Canadian Pacific Railway Company's Canal near Calgary, for 1910.

Day.	April.		May.		June.	
	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.	Gauge Height.	Dis-charge.
	Feet.	Sec.-ft.	Feet.	Sec.-ft.	Feet.	Sec.-ft.
1	....	....	1·8	186	2·0	216
2	....	....	1·8	186	1·25	106
3	....	....	1·75	178	0·25	....
4	....	....	1·7	171	0·65	28
5	....	....	1·7	171	1·3	113
6	....	....	1·7	171	1·6	156
7	....	....	1·75	178	1·7	171
8	....	....	1·9	201	1·7	171
9	....	....	2·35	271	1·7	171
10	....	....	2·4	279	1·7	171
11	....	....	1·65	163	1·8	186
12	....	....	1·6	156	2·05	224
13	....	....	1·5	141	2·1	231
14	....	....	1·5	141	2·1	231
15	....	....	1·5	141	2·0	216
16	....	....	1·5	141	2·7	328
17	....	....	1·5	141	2·7	328
18	....	....	1·5	141	0·0	....
19	....	....	1·4	127	1·85	194
20	....	....	1·5	141	1·6	156
21	....	....	1·5	141	2·0	216
22	....	....	1·5	141	2·2	247
23	....	....	1·9	201	2·2	247
24	....	....	1·9	201	2·5	295
25	....	....	2·2	247	2·65	320
26	....	....	2·2	247	3·05	388
27	1·8	186	2·2	247	3·3	432
28	1·8	186	2·0	216	3·3	432
29	1·9	201	2·0	216	3·3	432
30	1·85	193	2·0	216	3·35	441
31	....	....	2·0	216	....	....

Daily Gauge Height and Discharge of Canadian Pacific Railway Company's Canal near Calgary, for 1910.—*Continued.*

Day.	July.		August.		September.		October.	
	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	3·4	449	3·8	521	2·3	263	2·77	346
2	3·45	458	3·8	521	2·3	263	2·85	354
3	3·6	485	3·6	485	2·25	255	2·9	362
4	3·9	539	3·6	485	2·35	271	3·0	379
5	4·15	586	3·6	485	2·35	271	2·65	320
6	4·3	615	3·6	485	2·35	271	2·15	240
7	4·3	615	3·6	485	2·3	263	1·62	159
8	4·3	615	3·6	485	2·3	263	·80	46
9	4·3	615	3·6	485	2·3	263	·55	17
10	4·3	615	3·6	485	2·3	263	·35	*
11	4·0	558	3·09	395	2·35	271	....	....
12	3·7	503	2·54	302	2·33	268	....	....
13	3·7	503	2·53	300	1·65	164	....	....
14	3·85	530	2·25	255	1·0	72	....	....
15	4·3	615	2·25	255	1·0	72	....	....
16	4·5	653	2·2	247	·92	62	....	....
17	4·35	625	2·0	216	·93	63	....	....
18	4·3	615	2·15	240	·95	66	....	....
19	3·8	521	2·3	263	1·8	186	....	....
20	3·7	503	2·25	255	2·52	299	....	....
21	3·7	503	2·2	247	2·38	276	....	....
22	3·7	503	2·2	247	2·5	295	....	....
23	3·6	485	2·35	271	2·0	216	....	....
24	3·8	521	2·6	312	2·0	216	....	....
25	4·05	567	2·65	320	2·0	216	....	....
26	4·0	558	2·7	328	2·0	216	....	....
27	4·1	577	3·05	388	1·97	212	....	....
28	4·05	567	3·5	467	1·95	209	....	....
29	4·0	558	3·0	379	2·35	271	....	....
30	3·8	521	3·0	379	2·75	337	....	....
31	3·8	521	3·0	379	....	....	....	....

* Canal closed for the season.

Monthly Discharge of Canadian Pacific Railway Company's Canal near Calgary, for 1910.

Month.	Discharge in Second-Feet.			Total Discharge in acre-feet.
	Maximum.	Minimum.	Mean.	
April (27–30)	201	186	191·5	1,519
May	297	141	184·3	11,333
June	432	....	228·2	13,578
July	653	449	551·6	33,918
August	521	216	366·7	22,547
September	337	62	221·1	12,055
October (1–10)	379	......	221·7	4,396
The period	....	....	....	99,346

DISCHARGE MEASUREMENTS of Canadian Pacific Railway Company's Canal near Calgary, Alta., for 1911.

Date.	Hydrographer.	Width.	Area of Section.	Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
Apr. 17	H. C. Ritchie	63·0	57·9	2·35	....	136·3*
May 5	do	64·5	85·8	2·47	....	212·1*
May 18	do	44·5	45·6	1·26	1·87	57·6
June 6	B. Russell	53·0	87·3	1·84	2·60	161·1
July 10	do	59·6	190·[illegible]	2·11	3·75	401·5‡
Aug. 4	H. T. Thomas	56·4	101·2	1·44	2·60	145·3‡
Aug. 24	H. Brown	46·5	55·8	1·27	2·00	70·8
Sept. 13	do	56·2	125·3	2·30	3·29	288·8
Sept. 22	L. R. Brereton	50·0	75·8	1·61	2·40	122·3

* Gauging made at a wading section near the intake. Water was turned into the canal for a few days in April to fill the pool in the canal.

‡ Gauging made at a bridge (No. 1.) on the north side of Sec. 36, Tp. 23, Rge. 1, W. 5th Mer.

DAILY GAUGE HEIGHT AND DISCHARGE of Canadian Pacific Railway Company's Canal near Calgary, Alta., for 1911.

Day.	April.		May.		June.		July.		August.		September.	
	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	....	....	2·10	83	2·40	122	3·15	259	2·60	154	2·25	101
2	....	....	2·40	122	2·43	127	3·15	259	2·60	154	2·30	108
3	....	....	3·10	248	2·47	*133	3·15	259	2·60	154	2·35	115
4	....	....	3·00	228	2·87	†202	3·15	259	2·60	154	2·80	415
5	....	....	3·00	228	2·57	149	3·15	259	2·60	154	3·90	441
6	....	....	3·00	228	2·57	149	3·15	259	2·75	180	3·90	441
7	....	....	3·00	228	2·57	149	3·10	248	2·85	198	3·85	428
8	....	....	3·00	228	2·57	149	3·00	228	2·80	189	3·50	340
9	....	....	3·00	228	2·52	141	3·00	228	2·80	189	2·90	208
10	....	....	3·00	228	2·50	138	3·75	402	2·75	180	2·85	198
11	....	....	3·00	228	2·58	151	3·85	428	2·75	180	2·85	198
12	....	....	2·80	189	2·56	148	3·60	364	2·75	180	2·85	198
13	....	....	2·60	154	2·70	171	3·60	364	2·80	189	3·10	248
14	....	....	2·70	171	2·90	208	3·40	316	2·90	208	3·15	259
15	....	....	2·55	146	2·95	218	3·40	316	2·80	189	3·15	259
16	....	....	2·45	130	2·95	218	3·40	316	2·60	154	3·00	228
17	....	....	2·25	101	3·55	253	3·45	328	2·50	138	2·85	198
18	....	....	2·15	89	3·53	347	3·45	328	2·50	138	2·85	198
19	....	....	1·70	43	3·53	347	3·45	328	2·50	138	2·85	198
20	....	....	2·65	162	3·80	415	3·45	328	2·50	138	2·80	189
21	....	....	2·60	154	3·80	415	3·45	328	2·50	138	2·50	138
22	....	....	2·60	154	3·95	454	3·00	228	2·45	130	2·40	122
23	....	....	2·25	101	3·95	454	3·00	228	2·45	130	2·40	122
24	....	....	2·20	95	4·00	467	3·00	228	2·25	101	2·40	122
25	....	....	2·20	95	3·45	328	2·95	218	2·20	95	2·40	122
26	....	....	2·20	95	3·45	328	2·90	208	2·20	95	3·80	415x
27	....	....	2·22	97	3·45	328	2·70	171	2·20	95	3·85	428x
28	....	....	2·20	95	3·45	328	2·70	171	2·20	95	0·75	0·00
29	....	....	2·20	95	3·20	270	2·70	171	2·00	71	....	....
30	1·65	39	2·20	95	3·20	270	2·60	154	2·00	71	....	....
31	....	....	2·30	108	....	....	2·60	154	2·00	71	....	....

*Opened one gate at 7·00 p.m.

†Closed one gate at 8·30 p.m.

xWater shut off at intake for the season.

NOTE—Water was turned into the canal for a few days about the middle of April to fill the pool in the canal. Canal was opened for the irrigation season on April 30. Gauge heights from April 30 to May 17 were interpolated from observations made at bridge No. 2.

MONTHLY DISCHARGE of Canadian Pacific Railway Company's Canal near Calgary, Alta., for 1911.

Month.	Discharge in Second-Feet.			Total Discharge in acre-feet.
	Maximum.	Minimum.	Mean.	
April (30)	39	39	39	77
May	248	43	150	9,223
June	467	122	256	15,233
July	428	154	269	16,540
August	208	71	144	8,854
September (1-28)	441	0	230	12,774
The period (April 30 to Sept. 28)	...	...	...	62,701

DISCHARGE MEASUREMENTS of C.P.R. Main Canal "A" at Bridge No. 1, in 1912.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
May 4	H. C. Ritchie	49·5	79·6	1·03	2·06	81·35
May 8	F. R. Burfield	47·5	68·3	0·90	1·82	61·42
May 25	do	55·5	118·2	1·25	2·61	148·39
June 10	do	56·6	118·3	1·54	2·75	181·84
June 20	do	57·0	120·2	1·54	2·85	185·87
July 10	do	58·5	142·4	1·61	2·85	214.6
July 17	do	55·0	118·4	1·52	2·75	180·01
July 30	do	55·0	114·2	1·42	2·64	161·81
Aug. 9	do	54·5	113·2	1·47	2·66	166·02
Aug. 23	do	59·5	167·4	1·91	3·66	320·23
Sept. [illegible]	do	53·5	106·4	1·33	2·50	141·16
Sept. 21	do	59·0	163·5	1·80	3·54	293·26
Oct. 5	do	...	...	...	1·10	Nil.

DISCHARGE MEASUREMENTS of C.P.R. Main Canal "A" at Bridge No. 3, in 1912.

Date.	Hydrographer.	Width.	Area of Section.	Mean Velocity.	Gauge Height.	Discharge.
		Feet.	Sq. ft.	Ft. per sec.	Feet.	Sec.-ft.
May 4	H. C. Ritchie	48·0	63·9	1·52	...	97·19
May 8	F. R. Burfield	42·5	42·3	0·96	...	39·76
May 25	do	50·0	92·8	1·82	...	168·60
June 10	do	52·5	96·8	2·03	...	196·88
June 20	do	52·3	102·4	2·03	2·97	208·26
July 10	do	53·0	121·9	1·91	3·02	233·35
July 17	do	53·5	101·7	1·94	2·85	197·59
July 30	do	[illegible]3·0	95·8	1·89	2·75	171·26
Aug. 9	do	[illegible]2·5	97·1	1·75	2·84	169·61
Aug. 23	do	56·9	150·9	2·22	3·77	335·69
Sept. 7	do	51·5	93·1	1·68	2·75	156·53
Sept. 21	do	55·5	142·0	2·05	3·58	291·51

Daily Gauge Height and Discharge of C.P.R. Main Canal "A" near Calgary, for 1912.

Day.	April.		May.		June.		July.		August.		September.	
	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			3·20	247	2·65	167	3·10	232	2·50	146	2·40	132
2			2·40	132	2·60	160	3·00	217	2·50	146	2·50	146
3			2·40	132	2·65	167	2·90	202	2·50	146	2·50	146
4			2·30	118	3·00	217	2·90	202	2·50	146	2·50	146
5			1·90	71	3·00	217	3·00	217	3·60	160	2·50	146
6			1·90	71	2·90	202	2·90	202	3·60	160		
7			1·70	51	2·90	202	2·90	202	2·60	160	2·50	146
8			2·10	94	2·80	188	3·00	217	2·50	146	3·50	146
9			2·10	94	2·90	202	2·90	202	3·50	146	2·50	146
10			2·30	118	2·70	174	2·80	188	2·60	160	2·50	146
											2·70	174
11			2·30	118	3·15	240	2·70	174	3·00	217	3·30	262
12			2·40	132	3·20	247	2·70	174	3·00	217	4·00	368
13			2·40	132	3·20	247	2·70	174	3·00	217	3·00	217
14			2·50	146	3·40	277	2·70	174	3·00	217	3·80	188
15			2·70	174	3·20	247	2·70	174	3·00	217	3·90	202
16			2·70	174	3·10	232	2·70	174	3·30	262	2·90	202
17			2·70	174	2·70	174	2·70	174	3·30	262	3·00	217
18			2·50	146	2·70	174	2·75	181	3·30	262	3·30	262
19			2·50	146	3·70	174	2·70	174	3·30	262	3·50	292
20			2·40	132	2·60	150	2·75	181	3·30	262	3·50	292
21			2·40	132	2·60	160	2·50	146	3·10	232	3·50	292
22			2·50	146	3·80	188	2·50	146	3·10	232	3·50	292
23	2·00	*82	2·50	146	3·10	232	2·50	146	3·30	262	3·50	292
24	2·20	106	2·50	146	3·70	322	2·50	146	3·10	232	3·30	262
25	1·80	61	2·50	146	4·00	368	2·80	188	3·10	232	3·30	247
26	2·50	146	2·50	146	4·10	384	2·70	174	2·90	202	3·10	232
27	2·50	146	2·60	160	4·10	384	2·60	160	3·80	188	3·10	232
28	3·00	217	2·65	167	3·60	307	2·50	160	3·10	94	1·85	†66
29	3·00	217	2·65	167	3·10	232	2·50	146	2·10	94		
30	3·00	217	2·60	150	3·10	232	2·50	146	3·10	94		
31			2·65	167			2·60	160	2·10	94		

*Headgates opened.
†Headgates closed.

Monthly Discharge of C.P.R. Main Canal "A" near Calgary, for 1912.

Month.	Discharge in Second-Feet.				Run-Off.	
	Maximum.	Minimum.	Mean.	Per Square Mile.	Depth in inches on Drainage Area.	Total in Acre-feet.
April (23-30)	217	61	140			2,225
May	247	51	138			8,485
June	384	160	229			13,626
July	232	146	179			11,006
August	262	94	189			11,621
September (1-28)	368	66	210			11,662
The period						58,625

DAILY DISCHARGE of Bow River from records at Morley and Horseshoe Falls, 1910.

Day.	Jan.	Feb.	March.	April.	May.	June.
	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.
1	......	905*	......	757*	......	6,910
2	......	685*	......	[illegible]	......	7,660
3	......	1,130*	......	[illegible]	......	7,195
4	......	813*	......	815*	......	6,635
5	......	760*	949*	[illegible]	......	6,115
6	......	......	......	......	......	6,500
7	......	1,648*	......	802*	......	7,830
8	......	795*	843*	805*	......	8,175
9	......	825*	......	837*	......	7,660
10	......	1,456*	790*	800*	......	7,660
11	......	907*	904*	......	......	9,070
12	......	765*	1,015*	860	......	12,475
13	......	802*	1,058*	......	......	12,680
14	......	639*	......	1,447*	......	10,640
15	......	699*	955*	1,262*	......	10,040
16	......	682*	875*	1,021*	......	11,245
17	......	738*	833*	......	......	11,860
18	......	755*	......	......	......	13,090
19	......	725*	755*	......	......	11,245
20	......	......	......	1,438*	......	11,245
21	971*	675*	......	1,738*	......	12,680
22	......	......	979*	1,761*	......	11,450
23	......	......	1,105*	1,701*	......	9,840
24	......	......	1,011*	1,910*	......	8,525
25	......	......	1,110*	2,760*	8,350	7,830
26	......	......	1,010*	......	10,240	8,700
27	......	......	......	......	10,440	9,840
28	......	......	914*	......	9,070	10,840
29	......	......	830*	......	7,660	10,840
30	......	......	786*	......	7,050	9,840
31	972*	......	812*	......	6,500	......

*Discharge from records kept by the Calgary Power Co. at Horseshoe Falls. The remainder are from records of the Irrigation Branch taken at Morley.

