REPORT

Of

State Engineer

For

Period July 1st, 1920

To

June 30th, 1922

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NORMANDEN PUBLISHING CO.
STATE PRINTERS
GRAND FORKS, N. DAK.

Bismarck, North Dakota,
September 1, 1922.

Honorable R. A. Nestos, Governor.

Dear Sir:

I have the honor of transmitting herewith a report of the activities of the Department of State Engineer and the Highway Commission for the biennial period, July 1, 1920 to June 30, 1922.

Respectfully submitted,

W. H. ROBINSON, State Engineer.

INTRODUCTION

The office of the State Engineer was created primarily to care for irrigation needs of the state. Since its establishment, numerous other duties and responsibilities have been added. The greatest of these are in connection with the Highway Commission, of which the State Engineer is Chief Engineer and Secretary.

The Highway Department has grown to such an extent that it has overshadowed all other activities of the State Engineer's Office. The result of this is that practically all of the State Engineer's time is taken up with the duties and responsibilities in connection with this department. Under the present budget this leaves but one engineer to handle the irrigation needs of the state.

The extended dry period that has just ended has revived considerable interest in irrigation and it is hoped that it will not again be allowed to lapse and that an adequate budget will be provided by the next legislature to handle the growing needs of the state.

On April 20, 1922, an irrigation meeting was held at Bismarck. As a result of this meeting an Irrigation Congress was held in the House Chamber at the Capitol on June 7 and 8, 1922. This Congress was well attended by representatives from most of the counties in the western half of the state. At this session, the North Dakota Irrigation Association was organized to promote irrigation development.

Since the matter of irrigation is of such vital importance to many farmers of the western part of the state and has very great possibilities as an adjunct to flood control, considerable space is devoted to the subject with the purpose in view of furnishing as much information as possible to those interested in the matter.

Included in the above material is a summary of the resolutions passed by the Irrigation Congress recently held as well as extracts from papers and talks given during the session.

Since rainfall data and surface run-off, which is indicated by stream gauge records, are vital information for the use of those who expect to attempt irrigation, considerable space is also devoted to these two topics.

RECOMMENDATIONS

It is recommended that sufficient funds be provided for the next biennium period to provide three full-time engineers on irrigation. It is also suggested and recommended that the state establish one or more irrigation demonstration farms to prove beyond doubt the true value of irrigation under as many conditions as it is practicable to cover at the locations selected for such farms. These demonstration farms would

furnish a guide to those attemting irrigation projects as they should demonstrate the kind of produce that can be economically grown under the different methos of irrigation. It would establish the limits of height to which water may be successfully pumped, as well as settling other very numerous and important questions that arise in connection with irrigation. As the matter now stands in the state, it is largely up to the individual farmer who attempts irrigation to settle all these problems for himself. It is obvious that this method must necessarily be very expensive and in some cases disastrous to those who undertake irrigation. In connection with such a farm shquld be practical irrigators, that is men who have had the experience of actually and successfull farming under irrigation, whose duty it is to visit the different individual projects in the state and give all assistance possible to the farmer who undertakes work of this character for the first time.

Such a demonstration farm could also be used to train the various county agents located in the more arid portions of the state, so that through them, also, could information be secured and spread for the encouragement of this very important matter.

OFFICERS AND EMPLOYEES FOR BIENNIAL PEHIOD

W. H. Robinson.....State Engineer
J. M. Hansen (July 1920 to July 1921) .....Assistant State Engineer
Geo. McMahon (July 1921 to July 1922 .....Assistant State Engineer
Rose Sell ..... Stenographer
Mildred Crawford ..... Stenographer
Clara Christensen (July 1921 to July 1922) .....Stenographer

Employed Temporarily as Needed

C. W. Knuffen .....Assistant Engineer
A. S. Miller .....Assistant Engineer
L. H. Belk .....Assistant Engineer
Otto McGregor.....Rodman
Earl Gann .....Rodman
Fielden Shupe .....Rodman
John Larson .....Rodman
Clifford Darling .....Rodman
John W. Koehn .....Rodman
Harold D. Bowen .....Rodman
Carl Barneck .....Rodman
Clare Register .....Rodman
F. E. Galloway .....Rodman
Chas. Mc Garvey .....Rodman
M. Diehl .....Rodman

FINANCIAL STATEMENT

July 1st, 1920, to June 30th, 1921

Balance in fund June 30th, 1920	$ 9,010.00
Contingent Appropriation to Clerkhire Fund	275.00
Transfer to Miscellaneous Fund	200.00
	$ 9,485.00
Less Expenditures	8,609.24
Balance in fund June 30th, 1921	$ 875.76

July 1st, 1921, to June 30th, 1922

Balance in fund June 30th, 1921	$ 875.76
Credit by appropriation	19,520.00
	$20,395.76
Less Expenditures	8,173.61
Balance in State Engineer's Fund June 30th, 1922	$12,222.15

Note:- The ballance in the foregoing funds aggregating $875.76 were carried forward as State Engineer's Prior Fund.

Fees of State Engineer's Office July 1st, 1920 to June 30th, 1922

For field notes	$ 163.11
For special work	138.22
For water rights	138.45
	$ 439.78

FINANCIAL STATEMENT IN ACCORDANCE WITH THE SUBDIVISIONS OF THE APPROPRIATION FOR THE STATE ENGINEER'S OFFICE UNDER THE BUDGET BILL. S B. NO. 64
July 1st, 1920 to June 30th, 1921

SALARY STATE ENGINEER

Balance July 1st, 1920	$2,500.00
Less expenditures	2,499.96
Balance	$ .04

CLERK HIRE

Balance July 1st, 1920	$4,560.00
Collections	275.00
	$4,835.00
Less expenditures	4,835.00
Balance	$ 0.00

POSTAGE

Balance July 1st, 1920	$ 150.00
Less expenditures	2.00
Balance	$ 148.00

OFFICE SUPPLIES

Balance July 1st, 1920	$ 450.00
Less expenditures	450.00
Balance	$ 0.00

PRINTING

Balance July 1st, 1920	$ 250.00
Less expenditures	30.38
Balance	$ 219.62

MISCELLANEOUS

Balance July 1st, 1920	$ 100.00
Collections	200.00
	$ 300.00
Less expenditures	113.97
Balance	$ 186.03

TRAVELING EXPENSE

Balance July 1st, 1920	$ 600.00
Less expenditures	590.93
Balance	$ 9.07

HYDROGRAPHIC WORK

Balance July 1st, 1920	$ 400.00
Less expenditures	87.00
Balance	$ 313.00

FINANCIAL STATEMENT IN ACCORDANCE WITH THE SUBDIVISIONS OF THE APPROPRIATION FOR THE STATE ENGINEER'S OFFICE UNDER THE BUDGET BILL, S. B. NO. 25
July 1st, 1921 to June 30th, 1922

SALARY—STATE ENGINEER

Balance July 1, 1921	$5,000.00
Less expenditures	2,499.96
Balance	$2,500.04

CLERK HIRE

Balance July 1, 1921	$9,920.00
Less expenditures	4,158.82
Balance	$5,761.18

POSTAGE

Balance July 1, 1921	$ 300.00
No expenditures	

SUPPLIES

Balance July 1, 1921	$ 400.00
Less expenditures	233.71
Balance	$ 166.29

FURNITURE AND FIXTURES

Balance July 1, 1921	$ 600.00
Less expenditures	137.12
Balance	$ 462.88

PRINTING

Balance July 1, 1921	$ 700.00
Less expenditures	14.80
Balance	$ 685.20

MISCELLANEOUS

Balance July 1, 1921	$ 100.00
Less expenditures	27.80
Balance	$ 72.20

TRAVELING EXPENSE

Balance July1, 1921	$1,500.00
Less expenditures	706.67
Balance	$ .793.33

HYDROGRAPHIC WORK

Balance July 1, 1921	$1,000.00
Less expenditures	159.60
Balance	$840.40

HOW TO OBTAIN A WATER RIGHT

Section 10 of the constitution of the State of North Dakota provides that; "all flowing streams and natural water courses shall forever remain the property of the state for mining, irrigation and manufacturing purposes."

The irrigation code of March 1, 1905 provides that; "Beneficial use shall be the basis, the measure and the limit to the right to the use of water, and all waters appropriated for irrigation purposes shall be appurtenant to specified lands owned by the person claiming the right to use the water, so long as the water can be beneficially used thereon."

Priority in time shall give the better right.

The Irrigation Code makes provisions for the appointment of a State Engineer who is made responsible for the administration of this code and is authorized to make rules and regulations for its proper application.

This code can be found in Chapter 38 of the Compiled Laws of 1913.

It has been the aim of the State Engineer's Office to comply with this law and at the same time so see that the provisions of this law shall be as little burden as possible to bonafide applicants for water rights.

Where it has been convenient to do so in connection with other work this office has made preliminary investigations free of charge. In many cases their reports were negative, thus saving the owner from the expenditure of money on projects that were not practicable. In other cases the office has suggested plans of development and the details of these plans were worked out by a local engineer.

In other cases where no engineer experienced in irrigation work was available this office has made surveys and prepared the necessary plans for development. This work has been done at actual cost.

It has been the aim to cooperate with engineers in private practice supplying them with instructions for making surveys and maps to comply with the rules and regulations of the State Engineer's Office.

The following is a summary of the necessary steps for obtaining a water right:

1. File an application for a permit to appropriate water in the office of the State Engineer. This application must be acknowledged by a notary and must be accompanied by a plat made by a competent irrigation engineer and also a check for five dollars for filing fees. The application and plat, if correct, are then filed and the material for publication of notice is sent to the applicant. This notice describes in detail the lands to be irrigated and sets a date for a hearing of the application.

2. This material must be published for four consecutive weeks in a newspaper of general circulation in the same stream system where the project is located.

3. A certificate of publication with clipping attached is then acknowledged by the publisher and filed in the office of the State Engineer before the date set for the hearing. The certificate of publication is to be accompanied by a filing fee of one dollar.

