

SEEPAGE INVESTIGATION OF BLACKFOOT RIVER,
IDAHO

BY

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SEEPAGE INVESTIGATION ON BLACKFOOT RIVER, IDAHO.

I- PRELIMINARY

Scope of Investigation- This thesis is based on an investigation made by the writer in June, 1913, having for its purpose the determination of the net loss or gain of flow in an 18 mile section of the Blackfoot River near Blackfoot, Idaho. This section extends from the stream gaging station located one mile above the lower end of the Blackfoot Canyon to the intakes of the Fort Hall irrigation canals. These two canals divert water from the river for the lands of the Fort Hall Indian Reservation.

For the proper operation of this project it had been thought desirable by the Indian Service officials to determine the net loss or gain between the storage reservoir and the canal intakes, a distance of about 56 miles. Arrangements were therefore made between the United States Indian Service and the United States Geological Survey for the latter to carry on this work.

During the period October 10 to 15, 1909, Mr. E. C. La Rue, District Engineer, United States Geological Survey, made a seepage investigation on that part of the river lying between the reservoir and the stream gaging station near the mouth of the canyon. Measurements of discharge were made on the river below the reservoir, on all streams and springs entering, and on the river near the mouth of the canyon. No diversion canals were found on this section of the river. The stage of the stream remained constant, with a discharge of 338 second-feet at the can-

yon station; and the measurements were treated as having been made simultaneously. The net gain was found to be only a fraction of one per cent, a negligible quantity in ordinary stream measurement work.

During the period November 8 to 13, 1912, Mr. Lynn Grandall, Junior Engineer, United States Geological Survey, made a seepage investigation of the section of the Blackfoot River lying between the canyon gaging station and the intakes of the Upper and Lower Fort Hall Canals. This investigation was made during the low water period, the discharge being about 120 second-feet at the canyon station. As the irrigation season had closed, there was practically no diversion of water from the river. The results showed negligible seepage gains and losses.

The present report covers the investigation made during the period June 12 to 17, 1913. During this time the stage of the river was fairly high, there being a discharge of more than 800 second-feet at the canyon station. Farther, the irrigation season was at its height, and all the diversion ditches were flowing full. As the results of this investigation confirm those of November, 1912, and as the two investigations cover such a range of conditions, the results seem strongly conclusive for all conditions.

Acknowledgments- The field work in connection with the investigation of June, 1913, was done by the writer with the assistance of Mr. D. P. Olson, Hydraulic Engineer, of Idaho Falls, Idaho. Acknowledgment is also made for the assistance and hearty cooperation of the officials and employees of the Fort Hall Indian

Reservation and of the ranchers along the river, in maintaining as nearly as possible constant conditions of flow and diversion.

The writer is under personal obligation to Mr. H. W. Dietz, Superintendent of Irrigation, United States Indian Service, and to Mr. G. C. Baldwin, District Engineer, United States Geological Survey, for their permission to use in this thesis the results of the investigation as shown in the report made to them December 6, 1913.

II- CONDITIONS AND METHOD OF ATTACK

River and Drainage Area- The Blackfoot River rises on the western slopes of the Preuss and Caribou Ranges in the southeastern part of Bannock County, in southeastern Idaho. For the first 50 miles of its course it flows northwest to the point where it emerges from the hills at the lower end of the Blackfoot Canyon, whence its course is southwestward for about 30 miles to its junction with the Snake River, a few miles southwest of the town of Blackfoot.

Much of the Blackfoot drainage area is mountainous. Except at the higher elevations there is very little forest covering.

Irrigation Conditions- A map of the portion of the Blackfoot River covered in this report will be found on Sheet No. 1 of the Appendix. On this map are shown the canals and ditches diverting water from this part of the river; also the tributaries and other points of inflow are shown.

The only large irrigation system taking water from the Blackfoot River is the Fort Hall project. The United States Indian Service has built this irrigation system to furnish water for about 50,000 acres of land lying south of the Blackfoot River and east of the Snake River. The main source of water supply for this system is the Snake River, from which water is diverted through the Idaho Canal (formerly known as the Reservation or Government Canal). By court decree the Fort Hall project is given 600 second-feet of water, but at times of very low flow not more than about 50 or 60 per cent of this can be obtained. To

supplement this dry season flow the Blackfoot Marsh Reservoir, with a capacity of 200,000 acre-feet, has been built on the upper part of the Blackfoot River. The dam is 298 feet in length, is 40 feet high, and is located about 67 miles above the mouth of the river. Stored water is released from the reservoir as needed, is allowed to flow down the river, and is diverted onto the land through the Upper and Lower Fort Hall Canals. The Upper Fort Hall Canal is 26 miles in length and with its laterals covers approximately 30,000 acres. The Lower Fort Hall Canal is 12 miles in length and with its laterals will serve about 20,000 acres. The intakes of the two canals are two miles apart, the upper being located approximately 54 miles below the reservoir.

All the other canals diverting water from this section of the river were found to be small in comparison with the Fort Hall diversion canals. Arrangements were made to hold all the diversion canals at as nearly a constant stage as possible.

The most important point of inflow was found to be the waste of the Idaho Improvement Canal. This canal diverts water from the Snake River a number of miles up the valley; and, after serving a large body of land in the vicinity and south of the town of Idaho Falls, discharges the last of its surplus water into the Blackfoot River about 11 miles above the Upper Fort Hall Canal. Due to the fact that the lower waste-gate of this canal is the outlet of a large canal system, its flow is subject to considerable fluctuation.

Besides this large waste, a number of small wastes and points of return flow from irrigated fields were found.

Under normal conditions the Idaho Canal (Reservation or Government Canal), which as already stated diverts water from the Snake River, discharges into the Blackfoot River about eight miles above the Upper Fort Hall Canal. But during the time of this investigation this canal was not diverting water from the Snake River; moreover the small flow that was found in the canal was discharging through a broken flume into the East Idaho Slough, through which it found its way to the Blackfoot River at a point below the Lower Fort Hall Canal. As this was below the part of the river included in this investigation, it was not necessary to take account of the flow in the Idaho Canal.

Method of Attack- By securing records of the discharge at both the upper and lower end of the section of the river under investigation, by securing a record of each diversion and inflow in this section, and by securing the time interval of flow between each of the different points of diversion and inflow, it was believed that sufficient data would be available to make the necessary computations and comparisons to determine the net gain or loss in flow in this section of the river.

Besides maintaining an automatic gage at each of the two main river stations, it was considered necessary to maintain one at the Upper Fort Hall Canal station and on the waste of the Idaho Improvement Canal. It was planned to secure a sufficient number of miscellaneous measurements to fix within narrow limits the variations of flow at all the other points of diversion and inflow.

Regimen of River, Weather Conditions, etc.- The flow of Blackfoot River, as controlled at the Blackfoot Marsh Reservoir, was held fairly constant at about 740 second-feet, with a total variation of not to exceed 15 second-feet, during the period June 12 to 17. On June 17, after finishing the main part of the investigation, an additional flow of about 200 second-feet was turned down in order to determine the time interval between the canyon gaging station and the intakes of the Fort Hall diversion canals.

The flow at the canyon gaging station dropped from a maximum of 846 second-feet at the beginning of the investigation, to 803 second-feet at the close. The variations in flow at this and at the other stations will be discussed later.

The meteorological conditions encountered during the period were fairly favorable. Clear, warm weather prevailed with the exception of one day, June 13, during which local showers occurred. The effect of these showers is shown only in the flow of the Idaho Improvement Canal waste. However, the warm days had the effect of introducing a slight diurnal fluctuation in the flow of the river, and in producing fairly rapid evaporation losses.

III- HYDROMETRIC METHODS OF THE UNITED STATES GEOLOGICAL SURVEY

General Description- The securing of stream flow records at a station consists essentially of the following operations: the measurement of the volume of flow per second at a number of different gage heights covering the range of stage of the stream; the securing of the gage height record for the time under consideration either by daily or oftener gage readings, or by the use of an automatically recording gage from which a continuous record may be secured; and the computations giving the rating curve and rating table showing the relation between the measured discharges and the corresponding gage heights, and the application of this table to the gage height records, giving the daily discharges.