DAILY DISCHARGE of Bow River from records at Morley and Horseshoe Falls, 1910.—*Continued.*

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.
1	9,255	6,185	2,901	2,620	1,888	1,540*
2	9,440	5,070	2,816	2,490	1,930	1,583*
3	8,350	4,850	2,648	2,370	1,860	1,515*
4	8,176	4,740	2,799	2,370	1,930	1,430*
5	8,000	6,416	2,935	2,295	1,846	1,612*
6	8,000	6,500	3,115	2,220	1,874	1,617*
7	7,830	5,635	3,210	2,370	1,790	1,497*
8	8,000	5,500	3,077	2,620	2,322*	1,663*
9	8,175	5,115	2,765	2,445	2,257*	1,608*
10	7,830	5,115	2,680	2,680	2,283*	1,537*
11	7,830	5,875	2,731	2,850	2,284*	1,462*
12	8,175	5,875	2,568	2,935	2,238*	1,600*
13	8,700	5,760	2,552	2,765	2,230*	1,462*
14	9,255	6,645	2,475	2,799	2,010*	1,478*
15	9,255	5,530	2,475	2,600	2,070*	1,400*
16	9,640	5,300	2,520	2,600	2,038*	1,420*
17	9,070	4,960	2,731	2,850	1,765*	1,500*
18	9,440	4,740	2,765	2,986	1,765*	1,485*
19	8,885	4,630	2,850	2,884	1,788*	1,375*
20	8,175	4,410	2,935	2,748	1,902*	1,286*
21	7,830	4,410	2,901	2,680	2,063*	1,420*
22	7,660	4,305	3,020	2,600	1,920*	1,240*
23	7,340	4,200	3,096	2,520	1,877*	1,262*
24	7,050	4,095	2,901	2,430	1,837*	1,512*
25	6,240	3,685	3,020	2,445	1,500*	1,340*
26	6,370	3,485	2,969	2,370	1,315*	1,580*
27	5,990	3,305	2,765	2,265	1,340*	1,455*
28	5,760	3,305	2,600	2,160	1,373*	1,317*
29	5,990	3,115	2,536	2,070	1,382*	1,417*
30	5,921	2,986	2,460	2,000	1,4[illegible]*	1,373*
31	5,990	2,952	....	1,972	....	1,904*

*Discharge from records of the Calgary Power Co., Horseshoe Falls. The remainder are Irrigation Branch records taken at Morley Bridge.

DAILY DISCHARGE of Bow River from records at Morley and Horseshoe Falls, 1911.

Day.	Jan.	Feb.	March.	April.	May.	June.
	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.
1	823*	750*	710*	694	1,240	3,698*
2	823*	780*	710*	670	1,317	5,207*
3	862*	784*	730*	670	1,422	7,240*
4	1,117*	763*	720*	670	1,470	7,370*
5	1,360*	780*	722*	626*	1,720	6,839*
6	1,230	740*	722*	808	2,160	6,548*
7	1,310*	784*	788*	674	2,010	6,430*
8	1,243*	750*	775*	708	2,010	5,825*
9	770*	784*	775*	768	2,190*	5,960*
10	796*	818*	765*	768	1,815*	6,470*
11	935*	840*	740*	774	1,935	7,150*
12	...	800*	740*	755	2,010	8,490*
13	...	780*	735*	...	2,085	10,443*
14	...	784*	778*	755	2,010	12,375*
15	...	780*	780*	790	1,935	13,043*
16	...	710*	810*	776	2,240	13,189*
17	...	725*	725*	790	1,940*	13,105*
18	...	700*	800*	822	1,930*	12,695*
19	...	730*	900*	790	2,120*	11,660*
20	...	730*	855*	830	2,200*	11,660*
21	654	700*	830*	870	2,200*	11,475*
22	680	710*	902*	...	2,140*	11,780*
23	646	600*	925*	950	2,150*	13,820*
24	590	680*	880*	1,262	2,120*	14,770*
25	586	690*	935*	942*	2,100*	12,925*
26	1,120*	720*	750*	1,100	2,120*	11,725*
27	1,345*	725*	750*	1,190	2,150*	11,994*
28	980*	720*	810*	1,140	2,337*	12,014*
29	940*	...	880*	1,210	2,230*	11,700*
30	940*	...	855*	1,160	2,377*	11,640*
31	860*	...	855*	...	2,696*	...

*Discharges from Calgary Power Co. records taken at Horseshoe Falls.

DAILY DISCHARGE of Bow River at Horseshoe Falls from Calgary Power Co. records, 1911.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.
1	11,670	5,120	....	2,150	1,260	920
2	11,500	5,195	4,500	2,130	1,270	935
3	11,300	5,370	4,600	2,160	1,210	890
4	10,000	5,570	5,100	2,200	1,230	945
5	9,329	5,685	4,900	2,130	1,200	910
6	9,213	5,550	....	2,180	1,210	960
7	9,108	5,820	4,530	2,160	1,180	900
8	9,112	....	4,275	....	1,075	938
9	8,672	5,800	4,100	....	700	960
10	8,341	5,925	4,690	1,668	630	945
11	7,950	5,460	3,700	1,790	650	920
12	7,702	5,370	3,700	1,860	620	890
13	6,080	4,980	3,650	1,860	625	910
14	5,840	4,890	3,650	1,860	625	870
15	5,850	4,710	3,540	1,846	750	880
16	5,950	4,920	3,450	1,880	950	860
17	6,652	4,840	3,350	1,908	1,060	835
18	6,590	4,780	3,275	1,750	1,120	790
19	6,530	4,670	3,150	1,770	1,110	835
20	6,140	4,650	2,950	1,725	1,075	810
21	6,050	4,530	2,875	1,715	1,050	800
22	5,950	4,490	2,875	1,645	1,020	685
23	5,930	4,475	2,750	1,610	975	790
24	5,790	4,395	2,370	1,860	1,025	725
25	5,765	4,395	2,590	1,846	975	735
26	5,940	4,310	2,508	1,707	1,020	740
27	6,400	4,274	2,440	1,566	940	725
28	5,905	4,365	2,350	1,494	675	675
29	5,525	4,390	2,350	1,620	735	663
30	5,480	4,420	2,300	1,605	850	675
31	5,215	4,455	....	1,570	....	700

Daily Discharge Bow River at Horseshoe Falls from records of C. P. Co., 1912.

Day.	January.	February.	March.	April.	May.	June
	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.
1	685	770	661	698	819	3,054
2	710	765	662	702	792	2,930
3	700	780	672	763	837	2,868
4	687	785	677	780	855	2,754
5	730	780	684	765	842	2,657
6	780	760	692	743	832	2,501
7	780	765	695	720	868	2,401
8	780	775	699	762	994	2,946
9	755	790	644	757	1,390	3,807
10	750	800	708	802	1,194	4,858
11	750	755	708	837	1,381	4,971
12	760	763	710	805	1,512	5,304
13	810	775	704	825	1,788	5,528
14	820	780	707	777	2,317	8,007
15	790	770	718	795	3,106	8,871
16	910	790	709	814	4,542	10,671
17	835	800	705	687	4,467	11,106
18	780	780	706	722	4,370	10,616
19	790	780	709	666	4,356	10,639
20	830	735	707	727	3,420	10,464
21	850	790	707	724	2,905	10,378
22	820	790	704	737	2,825	10,128
23	842	755	705	750	2,752	9,494
24	810	780	702	739	2,679	9,490
25	790	770	700	704	3,334	9,759
26	830	755	702	767	4,166	9,518
27	810	725	703	777	4,646	9,230
28	820	695	704	754	5,208	9,204
29	785	660	771	777	5,040	9,135
30			731	784	4,932	8,439
31			713		3,795	

DAILY DISCHARGE Bow River at Horseshoe Falls from records of C. P: Co., 1912.

Day.	November.	December.
	Sec.-ft.	Sec.-ft.
1	....	1,000
2	....	1,160
3	....	1,500
4	....	1,400
5	....	1,125
6	1,645	1,085
7	1,630	1,100
8	1,610	1,250
9	1,660	1,100
10	1,650	1,000
11	1,650	700
12	1,680	730
13	1,650	960
14	1,620	1,130
15	1,600	1,050
16	860	1,020
17	1,245	1,050
18	2,000	1,120
19	2,000	1,020
20	1,890	1,090
21	1,860	1,020
22	1,660	1,090
23	1,640	1,000
24	1,620	1,020
25	1,490	1,100
26	800	1,250
27	800	960
28	1,300	1,140
29	1,300	1,020
30	1,100	1,010
31	....	1,000

DAILY DISCHARGE Bow River at Horseshoe Falls from records of C.P.R. Co., 1913.

Day.	January.	February.	March.
	Sec.-ft.	Sec.-ft.	Sec.-ft.
1	920	900	800
2	930	800	870
3	940	620	800
4	920	660	800
5	700	670	820
6	680	610	880
7	700	630	900
8	730	740	920
9	720	730	820
10	690	740	860
11	720	760	....
12	730	760	....
13	810	820	....
14	850	860	....
15	790	880	....
16	750	800	....
17	780	800	....
18	710	800	....
19	860	700	....
20	800	820	....
21	815	810	....
22	810	715	....
23	920	680	....
24	910	725	....
25	920	680	....
26	800	630	....
27	820	610	....
28	940	530	....
29	920	....	....
30	940	....	....
31	900	....	....

APPENDIX VIII.

PRECIPITATION DATA.

PRECIPITATION TABLES.

Table No. 1.—Year 1911-12.

Month.	Banff.	Jumping Pond.	Calgary.
	Precipitation.	Precipitation.	Precipitation.
	Inches.	Inches.	Inches.
October	0·56	....	0·51
November	1·64	....	0·61
December	1·04	....	0·08
January	0·94	....	0·60
February	0·20	....	0·08
March	0·32	....	0·34
April	1·35	....	2·05
May	1·06	....	1·42
June	3·02	....	4·31
July	5·03	....	5·60
August	3·94	....	2·75
September	1·03	....	2·80
Total	20·03	....	20·55

Mean for years 1903-11, at Banff, 17·89 inches. Mean for 20 years at Banff, 19·13 inches.
Mean for 27 years at Calgary, 16·11 inches.

Table No. 2.—Year 1910-11.

Month.	Banff.	Jumping Pond.	Calgary.
	Precipitation.	Precipitation.	Precipitation.
	Inches.	Inches.	Inches.
October	1·36	0·49	0·48
November	0·99	0·23	0·34
December	0·90	0·16	0·17
January	3·12	0·75	0·44
February	0·65	0·21	0·56
March	0·54	0·65	1·04
April	1·15	0·10	1·06
May	1·36	2·82	5·03
June	2·84	3·05	2·63
July	1·38	2·64	2·17
August	3·76	....	4·36
September	1·14	....	0·89
	19·19	11·10	19·17

Table No. 3.—Year 1909-10

Month.	Banff.	Jumping Pond.	Calgary.
	Precipitation.	Precipitation.	Precipitation.
	Inches.	Inches.	Inches.
October	0·70	0·63	0·64
November	4·67	0·81	0·21
December	1·02	0·43	0·44
January	0·46	0·48	0·21
February	1·94	0·80	0·88
March	1·59	0·87	0·88
April	1·19	0·64	0·80
May	0·66	0·16	1·08
June	2·77	3·24	1·54
July	0·46	0·28	0·44
August	1·25	3·78	1·02
September	0·77	1·42	1·50
Total	17·48	13·54	9·64

TABLE No. 4.—Year 1908-09.

Month.	Banff.	Jumping Pond.	Calgary.
	Precipitation.	Precipitation.	Precipitation.
	Inches.	Inches.	Inches.
October	1·87	0·85	0·55
November	1·18	0·06	0·03
December	1·71	0·34	0·20
January	3·94	0·38	0·58
February	1·38	0·29	0·36
March	0·78	0·79	0·68
April	0·92	0·76	1·14
May	1·49	4·36	4·87
June	1·81	2·53	2·07
July	2·68	3·54	4·09
August	0·99	1·28	0·59
September	1·18	0·29	0·36
Total	19·93	15·47	15·52

TABLE No. 5.—Year 1907-08.

Month.	Banff.	Jumping Pond.	Calgary.
	Precipitation.	Precipitation.	Precipitation.
	Inches.	Inches.	Inches.
October	0·96	0·21	0·15
November	1·22	0·30	0·08
December	1·11	0·34	0·10
January	0·10	0·15	0·08
February	1·03	0·13	0·29
March	1·58	1·70	0·55
April	1·66	0·97	0·87
May	4·14	4·06	4·59
June	2·61	6·44	7·26
July	1·06	1·18	1·75
August	1·74	2·97	1·52
September	1·41	0·69	0·58
Total	18·62	19·14	17·80

TABLE No. 6.—Year 1906-07.

Month.	Banff.	Jumping Pond.	Calgary.
	Precipitation.	Precipitation.	Precipitation.
	Inches.	Inches.	Inches.
October	1·95	...	0·82
November	0·87	...	1·20
December	1·50	...	0·00
January	1·64	...	0·40
February	0·56	...	0·20
March	1·55	...	0·76
April	1·72	...	1·79
May	3·39	...	1·04
June	2·83	...	3·76
July	1·90	...	0·85
August	4·26	...	3·34
September	2·60	...	1·20
Total	23·77	...	15·36

Table No. 7.—Year 1905-06.

Month.	Banff.	Jumping Pond.	Calgary.
	Precipitation.	Precipitation.	Precipitation.
	Inches.	Inches.	Inches.
October	1·66	....	0·11
November	0·54	....	1·20
December	0·45	....	0·00
January	0·77	....	0·04
February	0·40	....	0·14
March	0·19	....	0·70
April	0·32	....	0·37
May	2·98	....	6·96
June	1·91	....	2·35
July	0·89	....	1·15
August	2·26	....	3·00
September	0·54	....	0·04
Total	12·91	....	16·06

Table No. 8.—Year 1904-05.

Month.	Banff.	Jumping Pond.	Calgary.
	Precipitation.	Precipitation.	Precipitation.
	Inches.	Inches.	Inches.
October	0·57	....	1·35
November	0·90	....	0·20
December	1·28	....	0·31
January	0·55	....	1·04
February	0·30	....	0·30
March	0·90	....	0·65
April	0·56	....	0·80
May	3·06	....	2·06
June	3·91	....	6·01
July	1·43	....	0·91
August	0·89	....	0·69
September	1·72	....	0·35
Total	16·07	....	14·67

Table No. 9.—Year 1903-04.

Month.	Banff.	Jumping Pond.	Calgary.
	Precipitation.	Precipitation.	Precipitation.
	Inches.	Inches.	Inches.
October	0·72	....	0·00
November	2·00	....	0·60
December	0·64	....	0·25
January	1·31	....	0·15
February	1·73	....	0·15
March	1·35	....	0·86
April	0·96	....	0·14
May	0·78	....	1·56
June	2·63	....	1·99
July	0·87	....	1·74
August	1·49	....	2·75
September	0·74	....	0·69
Total	15·22	....	10·88

APPENDIX IX.

TEMPERATURE DATA.

TEMPERATURE TABLES.

1912 CALGARY.

January.					February.					March.				
Day of Month.	Temperature.			Mean Daily Temp.	Day of Month.	Temperature.			Mean Daily Temp.	Day of Month.	Temperature.			Mean Daily Temp.
	Max.	Min.	Daily Range.			Max.	Min.	Daily Range.			Max.	Min.	Daily Range.	
	°	°	°			°	°	°	°		°	°	°	°
1	14	0	14	7	1	47	16	31	31·5	1	11	−3	14	4
2	−2	−6	4	−4	2	49	32	17	40·5	2	11	−10	21	0·5
3	17	−11	28	3	3	20	15	5	17·5	3	22	−6	28	8
4	10	−6	16	2	4	33	12	21	22·5	4	16	−5	21	5·5
5	2	−5	8	−2	5	30	10	20	20	5	31	−6	37	12·5
6	−8	−23	15	−15·5	6	28	22	6	25	6	22	4	18	13
7	22	−10	32	6	7	17	15	2	16	7	25	−2	27	12
8	12	5	7	8·5	8	25	10	15	17·5	8	36	−3	39	17
9	−15	−20	5	−17·5	9	43	15	28	29	9	44	12	32	28
10	−15	−25	9	−20·5	10	46	24	22	35	10	40	12	28	26
11	−10	−30	20	−20	11	45	22	23	33·5	11	32	6	26	19
12	17	−10	27	3·5	12	45	20	25	32·5	12	20	11	9	15·5
13	3	−10	7	−3·5	13	44	17	27	30·5	13	26	−3	29	11·5
14	17	−5	25	4·5	14	46	31	15	38·5	14	42	3	39	22·5
15	[illegible]	13	35	30·5	15	44	34	10	39	15	30	7	23	18·5
16	[illegible]	15	17	23·5	16	43	28	15	35·5	16	25	9	16	17
17	[illegible]	10	10	15	17	45	26	19	35·5	17	42	11	31	26·5
18	[illegible]	−5	27	5·5	18	41	16	25	28·5	18	18	9	9	13·5
19	23	10	13	16·5	19	34	20	14	27	19	7	−16	23	−4·5
20	41	12	29	26·5	20	39	8	31	23·5	20	30	−6	36	12
21	46	31	15	38·5	21	39	24	15	31·5	21	46	11	35	28·5
22	44	28	16	36	22	44	22	22	33	22	45	28	17	36·5
23	38	18	20	28	23	38	21	17	29·5	23	45	21	24	33
24	38	21	17	29·5	24	34	17	17	25·5	24	55	29	26	42
25	42	27	15	34·5	25	40	6	34	23	25	50	32	18	41
26	21	11	10	16	26	32	15	17	23·5	26	52	24	28	38
27	37	12	25	24·5	27	17	10	7	13·5	27	60	26	34	43
28	30	9	21	19·5	28	14	−3	17	5·5	28	60	27	33	43·5
29	48	14	34	31	29	11	−7	18	2	29	28	24	4	26
30	45	28	17	37·5						30	46	13	33	29·5
31	39	15	24	27						31	58	28	30	43
	672	110	562			1,033	498	535			1,075	287	788	
	21·68	3·55	18·13			35·62	17·17	18·45			34·68	9·26	25·42	

1912 CALGARY—*Continued.*

April.

