BULLETIN No. 86.

U. S. DEPARTMENT OF AGRICULTURE,

OFFICE OF EXPERIMENT STATIONS,

A. C. TRUE, Director.

THE USE OF WATER IN IRRIGATION.

REPORT OF INVESTIGATIONS MADE IN 1899

UNDER THE SUPERVISION OF

ELWOOD MEAD, Expert in Charge,

AND

C. T. JOHNSTON, Assistant.

INCLUDING REPORTS BY SPECIAL AGENTS AND OBSERVERS W. M. REED, W. H. CODE, W. IRVING, O. V. P. STOUT, THOMAS BERRY, S. FORTIER, R. C. GEMMELL, G. L. SWENDSEN, AND D. W. ROSS.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1900.

LIST OF PUBLICATIONS OF THE OFFICE OF EXPERIMENT STATIONS ON IRRIGATION.[1]

Bul. 36. Notes on Irrigation in Connecticut and New Jersey. By C. S. Phelps and E. B. Voorhees. Pp. 64. Price, 10 cents.

Bul. 58. Water Rights on the Missouri River and its Tributaries. By Elwood Mead. Pp. 80. Price, 10 cents.

Bul. 60. Abstract of Laws for Acquiring Titles to Water from the Missouri River and its Tributaries, with the Legal Forms in Use. Compiled by Elwood Mead. Pp. 77. Price, 10 cents.

Bul. 70. Water-Right Problems of Bear River. By Clarence T. Johnston and Joseph A. Breckons. Pp. 40. Price, 15 cents.

Bul. 73. Irrigation in the Rocky Mountain States. By J. C. Ulrich. Pp. 64. Price, 10 cents.

Bul. 81. The Use of Water in Irrigation in Wyoming and its Relation to the Ownership and Distribution of the Natural Supply. By B. C. Buffum. Pp. 56. Price, 10 cents.

FARMERS' BULLETINS.

Bul. 46. Irrigation in Humid Climates. By F. H. King. Pp. 27.

Bul. 116. Irrigation in Fruit Growing. By E. J. Wickson. Pp. 48.

SEPARATE.

Rise and Future of Irrigation in the United States. By Elwood Mead. Reprinted from Yearbook of Department of Agriculture for 1899. Pp. 25.

---

[1] For those publications to which a price is affixed application should be made to the Superintendent of Documents, Union Building, Washington, D. C., the officer designated by law to sell Government publications.

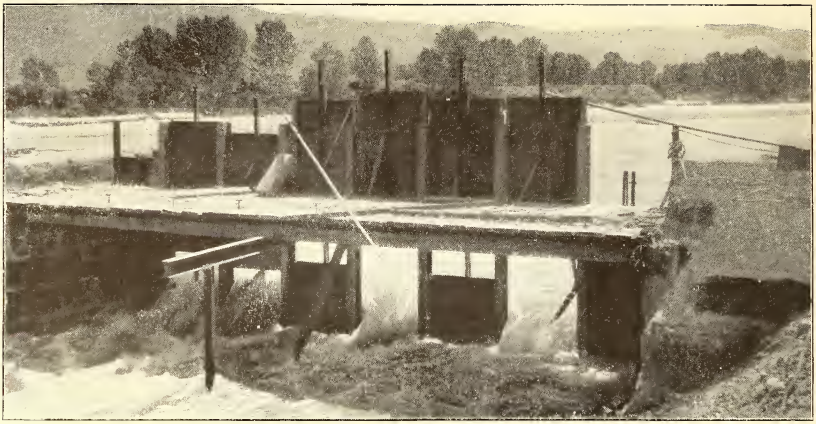


FIG. 1.—THE HEADGATES OF AN IDAHO CANAL.

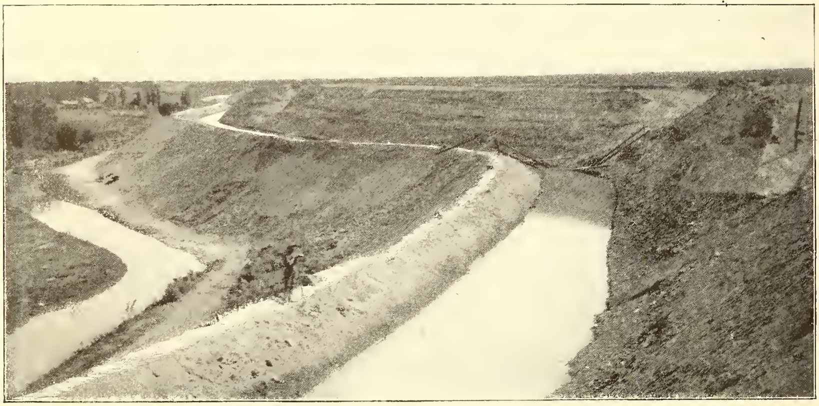


FIG. 2.—SIDE HILL CONSTRUCTION ON AN IDAHO CANAL.

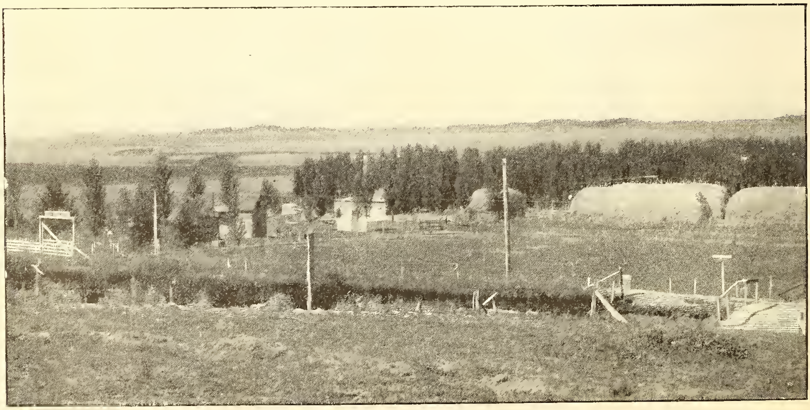


FIG. 3.—IRRIGATED FARM IN IDAHO.

U. S. DEPARTMENT OF AGRICULTURE,

OFFICE OF EXPERIMENT STATIONS,

A. C. TRUE, Director.

THE USE OF WATER IN IRRIGATION.

REPORT OF INVESTIGATIONS MADE IN 1899

UNDER THE SUPERVISION OF

ELWOOD MEAD, Expert in Charge,

AND

C. T. JOHNSTON, Assistant.

INCLUDING REPORTS BY SPECIAL AGENTS AND OBSERVERS W. M. REED, W. H. CODE, W. IRVING, O. V. P. STOUT, THOMAS BERRY, S. FORTIER, R. C. GEMMELL, G. L. SWENDSEN, AND D. W. ROSS.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1900.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., June 9, 1900.

Sir: I have the honor to transmit herewith a report of investigations on the use of water in irrigation made in 1899 under the supervision of Mr. Elwood Mead, expert in charge of irrigation investigations, and C. T. Johnston, assistant, and to recommend its publication as a bulletin of this Office.

These investigations were carried out in pursuance of the original plan and purpose of the Office to confine its work on irrigation mainly to two general lines: "(1) The collation and publication of information regarding the laws and institutions of the irrigated region in their relation to agriculture, and (2) the publication of available information regarding the use of irrigation waters in agriculture as shown by actual experience of farmers and by experimental investigations." Several bulletins bearing on the first phase of this subject have already been issued. The present bulletin deals primarily with the second. It records the results of observations on the duty of water in ten States and Territories of the arid region, namely: Texas, New Mexico, Arizona, California, Nebraska, Colorado, Wyoming, Montana, Utah, and Idaho.

The determination of the duty of water in irrigation was made a leading subject of these investigations, because it is believed that a more general understanding of the causes which increase or diminish the duty of water is one of the most urgent needs of agriculture in the irrigated region. Discussing the results obtained in the investigations reported in this bulletin, Mr. Mead says: "A comparison of the duties secured under many of the canals where measurements were made last year leads to the belief that it will be possible through improved methods to double the average duty now obtained, so that the quantity now required for one acre will serve to irrigate two. If this can be accomplished it will relieve the scarcity under many canals, put an end to many controversies growing out of such scarcity, lessen the expense per acre for water, and immensely increase the productive and taxable resources of the arid States."

Respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

ILLUSTRATIONS.

PLATES.

TEXT FIGURES.

THE USE OF WATER IN IRRIGATION.

DISCUSSION OF INVESTIGATIONS.

By Elwood Mead,
Expert in Charge of Irrigation Investigations.

INTRODUCTION.

The investigations described in this report deal with problems which perplex the irrigators and canal builders of the arid West, and which, for the last ten years, have been constantly growing more important. Their comprehensive study is a new feature of national aid to irrigation development in this country. Heretofore the leading object of such aid has been to promote the construction of new canals, to show how much of the land above existing ditches could be reclaimed, and the benefits which would come from such reclamation. It is believed that this investigation will also tend to secure these ends, but its primary purpose is to assist the cultivators under ditches already built, to render the farms now irrigated more profitable, to lessen the controversies over the distribution of water, and to secure its more systematic and economical use.

It is the opinion of those best informed that a better understanding of the existing situation must be had before we can wisely plan for future development. Controversies exist over the partial use of streams. These should be ended before an attempt is made to greatly augment such use. The claims to water for existing and prospective ditches on many streams amount in the aggregate to many times the supply. These rights are now vested, and their character must influence what is to be done in the future.

When irrigation first began, little attention was paid to the economical use of water or to the just division of rivers among irrigators. The area watered was so small that the owners of ditches did not need to consider how much was used or how much was wasted. They had all they wanted, and because it cost nothing and they were free to take it as they pleased they failed to realize its coming scarcity and importance. Every transaction which had to do with the disposal of streams was marked by a lavish prodigality. Ditches diverted more water than was used. Their owners claimed more than they could divert, while decrees gave appropriators titles to more water than ditches could carry and many times what the highest flood could supply. Little was known of the quantity of water needed to irrigate an acre of land, and in the absence of such information the ignorance and greed of the speculative appropriator had its opportunity.

In many cases the contracts which control the distribution of water from canals have been framed by people to whom the whole subject of irrigation was strange and new. It often happens, therefore, that these contracts do not promote the best interests of canal companies or meet the necessities of users. The laws which govern appropriations of water from streams have, in most cases, no relation to the actual practice of irrigators, and therefore fail to secure either the systematic distribution or best use of the available supply. As illustrating how little was formerly known of the actual necessities of irrigators, the contract of one canal company provides for delivering 1 cubic foot of water per second to 54 acres of land. In five months this would cover the land 5½ feet deep. Another canal contract provides for furnishing 1 inch to each acre. The laws of the State where this occurred make 40 inches equivalent to 1 cubic foot per second; hence, in an irrigation season of one hundred and fifty days this would involve the delivery of enough water to cover the area irrigated to a depth of 7½ feet. Another contract provides for furnishing 43,560 cubic feet for each acre irrigated, or enough to cover the land to a depth of 1 foot. The headgates of these three canals are only a few miles apart. They take water from the same stream and supply farms practically alike in every respect, yet the first contract provides for supplying 5½ times as much as the third and the second one 7½ times as much. In widely separated localities the difference is much more marked. The water-right contracts examined fix the duty of an "inch" of water anywhere from 1 to 10 acres, the lowest duty being found in sections where water is not used more than three months in the year, and the highest in California, where little rain falls and where the use of water is practically continuous.

The irrigated district watered by the Poudre River of Colorado is not surpassed by any other in either the intelligence of its irrigators or the excellence of the methods employed in the distribution of water from the stream. This high standing had already been established when the adjudication of its waters took place. The results, therefore, can be fairly taken as representing the best rather than the worst of the original conceptions of farmers and irrigation officials as to the actual necessities of irrigation. When this adjudication took place there were 23 early ditches which, taken together, irrigated about

1,000 acres of land.[1] These ditches were small and could not do more than irrigate the bottom lands along the stream, yet their combined appropriations as fixed by the decree amounted to 692 cubic feet per second, or enough water to have irrigated 41,520 acres on a duty of 60 acres per cubic foot per second, or more than 40 times the water actually used under wasteful methods, and more than 100 times the water actually needed under the methods now prevailing on that stream. From the report of the State engineer of Colorado for 1889–90, we find that the mean annual flow of the Poudre River in the first of these years was 735 cubic feet per second; in the second, 770 cubic feet per second, and that this volume of water served to irrigate 139,000 acres of land. This was a duty of 189 acres for each cubic foot per second in 1889, and 180 acres in 1890. The adjudication therefore gave to 1,000 acres of land almost as much water as serves to irrigate nearly 140,000 acres. The State engineer's report for 1898 states that in September of that year the discharge of the river was only 100 cubic feet per second, while in October it was 35 cubic feet per second.

Boyd's history of Greeley and the Union Colony gives additional illustrations of the extravagant rights which have grown out of a lack of knowledge of the actual necessities of irrigation. From it is taken the following extract:

> As instances of the excessive quantity of water awarded ditches under the decree, compared with the crops cultivated under them, we may take the Boyd and Freeman ditch, which has 99.38 cubic feet awarded to it in 1873, while the crops under it in 1888, said to be irrigated, were 320 acres, which is, I believe, all the land under the ditch owned by its proprietors. This would be a duty of less than 4 acres to the cubic foot per second. Again we may take the B. H. Eaton ditch, which was awarded for 1872, 41 cubic feet per second, and had in irrigated crops, 1888, 330 acres, or a duty of 8 acres per cubic foot per second. The John Coy ditch is credited with 31 feet and irrigated in same years 160 acres, or has a duty of about 5 acres per foot.[2]

In another State enough water was awarded to one man in 100 days to submerge his farm under a body of water 23 feet deep, while across a boundary fence his neighbor was given only enough to cover his land to a depth of 1.5 feet, the scarcity in one case being as injurious as the excess in the other.

SOCIAL AND INDUSTRIAL FEATURES OF IRRIGATION.

Before the period of crude structures and still cruder ideas had ended, it began to be manifest that the reclamation of arid lands involved more than the overcoming of physical obstacles. It has been found easier to dig ditches than to distribute the water they carry, and to plan headgates and flumes than to frame just laws for establishing titles to water or dividing rivers among rival claimants.

---

[1] History of Greeley and the Union Colony, by David Boyd, pp. 124, 125.
[2] Pages 125, 126.

The reason for this is found in the overshadowing importance of water. Wherever irrigation is required, water rather than land controls development. It is easy to realize this when it is remembered that in arid lands not a flower will bloom, not a tree bear fruit, nor a field bring forth its harvest unless water is supplied by the skill and industry of man; hence, as the reclaimed area has extended and the number of homes dependent on irrigation has been multiplied, the collection, sale, and distribution of water has grown to be a stupendous industry, in which many millions of dollars (estimates vary between $100,000,000 and $200,000,000) are invested.

The many thousands of miles of canals and laterals in the irrigated regions of the United States have reclaimed an area approximately as great as the State of New York, every acre and almost every square foot of which has to be artificially moistened from one to ten times each year. During the growing season this requires the services of an army of men to protect and regulate headgates, patrol the banks of canals, and adjust the measuring boxes of users.

The success or failure of these canals is a matter of more than local interest. Much of the money expended in their construction came from the East. The savings of thousands of thrifty New England people have been invested in stocks and bonds of irrigation companies, a single agency in Colorado having invested $15,000,000 in this class of securities for these customers. The failure of a canal company to find customers for water, or to supply water to the customers it has, affects many others besides the immediate parties to these transactions. Theirs is the immediate loss, but sooner or later this loss also shows itself in delayed or defaulted interest payments, and this affects the holder of the stock or bonds of the canal company. The justice and efficiency with which streams are divided and the e onomy with which water is used may, therefore, in this way augment or reduce the incomes of many Eastern as well as Western homes.

DISTRIBUTION OF WATER AMONG USERS.

Traffic in water is carried on under many peculiar and perplexing conditions. No matter from what source the supply is received, whether it is stored in reservoirs, pumped from wells, or taken from rivers, the distribution of water in irrigation is subject to unending uncertainties. Streams rise and fall with every passing cloud; the torrent of to-day may be a dry channel a month hence; wells which can not be exhausted in April are often empty in June. Even after water has passed the headgate and is safe from outside interference the waste and loss continue. It disappears through the bottom of the canal by seepage, and into the air by evaporation. The same vicissitude attends its use. As much water may escape from the lower side of the field of a careless irrigator as sinks into the soil. The waste from badly built laterals or poorly prepared fields does much to limit the area which a canal can serve, and hence the income it can be made to yield.

This commerce in water has been created by men born and reared in regions of ample rainfall and without prior training or experience in dealing with the problems of irrigation. They had to learn by trial how to frame satisfactory contracts for the disposal of water from canals and how to use that water properly when delivered. From the construction of the first small furrows in Utah and California up to the present the growth in acres irrigated has been accompanied by an equally important evolution in methods. The fixing of a unit of measure to be employed in delivering water to users will serve to illustrate this. It could not be sold by the pound or by the ton, nor were there any devices at hand for its measurement or delivery by the gallon. Farmers were at a loss to know how much to buy and canal companies as ignorant of how much they could sell or how to measure it when sold.

UNITS OF VOLUME EMPLOYED IN MEASURING WATER.

THE INCH.

In a number of the arid States placer mining was an important industry before irrigation began. Miners in measuring water employed the "inch." This is the volume which will flow through an inch-square orifice under a uniform and designated pressure. Later, the pressure to be employed and the manner in which the size of the orifice was to be increased or diminished was, in a number of States, fixed by law.[1]

In those sections where irrigation succeeded this form of mining, irrigators generally adopted this unit. In many respects it is entirely satisfactory. Where the flow is controlled by a device of reasonable accuracy it is a convenient method of delivery for canal companies and satisfactory to users, because they can tell at a glance whether or not the quantity contracted for is being delivered. It is not suited, however, to the measurement of rivers, or to the regulation of their division among large canals, as the prescribed conditions can not be

[1] Water sold by the inch by any individual or corporation shall be measured as follows, to wit: Every inch shall be considered equal to an inch-square orifice under a five-inch pressure, and a five-inch pressure shall be from the top of the orifice of the box put into the banks of the ditch to the surface of the water. Said boxes or any slot or aperture through which such water shall be measured shall in all cases be six inches perpendicular, inside measurement, except boxes delivering less than twelve inches, which may be square, with or without slides. All slides for the same shall move horizontally, and not otherwise, and said box put into the banks of ditch shall have a descending grade from the water in ditch of not less than one-eighth of an inch to the foot. (General Statutes of Colorado, sec. 3472.)

produced on a large stream of water. There are canals which carry 125,000 inches. To measure this volume under the conditions prescribed in the Colorado statute would require a slide so long and heavy that its use would be practically impossible. The use of the term "inch" has also been unfortunate. Many farmers have confused this expression with the surface or the cubic unit of the same name, and it frequently happens that the inches of water in use are determined by measuring the cross section of a ditch or lateral and paying no attention whatever to either grade or velocity. In one case a State law confuses cubic inches with the continuous flow from an inch-square orifice.

THE CUBIC FOOT PER SECOND.

The cubic foot per second is a definite and convenient unit of volume to employ in the gaging and division of rivers and in measuring the discharge of ditches and canals. A majority of the arid States and Territories have made it the legal unit in fixing the volume in water-right contracts between canal companies and irrigators and in defining the amounts of appropriations from streams. This unit has the double advantage of showing precisely what is meant and being well adapted to the measurement of large as well as small volumes of flowing water. It is the most satisfactory unit which can be employed in dividing rivers or in measurements where the flow is continuous. There is, however, an objection to its universal use. Where decrees or contracts provide for the delivery of a continuous flow it is presupposed that irrigators use water in this manner. This is not in accord with the best practice. Irrigators do not need water all the time. Few use it half the time. If they are required to pay for a continuous flow, they usually pay for something they do not get, and always for what they do not need. The best practice provides for rotation on the part of irrigators in the use of water and the use of a larger volume of water for only a part of the time. Where this occurs, a different unit of measurement is desirable, because it is not the continuous delivery of a stream of a designated size which is paid for, but the total volume furnished during the whole or any part of the irrigation season.

THE ACRE-FOOT.

The growing recognition of the fact that a continuous flow of water does not correspond to the needs of irrigators has recently brought into use another unit of volume—the acre-foot. It contains 43,560 cubic feet, or enough to cover an acre 1 foot deep. It is a convenient unit for selling stored water, since the capacity of reservoirs can be measured by the same unit.

Contracts in which the acre-foot is used provide for the delivery of water on the demand of the irrigator, or at intervals rather than in continuous flow, and canal companies have hestitated about adopting this unit because of a fear that satisfactory arrangements for delivery could not be made, but that more water would be called for at some time than the canal could supply, while at other times the entire volume would run to waste.

Wherever the acre-foot has been adopted it has proved acceptable to irrigators, because they share in the benefit resulting from care and skill in distribution.

FORM OF WATER CONTRACTS AND BENEFITS OF ROTATION.

The contracts between canal companies and irrigators take various forms. Some purport to be deeds to water; others are contracts for a perpetual right to water for a designated tract of land; others provide for payment of an annual rental for the area irrigated, to be renewed each year; while an increasing number provides for the measurement of and payment for the quantity delivered. Formerly the difference in conditions prescribed was much greater than at present, the tendency now being to follow precedent and copy the forms which have worked well in practice.

Contracts which provide for the delivery of a uniform constant flow are, as a rule, wasteful of water. They are not, therefore, to the interests of either ditch companies or the public. Contracts which charge for the acres irrigated, without regard to the volume used on these acres, are a temptation to extravagance on the part of the irrigator. The canal company which employs such contracts resembles the grocer who would agree to supply his customers with a year's provisions at so much per head, with no restrictions as to quantity or kind of goods which might be called for. On the other hand, contracts providing for payment proportioned to the quantity delivered and for its delivery in amounts which can be most efficiently distributed can not fail to lead to great economy in the use of water and consequently to a high duty, as the irrigator pays for what he wastes and also gets the benefit of his saving. Such contracts can be employed only in connection with a system of rotation in delivery to irrigators. This rotation benefits the canal company as much as the irrigator, because it lessens the loss from evaporation and seepage in the following manner: If a canal is large enough to supply 100 farms it will still supply them whether they are all irrigated every day or one-half given twice the usual supply every other day. On large canals the economy of such rotation is very great. It would permit of dividing them into sections and supplying the lands under one section at a time. A canal 60 miles long could be divided into three sections of 20 miles each and all the loss from seepage and evaporation on the lower 40 miles saved while the irrigators of the upper section were being supplied. In the same way, by keeping the full supply in the canal, water could be rushed through to users under the lower section with less loss than where the flow is depleted by laterals along the route. The geatest saving in rotation, however, would be made in laterals. The most wasteful system possible is where water is permitted to slowly dribble through these all the time. The engineer of a canal, by devising a system for dividing laterals into groups and inducing the irrigators therefrom to take water by turns, can do as much toward raising the duty obtained as can the actual cultivator. The use of a unit which favors rotation will also lead to rotation in the division of a river between canals. There is great waste in running the canals half full all the time, as the absolute loss from seepage and evaporation is nearly the same whether the canals are full or only half full. It would be far better when rivers are low to run half the canals at a time and provide them with a full supply, thus saving nearly half the water ordinarily lost in transit. As the loss from seepage and evaporation averages about 30 per cent of the water flowing in canals, the water saved will be a material addition to the available supply.

INVESTIGATIONS IN 1899.

REASONS FOR INVESTIGATION OF THE DUTY OF WATER.