4. If no objections are filed by the date of the hearing the applicant is notified that his application has been approved and a permit will be issued upon the receipt of his check for $1.75 to cover recording fees.

5. On the receipt of the recording fees a permit is issued to the applicant specifying the time necessary for the completion of the works and the appropriation of water for beneficial use.

6. Before the expiration of the time granted in the permit namely from two to five years the applicant must call for an inspection of works.

7. After this inspection is made and it is ascertained that the applicant has complied with all the provisions of the law, a water license is then issued.

FILINGS MADE UNDER THE IRRIGATION CODE FOR IRRIGATION PURPOSES FROM JULY 1, 1920 TO JUNE 30, 1922

No.	Name of Applicant	Lands to be Irrigated	Source of Supply	Amount of Water Claimed 2nd Feet	No. of Acres	Date of Claim
132		W½ of NW¼, Sec. 34, T. 157 N. R. 99 W.	East Fork Creek	1.0	80	April 23, 1920
133	W. L. Girton	E½ of Sec. 27, T. 140 N. R. 95 W.	Green River	1.25	100	June 7, 1920
134	H. A. Davis	E½ of NE¼ & NE¼ of SE¼ Sec. 1, T. 149 N. R. 98 W. & N½ of SW¼ Sec. 6, T. 149. R. 97 W.	Cherry Creek	1.06	85	June 7, 1920
135	Wm. D. Niehus	Parts of NE¼ Sec. 21, T. 129 N. R. 95 W. parts of NW¼ Sec. 22, T. 129 N. R. 95 W.	Hiddenwood Creek	1.45	116	June 17, 1921
136	Sumner & Esther Sand	Parts of Lots 3, 4, 5, 6 & 7, Sec. 6, T. 141, N. R. 101 W., parts of Lots 1 & 6, Sec. 1, T. 141 N. R. 102 W.	Little Missouri River	2.31	184.9	Feb. 25, 1921
137	Wm. H. Neuens	Parts of SW¼ of SE¼ Sec. 10, T. 155 N. R. 101 W.	Small stream	0.36	28.7	April 4, 1921
138	Nels Lundell	Parts of S½ of Sec. 8. T. 152 N. R. 97 W.; parts of N½ of Sec. 17, T. 152 N. R. 97 W.	Clear Creek	0.47	37.9	April 9, 1921
139	Jay Grantier	Parts of Sec. 10, 14, 15, T. 135 N. R. 105 W.	Little Missouri River	1.74	139.29	June 29, 1921
140	Highland Ranch Co..	Parts of N½ of Sec. 6, T. 133 N. R. 92 W.	North Fk. of Cannon Ball River	1.75	140	Dec. 29, 1921
141	A. M. Jackson	Parts of E½ of Sec. 30, T. 130 N. R. 98 W.	Buffalo Creek	2.5	200	Dec. 28, 1921
142	E. A. Voigt	Parts of SW¼ of Sec. 34, T. 129 N. R. 98 W.; parts of SE¼ Sec.				

143	Levi Dodge	33, T. 120, N. R. 98 W.	Lightning Creek	....	160	Jan. 3, 1922
144	Henry Derudder	Parts of E½ of Sec. 32, T. 149 N. R. 103 W.	Horse Creek ..	1.21	97	Feb. 6, 1922
145	Frank J. Kiebert ...	Parts of Secs. 34 & 35, T. 141 N. R. 82 W.	Square Butte Creek	1.50	120	Feb. 8, 1922
146	Frank A. Little	Parts of SE¼ Sec. 26, T. 144 N. R. 97 W.	Knife River ...	0.50	40	Feb. 8, 1922
147	Patrick J. Reagen ..	Parts of S½ of Sec. 30, T. 144 N. R. 96 W.	Knife River ...	0.75	60	Feb. 8, 1922
148	H. C. Short	Parts of Secs. 1, 2, 11 & 12, T. 142 N. R. 102 W.	Little Missouri .	1.13	90.17	March 1, 1921
149	Edward E. Ziner ...	Parts of N½ of Sec. 5, T. 142 N. R. 93 W.	Knife River ...	1.10	88	April 6, 1922
150	Albert Koesel	Parts of SE¼ of Sec. 20, T. 138 N. R. 92 W.	Heart River ...	0.50	40	June 3, 1922
151	Fred Bulte	Parts of SE¼ Sec. 19, T. 138 N. R. 92 W.	Heart River ...	0.50	40	June 15, 1922
152	Henry Englehardt ..	Parts of E½ of Sec. 13, T. 133 N. R. 89 W.	Cannon Ball River	0.50	40	May 24, 1922
153	W. T. Krebsbach	Parts of Sec. 34 & 35, T. 133 N. R. 98 W.	Cedar Creek ..	3.00	240	May 15, 1922
154	Fred W. Hammer ...	Parts of S½ of Sec. 32, T. 130 N. R. 98 W.	Buffalo Creek ..	1.00	80	May 22, 1922
155	C. G. Arnett	Parts of SW¼ of NW¼ Sec. 9, T. 134 N. R. 102 W.	Deep Creek	0.25	20	May 19, 1922

"BE IT RESOLVED, that the state engineer be asked to make surveys, design structures and supervise construction of such structures as may be necessary to accomplish the desired result."

"RE: Appropriation from State Legislature for $50,000 for Investigation og Irrigation Proposals within the State.

"WHEREAS, the promotion of irrigation development is of the utmost importance to the State of North Dakota; and,

"WHEREAS, the development of small irrigation projects can only be secured by means of detailed surveys and the advice of engineers qualified in the design of irrigation structures; and,

"WHEREAS, a detailed study of the larger projects in the state and the submission of definite scemes of development to the U. S. Reclamation Service will be the most expedient method of securing federal funds due the State of North Dakota from the sale of public lands;

"THEREFORE, BE IT RESOLVED, that this Congress do recommend to the members of the Senate and the House of Representatives of the State of North Dakota that a minimum appropriation of $50,000 be assigned to the State Engineer's Office for the next biennial period, to be expended for the investigation of Irrigation Projects."

"WHEREAS, the womanhood of America are rapidly coming to a comprehensive grasp of the duties of american citizenship and the responsibilities that such citizenship implies; and,

"WHEREAS, the comfort and prosperity of the home on farm and in village is a material factor in economic, social, and political contentment; and,

"WHEREAS, the conservation of the flood waters of the Missouri-Yellowstone watershed will effect irrigation of certain arid and semi-arid tracts and will likewise enable the development of hydroelectric power, which may be utilized to increase agricultural productivity and at the same time provide comforts and conveniences aforementioned; and,

"WHEREAS, the reclamation fund available to North Dakota, South Dakota and Montana may be wholly inadequate to so comprehensive project;

"THEREFORE, BE IT RSOLVED, that the womanhood of these several states urge and demand upon our representatives in Congress that immediate steps be taken with a view to the reclamation of this vast area in the interest of the development of and prosperity of the farms, villages and cities in the entire watershd of the Missouri-Yellowstone; and,

"RESOLVED, that if the funds available to the several states are inadequate to such comprehensive project, we urge and demand that our delegations in Washington call upon Congress for the appropriation of such additional funds as may be necessary to the completion of such a project; and,

"RESOLVED, that it is understood that all lands in the Mouse River and Des Laes watershed are considered a portion of the demand."

The following resolutions were read for the first time and adopted:

1. "Hon. R. A. Nestos, Governor,
State of North Dakota,
Bismarck, N. D.
Sir:

"WHEREAS, the provisions of the present law (Sec. 8276, Chapter 38 of the Civil Code) for the several irrigation districts of the state, have not been compiled with and the law thus made inoperative;

"THEREFORE, BE IT RESOLVED, that the Governor be requested to nominate to the Senate suitable persons to represent these several irrigation districts."

2. To the Federal Farm Loan Board:

"WHEREAS, The Federal Farm Loan Board advances money for farm improvements; and

WHEREAS, several small irrigation projects have been proven to be good farm improvements in the Slope Country; and,

"WHEREAS, lack of finances has been the greatest drawback in the future advancement of small irrigation projects;

"THEREFORE, BE IT RESOLVED, that the members of this organization go on record as requesting a ruling from the Federal Farm Loan Board permitting the advancement of money for small irrigation projects upon the recommendation of federal or state irrigation engineers."

3. "BE IT RESOLVED, that copies of these Resolutions be forwarded to the Secretary of the Association of Commerce at New Orleans."
4. "BE IT RESOLVED, that this Congress give a rising vote of thanks to General E. A. Williams for his untiring efforts which have added so much to the success of this meeting.
5. "BE IT RESOLVED, that the proceedings of this Congress be filed with Hon. Jos. A. Kichen, Commissioner of Agriculture and Labor, with the request that 10,000 copies be printed for general distribution, the cost of publication to be paid out of any funds available."
6. "To the North Dakota Engineers.

"WHEREAS, ther are numerous instances in the U. S. where combined dam and bridge structures are in use; and,

"WHEREAS, it is the opinion of this Congress that there are many points in North Dakota where the installation of such combined structures would be feasible from an engineering standpoint as well as vitally important to the work of flood control and irrigation.

"THEREFORE, BE IT RESOLVED, that this Congress respectfully request the State Highway Commission that it earnestly consider the building of such structures wherever feasible."

7. "BE IT RESOLVED, that all officers of this organization are members ex officio of the Executive Committee."

A motion was made and carried that the action of this Congress be made public by the press.

METHODS OF APPLYING WATER TO LAND IN NORTH DAKOTA.

The storage of water for irrigation has not been practiced on an extensive scale in North Dakota. Generally speaking, there are no large reservoir sites in the western half of the state suitable for the storage of water on an extensive scale. However, on the smaller streams of the state and their tributaries there are numerous small reservoir sites that should be developed and doubtless will be when a method is found to market the bonds of Irrigation Districts.

In the biennial reports of the State Engineer for 1904 and 1906 are given complete reports on the possibilities of the storage of water in the western portion of the state. During the past two years further investigations have been made on some of the projects mentioned as given below.