Day of Month.	Temperature. Max.	Min.	Daily Range.	Mean Daily Temp.
	°	°	°	°
1	58	28	30	43
2	66	33	33	49·5
3	64	26	38	42
4	42	27	15	34·5
5	41	26	15	33·5
6	53	14	39	33·5
7	54	20	34	47
8	63	27	36	45
9	65	29	36	47
10	60	34	26	47
11	36	33	3	34·5
12	38	32	6	35
13	40	30	10	35
14	54	28	26	41
15	58	26	32	42
16	60	34	15	42
17	54	28	26	41
18	55	26	29	40·5
19	54	27	27	40·5
20	56	24	32	40
21	58	32	26	45
22	54	27	27	40·5
23	55	34	21	44·5
24	60	26	34	43
25	47	30	17	38·5
26	53	28	25	40·5
27	47	30	17	38·5
28	51	34	27	47·5
29	60	29	31	44·5
30	40	37	3	38·5
	1,606	869	737	
	53·53	28·96	24·56	

May.

Day of Month.	Temperature. Max.	Min.	Daily Range.	Mean Daily Temp.
	°	°	°	°
1	37	33	4	35
2	42	33	9	37·5
3	50	31	19	40·5
4	54	28	26	41
5	60	32	28	46
6	64	40	24	52
7	74	41	33	57·5
8	74	44	30	59
9	54	36	18	45
10	60	35	25	47·5
11	65	32	33	48·5
12	57	30	37	49·5
13	78	36	42	57
14	81	44	37	63
15	82	44	38	63
16	68	49	19	58·5
17	57	42	25	54·5
18	64	40	24	52
19	46	40	6	43
20	52	42	10	47
21	54	33	21	43·5
22	50	40	10	45
23	63	41	22	52
24	72	40	32	56
25	72	39	33	55·5
26	66	51	15	58·5
27	60	49	11	54·5
28	66	33	33	49·5
29	66	35	31	50·5
30	58	35	23	45·5
31	68	30	38	49
	1,934	1,178	756	
	62·39	38·00	24·39	

June.

Day of Month.	Temperature. Max.	Min.	Daily Range.	Mean Daily Temp.
	°	°	°	°
1	70	38	32	54
2	58	33	25	45·5
3	59	30	29	44·5
4	54	36	18	45
5	60	33	27	46·5
6	66	29	37	47·5
7	77	35	42	56
8	87	40	47	63·5
9	70	60	20	60
10	75	40	35	57·5
11	85	42	43	63·5
12	86	45	40	66
13	70	54	16	62
14	54	42	22	63
15	64	46	18	55
16	69	60	19	59·5
17	73	48	25	60·5
18	80	44	36	52
19	82	51	31	66·5
20	84	50	34	67
21	85	49	36	67
22	86	60	25	73
23	84	59	25	71·5
24	88	57	31	72·5
25	89	59	30	74
26	90	52	38	71
27	81	59	22	70
28	71	49	22	60
29	55	48	7	51·5
30	51	47	4	49
	2,213	1,376	337	
	75·75	45·86	27·30	

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CALGARY—*Continued.*

July.					August.					September.				
Day of Month.	Temperature.			Mean Daily Temp.	Day of Month.	Temperature.			Mean Daily Temp.	Day of Month.	Temperature.			Mean Daily Temp.
	Max.	Min.	Daily Range.			Max.	Min.	Daily Range.			Max.	Min.	Daily Range.	
	°	°	°	°		°	°	°	°		°	°	°	°
1.......	54	43	11	48·5	1.......	74	49	25	61·5	1.......	60	35	25	37·5
2.......	50	47	3	48·5	2.......	69	55	14	62	2.......	56	36	20	46
3.......	72	36	36	54	3.......	67	48	19	57·5	3.......	53	35	18	44
4.......	72	43	29	57·5	4.......	68	56	12	62	4.......	53	32	21	42·5
5.......	63	50	13	56·5	5.......	68	44	24	56	5.......	45	42	3	43·5
6.......	63	48	15	55·5	6.......	67	42	25	56·5	6.......	63	33	30	48
7.......	53	48	5	50·5	7.......	73	50	23	61·5	7.......	64	45	19	54·5
8.......	58	46	12	52	8.......	75	47	28	61	8.......	52	45	7	48·5
9.......	68	46	22	57	9.......	80	48	32	64	9.......	65	40	25	52·5
10.......	65	42	23	53·5	10.......	75	54	21	64·5	10.......	66	40	26	53
11.......	66	50	16	58	11.......	56	46	10	51	11.......	72	40	32	56
12.......	74	43	31	58·5	12.......	67	45	22	56	12.......	66	46	20	56
13.......	51	45	6	48	13.......	68	44	24	56	13.......	54	42	12	48
14	71	33	38	52	14.......	72	[illegible]	30	57	14.......	51	34	17	42·5
15.......	76	45	31	60·5	15.......	71	[illegible]	28	57	15.......	59	25	34	42
16.......	61	45	16	53	16.......	60	53	7	56·5	16.......	68	30	38	49
17.......	66	46	20	56	17.......	60	45	15	52·5	17.......	71	37	34	54
18.......	72	40	32	56	18.......	68	42	26	55	18.......	63	36	27	49·5
19.......	69	47	22	58	19.......	70	46	24	58	19.......	54	36	18	45
20.......	56	48	8	52	20.......	78	46	32	62	20.......	58	33	25	45·5
21.......	75	48	27	61·5	21.......	80	54	26	67	21.......	66	32	34	49
22.......	75	49	26	62	22.......	82	56	26	69	22.......	39	35	4	37
23.......	65	51	14	58	23.......	78	53	25	65·5	23.......	40	32	8	36
24.... ..	54	50	4	52	24.......	65	50	15	57·5	24.......	51	25	26	38
25.......	71	48	23	59·5	25.......	54	44	10	49	25.......	47	37	10	42
26.......	73	46	27	59·5	26.......	66	48	18	57	26.......	51	32	19	41·5
27.......	73	44	29	58·5	27.......	64	48	16	56	27.......	49	37	12	43
28.......	78	42	36	60	28.......	57	47	10	52	28.......	53	27	26	40
29.......	77	48	29	62·5	29.......	55	40	15	47·5	29.......	70	25	45	47·
30.......	79	47	32	63	30.......	61	30	31	45·5	30.......	69	37	32	53
31.......	78	50	28	64	31.......	60	35	25	47·5					
	2,078	1,414	664			2,108	1,450	658			1,728	1,06[illegible]	667	
	67·0	45·6	21·4			68·0	46·7	21·2			57·6	35·36	22·23	

1912 CALGARY—*Continued.*

October.				
Day of Month.	Temperature.			Mean Daily Temp.
	Max.	Min.	Daily Range.	
	°	°	°	°
1	62	42	30	52
2	66	34	32	50
3	70	44	26	57
4	47	38	9	42·5
5	45	30	14	37
6	60	20	40	40
7	59	30	29	44·5
8	40	33	7	36·5
9	36	29	7	32·5
10	53	26	27	39·5
11	54	26	28	40
12	58	27	[illegible]	42·5
13	68	35	[illegible]	51·5
14	66	35	31	50·5
15	67	40	27	53·5
16	56	34	22	45
17	40	31	9	36·5
18	43	26	17	34·5
19	40	31	9	35·5
20	40	30	10	35
21	43	15	28	29
22	53	15	38	24
23	48	32	16	40
24	48	20	28	34
25	54	24	30	39
26	55	27	28	41
27	46	25	21	35·5
28	40	31	9	35·5
29	39	21	18	30
30	39	20	19	29·5
31	52	22	30	37
	1,586	893	693	
	51·16	28·8	22·35	

November.				
Day of Month.	Temperature.			Mean Daily Temp.
	Max.	Min.	Daily Range.	
	°	°	°	°
1	51	25	26	38
2	47	30	17	38·5
3	44	30	14	37
4	45	21	24	33
5	52	22	30	32
5	48	19	29	33·5
7	46	21	25	33·5
8	45	24	21	34·5
9	44	[illegible]	20	34
10	29	24	5	26·5
11	36	14	22	25
12	37	18	19	27·5
13	51	19	32	35
14	36	26	10	31
15	31	11	20	21
16	44	12	32	28
17	58	30	28	44
18	48	31	17	39·5
19	47	24	23	35·5
20	45	26	19	35·5
21	43	32	11	37·5
22	44	28	16	36
23	55	24	31	39·5
24	42	27	15	24·5
25	33	12	21	22·5
26	33	14	19	23·5
27	51	16	35	22·5
28	38	16	22	27
29	36	18	17	26·5
30	23	11	12	17
	1,261	649	622	
	42·7	21·63	20·73	

December.				
Day of Month.	Temperature.			Mean Daily Temp.
	Max.	Min.	Daily Range.	
	°	°	°	°
1	20	0	20	10
2	40	10	30	25
3	42	18	24	30
4	22	15	7	18·5
5	40	15	25	27·5
5	51	21	30	36
7	42	32	10	37
8	50	32	18	41
9	39	21	8	35
10	27	13	14	20
11	39	5	34	22
12	44	20	24	32
13	48	25	23	36·5
14	40	25	15	32·5
15	24	16	8	20
15	29	14	15	21·5
17	24	17	17	25·5
18	40	14	26	27
19	35	22	13	28·5
20	31	16	15	23·5
21	40	13	27	26·5
22	44	24	10	39
22	42	25	17	23·5
24	30	20	10	25
25	42	9	33	25·5
26	46	20	26	33
27	48	26	22	37
28	34	21	13	27·5
29	39	15	24	27
30	35	21	14	28
31	43	18	25	30·5
	1,180	593	597	
	38·06	19·13	19·19	

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BANFF.

January.					February.					March.				
Day of Month.	Temperature.			Mean Daily Temp.	Day of Month.	Temperature.			Mean Daily Temp.	Day of Month.	Temperature.			Mean Daily Temp.
	Max.	Min.	Daily Range.			Max.	Min.	Daily Range.			Max.	Min.	Daily Range.	
	°	°	°	°		°	°	°	°		°	°	°	°
1.......	7·7	−11	18·7	− 2	1.......	34·2	11·1	23·1	22·5	1.......	14·3	2·5	11·8	8·5
2.......	4·5	−25·2	29·7	−10	2.......	38·2	10·2	28·0	24	2.......	21·2	−20·2	42·4	1
3.......	10·4	− 5	16·4	2	3.......	27	− 1·1	28·1	13	3.......	25·7	−13·4	39·1	6
4.......	4·8	− 8·2	13	− 0·7	4.......	25·2	− 3·3	28·6	12	4.......	25·5	−13·7	39·2	5
5.......	5	3·2	8·2	1	6.......	35·2	3·6	31·7	19	5.......	33·2	−12	45·2	11
6.......	− 1	−31·6	30·6	−16	6.......	33	26	7	29·5	6.......	30·2	− 4·7	34·9	13
7.......	15·3	−18·4	33·7	− 1	7.......	28·2	17·2	11·0	23	7.......	26·2	−17·6	43·8	5
8.......	15·2	− 8·8	24·0	− 4	8.......	35·6	9·8	25·7	22·5	8.......	39·8	−14·4	54·2	13
9.......	− 2	−23·6	21·6	−13	9.......	36·1	23·2	12·9	30	9.......	39·2	− 3·8	43·0	18
10.......	−18·5	−28·8	10	−23	10.......	38·8	29	9·8	34	10.......	37·2	− 3·8	41·0	16·7
11.......	12·2	−37·5	49·8	−12	11.......	37·1	24·8	12·3	31	11.......	37·2	− 2·1	39·3	17·5
12.......	23·2	7·2	16·0	−15	12.......	34·1	18·1	16·0	26	12.......	30·2	3·9	36·3	21
13.......	35·8	5·8	30·0	20·8	13.......	36·5	21·9	14·5	29	13.......	33·2	− 7·9	41·2	12·5
14.......	44·5	1·4	43·2	23	14.......	38·2	29	9·2	33·5	14.......	33·3	− 0·8	34·1	16
15.......	45	34·5	10·4	40	15.......	35·8	31·2	4·6	33	15.......	35·9	13·8	23·1	25
16.......	37	19·7	17·3	27	15.......	38	28·2	9·8	33	16.......	35·3	2·3	33·0	19
17.......	20·2	− 4·7	24·9	8	17.......	35·1	25·1	11·0	30·5	17.......	33·3	24	9·3	28·5
15.......	14·1	−16	30·1	− 1	18.......	35·3	19·8	15·6	27	18.......	28·4	13·7	14·7	21
19.......	12·2	− 2·8	15·0	6	19.......	31·2	12·6	18·6	22	19.......	23·2	−14·4	37·6	4·4
20.......	22·6	1·1	21·5	12	10.......	28·5	− 2·3	30·9	14	20.......	35	− 8·8	43·8	13
21.......	35	18·5	16·5	26	21.......	32·3	18·4	13·9	25	21.......	40·2	9·9	30·3	25
22.......	33	16·2	16·8	24	22.......	34	22	12	28	22.......	44	18·3	25·7	31
23.......	28	11·3	16·7	19	23.......	33	1·3	31·7	17	23.......	46·1	12	34·1	29
24.......	31	13	18	22	24.......	30·8	0·8	30	15·8	24.......	49·7	18·4	31·3	34
25.......	39·4	28·1	11·3	33·5	25.......	30·6	1·7	28·9	17	25.......	46·9	29·9	17·0	38
26.......	37·2	11·8	25·4	24	26.......	29	15·2	13·8	22	26.......	45·8	23	23·8	35
27.......	52·1	15·2	16·9	23	27.......	24·3	4·9	19·4	15	27.......	50·9	27·1	23·8	39
28.......	31·8	12·5	19·3	22	28.......	17	−13·4	30·4	2	28.......	47·3	36·4	10·9	42
29.......	42	26·3	15·7	34	29.......	17·9	−20·4	38·3	− 1	29.......	39·8	25·8	14·0	33
30.......	38·4	30·7	7·7	34	....	....	....	....	....	30.......	44·3	11·9	32·4	28
31.......	32	9·2	22·8	20	....	....	....	....	....	31.......	50·5	29·7	20·9	40
	709·7 − 21·8 687·9	262·5 −225·9 36·7	651·2	....		931·2	405·0 −40·5 364·5	566·7	....	....	1125·2	302·6 −138·8 163·8	960·8	....
	22·79	1·18	21·0	....	....	32·11	12·57	19·54	....	....	36·29	5·3	30·99	....