As the water required to irrigate 1 acre of land should be the basis for fixing the dimensions of works required to irrigate any number of acres, there is need to know approximately its amount. In order to plan for the just distribution of the volume entering the headgate, the losses in transit must be provided for. Until more is known than is now known about the time of year when the irrigation season begins and when it ends, the part of the discharge of any stream which must run to waste unless stored can not be estimated. Until it is known how large an area an acre-foot of stored water will irrigate and the returns which will come from such irrigation, the value of reservoirs will have no more substantial basis than individual judgment or conjecture, nor can an intelligent estimate be made of the amount of money which can be profitably spent in their construction. Sooner or later a knowledge of the duty of water becomes a necessity in any irrigated district. It is now urgently needed to settle disputes over water-right contracts, and to provide for their intelligent reconstruction. Thus far it has been the uniform practice to make all rights to water perpetual and continuous. This is not the practice of European countries. Italy, France, and Spain each distinguishes clearly between rights to the summer and to the winter flow, the vernal and autumnal equinoxes being the dates when one begins and the other ends. The controversies which have recently arisen over rights to the winter flow of streams will doubtless soon lead to a similar distinction in Western irrigation laws. A comparison of the duties secured under many of the canals where measurements were made last year leads to the belief that it will be possible through improved methods to double the average duty now obtained, so that the quantity now required for 1 acre will serve to irrigate 2. If this can be accomplished, it will relieve the scarcity under many canals, put an end to many controversies growing out of such scarcity, lessen the expense per acre for water, and immensely increase the productive and taxable resources of the arid States.

Believing that a more general understanding of the causes which increase or diminish the duty of water is one of the most urgent needs of agriculture by irrigation, the determination of this duty was made a leading subject of these investigations.

METHODS EMPLOYED IN THE INVESTIGATION.

In carrying out this investigation laboratory methods will not answer; it must deal with the use of water on a large scale. The work requires the supervision of men of special training and wide practical experience. One of the chief difficulties encountered at the outset was to find the right men to take charge. Those engaged are, without exception, holding positions of responsibility and receiving ample compensation from other sources; the chief inducement for their taking part in this investigation has been the promotion of the public welfare. Through their interest and zeal this report includes a large amount of information which could not otherwise have been secured for ten times the actual outlay. It was left for the observers in each State to secure the cooperation of intelligent, practical farmers and to arrange with them to measure the water used on their fields. In nearly every case this was easily accomplished. Every farmer connected with the investigation received the same instruction. It was to use water whenever and wherever it was thought necessary, provided it could be had, and pay no attention to the fact that it was being measured. The results show that this was done. The descriptions of canal systems and the methods which govern their operation given in the reports of the special agents show how direct is the relation between good management and a high duty of water. They also show how prolific of waste and loss is a badly drawn water-right contract. Records were also kept of rainfall and evaporation; and an effort was made in each case to secure as much information as possible on the following factors of the duty of water in irrigation:

The quantity of water required by different crops.

The length of the irrigation period in different sections of the arid region.

The agreement or divergence between the quantity of water used in irrigation in the different months of the growing season and the rise and fall of streams during those months.

The benefits of reservoirs and the percentage of the total discharge of streams which must be stored in order to utilize the whole supply.

Losses in canals from seepage and evaporation.

Influence of different forms of water-right contracts in promoting economy or waste.

The returns from the use in irrigation of an acre-foot of water.

INSTRUMENTS EMPLOYED IN RECORDING AMOUNTS OF WATER USED.

In these studies an instrument was needed which would keep a continuous and automatic record of the quantity used. The quantity

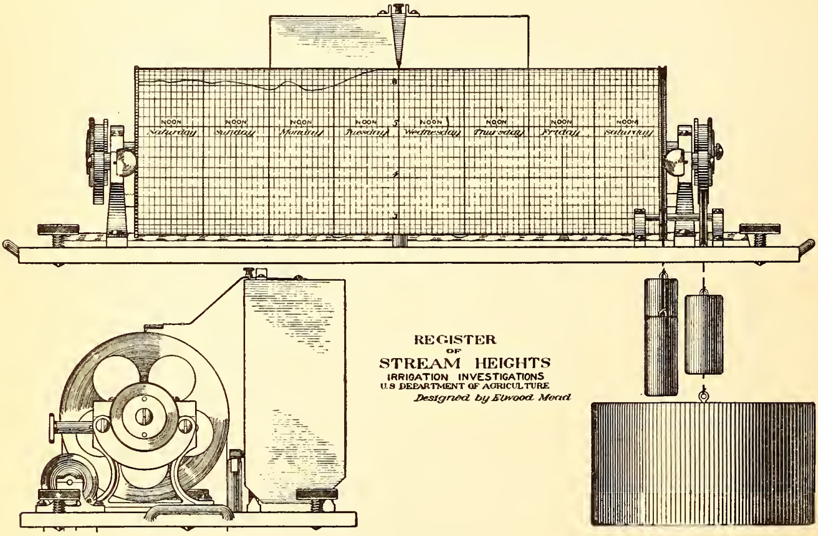


FIG. 1.—Water register No. 1.

received by each irrigator fluctuates with the flow in the main canal and with his own and his neighbors' demands on their lateral. Finding it impossible to employ a meter to measure the volume delivered, it was decided to place a weir or flume in each canal or lateral, and then by means of a suitable instrument keep a continuous record of the depth of water delivered. Wherever possible weirs were used, but in more than one-half of the cases where they were used the results proved that flumes would have been more satisfactory.

A study of the registers in use showed that none were wholly satis-

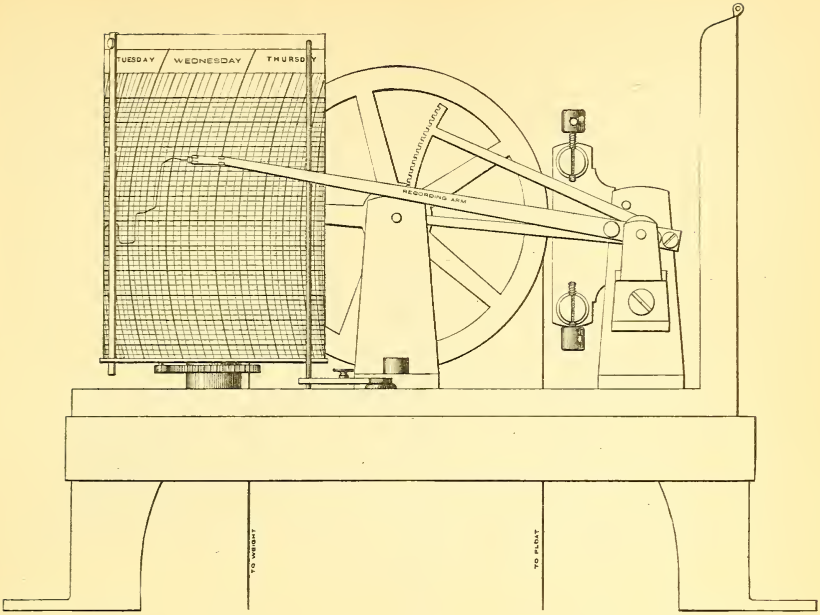


FIG. 2.—Richard Brothers' water register.

factory. The first requisite was a record on a natural scale, so that an inch rise or fall in the ditch would be so shown on the record sheets, thus enabling any farmer or ditch rider to determine at a glance whether or not the instrument was working accurately, and if not to correct it without the computation required where the scale is reduced. Not being able to obtain registers of this pattern, one was designed. Its form is shown in the accompanying drawing of register No. 1 (fig. 1).

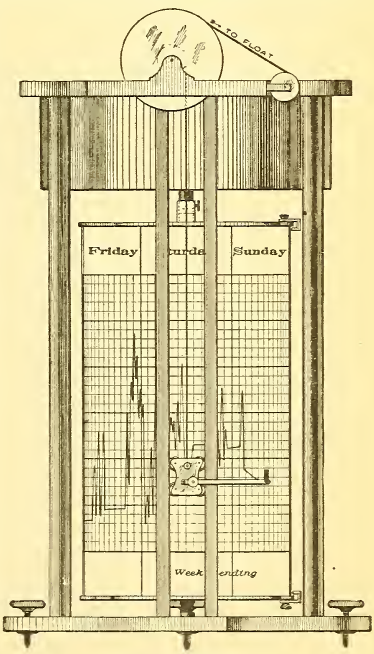


FIG. 3.—The Wyoming nilometer.

In this instrument the rise and fall of the water in the ditch or lateral raises and lowers a float and counterweight. The latter are connected by a cord which passes over the end of a cylinder which is revolved by the cord's movement as the float rises and falls with the changes of depth in the stream. Around this cylinder is fastened a paper divided into rectangular spaces, the time divisions being parallel to its axis and the depth divisions at right angles thereto. The pen or pencil making the record is moved along this cylinder by clockwork, passing from one end to the other in a week, when the paper is changed and the pen returned to the starting point. The character of the record is shown by the reproduction of a number of these sheets. The fluctuation in discharge creates a zigzag line, a wide variation in depth sometimes

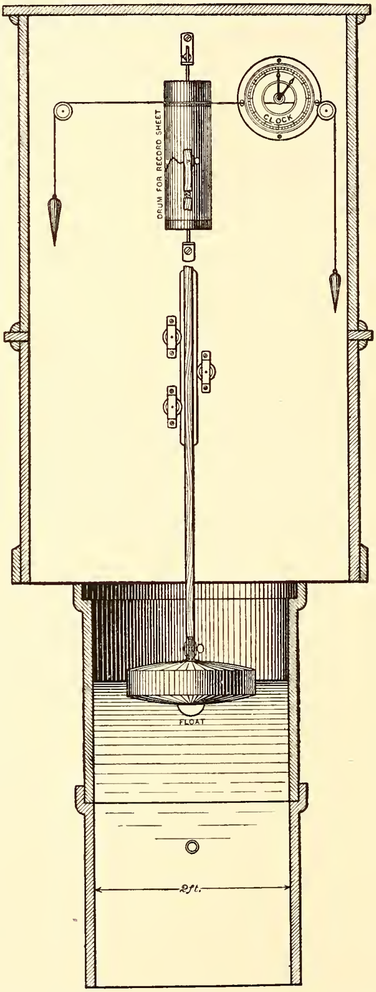


Fig. 4.—Water register used on the Gage Canal.

causing the cylinder to make a complete revolution; but as the pen or pencil follows this and records it, any number of revolutions could be made without a loss of the record.

Owing to delay in the construction of these instruments, all observers could not be supplied with them, and a number of registers of other patterns were used. The Richard Brothers' register (fig. 2) was utilized in the measurements in Arizona, the instruments being loaned by the University of Arizona. The Wyoming nilometer (fig. 3) was used at the Wyoming and Nebraska stations. The Irving register (fig. 4) was used on the Gage Canal in California. The Friez register (fig. 5) is a new form, which will be used in the investigations next year. Fig-

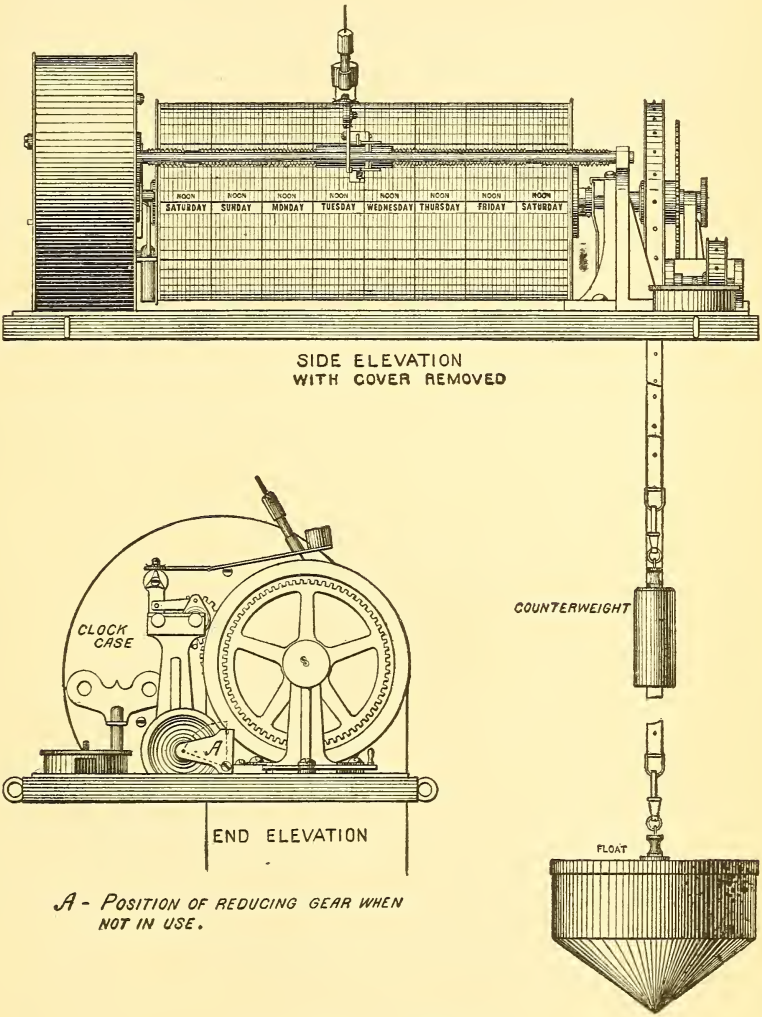


FIG. 5.—Friez water register No. 2.

ures 6, 7, and 8 are copies of sheets taken from the registers in use last year, figure 6 being taken from register No. 1, figure 7 from register No. 2, and figure 8 from register No. 4. The first and last of these give the variations in depth on a natural scale; the second reduces the variations to one-tenth of what actually occurs.

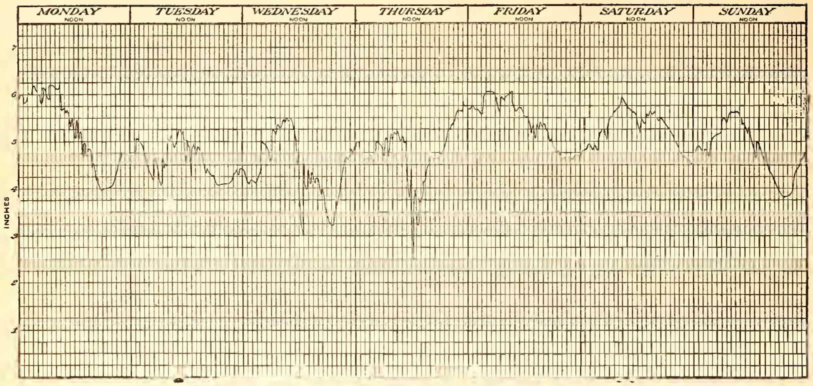


FIG. 6.—Copy of sample water register sheet.

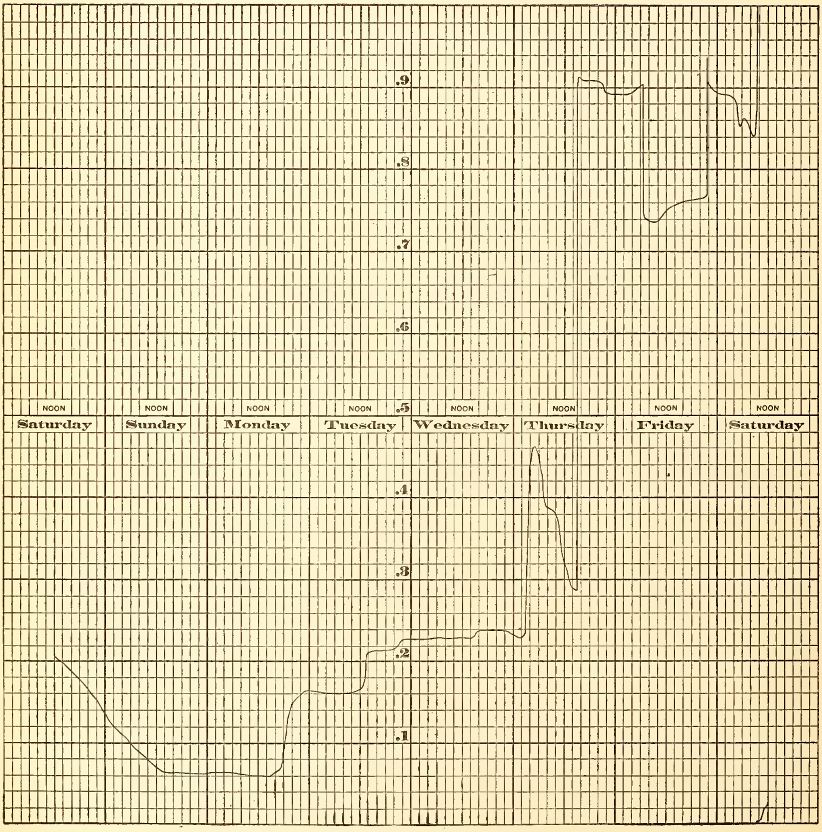


FIG. 7.—Copy of sample water register sheet.

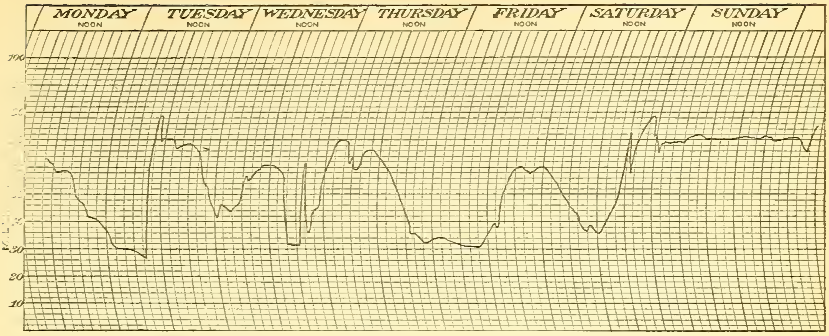


FIG. 8.—Copy of sample water register sheet.

INSTRUCTIONS TO OBSERVERS FOR THE PLACING OF WEIRS AND FLUMES.

The following abstract from the instructions to observers gives the regulations governing the placing of measuring weirs and flumes:

WEIRS.

Weirs are to be employed wherever the conditions will permit, and where not, a measuring flume is to be substituted. A Cippoletti weir is the form to be used. Figure 9 shows its detail and the method of placing the recording instrument with

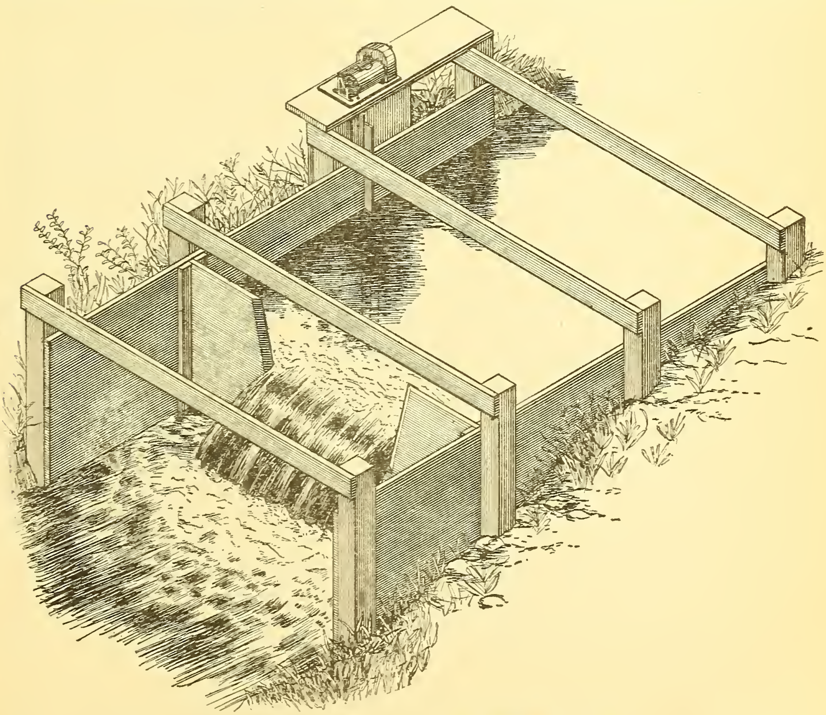


FIG. 9.—Cippoletti weir, with water register in place.

sufficient clearness to permit of its proper construction. The following directions should be observed:

(1) The dimensions of the flume in which the weir is placed will be governed by the volume of water to be measured, but in no case should the length be less than 16 feet nor the width be less than the surface water line of the ditch. The bottom of the flume should be level in both directions. Its upstream end should be placed on grade with the bottom of the ditch, so that water will enter without eddies or disturbance. The channel of the ditch should have a uniform grade and cross section for 100 feet upstream from the flume, and its axis should pass through and be parallel to the middle of the structure.

(2) The length of the weir should be sufficient to permit all water needed to pass over it without the depth in any case exceeding 2 feet.

(3) The end and bottom contractions of the weir must be complete. To secure this, (a) the crest of the weir must be horizontal, and the sides must be inclined to a vertical line at an angle whose tangent is 0.25; (b) the crest of the weir must be perpendicular to the axis of the ditch; (c) the upstream edge of both crest and sides of the weir must be sharp, and the walls cut away therefrom to prevent the creation of a vacuum; (d) the distance of the crest of the weir from the bottom of the flume must be three times the maximum depth of water intended to pass over the weir, and the distance from the end of the crest of the weir to the sides of the flume must not be less than twice the maximum depth of water to flow over the weir.

(4) The float which actuates the recording instrument should be placed far enough away from the weir to secure an accurate measurement of depth. This is 6 feet in the sketch. Connection with the well should be by one-half-inch orifice through the sides of the flume and well.

(5) A post for checking the record of the register should be fastened to the bottom or side of the flume, with a nail in its top exactly level with the crest of the weir. The accuracy of recorded depths should be tested each time the sheet on the register is changed.

(6) The depth of water on the weir can be determined by the following method: Having the perpendicular distance from the top of a crossbeam to the top of the post referred to (5), measure the distance from the top of the crossbeam to the water surface either with finely graduated scale or hook gauge. The difference between these two distances will give depth of water required.

MEASURING FLUMES.

Figure 10 is an isometric projection of the measuring flume proposed to be used where conditions do not permit of a weir. In constructing these flumes the following requirements should be observed:

(1) Bottom of flume (fig. 10) should be horizontal in both directions; the sides vertical. The length must in no case be less than 12 feet nor less than twice the width of the ditch or canal, and width must be equal to width of ditch on the bottom.

(2) The upstream end should have a submerged apron, extending 2 feet below the bottom, to prevent leakage. The wings at the side should extend into the bank beyond the surface water line of the ditch, and the angle of inclination to the axis of the ditch should not exceed 30 degrees.

(3) The channel of the ditch should have a uniform grade and cross section for 100 feet upstream from the flume, and should be straight for that distance, with its axis passing through the middle of the flume and parallel to it.

(4) The well for the register float should be placed three-fourths of the distance from the upstream end of the flume and be connected with the water therein by an orifice one-half inch in diameter.

(5) The well for the register float for both weirs and flumes should be made large enough to contain both float and counterweight, in order to protect them from the

action of the wind. To do this it should be 10 by 16 inches inside measurement in cross section, and its height above the bottom of the flume should be more than double the maximum depth of water the flume will carry.

(6) Where the water carries solid matter in suspension the bottom of the flume should be about one-tenth of a foot above the grade of the ditch, so that all silt may be carried through and not permitted to settle and destroy the form of cross section.

(7) The foundation timbers of all structures should be solidly embedded, and the earth around them and around the sides of the structure carefully and solidly rammed, in order to prevent any subsequent settlement or passage of water around either the bottom or sides.