Gaging Stations- In order to secure good records, a great deal of care and judgement must be used in choosing the place for a gaging station. Permanency of the relation between the discharge and the gage height, or, in other words, a non-shifting stream bed, is of more importance than the securing of the best location for making the measurements. With the exercise of the necessary precautions and by making a sufficient number of measurements, a good rating curve may often be developed in spite of rather poor measuring conditions; but with a shifting bed it is necessary, in the long run, to make a great many more measurements than with the rougher but more permanent one.

Since it is not necessary to locate the gage and the measuring section at the same point on the river, it is often pos-

sible to so place the gage that permanent conditions obtain, and to make the measurements of discharge at some nearby point on the river where the measuring conditions are good. It is necessary, of course, that there be no inflow or diversion between the gage and the measuring section.

The equipment of a gaging station consists essentially of a gage and, unless it is possible to make wading measurements, of some means of supporting the engineer while he is making the discharge measurements. For the larger streams a cable and small suspended car are ordinarily used, though sometimes a well located bridge or a boat running from a cross cable is used.

Discharge Measurements- Of the different methods of measuring stream flow described in the text books on hydraulics, that is, the slope method, the weir method, and the velocity method, the latter is used by the United States Geological Survey in the great majority of cases.

In a very limited number of cases the velocities are secured by timing floats, usually ice or drift wood, over a measured range. The practice of the Survey, however, is to use the current meter for securing velocities, except in cases where its use is impossible. The Price current meter has been adopted by that organization, and through years of development has been brought to a high standard.

The securing of a current-meter measurement involves the measurement of the depths and velocities at a number of points along a section perpendicular to the direction of the current. These points, called measuring points, are measured off above

and in the plane of the cross-section chosen, and are spaced not farther apart than five per cent of the width of the stream. These measuring points divide the cross-section into elementary strips, at each end of which observations of depth and velocity are made. The discharge through any elementary strip is secured by multiplying the average of the depths at the two ends, by the width of the strip, and this resultant area by the average of the mean velocities at the two ends of the strip. (Different methods of obtaining the mean velocity in the vertical plane through any measuring point will be given). The sum of the discharges through the elementary strips is the total discharge of the stream.

Four methods of measuring velocity with the current meter are in use in the Geological Survey: the 0.2 and 0.8 depth method, the 0.6 depth method, the subsurface method, and the vertical velocity curve method. Besides these methods that are in common use, there is the vertical integration method which has been used to some extent in the past; but so far as the writer knows, it is not now used in the Survey.

Of these methods the first is the one most used in the work of the Geological Survey. The meter is held successively at 0.2 and 0.8 of the depth, and the mean of the velocities measured at these two points is taken as the mean velocity for that vertical. Many observations under a wide range of conditions show that this method gives the mean velocity very closely for open-water conditions; moreover the indications are that it holds nearly as well for ice-covered streams.

In the 0.6 depth method the meter is held at 0.6 depth below the surface. Under ordinary conditions of flow this gives velocities very close to the true mean velocities, but the method is not applicable to such a ^{wide} range of conditions of flow as is the 0.2 and 0.8 depth method. The 0.6 depth method is mostly used in measuring shallow streams and ditches where the small depths make it impossible to get the center of the meter within 0.2 depth of the bottom. Depths of less than 1.2 feet, if the meter is held on a rod, or of less than 2.5 feet, if the meter and weight are suspended by a wire, make the use of the 0.6 depth method necessary.

In the sub-surface method the meter is held near the surface, usually one foot below. The coefficient for reducing the velocity so obtained to the mean velocity has been found to be, in general, from 0.85 to 0.95. This method is only used in making flood measurements where it is impossible to use any of the other methods.

The vertical velocity curve method is the most accurate, but it is too lengthy for common use. It has been used chiefly in developing and determining the accuracy of the other methods. In this method a series of velocity determinations are made at regular intervals in each vertical, usually about 10 to 20 per cent of the depth apart. By plotting these velocities as abscissas and their depths as ordinates, and drawing a smooth curve through the resulting points, the vertical velocity curve is developed. This furnishes data for securing the mean velocity in that vertical.

Gage Height Records- Gage height records may be secured either from a staff gage set vertically or slopingly, or from an automatically recording gage. In the latter case, however, it is

necessary to use a staff gage for securing the gage heights used in setting and checking the automatic gage.

Once-a-day or twice-a-day gage readings do not of necessity give the true mean gage height for the day. With a rapidly changing stage the reading for any one day is liable to be greatly in error. For a period of a month or more these errors usually nearly balance each other, but for important stations it is essential that continuous records be secured. Of the different automatic gages used by the United States Geological Survey, the Friez gage and the Stevens gage give the best results. The Bristol gage has been used but the results secured are not as good as with those previously mentioned.

Computations- By plotting the discharge measurements as abscissas and the corresponding gage heights as ordinates, and drawing a smooth curve among the points thus located, the rating curve, parabolic in form, is obtained. If the conditions of flow are permanent, that is, if there is no cutting or building up of the stream bed or interference with the relation between gage height and discharge, and if the measuring conditions are good, the points should all lie close to the rating curve thus developed.

If the conditions of flow are not permanent, special methods are necessary in working up the run-off records. The general assumption is that the new rating curve will be parallel to the old one unless radical changes of conditions have occurred. Experience has shown that this assumption is very general in its application.

With the rating curve drawn, the rating table is worked up

directly from it. This is applied to the daily gage heights, giving the daily discharges. The monthly and yearly records are computed from the daily discharges.

Blackfoot River at Mouth of Canyon near Challey, Idaho. - This station is located about one mile above the mouth of the canyon through which the river runs in its course from the Blackfoot Marsh Reservoir. It is 10 miles southeast of Challey, the nearest post-office and railway station, and 10 miles northwest from the town of Blackfoot.

The station was established June 22, 1909, to determine the amount of flood water available for storage. It has been regularly maintained since that time by the United States Geological Survey, in cooperation with the United States Indian Service.

A vertical staff gage, in a stilling box, is located on the right bank, 20 feet above the table from which the discharge measurements are made. A Friez automatic gage, enclosed in a small pipe house, is located 10 feet below the staff gage. The automatic gage is set to correspond with the staff gage whenever a new pipe house is put in place.

The stream bed through this part of the river is composed of cobble, heavy gravel, and a few small boulders. The cross-section at the gage is a little rough, being a great deal of sand and silt in making the measurements. At the lower stage the measuring conditions are poor, but at the stage holding during the time of this investigation good results may, with care, be secured.

Three very careful current meter measurements were made at

IV-DETAILED DESCRIPTION OF GAGING STATIONS AND
DISCUSSION OF DATA OBTAINED AT EACH

Blackfoot River at Mouth of Canyon near Shelley, Idaho.- This station is located about one mile above the mouth of the canyon through which the river runs in its course from the Blackfoot Marsh Reservoir. It is 10 miles southeast of Shelley, the nearest post-office and railway station, and 18 miles northeast from the town of Blackfoot.

The station was established June 26, 1909, to determine the amount of flood water available for storage. It has been regularly maintained since that time by the United States Geological Survey, in cooperation with the United States Indian Service.

A vertical staff gage, in a stilling box, is located on the right bank, 20 feet above the cable from which the discharge measurements are made. A Friez automatic gage, enclosed in a small gage house, is located 10 feet below the staff gage. The automatic gage is set to correspond with the staff gage whenever a new gage sheet is put in place.

The stream bed through this part of the river is composed of cobbles, heavy gravel, and a few small boulders. The cross-section at the cable is a little rough; hence a great deal of care must be used in making the measurements. At the lower stages the measuring conditions are poor, but at the stage holding during the time of this investigation good results may, with care, be secured.

Three very careful current meter measurements were made at

this station for this investigation.