On the Cannon Ball River at New England a survey was made to determine the amount of storage available if a combined dam and bridge structure were built as proposed by some citizens of New England. It was found that channel storage only was available but owing to the light fall of the stream a dam of sufficient height to raise the water eighteen feet at New England would back the water up the channel for a distance of four miles and provide a storage capacity of over two hundred acre feet. This water would be available for the irrigation of about twenty acres of land by gravity and over one hundred acres of level land in the flats above the dam could be irrigated by a low pumping lift not to exceed fifteen feet. This land under irrigation would furnish a certain supply of small fruits and vegetables to the city of New England as well as winter feed for dairy stock.

Apart from its use for irrigation purposes such a reservoir would be an asset to the city in many other ways as well.

In the NW¼ of Sec. 13, T. 136 N., R. 89 W., is located a dam site on the Heart River. A dam at this point 60 feet high and 200 feet wide at the base and 700 feet long on the top will afford a storage of 30,000 acre feet, which is about one-half the annual flow of the Heart River. This site as mentioned in the State Engineer's Report of 1906 is the best reservoir site in the Heart River.

There is a rock ledge at either end of the proposed dam and also large boulders weighing several tons each. It appears that conditions are favorable at this point for the construction of a rock fill dam with a concrete core.

This dam could supply water by gravity for the irrigation of the Heart River bottoms a short distance below the dam as well as affording a supply of water for pumping projects farther down stream.

The protection of the City of Mandan against floods is another factor to be considered in connection with this project.

The State Engineer's Office in cooperation with Mr. A. D. LaDue, County Surveyor of Grant County, made a preliminary survey of this project during the present season in order to determine the section of the proposed dam and also the approximate reservoir capacity. Funds were not available for a more extensive survey to determine the acreage that could be irrigated or a preliminary estimate of the cost of development.

At the request of property owners in the Grand River Basin this office made application to the U. S. Reclamation Service for the release of the waters of that stream. As a result of this action three small dams have been constructed.

At the mouth of Lightning Creek in the NW¼ of Sec. 34, T. 129 N., R. 98 W. Levi Dodge has constructed a dam to irrigate 160 acres by means of spring flooding and pumping. During the past spring water was turned on over 60 acres of land which is now in crop. When the project was visited the reservoir was full and Mr. Dodge believes that the gravel subsoil below the dam will afford sub-irrigation of a considerable area.

In the NE¼ of Sec. 30, T. 130 N., R. 98 W., E. A. Voigt has built a dam across Buffalo Creek to irrigate 200 acres of land by means of spring flooding and pumping. When visited by the writer the reservoir holding about 200 acre feet of water was filled and a plentiful supply of water was available for pumping during the summer season.

On Buffalo Creek about two miles below the Voigt Dam, Fred W. Hammer has filed on a water right to irrigate 80 acres of land by spring flooding and pumping. This project is not yet completed.

W. T. Krebsbach of Reeder, North Dakota, has filed on a water right to irrigate 240 acres of land from Cedar Creek by gravity and spring flooding. Mr. Krebsbach proposed to construct a dam caross Cedar Creek in Sec. 35, T. 133 N., R. 98 W. A preliminary survey of this project was made by the State Engineer's Office and construction of this dam was advised.

In Sec. 33, T. 149 N., R. 103 W. Henry Derudder has constructed a dam across Horse Creek to irrigate 97 acres of land by pumping. This dam provides a reservoir capacity of over 700 acre feet. The pumping plant consists of o 10" centrifugal pump and a 60 H. P. steam tractor using lignite coal as fuel.

Mr. Jay Grantier of Banks, N. D., has secured a permit for the construction of a dam on Clear Creek in the NE¼ of Sec. 17, T. 152 N., R. 97 W. This dam will be 20 feet high and 850 long and will be constructed of earth fill. The reservoir will have a storage capacity of [illegible] acre feet. Mr. Grantier already has 200 acres of alfalfa grown under irrigation. This project consists of a small diversion dam with timber outlet gates and a ditch of large sectin used for spring flooding. The proposed dam will afford a more certain supply of water for the existing project and also bring additional acreage under irrigation. This dam will be constructed during the present season. When this project was visited Mr. Grantier was cutting a very heavy crop of alfalfa.

Much could be done by the State Engineer's Office to encourage the construction of dams and reservoirs if funds could be made available for surveys and investigations along this line and bring the same to the attention of the citizens interested.

A large amount of labor has been wasted in the construction of ill-advised projects and numerous failures have been due to the construction of dams of too small a section and without providing the proper spillway capacity. It is recommended that the State Engineer's Office be provided with funds to give the proper assistance to individuals contemplating the

construction of such reservoirs as well as making surveys in connection with the larger storage projects.

Irrigation by means of spring flooding is the kind most generally practiced on individual projects in North Dakota.

There are several projects in the northwestern part of the state that have been in continuous operation for the past thirty to forty years. The crop most generally produced is blue joint hay, but in several cases with a proper control of the water supply alfalfa and sweet clover have been very successful crops.

Where spring flooding is practiced on lands growing row crops the moisture may be further conserved by using dry farming methods of cultivation.

Irrigation by spring flooding, though wasteful of water, is adapted to conditions where no storage is available without excessive cost. In many cases dikes may be constructed around a tract of land situated near the mouth of a coulee. These dikes will retard the flow of water until the frost leaves the ground and the moisture will then enter the ground and remain stored until needed by the crop.

Spring flooding where available is not only more satisfactory than summer fallowing but the construction cost is extremely small when compared with the results obtained. Many projects have been constructed in North Dakota at a cost varying from five to ten dollars per acre and sometimes less.

This method of irrigation is also adapted to small tributary streams where rock and timber dams may be constructed to retard the flow and flood a larger portion of the bottom lands. The crop yields obtained by this method are sometimes remarkable. Mr. Wm. Black of Sanish, N. D., who has irrigated 700 acres of the bottoms of the Little Knife River by the spring flooding method for the past thirty years reports an average yield of two tons of blue joint hay per acre, which is more than double the yield of the same land when not irrigated.

In parts of England where the rainfall is much greater than in North Dakota spring flooding for hay crops has been practiced for over nine hundred years.

The State Engineer's Office has spent considerable time in examining projects where this system of irrigation might be practiced. However, owing to the lack of funds available no general survey of the state with this end in view could be attempted.

Besides the above methods of irrigation lifting water by means of pumps is practiced to a considerable extent.

The installation of individual pumping plants for irrigation has made considerable progress during the past two years. This has been especially true in the development of irrigation on the Little Missouri River bottoms. The tendency in this district has been to replace smaller units with steam driven centrifugal pumps of 10" and 12" discharge, delivering sufficient water to irrigate from 150 to 200 acres. These pumps are for the most part operated by steam tractors using lignite coal as fuel. Where large seams of coal are near at hand some very low cost records were made.

The lift has varied from 20 to 50 feet and the latter figure appears to be close to the economic limit except where fuel is to be had at a very low cost. The market problem is not a factor in the development of individual projects in the Little Missouri Valley, as there is a home market at a good price for as much stock feed as can be raised in this district. The Little Missouri River bottoms offer possibly the best opportunity in the state to those wishing to irrigate by means of individual pumping plants.

There is another field in which irrigation by pumping means of small gas tractors has made remarkable progress. This is in locations where the water supply is insufficient or where the irrigable acreage is not large enough to warrant the installation of a steam plant. The field of economy for gas tractors is limited to five and six inch centrifugal pumps. The gas tractor in many cases being a part of the usual farm equipment it is not directly chargeable to the irrigation plant. The economic lift for gas tractors is confined to a maximum of about thirty feet and the area irrigated to thirty to forty acres.

Truck gardening near towns or cities, small fruits and vegetables, particularly potatoes, and the growing of winter feed for dairy cattle are the particular fields in which pumping plants operated by gas tractors excel.

The cost of irrigating small grains except as a rotation crop is prohibitive even on low cost gravity projects.

There are several hundred farms in westren North Dakota where the installation of pumping projects would be highly profitable. Particularly is this true on farms where a gas tractor is already in use.

Before any great number of these projects can be developed a certain amount of storage must be provided on our smaller streams and tributaries. This could be accomplished through the formation of Irrigation Districts which could possibly secure aid from the State or Federal Government in marketing their bonds.

The State Engineer's Office has been largely instrumental in encouraging the development of a number of individual pumping projects and insofar as the funds would permit rendered considerable aid in this direction, as well as in the location of storage reservoirs on our smaller streams.

DIVERSION OF THE MISSOURI RIVER.

The diversion of the Missouri River for the purpose of irrigation has been considered at various times in the past. As a result of a meeting held in Grand Forks in 1889 a memorial was sent to congress requesting that surveys be made for the purpose of considering the diversion of the Missouri River in eastern Montana and bringing it over the Coteau to the James River and also to Devils Lake. In 1891 Mr. Morris Bien of the U. S. Geological Survey, spent several months investigating the possibility of diverting the Missouri River by means of a canal over the Coteau to the James River. The project was reported infeasible in that form. However, due to the advance in construction methods and engineering knowledge in general, it seems that diversion by means of a long tunnel might be feasi-

ble under present conditions. Such a possibility was not considered in the previous investigation.

The diversion of the Missouri River might be accomplished in two ways. One plan would involve the construction of a dam in eastern Montana for the purpose of diverting water to the Missouri River bottoms in North Dakota.

The other method would be a diversion by means of a long tunnel from the Missouri River south of Garrison to the Mouse River Valley. The Missouri River at the point mentioned, being 200 feet above the Mouse River at Velva, 130 feet above Minot and 260 feet above Devils Lake. Such a project might also supply a sufficient quantity of water to maintain the present level of Devils Lake. While the very magnitude of this project makes it appear somewhat visionary, it is dwarfed in comparison with the Colorado River project and also the Columbia Basin project in the state of Washington, that was recently recommended by General Geo. W. Goethals. It is here recommended that an appropriation be made sufficient to cooperate with the federal government in making a complete topographical survey of this district.

THE UPPER MISSOURI RIVER PROJECT.