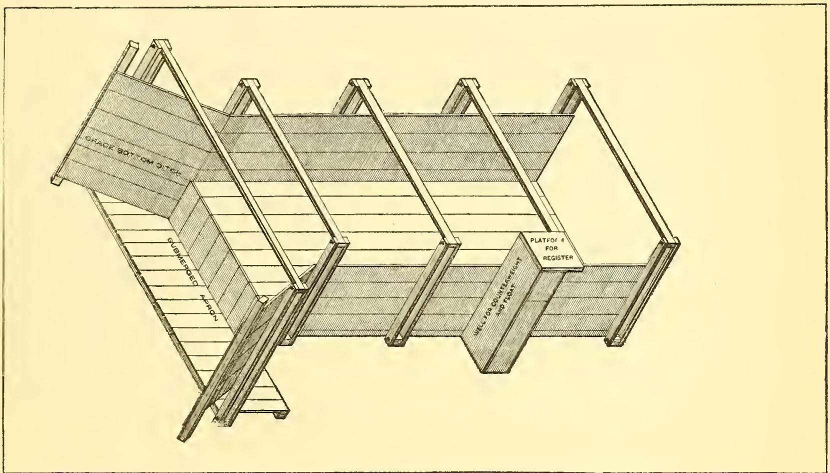


FIG. 10.—Measuring flume, showing place for water register.

The following instructions should be observed in placing the register:

The distance from the bottom of the register to high-water mark must be 6 inches more than the total rise and fall of the water.

Record sheets provide for eight days, but clocks should be wound and paper changed once each week. The sheets are designed for this to be done on Saturday.

The accuracy of the registered depth of water flowing over a weir or in a flume should be tested before and after the change of each sheet. Any inaccuracies in either depth or time should be noted on the sheet when observed and the same corrected. Care should be observed in returning pen to starting point that the gear and pinion do not become marred. The ball bearings should be oiled once each month. The ink in the pen, if a pen is used, should be renewed each week.

The report of land irrigated and the register sheets showing the depth of water should be mailed each week to the Cheyenne office.

LIST OF OFFICIAL STATIONS AND OBSERVERS.

The studies have been made by the following observers, at the places named:

Official stations for irrigation investigations, and names of observers.

State.	Location.	Observer.
New Jersey	New Brunswick	Prof. E. B. Voorhees, of the New Jersey Experiment Station.
Nebraska[1]	Gothenburg	A. M. Allen.
	Lincoln	Prof. O. V. P. Stout, of University of Nebraska.
Montana	Bozeman	Prof. S. Fortier, of the Montana Experiment Station.
Wyoming	Wheatland	M. R. Johnston.
	Laramie	Prof. B. C. Buffum, of the Wyoming Experiment Station.
Colorado	Holly	Thomas Berry, chief engineer Great Plains Water Co.
Texas	Beeville	S. A. McHenry, of the Texas Experiment Station.
New Mexico[2]	Carlsbad	W. M. Reed, chief engineer Pecos Valley Irrigation Co.
	Mesilla Park	Prof. C. T. Jordan, of the New Mexico Experiment Station.
Arizona	Phœnix	W. H. Code, chief engineer Consolidated Canal Co.
California	Riverside	W. Irving, chief engineer Gage Canal Co.
Utah	Logan	Prof. Geo. L. Swendsen, of the Utah Experiment Station.
	Salt Lake City	R. C. Gemmell, State engineer.
Idaho	Boise	D. W. Ross, State engineer.

[1] The State engineer of Nebraska, J. M. Wilson, also cooperated with this investigation in the collection of data.

[2] Records of the duty of water at Aztec and East Las Vegas are also being furnished us by the New Mexico Agricultural Experiment Station.

RELATIVE MERITS OF WEIRS AND FLUMES IN THE MEASUREMENT OF WATER.

Reference has already been made to the fact that some of the weirs put in did not prove satisfactory. This was due to the deposit of silt above them. Sediment investigations made during the season showed that certain Southern streams carry, during floods, as high as 5 per cent of solid matter in suspension, and that canals and laterals taking water from these streams have to be cleaned from two to three times each year. Even where the percentage was much less than this, the deposit of sediment was so rapid in some cases as to fill the lateral or ditch above the weir to a level with its crest in twenty-four hours. Where this happened the velocity of approach became a disturbing factor, the influence of which could not be determined owing to the constant change of conditions. Some canal companies which employ weirs operate in connection therewith a sluicing device which removes the accumulated sediment once each day, but the objection to this is that the conditions are never stable and it is impossible to tell for what length of time weir tables used agreed with the actual discharge. The recent investigations in the flow of water over dams and over weirs, other than those with sharp edges, may aid in securing the adoption of a form of weir better suited to the sediment-laden waters of the Southwest than that employed, but so far as knife-edged weirs are concerned there are few ditches in that section where it is not possible to secure rating tables for flumes which will give much more reliable and accurate results. It was also found tnat in a number of canals the grades were too small and the banks too low to

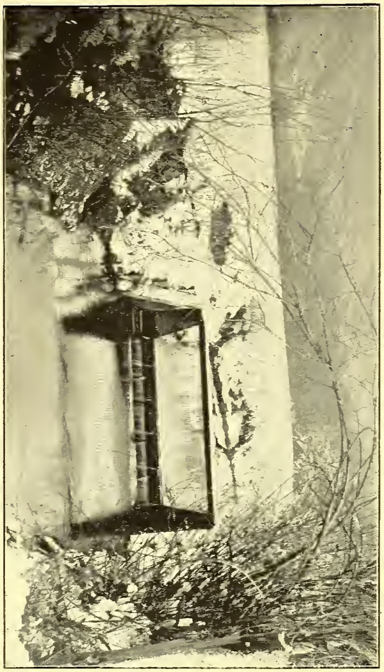


FIG. 1.—WEIR AT HEAD OF BIG DITCH, BIG COTTONWOOD CREEK, UTAH.

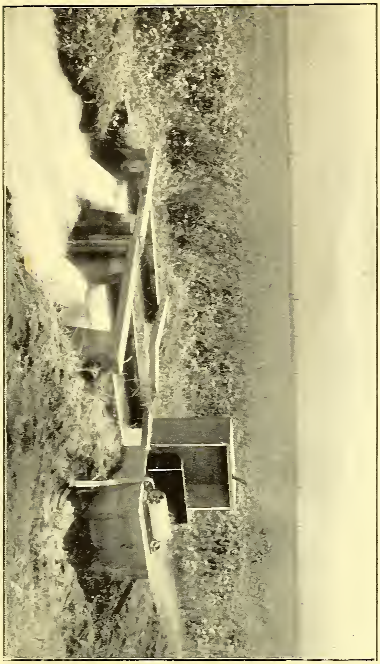


FIG. 2.—MEASURING WEIR AND REGISTER, MONTANA AGRICULTURAL EXPERIMENT STATION.

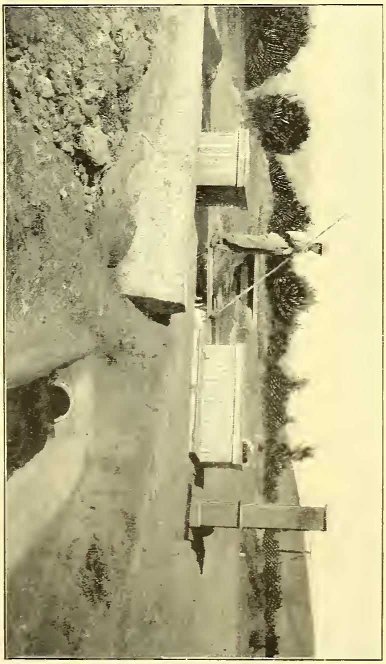


FIG. 3.—MEASURING FLUME AND REGISTER, GAGE CANAL, NEAR RIVERSIDE, CAL.

FIG. 4.—RATING FLUME NO. 1, KICKING BIRD CANAL, COLORADO.

secure the requisite fall below the weir, and in such cases flumes would not only be preferable, but an inevitable substitute.

The most serious objection to the use of flumes is the labor of preparing accurate rating tables, and the fact that a current meter is required for doing this. The recent improvements in these instruments, by which their convenience and accuracy have both been increased, has made it a simple matter to prepare a discharge table for flumes in which the flow is reasonably uniform. With ordinary care this discharge can be determined within the limits of accuracy permitted by the meter employed, and in the best instruments this error is as low as 1 per cent. This margin of error is below what is permissible in the delivery of water or attainable in this investigation.

THE UNIT OF MEASUREMENT EMPLOYED IN DISCUSSING THE DUTY OF WATER.

In the tables which follow the acre-foot is the unit of volume employed. This is, however, sometimes expressed by giving the equivalent depth to which the water used would have covered the surface irrigated.[1] This unit was chosen because it is definite and because it affords a convenient base for the comparison of quantities used in localities where the period of use was not the same.

It is usual in discussions of the duty of water to take a cubic foot per second as the unit of quantity and the period during which a crop requires water to bring it to maturity as the time during which the flow of that volume continues. Thus, when it is said that the duty of water is 60 or 80 acres to the cubic foot per second, the statement implies that the quantity of water used during the season had been measured and the average volume used during this season amounted to a cubic foot per second for each 60 or 80 acres irrigated. In order to make this expression definite, it is necessary that the duration of the irrigation period be known; but this varies so widely in actual practice and in different localities that it is difficult to compare the results obtained where both the volume used and the time of use are variables which have to be considered. Hence, the duration of the irrigation season or base, as it is often called, is usually assumed. In a number of discussions of this subject the assumed base for the Rocky Mountain regions has been taken as varying from one hundred to one hundred and fifty days. The records kept last year show, however, that water was used from the Gage Canal at Riverside, Cal., throughout the entire year, while the canal at Wheatland, Wyo., was only operated sixty days and water was used in irrigation a shorter time. Since the base or period of use varies so widely any attempt at fixing an average one would be wholly arbitrary. Even under the same

[1] This is really the reciprocal of the duty of an acre-foot, but its use is a convenience and involves no confusion of meaning.

canal the length of the season has to be assumed, because no two irrigators use water for the same length of time. The length of the irrigating period at the several stations is shown graphically in the accompanying diagrams (Pl. III). Nor does the assumption of a continuous flow accord with practice, because on many canals a system of rotation is already in operation in the delivery of water, and even where the contracts provide for a constant delivery it seldom happens that irrigators use water in this way. When, therefore, in practice 20 miner's or statutory inches are used on an acre for a day and none at all for the next twenty days it is misleading to discuss the duty as though a single inch had been used all the time. In nearly all of the Northern States fully three times as much water is used in July as in August. Hence, a discussion which deals with the delivery of water as though the use was uniform during this period is liable to lead to serious mistakes in practice.

By the use of the acre-foot as the unit of quantity, all of the arbitrary assumptions involved in the use of either the "inch" or the cubic foot per second are avoided, and its employment is equally correct and convenient whether the supply comes from streams, wells, or reservoirs, whether the use is continuous or intermittent, and whether it ends in two months or extends throughout the entire twelve. The flow of a cubic foot per second for twenty-four hours amounts to 1.98 acre-feet, so that the conversion of volumes from one unit to the other can be readily made.

SUMMARY OF MEASUREMENTS OF DUTY OF WATER.

The measurements made by observers show that the duties obtained vary from less than 1 acre-foot of water per acre irrigated to the use of over 15 acre-feet on an acre, but these wide and seemingly eccentric variations in the quantities used were the results of manifest causes. Where water was distributed through well-built ditches and used by careful irrigators there was a surprisingly close agreement in results, even in widely separated localities. The following table will serve to illustrate this:

Duty of water where measurements were made on small canals or laterals.

Location:	Acre-feet.
Cronquist farm, Utah	2.60
Long farm, Idaho	2.40
Gage Canal, California	2.24
Canal No. 2, Wyoming	2.53
Vance farm, Arizona	2.82
Biles Lateral, Colorado	[1] 1.82
Middle Creek Ditch, Montana	2.10
Daggett farm, Nebraska	2.47
Mean of all the above	2.37

[1] Low duty due in part to scanty supply of water.

DIAGRAM SHOWING DURATION OF IRRIGATION PERIOD ON MAIN CANALS INCLUDED IN INVESTIGATIONS.

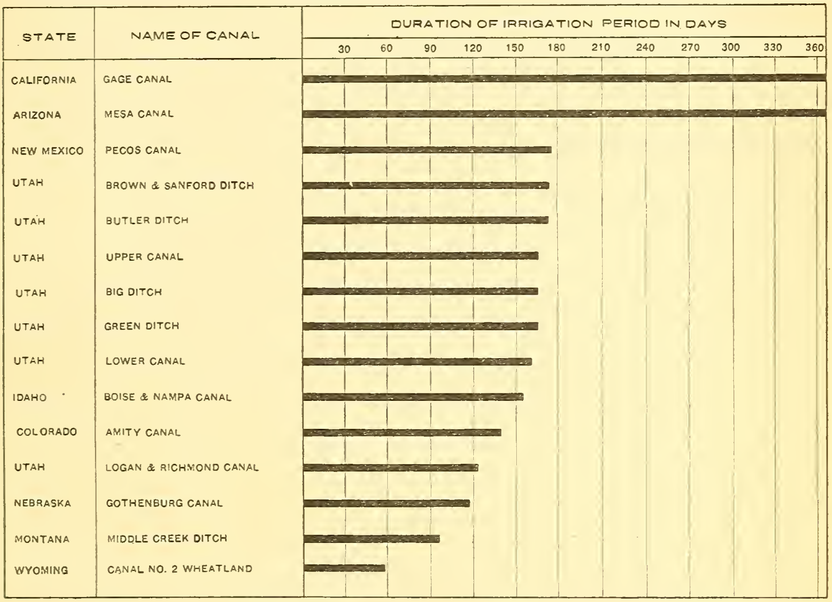
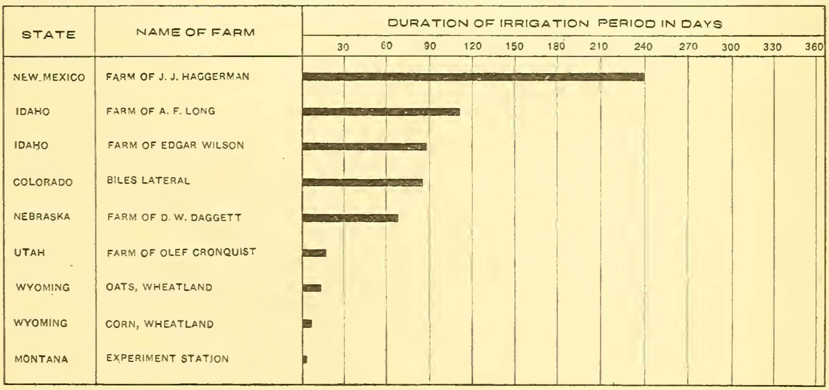


DIAGRAM SHOWING DURATION OF IRRIGATION ON FARMS WHERE WATER WAS MEASURED IN 1899.



DIAGRAMS SHOWING LENGTH OF IRRIGATION SEASON.

An interesting comparison with the above is afforded by the mean of the duties on all of the distributaries of the Ganges Canal for 1889–90, during the khareef season, as reported in Buckley's Irrigation Works in India. Here the mean volume of water used in the irrigation of an acre of land was 121,970 cubic feet, equal to 2.8 acre-feet for each acre irrigated.

Where the water was measured at the margin of the fields there was a still higher duty than where measured at the heads of the laterals. The following table shows the duty obtained where all losses in distribution were eliminated and nothing but the water actually spread over the fields was measured:

Duty of water where measurements were made at margin of fields.

Location:	Acre-feet.
J lateral, Wyoming, oats	1.55
J lateral, Wyoming, corn	.70
Farm, Edgar Wilson, Idaho	1.48
Lowest division, Gage Canal	1.78
Mean of measurements at Bozeman, Mont., Experiment Station	1.20

LOSSES OF WATER FROM CANALS.

The duties given in the foregoing tables were obtained on laterals, or on canals where the losses in transit were not large, and on fields where the water was measured at their margins. They therefore represent, approximately, the volume utilized. In practice, however, the losses in canals from percolation, leakage of flumes, evaporation, etc., are an important factor in fixing the average duty of water from a river or an extensive canal system. To determine this average duty the volume should be measured at the headgate, and the acres it irrigates is the duty which canal managers have to consider in determining the area their works will irrigate. This duty is much lower than that obtained by measurements made on laterals or at the margins of the fields where used, the influence of the losses between the headgate and the heads of laterals being greater than has usually been supposed. Where canals cross gravel beds or gypsum deposits the results closely resemble trying to carry water in a sieve. The following table gives the number of acre-feet used in the irrigation of an acre of land where the measurements were made at the canal headgates, and include the loss from seepage and evaporation:

Duty of water when losses in main canal are included.

Name of canal:	Acre-feet.
Pecos Canal, New Mexico	6.61
Mesa Canal, Arizona	3.81
Butler Ditch, Utah	6.24
Brown and Sanford Ditch, Utah	5.32
Upper Canal, Utah	6.30
Amity Canal, Colorado	4.92
Rust Lateral, Idaho	5.06
Average	5.47

A comparison of the duties in the above table with those obtained when the water was measured where used will show that more than twice as many acre-feet were required where the water was measured at the headgate as where measured at the place of use; or, in other words, the losses in the canals from seepage and evaporation amount to more than one-half the entire supply. This is in accord with many of the measurements made on irrigation canals in India. Among those recorded in Buckley's Irrigation Works in India is one which shows that the irrigation of wheat under the Jamda Canal, in Bombay, required 5.6 acre-feet of water for each acre irrigated where the water was measured at the head of the canal, but where the water was measured at the place of use it required, in two experiments, only 2.1 acre-feet and 1.4 acre-feet to irrigate an acre, the loss in the canal being more than 50 per cent. On the Hathmati Canal, in the same country, the loss from seepage and evaporation was 50 per cent. These losses in transit are much heavier than is the rule on the older canals of India, and are doubtless more general than they will be in this country when the banks of canals are older and when they are operated with greater regard for economy.

The report of Mr. Reed (p. 109) shows that 47.7 per cent of the water turned in at the head of the Pecos Canal reached the consumers, while 52.3 per cent was lost through seepage and evaporation. The causes of this loss are explained to be the checking of the velocity in the canal by dams in order to throw water on ground too high to be irrigated without this, certain defects in construction, and the nature of the soil in which the canal is built. The canal has a bank on one side only. This has produced stagnant lakes and pools on the upper side wherever the canal crosses ravines or where the ground on the upper side is so low that the water overflows it when the canal is filled. Mr. Reed's report also shows the variation in rate of seepage due to the character of the soil, three-fourths of the water entering one section of the canal 1 mile long being lost. To his summary of the causes of the great loss of water there may be added the fact that the water used in this canal is taken from reservoirs. Its temperature is already above that of most mountain streams, which facilitates alike its rapid filtration and evaporation. It is perfectly clear, owing to the fact that all of the sediment carried by the river is deposited in the reservoirs. This canal affords an illustration of a lower duty on a particular farm, measuring the water at its margin, than the average under the main canal, measuring the water near the headgates. Mr. Reed points out the causes for this, and shows that it does not illustrate the necessities of irrigation, but the possibilities of waste under encouraging conditions.

The water taken into the Mesa Canal during the four years that measurements have been made has varied from enough to cover the land to a depth of 5.9 feet in 1896 to 3.8 feet in 1899. A measurement was made in 1899 of the water used on a farm where the land had not before been irrigated and where more than the average amount of water was required. Owing to the fact that rotation was practiced on the lateral leading to this farm, it is impossible to determine the exact quantity lost in passing through it, but the water delivered at its head for this farmer would have covered the land to a depth of only 2.8 feet. The difference between the average depth under the main canal and the depth of water used on this farm was just 1 foot, or a difference in quantity of 1 acre-foot per acre irrigated. Mr. Code estimates that this difference would have been much larger if the loss in transit through the lateral had been determined. As it is, this shows a loss of over 25 per cent.

The construction of the Gage Canal is such as to make losses through seepage practically nothing, owing to the canal being cemented. The loss from evaporation is also small, because the canal is deep and narrow and has throughout its length a uniform cross section, with no pools of still water on the upper side. As compared to losses varying from 25 to 75 per cent shown in other canals, the loss of only 6 per cent in this canal has great significance. The water turned into the head would have served to cover the land irrigated to a depth of 2.24 feet, while the mean depth for the water delivered to irrigators' laterals was 2.11 feet, a loss of only 0.13 of an acre-foot per acre irrigated. Canals can only be cemented on earth, as is done in California, in localities where frosts in winter are not severe. There are other remedial measures which can be employed in other sections which will no doubt be largely adopted when the extent of the loss from this source is more generally realized. Dumping clay into the canal and causing it to be distributed by agitating the water has been tried with good results on some Nebraska ditches.

The report of the careful and interesting investigations of Professor Fortier at the Montana Agricultural Experiment Station shows that in the Middle Creek Canal nearly 22 per cent of the total flow was lost in seepage in the first 4 miles, while the probable loss in the entire canal was 35 per cent. The conclusions of Professor Fortier are in accord with those of other observers as to both the evils resulting from this loss and the methods by which it may be reduced.

The water taken into the Logan and Richmond Canal would cover the entire area it irrigates to a depth of 3.59 feet. The water actually used on the Cronquist farm would have covered it to a depth of only 2.6 feet, the difference between the average duty under the canal and the measured duty on one farm under it being nearly 1 acre-foot of water for each acre irrigated, or a difference of about 28 per cent. It is believed that this can be fairly taken as the loss resulting from seepage and evaporation in carriage.

The water entering the headgate of the Amity Canal in Colorado would have served to cover all of the land irrigated to a depth of 4.92 feet. The water delivered from the Biles Lateral would have covered the land under that lateral to a depth of only 1.82 feet. The difference between the average duty under the canal and the special duty under one lateral is 63 per cent. This seems to indicate that more than one-half of the water taken from the river disappears before it reaches the place of use. An examination of the map of the Amity Canal (Pl. XLI, p. 160) will show the reason for this excessive loss. The canal is a large, long one and much of the time last season was only partly filled. More than one-half of the time the water flowing through it was spread out in a broad, thin sheet, which reduced its velocity and gave abundant opportunity for the continuous sunshine to raise the temperature. This increase in temperature facilitated both its disappearance in the air and its filtration through the soil. Mr. Berry's report shows that the season of 1899 was unusually windy, making evaporation greater than usual.

Enough water was taken into Canal No. 2 at Wheatland, Wyo., to have covered all of the land irrigated to a depth of 2.53 feet, while only enough water was delivered through the J Lateral of that canal to cover the two fields on which the water used in irrigation was measured to a depth respectively of 0.7 and 1.55 feet, the apparent loss in the canal being one-half the water entering it. In this case this high rate of loss is what might have been expected. The canal is long. It traverses a steep hillside slope for 2 miles, in which distance the loss under the lower bank is excessive. In many places the bottom is gravel, through which water escapes freely.

In order to more carefully study the variations in these losses, arrangements were made early last season by Frank C. Kelsey, city engineer of Salt Lake City, Utah, to measure the seepage loss from the Jordan and Salt Lake Canal, from the Jordan River. This canal is 29 miles long, with a bottom width of 20 feet. It originally had a grade of 2 feet per mile, but when measured was in bad condition, with a flow of 30 cubic feet per second at the head. The loss in 29 miles was 45 per cent.[1]

The losses from seepage in new canals are excessive. For the past six months 500 inches of water have been flowing in at the head of a 10-mile lateral built at Billings, Mont., in 1899, but as yet not a drop has reached the lower end.[2] On a canal built in Salt River Valley, Wyoming, there was a loss in 1896 of 10 cubic feet per second in a distance of 100 feet, which continued for several weeks, with no apparent prospect of the loss diminishing. This was about one-third of the canal's flow. The canal was then abandoned. The canals which

---

[1] Letter, F. C. Kelsey, city engineer.