<u>No.</u>	<u>Date</u>	<u>Gage</u>	<u>Discharge</u>		<u>Error</u>	
			<u>Measured</u>	<u>Rating Table</u>	<u>Sec.Ft.</u>	<u>Per Cent</u>
31	5/26/13	5.21	897	889	+8	+0.90
32	6/9/13	5.145	846	844	+2	+0.24
33	6/17/13	5.10	804	813	-9	-1.11

In order to eliminate as far as possible from the final results any error due to irregularities of the stream bed, the measuring points used for measurement No. 32 were taken half way between the points marked on the cable and used for the other measurements.

On Sheet No. 5 of the Appendix is shown the standard rating curve for this station. The curve for this investigation has been drawn through the mean of the above three measurements, and parallel to the standard curve, giving a little less than two per cent lower discharge. As the same meter was used in rating all the other stations, it is thought that this will eliminate instrumental error. Moreover, although only one curve has, in the past, been used for this station, yet it is undoubtedly true that slight shifts sometimes occur when large volumes of water are turned down from the reservoir. By comparing measurements Nos. 31 to 35, inclusive, it will be seen that they all lie at about the same distance from the standard curve, indicating that for the corresponding period the true curve lay below the standard curve.

A first class gage height record was secured from the Friez automatic gage. (See Sheet No. 4 of the Appendix).

From the hydrograph plotted for this station (see Sheet No. 2

of the Appendix) will be noted the gradual drop in discharge. This was doubtless caused, for the most part, by the decrease in flow of those streams entering the river between the reservoir and this point. The slight diurnal fluctuation will also be noted.

Indian Ditch- This ditch is the first one diverting water from the Blackfoot River below the canyon gaging station. The point of diversion is about one mile below that station, and is just at the lower end of the canyon. The ditch furnishes water for a small body of Indian land lying on the south side of the river.

On June 14 a measurement, giving 6.9 second-feet, was made on this ditch at a point about three-fourths of a mile below the point of diversion. No water was being used for irrigation, and except for the losses in the ditch, all of it was wasting back into the river through two waste-gates. Measurements below these points gave 4.1 and 2.2 second-feet, respectively. From conversation with the Indian ranchers it was found that the flow in this ditch had remained practically constant for several days past, and that since no more irrigation would be done from it soon, it would hold constant for at least a week. The values given above for diversion and return flow have been taken as constant throughout the period June 12 to 17.

The measuring conditions on the ditch and below the two waste-gates were good.

Burrell Ditch- This ditch is the first one diverting water from the north side of the river. Its intake is a few hundred feet below that of the Indian ditch. For the first half mile the

Burrell ditch runs very close to the river bank through which there is some loss into the river; also within this distance there are two waste-gates. Below the second waste the ditch turns back from the river bank, and it is below this point that all the land irrigated from this ditch lies.

Measurements were made about one hundred feet below the rating flume, which is located just below the second waste-gate. Although rating flumes are put in, as required by the State of Idaho, for the purpose of securing good measuring conditions, it is often the case, as here, that the natural ditch bed furnishes better conditions than does the rating flume. A nail driven into the side of the flume furnished a reference point to which to refer the stage of the water.

A measurement made on this ditch on June 13 gave a flow of 20.0 second-feet. Another measurement made on June 17, at a 0.07 foot lower stage, gave 17.9 second-feet. A straight line hydrograph has been plotted through these two measurements. (See Sheet No. 2 of the Appendix). As the head-gates and waste-gates were held at a constant position, this slight decrease in flow was probably caused by the gradual lowering of the river.

Third Burrell Waste- The third waste-gate on the Burrell ditch is located about two miles below the head of the ditch. The water from this waste-gate flows directly into the Just ditch immediately above the point where the rating flume on the latter is located. Directly opposite the point where this inflow into the Just ditch occurs there is located a waste through which it was impossible to measure the flow. However, it will be seen that by

considering the waste from the Burrell ditch as return flow to the river, and by considering the flow in the Just ditch through the rating flume as direct diversion from the river, the correct results will be secured. This is equivalent to considering the part of the Just ditch above the rating flume as a part of the river.

The measurement on the third Burrell waste was made just below the point of flow from the ditch. The measuring conditions were poor, but as the flow was small, the actual probable error in second-feet is small. The stage of the water was referred to a stake set in the ditch bed.

A measurement made on this waste on June 13 gave a discharge of 5.1 second-feet. On June 16 the water in the waste stood 0.04 feet lower. From a knowledge of the depth of the stream and other conditions it was estimated that the flow at this time was approximately 4.6 second-feet. In the computations the 5.1 second-foot flow was used on June 15; on and after June 16 the flow was taken as 4.6 second-feet. While the above determination is somewhat rough, yet the results are probably correct within one-half of a second-foot.

Just Ditch- This ditch diverts water from the north side of the Blackfoot River at a point about one-half mile above the rating flume above mentioned. For this distance the ditch runs across a flat bottom land, and through this section it is virtually a river slough. About one-fourth mile below the rating flume lies the upper part of the land supplied with water from this ditch.

The measuring conditions in the Just ditch rating flume are

good. A nail in the side wall of the flume served as a gage datum. On June 13 a measurement was made giving a discharge of 22.1 second-feet; and on June 16, at a stage 0.07 feet lower, a discharge of 21.3 second-feet was measured. A straight line hydrograph through these two points has been used. (See Sheet No. 2 of the Appendix). The slight drop in discharge was probably due to the same cause as that given for the Burrell ditch.

Seepage from Just Meadow- The Just meadow, which is the first land lying below the Just ditch, was being irrigated during the period of investigation. The measurement on June 13 of several small streams of waste water finding their way back into the river from this meadow, gave a total flow of 0.8 second-feet. This has been taken as constant for the period.

Just & York Ditch- This ditch diverts from the north side of the river at a point about a mile below the intake of the Just ditch. The concrete rating flume, located near the head-gate, furnished good measuring conditions. The stage of the water was referred to a mark on the flume. A measurement made on June 13 gave 9.0 second-feet; and one made on June 17, at a stage 0.22 feet higher, gave 10.4 second-feet. A slight change was made in the position of the gate early on the morning of June 16, and this accounts for the increase in discharge. A flow of 9.0 second-feet has been used to June 15, and a flow of 10.4 second-feet has been used for June 16 and later.

Garden Creek- This creek rises in one of the small canyons south of the Blackfoot River. Under normal conditions it flows into the

river at a point about four and one-half miles below the canyon gaging station. However, on June 14 when this creek was visited, it was found that the small estimated flow of less than one second-foot was being diverted from the mouth of the canyon to a point about one-half mile down the main valley where it was wasting onto a sagebrush flat. None of it reached the river.

Idaho Improvement Canal Waste- The Idaho Improvement Canal takes its water from the Snake River, and wastes the last of its surplus into the Blackfoot, five and one-half miles below the canyon gaging station. At a point about three-eighths of a mile from the Blackfoot River the canal ends, discharging its water over a weir into a gully through which it finds its way into the river.

About 150 feet above the weir a Bristol automatic gage was installed. A nail driven into a post set in the canal bank furnished a datum to which all gage heights were referred. A good record was obtained for all the period except during the night of June 13 and forenoon of June 14. (See Sheet No. 7 of the Appendix). It is not known what made the gage work so erratically during this time. As the water marks showed a maximum gage height of 4.5 feet, a corrected trace has been drawn with this as a maximum.

Meter measurements were made from a foot-log. The measuring conditions were not the best, due to the relatively great depth as compared with the width; but by using the two point method and by taking measurements at half-foot intervals across the width of the canal, it is believed that fairly good results were secured.

Two meter measurements were obtained: the first, on June 12, at a gage height of 4.00 feet gave a discharge of 52.4 second-feet; the second, on June 13, at a gage height of 3.76 feet gave a discharge of 41.0 second-feet. It was found that the crest of the weir stood at an elevation of 2.30 feet as referred to the gage datum. The ends of the weir were uncontracted. Using Francis' formula and solving for the coefficient "c", with the two measurements given above as discharge, values of 3.15 and 3.20, respectively, were obtained. The coefficient "c" was taken as 3.18, and the discharge curve was computed on that basis. (See Sheet No. 8 of the Appendix). The hydrograph of this station is shown on Sheet No. 2; from this it will be seen that the flow was quite variable, as would be expected in a station of this character.