Efforts have been made during the past year to secure the co-operation of the States of Montana and South Dakota in urging the development of irrigation projects along the borders of those states.

During the summer of 1922 a reconnaissance was made by the State Engineer's Office to determine the feasibility of diverting the Missouri River in eastern Montana and bringing a portion of the water into western North Dakota by means of a canal. It was found that the plans of the Fort Peck Project of the U. S. Reclamation Service contemplate a diversion of the Missouri River by means of a canal 104 miles in length, located on the north side of the Missouri River and extending from the site of old Fort Peck to the Big Muddy River, which is about thirty-five miles west of the North Dakota line.

A reconnaissance was made from the point of diversion near old Fort Peck to the city of Williston to determine the feasibility of enlarging the proposed canal and of extending the survey into western North Dakota. The proposed canal follows a very favorable location and it appears that it would be feasible to build a canal of greater capacity.

The extension of the canal from the Big Muddy River to Williston involves some heavy work but it appears that the large acreage that could be reached by such a project would justify the expenditure.

It is recommended that the cooperation of the state of Montana be sought in securing an extension of this survey by the U. S. Reclamation Service.

The following is an extract from the report on the Missouri River Unit of the Fort Peck Project as taken from the Eighth Annual Report of the U. S. Reclamation Service:

MISSOURI RIVER UNIT.

At present the most feasible plan for the irrigation of an extended area provides for a gravity canal diverting water from Missouri River near the site of old Fort Peck, about 12 miles west of the reservation boundary and following approximately the line of the Great Northern Railway across the reservation. The main canal will have a total length of about 104 miles. The scarcity of cross drainage renders the project an unusually attractive one as regards economical construction and operation. It is proposed to construct at first only such works as are required for the irrigation of the 50,000 acres of clear bench land. This will require the diversion from Missouri River of 625 second-feet of water, and the main canal will have this capacity for a distance of 29 miles below the headworks. In this reach there will be required a concrete headworks structure, two concrete-lined tunnels, each with a net cross-sectional area of about 90 square feet, respectively 1,600 and 2,700 feet long, a double-barrelled 300-foot concrete siphon crossing at Milk River, and a crossing at Little Porcupine Creek. The first lateral turnout will be about 29 miles below the headworks. At Wolf Creek, about 48 miles below the headworks, a crossing will be required, and 2 miles below this crossing a drop is planned. At the site of this drop the main canal will carry 425 second-feet. A comparatively inexpensive structure will be required for crossing Popular River, at which point the canal will carry 150 second-feet. the other structures required are such as are used chiefly for operation and maintenance and will be comparatively small.

In June, 1909, a board of engineers considered the surveys and plans of construction proposed for the Fort Peck project, investigated on the ground the various features in detail, reported the project feasible, and approved the plan of construction as herein outlined.

During the field season of 1909 topographic surveys of the main canal location and the greater part of the irrigable lands have been made. Final locations are now being made, and it is proposed to begin construction work immediately at a number of points in order to employ Indians in the work as near their homes as is practicable. Temporary headquarters have been established in Oswego.

FOURTH IRRIGATION CONGRESS.

Considerable interest in irrigation has been manifested by the people of the state during the past year. The press in general has taken a marked interest in the possibilities of irrigation. An irrigation meeting was held in Bismarck on April 20th and as a result of this meeting an Irrigation Congress was called to meet in Bismarck on June 7th and 8th.

The congress was well attended and a permanent organization known as the North Dakota Irrigation Association was organized to promote irrigation development.

Listed below is a copy of the resolutions passed by the Irrigation Congress:

"To the Senators and Representatives in Congress from the states of North Dakota, South Dakota and Montana.

"Gentlemen:

"The Fourth Irrigation Congress for the state of North Dakota in session in the legislative chamber of the capitol at Bismarck this 7th and 8th day of June, 1922, send greetings.

"The purpose of this Congress is to undertake ways and means to a comprehensive reclamation project embracing irrigation, drainage, the development of hydroelectric power in the source streams of the Missouri-Yellowstone watershed, and by the impounding of the source waters and their use as above mentioned, materially decrease, if it will not eliminate, the disaster from floods in the lower Mississippi Valley.

"We urge that you, and each of you, give careful study to the vast importance of such a project to your several states and we respectfully submit that the states of North Dakota, South Dakota, and Montana are vitally interested, in the interest of agriculture, and in the interest of the development of these three great states, in the immediate appointment of a commission of engineers authorized and instructed to make such surveys and reports as may be required to control the situation inimical to agriculture from the head of navigation, and along the course of the several tributaries to the delta of the Mississippi at the Gulf of Mexico.

'We respectfully urge upon you that immediate steps be taken to reclaim this vast area from unprecendented and unnecessary loss by drought and flood.

"It is understood and agreed that all lands in the Mouse River and Des Lacs watershed are considered a portion of the demand.

"RE: Endorsement and Authorization to Executive Committee.

"WHEREAS, this, the Fourth Irrigation Congress, is regularly called by Hon. E. A. Williams, President of the North Dakota Irrigation Association for the purpose of seeking ways and means by which reclamation funds, credited to the state of North Dakota, may be made available for irrigation, drainage and the development of hydroelectric power; and,

"WHEREAS, all the states in the watershed of the Missouri-Yellowstone require seasonal irrigation, and likewise many of them have available reclamation funds from the sale of public lands within their several states; and,

"WHEREAS, by the aforesaid control and irrigation in the source streams of the Missouri-Yellowstone, the devastation resulting from flood in the lower Mississippi Valley may be materially decreased, if not eliminated;

"THEREFORE, BE IT RESOLVED, that we do urge upon the Secretary of the Interior the imperative demand that immediate steps to the appointment of a commission of engineers be taken with a view to full survey and actual determination as to the feasibility of a comprehensive reclamation project covering the entire watershed of the Missouri-Yellowstone; and,

"RESOLVED, that inasmuch as settlers by the thousand, in utmost good faith and predicating their success in these pioneer

lands upon the good will of the federal government, have been distressed by erratic and uncertain climatic conditions, it is highly important and imperative to their continued residence and success that available water, under a Missouri-Yellowstone Project be made immediately available to their use and that priority of consideration of right belongs to these settled lands as against vast unsettled arid areas of less certain agricultural values.

"RESOLVED, it is understood and agreed that all lands in the Mouse River and Des Lacs watershed are considered a portion of the demand."

"To the President of the United States and to his Cabinet.

"HON. WARREN G. HARDING,
President of the United States,
Washington, D. C.

"Dear Sir:

'The Fourth Irrigation Congress of the State of North Dakota is now in session in the legislative chambers of the State Capitol at Bismarck this seventh day of June, 1922, respectfully submits and merorializes as follows:

"That in the interest of the agricultural development of the states in the Missouri-Yellowstone watershed, and in the interest of flood prevention in the lower Mississippi Valley, you urge upon the Department of the Interior, the Department of Agriculture, and the Congress of the United States, the imminent necessity for a comprehensive reclamation project—which will embrace the conservation of the water in the source streams of the Missouri and the Yellowstone rivers and the impounding of these waters for irrigation purposes and for the development of hydroelectric power, thereby reducing the high floodhead in the lower Mississippi which constitutes a constant source of danger and frequently results in devastation and ruin.

"We respectfully call your attention to the necessity for immediate action and we urge that you give that consideration to this reclamation project which its comprehensive scope and its potentialities for good, demand.

"It is understood and agreed that all lands in the Mouse River and Des Lacs watershed are considered a portion of the demand."

"RE: Mouse River Project.

"WHEREAS, the bottom lands of the Mouse and Des Lacs River Valleys are among the richest in North Dakota; and,

"WHEREAS, the proper development of said lands by means or irrigation can only be accomplished by the construction of flood control gates; and,

"WHEREAS, the U. S. Department of Agriculture has made an offer to cooperate in the surveys of said lands and design of suitable structures; therefore,

MEAN ANNUAL PRECIPITATION BY MONTHS FOR VARIOUS STATIONS IN N. D.