[2] Statement of I. D. O'Donnell, Billings, Mont.

take water from the North Platte River are all subject to excessive losses when first built, because of the sandy soil through which they must pass. In high water, however, this river is heavily charged with a white clay, due to the erosion of its banks. When this is deposited on the sides and bottom of ditches, it forms a coating only less impervious than cement, and after a few weeks' operation during high water seepage losses always show great diminution.

Mr. Code reports that the water of Salt River, Arizona, contains a cementing material which in time renders its banks almost water-tight, so long as they remain undisturbed. This has not heretofore been possible on the Mesa Canal because it has been undergoing constant repairs and improvements.

RELATION OF LOSSES IN TRANSIT TO THE AMOUNTS OF APPROPRIATIONS.

This loss from canals has given rise to a number of perplexing questions regarding appropriations. The States of Nebraska, Wyoming, and Idaho have fixed a maximum limit on the amount of water per acre which an appropriator can acquire. In two of these States no one is permitted to appropriate more than 1 cubic foot per second for each 70 acres irrigated. This limitation has given rise to the question as to whether the water so appropriated is to be measured at the margin of the irrigated field or at the head of the canal. Appropriators have claimed that if measured at the headgate the losses in the canal will be so great that the amount delivered will be inadequate for their needs; while water commissioners have insisted that it will be practically impossible to measure each appropriation at the head of the user's lateral. Several contests over this matter have already arisen and sooner or later an authoritative decision will have to be reached. In one instance no water is drawn from a canal for a distance of 11 miles below its head. Measurements were made to determine the loss in this distance and it was found to vary from 18 to 36 per cent. It was urged that this loss was so great that the amount turned into the canal should be increased enough to compensate therefor, but the State authorities refused to recognize this claim on the ground that such a concession would put an end to the improvement of ditches, since the greater the loss the larger the appropriation which would be secured and that its practical effect would be to place a premium on poor construction and wasteful operating of canals.

Much of the water which escapes from canals finds its way to the surface below in the form of springs in what were originally dry ravines. Irrigators have filed on these springs and secured thereby an ample water supply without having to pay the canal company which furnishes it anything for operating expenses or for the purchase of a water right. On the South Platte River alone there are over 400 of these filings on seepage waters. The report of the State engineer of Colorado for 1898 shows that 5,000 acres in the Poudre Valley were irrigated with seepage water in that year. In a number of instances canal companies have sought to establish a title to the water of these springs and to collect for its transportation from their users; but the decisions of the courts in these cases have been conflicting and no settled policy has as yet been established.

In some cases, where slopes are crossed by several canals, the lowest one frequently is benefited rather than injured by filtration, as it intercepts the water lost above. In one instance, where it is known that a large volume of seepage water is escaping from high line canals, a ditch has been cut parallel with the river bank, but some distance away from it, to intercept this percolating supply. This has led to litigation to determine whether or not this is an interference with the rights of prior appropriators below on the main stream.

The percolating water from canals and irrigated fields materially increases the water supply of Western rivers. Measurements of this return or seepage water have shown that this reaches in many instances 30 per cent of the original volume.

The serious losses from evaporation do not occur in the main canals, but from the fields where water is distributed. During midsummer the continuous sunshine heats the surface of the ground to a very high temperature. A test made last summer showed the surface soil in southern California to have a temperature of 120° F. When a thin layer of water is spread over land thus heated, as is frequently done where flooding is practiced, the loss from evaporation must be excessive. Mr. Reed discusses this in his report (p. 98), showing instances where it has become so great as to entirely absorb the volume supplied. Irrigators know by practice how much faster an irrigation head of water travels over fields at night and in the early morning than during the afternoon. This is due to the difference in the rate of evaporation. In order to lessen this loss it is important that fields be irrigated as quickly as possible. To this end each irrigator should be supplied with all the water he can distribute. Where only a small stream is used progress is slow; the soil next the laterals is supersaturated; it is hard work to reach the high spots while the low ones are overirrigated by the delay this causes. The contracts of the Gothenburg Canal in Nebraska agree to furnish 1 cubic foot per second for 80 acres, but in supplying the owners of small tracts their practice is to give to each patron a flow of and not less than 2 cubic feet per second and then shorten the time of delivery. Professor Stout, special agent in Nebraska, says this plan is much more satisfactory to farmers and to the canal company than to deliver a constant flow of a smaller volume.

INFLUENCE OF FLUCTUATIONS IN SUPPLY ON THE DUTY OBTAINED.

A low duty does not of necessity indicate a wasteful or unskillful use of water. An illustration of this is found on streams which furnish more water than can be used during the flood season, but where the period of plenty is followed by an equally assured period of drought. Irrigators have learned to provide against the latter by pouring on their land all the water it will hold while it can be had. By thus saturating the subsoil they store up a reserve supply which plants draw upon when the ditches fail. The report of Mr. Code deals with this practice, and the diagram of the flow of water in the Mesa Canal (Pl. VI, p. 72) shows graphically how marked is the scarcity during the hottest part of the year. It will be seen by examining this diagram that at the time when the most water would be used, if it could be had, less was actually used than at any other time in the season. That it is better to waste water on the land when there is a surplus than to let it escape down the river and have crops burn later in the season is beyond question, but the results of such irrigation are not nearly so satisfactory as they would be if this flood supply could be stored in reservoirs and be available for use when needed. Mr. Code's report shows clearly the necessity of reservoirs in localities like the Salt River Valley. They are needed to store the floods which now run to waste; they are needed to enable farmers to use water when crops demand moisture and to relieve them from the alternating floods and droughts, which dependence on the stream alone renders inevitable. No one can study Plate VI without realizing the injury to land and to crops which results from the fluctuating use which it discloses.

REQUIREMENTS OF DIFFERENT CROPS.

The instructions to farmers to use water as they had hitherto been in the habit of doing made the results show more clearly than they otherwise would the influence of waste in lowering the duty, and of care and skill in increasing it, but they also made it next to impossible to derive any certain conclusions as to the relative needs of different crops. It is known for example that less water is needed for corn than for alfalfa, but it is possible for a careless irrigator to waste more water on his cornfield than another uses on his alfalfa meadow, and this is what sometimes happens. It is also known that where economy prevails it requires less water for orchards than for alfalfa, and this is the general rule in these measurements; but in the case of Mr. Cronquist, in Utah (see p. 217), the orchard absorbed more water than either the meadow or grain field. This was due to waste in the lateral. It was a parallel case to one cited (p. 98) by Mr. Reed, who, in discussing the benefits of rapid distribution, showed how all the water entering a small lateral may be dissipated by seepage and evaporation. The study of the relative requirements of different crops demands special preparation and special methods. It is a line of work specially suited to the agricultural experiment stations of the arid States, where it is hoped it will receive increased attention.

THE RETURN RECEIVED FROM THE USE OF AN ACRE-FOOT OF WATER.

The following table, giving the return from the use of an acre-foot of water, was prepared by taking the prices received for the crops grown on an acre of land and dividing it by the water used in the irrigation of that land, the places chosen being taken from among those where water was measured:

Value of the crops matured for each acre-foot of water used.

Average of six crops in Montana	$18.42
Average for crops irrigated from Big Cottonwood Creek, Utah	6.34
Average for crops irrigated from Canal No. 2, Wheatland, Wyo	7.69
Average for crops irrigated from Mesa Canal, Arizona	3.37
Value of crop from almond orchard under Mesa Canal	30.00
Average for crops irrigated from Gage Canal, California:	
Farm No. 1	207.00
Farm No. 2	237.00
Farm No. 3	180.00

THE DIFFERENCE BETWEEN THE DUTY ASSUMED IN CANAL CONTRACTS AND THE DUTY FOUND BY THE YEAR'S MEASUREMENTS.

A comparison of the results of the year's measurements with the duty of water assumed in many important water-right contracts is interesting as showing their agreement with, or departure from, actual practice. Below is given the quantity of water agreed to be furnished by a number of canal companies:

ARIZONA.

Arizona Water Company.—Sells perpetual water rights for 0.83⅓ cubic feet per second, to be used on not to exceed 80 acres. This gives a duty of a little less than 100 acres per cubic foot per second, or a depth of 7.5 feet on the land irrigated.

Consolidated Canal Company.—Sells perpetual water rights for not to exceed one-third of a miner's inch per acre. This gives a duty of 120 acres per cubic foot per second, or a depth of 6 feet.

Rio Verde Canal Company.—This company sells water by quantity, agreeing to furnish sufficient water to cover land to a depth of 2 feet if it is called for, and more at the option of the company.

CALIFORNIA.

Gage Canal.—Allows 1 inch to 5 acres, or 1 cubic foot per second to 250 acres. This water is not delivered in a continuous flow, but in large streams for short periods, at the convenience of the consumer. This flow gives a depth of 2.89 feet.

COLORADO.

Larimer County Ditch.—Sells water rights for one six-hundredth of the capacity of the ditch, without specifying how much land is to be irrigated.

New Loveland and Greeley Irrigation and Land Company.—Sells one water right for each 80 acres, allowing a flow of 1.44 cubic feet per second. The Colorado law compels companies to furnish water from April 1 to November 1. For that length of season 1.44 cubic feet per second would cover 80 acres to a depth of 5.3 feet.

Platte Valley Irrigation Company.—Sells a water right for each 80 acres, allowing a flow of 1.44 cubic feet per second, or a depth of 5.3 feet.

Fort Morgan Land and Canal Company.—Sells a water right for each 80 acres, allowing a flow of not to exceed 1.44 cubic feet per second for the irrigating season, or a depth of 5.3 feet.

Arkansas River Land, Reservoir, and Canal Company.—Sells a water right for each 80 acres, allowing a flow of not to exceed 1.44 cubic feet per second, or a depth of 5.3 feet.

Dolores No. 2 Land and Canal Company.—Sells water by the cubic foot per second, without limiting the consumer as to the area which he may irrigate.

IDAHO.

Phyllis Canal.—Contracts provide that the amount of water delivered shall not at any time exceed an amount equivalent to 1 cubic foot per second for 50 acres, and that the total maximum quantity allowed shall not exceed 2 feet in depth on the land irrigated. Since 1899 will sell water by the cubic foot per second, with no limitations as to the area to be irrigated.

Boise and Nampa Canal.—Until 1899 delivered water at the rate of 1 miner's inch to the acre, but not to exceed 3 feet in depth on the land irrrigated. Since 1899 sells water by the cubic foot per second, with no limitations as to the area to be irrigated.

MONTANA.

Minnesota and Montana Land and Improvement Company.—Sells water by the miner's inch without regard to the area to be irrigated. For the season of 1899 the farmers under this company's canal ordered, on an average, 1 miner's inch for 3.77 acres, showing a duty of about 150 acres per cubic foot per second.

NEBRASKA.

North Platte Irrigation and Land Company.—Sells water rights for 1.44 cubic feet per second and describes land on which it shall be used.

Interstate Canal and Water Supply Company (Wyoming and Nebraska).—Agrees to furnish 1 inch per acre, or 1 cubic foot per second, for 50 acres. The legal season in Nebraska is 200 days, from April 15 to November 1. One cubic foot per second will cover 50 acres to a depth of 7.9 feet in that time.

NEW MEXICO.

Pecos Irrigation and Improvement Company.—Water-right contracts provide for the delivery of 43,560 cubic feet of water per acre, sufficient to cover the land to a depth of 1 foot, delivered at such times and in such quantities as may be necessary for the proper irrigation of crops.

TEXAS.

T. C. Purdy.—Water-right contracts call for the delivery of 43,560 cubic feet per acre, to be delivered in not more than 5 irrigations per annum.

WASHINGTON.

Yakima Investment Company.—Contracts to deliver not to exceed 1 cubic foot per second per 160 acres, from April 1 to October 31. This gives a depth of 2.65 feet.

WYOMING.

Wyoming Development Company.—Sells water rights giving the right to part of the total flow of canal.

Fetterman Canal Company.—Sells a water right for each 8 acres, allowing a flow of one-tenth cubic foot per second. Wyoming canals do not ordinarily run more than 60 days. In that time this flow would give a depth of 1.46 feet.

Cody Canal.—Shares represent water for 40 acres, and the quantity delivered is not to exceed one-half cubic foot per second. This gives a depth of 1.46 feet in 60 days.

In the following table is summarized the results of the actual meas urements of the duty of water:

Tabular summary of season's measurements of precipitation, evaporation, and duty of water.

Station.	Period during which water was used.	Rainfall.	Evaporation.	General duty.		Special measurements of duty.			Remarks.
				Depth of irrigation.	Depth of irrigation and rainfall.	Location.	Depth of irrigation.	Depth of irrigation and rainfall.	
		Feet.	*Feet.*	*Feet.*	*Feet.*		*Feet.*	*Feet.*	
Carlsbad, N. Mex.: Pecos Canal	Entire year	[1]10.31	4.55	6.26	6.57	Hagerman farm	15.44	15.75	Measurements carried on from April to October.
Mesa, Ariz., Mesa Canal:									
1896	do	.78		5.91	6.69				
1897	do	1.04		5.55	6.59				
1898	do	.57		5.01	5.58				
1899	do	.39		3.81	4.20				
Riverside, Cal.: Gage Canal	do	.47		2.24	2.71	District No. 1	2.32	2.79	
						District No. 2	2.23	2.70	
Salt Lake City, Utah:						District No. 3	1.78	2.25	
Butler Ditch	April–September	.49		6.24	6.73				
Brown & Sanford Ditch	do	.49		5.32	5.81				
Upper Canal	do	.49		6.30	6.79				
Green Ditch	do	.49		4.52	5.01				
Lower Canal	do	.49		2.83	3.32				
Big Ditch	do	.49		3.09	3.58				
Logan, Utah: Logan and Richmond Canal.	June–September	.27	3.27	3.59	3.86	Cronquist farm	2.60	2.87	
Lamar, Colo.: Amity Canal	March–September	.91		4.92	5.83	Biles lateral	1.82	2.50	Water used under Biles lateral April to September. Rainfall, Holly, Colo., 0.68 feet.
Gothenburg, Nebr.: Gothenburg Canal.	June 7–Sept. 30	1.26		2.57	3.83	Daggett farm	4.24	5.50	Rainfall April to September. Water used after harvest.
Wheatland, Wyo.: Canal No. 2.	June–August	.37	[2]1.26	2.53	2.90	J lateral:			
						Oats	1.55	1.92	
						Corn	.70	1.07	
Boise, Idaho: Boise and Nampa Canal.	May–September	.22				Rust lateral	5.06	5.28	
						A. F. Long farm	2.40	2.62	Rainfall at Boise.
						Wilson orchard	1.48	1.70	Do.
Bozeman, Mont.: Middle Creek Ditch.	June 16–Sept. 16	.42	[3]1.74	2.10	2.52	Station farm:			
						Clover	1.02	1.46	Rainfall, 0.44 foot.
						Peas	1.10	1.51	Rainfall, 0.41 foot.
						Grain	1.98	2.40	Rainfall, 0.42 foot.
						Barley	.98	1.39	Rainfall, 0.41 foot.
						Oats	1.53	1.91	Rainfall, 0.38 foot.
						Do	1.34	1.70	Rainfall, 0.36 foot.
						Do	2.16	2.52	Rainfall, 0.36 foot.
						Do	1.28	1.72	Rainfall, 0.44 foot.

[1] May 1 to November 11, 1899.

[2] Evaporation at Laramie, Wyo.

[3] Evaporation from July 6 to September 30.

NEED OF CONTINUING THE INVESTIGATION.

This report does not deal with all the factors which influence the duty of water, because time did not permit of their study. All of the arrangements for the work performed had to be made after the irrigation season in the South had begun. This included securing special agents, enlisting the cooperation of farmers, placing apparatus in ditches and canals, and in some cases the devising of special instruments. For these reasons the necessity for storage reservoirs has been left for subsequent study and discussion. The subject is of commanding importance, because it can not be considered apart from the fundamental question of who is to own or control the stored water, and what is to be the character of rights to store water from streams. Sooner than is generally realized the public or private ownership of Western rivers is destined to be one of the great social and industrial questions of this country. Their waters are worth more than the land, public or private, through which they flow, and the manner of their disposal will do more to shape Western civilization and promote or retard Western development than all other causes combined. The study of the duty of water is a study of the farmer's needs, and it is hoped that the presentation of these needs will tend to promote the creation of an irrigation system which will make the supplying of his necessities of first importance and be a matter of just pride to the nation.

COMPUTATION OF DISCHARGE RECORDS AND PREPARATION OF DIAGRAMS.

By C. T. Johnston,
Assistant in Irrigation Investigations.

From twenty to thirty stations were maintained during the irrigation season of 1899. From these weekly reports were forwarded to the writer at Cheyenne, where all computations were made under his supervision. The reports consisted primarily of register sheets giving the depth of water flowing in ditches and canals. Register No. 1, which has been described in another portion of the report, was generally employed in the work. Its sheets are 1 foot square, and are divided into time and feet divisions running at right angles to each other. The smallest time division is two hours, shown on a scale of one-eighth inch. The smallest depth or feet division is 0.02 of a foot, which permits the depths shown on the sheets being read to 0.01 foot with ease. The sheets begin with Saturday and run through the following Saturday, thus allowing half a day at each end of the week for the observer to visit the register, change the register sheet, and wind the clockwork. Weekly report cards, giving the depth of rainfall and such other information as would affect the use of water, were received with the register sheets.

COMPUTATIONS.

On September 15 five hundred register sheets were on file in the office. Each station was given a number, beginning with 1 in Texas and running west through New Mexico, Arizona, and California, east through Utah and Colorado, west including Nebraska, Wyoming, and Idaho, and finally terminating with Montana. As the sheets and cards were received they were dated and filed under their station number.

The register sheets give a continuous record of the depth of water passing through a flume or over a weir. The relation between these depths and the corresponding discharges is more or less complex, depending on the perfection of the measuring device. If a weir is used, the velocity of approach may make the relation more complicated, and in case of a rectangular weir the end contractions add difficulty to the computations. The Cippoletti weir has been generally adopted in the work. The relation between the depth and discharge is expressed by the formula $Q=3.3\frac{2}{3}Lh^{\frac{3}{2}}$, where Q is the discharge in cubic feet per second, L is the length of the crest of the weir in feet, and h is the depth of water flowing over the crest in feet. The only correction to be made when this weir is installed properly is for the velocity of approach. Whenever this exceeds one-half foot per second the results must be increased slightly. Where flumes are properly constructed they afford a simple means of measuring water, and the relation between the discharge and the corresponding depths is less complex than in case of weirs.

WEIR TABLES.

Tables giving the discharge of weirs of various lengths and depths have been prepared and published many times. None fill the requirements of this investigation, as the range of depths and lengths of the crests are not sufficient. It being impossible to compile from the various sources satisfactory tables, the preparation of new ones was undertaken. The tables were computed from the formula of the Cippoletti weir. They include weirs from 1 to 10 feet in length, and depths ranging from 0.01 foot to one-fifth the length of the weir. As some stations had used weirs 1.5 feet in length, it was included in the table. Table No. 2 was derived from Table No. 1 by dividing each discharge of the latter by 6.05. Table No. 2 is in acre-feet for a period of two hours. The divisor 6.05 is obtained from $\frac{43560}{7200}$, or the number of square feet in an acre divided by the number of seconds in two hours. Table number No. 2 has been used in the reduction of the register sheets, the smallest time division on which is two hours. The depth can be seen at a glance, and the corresponding discharge can be taken from the table. This table should prove of value to those having the measurement of water in charge, as it eliminates the time feature of the cubic foot per second and yet puts the results in a comprehensive unit.

Many rectangular weirs are already in existence and several agents have employed this type. It is often the more convenient form in large canals. Where the velocity of approach is not excessive and the grade of the canal will warrant it a weir can be installed in a flume or other structure. Often this can be done only when the section of the canal can not be reduced in width. By the use of a rectangular weir without end contractions this can be accomplished and approximate results obtained.

To enable the reports from such stations to be computed Tables Nos. 3, 4, 5, 6, and 7 have been prepared. The first two of these tables give the discharge of rectangular weirs without end contractions in cubic feet per second and acre-feet for two-hour periods. Tables 5 and 6 give the discharge of weirs with end contractions in the same units. Table 7 gives the discharge in both units of rectangular weirs without end contractions for each foot in width. The fourth column of this table contains the contraction correction in cubic feet per second.

TABLE 1.—*Discharges of Cippoletti weirs of different lengths, computed from the formula* $Q=3.3\frac{2}{3}\ Lh^{\frac{3}{2}}$.