Seepage from York Alfalfa Field- During the period from 8:30 a.m., June 13, to 6:00 p.m., June 14, the York alfalfa field lying west of the Idaho Improvement Canal waste ditch was being irrigated. The surplus water, estimated at 1.0 second-foot on June 13, was wasting into the river. From information furnished by the rancher it was found that this flow of waste water remained about constant during the two days while irrigation was in progress.

York Waste Ditch- A small waste ditch leads through the York Brothers' ranch. A measurement made on June 13 showed a discharge of 6.0 second-feet. The writer was informed that the flow in the ditch had been running fairly constant during the preceeding two days. On June 14 the flow was slightly lower, and was estimated at 5.0 second-feet. The flow late in the afternoon of June 16 was

estimated at 2.5 second-feet, and on the afternoon of June 17 it was estimated at 1.0 second-foot. The latter estimate and the first measurement were made by the writer, but the estimates of June 14 and 16 are from information furnished by the ranch foreman.

The measuring conditions were fairly good, but due to the fact that the records are based on one meter measurement and one estimated discharge, supplemented by two approximate gage height estimates, the estimated flow for the different days is not as accurate as could be desired. However, the error for any one day is probably not more than one or two second-feet. The hydrograph for this station is shown on Sheet No. 2 of the Appendix.

East Idaho Slough- This slough, probably an old river channel, runs from a point about a mile downstream from the Idaho Improvement Canal waste to a point directly south of the town of Blackfoot, below both of the intakes of the Fort Hall diversion canals. Water is diverted through this slough to supply several ranches along its course. The amount diverted is controlled by headworks.

A meter measurement on June 14, made about a mile below the head of the slough, gave a discharge of 15.5 second-feet. Due to the sluggish current this measurement was not considered to be very good. Another measurement, on June 16, made near the intake and under good conditions, gave a discharge of 16.7 second-feet. The head-gates were held at the same position during the investigation, but because of the gradually lowering stage of the river there probably was an actual drop in discharge of about two second-feet during that period. As only one reliable measurement

was secured, the flow during the time of the investigation has been taken as constant at that amount. If a gradually lowering discharge had been used, it would tend to render the final results more uniform.

Rue Waste- From 6:00 p.m., June 16, to the end of the period, there was a return flow from the Rue ranch due to the use of an excessive amount of irrigation water. A measurement late in the afternoon of June 16 gave this as 1.9 second-feet.

Idaho (Reservation or Government) Canal- As already mentioned, in the description of the irrigation conditions along the Blackfoot River, there was no flow from this canal into the river within the section under investigation. Due to a broken flume the small seepage flow then in the Idaho Canal was running into the East Idaho Slough (below the point where that was measured), and through that into the Blackfoot below the Lower Fort Hall Canal.

Dunn Ditch- This ditch diverts water to the Dunn ranch, on the north side of the river and four or five miles above the Upper Fort Hall Canal. A meter measurement made on June 14 gave a discharge of 3.8 second-feet. From information furnished by the rancher it was assumed that the flow held constant for the period under investigation.

Lincoln Creek- This creek rises in the low hills south of the river and enters it about four miles above the Upper Fort Hall Canal. A meter measurement made about a mile above the mouth on June 12, under fairly good conditions, gave a discharge of 5.5

second-feet. As this creek is spring fed at this time of the year, this flow has been taken as constant for the period.

Little Butte Ditch- This ditch diverts water from the north side of the river a short distance above the Upper Fort Hall Canal. The ditch was closed for repairs from the evening of June 10 to 8:00 a.m. of June 13 during which time the flow was entirely cut off. On the morning of June 13 the ditch was opened to capacity and continued at the same gate opening until after the investigation had closed. A meter measurement on June 16, under good measuring conditions, at a point about one-fourth mile below the head-gate, gave a discharge of 35.5 second-feet. The comparatively small change in the stage of the river above the Upper Fort Hall Canal diversion weir could make only a small difference in the flow of this canal because of the fact that the head on the gate opening was at least four feet. Since the gate was kept in the same position after 8:00 a.m., June 13, the flow has been taken as constant during this time.

Upper Fort Hall Canal- This canal, the upper one of the two diverting water for the main Fort Hall irrigation project, takes its water from the Blackfoot River about two and one-half miles east of the town of Blackfoot. A low diversion weir raises the water to the canal level. The small reservoir thus formed is very little wider than the stream itself, and extends upstream only a short distance at ordinary stages; hence it will be seen that it can have very little if any effect in regulating the flow of the stream.

A gaging station is regularly maintained near the head of the Upper Fort Hall Canal by the United States Geological Survey in cooperation with the United States Indian Service. The gaging station is located at the rating flume, about 100 yards below the head of the canal. This flume is built of concrete, and is of the best known type. It consists of a smooth concrete lining about 40 feet long, built with a trapezoidal cross-section to conform to the shape of the canal, with a cut-off wall or weir extending across the downstream end and projecting about one-half foot up from the floor of the flume. Meter measurements are made from a suspension bridge across the middle of the flume. An iron inlet pipe extends from the side of the flume to a concrete gage-well located in the canal bank. This well contains a Bristol automatic gage and a vertical staff gage. A sloping gage is set into the side of the flume, flush with the concrete surface. This sloping, or outside gage, was originally graduated to correspond to the vertical, or inside gage; but because of the fact that the sloping gage has warped a little, the agreement is not exact. At the stage prevailing during the time of the investigation there was a difference of about 0.02 feet in the reading of the two gages. Since the inside gage was believed to be the most accurate, it was used for the measurements and daily gage heights.

The Bristol automatic gage installed here gave a fairly good record during the time of the investigation. (See Sheet No. 9 of the Appendix). This record was supplemented by twice-a-day staff gage readings by the regular observer.

The following meter measurements were made at this station

for this investigation: May 26, gage height 3.04 feet, discharge 185 second-feet; June 16, gage height 3.155 feet, discharge 198 second-feet. As the rating of this station is slightly shifting in character, a rating curve through these two measurements and parallel to the standard curve has been used. (See Sheet No. 10 of the Appendix).

The hydrograph of this station shows a very uniform flow. (See Sheet No. 2 of the Appendix).

Blackfoot River between Intakes of Fort Hall Canals- A temporary gaging station was established at a point on the Blackfoot River about midway between the intakes of the Upper and Lower Fort Hall Canals. This was at the same point that a station was maintained during the seepage investigation of 1912, and was at the best available location. The cross-section at this point was good, but the flow was not very uniform due to a bend in the river above. At the stage prevailing during the time of this investigation there was no sharply defined 'control' or riffle nearer than the diversion weir of the Lower Fort Hall Canal, nearly a mile downstream. Although there was a stiff current at the gaging station, it is probable that there was some backwater effect from the weir below. For this reason it was thought necessary to hold the head-gates and control gates of the Lower Fort Hall Canal at a constant position throughout the investigation.

A Friez automatic gage was installed at this temporary station, and an excellent record was secured. (See Sheet No. 12 of the Appendix).

The meter measurements were made from a boat. The meter was

supported by a cable passing over a sheave which was attached to a boom projecting about two feet beyond the bow of the boat. A wire, tagged at five foot intervals, gave the position for the measuring points. Another wire across the river served to hold the boat in position. In making the measurements the boat was placed very nearly at right angles to the current, and held to position by snubbing the bow tightly to the cross wire and by holding the stern well up to the wire by means of a short line.

It was recognized that the measuring conditions at this station were not the best, hence a great deal of care and refinement was used in making the measurements. The measuring points were taken at frequent intervals, and for the different measurements the position of the measuring points was varied.

Five meter measurements were secured at this station during this investigation.