	Alt.	Yrs.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Amidon	....	8	.49	.59	.94	1.49	2.37	2.66	2.69	1.23	1.27	1.11	.38	.53	15.75
Beach	2579	15	.63	.51	.78	1.42	2.81	3.48	1.80	2.05	1.27	.99	.54	.51	16.79
Berthold	2082	28	.40	.55	.84	1.16	2.46	3.88	1.97	1.77	1.44	.86	.48	.40	16.21
Bismarck	1674	47	.52	.48	1.03	1.63	2.43	3.41	2.21	1.99	1.25	.95	.62	.58	17.10
Bottineau	1638	29	.46	.37	.80	.87	2.04	3.14	2.28	2.21	1.57	.99	.54	.49	15.75
Bowbells	1958	9	.73	.37	.53	1.28	2.17	2.82	2.08	2.35	1.49	.80	.51	.49	15.62
Bowman	2961	7	.50	.21	.53	1.54	1.96	2.08	3.00	1.01	.92	.64	.28	.28	13.95
Buford	1950	41	.57	.49	.55	1.01	2.27	2.89	1.66	1.37	.98	.87	.47	.54	13.67
Carson	2500	9	.34	.13	.65	1.56	2.53	4.18	2.05	1.51	1.65	.87	.51	.55	16.53
Crosby	1954	14	.55	.26	.66	1.02	2.02	2.96	1.98	2.21	1.24	.76	.76	.51	14.93
Dickinson	2543	29	.42	.43	.84	1.23	2.43	3.04	2.32	1.95	1.07	.78	.48	.42	15.41
Donnybrook	1760	22	.39	.51	.77	1.05	2.24	2.86	2.63	2.14	1.66	.98	.59	.48	16.30
Dunn Center	2191	22	.51	.56	1.11	1.32	2.54	4.30	2.05	1.57	1.12	.63	.62	.56	16.89
Dunseith	1682	25	.47	.42	.77	.83	1.70	2.96	2.34	2.41	1.57	.75	.43	.41	15.06
Eckman	1500	16	.56	.35	.50	1.05	2.18	2.76	2.44	2.32	1.13	0.85	0.54	0.62	15.30
Energy	1750	9	.31	.23	.68	1.08	2.25	3.72	2.06	2.14	1.40	.75	.24	.34	15.20
Epping	2224	13	.56	.35	.56	1.15	2.31	3.34	1.92	2.15	1.46	.89	.42	.43	15.54
Fort Yates	1670	26	.53	.64	1.02	1.67	1.90	3.62	2.52	1.97	.98	.79	.53	.43	16.06
Garrison	1901	45	.43	.53	1.04	1.20	2.17	3.32	2.10	2.00	1.36	.90	.58	.57	16.20
Glen Ullin	2070	12	.60	.46	.89	.79	2.13	3.75	2.20	2.07	1.11	.70	.66	.44	15.80
Granville	1504	14	.51	.38	.57	.96	1.84	2.75	2.07	2.09	1.25	.88	.61	.55	14.46
Haley	2260	7	.41	.60	.97	1.06	2.72	3.78	1.85	1.27	1.79	1.07	.20	.26	15.98
Hettinger	2675	14	.32	.28	.76	1.16	2.12	3.24	2.79	1.25	1.30	.64	.32	.34	14.52
Howard	2275	14	.75	.69	1.14	1.40	2.18	2.59	1.60	1.89	1.37	.81	.51	.82	15.75
Lamoine	1936	16	.61	.39	.77	.97	2.36	3.32	2.55	1.98	1.28	.58	.54	.50	15.85
McKinney	1640	27	.37	.28	.73	.89	1.96	3.22	2.06	1.79	1.43	.84	.59	.44	14.60
Mandan	1644	27	.35	.45	.80	1.89	2.26	3.52	2.14	1.79	.91	.76	.42	.61	15.90
Marmarth	2714	12	.30	.39	.45	1.13	2.28	3.11	1.66	1.62	1.23	.79	.33	.34	13.63
Medora	2270	22	.62	.48	.90	.93	2.66	3.06	2.16	1.71	1.15	.73	.46	.45	15.31
Minot	1557	25	.45	.46	.77	1.32	1.97	3.26	1.85	2.20	1.58	.94	.68	.51	15.99
Mott	2424	14	.88	.57	1.04	1.50	2.36	3.40	2.37	1.64	1.57	1.09	.46	.58	17.46
New England	2400	27	.42	.54	.87	1.02	2.15	2.69	2.01	1.77	1.12	.65	.49	.41	14.14
New Salem	2163	17	.63	.38	.96	1.23	2.37	3.71	2.10	1.67	1.35	.95	.35	.53	16.23
Orange	2586	14	.34	.59	.89	1.11	2.52	3.14	1.77	1.35	1.30	.96	.41	.59	14.97

Portal	1954	15	.38	.45	.74	1.08	1.99	3.96	1.97	1.84	1.57	.65	.64	.55	15.82
Powers Lake	2205	16	.78	.48	.88	1.56	1.80	2.86	1.78	1.59	1.09	.82	.56	.63	14.83
Towner	1482	19	.49	.38	.90	1.10	2.32	3.08	2.23	2.09	1.65	.90	.48	.41	16.03
Turtle Lake	1899	8	.41	.35	.99	.95	2.46	4.88	1.75	1.94	1.37	.92	.40	.52	16.94
Washburn	1731	22	.39	.39	.65	1.10	2.38	3.55	2.30	1.33	1.19	.94	.64	.34	15.20
Westhope	1508	15	.56	.19	.49	1.06	2.04	2.94	1.95	2.23	1.19	.67	.58	.37	14.27
Williston	1875	27	.54	.42	.86	1.10	2.11	3.21	1.69	1.67	1.01	.69	.63	.49	14.42
Willow City	1471	29	.58	.46	.73	.95	1.92	3.18	2.09	2.08	1.55	.70	.51	.54	15.29
Zap	1800	14	.36	.26	.67	1.08	2.38	3.80	2.17	2.05	1.21	1.06	.36	.35	15.75

RIVER RECORDS

By E. F. CHANDLER.

Hydraulic Engineer, United States Geological Survey.

By permission of the United States Geological Survey, with which the office of the State Engineer has been cooperating in this work, the following tables of flow of the more important or typical streams of North Dakota and the Red River valley have been selected and compiled from the records in the office of the Survey in advance of their regular publication by the Survey, for use here. A large portion of the expense entailed in the continuous maintenance of these records for the past ten or twenty years has been carried from Federal appropriations, but a part of the expense, (in particular, usually the payment of gage-observers in each locality) has through most of the time been carried from appropriate state funds of the states concerned.

The methods followed in this work were described in detail in the First Report of the North Dakota State Engineer (1905), pages 49 to 62, and also in the Second Report (1907) pages 47 to 49. A discussion of the conclusions which can be drawn from these records in regard to the available water supply in different parts of the state appears in the Third Report (1909), pages 53 to 66, although some of the conclusions there stated now require slight modification on the basis of the fourteen years additional records now available. A brief summary of some of the long records for the eastern part of the state and Red River valley is included in the Eight Report (1918), pages 45 to 47, and a similar summary for the western part of the state is included in this report under heading "Waste of Dakota Streams." The following is a short statement covering the general methods of obtaining these records.

At each "river station" or "gaging station" a gage is established and an observer appointed who make regular observations (usually once each day) and keeps a record of the daily height of the water. The gage-heights are recorded in feet and tenths of a foot. It is intended to place the gage so that its zero shall be below the lowest known low water, and at most of the stations the zero has been set below the bottom of the river; but the height of floods is easily seen by a comparison beween the maximum gage-heights recorded during the floods and the minimum gage-heights recorded during low water periods.

At suitable intervals, an engineer or assistant (called in this work a "hyrdographer") equipped with appropriate meter and other instruments makes measurements of the discharge (that is, of the actual number of gallons of water per day flowing by the gage) and records the discharge and gage-height found at that time. It is thus known how much water will be flowing whenever the river happens to be at the same gage-height again, provided the river channel does not suffer change in the meantime. In this region, almost all channels change gradually; but if the changes are slow and checked by reasonable frequent measurements, the records can be corrected so as to eliminate all except small inaccuracies.

When enough such measurements have been secured at different heights of the river, (low, medium and flood), it becomes possible to determine by intrepolation how much water flowed by the gage at any foot and tenth of gage-height between lowest and highest stages. Upon this basis, from the record of daily gage-heights that has been made by the observer a computation is made of the actual daily quantities that have flowed by the gage, and these are tabulated in such form as needed for reference. In the following pages these results have been arranged as "Tables of Monthly Discharge" showing for each month the average flow (for the twenty-four hours) of that day in the month when the flow was the greatest or maximum, the flow for the minimum day, and the mean flow or average for the entire months taken as a whole.

All figures of discharge given here are in "second-feet." One second-foot is a flow that carries by the observer one cubic foot of water each second; a rapid current in a small channel, or a slow current in a large channel, can carry the same amount of water past the observer each second. For example, a stream five feet wide and one foot deep flowing with a velocity of six feet per second, and a stream twenty feet wide and three feet deep flowing with a velocity of one-half foot per second, would each carry thirty second-feet of water. According to North Dakota law, fifty "miner's inches" of water is the same quantity as one second-foot.

One second-foot amounts to 646,272 gallons per day, and will cover almost two acres one foot deep in twenty-four hours.

As successive years vary very much, an absolutely exact record of the quantity of flow of a river through one year would not tell how much might flow the next year; it sometimes happens that the flow of one year is five, ten, twenty or even fifty or a hundred times as great as the total entire flow of a previous year. Nor can these records be blindly transferred to adjoining rivers, for no two rivers are precisely alike in their conditions and behavious, so the records of as many streams as practicable should be secured if dependence is to be placed on them for all uses. Therefore, rather than spend a large appropriation in making a very precise record of a single stream for a single year, it is very much more advantageous to extend the work to as many streams through as long a period of years as the available funds will possibly permit; provided of course that care is taken that the work and attention devoted to each station are not too greatly reduced so as to bring about a disproportionate or inexcusably great loss of accuracy.

The column headed "accuracy" in the tables of monthly discharge applies to the mean flow for the month, but not necessarily to the maximum or minimum (which might have been affected by an accidental error applying only to a single day, such for example as the brief absence of the observer.) It depends on the reliability of the daily observer, on the permanency of the stream channel and the gage, on the number and the consisency of the measurements of discharge, and on various other less evident factors. After a sufficient assortment of measurements of dishcarges had been secured, few would be needed in following years if the channel were absolutely permanent, and less than during the first few seasons even if the

channel is gradually changing according to the custom of most North Dakota streams. However, stating it in a single sentence, the accuracy of the final results depends on the accuracy and frequency both of the gage observations and of the discharge measurements.

The mean for any month marked A in these tables may properly be assumed as correct within five per cent; of any month marked B, within ten per cent; C, within fifteen per cent; D, within twenty-five per cent; E indicates a rough estimate which is presumably within fifty per cent of the fact, although in the case of some of the estimates for winter months, when the flow was certainly known to be so very small as not to exceed the estimates by more than fifty per cent, it is possible that the actual flow was even more than fifty per cent below the estimate.

Included in the following pages are summaries of the records of these streams:

Red River at Grand Forks, N. D.
Red River at Fargo, N. D.
Red Lake River at Crookston, Minn.
Thief River near Thief River Falls, Minn.
Bois Des Sioux River near Fairmount, N. D.
Mustinka River above Wheaton, Minn.
Pembina River at Neche, N. D.
Mouse River at Minot, N. D.
Cannon Ball River at Stevenson, N. D.
Heart River near Richardton, N. D.
Knife River at Broncho, N. D.

The tables run from the close of the tables published in the last biennial report of the State Engineer (September 1, 1920) to August 31, 1922. The portions of the summaries for the year 1922 have been extracted from the official records in advance of the completion of the final computations of the season's work as made for regular publicatin by the U. S. Geological Survey, and are therefore to be considered as "preliminary computations" still subject to minor revisions. But in no case is it to be expected that the final revisions will introduce any large changes in the figures here given, and in most of these tables the later changes will be so small as to be inappreciable or the final publication will be without change.