Depth of water on crest.	1-foot weir.	1½-foot weir.	2-foot weir.	3-foot weir.	4-foot weir.	5-foot weir.	6-foot weir.	7-foot weir.	8-foot weir.	9-foot weir.	10-foot weir.
Feet.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*
0.01	0.0034	0.0051	0.0067	0.0101	0.0135	0.0168	0.0202	0.0236	0.0269	0.0303	0.0337
.02	.0095	.0143	.0190	.0286	.0381	.0476	.0571	.0667	.0762	.0857	.0952
.03	.0175	.0262	.0350	.0525	.0700	.0875	.1050	.1225	.1400	.1574	.1749
.04	.0269	.0404	.0539	.0808	.1077	.1347	.1616	.1885	.2155	.2424	.2693
.05	.0376	.0565	.0753	.1129	.1506	.1882	.2258	.2635	.3011	.3388	.3764
.06	.0495	.0742	.0990	.1484	.1979	.2474	.2969	.3464	.3958	.4453	.4948
.07	.0624	.0935	.1247	.1871	.2494	.3118	.3741	.4365	.4988	.5612	.6235
.08	.0762	.1143	.1524	.2285	.3047	.3809	.4571	.5333	.6095	.6856	.7618
.09	.0909	.1364	.1818	.2727	.3636	.4545	.5454	.6363	.7272	.8181	.9090
.10	.1065	.1597	.2129	.3194	.4259	.5323	.6388	.7452	.8517	.9582	1.0646
.11	.1228	.1842	.2457	.3685	.4913	.6141	.7370	.8598	.9826	1.1054	1.2283
.12	.1399	.2099	.2799	.4198	.5598	.6997	.8397	.9796	1.1196	1.2595	1.3995
.13	.1578	.2367	.3156	.4734	.6312	.7890	.9468	1.1046	1.2624	1.4202	1.5780
.14	.1764	.2645	.3527	.5291	.7054	.8818	1.0581	1.2345	1.4108	1.5872	1.7336
.15	.1956	.2934	.3912	.5868	.7823	.9779	1.1735	1.3691	1.5647	1.7603	1.9559
.16	.2155	.3232	.4309	.6464	.8619	1.0773	1.2928	1.5083	1.7237	1.9392	2.1547
.17	.2360	.3540	.4720	.7079	.9439	1.1799	1.4159	1.6519	1.8878	2.1238	2.3598
.18	.2571	.3857	.5142	.7713	1.0284	1.2855	1.5426	1.7997	2.0568	2.3139	2.5710
.19	.2788	.4182	.5576	.8365	1.1153	1.3941	1.6729	1.9518	2.2306	2.5094	2.7882
.20	.3011	.4517	.6022	.9034	1.2045	1.5056	1.8068	2.1079	2.4090	2.7101	3.0112
.21	.3240	.4860	.6480	.9720	1.2960	1.6199	1.9439	2.2679	2.5919	2.9159	3.2399
.22	.3474	.5211	.6948	1.0422	1.3896	1.7370	2.0844	2.4318	2.7792	3.1266	3.4740
.23	.3714	.5570	.7427	1.1141	1.4854	1.8568	2.2281	2.5995	2.9709	3.3422	3.7136
.24	.3958	.5938	.7917	1.1875	1.5834	1.9792	2.3750	2.7709	3.1667	3.5625	3.9584
.25	.4208	.6312	.8417	1.2625	1.6833	2.1042	2.5250	2.9458	3.3666	3.7875	4.2083
.26	.4463	.6695	.8927	1.3390	1.7853	2.2317	2.6780	3.1243	3.5707	4.0170	4.4633
.27	.4723	.7085	.9447	1.4170	1.8893	2.3617	2.8340	3.3063	3.7787	4.2510	4.7233
.28	.4988	.7482	.9976	1.4964	1.9952	2.4941	2.9929	3.4917	3.9905	4.4893	4.9881
.29	.5258	.7887	1.0515	1.5773	2.1031	2.6289	3.1546	3.6804	4.2062	4.7319	5.2577
.30	.5532	.8298	1.1064	1.6596	2.2128	2.7660	3.3192	3.8724	4.4256	4.9788	5.5320
.31	.5811	.8716	1.1622	1.7433	2.3244	2.9054	3.4865	4.0676	4.6487	5.2298	5.8109
.32	.6094	.9141	1.2189	1.8283	2.4377	3.0472	3.6566	4.2660	4.8754	5.4849	6.0943
.33	.6382	.9573	1.2764	1.9147	2.5529	3.1911	3.8293	4.4675	5.1058	5.7440	6.3822
.34	.6674	1.0012	1.3349	2.0023	2.6698	3.3372	4.0047	4.6721	5.3396	6.0070	6.6745
.35	.6971	1.0457	1.3942	2.0913	2.7884	3.4856	4.1827	4.8798	5.5769	6.2740	6.9711
.36	.7272	1.0908	1.4544	2.1816	2.9088	3.6360	4.3632	5.0904	5.8176	6.5448	7.2720
.37	.7577	1.1366	1.5154	2.2731	3.0308	3.7885	4.5463	5.3040	6.0617	6.8194	7.5771
.38	.7886	1.1830	1.5773	2.3659	3.1545	3.9432	4.7318	5.5204	6.3091	7.0977	7.8863
.39	.8200	1.2300	1.6399	2.4599	3.2799	4.0998	4.9198	5.7398	6.5597	7.3797	8.1997
.40	.8517	1.2776	1.7034	2.5551	3.4068	4.2585	5.1102	5.9619	6.8137	7.6654	8.5171
.41	.8838	1.3258	1.7677	2.6515	3.5354	4.4192	5.3031	6.1869	7.0708	7.9546	8.8384
.42	.9164	1.3746	1.8328	2.7491	3.6655	4.5819	5.4983	6.4146	7.3310	8.2474	9.1638
.43	.9493	1.4239	1.8986	2.8479	3.7972	4.7465	5.6958	6.6451	7.5944	8.5437	9.4930
.44	.9826	1.4739	1.9652	2.9478	3.9304	4.9130	5.8956	6.8782	7.8608	8.8434	9.8261
.45	1.0163	1.5244	2.0326	3.0489	4.0652	5.0815	6.0978	7.1141	8.1303	9.1466	10.1629
.46	1.0504	1.5755	2.1007	3.1511	4.2014	5.2518	6.3021	7.3525	8.4029	9.4532	10.5036
.47	1.0848	1.6272	2.1696	3.2544	4.3392	5.4240	6.5088	7.5936	8.6783	9.7631	10.8479
.48	1.1196	1.6794	2.2392	3.3588	4.4784	5.5980	6.7178	7.8372	8.9567	10.0764	11.1960
.49	1.1548	1.7321	2.3095	3.4643	4.6191	5.7738	6.9286	8.0834	9.2381	10.3929	11.5477
.50	1.1903	1.7854	2.3806	3.5709	4.7612	5.9515	7.1418	8.3321	9.5224	10.7127	11.9030
.51	....	1.8393	2.4524	3.6785	4.9047	6.1309	7.3571	8.5833	9.8095	11.0356	12.2618
.52	....	1.8936	2.5248	3.7873	5.0497	6.3121	7.5745	8.8370	10.0994	11.3618	12.6242
.53	....	1.9485	2.5980	3.8970	5.1961	6.4951	7.7941	9.0931	10.3921	11.6911	12.9901
.54	....	2.0039	2.6719	4.0079	5.3438	6.6798	8.0157	9.3517	10.6876	12.0236	13.3595
.55	....	2.0598	2.7465	4.1197	5.4929	6.8662	8.2394	9.6126	10.9859	12.3591	13.7323
.56	....	2.1163	2.8217	4.2326	5.6434	7.0543	8.4651	9.8760	11.2868	12.6977	14.1085
.57	....	2.1732	2.8976	4.3464	5.7953	7.2441	8.6929	10.1417	11.5905	13.0393	14.4881
.58	....	2.2307	2.9742	4.4613	5.9484	7.4355	8.9226	10.4097	11.8969	13.3840	14.8711
.59	....	2.2886	3.0515	4.5772	6.1029	7.6287	9.1544	10.6801	12.2059	13.7316	15.2573
.60	....	2.3470	3.1294	4.6940	6.2587	7.8234	9.3881	10.9527	12.5174	14.0821	15.6468
.61	....	2.4059	3.2079	4.8119	6.4159	8.0198	9.6238	11.2278	12.8317	14.4357	16.0396
.62	....	2.4654	3.2871	4.9307	6.5743	8.2178	9.8614	11.5050	13.1486	14.7921	16.4357
.63	....	2.5252	3.3670	5.0505	6.7340	8.4175	10.1009	11.7844	13.4679	15.1514	16.8349
.64	....	2.5856	3.4475	5.1712	6.8949	8.6187	10.3424	12.0661	13.7899	15.5136	17.2373
.65	....	2.6464	3.5286	5.2929	7.0572	8.8215	10.5857	12.3500	14.1143	15.8786	17.6429
.66	....	2.7077	3.6103	5.4155	7.2206	9.0258	10.8310	12.6361	14.4413	16.2465	18.0516
.67	....	2.7695	3.6927	5.5390	7.3854	9.2317	11.0781	12.9244	14.7707	16.6171	18.4634
.68	....	2.8317	3.7757	5.6635	7.5513	9.4392	11.3270	13.2148	15.1027	16.9905	18.8783
.69	....	2.8944	3.8593	5.7889	7.7185	9.6481	11.5778	13.5074	15.4370	17.3667	19.2963
.70	....	2.9576	3.9435	5.9152	7.8869	9.8586	11.8304	13.8021	15.7738	17.7456	19.7173
.71	....	3.0212	4.0283	6.0424	8.0565	10.0706	12.0848	14.0989	16.1130	18.1272	20.1413
.72	....	3.0852	4.1137	6.1705	8.2273	10.2842	12.3410	14.3978	16.4547	18.5115	20.5683
.73	....	3.1497	4.1997	6.2995	8.3993	10.4992	12.5990	14.6988	16.7987	18.8985	20.9983
.74	....	3.2147	4.2863	6.4294	8.5725	10.7156	12.8588	15.0019	17.1450	19.2881	21.4313
.75	....	3.2801	4.3734	6.5601	8.7469	10.9336	13.1203	15.3070	17.4937	19.6804	21.8671

TABLE 1.—*Discharges of Cippoletti weirs of different lengths, computed from the formula* $Q=3.3\frac{2}{3}\ Lh^{\frac{3}{2}}$—Continued.

Depth of water on crest.	1-foot weir.	1½-foot weir.	2-foot weir.	3-foot weir.	4-foot weir.	5-foot weir.	6-foot weir.	7-foot weir.	8-foot weir.	9-foot weir.	10-foot weir.
Feet.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*
0.76			4.4612	6.6918	8.9224	11.1530	13.3836	15.6142	17.8447	20.0753	22.3059
.77			4.5495	6.8243	9.0991	11.3738	13.6486	15.9233	18.1981	20.4729	22.7476
.78			4.6384	6.9577	9.2769	11.5961	13.9153	16.2345	18.5538	20.8730	23.1922
.79			4.7279	7.0919	9.4559	11.8198	14.1838	16.5477	18.9117	21.2757	23.6396
.80			4.8180	7.2270	9.6360	12.0450	14.4539	16.8629	19.2719	21.6809	24.0899
.81			4.9086	7.3629	9.8172	12.2715	14.7258	17.1801	19.6344	22.0887	24.5430
.82			4.9998	7.4997	9.9996	12.4995	14.9993	17.4992	19.9991	22.4990	24.9989
.83			5.0915	7.6373	10.1830	12.7288	15.2746	17.8202	20.3661	22.9118	25.4576
.84			5.1838	7.7757	10.3676	12.9595	15.5514	18.1433	20.7352	23.3271	25.9191
.85			5.2767	7.9150	10.5533	13.1916	15.8300	18.4683	21.1066	23.7449	26.3833
.86			5.3700	8.0551	10.7401	13.4251	16.1101	18.7952	21.4802	24.1652	26.8502
.87			5.4640	8.1960	10.9280	13.6599	16.3919	19.1239	21.8559	24.5879	27.3199
.88			5.5585	8.3377	11.1169	13.8961	16.6754	19.4546	22.2338	25.0131	27.7923
.89			5.6535	8.4802	11.3069	14.1337	16.9604	19.7872	22.6139	25.4406	28.2674
.90			5.7490	8.6235	11.4980	14.3726	17.2470	20.1216	22.9961	25.8706	28.7451
.91			5.8451	8.7677	11.6902	14.6128	17.5353	20.4579	23.3804	26.3030	29.2255
.92			5.9417	8.9126	11.8834	14.8543	17.8251	20.7960	23.7669	26.7377	29.7086
.93			6.0389	9.0583	12.0777	15.0971	18.1166	21.1360	24.1554	27.1748	30.1943
.94			6.1365	9.2048	12.2730	15.3413	18.4096	21.4778	24.5461	27.6143	30.6826
.95			6.2347	9.3520	12.4694	15.5867	18.7041	21.8214	24.9388	28.0561	31.1735
.96			6.3334	9.5001	12.6668	15.8335	19.0002	22.1669	25.3336	28.5003	31.6670
.97			6.4326	9.6489	12.8652	16.0815	19.2979	22.5142	25.7305	28.9468	32.1631
.98			6.5323	9.7985	13.0647	16.3309	19.5970	22.8632	26.1294	29.3956	32.6617
.99			6.6326	9.9489	13.2652	16.5815	19.8978	23.2141	26.5303	29.8467	33.1629
1.00			6.7333	10.1000	13.4667	16.8333	20.2000	23.5667	26.9333	30.3000	33.6667
1.01							20.5038	23.9211	27.3384	30.7556	34.1729
1.02							20.8090	24.2772	27.7454	31.2135	34.6817
1.03							21.1158	24.6351	28.1544	31.6737	35.1930
1.04							21.4240	24.9947	28.5654	32.1361	35.7067
1.05							21.7338	25.3561	28.9784	32.6007	36.2230
1.06							22.0450	25.7192	29.3933	33.0675	36.7417
1.07							22.3577	26.0840	29.8103	33.5365	37.2628
1.08							22.6719	26.4505	30.2291	34.0078	37.7864
1.09							22.9875	26.8187	30.6499	34.4812	38.3124
1.10							23.3045	27.1886	31.0727	34.9568	38.8409
1.11							23.6230	27.5602	31.4974	35.4346	39.3717
1.12							23.9430	27.9335	31.9240	35.9145	39.9050
1.13							24.2644	28.3084	32.3525	36.3965	40.4406
1.14							24.5872	28.6850	32.7829	36.8808	40.9786
1.15							24.9114	29.0633	33.2152	37.3671	41.5190
1.16							25.2370	29.4432	33.6494	37.8556	42.0617
1.17							25.5641	29.8248	34.0854	38.3461	42.6068
1.18							25.8925	30.2079	34.5234	38.8388	43.1542
1.19							26.2224	30.5928	34.9631	39.3335	43.7039
1.20							26.5536	30.9792	35.4048	39.8304	44.2560
1.21								31.3672	35.8483	40.3293	44.8103
1.22								31.7569	36.2936	40.8303	45.3670
1.23								32.1481	36.7407	41.3333	45.9259
1.24								32.5410	37.1897	41.8384	46.4871
1.25								32.9354	37.6405	42.3455	47.0506
1.26								33.3314	38.0931	42.8547	47.6163
1.27								33.7290	38.5474	43.3659	48.1843
1.28								34.1282	39.0036	43.8791	48.7545
1.29								34.5289	39.4616	44.3943	49.3270
1.30								34.9312	39.9213	44.9115	49.9017
1.31								35.3350	40.3829	45.4307	50.4786
1.32								35.7404	40.8461	45.9519	51.0577
1.33								36.1473	41.3112	46.4751	51.6390
1.34								36.5557	41.7780	47.0002	52.2225
1.35								36.9657	42.2465	47.5273	52.8081
1.36								37.3772	42.7168	48.0564	53.3960
1.37								37.7902	43.1888	48.5874	53.9860
1.38								38.2047	43.6625	49.1203	54.5781
1.39								38.6207	44.1380	49.6552	55.1725
1.40								39.0382	44.6151	50.1920	55.7689
1.41									45.0940	50.7307	56.3675
1.42									45.5746	51.2714	56.9682
1.43									46.0568	51.8139	57.5710
1.44									46.5408	52.3584	58.1760
1.45									47.0264	52.9047	58.7831
1.46									47.5138	53.4530	59.3922
1.47									48.0027	54.0031	60.0034
1.48									48.4934	54.5551	60.6168
1.49									48.9857	55.1089	61.2322
1.50									49.4797	55.6647	61.8496

TABLE 1.—*Discharges of Cippoletti weirs of different lengths, computed from the formula* $Q=3.3\frac{2}{3}\ Lh^{\frac{3}{2}}$—Continued.

Depth of water on crest.	1-foot weir.	1½-foot weir.	2-foot weir.	3-foot weir.	4-foot weir.	5-foot weir.	6-foot weir.	7-foot weir.	8-foot weir.	9-foot weir.	10-foot weir.
Feet.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*
1.51									49.9753	56.2222	62.4691
1.52									50.4726	56.7817	63.0907
1.53									50.9715	57.3429	63.7143
1.54									51.4720	57.9060	64.3400
1.55									51.9742	58.4710	64.9677
1.56									52.4780	59.0377	65.5975
1.57									52.9834	59.6063	66.2292
1.58									53.4904	60.1767	66.8630
1.59									53.9990	60.7489	67.4988
1.60									54.5092	61.3229	68.1365
1.61										61.8987	68.7763
1.62										62.4763	69.4181
1.63										63.0557	70.0618
1.64										63.6368	70.7075
1.65										64.2197	71.3553
1.66										64.8044	72.0049
1.67										65.3909	72.6566
1.68										65.9791	73.3101
1.69										66.5691	73.9657
1.70										67.1608	74.6231
1.71										67.7543	75.2825
1.72										68.3495	75.9439
1.73										68.9464	76.6071
1.74										69.5451	77.2723
1.75										70.1455	77.9394
1.76										70.7476	78.6084
1.77										71.3514	79.2793
1.78										71.9569	79.9521
1.79										72.5641	80.6268
1.80										73.1731	81.3034
1.81											81.9819
1.82											82.6622
1.83											83.3445
1.84											84.0285
1.85											84.7145
1.86											85.4023
1.87											86.0919
1.88											86.7834
1.89											87.4768
1.90											88.1720
1.91											88.8690
1.92											89.5678
1.93											90.2685
1.94											90.9709
1.95											91.6752
1.96											92.3813
1.97											93.0892
1.98											93.7989
1.99											94.5104
2.00											95.2237

TABLE 2.—*Discharges, in acre-feet for two-hour periods, of Cippoletti weirs of different lengths, computed from the formula* $Q=3.3\frac{2}{3}\ Lh^{\frac{3}{2}}$.

Depth of water on crest.	1-foot weir.	1½-foot weir.	2-foot weir.	3-foot weir.	4-foot weir.	5-foot weir.	6-foot weir.	7-foot weir.	8-foot weir.	9-foot weir.	10-foot weir.
Feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
0.01	0.0006−	0.0008+	0.0011+	0.0017−	0.0022+	0.0028−	0.0033+	0.0039−	0.0045−	0.0050+	0.0056−
.02	.0016−	.0024−	.0031+	.0047+	.0063−	.0079−	.0094+	.0110−	.0126−	.0142−	.0157+
.03	.0029−	.0043+	.0058−	.0087−	.0116−	.0145−	.0173+	.0202+	.0231+	.0260+	.0289+
.04	.0045−	.0067−	.0089+	.0134−	.0178+	.0223−	.0267+	.0312−	.0356+	.0401−	.0445+
.05	.0062+	.0093+	.0124+	.0187−	.0249−	.0311+	.0373+	.0436−	.0498−	.0560−	.0622+
.06	.0082−	.0123−	.0164−	.0245+	.0327+	.0409	.0491−	.0572+	.0654+	.0736+	.0818+
.07	.0103+	.0155−	.0206+	.0309+	.0412+	.0515+	.0618+	.0721+	.0824+	.0928−	.1031−
.08	.0126−	.0189−	.0252−	.0378−	.0504−	.0630−	.0755+	.0881+	.1007+	.1133+	.1259+
.09	.0150+	.0225+	.0300+	.0451−	.0601−	.0751+	.0901+	.1052−	.1202−	.1352+	.1502+
.10	.0176−	.0264−	.0352−	.0528−	.0704−	.0880−	.1056−	.1232−	.1408−	.1584−	.1760−
.11	.0203+	.0305−	.0406+	.0609+	.0812+	.1015+	.1218+	.1421+	.1624+	.1827+	.2030+
.12	.0231+	.0347−	.0463−	.0694−	.0925+	.1157−	.1388−	.1619+	.1851−	.2082−	.2313+
.13	.0261−	.0391+	.0522−	.0782+	.1043+	.1304+	.1565−	.1826−	.2087−	.2347+	.2608+
.14	.0291+	.0437+	.0583−	.0874+	.1166−	.1457+	.1749−	.2040+	.2332−	.2623+	.2915−
.15	.0323+	.0485−	.0647−	.0970−	.1293+	.1616+	.1940−	.2263−	.2586+	.2910−	.3233−
.16	.0356+	.0534+	.0712+	.1068+	.1425−	.1781−	.2137−	.2493+	.2849+	.3205+	.3561+
.17	.0390+	.0585+	.0780+	.1170+	.1560+	.1950+	.2340+	.2730+	.3120+	.3510+	.3900+
.18	.0425−	.0637+	.0850−	.1275−	.1700−	.2125−	.2550−	.2975−	.3400−	.3823−	.4250−
.19	.0461−	.0691+	.0922−	.1383−	.1843+	.2304+	.2765+	.3226+	.3687−	.4148−	.4609−
.20	.0498−	.0747−	.0995+	.1493+	.1991−	.2489−	.2986+	.3484+	.3982−	.4480−	.4977+
.21	.0536−	.0803+	.1071+	.1607−	.2142+	.2678−	.3213+	.3749−	.4284+	.4820−	.5355+
.22	.0574+	.0861+	.1148+	.1723−	.2297−	.2871+	.3445+	.4020−	.4594−	.5168−	.5742+
.23	.0614−	.0921−	.1228−	.1841+	.2455+	.3069+	.3683−	.4297−	.4911−	.5524+	.6138+
.24	.0654+	.0981+	.1309−	.1963−	.2617+	.3271+	.3926−	.4580−	.5234+	.5888+	.6543−
.25	.0696−	.1043+	.1391+	.2087−	.2782+	.3478−	.4174−	.4869+	.5565−	.6259+	.6956−
.26	.0738−	.1107−	.1475+	.2213+	.2951−	.3689−	.4426+	.5164+	.5902−	.6640−	.7377+
.27	.0781−	.1171+	.1561+	.2342+	.3123−	.3904−	.4684+	.5465−	.6246−	.7026+	.7807+
.28	.0824+	.1237−	.1649−	.2473+	.3298−	.4122+	.4947−	.5771+	.6596−	.7420+	.8245−
.29	.0869+	.1304−	.1738+	.2607+	.3476+	.4345+	.5214+	.6083+	.6952+	.7821+	.8690+
.30	.0914+	.1372−	.1829−	.2743+	.3658−	.4572−	.5486+	.6401−	.7315+	.8229+	.9144−
.31	.0960+	.1441−	.1921−	.2881+	.3842−	.4802+	.5763−	.6723+	.7684−	.8644+	.9605−
.32	.1007+	.1511−	.2015−	.3022−	.4029+	.5037−	.6044−	.7051+	.8059−	.9066−	1.0073+
.33	.1055−	.1582+	.2110−	.3165−	.4220−	.5275−	.6329+	.7384+	.8439+	.9494+	1 0549+
.34	.1103+	.1655−	.2206+	.3310−	.4413−	.5516+	.6619+	.7723−	.8826−	.9929−	1.1032+
.35	.1152+	.1728+	.2305−	.3457−	.4609+	.5761+	.6914−	.8066−	.9218+	1.0370+	1.1523−
.36	.1202−	.1803−	.2404−	.3606−	.4808−	.6010−	.7212−	.8414−	.9616−	1.0818−	1.2020−
.37	.1252+	.1879−	.2505−	.3757+	.5010−	.6262+	.7514+	.8767−	1.0019+	1.1272−	1.2524+
.38	.1304−	.1955+	.2607+	.3911−	.5214+	.6518−	.7821+	.9125−	1.0428+	1.1732−	1.3035+
.39	.1355+	.2033−	.2711−	.4066−	.5421+	.6777−	.8132−	.9487+	1.0843−	1.2198−	1.3553+
.40	.1408−	.2112−	.2816−	.4223+	.5631+	.7039−	.8447−	.9854+	1.1262+	1.2670+	1.4078−
.41	.1461−	.2191+	.2922−	.4383−	.5844−	.7305−	.8765+	1.0226+	1.1687+	1.3148+	1.4609+
.42	.1515−	.2272+	.3029+	.4544+	.6059−	.7573+	.9088+	1.0603−	1.2117+	1.3632+	1.5147−
.43	.1569+	.2354−	.3138+	.4707+	.6276+	.7845+	.9415−	1.0984−	1.2553−	1.4122−	1.5691−
.44	.1624+	.2436+	.3248+	.4872+	.6497−	.8121−	.9745−	1.1369−	1.2993+	1.4617+	1.6241+
.45	.1680−	.2520−	.3360−	.5039+	.6719+	.8399+	1.0079−	1.1759−	1.3439−	1.5118+	1.6798+
.46	.1736+	.2604+	.3472+	.5208+	.6945−	.8681−	1.0417+	1.2153−	1.3889+	1.5625+	1.7361+
.47	.1793+	.2690−	.3586+	.5379+	.7172+	.8965+	1.0758+	1.2551+	1.4344+	1.6137+	1.7930+
.48	.1851−	.2776−	.3701+	.5552−	.7402+	.9253−	1.1103+	1.2954+	1.4805−	1.6655+	1.8506−
.49	.1909−	.2863+	.3817+	.5726+	.7635−	.9544−	1.1452+	1.3361−	1.5270−	1.7178+	1.9087+
.50	.1967+	.2951+	.3935−	.5902+	.7870−	.9837+	1.1805−	1.3772+	1.5739+	1.7707−	1.9674+
.51	....	.3040+	.4053+	.6080+	.8107−	1.0134−	1.2160+	1.4187+	1.6214−	1.8241−	2.0267+
.52	....	.3130−	.4173+	.6260−	.8347−	1.0433+	1.2520−	1.4607−	1.6693+	1.8780−	2.0867−
.53	....	.3221−	.4294+	.6441+	.8589−	1.0736−	1.2883−	1.5030−	1.7177+	1.9324+	2.1471+
.54	....	.3312+	.4416+	.6625−	.8833−	1.1041−	1.3249+	1.5457+	1.7665+	1.9874−	2.2082−
.55	....	.3405−	.4540−	.6809+	.9079+	1.1349+	1.3619−	1.5889−	1.8158+	2.0428+	2.2698+
.56	....	.3498−	.4664−	.6996−	.9328−	1.1660−	1.3992−	1.6324−	1.8656−	2.0988−	2.3320−
.57	....	.3592+	.4789+	.7184+	.9579−	1.1974−	1.4368+	1.6763+	1.9158−	2.1553−	2.3947+
.58	....	.3687+	.4916+	.7374+	.9832+	1.2290+	1.4748+	1.7206+	1.9664+	2.2122+	2.4580+
.59	....	.3783−	.5044−	.7566−	1.0087+	1.2609+	1.5131+	1.7653+	2.0175−	2.2697−	2.5219−
.60	....	.3879+	.5173−	.7759−	1.0345+	1.2931+	1.5518−	1.8104−	2.0690+	2.3276+	2.5863−
.61	....	.3977−	.5302+	.7954−	1.0605−	1.3256−	1.5907+	1.8558+	2.1209+	2.3861−	2.6512−
.62	....	.4075−	.5433+	.8150−	1.0867−	1.3583+	1.6300−	1.9016+	2.1733+	2.4450−	2.7166+
.63	....	.4174−	.5565+	.8348−	1.1131−	1.3913+	1.6696−	1.9478+	2.2261+	2.5044−	2.7826+
.64	....	.4274−	.5698+	.8547+	1.1397+	1.4246−	1.7095−	1.9944+	2.2793+	2.5642+	2.8491+
.65	....	.4374+	.5832+	.8749−	1.1665−	1.4581−	1.7497+	2 0413+	2.3329+	2.6246−	2.9162−
.66	....	.4476−	.5967+	.8951+	1.1935−	1.4919−	1.7902+	2.0886+	2.3870−	2.6854−	2.9837+
.67	....	.4578−	.6104−	.9155+	1.2207+	1.5259+	1.8311−	2.1363−	2.4414+	2.7466+	3.0518+
.68	....	.4681−	.6241−	.9361+	1.2482−	1.5602−	1.8722+	2.1843−	2.4963+	2.8083+	3.1204−
.69	....	.4784+	.6379−	.9568+	1.2758−	1.5947+	1.9137−	2.2326+	2.5516−	2.8705+	3.1895−
.70	....	.4889−	.6518+	.9777+	1.3036+	1.6295+	1.9554+	2.2813+	2.6072+	2.9331+	3.2591−
.71	....	.4994−	.6658+	.9987+	1.3317−	1.6646−	1.9975−	2.3304−	2.6633+	2.9962+	3.3291+
.72	....	.5100−	.6799+	1.0199+	1.3599−	1.6999−	2.0398+	2.3798+	2.7198−	3.0598−	3.3997+
.73	....	.5206+	.6942−	1.0412+	1.3883+	1.7354−	2 0825−	2.4296−	2.7766+	3.1237+	3.4708−
.74	....	.5314−	.7085−	1.0627+	1.4169+	1.7712−	2.1254+	2.4796+	2.8339−	3.1881+	3.5424−
.75	....	.5422−	.7229−	1.0843+	1.4458−	1.8072+	2.1686+	2.5301−	2.8915+	3.2530−	3.6144+

TABLE 2.—*Discharges, in acre-feet for two-hour periods, of Cippoletti weirs of different lengths, computed from the formula* $Q=3.3\frac{2}{3}\ Lh^{\frac{3}{2}}$—Continued.