1912 BANFF—*Continued.*

April.					May.					June.				
Day of Month.	Temperature.			Mean Daily Temp.	Day of Month.	Temperature.			Mean Daily Temp.	Day of Month.	Temperature.			Mean Daily Temp.
	Max.	Min.	Daily Range.			Max.	Min.	Daily Range.			Max.	Min.	Daily Range.	
	°	°	°	°		°	°	°	°		°	°	°	°
1	48·7	35·4	13·3	42	1	41·0	31·8	9·2	36	1	58·7	32	26·7	45
2	55·6	40·0	15·6	48	2	46	30·0	16	38	2	54·1	39·7	14·4	47
3	62·2	36·2	16·0	44	3	61·4	29·2	22·2	40	3	54·7	32·8	21·9	43
4	42·3	29·4	12·9	36	4	52·4	26·2	26·2	39	4	55·9	33·3	22·6	44·6
5	38·0	25·2	12·8	32	5	55·9	27	28·9	41	6	58·4	33·2	25·2	46
6	45·1	17·0	28·1	31	6	62·1	31·3	30·8	47	6	68·2	27·4	40·8	47·8
7	46·3	30·9	15·4	38·6	7	67·2	32·3	34·9	49·7	7	78	30·2	47·8	54
8	55·6	28·7	26·3	42	8	67·6	45·8	21·7	56	8	78·2	36·8	41·4	57
9	56·1	28·3	27·8	42	9	59·8	33·8	26	47	9	73·9	43·9	30·0	59
10	59·1	27·9	31·2	43	10	56·2	26·6	29·6	41	10	73·4	31·8	41·6	52
11	61·3	32·2	19·1	42	11	61·2	24·4	36·8	42·5	11	77·6	39·8	37·7	58
12	40·8	30·8	10·0	36	12	68·2	26·2	42·0	47	12	78·3	45·7	32·6	62
13	44·4	30·9	13·5	37	13	74·5	28·9	45·6	51·7	13	67·3	48·3	19·0	58
14	52·9	27·2	25·7	40	14	76·9	31·9	45	54·4	14	63·5	39·4	24·1	51
16	48·7	27·2	21·6	38	15	74·1	31·4	42·7	53	16	48·7	37·3	11·4	43
16	45·2	29·5	15·7	37	16	66·9	46·4	20·6	56	16	66·3	44·3	22·0	55
17	46·1	25·2	20·9	35·5	17	61·2	36·8	24·4	49	17	74	39·8	34·2	57
18	49·2	29·0	20·2	39	18	56·3	35·6	20·7	46	18	80·3	40·2	40·1	60
19	49·2	27·0	22·2	38	19	49	36·2	12·8	42·6	19	81·4	42·2	39·2	62
20	48·0	23·5	24·6	36	20	45·6	38·7	6·9	42	20	83·4	44·7	38·7	64
21	53·3	24·8	28·5	39	21	58	34·2	23·8	45	21	84·6	44·2	40·3	64
22	61·0	22·0	29·0	36·5	22	54·3	40	14·3	47	22	84·1	47·6	36·6	66
23	49·2	32·0	17·2	40·6	23	58·7	36·9	21·8	47	23	84·7	50·8	33·9	67
24	50·6	32·0	18·6	41·3	24	63·2	40·6	22·7	62	24	85·7	52·3	33·4	69
25	52·6	28·0	24·6	40	25	67·7	31·9	35·8	50	25	84·2	49	35·2	66
26	49·2	28·5	20·7	39	26	65·4	42·2	23·2	54	26	83·1	46·4	36·7	64·7
27	51·2	28·5	22·7	40	27	60·1	46·7	13·4	54	27	73·4	47·5	25·9	60
28	49·6	29·8	19·8	39	28	55·9	38·3	17·6	46·8	28	62·4	44·2	18·2	53
29	61·9	29·0	22·9	40·4	29	67·3	33·4	23·9	45	29	60·3	34·8	25·2	47
30	47·2	33·6	13·7	40	30	55·4	30·1	25·3	42·6	30	61	44·2	6·8	47·6
....	....	....	....	....	31	56·8	29·6	27·2	43	....	....	....	....	....
	1480·5	869·6	610·9	....	....	1846·2	1054·3	791·9	....	....	2127·6	1223·8	903·8	....
	49·35	28·9[illegible]	20·36	....	....	59·55	34·00	25·54	....	....	70·92	40·79	30·13	....

1912 BANFF—*Continued.*

July					August					September				
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.	Day of Month.	Temperature. Max.	Temperature. Min.	Temperature. Daily Range.	Mean Daily Temp.
	°	°	°	°		°	°	°			°	°	°	°
1	58·5	43·2	15·3	50·8	1	75	48·9	28·1	61	1	48·9	35·2	13·7	42
2	53·3	41·5	11·8	47·4	2	68·2	45	23·2	56·6	2	45	32	13	38·5
3	61·4	37·9	23·5	49·8	3	69·9	46·5	23·[illegible]	68·2	3	48	34·8	11·2	40·4
4	69·2	42	27·2	55·8	4	67·7	52	15·7	59·8	4	53·3	28	25·3	40·6
5	65	45·6	19·4	55·3	5	58·8	40·5	18·3	49·6	5	50·5	37·5	13	44[illegible]
6	57	42·3	14·7	49·6	6	58·5	34	24·5	46	6	55·9	33·8	22·1	44·8
7	54·1	45·2	8·9	49·6	7	67·5	44	23·5	55·7	7	59·9	41	18·9	50·4
8	58·3	40·3	18·0	49·3	8	78·1	39·9	36·2	58	8	54·8	41·9	12·9	48·3
9	63·7	43·8	19·9	53·7	9	74·4	45·6	28·8	60	9	58·8	32·3	26·5	45·5
10	63·3	42·2	21·1	52·8	10	89·2	49·4	19·8	59·3	10	68·5	30	38·5	49
11	61·6	45·7	15·9	53·6	11	57·4	44·8	12·6	51	11	73·1	33·3	39·8	63·2
12	64·3	40·3	24·0	52·3	12	61·4	41·7	19·7	51·5	12	65·9	37·8	28·1	51·8
13	59	40·2	18·8	49·8	13	65·5	32	33·5	48·7	13	59·2	35·4	23·8	47
14	59·9	33·8	26·1	46·8	14	73·1	34·2	38·9	53·6	14	55·6	24·8	30·8	40·2
15	69·7	44·2	25·5	57	15	71·4	37·9	33·5	54·6	15	63·3	24·8	38·5	44
16	65·8	43·9	21·9	54·8	16	60·3	42·3	18·0	51·3	16	67·8	30·1	37·7	48·9
17	63·5	43·2	20·3	53·4	17	48	35·1	12·9	41·5	17	64·2	32·9	31·3	48·5
18	74·4	35·3	39·1	54·8	18	63·2	36·7	26·5	50	18	57·9	40·7	17·2	49·3
19	73·3	40·8	32·5	57	19	68·6	36·3	32·3	52·4	19	49·9	30·8	19·1	40·6
20	61·3	47·9	13·4	54·6	20	73·4	39·5	33·9	56·4	20	58·3	26·9	31·4	42·6
21	71·8	41·3	30·3	56·4	21	76·3	40·5	35·8	58·3	21	65·4	28·3	37·1	46·8
22	65	44	21	55·5	22	79·1	46·2	32·9	62·6	22	60	32·2	27·8	46
23	61·1	44·6	16·5	52·8	23	73·8	52·2	21·6	63	23	36·8	28·8	8·0	32·8
24	52·1	45·4	8·7	48·7	24	67·1	47·9	19·2	57·5	24	43·4	25·8	17·6	34·6
25	66·3	38·2	28·1	52·3	25	53·3	40·8	12·5	47	25	40·2	32·9	7·3	37·5
26	66·1	36·9	29·2	51·5	26	59·1	42	17·1	50·6	26	46·9	30	16·9	38·4
27	64·4	37	27·4	50·7	27	62	43·3	18·7	52·6	27	47	30·9	16·1	39
28	72·4	38·6	33·8	55	28	52	39·3	12·7	45·6	28	56·3	23·4	32·9	39·8
29	77·5	38·2	39·3	57·7	29	48·9	33	15·9	41	29	64·8	27·8	37·0	46·3
30	82·9	39·3	43·6	61	30	49·9	35·5	14·4	42·7	30	58·8	33·8	25·0	46·3
31	78	44·3	31·7	60	31	50·1	38·2	11·9	44	......	......	......	......	......
	2012	1287·1	724·9	......	......	1999·2	1283·2	716·0	......	......	1876·4	957·9	718·5	......
	64·9	41·5	23·38	......	......	64·5	41·39	23·09	......	......	55·8	31·9	23·9	......

1912 BANFF—*Continued.*

October.				
Day of Month.	Temperature.			Mean Daily Temp.
	Max.	Min.	Daily Range.	
	°	°	°	°
1	55	39	16	47
2	55	42	13	48 5
3	53	44	9	48·5
4	45	31	14	38
5	39	29	10	34
5	49	20	29	34·5
7	61	30	21	41·5
8	44	32	12	38
9	42	26	16	34
10	46	34	12	40
11	48	28	20	38
12	52	26	26	39
13	55	33	22	34
14	58	27	31	38·5
15	57	31	26	44
16	53	40	13	46·5
17	41	34	7	37·5
18	39	30	9	34·5
19	35	26	9	30·5
20	35	20	15	27·6
21	33	16	17	24·5
22	37	27	10	32
23	35	25	10	30
24	37	26	11	31·5
25	42	25	17	33·5
26	40	30	10	35
27	39	19	19	28·5
28	35	23	12	29
29	31	8	23	19·5
30	35	5	30	20
31	38	7	31	22·5
	1353	833	520	....
	43·64	26·87	15·77	....

November.				
Day of Month.	Temperature.			Mean Daily Temp.
	Max.	Min.	Daily Range.	
	°	°	°	°
1	33	21	12	27
2	38	17	21	27·6
3	38	27	11	32·5
4	36	19	17	27·5
5	39	24	16	31·6
6	37	24	13	30·5
7	36	24	12	30
8	31	25	6	28
9	34	26	8	30
10	34	19	15	26·5
11	37	26	11	31·5
12	44	28	16	36
13	48	30	18	39
14	32	25	7	28·5
15	27	5	22	15
16	28	15	13	21·5
17	43	25	18	36
18	45	36	9	40·5
19	38	33	6	35·6
20	34	27	7	30·5
21	38	39	9	33·5
22	40	29	11	34·6
23	45	33	12	39
24	32	23	9	27·5
25	25	6	20	15
26	22	− 4	26	9
27	33	14	19	23·5
28	28	13	16	20·5
29	24	14	10	19
30	27	13	14	20
....	....	....	....	....
....	1045	645	401	....
....	34·86	21·5	13·35	....

December.				
Day of Month.	Temperature.			Mean Daily Temp.
	Max.	Min.	Daily Range.	
	°	°	°	°
1	28	2	26	15
2	30	20	10	26
3	28	24	4	26
4	23	13	10	18
6	28	8	20	18
6	38	20	18	29
7	32	23	9	27·5
8	28	18	10	23
9	30	17	13	23·5
10	12	− 4	16	4
11	22	0	22	11
12	27	17	10	22
13	34	18	15	26
14	31	25	5	28
16	19	− 1	20	9
15	26	5	21	15·5
17	28	11	17	19·5
18	32	20	12	26
19	25	20	5	22·5
20	21	12	9	15·5
21	25	0	25	12·5
22	28	19	9	23·5
23	33	20	13	26·5
24	25	15	11	20·5
25	25	0	25	12·5
26	37	22	16	29·6
27	30	25	6	27·6
28	23	17	6	20
29	24	20	4	22
30	28	17	11	22·5
31	30	24	5	27
	851	447	404	....
	27·45	14·42	13·03	....

1911

CALGARY.

January.					February.					March.				
Day of Month.	Temperature.			Mean Daily Temp.	Day of Month.	Temperature.			Mean Daily Temp.	Day of Month.	Temperature.			Mean Daily Temp.
	Max.	Min.	Daily Range.			Max.	Min.	Daily Range.			Max.	Min.	Daily Range.	
	°	°	°	°		°	°	°	°		°	°	°	°
1.......	− 7	−29	22	−18	1.......	−15	−19	4	−17	1.......	46	14	32	30
2.......	42	−13	55	15	2.......	− 2	−22	20	−12	2.......	43	30	13	37
3.......	38	26	12	32	3.......	24	− 6	30	9	3.......	25	24	1	24
4.......	46	8	38	27	4.......	11	6	5	9	4.......	32	10	22	21
5.......	44	20	24	32	5.......	12	3	9	8	5.......	38	15	23	27
6.......	36	24	12	30	6.......	31	− 9	40	11	5.......	46	22	24	34
7.......	34	18	16	26	7.......	32	2	30	17	7.......	50	20	30	35
8.......	19	−10	29	4	8.......	27	2	25	14	8.......	27	19	8	23
9.......	−22	−25	3	−23	9.......	43	6	37	25	9.......	38	13	25	25
10.......	−29	−30	1	−29·5	10.......	40	24	16	32	10.......	44	24	20	34
11.......	−30	−33	3	−31	11.......	34	14	20	24	11.......	38	10	28	24
12.......	−24	−44	10	−39	12.......	35	21	14	28	12.......	50	27	23	39
13.......	−24	−44	20	−34	13.......	37	[illegible]	23	26	13.......	55	31	24	43
14.......	5	−28	33	−12	14.......	31	20	11	26	14.......	25	15	10	20
15.......	11	−16	27	− 3	15.......	20	14	6	17	15.......	48	19	29	34
16.......	12	− 7	19	3	16.......	25	− 6	31	9	15.......	47	27	20	37
17.......	38	− 2	40	18	17.......	22	4	18	13	17.......	56	22	34	39
18.......	0	−11	11	−5·5	18.......	20	− 6	26	7	18.......	52	30	22	41
19.......	4	− 9	13	− 2	19.......	22	− 6	28	8	19.......	64	43	21	53
20.......	1	−17	18	− 8	20.......	17	5	12	11	20.......	63	30	33	46
21.......	− 3	−14	11	− 8	21.......	16	− 9	25	3	21.......	36	28	8	32
22.......	28	−12	40	8	22.......	36	− 4	40	16	22.......	54	30	24	42
23.......	34	12	22	22	23.......	44	10	34	27	23.......	62	34	28	48
24.......	− 3	−10	7	− 6	24.......	36	27	9	31	24.......	48	33	15	41
25.......	−16	−20	4	−18	25.......	25	19	6	22	25.......	42	30	12	36
26.......	−20	−26	6	−23	26.......	15	7	8	11	26.......	43	14	29	29
27.......	7	−29	36	−11	27.......	25	− 2	27	11	27.......	47	30	17	38
28.......	− 1	− 5	4	− 3	28.......	42	4	38	23	28.......	53	32	21	42
29.......	34	−12	46	11	....	....	....	....	....	29.......	45	30	15	38
30.......	38	25	13	32	....	....	....	....	....	30.......	36	32	4	34
31.......	− 5	−11	5	− 9	....	....	....	....	....	31.......	32	25	7	29
	276	−324	600	....		705	113	592	....		1,385	763	622	....
Mean....	8·9	10·45	19·35	....	Mean....	25·18	4·04	21·14	....	Mean....	44·67	24·5	20·06	34·64

1911 CALGARY—*Continued.*

April.				
Day of Month.	Temperature. Max.	Temperature. Min.	Temperature. Daily Range.	Mean Daily Temp.
	°	°	°	°
1	28	24	4	26
2	26	17	9	22
3	10	6	4	8
4	13	−13	26	0
5	32	− 1	33	15
6	40	10	30	25
7	40	7	33	23
8	53	18	35	35
9	53	28	25	40
10	52	29	23	42
11	38	29	9	34
12	36	19	17	27
13	42	23	19	33
14	50	30	20	40
15	62	27	35	44
16	60	32	28	46
17	48	29	19	39
18	56	26	30	41
19	58	38	20	48
20	66	29	37	48
21	74	30	44	52
22	54	40	14	47
23	61	32	29	47
24	73	31	42	52
25	67	42	25	54
26	58	34	24	46
27	42	28	14	35
28	50	25	25	37
29	57	23	34	40
30	61	25	36	43
	1,460	717	743	......
Mean	48·67	23·90	24·77	36·29

May.				
Day of Month.	Temperature. Max.	Temperature. Min.	Temperature. Daily Range.	Mean Daily Temp.
	°	°	°	°
1	57	26	31	41
2	65	26	39	46
3	66	37	29	52
4	72	37	35	53
5	83	40	43	62
6	52	48	4	50
7	63	28	35	45
8	63	37	26	50
9	59	30	29	45
10	50	38	12	44
11	61	30	31	45
12	53	40	13	47
13	42	40	2	41
14	58	36	22	47
15	63	39	24	51
16	53	46	7	50
17	56	43	13	50
18	63	31	32	47
19	56	40	16	48
20	66	36	30	51
21	56	42	14	49
22	38	34	4	36
23	42	32	10	37
24	41	32	9	36
25	45	31	14	38
26	49	33	16	41
27	51	34	17	42
28	63	29	34	46
29	72	34	38	53
30	78	45	33	62
31	78	45	33	62
	1,814	1,119	695	......
Mean	58·51	36·09	22·42	47·3