The drainage areas were carefully measured by comparison of all the latest and most accurate maps of Dakota recently, by E. F. Chandler, and are somewhat different from the figures for drainage areas previously used for most of the river-stations.

Similar summaries of the most important river records for this region can be found in the following reports.

North Dakota Geological Survey, Third Report, for year 1903-04.

North Dakota State Engineer, Second Report, for years 1905-06. Third Report, 1907-08. Fourth Report, 1909-10. Fifth Report, 1911-12. Sixth Report, 1913-14. Seventh Report, 1915-16. Eighth Report, 1917-18. Ninth Report, 1919-20.

More complete records are published from year to year in the Water Supply Papers series of the United States Geological Survey, in which all the methods and other details are fully itemized.

These summaries and records and many other less important ones are on file in the office of the State Engineer at Bismarck. The original data of every kind on which all the publications are based are filed in the Washington office of the U. S. Geological Survey. Copies of all the data are also kept on file in the office of the resident hydrographer of the survey, under whose general supervision most of the field work of this class in this region through the past nineteen years has been done and the computations made; this is E. F. Chandler, at the postoffice address University. On request to any of these offices full information can be obtained if desired by anyone who has reason for interest in any of these records or investigations.

RED RIVER AT GRAND FORKS, N. D.

Gagings of the flow of the Red River at Grand Forks, N. D. were begun by the U. S. Geological Survey in 1901, but a gage height record was kept under the direction of the Corps of Engineers, (War Department) by whom the dredging fleet was operated for the improvement of the river, for about twenty years previously, and a few discharge measurements were made by them; thus fairly good run-off summaries begin with the year 1882. The gaging station is located below the confluence of the Red and Red Lake Rivers. The total drainage area is 25,480 square miles, of which 670 is in South Dakota, 12,890 in Minnesota, and 11,920 in North Dakota.

The tables of discharge, based on gage observations twice daily through the open season and twice weekly through the winter, and on the measurements in the list below and a hundred and twenty-eight measurements made during the nineteen preceding years, are fairly accurate through the entire year.

MEASUREMENTS OF DISCHARGE.

Date	Hydrographer	Gage-height	Discharge
9-28-1920	E. E. Foster	5.70	1,094
1-13-1921	W. L. Stockwell	5.80 *	729
2-26-1921	W. L. Stockwell	6.39 *	721
4-19-1921	Stockwell and Oakley	8.20	2,540
8- 5-1921	E. E. Foster	4.69	859
10-28-1921	Chandler and Oakley	4.40	735
11-26-1921	Oakley and Tilley	4.23 *	469
12-26-1921	Oakley and Tilley	5.11 *	655
1- 7-1922	Foster and Oakley	4.47 *	406
4-15-1922	Chandler and Tilley	25.16	13,200

* Frozen; mean thickness of ice from 0.7 feet to 1.4 feet at different times of measurement.

MONTHLY DISCHARGE OF RED RIVER AT GRAND FORKS, N. D.

	Month	Maximum	Minimum	Mean	Accuracy
1920	September	1,340	833	1,040	B
	October	1,340	1,030	1,180	A
	November	1,160	990	1,070	B
	December	1,160	950	1,030	C
1921	January	.....	.....	797	C
	February	.....	.....	727	C
	March	4,180	689	1,550	C
	April	11,500	2,500	4,860	B
	May	2,800	1,340	1,870	A
	June	3,400	1,690	2,720	A
	July	2,140	833	1,380	A
	August	1,300	230	603	B
	September	1,970	1,030	1,470	A
	October	1,390	497	786	B
	November	760	.....	608	B
	December	.....	.....	689	C
1922	January	.....	.....	385	C
	February	.....	.....	418	C
	March	.....	.....	3,210	D
	April	19,170	5,500	11,590	A
	May	13,850	3,580	6,540	A
	June	3,880	1,800	2,820	A
	July	1,690	689	1,150	B
	August	.....	.....	.....	..

Maximum gage-heights; 20.9 feet April 10, 1921; 28.7 feet April 11, 1922; 23.5 feet May 14, 1922; maximum ever recorded, 50.2 feet April 10, 1897.

Minimum gage heights; 4.7 feet Sept. 17, 1920; 2.5 feet Aug. 24, 1921; 3.6 feet Aug. 19, 1922; Minimum ever recorded, 2.5 feet Aug. 24, 1921.

RED RIVER AT FARGO, N. D.

The gaging station on the Red River of the North at Fargo, N. D. was established May 27, 1901. The drainage area above this point is 6,420 square miles, of which 670 square miles is in South Dakota, 3,590 square miles in Minnesota, and 2,160 square miles in North Dakota.

In September, 1914, the gage location for the Geological Survey was changed from the Front Street bridge (where there is a gage still used by the Weather Bureau) to a point immediately above the Island Park dam. The zero of the gage at Island Park is about one foot below the crest of the dam, and is so related to the zero of the Front Street gage that at extreme flood stages, when the dam is drowned out and causes no irregularity in the surface slope of the river, readings on the Front Street gage are numerically about 10.2 feet greater than on the Island Park gage now used; at low stage, a reading of 7.0 feet on the Front Street gage

indicates nearly the same quantity of flow as a reading of 2.0 feet on the Island Park gage.

The tables of discharge, based on the measurements in the list below and on ninety-nine measurements made during the nineteen preceding years, are unusually accurate except during the frozen season when observations were made only weekly.

MEASUREMENTS OF DISCHARGE.

Date	Hydrographer	Gage-height	Discharge
10-10-1920	E. F. Chandler	2.35	375
11-11-1920	W. L. Stockwell	2.38	479
2- 7-1921	W. L. Stockwell	1.90 *	234
4- 2-1921	W. L. Stockwell	2.63	755
5- 2-1921	W. L. Stockwell	2.70	566
5-20-1921	W. L. Stockwell	2.33	456
6-16-1921	Chandler and Stockwell ...	2.48	501
8-31-1921	E. F. Chandler	1.56	136
10-15-1921	E. F. Chandler	1.63	145
10-23-1921	K. H. Oakley	1.31	110
5- 6-1922	E. F. Chandler	3.48	1,024
8-17-1922	E. F. Chandler	1.10	29

* Frozen; mean thickness of ice 1.0 foot.

MONTHLY DISCHARGE OF RED RIVER AT FARGO, N. D.

	Month	Maximum	Minimum	Mean	Accuracy
1920	September	580	400	458	B
	October	485	440	466	A
	November	485	300	414	A
	December	462	192	306	B
1921	January	280	175	217	C
	February	280	200	244	C
	March	890	300	480	C
	April	1,970	475	738	B
	May	619	453	513	B
	June	1,150	303	613	A
	July	303	159	254	A
	August	284	102	183	B
	September	344	48	140	B
	October	430	32	145	B
	November	227	.....	95	C
	December	.....	.....	70	C
1922	January	.....	.....	25	D
	February	.....	.....	23	D
	March	4,560	.....	1,890	C
	April	5,200	1,200	2,650	B
	May	1,370	918	1,070	A
	June	890	474	695	A
	July	498	147	303	A
	August	.....	.....	.....	..

Maximum gage-heights; 4.7 feet April 6, 1921; 3.7 feet June 4, 1921; 9.5 feet March 27, 1922; 11.0 feet April 11, 1922; maximum ever recorded, 19.9 feet (30.1 feet on Front Street gage) April 6, 1916.

Minimum gage-heights: 1.7 feet Jan. 20, 1921; 1.1 feet Oct. 6, 1921; minimum ever recorded on Front Street gage, 5.7 feet Nov. 1, 1910.

RED LAKE RIVER AT CROOKSTON, MINN.

The Red Lake River is the principal tributary of the Red River, and its average flow is approximately equal to that of the Red River above the confluence, although it is usually more regular than the Red, and brings less than the Red when both are at flood stages, and more than the Red during low stage periods; it is an important factor therefore in any problem concerning the lower Red River. The gaging station on the Red Lake River at Crookston, Minn., was established May 19, 1901.

The drainage area above Crookston is 5,320 square miles all in Minnesota; there are no considerable tributaries between Crookston and the mouth of the river, so that almost its entire discharge is shown.

The tables of discharge are based on the measurements in the list below and a hundred and thirty-three measurements in the nineteen preceding years. By the operation of power plants above the station there are sometimes abrupt variations in flow which cause small discrepancies in the records but are in general unimportant. The figures for monthly discharge are accurate except during the winter, when they are based chiefly on comparisons between the records from the Red Lake River at Thief River Falls above, and the Red River at Grand Forks below.

MEASUREMENTS OF DISCHARGE.

Date	Hydrographer	Gage-height	Discharge
10- 5-1920	W. L. Stockwell	3.80	503
2-12-1921	W. L. Stockwell	4.95 *	546
4-16-1921	W. L. Stockwell	5.65	1,434
5-14-1921	E. E. Foster	4.74	943
5-18-1921	K. H. Oakley	4.75	1,019
6-23-1921	E. F. Chandler	5.19	1,106
11-13-1921	K. H. Oakley	3.49	116
12-28-1921	K. H. Oakley	5.30 *	353
4-22-1922	K. H. Oakley	7.34	2,194
6-13-1922	K. H. Oakley	5.18	1,215
8-22-1922	E. F. Chandler	3.21	155

* Frozen; mean thickness of ice 0.8 foot to 1.6 feet at different measurements.

MONTHLY DISCHARGE OF RED LAKE RIVER AT CROOKSTON, MINNESOTA.