Depth of water on crest.	1-foot weir.	1½-foot weir.	2-foot weir.	3-foot weir.	4-foot weir.	5-foot weir.	6-foot weir.	7-foot weir.	8-foot weir.	9-foot weir.	10-foot weir.
Feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
0.76			0.7374−	1.1061−	1.4748−	1.8435−	2.2122−	2.5809−	2.9495+	3.3182+	3.6869+
.77			.7520−	1.1280−	1.5040−	1.8800−	2.2560−	2.6320−	3.0080−	3.3839+	3.7599+
.78			.7667−	1.1500+	1.5334−	1.9167+	2.3001−	2.6834−	3.0667+	3.4501−	3.8334+
.79			.7815−	1.1722+	1.5630−	1.9537−	2.3444+	2.7352−	3.1259+	3.5166+	3.9074−
.80			.7964−	1.1945+	1.5927+	1.9909+	2.3891−	2.7873−	3.1854+	3.5836+	3.9818+
.81			.8113+	1.2170+	1.6227−	2.0283+	2.4340+	2.8397−	3.2454−	3.6510+	4.0567−
.82			.8264+	1.2396+	1.6528+	2.0660+	2.4792+	2.8924+	3.3056+	3.7188+	4.1321−
.83			.8416−	1.2624−	1.6831+	2.1039+	2.5247+	2.9455+	3.3663−	3.7871−	4.2079−
.84			.8568+	1.2852+	1.7137−	2.1421−	2.5705−	2.9989−	3.4273+	3.8557+	4.2841+
.85			.8722−	1.3083−	1.7443+	2.1804+	2.6165+	3.0526+	3.4887−	3.9248−	4.3609−
.86			.8876+	1.3314+	1.7752+	2.2190+	2.6628+	3.1066+	3.5504+	3.9942+	4.4381−
.87			.9031+	1.3547+	1.8063−	2.2578+	2.7094+	3.1610−	3.6125+	4.0641+	4.5157−
.88			.9188−	1.3781+	1.8375+	2.2969−	2.7563−	3.2156+	3.6750+	4.1344−	4.5938−
.89			.9345−	1.4017−	1.8689+	2.3361+	2.8034−	3.2706+	3.7378+	4.2051−	4.6723−
.90			.9503−	1.4254−	1.9005+	2.3756+	2.8508−	3.3259−	3.8010+	4.2761+	4.7513−
.91			.9661+	1.4492−	1.9323−	2.4153+	2.8984−	3.3815−	3.8645+	4.3476−	4.8307−
.92			.9821+	1.4732−	1.9642+	2.4553−	2.9463+	3.4374−	3.9284+	4.4195−	4.9105+
.93			.9982−	1.4972+	1.9963+	2.4954−	2.9945−	3.4936−	3.9926+	4.4917+	4.9908−
.94			1.0143+	1.5215−	2.0286+	2.5358−	3.0429+	3.5501−	4.0572+	4.5644−	5.0715+
.95			1.0305+	1.5458−	2.0611−	2.5763+	3.0916−	3.6069−	4.1221+	4.6374−	5.1526+
.96			1.0468+	1.5703−	2.0937−	2.6171+	3.1405+	3.6639+	4.1874−	4.7108−	5.2342+
.97			1.0632+	1.5949−	2.1265−	2.6581+	3.1897+	3.7213+	4.2530−	4.7846−	5.3162+
.98			1.0797+	1.6196−	2.1595−	2.6993+	3.2392−	3.7790+	4.3189+	4.8588−	5.3986+
.99			1.0963−	1.6444+	2.1926−	2.7407+	3.2889−	3.8370+	4.3852−	4.9333+	5.4815−
1.00			1.1129+	1.6694+	2.2259−	2.7824−	3.3388+	3.8953+	4.4518−	5.0083−	5.5647+
1.01							3.3891−	3.9539−	4.5187+	5.0836−	5.6484+
1.02							3.4395+	4.0128−	4.5860+	5.1593−	5.7325+
1.03							3.4902+	4.0719+	4.6536+	5.2353+	5.8170+
1.04							3.5412−	4.1314−	4.7216−	5.3117+	5.9019+
1.05							3.5924−	4.1911−	4.7898+	5.3886−	5.9873−
1.06							3.6438+	4.2511+	4.8584+	5.4657+	6.0730+
1.07							3.6955−	4.3114+	4.9273+	5.5432+	6.1591+
1.08							3.7474+	4.3720−	4.9966−	5.6211+	6.2457−
1.09							3.7996−	4.4328+	5.0661+	5.6994−	6.3326+
1.10							3.8520−	4.4940−	5.1360−	5.7780−	6.4200−
1.11							3.9046+	4.5554+	5.2062−	5.8570−	6.5077+
1.12							3.9575+	4.6171+	5.2767−	5.9363−	6.5959−
1.13							4.0106+	4.6791−	5.3475+	6.0160−	6.6844−
1.14							4.0640−	4.7413+	5.4187−	6.0960−	6.7733+
1.15							4.1176−	4.8039−	5.4901+	6.1764−	6.8626+
1.16							4.1714+	4.8666+	5.5619−	6.2571+	6.9524−
1.17							4.2255−	4.9297+	5.6340−	6.3382+	7.0424+
1.18							4.2798−	4.9930+	5.7063+	6.4196+	7.1329+
1.19							4.3343−	5.0567−	5.7790+	6.5014+	7.2238−
1.20							4.3890+	5.1205+	5.8520+	6.5835+	7.3150+
1.21								5.1847−	5.9253+	6.6660−	7.4067−
1.22								5.2491−	5.9989+	6.7488+	7.4987−
1.23								5.3137+	6.0728+	6.8320−	7.5911−
1.24								5.3787−	6.1471−	6.9154+	7.6838+
1.25								5.4439−	6.2216−	6.9993−	7.7770−
1.26								5.5093+	6.2964−	7.0834+	7.8705−
1.27								5.5750+	6.3715−	7.1679+	7.9643+
1.28								5.6410+	6.4469−	7.2527+	8.0586+
1.29								5.7073−	6.5226−	7.3379−	8.1532+
1.30								5.7737+	6.5986−	7.4234−	8.2482+
1.31								5.8405−	6.6749−	7.5092+	8.3436−
1.32								5.9075−	6.7514+	7.5954−	8.4393−
1.33								5.9748−	6.8283−	7.6818+	8.5354−
1.34								6.0423−	6.9054+	7.7686+	8.6318+
1.35								6.1100+	6.9829−	7.8558−	8.7286+
1.36								6.1780+	7.0606+	7.9432+	8.8258−
1.37								6.2463+	7.1386+	8.0310−	8.9233+
1.38								6.3148+	7.2169+	8.1191−	9.0212−
1.39								6.3836−	7.2955+	8.2075−	9.1194+
1.40								6.4526	7.3744	8.2962	9.2180
1.41									7.4536−	8.3852+	9.3169+
1.42									7.5330−	8.4746+	9.4162+
1.43									7.6127−	8.5643−	9.5159−
1.44									7.6927−	8.6543−	9.6159−
1.45									7.7730−	8.7446−	9.7162+
1.46									7.8535+	8.8352−	9.8169−
1.47									7.9343+	8.9261+	9.9179+
1.48									8.0154+	9.0174−	10.0193−
1.49									8.0968+	9.1089+	10.1210+
1.50									8.1785−	9.2008−	10.2231−

TABLE 2.—*Discharges, in acre-feet for two-hour periods, of Cippoletti weirs of different lengths, computed from the formula* $Q=3.3\frac{2}{3}\ Lh^{\frac{3}{2}}$—Continued.

Depth of water on crest.	1-foot weir.	1½-foot weir.	2-foot weir.	3-foot weir.	4-foot weir.	5-foot weir.	6-foot weir.	7-foot weir.	8-foot weir.	9-foot weir.	10-foot weir.
Feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1.51	....	....	....	....	....	....	....	....	8.2604−	9.2929+	10.3255−
1.52	....	....	....	....	....	....	....	....	8.3426−	9.3854−	10.4282+
1.53	....	....	....	....	....	....	....	....	8.4250+	9.4782−	10.5313−
1.54	....	....	....	....	....	....	....	....	8.5078−	9.5712+	10.6347+
1.55	....	....	....	....	....	....	....	....	8.5908−	9.6646+	10.7385−
1.56	....	....	....	....	....	....	....	....	8.6740+	9.7583−	10.8426−
1.57	....	....	....	....	....	....	....	....	8.7576−	9.8523−	10.9470−
1.58	....	....	....	....	....	....	....	....	8.8414−	9.9466−	11.0517+
1.59	....	....	....	....	....	....	....	....	8.9255−	10.0411+	11.1568+
1.60	....	....	....	....	....	....	....	....	9.0098−	10.1360+	11.2622+
1.61	....	....	....	....	....	....	....	....	....	10.2312−	11.3680−
1.62	....	....	....	....	....	....	....	....	....	10.3267−	11.4741−
1.63	....	....	....	....	....	....	....	....	....	10.4224+	11.5805−
1.64	....	....	....	....	....	....	....	....	....	10.5185−	11.6872−
1.65	....	....	....	....	....	....	....	....	....	10.6148+	11.7943−
1.66	....	....	....	....	....	....	....	....	....	10.7115−	11.9016+
1.67	....	....	....	....	....	....	....	....	....	10.8084+	12.0093+
1.68	....	....	....	....	....	....	....	....	....	10.9056+	12.1174−
1.69	....	....	....	....	....	....	....	....	....	11.0032−	12.2257+
1.70	....	....	....	....	....	....	....	....	....	11.1010−	12.3344+
1.71	....	....	....	....	....	....	....	....	....	11.1991−	12.4434−
1.72	....	....	....	....	....	....	....	....	....	11.2974+	12.5527+
1.73	....	....	....	....	....	....	....	....	....	11.3961+	12.6623+
1.74	....	....	....	....	....	....	....	....	....	11.4951−	12.7723−
1.75	....	....	....	....	....	....	....	....	....	11.5943−	12.8825+
1.76	....	....	....	....	....	....	....	....	....	11.6938+	12.9931+
1.77	....	....	....	....	....	....	....	....	....	11.7936+	13.1040+
1.78	....	....	....	....	....	....	....	....	....	11.8937+	13.2152+
1.79	....	....	....	....	....	....	....	....	....	11.9941−	13.3267+
1.80	....	....	....	....	....	....	....	....	....	12.0947+	13.4386−
1.81	....	....	....	....	....	....	....	....	....	....	13.5507+
1.82	....	....	....	....	....	....	....	....	....	....	13.6632−
1.83	....	....	....	....	....	....	....	....	....	....	13.7759+
1.84	....	....	....	....	....	....	....	....	....	....	13.8890+
1.85	....	....	....	....	....	....	....	....	....	....	14.0024−
1.86	....	....	....	....	....	....	....	....	....	....	14.1161−
1.87	....	....	....	....	....	....	....	....	....	....	14.2301−
1.88	....	....	....	....	....	....	....	....	....	....	14.3444−
1.89	....	....	....	....	....	....	....	....	....	....	14.4590−
1.90	....	....	....	....	....	....	....	....	....	....	14.5739−
1.91	....	....	....	....	....	....	....	....	....	....	14.6891−
1.92	....	....	....	....	....	....	....	....	....	....	14.8046−
1.93	....	....	....	....	....	....	....	....	....	....	14.9204+
1.94	....	....	....	....	....	....	....	....	....	....	15.0365+
1.95	....	....	....	....	....	....	....	....	....	....	15.1529+
1.96	....	....	....	....	....	....	....	....	....	....	15.2696+
1.97	....	....	....	....	....	....	....	....	....	....	15.3866+
1.98	....	....	....	....	....	....	....	....	....	....	15.5040−
1.99	....	....	....	....	....	....	....	....	....	....	15.6216−
2.00	....	....	....	....	....	....	....	....	....	....	15.7395−

TABLE 3.—*Discharges, in cubic feet per second for two-hour periods, of rectangular weirs from 1 to 10 feet long, without end contractions, computed from the formula* $Q=3.33\ Lh^{\frac{3}{2}}$.

Depth of water on crest.	1-foot weir.	1½-foot weir.	2-foot weir.	3-foot weir.	4-foot weir.	5-foot weir.	6-foot weir.	7-foot weir.	8-foot weir.	9-foot weir.	10-foot weir.
Feet.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*
0.01	0.0033+	0.0050−	0.0067−	0.0100−	0.0133+	0.01665	0.0200−	0.0233+	0.0266+	0.0300−	0.0333
.02	.0094+	.0141+	.0188+	.0283−	.0377−	.0471−	.0565+	.0659+	.0753+	.0848−	.0942−
.03	.0173+	.0260−	.0346+	.0519+	.0692+	.0865+	.1038+	.1211+	.1384+	.1557+	.1730+
.04	.0266+	.0400−	.0533−	.0799+	.1066−	.1332	.1598+	.1865−	.2131+	.2398−	.2664
.05	.0372+	.0558+	.0745−	.1117−	.1489+	.1862−	.2234−	.2606+	.2978+	.3351−	.3723+
.06	.0489+	.0734+	.0979−	.1468+	.1958−	.2447+	.2936+	.3426−	.3915+	.4405−	.4894+
.07	.0617−	.0925+	.1233+	.1850+	.2467−	.3084−	.3700+	.4317+	.4934−	.5551−	.6167+
.08	.0753+	.1130+	.1507−	.2260+	.3014−	.3767+	.4521−	.5274+	.6028−	.6781+	.7535−
.09	.0899+	.1349−	.1798+	.2697+	.3596+	.44955	.5395−	.6294−	.7193−	.8092−	.8991
.10	.1053+	.1580−	.2106+	.3159+	.4212+	.5265+	.6318+	.7371+	.8424+	.9477+	1.0530+
.11	.1215−	.1822+	.2430−	.3645−	.4860−	.6074+	.7289+	.8504+	.9719+	1.0934−	1.2149−
.12	.1384+	.2076+	.2769−	.4153−	.5537+	.6921+	.8306−	.9690−	1.1074+	1.2458+	1.3843−
.13	.1561−	.2341+	.3122−	.4683−	.6243+	.7804+	.9365+	1.0926−	1.2487−	1.4048−	1.5608+
.14	.1744+	.2617−	.3489−	.5233+	.6977+	.8722−	1.0466+	1.2211−	1.3955−	1.5699+	1.7444−
.15	.1935−	.2902−	.3869+	.5804−	.7738+	.9673−	1.1607+	1.3542−	1.5476+	1.7411−	1.9346−
.16	.2131+	.3197−	.4262+	.6394−	.8525−	1.0656	1.2787+	1.4918+	1.7050−	1.9181−	2.1312
.17	.2334+	.3501+	.4668+	.7002+	.9336+	1.1670+	1.4005−	1.6339−	1.8673−	2.1007−	2.3341−
.18	.2543+	.3815−	.5086+	.7629+	1.0172+	1.2715+	1.5258+	1.7801+	2.0344+	2.2887+	2.5430+
.19	.2758−	.4137−	.5516−	.8274−	1.1032−	1.3789+	1.6547+	1.9305+	2.2063+	2.4821−	2.7579−
.20	.2978+	.4468−	.5957−	.8935+	1.1914−	1.4892+	1.7871−	2.0849+	2.3828−	2.6806−	2.9784+
.21	.3205−	.4807−	.6409+	.9614−	1.2818+	1.6023−	1.9228−	2.2432+	2.5637−	2.8841+	3.2046−
.22	.3436+	.5154+	.7872+	1.0309−	1.3745−	1.7181−	2.0617+	2.4053+	2.7490−	3.0926−	3.4362−
.23	.3673+	.5510−	.7346+	1.1019+	1.4693−	1.8366−	2.2039−	2.5712−	2.9385+	3.3058+	3.6731+
.24	.3915+	.5873−	.7831−	1.1746−	1.5661+	1.9576+	2.3492−	2.7407−	3.1322+	3.5237+	3.9153−
.25	.41625	.6244−	.8325	1.24875	1.6650	2.08125	2.4975	2.91375	3.3300	3.74625	4.1625
.26	.4415−	.6622+	.8829+	1.3244+	1.7659−	2.2074−	2.6488+	3.0903+	3.5318−	3.9733−	4.4147+
.27	.4672−	.7008−	.9344−	1.4016−	1.8687+	2.3359+	2.8031+	3.2703+	3.7375−	4.2047−	4.6719−
.28	.4934−	.7401−	.9868−	1.4801+	1.9735+	2.4669−	2.9603−	3.4537−	3.9470+	4.4404+	4.9338−
.29	.5200+	.7801−	1.0401−	1.5601+	2.0802−	2.6002+	3.1203−	3.6403+	4.1604−	4.6804+	5.2005−
.30	.5472−	.8208−	1.0943+	1.6415+	2.1887−	2.7359−	3.2830+	3.8302+	4.3774−	4.9246−	5.4717+
.31	.5748−	.8621+	1.1495+	1.7243−	2.2990+	2.8738+	3.4486−	4.0233+	4.5981−	5.1728+	5.7476+
.32	.6028−	.9042−	1.2056−	1.8084−	2.4112−	3.0140−	3.6168−	4.2196−	4.8224−	5.4251+	6.0279+
.33	.6313−	.9469+	1.2625+	1.8938+	2.5251−	3.1563+	3.7876+	4.4189−	5.0502−	5.6814+	6.3127−
.34	.6602−	.9903−	1.3204−	1.9805+	2.6407+	3.3009+	3.9611−	4.6213−	5.2814+	5.9416+	6.6018+
.35	.6895+	1.0343−	1.3790+	2.0686−	2.7581−	3.4476−	4.1371+	4.8266+	5.5162−	6.2057−	6.8952−
.36	.7193−	1.0789+	1.4386−	2.1578+	2.8771+	3.5964	4.3157−	5.0350−	5.7542+	6.4735+	7.1928
.37	.7495−	1.1242−	1.4989+	2.2484−	2.9978+	3.7473−	4.4967+	5.2462+	5.9957−	6.7451+	7.4946−
.38	.7800+	1.1701−	1.5601−	2.3401+	3.1202−	3.9002+	4.6803−	5.4603+	6.2404−	7.0204+	7.8004+
.39	.8110+	1.2166−	1.6221−	2.4331+	3.2442−	4.0552−	4.8662+	5.6773−	6.4883+	7.2993+	8.1104−
.40	.8424+	1.2636+	1.6849−	2.5273−	3.3697+	4.2122−	5.0546−	5.8970+	6.7394+	7.5819−	8.4243+
.41	.8742+	1.3113+	1.7484+	2.6227−	3.4969−	4.3711−	5.2453+	6.1195+	6.9937+	7.8680−	8.7422−
.42	.9064−	1.3596−	1.8128−	2.7192−	3.6256−	4.5320−	5.4384−	6.3448−	7.2512−	8.1576−	9.0640−
.43	.9390−	1.4084+	1.8779+	2.8169−	3.7558+	4.6948−	5.6338−	6.5727+	7.5117−	8.4506+	9.3896−
.44	.9719+	1.4579−	1.9438+	2.9157+	3.8876+	4.8595+	5.8314+	6.8033+	7.7752+	8.7471+	9.7190+
.45	1.0052+	1.5078+	2.0104+	3.0157−	4.0209−	5.0261+	6.0313+	7.0366−	8.0418−	9.0470+	10.0522+
.46	1.0389+	1.5584−	2.0778+	3.1168−	4.1557−	5.1946−	6.2335+	7.2724+	8.3113+	9.3503−	10.3892−
.47	1.0730−	1.6095−	2.1460−	3.2189+	4.2919+	5.3649−	6.4379−	7.5108+	8.5838+	9.6568+	10.7298−
.48	1.1074+	1.6611+	2.2148+	3.3222+	4.4296+	5.5370+	6.6444+	7.7518+	8.8592+	9.9666+	11.0740+
.49	1.1422−	1.7133−	2.2844−	3.4266−	4.5688−	5.71095	6.8531+	7.9953+	9.1375+	10.2797+	11.4219
.50	1.1773−	1.7660−	2.3547−	3.5320−	4.7093+	5.8867−	7.0640−	8.2413+	9.4187−	10.5960−	11.7733+
.51	....	1.8192+	2.4257−	3.6385−	4.8513+	6.0641+	7.2770−	8.4898+	9.7026+	10.9155−	12.1283−
.52	....	1.8730+	2.4973+	3.7460+	4.9947−	6.2434−	7.4920+	8.7407+	9.9894−	11.2381−	12.4867+
.53	....	1.9273−	2.5697+	3.8546−	5.1395−	6.4243+	7.7092−	8.9941−	10.2789+	11.5638−	12.8487−
.54	....	1.9821+	2.6428+	3.9642+	5.2856+	6.6070+	7.9284+	9.2498+	10.5712+	11.8926+	13.2140+
.55	....	2.0374+	2.7166−	4.0748+	5.4331+	6.7914−	8.1497−	9.5079+	10.8662+	12.2245−	13.5828−
.56	....	2.0932+	2.7910−	4.1865−	5.5820−	6.9774+	8.3729+	9.7684+	11.1639+	12.5594−	13.9549−
.57	....	2.1496−	2.8661−	4.2991+	5.7321+	7.1652−	8.5982+	10.0312+	11.4643−	12.8973+	14.3303+
.58	....	2.2064−	2.9418+	4.4127+	5.8836+	7.3546+	8.8255−	10.2964−	11.7673−	13.2382−	14.7091+
.59	....	2.2637−	3.0182+	4.5273+	6.0365−	7.5456−	9.0547−	10.5638+	12.0729+	13.5820+	15.0911+
.60	....	2.3215−	3.0953−	4.6429+	6.1906−	7.7382+	9.2859−	10.8335+	12.3812−	13.9288−	15.4764+
.61	....	2.3797+	3.1730−	4.7595−	6.3460−	7.9325−	9.5190−	11.1055−	12.6920−	14.2785−	15.8650−
.62	....	2.4385+	3.2513+	4.8770+	6.5027−	8.1283+	9.7540+	11.3797−	13.0053+	14.6310+	16.2567−
.63	....	2.4977+	3.3303+	4.9955−	6.6606+	8.3258−	9.9909+	11.6561−	13.3213−	14.9864+	16.6516−
.64	....	2.5574+	3.4099+	5.1149−	6.8198+	8.5248	10.2298−	11.9347+	13.6397−	15.3446+	17.0496
.65	....	2.6176+	3.4902−	5.2352+	6.9803+	8.7254−	10.4705−	12.2155+	13.9606+	15.7057−	17.4508−
.66	....	2.6783−	3.5710+	5.3565+	7.1420+	8.9275+	10.7130+	12.4985+	14.2840+	16.0695+	17.8550+
.67	....	2.7394−	3.6525−	5.4787+	7.3049+	9.1312−	10.9574+	12.7836+	14.6099−	16.4361+	18.2623+
.68	....	2.8009+	3.7345+	5.6018+	7.4691−	9.3364−	11.2036+	13.0709+	14.9382−	16.8054+	18.6727+
.69	....	2.8629+	3.8172+	5.7258+	7.6345−	9.5431−	11.4517−	13.3603−	15.2689+	17.1775+	19.0861+
.70	....	2.9254−	3.9005+	5.8508−	7.8010+	9.7513−	11.7015+	13.6518−	15.6020+	17.5523−	19.5025+
.71	....	2.9883−	3.9844−	5.9766−	7.9688−	9.9610−	11.9532−	13.9454−	15.9376−	17.9298−	19.9219+
.72	....	3.0516+	4.0689−	6.1033−	8.1377+	10.1722−	12.2066−	14.2410+	16.2754+	18.3099−	20.3443+

TABLE 3.—*Discharges, in cubic feet per second for two-hour periods, of rectangular weirs from 1 to 10 feet long, without end contractions, computed from the formula* $Q=3.33\ Lh^{\frac{3}{2}}$—Continued.