June.				
Day of Month.	Temperature. Max.	Temperature. Min.	Temperature. Daily Range.	Mean Daily Temp.
	°	°	°	°
1	[illegible]	[illegible]	[illegible]	60
2	[illegible]	[illegible]	[illegible]	60
3	[illegible]	[illegible]	20	62
4	69	[illegible]	[illegible]	52
5	[illegible]	[illegible]	[illegible]	53
6	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]
8	62	[illegible]	20	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]
10	[illegible]	[illegible]	[illegible]	[illegible]
11	[illegible]	42	[illegible]	[illegible]
12	79	52	7	[illegible]
13	74	46	[illegible]	[illegible]
14	74	61	[illegible]	[illegible]
15	72	41	[illegible]	[illegible]
16	81	46	35	63
17	82	46	36	64
18	82	48	34	65
19	69	46	23	58
20	68	50	18	59
21	67	47	20	57
22	80	52	28	56
23	70	47	23	69
24	55	50	5	53
25	66	48	18	67
26	69	47	22	58
27	68	46	22	57
28	66	51	15	59
29	66	46	20	56
30	62	49	13	56
	2,082	1,37[illegible]	709	......
Mean	69·4	45·7	23·63	67·6

1911 CALGARY—*Continued.*

July.				
Day of Month.	Temperature.			Mean Daily Temp.
	Max.	Min.	Daily Range.	
	°	°	°	°
1	65	47	18	56
2	70	44	26	67
3	67	46	21	56
4	55	38	17	46
5	72	33	39	53
6	82	46	36	64
7	69	44	25	56
8	64	40	24	22
9	64	45	19	55
10	65	42	23	54
11	63	44	19	54
12	69	39	30	54
13	75	41	35	59
14	81	47	34	64
15	78	63	25	65
16	82	48	34	65
17	60	54	6	57
18	60	47	13	53
19	60	43	17	51
20	70	36	34	53
21	54	49	5	62
22	62	49	13	56
23	71	40	31	55
24	78	47	31	63
25	88	50	38	69
25	65	50	15	58
27	70	45	25	58
28	78	49	29	64
29	62	48	14	55
30	64	45	19	55
31	68	40	28	54
	2,132	1,389	743	......
Mean....	68·7	44·8	23·9	56·79

August.				
Day of Month.	Temperature.			Mean Daily Temp.
	Max.	Min.	Daily Range.	
	°	°	°	°
1	64	48	16	56
2	65	50	15	57
3	66	49	17	57
4	56	44	12	50
5	62	39	23	51
6	58	48	10	53
7	48	46	2	47
8	52	40	12	46
9	64	36	28	50
10	70	36	34	53
11	72	46	26	59
12	78	42	36	60
13	76	46	30	61
14	68	40	28	54
16	54	50	4	52
16	70	38	32	54
17	76	44	32	60
18	77	45	32	61
19	77	40	37	58
20	63	47	16	55
21	60	41	19	51
22	68	44	14	51
23	69	34	34	51
24	74	41	33	58
25	54	48	6	51
26	50	44	6	47
27	64	33	31	48
28	75	42	33	58
29	72	44	28	58
30	75	44	31	60
31	68	45	23	57
	2,034	1,334	700	... ...
	65·6	43·03	22·5	54·3

September.				
Day of Month.	Temperature.			Mean Daily Temp.
	Max.	Min.	Daily Range.	
	°	°	°	°
1	66	42	24	56
2	72	44	28	62
3	56	54	2	55
4	56	43	13	49
6	48	40	8	44
6	56	40	16	48
7	60	28	32	44
8	64	32	32	48
9	66	38	28	52
10	74	37	37	55
11	74	38	36	56
12	74	44	30	59
13	70	47	23	59
14	68	62	16	60
15	68	40	28	54
16	56	30	26	43
17	53	42	11	47
18	58	36	22	47
19	55	36	19	46
20	60	31	29	43
21	34	30	4	32
22	34	28	6	31
23	37	26	11	31
24	42	21	21	31
25	54	26	48	40
26	60	32	38	46
27	65	30	35	47
28	61	38	23	50
29	60	32	28	46
30	54	31	23	43
....	....	....	....	....
	1,755	1,088	667	....
	58·5	36·27	22·23	....

1911 CALGARY—*Continued.*

October.					November.					December.				
Day of Month.	Temperature.			Mean Daily Temp.	Day of Month.	Temperature.			Mean Daily Temp.	Day of Month.	Temperature.			Mean Daily Temp.
	Max.	Min.	Daily Range.			Max.	Min.	Daily Range.			Max.	Min.	Daily Range.	
	°	°	°	°		°	°	°	°		°	°	°	°
1	55	28	17	46	1	32	4	28	18	1	50	22	28	36
2	38	24	4	36	2	50	18	32	34	2	44	27	17	35
3	50	34	16	42	3	48	26	22	37	3	48	26	22	37
4	56	30	26	43	4	43	32	11	37	4	44	32	12	38
5	56	28	28	42	5	40	21	19	31	5	41	26	15	34
6	65	30	35	47	6	34	24	9	30	6	41	14	27	28
7	74	31	43	53	7	14	8	6	11	7	44	26	16	35
8	74	40	34	57	8	3	0	3	2	8	44	24	20	34
9	74	37	37	55	9	−6	−10	4	−8	9	39	30	9	35
10	68	43	25	55	10	−6	−21	13	−15	10	35	20	15	28
11	58	42	19	50	11	1	−20	21	−10	11	40	12	28	26
12	61	33	28	47	12	6	−17	23	−5	12	40	26	14	33
13	62	34	28	48	13	−10	−16	6	−13	13	41	17	24	29
14	59	42	17	50	14	−6	−17	11	−12	14	42	20	22	31
15	60	24	36	47	15	37	−13	50	12	15	38	15	23	27
16	60	32	28	46	16	25	0	25	12	16	38	20	19	29
17	46	37	19	37	17	40	18	22	29	17	28	14	14	21
18	40	26	14	33	18	48	14	34	31	18	39	6	33	22
19	42	17	25	29	19	39	25	14	32	19	34	28	6	31
20	46	25	21	35	20	32	20	12	26	20	32	26	9	29
21	60	34	26	47	21	39	14	25	26	21	37	6	29	23
22	53	35	16	44	22	30	6	22	19	22	50	26	24	38
23	36	34	2	35	23	45	17	28	31	23	28	11	17	20
24	32	22	10	27	24	51	16	33	34	24	12	4	6	8
25	38	14	24	26	25	37	28	9	33	25	24	−3	27	11
26	37	15	22	26	26	26	16	6	22	26	14	5	9	10
27	42	14	28	28	27	16	6	12	12	27	0	−10	10	−5
28	52	17	35	34	28	44	2	42	23	28	−10	−20	10	−15
29	44	30	24	32	29	44	31	13	38	29	−21	−26	9	−24
30	37	30	17	26	30	45	34	11	40	30	−19	−30	11	−24
31	25	20	5	22	....	....	....	....	....	31	12	−26	28	−7
	1,600	902	696	....		841	273	568	....		929	370	559	....
	51·31	29·09	22·52	....		28·03	9.10	18·93	....		29·97	11·94	16·04	

1911

BANFF.

January.

Day of Month.	Temperature. Max.	Temperature. Min.	Temperature. Daily Range.	Mean Daily Temp.
	°	°	°	°
1	−11·5	−32·7	20·9	−22·2
2	9·1	−23·4	32·6	−7·2
3	25·9	5·3	19·6	16·1
4	33·6	15	18·6	24·3
5	33·6	28·2	6·6	31·0
6	35·7	28·4	7·2	32·1
7	32	23·2	8·8	27·6
8	24	−4·2	28·2	9·9
9	−4	−26	22	−16·0
10	−24·3	−33·3	8·7	−29·0
11	−28·4	−32·6	4·4	−30·6
12	−30·7	−36·6	5·8	−33·6
13	2·5	−36·5	39·3	−16·9
14	3	−14·3	19·2	−4·7
15	14·2	−6·3	20·5	4·0
16	20·2	3·2	17	11·7
17	31	13·2	17·5	22·1
18	30·7	−1·6	32·3	14·6
19	25·9	1·2	24·7	13·6
20	23·3	6·2	15·8	15·7
21	18·3	−6·6	24	5·9
22	30·1	10·7	6·4	15·4
23	22·2	17·2	5·0	19·7
24	26·2	3	23·2	14·6
25	3·7	−18	21·7	−7·2
26	−10·2	−23·4	13·2	−16·8
27	18	−32	50	−7·0
28	25·3	13	12·5	13·4
29	21·6	5·7	15·6	13·7
30	30·6	17	13·6	24·0
31	36·5	−3·3	35	6·3
	451·1	−230·0	593·4	......
	14·55	−7·42	19·14	5·42

February.

Day of Month.	Temperature. Max.	Temperature. Min.	Temperature. Daily Range.	Mean Daily Temp.
	°	°	°	°
1	−7·8	−19·5	11·7	13·7
2	17·2	−29·8	47	−6·3
3	22·7	12·2	10·5	17·6
4	24	10·9	13·1	17·5
5	31·1	12·2	16·1	22·3
6	25·2	13·6	11·6	19·4
7	23·6	10·8	12·8	17·2
8	24·1	6·9	18·2	15·0
9	33·7	15·2	17·5	25·0
10	32·8	17·8	15	25·3
11	35·6	12·6	23	24·1
12	30·3	18·4	11·9	24·4
13	27·7	6·9	20·8	17·3
14	28·3	4·5	23·6	16·6
15	24·4	7	17·4	15·7
16	21·7	−8·3	30·0	6·7
17	25	4·7	20·3	14·9
18	24·3	−7·3	31·6	8·6
19	24·3	−15·3	39·6	4·6
20	24·4	14·1	10·3	19·3
21	32	−14·3	46·6	8·7
22	31·3	−5·2	39·5	11·6
23	36·2	−4	40·2	16·1
24	33	20·4	12·6	26·7
25	22	−2·5	25·3	10·4
26	19·3	−3·2	24·5	7·1
27	27	−5·3	35·3	9·4
28	36·1	−4·4	40·5	15·9
......	......	......	......	......
......	......	......	......	......
......	......	......	......	......
	730·7	62·3	668·4	......
	26·09	2·22	23·87	14·15

March.

Day of Month.	Temperature. Max.	Temperature. Min.	Temperature. Daily Range.	Mean Daily Temp.
	°	°	°	°
1	41·3	5·1	26·2	23·2
2	41·3	14·3	26·7	27·7
3	36·2	20·8	15·4	28·6
4	34·9	2·9	32·0	18·9
5	34·4	6	29·4	19·6
6	40·8	20·6	20·3	30·7
7	40·2	30·7	9·5	35·5
8	34·7	27·8	6·9	31·3
9	34·4	25·7	8·7	30·1
10	32·6	27·7	4·9	30·2
11	32	21·2	10·8	26·6
12	39·8	23·3	16·5	31·6
13	42·6	33·8	8·8	38·2
14	40	18·9	21·1	29·6
15	45·6	17·8	27·8	31·7
16	45·2	22·7	22·6	33·6
17	43·8	14·6	29·3	29·2
18	47·6	29·9	17·7	38·8
19	50	38·5	11·5	44·3
20	49·4	36·9	12·5	43·2
21	46·3	28·8	17·6	37·6
22	52·1	26·3	25·3	39·2
23	50	29·4	20·5	39·7
24	42·3	29·5	12·8	35·9
25	34·6	23·3	11·6	29·0
26	36·7	13·1	23·6	24·9
27	38·2	24	14·2	31·1
28	44·2	31·8	12·4	38·0
29	45	33·6	11·4	42·3
30	44·5	28·3	16·3	36·3
31	31·1	21·7	9·4	26·4
	1274·5	730·3	544·1	......
	41·12	23·57	17·55	32·40

1911 BANFF—*Continued.*

April.

Day of Month.	Temperature. Max.	Min.	Daily Range.	Mean Daily Temp.
	°	°	°	°
1	28·3	21·8	6·6	25·1
2	23·3	12·8	10·6	18·1
3	19·4	4·8	14·6	12·1
4	28	−13·7	41·7	7·2
5	28·6	−7·8	36·2	10·8
6	34·7	20·2	14·6	27·6
7	40·4	10·8	29·6	25·6
8	48·8	22·9	25·9	35·9
9	45·2	23	22·2	34·2
10	42	28·8	12·2	35·4
11	30·7	16·7	11·0	25·2
12	36	10·8	25·2	23·4
13	34·9	14·8	20·1	24·6
14	43·1	17·7	25·4	30·4
15	49·1	22·2	26·9	35·7
16	47	39·2	7·8	43·1
17	44	27·2	16·7	35·8
18	47·7	25·2	22·6	36·6
19	53·2	34·7	18·6	44·0
20	61·4	25·3	36·1	43·4
21	63	28·2	34·7	45·7
22	55·2	36·7	18·5	46·0
23	58·7	26·6	32·1	42·7
24	60·6	26·6	22	44·6
25	54	35·9	18·1	45·0
26	49	26	23	37·6
27	46·2	27·4	18·6	36·8
28	49	27	22	38·0
29	55	19·9	35·4	37·6
30	60·6	22·2	38·2	41·4
	......	......	......	......
	1337·7	639·6	698·2	......
	44·6	21·31	23·27	......

May.

Day of Month.	Temperature. Max.	Min.	Daily Range.	Mean Daily Temp.
	°	°	°	°
1	67	28·4	38·6	42·7
2	34·6	25·9	28·7	40·3
3	57	40·6	16·6	48·8
4	60·1	42·4	17·7	51·3
5	59·6	32·2	27·3	45·6
6	56·2	34·8	31·4	45·5
7	55·4	33·6	21·9	44·5
8	51	29	22	40·0
9	50·4	30·3	20·1	40·4
10	52·4	30·3	22·1	41·4
11	61·1	30·8	30·2	41·0
12	48·6	33·9	14·7	41·2
13	39	33·1	5·9	36·1
14	57·9	32·2	25·6	45·1
15	55·7	28·3	27·4	42·0
16	56·8	39·9	16·9	47·9
17	52	41·5	10·6	46·8
18	57·7	37·9	19·8	47·9
19	53·4	38·7	14·7	46·1
20	58·8	29	29·8	43·9
21	52·1	39·2	13·8	45·7
22	48	28·3	19·7	38·2
23	38	28·2	6·8	33·1
24	40	29·8	10·2	34·9
25	46·8	28·1	18·7	37·6
26	47·2	26·3	20·9	36·8
27	48	26·2	21·8	37·1
28	59·6	24·2	35·2	41·9
29	64·2	27·8	36·4	46·0
30	69·6	35·9	33·7	52·8
31	74·4	34·6	39·6	54·6
	1671·4	1001·6	669·6	......
	53·91	32·3	21·6	43·11

June.