	Month	Maximum	Minimum	Mean	Accuracy
1920	September	675	358	543	B
	October	.....	.....	549	C
	November	.....	.....	480	D
	December	.....	.....	470	D
1921	January	.....	.....	430	D
	February	.....	.....	410	D
	March	.....	.....	400	D
	April	.....	.....	1,590	D
	May	1,260	595	959	B
	June	1,690	675	1,190	B
	July	805	436	551	B
	August	675	284	517	B
	September	675	320	547	B
	October	595	436	521	B
	November	.....	.....	501	C
	December	.....	.....	440	D
1922	January	.....	.....	340	D
	February	.....	.....	340	D
	March	.....	.....	360	D
	April	5,400	895	2,540	C
	May	7,100	1,030	2,620	B
	June	1,500	500	962	B
	July	865	280	518	C
	August	.....	.....	.....	..

Maximum gage-height; 13.0 feet May 13, 1922; maximum ever recorded, 25.2 feet April 11, 1897.

Minimum gage-height; 3.8 feet August 3, 1921; 3.2 feet August 22, 1922; minimum ever recorded, 2.2 feet October 9, 1911.

THIEF RIVER NEAR THIEF RIVER FALLS, MINN.

The gaging station on the Thief River is located about five miles above the confluence with the Red River at Thief River Falls, Minn., and is in Section 3, Town 154, Range 43. This river is typical of many on the east side of the Red River valley, which are occasionally the source of serious spring floods. The drainage area above the section is 1,010 square miles, all in Minnesota. The station was established July 1, 1909, but was temporarily discontinued because of lack of funds during the years 1918 and 1919.

The tables of discharge are based on the measurements in the list below and forty-seven measurements made in previous years, and have fair accuracy except during the spring break-up when the effect of ice in raising the gage-height is not readily determined during a few days of the thaw.

MEASUREMENTS OF DISCHARGE.

Date	Hydrographer	Gage-height	Discharge
10- 7-1920	W. L. Stockwell	4.04	7.4
4- 4-1921	W. L. Stockwell	8.68	505
5-17-1921	K. H. Oakley	4.75	49
6-25-1921	E. F. Chandler	4.20	13.8
8-10-1921	E. E. Foster	4.42	19
11- 6-1921	K. H. Oakley	4.54	6.8
4-18-1922	K. H. Oakley	6.97	732
4-21-1922	K. H. Oakley	6.12	425
5-13-1922	K. H. Oakley	9.72	1,790
6-13-1922	K. H. Oakley	5.13	81
8-23-1922	E. F. Chandler	3.71	0.9

MONTHLY DISCHARGE OF THIEF RIVER NEAR THIEF RIVER FALLS, MINN.

	Month	Maximum	Minimum	Mean	Accuracy
1920	September	2	0.4	0.9	B
	October	13	0.8	6.8	B
	November	6	0	1.3	D
	December	.....	.....	0.2	E
1921	January	.....	.....	0.2	E
	February	.....	.....	0.2	E
	March	.....	.....	0.3	E
	April	1,700	.....	441	C
	May	.....	.....	49	D
	June	.....	.....	121	D
	July	46	6.5	22	B
	August	17	0.8	8.4	B
	September	36	0.8	15	B
	October	36	17	23	C
	November	.....	.....	18	D
	December	.....	.....	10	E
1922	January	.....	.....	6	E
	February	.....	.....	5	E
	March	.....	.....	8	E
	April	1,160	8	468	C
	May	2,680	46	924	B
	June	580	116	342	B
	July	75	11	22	C
	August	.....	.....	.....	..

Maximum gage-heights; 9.9 feet April 5, 1921; 8.4 feet April 11, 1922; 11.9 feet May 12, 1922; maximum ever recorded, 14.5 feet April 23, 1916; but on or about July 12, 1919, a gage-height about 16.6 feet was reached.

Minimum gage-heights; 3.3 feet Nov. 20, 1920; 3.7 feet Aug. 23, 1922.

BOIS DES SIOUX RIVER NEAR FAIRMOUNT, N. D.

The gaging station on the Bois Des Sioux River was established April 5, 1919 at the highway bridge southeast of Fairmount; April 1, 1920, it was moved to the Soo Railway bridge. The elevation of the zero of the gage at the highway bridge is 962.13 feet above sea-level; at the railway bridge the gage zero is 961.08 feet above sea-level. The drainage area above the station is 1,460 square miles, of which 360 square miles is in South Dakota, 980 square miles in Minnesota, and 120 square miles in North Dakota.

The tables of discharge are based on the measurements in the list below and eleven measurements in the preceding two years, and are fairly accurate except when the interval between discharge measurements is unusually long; channel conditions are such that the growth of weeds obstructs the flow, and changes the relation between gage-height and discharge progressively through the season, and the amount of this change at any time cannot be definitely determined unless discharge measurements have been made within a reasonable number of weeks before and after.

MEASUREMENTS OF DISCHARGE.

Date	Hydrographer	Gage-height	Discharge
10- 9-1920	E. F. Chandler	3.04	41
5- 1-1921	W. L. Stockwell	2.85	37.5
6-17-1921	E. F. Chandler	2.73	15.8
7- 9-1921	E. F. Chandler	2.27	9.8
8- 2-1921	E. E. Foster	1.66	1.4
10-22-1921	K. H. Oakley	1.32	1.0
4- 7-1922	K. H. Oakley	5.18	184
4-14-1922	E. E. Foster	5.11	284
4-22-1922	E. F. Chandler	5.68	392
5- 6-1922	K. H. Oakley	5.07	263
6- 3-1922	R. V. Tilly	4.04	91
8-18-1922	E. F. Chandler	1.64	1.3

MONTHLY DISCHARGE OF BOIS DES SIOUX RIVER NEAR FAIRMOUNT, N. D.

	Month	Maximum	Minimum	Mean	Accuracy
1920	September	58	43	50	B
	October	43	31	38	B
	November	30	18	24	C
	December	.....	.....	15	D
1921	January	.....	.....	7	E
	February	.....	.....	3	E
	March	.....	.....	11	E
	April	64	34	39	C
	May	36	30	33	B
	June	38	10	20	B
	July	11	3	7	B
	August	2	0	0.6	B
	September	11	0	4	B
	October	4	1	1.7	C
	November	.....	.....	0.6	D
	December	.....	.....	0	C
1922	January	.....	.....	0	C
	February	.....	.....	0	C
	March	.....	.....	14	D
	April	390	43	262	B
	May	321	119	210	B
	June	116	43	64	B
	July	42	14	28	B
	August	.....	.....	.....	..

Maximum gage-height; 4.0 feet April 1, 1921; 5.7 feet April 22, 1922; during the highest flood of 1916 the highest stage reached was 9.0 feet.

Minimum gage-height; 1.2 feet August 19, 1921; 1.6 feet Aug. 18, 1922.

MUSTINKA RIVER ABOVE WHEATON, MINN.

A station was established on the Mustinka River June 7, 1916, about three miles below (southwest from) Wheaton, Minn., but it was found that the stage at this point was likely to be effected by backwater from Lake Traverse. Accordingly the station was transferred March 1, 1917 to its present location, one mile above (northwest from) Wheaton. Because of lack of funds the station was temporarily discontinued from October 1, 1917 to June 24, 1919. The drainage area above the station is 776 square miles, all in Minnesota.

The tables of discharge, based on the measurements in the list below and seventeen measurements in previous years, are fairly accurate.

MEASUREMENTS OF DISCHARGE.

Date	Hydrographer	Gage-height	Discharge
10-10-1920	E. F. Chandler	1.39	1.6
5- 1-1921	W. L. Stockwell	2.24	32
6-19-1921	E. F. Chandler	1.54	3.9
8- 3-1921	E. E. Foster	1.48	3.4
10-22-1921	K. H. Oakley	1.41	1.7
4- 8-1922	K. H. Oakley	10.51	1,093
4-15-1922	E. E. Foster	4.21	118
5- 7-1922	K. H. Oakley	2.46	39
5- 7-1922	K. H. Oakley	2.46	40
6- 4-1922	R. V. Tilly	1.95	10
6- 4-1922	R. V. Tilly	1.95	8
6- 4-1922	R. V. Tilly	1.92	8
6- 5-1922	R. V. Tilly	1.93	9
8-18-1922	E. F. Chandler	1.06	0

MONTHLY DISCHARGE OF MUSTINKA RIVER NEAR WHEATON, MINN.

	Month	Maximum	Minimum	Mean	Accuracy
1920	September	4	0.9	2.1	B
	October	3.2	1.1	1.7	B
	November	.....	.....	2.9	C
	December	.....	.....	1.6	E
1921	January	.....	.....	1.0	E
	February	.....	.....	1.1	E
	March	.....	.....	4.5	E
	April	287	17	59	B
	May	62	0.8	16	A
	June	.....	.....	4.0	B
	July	.....	.....	3.0	C
	August	.....	0.2	0.7	C
	September	.....	.....	4.1	C
	October	.....	.....	1.9	B
	November	.....	.....	1.4	E
	December	.....	.....	1.0	E
1922	January	.....	.....	0.7	E
	February	.....	.....	0.5	E
	April	1,290	.....	381	D
	April	1,200	54	272	B
	May	51	9	26	B
	June	10	1.5	3.9	B
	July	1.4	0.2	0.6	B
	August	.....	.....	.....	..

Maximum gage-heights; 5.5 feet April 2, 1921; 12.9 feet March 23, 1922; 10.5 feet April 7, 1922; maximum recorded at station, 14.7 feet April 1, 1917; it is reported that a gage-height about 17 feet was reached in the 1916 spring flood.

Minimum gage-heights; 1.2 feet September 19, 1920; 1.1 feet August 29, 1921; 1.0 feet August 18, 1922.

PEMBINA RIVER AT NECHE, N. D.

The gaging station on the Pembina River was established April 29, 1903, but was temporarily discontinued during the years 1916, 1917, and 1918 because of lack of funds. It is located at Neche, N. D., sixteen miles above the mouth of the river, at the Great Northern Railway bridge. The drainage area above this point is 2,960 square miles, of which 1,950 square miles is in Manitoba and 1,010 square miles in North Dakota.

The tables of discharge, based on the measurements in the list below and fifty-eight measurements in previous years, are fairly accurate through the open season, but are merely estimates based on a few gage observations in winter.