Depth of water on crest.	1-foot weir.	1½-foot weir.	2-foot weir.	3-foot weir.	4-foot weir.	5-foot weir.	6-foot weir.	7-foot weir.	8-foot weir.	9-foot weir.	10-foot weir.
Feet.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*
0.73		3.1154+	4.1539+	6.2309−	8.3078+	10.3848+	12.4618−	14.5387+	16.6157−	18.6927−	20.7696+
.74		3.1797−	4.2396−	6.3594−	8.4791+	10.5989+	12.7187+	14.8385−	16.9583−	19.0781−	21.1978+
.75		3.2443+	4.3258−	6.4887−	8.6516−	10.8145−	12.9774−	15.1403−	17.3032−	19.4661−	21.6290−
.76			4.4126+	6.6186+	8.8252+	11.0315+	13.2378+	15.4441+	17.6504+	19.8567+	22.0630+
.77			4.5000−	6.7500−	9.0000−	11.2499+	13.4999+	15.7499+	17.9999+	20.2499−	22.4999−
.78			4.5879+	6.8819−	9.1758+	11.4698+	13.7638−	16.0577+	18.3517−	20.6457−	22.9396+
.79			4.6764+	7.0147−	9.3529−	11.6911−	14.0293+	16.3675+	18.7057+	21.0440−	23.3822−
.80			4.7655+	7.1483−	9.5310+	11.9138−	14.2965+	16.6793−	19.0620+	21.4448−	23.8275+
.81			4.8551+	7.2827+	9.7103−	12.1378+	14.5654+	16.9930−	19.4206−	21.8481+	24.2757
.82			4.9453+	7.4180−	9.8907−	12.3633+	14.8360−	17.3086+	19.7813+	22.2540−	24.7266+
.83			5.0361−	7.5541−	10.0721+	12.5902−	15.1082−	17.6262+	20.1443−	22.6623−	25.1803+
.84			5.1274−	7.6910+	10.2547+	12.8184−	15.3821−	17.9457+	20.5094+	23.0731−	25.6368−
.85			5.2192−	7.8288−	10.4384−	13.0484−	15.6576−	18.2671+	20.8767+	23.4863+	26.0959+
.86			5.3116−	7.9673+	10.6231+	13.2789−	15.9347−	18.5905−	21.2462+	23.9020+	26.5578−
.87			5.4045−	8.1067+	10.8089+	13.5112−	16.2134+	18.9156+	21.6179−	24.3201+	27.0223+
.88			5.4979+	8.2469−	10.9958+	13.7448−	16.4938−	19.2427+	21.9917−	24.7406+	27.4896−
.89			5.5919−	8.3878+	11.1838−	13.9797+	16.7757−	19.5716+	22.3676−	25.1635+	27.9595−
.90			5.6864+	8.5296+	11.3728+	14.2160+	17.0592+	19.9024+	22.7456+	25.5888+	28.4320+
.91			5.7814+	8.6722−	11.5629−	14.4536+	17.3443+	20.2351−	23.1258−	26.0165−	28.9072+
.92			5.8770+	8.8155+	11.7540+	14.6925+	17.6310+	20.5695+	23.5080+	26.4465+	29.3850+
.93			5.9731−	8.9596+	11.9462−	14.9327+	17.9193−	20.9058−	23.8923+	26.8789−	29.8654+
.94			6.0697−	9.1045+	12.1394−	15.1742+	18.2090+	21.2439−	24.2787+	27.3136−	30.3484+
.95			6.1668−	9.2502−	12.3336−	15.4170−	18.5004−	21.5838−	24.6672−	27.7506−	30.8340−
.96			6.2644+	9.3966+	12.5288+	15.6611−	18.7933−	21.9255−	25.0577−	28.1899+	31.3221+
.97			6.3626−	9.5438+	12.7251+	15.9064−	19.0877−	22.2690−	25.4502+	28.6315+	31.8128−
.98			6.4612+	9.6918+	12.9224+	16.1530+	19.3836+	22.6142+	25.8448+	29.0754+	32.3060+
.99			6.5604−	9.8405+	13.1207+	16.4009−	19.6811−	22.9612+	26.2414+	29.5216−	32.8018−
1.00			6.6600	9.9900	13.3200	16.6500	19.9800	23.3100	26.6400	29.9700	33.3000
1.01							20.2804+	23.6605+	27.0406−	30.4207−	33.8007+
1.02							20.5824−	24.0128−	27.4432−	30.8736−	34.3040−
1.03							20.8858+	24.3668−	27.8477+	31.3287+	34.8097−
1.04							21.1907+	24.7225−	28.2543−	31.7861−	35.3178+
1.05							21.4971−	25.0799+	28.6628−	32.2456+	35.8285−
1.06							21.8049+	25.4391−	29.0732+	32.7074−	36.3415+
1.07							22.1142−	25.7999−	29.4856−	33.1713−	36.8570−
1.08							22.4249+	26.1624+	29.8999+	33.6374−	37.3749−
1.09							22.7371+	26.5266+	30.3161+	34.1057−	37.8952−
1.10							23.0507+	26.8925+	30.7343−	34.5761−	38.4179−
1.11							23.3658−	27.2601−	31.1543+	35.0486+	38.9429+
1.12							23.6822+	27.6293−	31.5763+	35.5233+	39.4704−
1.13							24.0001+	28.0001+	32.0001+	36.0002−	40.0002−
1.14							24.3194−	28.3726+	32.4259−	36.4791−	40.5323+
1.15							24.6401−	28.7468−	32.8534+	36.9601+	41.0668+
1.16							24.9622−	29.1225+	33.2829+	37.4433−	41.6036+
1.17							25.2857−	29.4999+	33.7142+	37.9285−	42.1428−
1.18							25.6105+	29.8789+	34.1474−	38.4158−	42.6842+
1.19							25.9368−	30.2596−	34.5824−	38.9052−	43.2280−
1.20							26.2644−	30.6418−	35.0192−	39.3966−	43.7740−
1.21								31.0256+	35.4578+	39.8901−	44.3223
1.22								31.4110+	35.8983+	40.3856−	44.8729−
1.23								31.7980+	36.3406−	40.8832−	45.4257+
1.24								32.1866−	36.7847−	41.3827+	45.9808+
1.25								32.5767+	37.2305+	41.8843+	46.5382−
1.26								32.9684+	37.6782−	42.3880−	47.0977+
1.27								33.3617−	38.1276+	42.8936−	47.6595+
1.28								33.7565−	38.5788+	43.4012−	48.2236−
1.29								34.1528+	39.0318+	43.9108−	48.7898−
1.30								34.5507+	39.4866−	44.4224−	49.3582−
1.31								34.9502−	39.9430+	44.9359+	49.9288+
1.32								35.3511+	40.4013−	45.4514+	50.5016−
1.33								35.7536−	40.8613−	45.9689+	51.0766−
1.34								36.1576−	41.3230−	46.4883+	51.6537−
1.35								36.5631−	41.7864−	47.0097−	52.2330−
1.36								36.9701+	42.2515+	47.5330−	52.8144+
1.37								37.3786+	42.7184+	48.0582+	53.3980+
1.38								37.7886+	43.1870−	48.5854−	53.9837+
1.39								38.2001−	43.6573−	49.1144+	54.5716−
1.40								38.6131−	44.1292+	49.6454−	55.1615+
1.41									44.6029−	50.1782+	55.7536−
1.42									45.0782+	50.7130−	56.3478−

Table 3.—*Discharges, in cubic feet per second for two-hour periods, of rectangular weirs from 1 to 10 feet long, without end contractions, computed from the formula* $Q=3.33\,Lh^{\frac{3}{2}}$—Continued.

Depth of water on crest.	1-foot weir.	1½-foot weir.	2-foot weir.	3-foot weir.	4-foot weir.	5-foot weir.	6-foot weir.	7-foot weir.	8-foot weir.	9-foot weir.	10-foot weir.
Feet.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*
1.43									45.5552+	51.2496+	56.9440+
1.44									46.0339+	51.7882−	57.5424
1.45									46.5143−	52.3286−	58.1428+
1.46									46.9963−	52.8708+	58.7454−
1.47									47.4799+	53.4149+	59.3499+
1.48									47.9653−	53.9609+	59.9566−
1.49									48.4522+	54.5087+	60.5653−
1.50									48.9408+	55.0584+	61.1760+
1.51									49.4310+	55.6099+	61.7888−
1.52									49.9229−	56.1632+	62.4036−
1.53									50.4163+	56.7184−	63.0204+
1.54									50.9114+	57.2754−	63.6393−
1.55									51.4081+	57.8341+	64.2602−
1.56									51.9064+	58.3947+	64.8830+
1.57									52.4063+	58.9571+	65.5079+
1.58									52.9078+	59.5213−	66.1348−
1.59									53.4109+	60.0873−	66.7636+
1.60									53.9156−	60.6550+	67.3945−
1.61										61.2245+	68.0273−
1.62										61.7958+	68.6620+
1.63										62.3689+	69.2988−
1.64										62.9437+	69.9375−
1.65										63.5203+	70.5781+
1.66										64.0986+	71.2207+
1.67										64.6787+	71.8652+
1.68										65.2605+	72.5117+
1.69										65.8441−	73.1601
1.70										66.4294−	73.8104+
1.71										67.0164−	74.4626+
1.72										67.6051−	75.1168−
1.73										68.1955+	75.7728+
1.74										68.7877−	76.4207+
1.75										69.3815+	77.0906−
1.76										69.9771−	77.7523−
1.77										70.5743+	78.4159+
1.78										71.1732+	79.0814−
1.79										71.7739−	79.7487+
1.80										72.3762−	80.4179+
1.81											81.0890+
1.82											81.7620−
1.83											82.4368−
1.84											83.1134−
1.85											83.7919−
1.86											84.4722−
1.87											85.1543+
1.88											85.8383−
1.89											86.5241−
1.90											87.2117−
1.91											87.9011−
1.92											88.5923+
1.93											89.2853+
1.94											89.9802−
1.95											90.6768−
1.96											91.3752
1.97											92.0754−
1.98											92.7774−
1.99											93.4811+
2.00											94.1866+

TABLE 4.—*Discharges, in acre-feet for two-hour periods, of rectangular weirs from 1 to 10 feet long, without end contractions, computed from the formula* $Q=3.33\ Lh^{\frac{3}{2}}$.

Depth of water on crest.	1-foot weir.	1½-foot weir.	2-foot weir.	3-foot weir.	4-foot weir.	5-foot weir.	6-foot weir.	7-foot weir.	8-foot weir.	9-foot weir.	10-foot weir.
Feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
0.01	0.0006−	0.0008+	0.0011+	0.0017−	0.0022+	0.0028−	0.0033+	0.0039−	0.0044+	0.0050−	0.0055+
.02	.0016−	.0023+	.0031+	.0047−	.0062+	.0078−	.0093+	.0109−	.0125−	.0140+	.0156−
.03	.0029−	.0043−	.0057+	.0086−	.0114+	.0143+	.0172−	.0200+	.0229−	.0257+	.0286+
.04	.0044+	.0066+	.0088+	.0132+	.0176+	.0220+	.0264+	.0308+	.0352+	.0396+	.0440+
.05	.0062−	.0092+	.0123+	.0185−	.0246+	.0308−	.0369+	.0431−	.0492+	.0554	.0615+
.06	.0081−	.0121+	.0162−	.0243−	.0324−	.0404+	.0485+	.0566+	.0647+	.0728+	.0809−
.07	.0102−	.0153−	.0204−	.0306−	.0408−	.0510−	.0612−	.0714−	.0816−	.0917+	.1019+
.08	.0125−	.0187−	.0249+	.0374−	.0498+	.0623−	.0747+	.0872−	.0996+	.1121−	.1245+
.09	.0149−	.0223−	.0297+	.0446−	.0594+	.0743+	.0892−	.1040+	.1189−	.1338−	.1486+
.10	.0174+	.0261+	.0348+	.0522+	.0696+	.0870+	.1044+	.1218+	.1392+	.1567−	.1741−
.11	.0201−	.0301+	.0402−	.0602+	.0803+	.1004+	.1205−	.1406−	.1606+	.1807+	.2008+
.12	.0229−	.0343+	.0458−	.0686+	.0915+	.1144+	.1373−	.1602−	.1830+	.2059+	.2288+
.13	.0258−	.0387−	.0516−	.0774−	.1032−	.1290−	.1548−	.1806−	.2064−	.2322−	.2580−
.14	.0288+	.0432+	.0577−	.0865−	.1153+	.1442−	.1730−	.2018+	.2307−	.2595−	.2883+
.15	.0320−	.0480−	.0640−	.0959+	.1279+	.1599−	.1919−	.2238+	.2558+	.2878−	.3198−
.16	.0352+	.0528+	.0705−	.1057−	.1409+	.1761+	.2114−	.2466−	.2818+	.3170+	.3523−
.17	.0386−	.0579−	.0772−	.1157+	.1543+	.1929+	.2315−	.2701−	.3086+	.3472+	.3858+
.18	.0420+	.0631−	.0841−	.1261+	.1681+	.2102−	.2522+	.2942+	.3363−	.3783+	.4203+
.19	.0456−	.0684−	.0912−	.1368−	.1823+	.2279+	.2735+	.3191−	.3647−	.4103−	.4558+
.20	.0492+	.0738+	.0985−	.1477−	.1969+	.2462−	.2954−	.3446+	.3938+	.4431−	.4923+
.21	.0530−	.0795−	.1059+	.1589+	.2119−	.2648+	.3178+	.3708−	.4237+	.4767+	.5297−
.22	.0568−	.0852−	.1136−	.1704−	.2272−	.2840−	.3408−	.3976−	.4544−	.5112−	.5680−
.23	.0607+	.0911−	.1214+	.1821+	.2429−	.3036−	.3643−	.4250−	.4857+	.5464+	.6071+
.24	.0647+	.0971−	.1294+	.1941+	.2589−	.3236−	.3883−	.4530+	.5177+	.5824+	.6472−
.25	.0688+	.1032+	.1276+	.2064+	.2752+	.3440+	.4128+	.4816+	.5504+	.6192+	.6880+
.26	.0730−	.1095−	.1459+	.2189+	.2919−	.3649−	.4378+	.5108−	.5838−	.6567+	.7297+
.27	.0772+	.1158+	.1544+	.2317−	.3089−	.3861+	.4633+	.5405+	.6178−	.6950−	.7722+
.28	.0816−	.1223+	.1631+	.2447−	.3262+	.4078−	.4893+	.5709−	.6524+	.7340−	.8155+
.29	.0860−	.1289+	.1719+	.2579−	.3438+	.4298−	.5157+	.6017+	.6877−	.7736+	.8596−
.30	.0904+	.1357−	.1809−	.2713+	.3618−	.4522+	.5427−	.6331−	.7235+	.8140−	.9044+
.31	.0950+	.1425+	.1900+	.2850+	.3800+	.4750+	.5700+	.6650+	.7600+	.8550+	.9500+
.32	.0996+	.1495−	.1993−	.2989+	.3985+	.4982−	.5978+	.6974+	.7971−	.8967+	.9964−
.33	.1043+	.1565+	.2087−	.3130+	.4174−	.5217+	.6261−	.7304−	.8347+	.9391−	1.0434+
.34	.1091+	.1637−	.2182+	.3274−	.4365−	.5456+	.6547+	.7638+	.8730−	.9821−	1.0912+
.35	.1140−	.1710−	.2279+	.3419+	.4559−	.5699−	.6838+	.7978−	.9118−	1.0257+	1.1397+
.36	.1189−	.1783+	.2378−	.3567−	.4756−	.5944+	.7133+	.8322+	.9511+	1.0700+	1.1889−
.37	.1239−	.1858+	.2478−	.3716+	.4955+	.6194−	.7433−	.8671+	.9910+	1.1149−	1.2388−
.38	.1289+	.1934−	.2579−	.3868−	.5157+	.6447−	.7736−	.9025+	1.0315−	1.1604−	1.2893+
.39	.1341−	.2011−	.2681+	.4022−	.5362+	.6703−	.8043+	.9384−	1.0724+	1.2065+	1.3406−
.40	.1392+	.2089−	.2785−	.4177+	.5570−	.6962+	.8355−	.9747+	1.1140−	1.2532+	1.3924+
.41	.1445−	.2167+	.2890−	.4335−	.5780−	.7225−	.8670−	1.0115−	1.1560−	1.3005−	1.4450−
.42	.1498+	.2247+	.2996+	.4495−	.5993−	.7491−	.8989+	1.0487+	1.1985+	1.3484−	1.4982−
.43	.1552−	.2328−	.3104−	.4656−	.6208−	.7760−	.9312−	1.0864−	1.2416−	1.3968	1.5520−
.44	.1606+	.2410−	.3213−	.4819+	.6426−	.8032+	.9639−	1.1245+	1.2852−	1.4458+	1.6065−
.45	.1662−	.2492+	.3323+	.4985−	.6646+	.8308−	.9969+	1.1631−	1.3292+	1.4954−	1.6615+
.46	.1717+	.2576−	.3434+	.5152−	.6859−	.8586+	1.0303+	1.2021−	1.3738−	1.5455−	1.7172+
.47	.1774−	.2660+	.3547+	.5321−	.7094+	.8868−	1.0641+	1.2415−	1.4188+	1.5962−	1.7735+
.48	.1830+	.2746−	.3661−	.5491+	.7322−	.9152+	1.0983−	1.2813−	1.4643+	1.6474−	1.8304+
.49	.1888−	.2832−	.3776−	.5664−	.7552−	.9440−	1.1328−	1.3215+	1.5103+	1.6991+	1.8879+
.50	.1946+	.2919+	.3892+	.5838+	.7784+	.9730+	1.1676+	1.3622+	1.5568+	1.7514+	1.9460+
.51	....	.3007+	.4009+	.6014+	.8019−	1.0023+	1.2028+	1.4033−	1,6037+	1.8042+	2.0047−
.52	....	.3096−	.4128−	.6192−	.8256−	1.0320−	1.2384−	1.4447+	1.6511+	1.8575+	2.0639+
.53	....	.3186−	.4247+	.6371+	.8495−	1.0619−	1.2742+	1.4866+	1.6990−	1.9114−	2.1237+
.54	....	.3276+	.4368+	.6552+	.8737−	1.0921−	1.3105−	1.5289−	1.7473+	1.9657+	2.1841+
.55	....	.3368−	.4490+	.6735+	.8980+	1.1225+	1.3471−	1.5716−	1.7961−	2.0206−	2.2451−
.56	....	.3460−	.4613+	.6920−	.9226+	1.1533−	1.3840−	1.6146+	1.8453−	2.0759+	2.3066−
.57	....	.3553−	.4737+	.7106−	.9475−	1.1843+	1.4212−	1.6581−	1.8949+	2.1318−	2.3687−
.58	....	.3647−	.4863−	.7294−	9725+	1.2156+	1.4588−	1.7019−	1.9450+	2.1881+	2.4313−
.59	....	.3742−	.4989−	.7483+	.9978−	1.2472+	1.4966+	1.7461−	1.9955+	2.2450−	2.4944+
.60	....	.3837+	.5116+	.7674+	1.0232+	1.2790+	1.5349−	1.7907−	2.0465−	2.3023−	2.5581−
.61	....	.3933+	.5245−	.7867−	1.0489+	1.3112−	1.5734−	1.8356+	2.0978+	2.3601−	2.6223+
.62	....	.4031−	.5374+	.8061+	1.0748+	1.3435+	1.6122+	1.8809+	2.1496+	2.4183+	2.6871−
.63	....	.4128−	.5505−	.8257−	1.1009+	1.3762−	1.6514−	1.9266+	2.2019−	2.4771−	2.7523+
.64	....	.4227+	.5636+	.8454+	1.1272+	1.4091−	1.6909−	1.9727−	2.2545−	2.5363+	2.8181+
.65	....	.4327−	.5769−	.8653+	1.1538−	1.4422+	1.7307−	2.0191−	2.3075+	2.5960−	2.8844+
.66	....	.4427−	.5902+	.8854−	1.1805−	1.4756+	1.7707+	2.0659−	2.3610−	2.6561+	2.9512+
.67	....	.4528−	.6037+	.9056−	1.2074+	1.5093−	1.8111+	2.1130−	2.4149−	2.7167+	3.0186−
.68	....	.4630−	.6173−	.9259+	1.2346−	1.5432+	1.8518+	2.1605−	2.4691+	2.7778−	3.0864+
.69	....	.4732+	.6309+	.9464+	1.2619−	1.5774−	1.8928+	2.2083+	2.5238−	2.8393−	3.1547+
.70	....	.4835+	.6447+	.9671−	1.2894+	1.6118−	1.9341+	2.2565−	2.5788+	2.9012+	3.2236−
.71	....	.4939+	.6586−	.9879−	1.3172−	1.6464+	1.9757+	2.3050+	2.6343+	2.9636−	3.2929−
.72	....	.5044+	.6725+	1.0088+	1.3451−	1.6813+	2.0176+	2.3539−	2.6902−	3.0264+	3.3627−
.73	....	.5149+	.6866−	1.0299−	1.3732−	1.7165−	2.0598−	2.4031−	2.7464−	3.0897−	3.4330−
.74	....	.5256−	.7008−	1.0511+	1.4015+	1.7519−	2.1023−	2.4526+	2.8030+	3.1534−	3.5038−
.75	....	.5363−	.7150+	1.0725+	1.4300+	1.7875+	2.1450+	2.5025+	2.8600+	3.2175+	3.5750+

TABLE 4.—*Discharges, in acre-feet for two-hour periods, of rectangular weirs from 1 to 10 feet long, without end contractions, computed from the formula* $Q=3.33\ Lh^{\frac{3}{2}}$—Cont'd.