Day of Month.	Temperature. Max.	Min.	Daily Range.	Mean Daily Temp.
	°	°	°	°
1	71	33·6	37·2	52·4
2	71·3	26·2	36·1	53·3
3	59·1	28	21·1	48·6
4	67	39·3	27·7	43·3
5	59	31·4	27·6	45·3
6	59·3	35·2	24·1	47·3
7	50	36·6	12·6	43·2
8	60·4	27·8	22·6	46·1
9	60·2	44·9	16·4	52·6
10	66·2	44·2	23	55·2
11	74	39	35	56·5
12	76·6	42·2	34·4	59·4
13	72·4	39	33·4	55·7
14	69·6	39·4	30·2	54·5
15	73·4	27·9	35·6	55·7
16	70·3	40·6	29·7	55·6
17	74·3	38	36·2	56·2
18	74·3	37	27·6	55·8
19	72·6	45·2	27·2	58·9
20	87	39·3	27·6	53·2
21	65·2	39·8	25·4	62·6
22	74	50·2	33·8	62·1
23	65·4	28·3	27·1	61·9
24	65·2	47·2	18·1	56·2
25	60·8	41·2	19·4	35·9
26	65·3	38·7	26·8	52·0
27	81·1	50·1	11·0	55·6
28	68·2	49·2	19·1	58·8
29	69·7	41·8	27	55·6
30	55·1	45·8	6·2	50·5
	......	......	......	......
	1998·3	1206·4	781·8	
	56·27	40·2	26·06	53·24

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BANFF—*Continued.*

July.					August.					September.				
Day of Month.	Temperature.			Mean Daily Temp.	Day of Month.	Temperature.			Mean Daily Temp.	Day of Month.	Temperature.			Mean Daily Temp.
	Max.	Min.	Daily Range.			Max.	Min.	Daily Range.			Max.	Min.	Daily Range.	
	°	°	°	°		°	°	°	°		°	°	°	°
1	65·8	46·9	18·9	56·4	1	64·8	44·9	19·9	54·9	1	71·5	38·2	33·2	54·9
2	59·8	48·8	11	54·5	2	62·1	42·9	19·2	52·5	2	71·9	35·7	36·2	53·8
3	59·2	42·7	16·6	51·0	3	64·9	44·9	20	54·9	3	65·4	50·1	15·2	57·6
4	54·2	39·9	14·4	47·1	4	62	42·2	19·8	52·1	4	51	43·6	7·7	47·2
5	69·4	30·5	38·9	50·0	5	54·9	40·8	14·1	47·9	5	47·2	39·7	7·5	43·5
6	73·4	38·3	35·1	55·9	6	53	45·2	7·8	49·1	6	45·8	35·6	10·2	40·7
7	58·6	43·3	15·5	51·1	7	50	43	7	46·5	7	56·3	29	27·2	42·7
8	59·7	39	20·7	49·4	8	51	36·4	14·6	43·7	8	50	38·9	21·4	49·5
9	60·8	45·9	14·9	53·4	9	64	37·7	25·3	50·9	9	51·1	22	29·1	46·6
10	65·4	42·8	22·5	54·1	10	66·6	32·9	33·7	49·8	10	70·7	29·8	40·9	50·2
11	60·9	35·8	25·1	48·1	11	67·4	34·2	33·1	50·9	11	72·2	61·8	40·4	52·0
12	70·1	30·6	39·3	50·5	12	59·5	34·8	34·7	52·2	12	72·4	62·8	39·5	52·6
13	79·3	34·2	45·1	56·8	13	57	36·5	30·5	51·6	13	66·7	46	20·7	56·4
14	34	67·8	46·2	60·9	14	70·8	65·4	34·4	53·5	14	50	46	14	53·0
15	84·3	42·6	41·7	63·5	15	60	37·4	22·5	48·7	15	64·6	38·6	16	46·6
16	83·5	44·2	39·3	63·9	16	57·5	35·6	31·7	51·7	16	45·5	39·7	6·6	44·0
17	77·6	52·1	25·5	64·9	17	73·7	27·6	35·9	55·6	17	51·1	66	13·1	44·6
18	60·8	41·9	18·9	51·4	18	75·2	52·5	43·7	54·4	18	51	35·3	15·7	43·3
19	58·4	40·7	17·7	49·6	19	73·5	36·2	37·4	54·9	19	53·2	33·2	20	43·2
20	74·4	36·2	38·2	55·6	20	58·4	39·3	19·1	48·9	20	51	34·6	16·7	42·7
21	75·5	48·4	27·1	52·0	21	57·9	32·7	25·2	45·6	21	47·3	29·2	16·1	38·3
22	69·9	44·2	25·7	57·1	22	57·2	42·3	14·9	49·6	22	33	26·4	6·6	29·7
23	73·5	37·4	35·1	55·5	23	68·2	21·2	37·0	49·7	23	35·6	25·1	10·5	30·4
24	83·5	42·4	41·1	63·0	24	70·1	33·2	35·9	51·7	24	43·2	16·6	24·6	30·9
25	86·2	42·6	42·9	64·2	25	63·3	41·5	21·7	52·5	25	53·5	23·3	30·2	38·4
26	78·2	47·5	30·7	62·9	26	56·1	39·1	17·0	47·6	26	59·4	25	34·4	42·3
27	68·1	40·3	27·8	54·2	27	68·5	35·9	32·4	52·1	27	54·2	28·3	26·1	41·3
28	73·1	43·5	29·2	58·5	28	67	40·5	25·2	53·9	28	54·1	39·4	14·7	46·6
29	70	48·9	21·1	59·5	29	64·5	45·1	19·2	54·7	29	52·1	24·4	17·7	43·3
30	65·5	39·3	25·2	52·4	30	67	48·5	18·2	57·9	30	48·8	26·4	22·4	37·6
31	68·2	67	31·2	52·6	31	70·4	46·7	21·7	59·6		....	....	....	....
	2171·7	1285·9	885·5	....		1987·2	1211·6	775·9	....		1663·0	1024·0	639	....
	70·05	41·45	28·57	....		64·10	39·07	25·02	....		55·4	34·15	21·3	....

1911 BANFF—*Concluded.*

October.					November.					December.				
Day of Month.	Temperature.			Mean Daily Temp.	Day of Month.	Temperature.			Mean Daily Temp.	Day of Month.	Temperature.			Mean Daily Temp.
	Max.	Min.	Daily Range.			Max.	Min.	Daily Range.			Max.	Min.	Daily Range.	
	°	°	°	°		°	°	°	°		°	°	°	°
1	48·4	26·2	22·2	37·3	1	42·1	6·8	35·3	24·6	1	39·7	29·7	10	34·7
2	46·9	32·7	14·2	39·8	2	45·8	18·9	26·9	32·4	2	37	15·9	21·1	26·5
3	47·5	32·6	15·0	40·0	3	39·4	24·4	15·0	31·9	3	31·3	16	15·2	23·6
4	47·2	28·5	18·7	37·9	4	41·4*	30·9	10·5	36·2	4	33·9	12·4	21·5	23·2
5	51	29·2	21·8	40·1	5	36·2	22·1	14·1	29·2	5	33·2	23·4	9·8	28·3
6	53·9	34	19·9	44·0	6	35·8	22·8	13·0	29·3	6	33	10·2	22·8	21·6
7	54·6	29·3	25·3	41·9	7	31·6	8	23·6	19·9	7	32·2	24·2	8·0	28·2
8	62·4	29·8	32·6	46·1	8	9·5	−4·2	13·7	2·7	8	36·2	28	8·2	32·1
9	63·4	27·6	35·8	45·6	9	−1·5	−16·3	14·8	−8·9	9	35·0	26·6	8·4	30·8
10	60	31·8	28·2	45·9	10	−8·8	−35·7	26·9	−22·3	10	30	18	12	24·0
11	57·3	27·3	30	42·3	11	0·4	−37·1	37·5	−18·7	11	26·3	6	20·3	16·2
12	60·6	27·3	33·3	44·0	12	1·2	−11·4	12·6	−5·1	12	30·3	22·1	8·2	26·2
13	56·3	31·4	24·9	43·9	13	−8·2	−17·6	9·4	−12·9	13	29	12·7	16·3	20·9
14	51·6	39·9	11·7	46·7	14	19·2	−17·1	36·3	1·1	14	28·3	19·2	9·1	23·7
15	52	35·7	16·3	43·9	15	32·8	17·8	15·0	25·3	15	27	15·9	11·1	21·5
16	53·3	43·6	9·7	48·5	16	28	16·8	11·2	24·4	16	24·2	9·6	14·6	16·9
17	45	26·8	18·2	35·9	17	33·4	24·2	9·2	28·8	17	13	−8·3	21·3	2·4
18	40·2	26·1	14·1	33·2	18	42·3	31·7	10·6	37·0	18	20·8	2·9	17·9	11·9
19	38	17·4	20·6	27·7	19	37	27·7	9·3	32·4	19	22·8	10·9	11·9	16·9
20	43·7	23·8	19·9	33·8	20	35·5	22·8	12·7	29·2	20	26·7	10	16·7	18·4
21	53·6	28·3	25·5	41·1	21	37·3	21·8	15·6	34·6	21	18·9	−0·1	19	9·4
22	49·2	22·3	26·9	35·6	22	31·2	8·8	22·4	20·0	22	36·5	16·8	19·7	26·7
23	39·3	28	11·3	33·7	23	32·9	14·0	18·9	23·5	23	33	11·8	21·2	22·4
24	38·3	23·6	14·5	31·1	24	36·9	20·7	16·2	28·8	24	13	−12·9	25·9	0·1
25	41·6	9·8	31·8	25·7	25	35·8	27·8	8·0	31·8	25	13·4	−13·7	26·1	0·4
26	41·4	6·8	34·6	24·1	26	26·3	6·5	19·8	18·4	26	11·2	−13·3	24·5	−1·1
27	40·6	9	31·5	24·8	27	16	−13·9	28·9	−0·6	27	11·6	−11	22·6	0·3
28	47·9	11	36·9	29·6	28	20·8	0·8	20·0	10·8	28	−8·9	−17·4	8·5	−13·2
29	41·3	10	31·3	25·7	29	25·7	13·3	12·4	19·5	29	−15	−25·7	10·7	−20·3
30	44	11·5	32·5	27·7	30	33·2	20·3	12·9	26·8	30	0·2	−28·8	29	−14·3
31	32·2	15·6	16·6	24·1		....	....	....	....	31	7·3	−26·3	33·6	−9·6
	1513·7	786·9	725·8	....		792·4	259·6	532·8	....		711·0	185·8	526·2	....
	48·79	25·4	23·4	....		26·41	8·65	17·76	....		22·93	5·99	16·94	....

1910

CALGARY.

January.					February.					March.				
Day of Month.	Temperature.			Mean Daily Temp.	Day of Month.	Temperature.			Mean Daily Temp.	Day of Month.	Temperature.			Mean Daily Temp.
	Max.	Min.	Daily Range.			Max.	Min.	Daily Range.			Max.	Min.	Daily Range.	
	°	°	°	°		°	°	°	°		°	°	°	°
1	2	-16	18	-7	1	21	6	15	13·5	1	48	16	32	32
2	9	-9	16	0	2	34	0	34	17	2	50	32	18	41
3	14	-2	16	6	3	41	15	26	28	3	48	20	28	34
4	14	3	11	8·5	4	40	14	26	27	4	30	20	10	25
5	24	2	22	13	5	49	17	32	33	5	36	16	20	26
6	27	2	25	14·5	6	47	26	21	36·5	6	37	10	27	23·5
7	30	16	14	23	7	30	23	7	26·5	7	44	18	26	31
8	30	16	14	23	6	26	2	24	14	8	34	18	16	26
9	26	12	14	19	9	37	4	33	20·5	9	50	12	38	31
10	26	4	22	15	10	27	20	7	23·5	10	58	40	18	49
11	27	7	20	17	11	30	12	18	21	11	62	37	25	49·5
12	32	5	27	16·5	12	34	4	30	19	12	60	36	24	48
13	36	7	29	21·5	13	18	16	2	17	13	60	26	34	43
14	39	9	30	24	14	0	-2	2	-1	14	62	30	32	46
15	22	12	10	17	15	-2	-17	15	-9·5	15	62	34	28	48
16	33	-2	35	15·5	16	5	-23	28	-9	16	64	29	35	46·5
17	36	7	29	21·5	17	4	-14	18	-5	17	62	32	30	47
18	41	22	19	31·5	18	12	-5	17	3·5	18	62	32	30	47
19	30	22	8	26	19	6	0	6	3	19	59	32	27	45·5
20	34	3	31	18·5	20	-7	-10	3	8·5	20	66	31	35	48·5
21	42	13	29	27·5	21	-12	-18	6	-15	21	67	40	27	53·5
22	40	32	8	36	22	-7	-32	25	-19·5	22	63	31	32	47
23	30	24	6	27	23	4	-25	29	-10·5	23	47	40	7	43·5
24	49	21	28	35	24	0	-15	15	-7·5	24	42	32	10	37
25	40	32	8	36	25	1	-14	15	-6·5	25	48	27	21	37·5
26	37	19	18	28	26	36	-10	46	13	26	52	25	27	38·5
27	45	15	30	30	27	41	20	21	31·5	27	51	36	15	43·5
28	31	24	7	27·5	28	24	16	8	20	28	48	24	24	36
29	40	5	35	22·5						29	48	13	35	30·5
30	50	25	25	37·5						30	56	35	21	45·5
31	28	22	6	25						31	44	27	17	35·5
	964	352	612			539	10	529			1620	851	769	
Mean.	31·09	11·35	19·74		Mean.	19·25	·357	18·89		Mean.	52·26	27·45	24·81	

1910 CALGARY—*Continued.*

April.					May.					June.				
Day of Month.	Temperature.			Mean Daily Temp.	Day of Month.	Temperature.			Mean Daily Temp.	Day of Month.	Temperature.			Mean Daily Temp.
	Max.	Min.	Daily Range.			Max.	Min.	Daily Range.			Max.	Min.	Daily Range.	
	°	°	°	°		°	°	°	°		°	°	°	°
1	54	28	25	41	1	53	18	35	35·5	1	60	37	23	48·5
2	46	24	23	35	2	62	22	40	42	2	41	30	11	36·5
3	50	26	24	38	3	65	30	35	47·5	3	56	33	23	44·5
4	59	22	37	40·5	4	59	31	38	60	4	70	37	33	53·5
5	65	22	43	43·5	5	74	36	38	55	5	76	37	39	56·5
6	40	34	6	37	6	77	38	39	57·5	6	77	47	30	52
7	56	22	34	39	7	74	46	28	60	7	60	44	16	52
8	60	26	34	43	8	56	40	16	48	8	66	46	20	56
9	65	28	38	47	9	60	33	17	41·5	9	75	40	35	57·5
10	60	33	27	46·5	10	42	34	8	38	10	64	44	40	64
11	53	35	18	44	11	52	33	19	42·5	11	87	46	41	66·5
12	57	27	40	47	12	70	33	37	51·5	12	64	44	20	54
13	60	32	18	41	13	68	39	23	53·5	13	75	36	39	55·5
14	60	24	15	37	14	54	40	14	47	14	78	42	36	60
15	64	20	44	42	15	54	35	19	44·5	15	83	44	39	63·5
16	64	40	34	52	16	70	26	44	48	16	77	51	26	64
17	63	26	37	44·5	17	74	46	28	60	17	72	52	20	62
18	78	30	48	54	18	51	40	11	45·5	18	72	42	30	67
19	80	36	44	58	19	52	36	16	44	19	79	42	37	60·5
20	57	60	7	53·8	20	58	33	25	45·5	20	72	60	22	61
21	59	25	34	42·5	21	75	32	43	53·5	21	64	47	17	55·5
22	68	29	39	48·5	22	67	47	20	57	22	61	34	27	47·5
23	76	40	36	58	23	75	37	38	56	23	51	46	15	53·5
24	83	40	43	51·5	24	80	40	40	60	24	77	42	35	59·5
25	84	42	42	63	25	60	45	35	62·5	25	84	43	41	63·5
26	58	47	11	52·5	26	70	44	26	57	26	87	44	43	65·5
27	68	28	40	45	27	64	36	28	60	27	83	46	37	64·5
28	48	40	8	44	28	60	33	27	46·5	28	70	50	30	60
29	54	36	18	45	29	70	38	32	54	29	75	48	27	61·5
30	38	31	7	34·5	30	72	37	35	54·5	30	74	48	26	61·0
					31	60	47	13	53·5					
	1818	943	875			1998	1125	873			2160	1292	868	
Mean.	60·6	31·43	29·15		Mean.	64·45	36·29	28·16		Mean.	72·0	43·07	28·93	