MEASUREMENTS OF DISCHARGE.

Date	Hydrographer	Gage-height	Discharge
9- 8-1920	E. F. Chandler	3.48	9.5
9- 9-1920	E. F. Chandler	3.49	9.0
5-12-1921	E. E. Foster	4.68	165
6-28-1921	E. F. Chandler	4.13	51
8-30-1921	E. F. Chandler	3.81	18
8-16-1922	E. F. Chandler	3.53	7.0

MONTHLY DISCHARGE OF PEMBINA RIVER AT NECHE, N. D.

	Month	Maximum	Minimum	Mean	Accuracy
1920	September	44	10	17	B
	October	146	44	123	C
	November	.....	.....	89	D
	December	.....	.....	52	E
1921	January	.....	.....	55	E
	February	.....	.....	50	E
	March	.....	.....	46	E
	April	827	122	405	B
	May	290	122	176	B
	June	168	79	104	B
	July	390	34	125	B
	August	34	10	19	C
	September	46	5	17	C
	October	168	79	117	B
	November	.....	.....	54	D
	December	.....	.....	30	E
1922	January	.....	.....	8	E
	February	.....	.....	5	E
	March	.....	.....	43	D
	April	1,400	.....	504	B
	May	827	192	280	B
	June	192	79	160	B
	July	61	17	26	B
	August	.....	.....	.....	..

Maximum gage-heights; 7.4 feet April 13, 1921; 11.4 feet April 5, 1922; 7.4 feet May 13, 1922; maximum ever recorded, 20.9 feet May 2, 1904; height said to be 21.5 feet April 19, 1916.

Minimum gage-heights; 3.5 feet September 11, 1920; 3.3 feet September 24, 1921; 3.5 feet August 18, 1922.

MOUSE RIVER AT MINOT, N. D.

The gaging station on the Mouse River at Minot, N. D., was established May 5, 1903. The drainage area above this point is 10,270 square miles, of which 3,280 square miles is in North Dakota, 30 square miles in Montana, and 6,960 square miles in Canada. The gage is located directly north of the Great Northern Roundhouse, at the Anne Street bridge, so that the gage-heights refer to the water level in the river at that point, which is approximately the same as at the Great Northern Railway bridge.

The tables of discharge, based on the measurements in the list below and seventy-one measurements in the seventeen years previous, are fairly accurate for all seasons.

MEASUREMENTS OF DISCHARGE.

Date	Hydrographer	Gage-height	Discharge
7- 6-1921	E. F. Chandler	7.31	531
9- 5-1921	E. F. Chandler	4.86	39
8- 8-1922	E. F. Chandler	4.29	21

MONTHLY DISCHARGE OF MOUSE RIVER AT MINOT, N. D.

	Month	Maximum	Minimum	Mean	Accuracy
1920	September	11	2.4	6.3	B
	October	11	7	8.5	B
	November	9	.....	7.6	C
	December	.....	.....	5	C
1921	January	.....	.....	1.7	D
	February	.....	.....	1.1	D
	March	93	.....	28	C
	April	296	68	176	A
	May	104	34	60	B
	June	272	21	54	B
	July	790	215	381	A
	August	194	14	49	B
	September	29	14	21	B
	October	14	11	13	C
	November	.....	.....	14	D
	December	.....	.....	11	D
1922	January	.....	.....	11	D
	February	.....	.....	11	D
	March	.....	.....	162	C
	April	2,600	230	1,460	B
	May	730	240	401	B
	June	375	80	195	B
	July	148	30	66	B
	August	.....	.....	.....	..

Maximum gage-heights; 6.4 feet April 12, 1921; 8.5 feet July 10, 1921; 17.2 feet April 22, 1922; baximum ever recorded, 21.9 feet April 20, 1904.

Minimum gage-heights; 4.3 feet Sept. 14, 1920; 3.7 feet Feb. 19, 1921; 4.1 feet August 19, 1922.

CANNON BALL RIVER NEAR STEVENSON, N. D.

The gaging station on the Cannon Ball River was established June 10, 1903, at the post office of Stevenson, which was at that time located about thirty miles above the mouth of the Cannon Ball River and four miles above the mouth of Dogtooth Creek, at a point four miles south of the present post office and railway station Timmer, N. D. Because of lack of available observer the station was discontinued two years, and was re-established August 9, 1911 and maintained until August, 1915 about a

mile upstream from the original location, at M. H. Burdick's, at which place the gage was so placed that readings were numerically approximately 10 feet more than at the original location. In August, 1915, the station was transferred back to the original location, now occupied by F. H. Bingenheimer, but records were temporarily discontinued because of lack of funds from October, 1918 until October, 1921.

The drainage area above this point is 3,650 square miles, or which 70 square miles is in South Dakota and 3,580 square miles in North Dakota. The tables of discharge, based on the measurements in the list below and seventy-six measurements in previous years, are excellent in accuracy except for a few days during the spring break-up when the effect of ice is not exactly determinable, and except in winter when they are merely estimates based on occasional gage-readings.

MEASUREMENTS OF DISCHARGE.

Date	Hydrographer	Gage-height	Discharge
10-13-1921	G. H. McMahon	2.65	4.1
5-20-1922	G. H. McMahon	3.25	72
8-10-1922	Chandler and McMahon	3.45	81

MONTHLY DISCHARGE OF CANNON BALL RIVER AT STEVENSON, NORTH DAKOTA.

	Month	Maximum	Minimum	Mean	Accuracy
1921	October	.....	.....	12	C
	November	.....	.....	6	C
	December	.....	.....	5	E
1922	January	.....	.....	5	E
	February	.....	.....	5	E
	March	.....	.....	516	D
	April	4,400	90	1,140	B
	May	1,310	54	152	B
	June	2,870	111	956	B
	July	740	67	166	B
	August	.....	.....	.....	..

Maximum gage-heights; 9.7 feet March 16, 1922; 9.4 feet April 7, 1922; maximum ever recorded, 11.2 feet March 18, 1916.

Minimum gage-heights; 2.6 feet November 16, 1921; 3.2 feet May 22, 1922; minimum ever recorded, 1.4 feet October 23, 1907.

HEART RIVER NEAR DICHARDTON, N. D.

The gaging station on the Heart River was established May 18, 1903, at the steel highway bridge ten miles south of Richardton, N. D. On September 4, 1911 it was transferred one mile downstream, and the gage-datum so changed that all readings at the new location are approximately 20.0 feet numerically greater than at the original location. The drainage area above this point is 1,250 square miles.

The tables of discharge, based on the measurements in the list below and fifty-five measurements in preceding years, are only approximate through most of the season, for the reason that channel conditions there are such as to cause occasional small changes in the relation between gage-height and discharge, and the discharge measurements have been too infrequent to determine these changes accurately.

MEASUREMENTS OF DISCHARGE.

Date	Hydrographer	Gage-height	Discharge
9- 2-1921	E. F. Chandler	24.62	17.8
10-10-1921	E. F. Chandler	24.13	0.9
5-26-1922	G. H. McMahon	24.74	29
8-12-1922	McMahon and Chandler	24.72	22

MONTHLY DISCHARGE OF HEART RIVER NEAR RICHARDTON, NORTH DAKOTA.

	Month	Maximum	Minimum	Mean	Accuracy
1920	September	10	1	1.9	C
	October	17	1.4	3	C
	November	.....	.....	3.7	D
	December	.....	.....	2.2	D
1921	January	.....	.....	0.7	D
	February	.....	.....	0.6	D
	March	170	.....	40	C
	April	32	11	18.4	C
	May	36	6	10.3	D
	June	714	1.8	66	C
	July	103	1.8	20	C
	August	110	0.1	5.7	D
	September	28	2.6	7.8	C
	October	4.6	1.4	2.6	C
	November	.....	.....	3.5	D
	December	.....	.....	2	E
1922	January	.....	.....	2	E
	February	.....	.....	2	E
	March	.....	.....	61	E
	April	.....	24	540	D
	May	203	8	43	C
	June	1,320	8	407	D
	July	450	16	80	C
	August	.....	.....	.....	..

Maximum gage-heights; 25.9 feet March 22, 1921; 28.6 feet June 19, 1921; 30.9 feet June 20, 1922; maximum ever recorded, 25.9 feet June 10, 1906.

KNIFE RIVER NEAR BRONCHO, N. D.

The gaging station on the Knife River is about twenty miles north of Hebron, N. D., in Section 4, Township 142, Range 90, at the ranch of C. D. Smith, the lormer location of Broncho postoffice. The drainage area above this station is 1,200 square miles. A station was first established on the river near this point May 29, 1903, and transfered to the present location March 23, 1905; the station was temporarily discontinued because of lack of funds from November, 1919 until October, 1921.

The tables of discharge. based on the measurements in the list below and forty-seven measurements in previous years are fairly accurate except for a few days during the spring break-up when the effect of ice is not exactly determinable, and except in winter when they are merely estimates based on occasional gage-readings.

MEASUREMENTS OF DISCHARGE.

Date	Hydrographer	Gage-height	Discharge
10-10-1921	E. F. Chandler	3.56	3.6
5-24-1922	G. H. McMahon	3.90	19
8-11-1922	McMahon and Chandler	3.96	30

MONTHLY DISCHARGE OF KNIFE RIVER NEAR BRONCHO, N. D.

	Month	Maximum	Minimum	Mean	Accuracy
1921	October	.....	.....	4.5	C
	November	.....	.....	7.4	D
	December	.....	.....	7	E
1922	January	.....	.....	6	E
	February	.....	.....	16	E
	March	.....	.....	228	D
	April	1,260	36	250	B
	May	46	13	25	B
	June	3,200	9	331	B
	July	193	13	32	B
	August	.....	.....	.....	..

Maximum gage-heights; 10.6 feet March 16, 1922; 15.6 feet June 17, 1922; maximum ever recorded, 24.0 feet June 26, 1914.

Minimum gage-heights; 3.5 feet October 13, 1921; 3.6 feet June 6, 1922; minimum ever recorded, 3.1 feet September 18, 1908.