<u>No.</u>	<u>Date</u>	<u>Gage</u>	<u>Discharge</u>		<u>Error</u>	
			<u>Measured</u>	<u>Rating Table</u>	<u>Sec.Ft.</u>	<u>Per Cent</u>
1	6/15/13	5.19	569	568	+ 1	+ 0.18
2	6/15/13	5.18	557	567	-10	- 1.76
3	6/16/13	5.10	554	555	- 1	- 0.18
4	6/18/13	5.20	586	570	+16	+ 2.81
5	6/19/13	5.62	633	634	- 1	- 0.16

In drawing the rating curve (see Sheet No. 13 of the Appendix), measurement No. 4 was not given as much weight as No. 2, since the former was made on a rapidly rising stage. From a knowledge of the conditions at the station and the behavior of rating curves of stations under similar conditions, it is known that for the range of stage encountered during this investigation,

the rating curve is very nearly a straight line. A slight uncertainty is introduced by the fact that the slope of the rating curve is given by only one measurement, No. 5. However, assuming an error in this measurement as large as that of No. 2 or No. 4, the rating curve for the range of stage encountered during the period from noon, June 14, to noon, June 17 — which is the period used for final comparison — would not be materially affected.

Due to the probable difference in rating for this station, because of the difference in the position of the gates of the Lower Fort Hall Canal during the investigation of 1912 as compared with the present investigation, it has not been considered advisable to use the measurements of 1912 in rating the station for this last investigation. If any weight were given to them, the slope of the rating curve would be decreased, thus increasing the flow for the early part of the investigation and decreasing the flow for the latter part. This would cause the final determination of net gain or loss for daily periods to be somewhat more uniform, but would not otherwise appreciably affect the results.

The hydrograph for this station is shown on Sheet No. 2 of the Appendix.

Lower Fort Hall Canal- As already explained the head-gates of this canal were held to the same position throughout the investigation. A measurement made on this canal on June 18, at a gage height of 2.07 feet, gave a discharge of 81.8 second-feet. This flow, as indicated by the automatic gage sheet, remained almost constant during the period. Although the flow in this canal bears

V- COMPARISON OF DATA

Time Interval- In order to make the proper comparison of the flow at the different gaging stations it was realized that it would be necessary to determine the time interval of flow between the stations, and to reduce the time at each to a common standard. The time at the canyon station was adopted as the standard. To get the standard time at any other station the time interval, or time of flow, between the canyon station and the station in question was subtracted from the actual time at the latter station.

The time interval between the canyon station and the lower river station, between the intakes of the Fort Hall Canals, was secured by the following method. After the main part of the investigation had been finished, an additional 200 second-feet of water was turned into the river from the Blackfoot Marsh Reservoir. By comparing the gage sheets, the time of flow between the two stations was secured. At the canyon station the stage began to rise at 5:00 p.m. on June 17, while at the lower river station the stage started to rise at 4:00 a.m., June 18. This gave an interval of 11 hours, with a probable error of not more than one hour. Because a considerable part of this additional flow was being taken up in filling old river channels and sloughs between the canyon station and the lower river station, the stage at the latter point did not reach an equilibrium as it did for the higher stage at the upper station. The time interval, as indicated by the beginning of the falling stage, extended from midnight on June 18 at the upper station to noon on June 19 at the lower station,

giving an interval of 12 hours. This latter determination is not considered to be as accurate as the first one, since it was not made under such normal conditions.

The time interval between the canyon station and the Idaho Improvement Canal waste was secured by the following method. The approximate distance down to this latter point from the canyon station is 5.5 miles, while the approximate total distance down to the lower river station is 17.5 miles. Taking the time interval as proportional to the distance, we get $(5.5/17.5) \times 11$ equals 3.46 hours. However, the velocity on the upper part of the river is a little more than on the lower part; hence the time interval between the canyon station and the Idaho Improvement Canal waste has been taken as three hours. For the smaller ditches the time has been taken as proportional to the distances between their intakes and these three principal points.

In making up the hydrographs for the different stations (see Sheet No. 2 of the Appendix) the time intervals have been taken into account; therefore the flow at the different stations may be compared directly.

The average slope of the hydrograph of the lower river station indicates that an error of one hour in the time interval would make an error of only one-half second-foot in the discharge. This is well within the limit of probable error.

Computations to Determine Net Loss or Gain in Flow- On Sheet No. 2 of the Appendix are shown the hydrographs of all the gaging stations maintained during this investigation. From this sheet a comparison of all the discharges may be made for any particular time;

but due to the diurnal fluctuation at the canyon station, to the rapid variation in flow at the Idaho Improvement Canal station, and to whatever regulative effect there may have been in the 17 or 18 miles of flow, no attempt has been made to determine the net gain or loss by comparing individual discharges. Instead, periods covering 24 hours have been used except on June 12 and 17 when 12 hour periods were used. The table on page 33 shows these comparisons by periods.

On referring to the table it will be seen that the net losses and gains varied from -11.0 to +2.7 second-feet (minus sign indicating loss and plus sign indicating gain). The determination of June 12 is probably not as accurate as those for the latter days of the investigation, because the stage at the lower river station for that day was outside the range of stage for which the station was well rated; moreover there is some uncertainty in the record of the Idaho Improvement Canal waste for the period from noon, June 13, to noon, June 14. Hence, for the time previous to noon, June 14, the determinations are probably not as accurate as for the time after that.

A determination covering the period from noon, June 14, to noon, June 17, appears in the last column on page 33. This determination, probably the most accurate, indicates a net gain of 1.7 second-feet, or 0.21 per cent of the flow at the canyon station. On Sheet No. 3 of the Appendix there is a diagram showing graphically, for this period, the mean inflow and outflow at the various points along the river.

The average evaporation loss on the river has been figured

how?

COMPUTATIONS TO DETERMINE LOSS OR GAIN

Gaging Stations	Noon to midnight June 12 Thursday	Midnight to midnight				Midnight to noon June 17 Tuesday	72 hours Noon June 14 to Noon June 17
		June 13 Friday	June 14 Saturday	June 15 Sunday	June 16 Monday		
Inflow							
Blackfoot at Canyon	841.0	835.0	827.0	815.0	813.0	810.0	814.0
3rd Burrell Waste	5.1	5.1	5.1	5.1	4.6	4.6	4.8
Seepage from meadow	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Indian Ditch Wastes	6.3	6.3	6.3	6.3	6.3	6.3	6.3
Seepage from alfalfa	0.0	0.8	0.6	0.0	0.0	0.0	0.0
Idaho Improvement Waste	52.6	47.3	46.3	36.0	36.3	17.2	32.8
York Waste	6.0	6.0	5.0	5.0	3.0	2.0	4.0
Rue Waste	0.0	0.0	0.0	0.0	0.7	1.3	0.6
Lincoln Creek	5.5	5.5	5.5	5.5	5.5	5.5	5.5
Total Inflow	317.3	306.8	296.6	273.7	270.2	248.3	268.8
Outflow							
Indian Ditch	6.9	6.9	6.9	6.9	6.9	6.9	6.9
Burrell Ditch	20.5	20.0	19.5	19.0	18.5	18.0	19.0
Just Ditch	22.5	22.0	21.5	21.5	21.0	20.5	21.0
Just & York Ditch	9.0	9.0	9.0	9.0	10.4	10.4	9.6
East Idaho Slough	16.7	16.7	16.7	16.7	16.7	16.7	16.7
Dunn Ditch	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Little Butte Ditch	8.9	35.5	35.5	35.5	35.5	35.5	35.5
Upper Ft Hall Canal	203.0	203.5	204.0	200.0	201.5	201.0	201.0
Blackfoot below	615.0	582.0	578.0	564.0	554.0	535.0	557.0
Total Outflow	306.3	293.4	294.3	276.4	268.3	249.8	270.5
Gain or Loss	-11.0	-7.4	-1.7	+2.7	-1.9	-0.5	+1.7
Percentage	-1.31%	-0.83%	-0.21%	+0.33%	-0.25%	-0.06%	+0.21%

to be about two second-feet for this time of the year. Adding this to the net gain would give less than four second-feet, or less than one-half of one per cent of the total flow at the canyon gaging station. This would be the net gain should evaporation entirely stop, a condition that might virtually prevail on cold, damp days. During the period under consideration however (from noon, June 14, to noon, June 17), the weather was clear and warm. This is the normal condition for this locality during the month of June; hence it is not considered justifiable to consider the evaporation loss.