1910 CALGARY—*Continued.*

July.					August.					September.				
Day of Month.	Temperature.			Mean Daily Temp.	Day of Month.	Temperature.			Mean Daily Temp.	Day of Month.	Temperature.			Mean Daily Temp.
	Max.	Min.	Daily Range.			Max.	Min.	Daily Range.			Max.	Min.	Daily Range.	
	°	°	°	°		°	°	°	°		°	°	°	°
1.......	74	49	25	61·5	1.......	72	46	26	59	1	60	42	18	51
2.......	75	44	31	59·5	2.......	72	46	26	59	2.......	70	35	35	52·5
3.......	74	42	32	58	3.......	77	41	36	59	3.......	67	45	22	56
4.......	77	41	36	59	4.......	76	44	32	59	4.......	59	45	14	52
5.......	78	43	35	60·5	5.......	54	52	2	53	5.......	56	45	11	50·5
6.......	81	44	37	62·5	6.......	72	50	22	61	6.......	44	41	3	42·5
7.......	68	51	17	59·6	7.......	71	48	23	59·5	7.......	45	34	11	39·5
8.......	68	46	22	57	8.......	79	42	37	60·5	8.......	47	33	14	40
9.......	76	44	32	60	9.......	81	48	23	64·5	9.......	62	28	34	45
10.......	66	46	20	56	10.......	78	50	28	64	10.	58	34	24	46
11.......	79	41	38	60	11.......	76	46	30	61	11.......	46	33	13	39·5
12.......	88	47	41	67·5	12.......	72	46	26	59	12.......	60	30	30	45
13.......	90	52	38	71	13.......	66	48	18	57	13.......	62	34	28	48
14.......	80	54	26	67	14.......	65	50	15	57·5	14.......	70	32	38	51
15.......	83	57	26	70	15.......	59	42	17	50·5	15... ...	80	44	36	62
16.......	92	51	41	71·5	16.......	67	42	15	49·5	16.......	76	50	26	63
17.......	88	50	38	69	17.......	70	36	34	53	17.......	72	43	26	59
18.......	80	49	41	64·5	18.......	76	42	34	59	18.......	75	43	32	59
19.......	82	44	38	63	19.......	84	43	41	64	19	76	44	32	60
20.......	84	45	39	64·5	20.......	80	45	35	62·5	20.......	77	50	27	63·5
21.......	85	55	30	70	21.......	72	40	32	56	21.......	62	46	16	54
22.......	80	55	25	67·5	22.......	61	40	21	50·5	22.......	52	39	13	45·5
23.......	78	53	25	65·5	23.......	42	34	8	42	23.......	60	38	22	49
24.......	75	42	33	58·5	24... ...	62	30	32	46	24.......	36	31	5	33·2
25.......	77	37	40	57	25.......	68	33	35	50·5	25.......	64	18	36	36
26.......	59	43	16	51	26.......	64	32	32	48	26.......	66	36	30	41
27.......	74	35	39	54·5	27.......	67	36	31	61·5	27.......	63	38	25	50·5
28.......	67	48	19	67·5	28.......	64	40	24	52	28.......	62	34	28	48
29.......	74	50	24	62	29.......	56	41	15	48·5	29.......	65	39	26	52
30.......	75	48	27	61·5	30.......	56	38	18	47	30.......	59	36	23	47·5
31.......	78	48	30	63	31.......	50	44	6	47					
	2405	1454	951			2099	1315	784			1841	1143	698	
Mean.	77·58	46·9	30·68		Mean.	67·71	42·42	25·29		Mean.	61·36	38·1	23·26	

1910 CALGARY—*Concluded.*

October. Day of Month.	Temperature. Max.	Temperature. Min.	Temperature. Daily Range.	Mean Daily Temp.
	°	°	°	°
1	64	39	25	51·5
2	57	33	24	45·0
3	54	28	26	41
4	52	37	15	44·5
5	60	28	32	44
6	68	34	34	51
7	59	42	17	50·5
8	76	34	42	55
9	52	41	11	46·5
10	50	38	12	44
11	48	34	14	41
12	48	39	9	43·5
13	62	28	34	45
14	64	36	28	50
15	75	58	17	66·5
16	62	42	20	52
17	44	39	5	41·5
18	42	34	8	38
19	52	22	30	37
20	58	33	25	45·5
21	51	32	19	41·5
22	52	31	21	41·5
23	49	26	23	37·5
24	48	33	15	40·5
25	44	31	13	37·5
26	38	26	12	52
27	44	12	32	28
28	59	27	32	43
29	58	36	22	47
30	46	26	20	36
31	42	22	20	32
	1578	1021	657	
Mean.	54·13	32·6	21·19	

November. Day of Month.	Temperature. Max.	Temperature. Min.	Temperature. Daily Range.	Mean Daily Temp.
	°	°	°	°
1	39	20	19	29·5
2	55	24	31	39·5
3	32	51	1	31·5
4	38	20	18	29
5	47	20	17	28·5
6	42	51	11	36·5
7	30	20	10	25
8	40	26	14	33
9	22	17	5	19·5
10	15	15	10	20
11	45	21	24	33
12	45	15	29	30·5
13	39	12	27	25·5
14	25	17	28	31
15	42	21	21	31·5
16	57	20	17	28·5
17	47	16	31	31·5
18	32	20	12	26
19	32	16	16	24
20	30	16	14	21
21	48	20	28	34
22	44	26	18	35
23	38	22	16	30
24	34	18	16	24
25	24	14	10	19
26	21	18	3	19·5
27	20	14	6	17
28	19	12	7	15·5
29	14	11	3	12·5
30	15	11	4	13
	1041	565	476	
Mean.	34·7	18·3	15·3	

December. Day of Month.	Temperature. Max.	Temperature. Min.	Temperature. Daily Range.	Mean Daily Temp.
	°	°	°	°
1	13	6	7	9·5
2	10	7	3	8·5
3	11	4	7	7·5
4	11	5	6	8
5	20	0	20	10
6	20	15	5	17·5
7	39	5	34	22
8	40	17	23	28·5
9	34	18	16	24
10	27	6	21	16·5
11	44	8	36	26
12	46	30	15	38
13	53	27	26	40
14	43	29	14	36
15	44	30	14	37
16	44	26	18	35
17	38	30	8	34
18	48	26	22	37
19	51	34	17	42·5
20	53	33	20	43
21	38	28	10	33
22	33	5	28	19
23	42	19	23	30·5
24	37	18	19	27·5
25	41	14	27	27·5
26	31	24	7	27·5
27	21	20	1	20·5
28	28	5	23	16·5
29	2	-3	5	-0·5
30	1	-7	8	-3·0
31	-10	-15	3	-11·5
	953	466	487	
Mean.	30·74	15·03	15·71	

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BANFF.

January.					February.					March.				
Day of Month.	Temperature.			Mean Daily Temp.	Day of Month.	Temperature.			Mean Daily Temp.	Day of Month.	Temperature.			Mean Daily Temp.
	Max.	Min.	Daily Range.			Max.	Min.	Daily Range.			Max.	Min.	Daily Range.	
	°	°	°	°		°	°	°	°		°	°	°	°
1	3·8	−32·7	36·5	−14·5	1	22·2	− 4·4	26·6	9	1	39·3	16·2	23·1	27·7
2	− 6·2	−35	28·8	−20·4	2	19·9	− 2·3	22·2	9	2	41·5	32·8	8·7	37·1
3	8·6	−11·1	19·6	− 1·8	3	31·1	14·4	16·7	22·7	3	39·3	30·7	8·6	35·0
4	7·8	−19·6	27·4	− 6	4	30	13·8	16·2	22	4	33·2	27·9	5·3	30·5
5	13·2	− 1	14·2	6	5	28·6	3	25·6	15·8	5	30·2	21	9·2	25·6
6	14	1·2	12·8	7·6	6	28·8	10·4	18·4	19·6	6	31·2	5·7	25·5	18·4
7	15·2	8	7·2	11·6	7	28·3	5·7	22·6	17	7	35·2	24·3	10·9	29·7
8	20·6	5·5	15·1	13	8	22·9	−13·4	36·3	4·7	8	34·2	15·8	18·4	36·0
9	16	− 2·8	18·8	6·6	9	24·9	− 0·1	25	12·4	9	38·7	6	32·7	22·3
10	15·7	− 2·8	18·5	6·4	10	28·2	16·7	11·5	22·3	10	46·2	26·9	19·3	36·5
11	17·6	− 3·1	20·7	7·2	11	26·9	2·2	24·7	14·5	11	48·2	26·1	22·1	37·1
12	22	− 2·3	24·3	10	12	23	− 7·1	30·1	8·0	12	50·1	42·1	8·0	46·1
13	23·2	2·4	20·8	12·8	13	19	11	8	15	13	53·1	22·2	30·9	37·6
14	23	6·3	16·7	14·6	14	14·2	− 1	15·2	6·6	14	52·9	22	30·9	37·4
15	22·2	12	10·2	17·1	15	3·2	−15·1	18·3	− 6	15	52·6	18·4	34·2	35·5
16	16·6	− 8·7	25·3	4·1	16	8·5	−26·5	35	− 9·5	16	52·7	19·3	33·4	36·0
17	23·5	10·9	12·6	16·9	17	15	− 0·7	15·7	7	17	49·1	26	23·1	37·6
18	35·3	19·2	16·1	27·2	18	15·8	−17·6	33·4	− 1·1	18	49·3	36	13·3	42·6
19	31·4	18·3	13·1	24·8	19	13·8	− 6·9	20·7	3·4	19	53·3	25·1	28·2	39·2
20	27·8	15·3	12·5	21·5	20	5·5	−11	16·5	− 3	20	50·8	30·3	20·5	40·6
21	30·8	17·8	13·0	24·3	21	− 5·8	−21·6	15·8	− 3·7	21	53·2	34·3	18·9	43·7
22	41·9	36·4	15·5	34	22	0·1	−30·4	30·5	−15·2	22	52·8	29·8	23·0	41·3
23	43·9	34·5	9·4	39·2	23	14·4	−10	24·4	− 2·2	23	48	30·3	17·7	39·1
24	41·7	33·8	7·9	37·7	24	20	1·0	19	10·5	24	36·3	29·4	6·9	32·7
25	39·3	25·7	13·6	32·5	25	28·3	− 2·9	31·2	12·7	25	38·9	20·7	18·2	29·8
26	27·3	13·9	13·4	20·6	26	26·8	− 2·1	28·9	12·3	26	38·2	29·4	8·8	33·8
27	29·8	21·7	8·1	25·7	27	32	23·4	8·6	27·7	27	39·8	25·1	14·7	32·4
28	28	18·9	9·1	23·4	28	28·2	8·4	19·8	18·3	28	37·9	24·8	13·1	31·3
29	30·2	3·6	26·6	17						29	38·8	21·2	17·6	30·0
30	37·2	24·2	13	30·7						30	42·1	33	9·1	37·5
31	32·8	21·3	11·5	27·0						31	38·1	19·6	18·5	24·8
	734·1	221·8	512·3			553·8	−63·1	616·9			1,345·2	772·4	572·8	
Mean	23·68	7·15	16·52		Mean	19·77	−2·25	22·03		Mean	43·39	24·91	18·47	

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BANFF—*Continued.*

April.

Day of Month.	Temperature. Max.	Min.	Daily Range.	Mean Daily Temp.
	°	°	°	°
1.......	43	18·9	24·1	31
2.......	37	26·1	10·9	31·6
3.......	39·3	12·9	26·4	26·1
4.......	42·3	27·9	14·4	35·1
5.......	41·1	33·6	7·6	37·8
6.......	40·9	32·7	8·2	36·8
7.......	40	25·8	14·2	32·9
8.......	46·3	29·8	16·6	38
9.......	53·8	29·2	24·6	41·5
10.......	57	29·9	27·1	43·6
11.......	56·9	34·7	22·2	45·8
12.......	62·4	31·8	20·6	42·1
13.......	43·3	29·4	13·9	36·3
14.......	41·1	18·4	22·7	29·7
15.......	33·3	24·7	28·6	39
16.......	56·4	35·1	21·3	45·7
17.......	59	28·8	30·2	44
18.......	61·1	31·6	29·5	46·3
19.......	65·4	32·7	32·7	49
20.......	63·8	39·3	24·5	51·5
21.......	48·9	31·2	17·7	40
22.......	59	37·7	21·3	48·3
23.......	69·5	31·1	38·4	50·3
24.......	72·6	37·3	35·3	55·0
25.......	75·4	30·6	44·9	53·0
26.......	72·6	33·3	39·6	53
27.......	63	36·4	26·6	49·7
28.......	54·3	33·6	20·7	44·0
29.......	44·5	31·9	12·6	38·2
30.......	42·6	30·2	12·6	36·6
	1,596·2	906·4	689·8	
Mean....	53·20	30·21	22·99	

May.

Day of Month.	Temperature. Max.	Min.	Daily Range.	Mean Daily Temp.
	°	°	°	°
1......	47·9	18·3	29·6	33
2......	54·9	22·4	32·6	38·6
3......	59·9	23·9	36·0	42
4......	65·6	26·9	38·6	46·2
5......	71·3	30·1	41·2	50·7
6......	67·8	34·1	33·7	51
7......	67	40·1	26·9	53·5
8......	60·8	39·3	21·5	50
9......	56·9	27·3	29·6	42
10......	45·3	33·2	12·1	39·2
11......	60·8	29·3	31·5	45
12......	58·7	36·9	21·8	47·3
13......	58·4	34·7	23·7	46·6
14......	50·2	34·3	15·9	42·2
15......	50·9	30·4	20·5	40·6
16......	60·9	27·9	33·0	44·4
17......	61·8	45	16·8	53·4
18......	56·2	37·2	19·0	46·7
19......	47·7	32·4	15·3	40
20......	53·8	32·2	21·6	43
21......	66·6	28·3	38·2	47·4
22......	71·6	37·9	33·6	54·7
23......	76·6	31·6	44·0	33·6
24......	75·6	36·7	38·9	56·1
25......	73·3	44·4	28·9	58·8
26......	58	41·2	16·2	49·3
27......	53·2	37·2	16·0	45·2
28......	67·1	28·8	28·3	42·9
29......	62·6	42·2	20·3	52·3
30......	61·4	30·9	30·5	46·1
31......	60·2	41·9	18·3	51·0
	1,871·6	1,037·0	834·6	
Mean...	60·37	33·46	26·92	

June.

Day of Month.	Temperature. Max.	Min.	Daily Range.	Mean Daily Temp.
	°	°	°	°
1......	59	36·4	22·6	47·7
2......	42·6	29·3	13·3	35·9
3......	54·5	30·7	23·8	42·6
4......	66·5	33·9	32·6	50·2
5......	70·1	32·3	37·8	51·2
6......	67·2	41·7	25·6	54·5
7......	56	33·9	22·1	45·0
8......	62·4	39·8	22·6	51·0
9......	61·8	35·2	26·1	48·3
10......	77	41·8	35·2	69·4
11......	76·6	48·8	37·7	57·6
12......	56·3	43·3	13·0	49·8
13......	66·3	43·3	23·0	54·8
14......	70·4	33·5	36·9	52·0
15......	74·2	42·2	32·0	58·2
16......	70	37	33·0	53·6
17......	60·2	45	15·2	52·6
18......	59·7	40·2	19·6	49·9
19......	68·2	36	32·2	52·1
20......	60·3	44·5	15·8	62·4
21......	53·9	38	15·9	46·0
22......	61·3	32	29·3	46·6
23......	58·3	32	26·3	44·2
24......	68·6	35	33·6	61·6
25......	74	40·6	33·5	67·3
26......	75·4	40·2	35·2	57·8
27......	76	36·8	38·2	55·9
28......	71·2	41·9	29·3	56·6
29......	66·0	41·0	25·0	53·5
30......	54·7	40·5	24·2	52·6
	1,947·1	1,136·7	810·4	
Mean...	54·9	37·8	27·0	.

1910 BANFF—*Continued.*

July.					August.					September.				
Day of Month.	Temperature.			Mean Daily Temp.	Day of Month.	Temperature.			Mean Daily Temp.	Day of Month.	Temperature.			Mean Daily Temp.
	Max.	Min.	Daily Range.			Max.	Min.	Daily Range.			Max.	Min.	Daily Range.	
	°	°	°	°		°	°	°	°		°	°	°	°
1	67·0	42·8	24·2	55·0	1	73	36·7	36·3	54·9	1	59·4	40·1	19·3	49·7
2	63	34·5	28·5	48·8	2	70·1	39·7	30·4	54·9	2	64·6	31	33·6	47·8
3	63·2	36	27·2	49·6	3	73·3	39·9	33·4	56·6	3	58·3	46·7	11·6	52·5
4	68·3	36·5	31·8	52·4	4	73·2	40·5	32·7	56·8	4	58·2	42·8	15·4	50·5
5	72·7	34·8	37·9	53·8	5	51·2	40·1	11·1	45·7	5	56·3	40·2	16·1	48·3
6	70·9	45·5	25·4	58·2	6	67·2	41·7	25·5	54·5	6	45	38·2	6·8	41·6
7	67	52·2	14·8	59·6	7	71·2	39·5	31·7	55·4	7	40·3	32·8	7·5	36·6
8	69	40·8	28·2	54·9	8	76·1	38·2	37·9	57·2	8	39·7	31·3	8·4	35·5
9	74·7	36·8	37·9	55·6	9	74·4	42	32·4	58·2	9	56·1	25	31·1	40·6
10	70	43·5	26·5	56·7	10	72	43·5	28·5	57·8	10	53·3	29·2	24·1	41·3
11	79·4	39·8	39·6	59·6	11	72·9	42·3	30·6	57·6	11	48·3	31·2	17·1	39·7
12	84	41·2	42·8	47·6	12	70·6	40·3	30·3	55·5	12	56	24·3	31·7	40·2
13	80	47·8	32·2	63·9	13	63·2	45·7	17·5	54·5	13	60·5	25·2	35·3	42·8
14	81·4	46	35·4	63·7	14	55·2	43·1	12·1	49·2	14	73·5	26·8	46·7	50·2
15	76·9	52·2	24·7	64·6	15	59	42·3	16·7	50·6	15	72·6	30·8	41·8	51·7
16	85	44·3	40·7	64·7	16	57	32·2	24·8	44·6	16	73	36·8	36·2	54·9
17	84·9	45·9	39·0	65·4	17	67·4	32·8	34·6	50·1	17	70·5	38·9	31·6	54·7
18	80·2	46·7	33·5	63·4	18	72·5	34	38·5	53·2	18	72·4	38·8	33·6	55·6
19	83·4	37·3	46·1	60·4	19	76·4	39·5	36·9	58·0	19	76·3	35·5	40·8	55·9
20	84·6	39	45·6	61·8	20	73·6	57·8	15·8	65·7	20	77·4	33·9	43·5	55·7
21	82·5	41·6	40·9	62·1	21	68·8	41·3	27·5	55·1	21	70·4	34·4	36·0	52·4
22	75·2	49·3	25·9	62·3	22	60·2	43·8	16·4	52·0	22	61·4	38·8	22·6	50·1
23	69·5	48·2	21·3	58·9	23	54·4	32·8	21·6	43·6	23	58	39·3	18·7	48·6
24	67·1	50·8	16·3	59·0	24	54·4	26	28·4	40·2	24	39·8	28·3	11·5	34·1
25	72·2	33·9	38·3	53·1	25	65·2	29·3	35·9	47·3	25	53·2	21·6	31·6	37·4
26	68·9	44·8	24·1	56·8	26	61·9	28·5	33·4	45·2	26	54·4	39·2	15·2	46·8
27	73·5	34·3	39·2	53·9	27	64·4	28·4	36·0	46·8	27	58	32·3	25·7	45·1
28	68·4	40·1	28·3	54·2	28	60·2	33·8	26·4	47·0	28	53·3	43·5	9·8	48·4
29	71·4	44·3	27·1	57·8	29	55·3	37·9	17·4	46·6	29	50·9	39·9	11·0	45·4
30	77	41	36	59·0	30	56·2	38·3	17·9	47·2	30	48·5	36·4	12·1	42·8
31	75·9	43	32·9	59·5	31	50·8	41·9	8·9	46·3					
	2,307·2	1,315	992·3			2,021·3	1,193·8	827·5			1,759·6	1,033·2	726·4	
Mean	74·42	42·42	32·00		Mean	65·20	38·51	26·69		Mean	58·65	34·44	24·21	

1910 BANFF—*Concluded.*

October.

Day of Month.	Temperature. Max.	Temperature. Min.	Temperature. Daily Range.	Mean Daily Temp.
	°	°	°	°
1	48	36·2	11·8	42·1
2	46·3	31	15·3	38·7
3	44·1	34·3	9·8	39·2
4	46·7	33·9	12·8	40·3
5	50·7	35	15·7	42·8
6	49·2	38·7	10·5	44·0
7	49·5	38·3	11·2	43·9
8	59·9	37·6	22·3	48·8
9	59·4	41·8	17·6	50·6
10	42·2	34·8	7·4	38·5
11	44	34·3	9·7	39·2
12	50·1	38	12·1	44·1
13	55·1	31·7	23·4	43·4
14	54·5	46·5	8·0	50·5
15	62·5	49·8	12·7	56·1
16	61·3	32·9	28·4	47·1
17	56·3	35·2	21·1	45·8
18	41·2	32·9	8·3	37·1
19	48·6	24·6	24·2	36·7
20	52·7	34·6	18·5	43·5
21	54·9	30·6	24·3	47·8
22	51	41·4	9·6	46·2
23	42·3	33·3	9·0	37·8
24	41	32·4	8·6	36·7
25	41	31·5	9·5	36·3
26	33·3	21	12·3	27·2
27	36·1	7·7	28·4	21·9
28	44·1	23·5	20·6	33·8
29	50·3	37	13·3	43·7
30	46·8	26·3	20·5	36·6
31	42·8	29·3	13·5	36·1
	1,506·1	1,053·7	470·4	
Mean	48·58	33·4	15·17	

November.

Day of Month.	Temperature. Max.	Temperature. Min.	Temperature. Daily Range.	Mean Daily Temp.
	°	°	°	°
1	39·2	21·2	18	30·2
2	43·8	32·8	11	38·3
3	37	27·4	9·6	32·2
4	37	20	17	28·5
5	38	29·7	8·3	33·9
6	39·2	30·8	8·4	35·0
7	44·5	30·8	13·7	37·6
8	44·4	28·2	18·2	36·3
9	32	20·5	11·5	26·2
10	35	20·5	14·2	27·9
11	38·3	31·8	6·5	35·1
12	34·2	14·6	19·6	24·4
13	30·3	13·5	16·8	21·9
14	34·2	22·1	12·1	28·2
15	32·7	11·6	21·1	22·1
16	29·1	9·6	19·5	19·4
17	30·7	18·7	12	24·7
18	28·3	18·3	10	23·3
19	32·7	23·8	8·9	28·3
20	35·4	25·1	10·3	30·3
21	36·8	32·1	4·7	34·4
22	34·7	27·2	7·5	30·9
23	32·6	19·4	13·2	26·0
24	29	9·3	19·7	19·2
25	14·8	− 8	22·8	3·4
26	19·3	0·8	18·5	10·1
27	16·2	3·4	14·6	10·8
28	22·8	5·6	17·2	14·2
29	21·3	5·7	15·6	13·5
30	17·2	8·6	8·6	12·9
	962·7	555·4	407·3	
Mean	32·09	18·51	13·58	

December.

Day of Month.	Temperature. Max.	Temperature. Min.	Temperature. Daily Range.	Mean Daily Temp.
	°	°	°	°
1	33·8	15·2	13·6	24·5
2	33·7	8·2	25·5	21·0
3	13·2	1·8	11·4	7·5
4	34·3	2·2	32·1	18·3
5	27·9	6·9	21·0	17·4
6	26·5	11·5	15	19·0
7	33·7	15·4	18·3	24·6
8	32·7	25·2	7·5	28·9
9	29	22·3	6·7	25·6
10	23·1	7·9	15·2	15·5
11	29·2	5·9	23·3	17·6
12	42·2	24·2	18	33·2
13	41	30·8	10·2	35·9
14	35	18·5	16·5	26·8
15	30·3	18	12·3	24·2
16	31·2	20·3	10·9	25·7
17	29·8	16	13·8	22·9
18	35·3	16	19·3	25·6
19	33·2	19·6	13·6	26·4
20	31·7	19·1	12·6	25·4
21	31·1	20·8	10·3	26·0
22	21·6	6·1	15·5	13·9
23	26·1	18·2	7·9	22·2
24	28·6	21·7	6·9	25·2
25	30·8	15·8	15	23·3
26	30	25·3	4·7	27·6
27	26·3	11·2	15·1	16·3
28	26·3	11·2	15·1	18·8
29	28·6	20·1	6·7	24·4
30	28·9	13·2	15·7	21·1
31	13	−14·5	27·5	− 0·7
	913·1	454·1	464	
Mean	29·61	14·64	14·97	

APPENDIX X.

EVAPORATION DATA.

OBSERVATION OF EVAPORATIONS.

Station No. 1.—Calgary. (Pan in water.) 1896.

Interval, 1896.	Excess of Evaporation over Precipitation.	Excess of Precipitation over Evaporation.	Precipitation.	Total Evaporation.
	Inches.	Inches.	Inches.	Inches.
May 18 - May 29	1·626	....	0·46	2·086
May 29 - June 29	3·354	....	1·22	4·574
June 29 - July 30	1·704	....	1·84	3·544
July 30 - Aug. 31	1·188	....	1·66	2·848
Aug. 31 - Sept. 29	1·200	....	1·46	2·660
Sept. 29 - Oct. 23	1·224	....	0·70	1·924
Totals	10·296	....	7·34	17·636

Station No. 2.—Calgary. (Pan in ground.) 1896.

Interval, 1896.	Excess of Evaporation over Precipitation.	Excess of Precipitation over Evaporation.	Precipitation.	Total Evaporation.
	Inches.	Inches.	Inches.	Inches.
May 21 - May 28	0·894	....	0·46	1·354
May 28 - June 29	3·060	....	1·22	4·280
June 29 - July 27	2·148	....	1·84	3·988
July 27 - Aug. 31	1·284	....	1·66	2·944
Aug. 31 - Sept. 29	0·900	....	1·46	2·360
Sept. 29 - Oct. 23	3·312	....	0·70	4·012
Totals	11·598	....	7·34	18·938

Taken from Report on Irrigation Surveys, 1896, 1897, 1898, by J. S. Dennis.

STATION No. 1.—Rating Station Calgary. (Pan submerged.) 1896

Date, 1896.		Gauge Readings.		Difference in Feet.	
		At Date.	Previous.	Plus.	Minus.
May	18	0·2145	0·2145		
	21	0·2405	0·2145	·0260	
	25	0·1790	0·2405		·0615
	29	0·0790	0·1790		·1000
June	1	0·0615	0·0790		·0175
	4	0·0096	0·0615		·0519
	5	0·0015	0·0096		·0081
	8	0·417	0·0015		
	11	0·429	0·417	·012	
	15	0·371	0·429		·058
	18	0·352	0·371		·019
	22	0·281	0·352		·071
	25	0·2755	0·281		·0055
	29	0·215	0·2755		·0605
July	2	0·254	0·215	·039	
	6	0·209	0·254		·045
	9	0·231	0·209	·022	
	13	0·152	0·231		·079
	16	0·133	0·152		·019
	20	0·100	0·133		·033
	23	0·090	0·100		·010
	27	0·053	0·090		·037
	30	0·073	0·053	·020	
Aug.	3	0·030	0·073		·043
	6	0·059	0·030	·029	
	11	0·096	0·059	·037	
	13	0·093	0·096		·003
	15	0·043	0·093		·051
	20	0·069	0·042	·027	
	24	0·022	0·069		·047
	27	0·017	0·022		·005
	31	0·609	0·652		·043
Sept.	3	0·582	0·609		·027
	7	0·566	0·582		·016
	13	0·578	0·566	·012	
	17	0·584	0·578	·006	
	21	0·550	0·584		·034
	25	0·551	0·550	·001	
	29	0·509	0·551		·042
Oct.	5	0·443	0·509		·066
	12	0·474	0·443	0·031	
	15	0·437	0·474		·037
	19	0·419	0·437		·018
	23	0·407	0·419		·012
Nov.	8	0·417	0·407	·010	
Total				·2720	1·1200

STATION No. 2.—Calgary. (Pan in ground.) 1896.

DATE, 1896.	Gauge Readings.		Difference in Feet.	
	At Date.	Previous.	Plus	Minus.
May 21	1·6305			
25	1·5905	1·6305		·040
28	1·5640	1·5905		·0345
June 1	1·5250	1·5640		·0390
4	1·4970	1·5250		·0280
8	1·5040	1·4970	·007	
11	1·488	1·5040		·016
15	1·449	1·488		·039
18	1·417	1·449		·032
22	1·357	1·417		·060
25	1·348	1·357		·009
29	1·309	1·348		·039
July 2	1·347	1·309	·038	
6	1·305	1·347		·042
9	1·295	1·305		·010
13	1·246	1·295		·049
16	1·208	1·246		·038
20	1·166	1·208		·042
23	1·160	1·166		·006
27	1·130	1·160		·030
Aug. 3	1·109	1·130		·021
6	1·147	1·109	·038	
·1	1·105	1 147		·042
13	1·091	1·105		·014
18	1·069	1·091		·022
20	1·105	1·069	·036	
24	1·080	1·105		·025
27	1·059	1·080		·021
31	1·023	1·059		·036
Sept. 3	0·9925	1·023		·0305
7	0·977	0·9925		·0155
13	1·000	0·977	·023	
17	0·995	1·000		·005
21	0·994	0·995		·001
24	0·976	0·994		·018
29	0·948	0·976		·028
Oct. 5	0·912	0·948		·036
12	0·708	0·912		·204
15	0·698	0·708		·010
19	0·683	0·698		·015
23	0·672	0·683		·011
Nov. 8	0·901	0·672	·229	
			·371	1·1085

STATION No. 1.—Calgary. (Pan submerged). 1897.

DATE 1897.	GAUGE READINGS.		DIFFERENCE IN FEET.		GENERAL REMARKS.
	At Date.	Previous.	Gain.	Loss	
May 1	0·0253	0·0253			Initial reading.
" 8	0·0163	0·0253		0·0090	
" 15	0·0061	0·0163		0·0102	
" 22	0·0069	0·0061	0·0008		Very windy.
" 29	0·0001	0·0069		0·0068	
June 5	0·0001	0·0001			Before refilling
" 5	0·0377	0·0377			After refilling.
" 12	0·[illegible]66	0·0377	0·0089		Very windy.
			0·0097	0·0260	

Total evaporation to June 5, 0·0260 feet.

Station No. 2.—Calgary. (Pan in ground. 1897.

Date, 1897.	Gauge Readings.		Difference in Feet.		Remarks.
	At Date.	Previous.	Gain.	Loss.	
May 1	0·0599	0·0599	....	....	
" 6	0·0349	0·0599	....	0·0050	Before refilling.
" 6	0·0875	0·0875	....	....	After refilling.
" 15	0·0821	0·0875	....	0·0054	
" 22	0·0751	0·0821	....	0·0070	
" 29	0·0693	0·0751	....	0·0058	
June 5	0·0660	0·0693	....	0·0033	
" 12	0·0710	0·0660	0·0050	....	Very windy.
	....	....	0·0050	0·0265	

Total evaporation to June 5, 0·0265 feet.

Station No. 1.—Calgary. (Pan in ground.) 1898.

Interval, 1898.	Excess of Evaporation over Precipitation.	Excess of Precipitation over Evaporation.	Precipitation	Total Evaporation.
	Inches.	Inches.	Inches.	Inches.
June 8-June 29	0·792	....	3·21	4·002
June 29-July 31	2·604	....	3·87	6·474
July 31-Aug. 30	2·160	....	2·17	4·330
Aug. 30-Sept. 30	2·688	....	0·54	3·228
Sept. 30-Oct. 31	6·576	....	0·28	6·856
Oct. 31-Nov. 5	0·372	....	0·00	0·372
Totals	15·192	....	10·07	25·262

Station No. 1.—Calgary. (Pan in ground.) 1899

Interval, 1899.	Excess of Evaporation over Precipitation.	Excess of Precipitation over Evaporation.	Precipitation.	Evaporation.
	Inches.	Inches.	Inches.	Inches.
April 13-May 1	1·140	....	0·05	1·190
May 1-May 31	....	3·696	5·44	1·744
May 31-June 30	1·380	....	3·52	4·900
June 30-July 31	2·376	....	2·11	4·486
July 31-Aug. 31	....	6·676	9·40	3·524
Aug. 31-Sept. 30	2·160	....	0·99	3·150
Sept. 30-Oct. 31	....	0·192	1·31	1·116
Oct. 31-Nov. 30	0·192	....	0·26	0·452
Totals	7·248	9·764	23·08	20·564

Station No. 1.—Calgary. (Pan in ground.) 1900.

Interval, 1900.	Excess of Evaporation over Precipitation.	Excess of Precipitation over Evaporation.	Precipitation.	Total Evaporation.
	Inches.	Inches.	Inches	Inches.
Apr. 1-Apr. 30	0·372	...	2·04	2·412
Apr. 30-May 31	2·724	...	1·32	4·044
May 31-June 30	1·032		3·56	4·592
June 30-July 31	2·424		2·02	4·444
July 31-Aug. 31	2·400		1·29	3·690
Aug. 31-Sept. 30		3·024	3·99	0·966
Sept. 30-Oct. 31	0·108	.....	0·40	0·508
Oct. 31-Nov. 14	0·504	....	0·00	0·504
Totals	9·564	3·024	....	21·180

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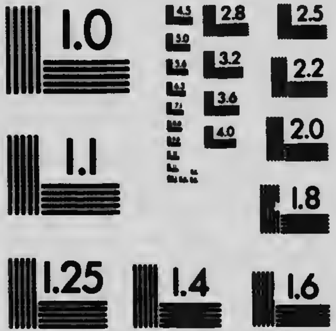
MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



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