Accuracy- At the beginning of the investigation it was realized that the final accuracy of the work would depend largely on the accuracy obtained at the two river stations. Every possible precaution was taken to secure the best results at those stations. It is believed that instrumental error was very nearly eliminated by using the same meter for the whole investigation. It is also believed that whatever errors have come into the work are of the accidental rather than of the cumulative kind, and hence tend to balance each other.

Referring to page 15, it is seen that the measurements at the canyon station varied 0.90 per cent, 0.24 per cent, and 1.11 per cent, respectively, from the values derived for the rating table. Giving the same weight to all the measurements, the probable error of the rating table, by the method of Least Squares, is found to be 0.40 per cent, or 3.3 second-feet. It is believed however, that a larger probable error was introduced into the records of the flow at this station through the gage heights

than through the discharge measurements and rating table. It is difficult to estimate the probable error in the gage height record, but the writer is of the opinion that it should be placed at 0.01 feet. At a gage height of 5.10 feet, the stage prevailing during the period of comparison, this would give an error of 6.7 second-feet, or 0.82 per cent of the flow. (See Sheets Nos. 4 and 6 of the Appendix). Taking into consideration these two sources of error, it seems that the probable error in the flow at the canyon station should be placed at a little less than one per cent.

Referring to page 27, it is found that the measurements at the lower river station for the range covered in the three day determination from noon, June 14, to noon, June 17, varied 0.18 per cent, 1.76 per cent, 0.18 per cent, and 2.81 per cent, respectively, from the values derived for the rating table. Giving the same weight to all the measurements, it is found by the method of Least Squares that the probable error of the rating table (for the range of stage covered by these four measurements, and assuming that the slope and shape of the rating curve are correct) is 0.65 per cent, or 3.6 second-feet. Considering the gage height record at this station, the writer believes that the probable error in gage height should be estimated at 0.02 feet. At the average gage height for the period of comparison an error of 0.02 feet in gage height produces an error of 3.0 second-feet in discharge. (See Sheets Nos. 12 and 13 of the Appendix). With the probable errors of 3.6 second-feet and 3.0 second-feet from rating table and gage height record, respectively, it is thought

that the probable error in the record of the flow at this station during the period of final comparison should be placed at about 4.0 second-feet. This is about one-half of one per cent of the flow at the canyon station.

The probable error in the records secured at each of the other gaging stations is believed to be less than these values given for the two river stations. For the Upper Fort Hall Canal there is an estimated probable error of two second-feet; for the Idaho Improvement Canal waste during the period from noon, June 14, to noon, June 17, there is an estimated probable error of three second-feet. The estimated probable error at each of the remaining stations is three second-feet or less.

With a probable error of one per cent at the station where the results are liable to be most in error, and with considerably smaller errors at all of the other stations, it would seem that the probable error for the entire determination would be about one per cent (in terms of the flow at the canyon gaging station). It is believed that under the conditions this is about as high a degree of accuracy as could be expected.

VI- CONCLUSIONS

Since there is an estimated probable error of one per cent for the three day determination, taking into consideration all factors, and since the net gain shown for this period is only one-fifth to one-half of one per cent (depending on whether or not evaporation is considered), it may be safely stated that for fairly high stages during the irrigation season the net loss or gain in the flow of that section of the Blackfoot River lying between the canyon gaging station and the intakes of the Fort Hall Canals is negligible.

RANGE 36 E.

RANGE 37 E.

RANGE 38 E.



RANGE 35 E.



MAP SHOWING
LOCATION OF MEASURING POINTS
BLACKFOOT SEEPAGE INVESTIGATION
JUNE 12-17, 1913

Note— O indicates automatic stations
 X indicates miscellaneous measurements



HYDROGRAPHS SHOWING DISCHARGE
AT
RIVER AND CANAL GAGING STATIONS
MAINTAINED DURING
BLACKFOOT SEEPAGE INVESTIGATION
JUNE 12-17
1915

Note—Corrections have been made for time interval between measuring points. Time at Mouth of Canyon Station used as standard.

Dams June 12
STEVENS CROSS SECTION PAPER 10 x 10

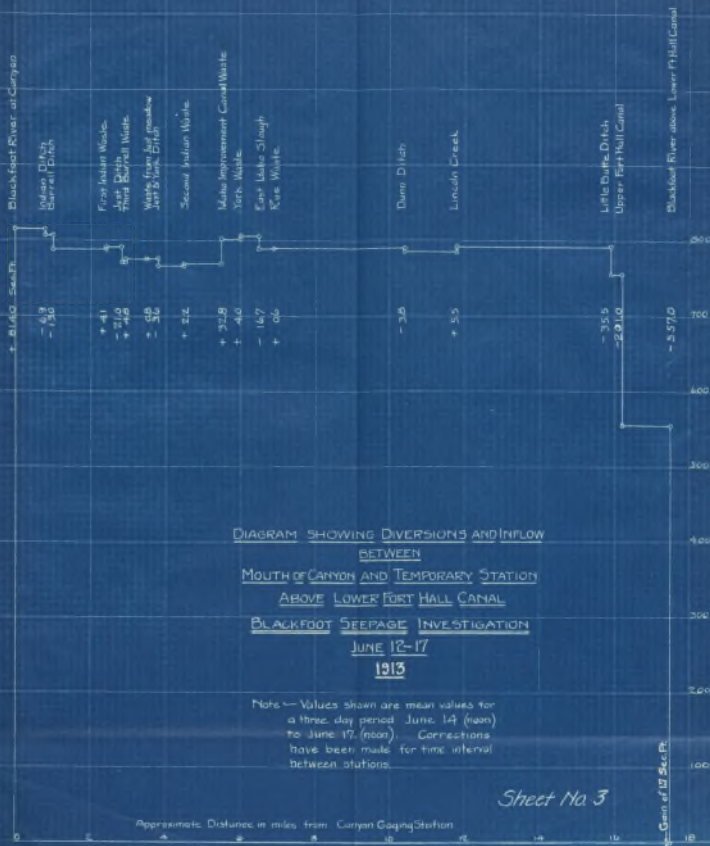


DIAGRAM SHOWING DIVERSIONS AND INFLOW
 BETWEEN
 MOUTH OF CANYON AND TEMPORARY STATION
 ABOVE LOWER FORT HALL CANAL
 BLACKFOOT SEEPAGE INVESTIGATION
 JUNE 12-17
 1913

Note -- Values shown are mean values for a three day period June 14 (noon) to June 17, (noon). Corrections have been made for time interval between stations.

Sheet No 3

SATURDAY SUNDAY MONDAY TUESDAY WEDNESDAY THURSDAY FRIDAY SATURDAY

June 9 10 11 12 13 14

June 15 16 17 18 19 20 21

515 at 1:00

510 at 6:00

511 at 8:15

510 at 3:15
510 at 11:40

505 at 2:00

UNITED STATES GEOLOGICAL SURVEY
WATER RESOURCES BRANCH

BLACKFOOT RIVER Intermittent at MOUTH of CANYON near SHELLEY, IDAHO

Vertical scale - One inch = _____ feet

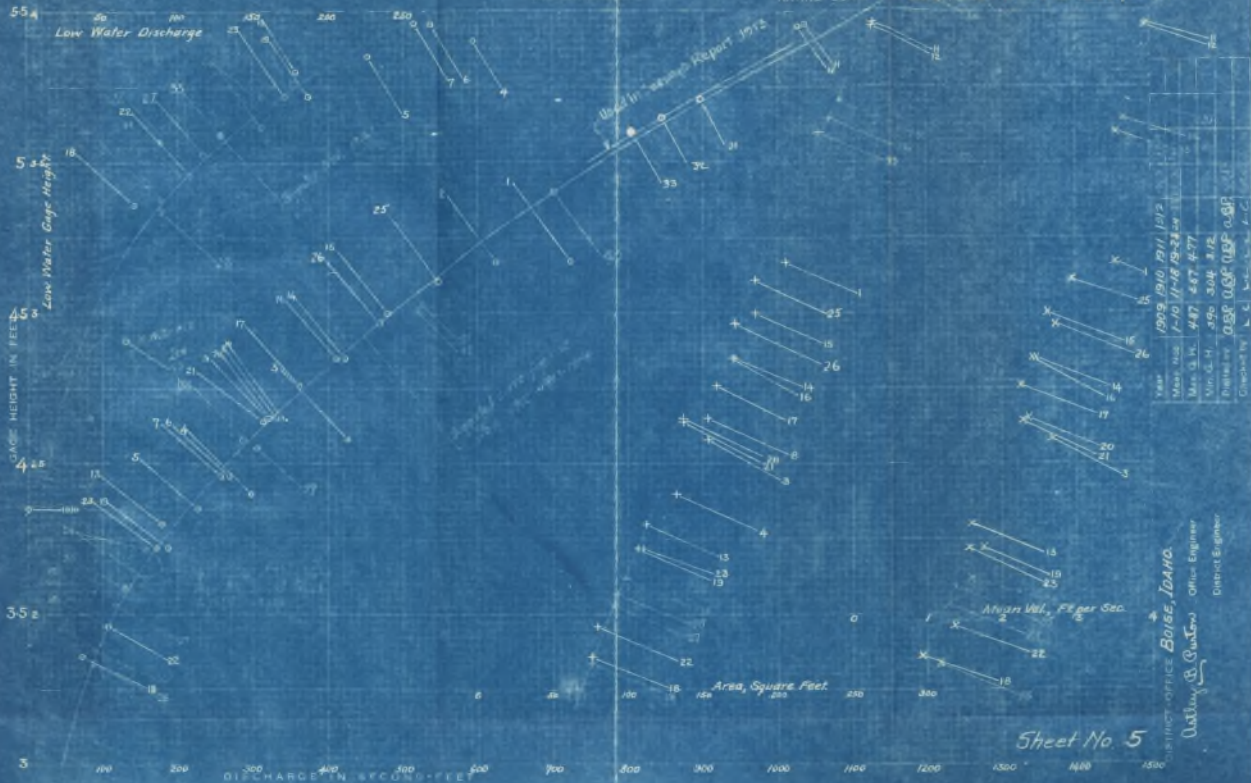
FRIEZ GAGE HEIGHT RECORD

Sheet placed by R.C.P.
1:30 P.M. June 9 1913
Staff gage height 515

Sheet removed by R.C.P.
2:00 June 21 1913
Staff gage height 505

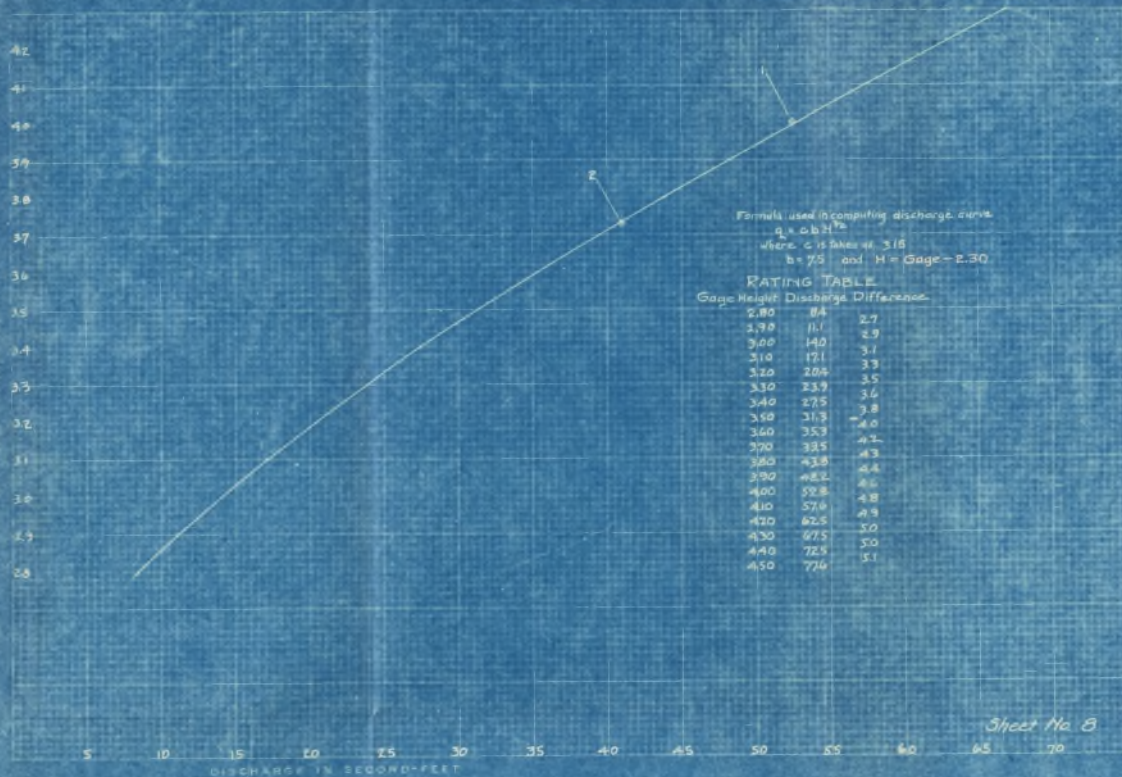
District office _____
R.C.P.
G.C.B.
Office Engineer
District Engineer

For notes relative to this sheet see Sheet No 4
Corrected curve drawn by R.C.P. Checked by ABP Record tabulated by R.C.P. Tabulation checked by R.C.P.



Sheet No. 5

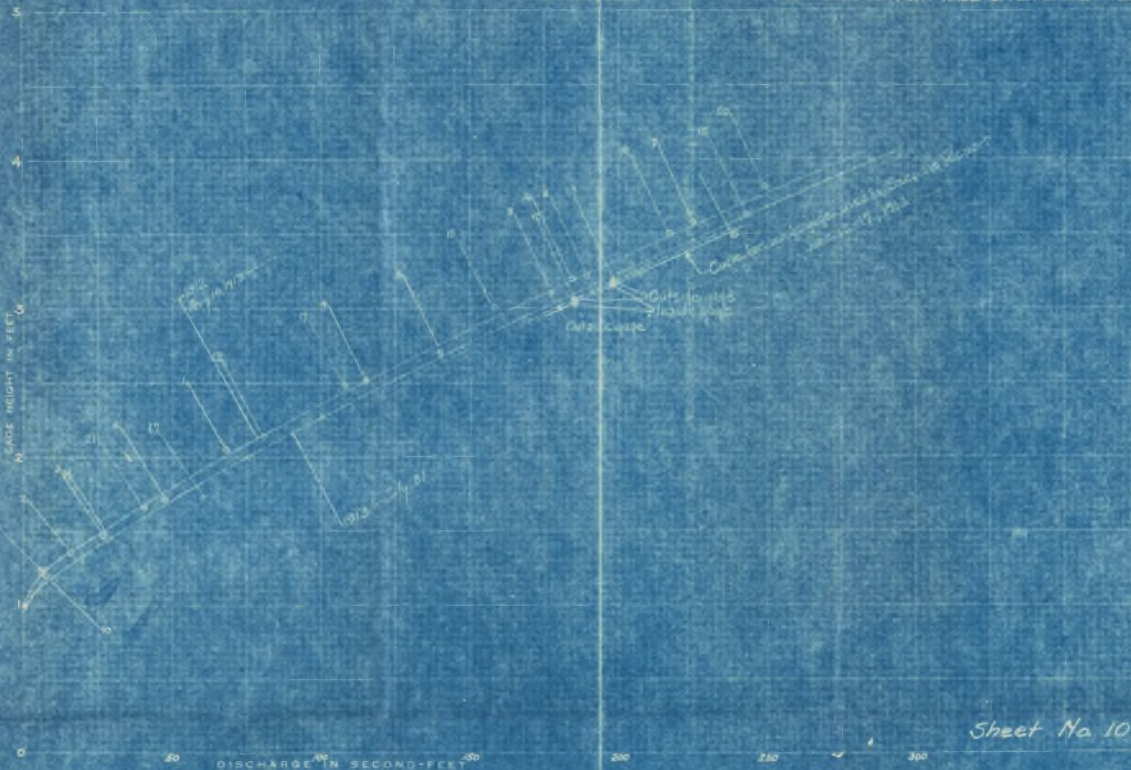
DISTRICT OFFICE *BOISE, IDAHO*
Walter B. ... Office Engineer
District Engineer



Year	1875		
Obs. Hgt.			
Max. G. H.			
Min. G. H.			
Pointed by	A. J. P.		
Checked by	DBF		

 DISTRICT OFFICE
 N. C. Pease
 Chief Engineer
 W. J. B. ...
 District Engineer

Sheet No. B



Year	1912	1913	1914	1915	1916	1917	1918	1919	1920
Max. No.	1	1	1	1	1	1	1	1	1
Min. G. H.									
Min. D. H.									
Profile No.	169	170	171	172	173	174	175	176	177
Checked by	de								

Sheet No 10

DISTRICT OFFICE Boise, Idaho
 Arthur S. Johnston, District Engineer
 District Engineer

UNITED STATES GEOLOGICAL SURVEY
 WATER RESOURCES BRANCH
Computed by R.C.P.Checked by ABPDate Nov 1, 1913
 Rating table for Upper Ft. Hall Canal (Inside gage) River at Head of canal
 near Blackfoot, Idaho, from June 12, 1913, to June 17, 1913.

Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference	Gage height	Discharge	Difference
Feet	Sec.-ft.	Sec.-ft.	Feet	Sec.-ft.	Sec.-ft.	Feet	Sec.-ft.	Sec.-ft.	Feet	Sec.-ft.	Sec.-ft.	Feet	Sec.-ft.	Sec.-ft.
3.00	181	11	.00			.00			.00			.00		
3.10	192	11	.10			.10			.10			.10		
3.20	203	11	.20			.20			.20			.20		
3.30	214	11	.30			.30			.30			.30		
3.40	225	11	.40			.40			.40			.40		
3.50	236		.50			.50			.50			.50		
.60			.60			.60			.60			.60		
.70			.70			.70			.70			.70		
.80			.80			.80			.80			.80		
.90			.90			.90			.90			.90		
.00			.00			.00			.00			.00		
.10			.10			.10			.10			.10		
.20			.20			.20			.20			.20		
.30			.30			.30			.30			.30		
.40			.40			.40			.40			.40		
.50			.50			.50			.50			.50		
.60			.60			.60			.60			.60		
.70			.70			.70			.70			.70		
.80			.80			.80			.80			.80		
.90			.90			.90			.90			.90		

The above table is not applicable for ice or obstructed channel conditions. It is based on discharge measurements made during this table used only in Blackfoot Seepage Report. Rating curve is parallel to standard curve, and is through measurements 12 & 13. plotted to inside gage and is well defined between gage heights feet and feet. Above gage height feet the rating curve is a tangent, the difference being per tenth.

Sheet No 11



UNITED STATES GEOLOGICAL SURVEY
WATER RESOURCES BRANCH

BLACKFOOT RIVER River at
Creek Head above LOWER FT. HALL CANAL

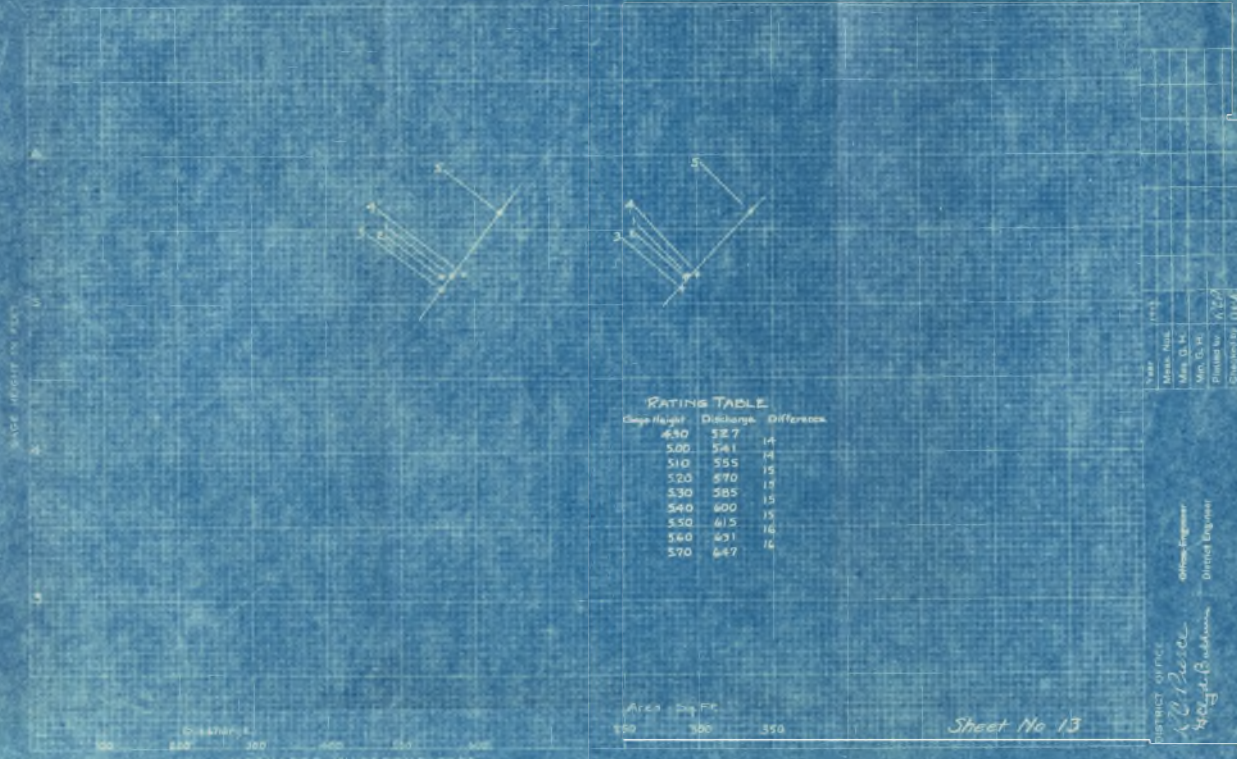
Vertical scale - One inch = _____ feet

PIEZE GAGE HEIGHT RECORD

Sheet placed by R.C.P. Sheet removed by R.C.P.
 11:00 AM. June 11 1913 3:05 June 20 1913
hour month day year hour month day year
 Staff gage height 5.52 Staff gage height 4.75

District office _____
R.C.P. Office Engineer
W.C.B. District Engineer

For notes relative to this sheet see Sheet No 12
 Connected curve drawn by R.C.P. Checked by W.C.P. Record tabulated by R.C.P. Tabulator checked by R.C.P.



RATING TABLE

Gage Height	Discharge	Differences
490	527	14
500	541	14
510	555	15
520	570	17
530	585	15
540	600	15
550	615	16
560	631	16
570	647	16

Area	Sq. Ft.
100	300
350	

Year	1923
Meas. No.	
Meas. G. H.	
Meas. G. W.	
Plotted by	A. J. P.
Checked by	U. L. C.

DISTRICT OFFICE
A. C. Reese District Engineer
H. C. B. Williams District Engineer

Sheet No 13