Depth of water on crest.	1-foot weir.	1½-foot weir.	2-foot weir.	3-foot weir.	4-foot weir.	5-foot weir.	6-foot weir.	7-foot weir.	8-foot weir.	9-foot weir.	10-foot weir.
Feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
0.76			0.7294−	1.0940+	1.4587+	1.8234−	2.1881−	2.5527+	2.9174+	3.2821−	3.6468−
.77			.7438−	1.1157−	1.4876−	1.8595−	2.2314−	2.6033−	2.9752−	3.3471−	3.7190−
.78			.7583+	1.1375+	1.5167−	1.8958+	2.2750+	2.6542−	3.0333−	3.4125+	3.7917−
.79			.7730−	1.1594+	1.5459+	1.9324+	2.3189−	2.7054−	3.0919−	3.4783+	3.8648+
.80			.7877−	1.1815+	1.5754−	1.9692+	2.3631−	2.7569+	3.1507+	3.5446−	3.9384+
.81			.8025+	1.2038−	1.6050+	2.0063−	2.4075+	2.8088−	3.2100+	3.6113−	4.0125+
.82			.8174+	1.2261+	1.6348+	2.0435+	2.4522+	2.8609+	3.2696+	3.6783+	4.0870+
.83			.8324+	1.2486+	1.6648+	2.0810+	2.4972+	2.9134+	3.3296+	3.7458+	4.1620+
.84			.8475−	1.2712+	1.6950−	2.1187+	2.5425−	2.9662+	3.3900−	3.8137+	4.2375−
.85			.8627−	1.2940+	1.7254−	2.1567−	2.5880+	3.0194−	3.4507+	3.8820+	4.3134−
.86			.8779+	1.3169+	1.7559−	2.1949−	2.6338+	3.0728+	3.5118−	3.9507+	4.3897+
.87			.8933+	1.3400−	1.7866+	2.2333−	2.6799+	3.1266−	3.5732+	4.0199−	4.4665+
.88			.9087+	1.3631+	1.8175−	2.2719−	2.7262+	3.1806+	3.6350−	4.0894−	4.5437+
.89			.9243−	1.3864+	1.8486−	2.3107+	2.7728+	3.2350−	3.6971+	4.1593−	4.6214+
.90			.9399+	1.4099−	1.8798+	2.3498−	2.8197+	3.2897−	3.7596+	4.2296−	4.6995+
.91			.9556+	1.4334+	1,9112+	2.3890+	2.8668+	3.3446+	3.8224+	4.3002+	4.7781−
.92			.9714+	1.4571+	1.9428+	2.4285+	2.9142+	3.3999+	3.8856+	4.3713+	4.8570+
.93			.9873−	1.4809+	1.9746−	2.4682+	2.9619−	3.4555+	3.9491+	4.4428−	4.9364+
.94			1.0033−	1.5049−	2.0065+	2.5081+	3.0098−	3.5114−	4.0130+	4.5146+	5.0163−
.95			1.0193+	1.5290−	2.0386+	2.5483−	3.0579+	3.5676−	4.0772+	4.5869−	5.0965+
.96			1.0354+	1.5532−	2.0709−	2.5886+	3.1063+	3.6240+	4.1418−	4.6595−	5.1772+
.97			1.0517−	1.5775−	2.1033+	2.6292−	3.1550−	3.6808+	4.2067−	4.7325−	5.2583+
.98			1.0680−	1.6020−	2.1359+	2.6699+	3.2039+	3.7379−	4.2719−	4.8059−	5.3398+
.99			1.0844−	1.6265+	2.1687+	2.7109−	3.2531−	3.7952+	4.3374+	4.8796−	5.4218−
1.00			1.1008+	1.6512+	2.2017−	2.7521−	3.3025−	3.8529−	4.4033+	4.9537+	5.5041+
1.01							3.3521+	3.9108+	4.4695+	5.0282+	5.5869+
1.02							3.4020+	3.9691−	4.5361−	5.1031−	5.6701−
1.03							3.4522+	4.0276−	4.6029+	5.1783+	5.7537−
1.04							3.5026−	4.0864−	4.6701+	5.2539−	5.8377−
1.05							3.5532+	4.1454+	4.7376+	5.3299−	5.9221−
1.06							3.6041+	4.2048+	4.8055−	5.4062−	6.0069−
1.07							3.6552+	4.2644+	4.8737−	5.4829−	6.0921−
1.08							3.7066+	4.3244−	4.9421+	5.5599+	6.1777−
1.09							3.7582−	4.3846−	5.0109+	5.6373−	6.2637−
1.10							3.8100+	4.4450+	5.0800+	5.7151−	6.3501−
1.11							3.8621+	4.5058−	5.1495−	5.7932−	6.4368+
1.12							3.9144+	4.5668+	5.2192+	5.8716+	6.5240+
1.13							3.9670−	4.6281+	5.2893−	5.9504+	6.6116−
1.14							4.0197+	4.6897−	5.3596+	6.0296+	6.6996−
1.15							4.0727+	4.7515+	3.4303+	6.1091+	6.7879+
1.16							4.1260−	4.8136+	5.5013+	6.1890−	6.8766+
1.17							4.1794+	4.8760+	5.5726−	6.2692−	6.9657+
1.18							4.2331+	4.9387−	5.6442−	6.3497+	7.0552+
1.19							4.2871−	4.0016−	5.7161−	6.4306+	7.1451+
1.20							4.3412+	5.0648−	5.7883−	6.5118+	7.2354−
1.21								5.1282	5.8608	6.5934	7.3260
1.22								5.1919+	5.9336+	6.6753+	7.4170+
1.23								5.2559−	6.0067+	6.7575+	7.5084−
1.24								5.3201−	6.0801+	6.8401+	7.6001+
1.25								5.3846−	6.1538+	6.9230+	7.6923−
1.26								5.4493+	6.2278+	7.0063−	7.7848−
1.27								5.5143+	6.3021−	7.0898+	7.8776+
1.28								5.5796−	6.3767−	7.1738−	7.9708+
1.29								5.6451−	6.4515+	7.2580−	8.0644+
1.30								5.7109−	6.5267+	7.3425+	8.1584−
1.31								5.7769−	6.6022−	7.4274+	8.2527−
1.32								5.8432−	6.6779−	7.5126+	8.3474−
1.33								5.9097−	6.7539+	7.5982−	8.4424+
1.34								5.9765−	6.8302+	7.6840+	8.5378+
1.35								6.0435−	6.9068+	7.7702−	8.6336−
1.36								6.1108−	6.9837+	7.8567−	8.7297−
1.37								6.1783−	7.0609−	7.9435+	8.8261+
1.38								6.2461−	7.1383+	8.0306+	8.9229+
1.39								6.3141−	7.2161−	8.1181−	9.0201−
1.40								6.3823+	7.2941−	8.2058+	9.1176+
1.41									7.3724−	8.2939+	9.2155−
1.42									7.4509+	8.3823+	9.3137−
1.43									7.5298−	8.4710+	9.4122+
1.44									7.6089+	8.5600+	9.5111+
1.45									7.6883+	8.6493+	9.6104−
1.46									7.7680−	8.7390−	9.7100−
1.47									7.8479+	8.8289+	9.8099+
1.48									7.9281+	8.9192−	9.9102−
1.49									8.0086+	9.0097+	10.0108−
1.50									8.0894−	9.1006−	10.1117+

TABLE 4.—*Discharges, in acre-feet for two-hour periods, of rectangular weirs from 1 to 10 feet long, without end contractions, computed from the formula* $Q=3.33\ Lh^{\frac{3}{2}}$—Cont'd.

Depth of water on crest.	1-foot weir.	1½-foot weir.	2-foot weir.	3-foot weir.	4-foot weir.	5-foot weir.	6-foot weir.	7-foot weir.	8-foot weir.	9-foot weir.	10-foot weir.
Feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1.51	....	....	....	....	....	....	....	....	8.1704+	9.1917+	10.2130+
1.52	....	....	....	....	....	....	....	....	8.2517+	9.2832−	10.3146+
1.53	....	....	....	....	....	....	....	....	8.3333−	9.3749+	10.4166+
1.54	....	....	....	....	....	....	....	....	8.4151+	9.4670+	10.5189−
1.55	....	....	....	....	....	....	....	....	8.4972+	9.5594−	10.6215+
1.56	....	....	....	....	....	....	....	....	8.5796−	9.6520+	10.7245−
1.57	....	....	....	....	....	....	....	....	8.6622+	9.7450−	10.8278−
1.58	....	....	....	....	....	....	....	....	8.7451−	9.8382+	10.9314−
1.59	....	....	....	....	....	....	....	....	8.8282+	9.9318−	11.0353+
1.60	....	....	....	....	....	....	....	....	8.9117−	10.0256+	11.1396−
1.61	....	....	....	....	....	....	....	....	....	10.1198−	11.2442−
1.62	....	....	....	....	....	....	....	....	....	10.2142−	11.3491−
1.63	....	....	....	....	....	....	....	....	....	10.3089+	11.4543+
1.64	....	....	....	....	....	....	....	....	....	10.4039+	11.5599+
1.65	....	....	....	....	....	....	....	....	....	10.4992+	11.6658+
1.66	....	....	....	....	....	....	....	....	....	10.5948+	11.7720+
1.67	....	....	....	....	....	....	....	....	....	10.6907−	11.8786−
1.68	....	....	....	....	....	....	....	....	....	10.7869−	11.9854+
1.69	....	....	....	....	....	....	....	....	....	10.8833+	12.0926−
1.70	....	....	....	....	....	....	....	....	....	10.9801−	12.2001−
1.71	....	....	....	....	....	....	....	....	....	11.0771−	12.3079−
1.72	....	....	....	....	....	....	....	....	....	11.1744−	12.4160−
1.73	....	....	....	....	....	....	....	....	....	11.2720−	12.5244+
1.74	....	....	....	....	....	....	....	....	....	11.3699−	12.6332−
1.75	....	....	....	....	....	....	....	....	....	11.4680+	12.7422+
1.76	....	....	....	....	....	....	....	....	....	11.5665−	12.8516+
1.77	....	....	....	....	....	....	....	....	....	11.6652−	12.9613+
1.78	....	....	....	....	....	....	....	....	....	11.7642−	13.0713+
1.79	....	....	....	....	....	....	....	....	....	11.8634+	13.1816+
1.80	....	....	....	....	....	....	....	....	....	11.9630+	13.2922+
1.81	....	....	....	....	....	....	....	....	....	....	13.4031+
1.82	....	....	....	....	....	....	....	....	....	....	13.5144−
1.83	....	....	....	....	....	....	....	....	....	....	13.6259+
1.84	....	....	....	....	....	....	....	....	....	....	13.7377+
1.85	....	....	....	....	....	....	....	....	....	....	13.8499−
1.86	....	....	....	....	....	....	....	....	....	....	13.9623+
1.87	....	....	....	....	....	....	....	....	....	....	14.0751−
1.83	....	....	....	....	....	....	....	....	....	....	14.1881+
1.89	....	....	....	....	....	....	....	....	....	....	14.3015−
1.90	....	....	....	....	....	....	....	....	....	....	14.4152−
1.91	....	....	....	....	....	....	....	....	....	....	14.5291+
1.92	....	....	....	....	....	....	....	....	....	....	14.6434−
1.93	....	....	....	....	....	....	....	....	....	....	14.7579+
1.94	....	....	....	....	....	....	....	....	....	....	14.8728−
1.95	....	....	....	....	....	....	....	....	....	....	14.9879−
1.96	....	....	....	....	....	....	....	....	....	....	15.1033+
1.97	....	....	....	....	....	....	....	....	....	....	15.2191−
1.98	....	....	....	....	....	....	....	....	....	....	15.3351+
1.99	....	....	....	....	....	....	....	....	....	....	15.4514+
2.00	....	....	....	....	....	....	....	....	....	....	15.5680+

TABLE 5.—*Discharges, in cubic feet per second for two-hour periods, of rectangular weirs from 1 to 10 feet long, with two end contractions, computed from the formula* $Q=3.33 (L-.2H) h^{\frac{3}{2}}$.

Depth of water on crest.	1-foot weir.	1½-foot weir.	2-foot weir.	3-foot weir.	4-foot weir.	5-foot weir.	6-foot weir.	7-foot weir.	8-foot weir.	9-foot weir.	10-foot weir.
Feet.	Cu. ft. per sec.	Cu. ft. per sec.	Cu. ft. per sec.	Cu. ft. per sec.	Cu. ft. per sec.	Cu. ft. per sec.	Cu. ft. per sec.	Cu. ft. per sec.	Cu. ft. per sec.	Cu. ft. per sec.	Cu. ft. per sec.
0.01	0.0033+	0.0050−	0.0067−	0.0100−	0.0133+	0.0166+	0.0200−	0.0233+	0.0266+	0.0300−	0.0333−
.02	.0094−	.0141−	.0188−	.0282+	.0376+	.0471−	.0565−	.0659−	.0753+	.0847+	.0941+
.03	.0172−	.0259−	.0345+	.0518+	.0691+	.0864+	.1037+	.1210+	.1383+	.1556+	.1729+
.04	.0264+	.0397+	.0531−	.0797+	.1063+	.1330−	.1596+	.1863−	.2129+	.2395+	.2662−
.05	.0369−	.0555−	.0741−	.1113+	.1485+	.1858−	.2230+	.2602+	.2975−	.3347+	.3719+
.06	.0484−	.0728+	.0973−	.1462+	.1952−	.2441+	.2931−	.3420−	.3909+	.4399−	.4888+
.07	.0608+	.0916+	.1225−	.1842−	.2458+	.3075−	.3692−	.4308+	.4925+	.5542−	.6159−
.08	.0741+	.1118+	.1495−	.2248+	.3002−	.3755+	.4509−	.5262+	.6016−	.6769+	.7523−
.09	.0883−	.1332+	.1782+	.2681+	.3580+	.4479+	.5378+	.6278−	.7177−	.8076−	.7975−
.10	.1032−	.1558+	.2085+	.3138+	.4191+	.5244+	.6207+	.7350+	.8403+	.9456+	1.0509+
.11	.1188+	.1796−	.2403+	.3618−	.4833−	.6048−	.7263−	.8477+	.9692+	1.0907+	1.2122+
.12	.1351+	.2043+	.2735+	.4120−	.5504−	.6888+	.8272+	.9657−	1.1041−	1.2425+	1.3809+
.13	.1520+	.2301−	.3081+	.4642−	.6203−	.7764−	.9324+	1.0885+	1.2446+	1.4007+	1.5568−
.14	.1696−	.2568−	.3440−	.5184+	.6929−	.8673−	1.0417+	1.2162−	1.3906+	1.5650+	1.7395−
.15	.1877−	.2844−	.3811+	.5746−	.7680+	.9615−	1.1549+	1.3484−	1.5418+	1.7353−	1.9288−
.16	.2063+	.3129−	.4194+	.6325+	.8457−	1.0588−	1.2719+	1.4850+	1.6981+	1.9113−	2.1244−
.17	.2255−	.3422−	.4589−	.6923−	.9257+	1.1591+	1.3925+	1.6259+	1.8593+	2.0927+	2.3262−
.18	.2451+	.3723+	.4995−	.7538−	1.0081−	1.2624−	1.5167−	1.7710−	2.0253−	2.2796−	2.5339−
.19	.2653+	.4032+	.5411−	.8169−	1.0927−	1.3685−	1.6442+	1.9200+	2.1958+	2.4716+	2.7474−
.20	.2859+	.4349−	.5838−	.8816+	1.1795−	1.4773+	1.7752−	2.0730−	2.3708+	2.6687−	2.9665+
.21	.3070+	.4672+	.6275−	.9479+	1.2684−	1.5888+	1.9093−	2.2298−	2.5502+	2.8707−	3.1911+
.22	.3285+	.5003+	.6721+	1.0157+	1.3594−	1.7030−	2.0466−	2.3902+	2.7338+	3.0775−	3.4211−
.23	.3504+	.5341−	.7177+	1.0850+	1.4524−	1.8197−	2.1870−	2.5543−	2.9216+	3.2889+	3.6562+
.24	.3727+	.5685−	.7643−	1.1558−	1.5473+	1.9388+	2.3304−	2.7219−	3.1134+	3.5049+	3.8965−
.25	.3954+	.6036−	.8117−	1.2279+	1.6442−	2.0604+	2.4767−	2.8929+	3.3092−	3.7254+	4.1417−
.26	.4185+	.6393−	.8600−	1.3015−	1.7429+	2.1844+	2.6259−	3.0674−	3.5088+	3.9503+	4.3918−
.27	.4420−	.6756−	.9091+	1.3763+	1.8435+	2.3107+	2.7779−	3.2451−	3.7123−	4.1794+	4.6466+
.28	.4658−	.7124+	.9591+	1.4525+	1.9459−	2,4393−	2.9326+	3.4260+	3.9194+	4.4128−	4.9062−
.29	.4899−	.7499+	1.0099+	1.5300−	2.0500+	2.5701−	3.0901+	3.6102−	4.1302+	4.6502+	5.1703−
.30	.5143+	.7879+	1.0615+	1.6087−	2.1559−	2.7030+	3.2502+	3.7974−	4.3446−	4.8917+	5.4389+
.31	.5391+	.8265+	1.1139−	1.6886+	2.2634+	2.8382−	3.4129+	3.9877−	4.5624+	5.1372+	5.7120−
.32	.5642+	.8656+	1.1670+	1.7698+	2.3726−	2.9754−	3.5782−	4.1810−	4.7838−	5.3866−	5.9894−
.33	.5896+	.9052+	1.2209−	1.8521+	2.4834+	3.1147−	3.7460−	4.3772+	5.0085−	5.6398−	6.2710+
.34	.6153−	.9454−	1.2755−	1.9356+	2.5958+	3.2560+	3.9162−	4.5764−	5.2366−	5.8967+	6.5569+
.35	.6413−	.9860+	1.3308−	2.0203−	2.7098+	3.3993+	4.0888+	4.7784−	5.4679−	6.1574+	6.8469+
.36	.6675−	1.0271+	1.3868−	2.1061−	2.8253+	3.5446+	4.2639−	4.9832−	5.7025−	6.4217+	7.1410+
.37	.6940−	1.0687+	1.4435−	2.1929+	2.9424−	3.6918+	4.4413−	5.1907+	5.9402−	6.6897−	7.4391+
.38	.7208−	1.1108−	1.5008+	2.2809−	3.0609−	3.8409+	4.6210−	5.4010+	6.1811−	6.9611+	7.7412−
.39	.7478−	1.1533−	1.5588+	2.3699−	3.1809−	3.9919+	4.8030−	5.6140+	6.4250+	7.2361−	8.4471+
.40	.7750+	1.1963−	1.6175−	2.4599−	3.3023+	4.1448−	4.9872−	5.8296+	6.6721−	7.5145−	8.3569+
.41	.8025+	1.2396+	1.6768−	2.5510−	3.4252−	4.2994+	5.1736+	6.0478+	6.9221−	7.7963−	8.6705−
.42	.8303−	1.2835−	1.7367−	2.6431−	3.5494+	4.4558+	5.3622+	6.2686+	7.1750+	8.0814+	8.9878+
.43	.8582+	1.3277−	1.7972−	2.7361+	3.6751−	4.6140+	5.5530+	6.4920−	7.4309+	8.3699−	9.3088+
.44	.8864−	1.3723+	1.8583−	2.8302−	3.8021−	4.7740−	5.7459−	6.7178−	7.6897+	8.6616+	9.6335+
.45	.9148−	1.4174−	1.9200−	2.9252+	3.9304+	4.9357−	5.9409−	6.9461+	7.9513+	8.9565+	9.9618−
.46	.9433+	1.4628−	1.9823−	3.0212−	4.0601−	5.0990+	6.1379+	7.1768+	8.2158−	9.2547−	10.2936−
.47	.9721+	1.5086+	2.0451−	3.1181−	4.1911−	5.2640+	6.3370+	7.4100−	8.4830−	9.5559+	10.6289+
.48	1.0011−	1.5548−	2.1085−	3.2159+	4.3233+	5.4307+	6.5381+	7.6455+	8.7529+	9.8603+	10.9677+
.49	1.0303−	1.6014−	2.1724+	3.3146+	4.4568+	5.5990+	6.7412+	7.8834−	9.0256−	10.1678−	11.3100−
.50	1.0596−	1.6483−	2.2369+	3.4143−	4.5916−	5.7689+	6.9463−	8.1236−	9.3009+	10.4783−	11.6556−
.51	....	1.6955+	2.3019+	3.5148−	4.7276+	5.9404+	7.1533−	8.3661−	9.5789+	10.7918−	12.0046−
.52	....	1.7431+	2.3675−	3.6162−	4.8648+	6.1135+	7.3622−	8.6109−	9.8595+	11.1082+	12.3569−
.53	....	1.7911+	2.4335+	3.7184+	5.0033−	6.2881+	7.5730+	8.8579−	10.1427+	11.4276+	12.7125−
.54	....	1.8394−	2.5001−	3.8215−	5.1429−	6.4643−	7.7857−	9.1071+	10.4285+	11.7499+	13.0713+
.55	....	1.8880+	2.5671+	3.9254+	5.2837−	6.6420−	8.0003−	9.3585+	10.7168+	12.0751−	13.4334−
.56	....	1.9369+	2.6347−	4.0302−	5.4257−	6.8211+	8.2166+	9.6121+	11.0076+	12.4031+	13.7986−
.57	....	2 9862−	2.7027+	4.1357+	5.5688−	7.0018+	8.4348+	9.8679−	11.3009+	12.7339+	14.1670−
.58	....	2.0357+	2.7712−	4.2421+	5.7130+	7.1839+	8.6548+	10.1257+	11.5967−	13.0676−	14.5385−
.59	....	2.0856−	2.8402−	4.3493−	5.8584−	7.3675−	8.8766+	10.3857+	11.8948+	13.4040−	14.9131−
.60	....	2.1357+	2.9096−	4.4572+	6.0049−	7.5525+	9.1001+	10.6478−	12.1954+	13.7431−	15.2907+
.61	....	2.1862−	2.9794+	4.5659+	6.1524+	7.7389+	9.3254+	10.9119+	12.4984+	14.0849+	15.6714+
.62	....	2.2369+	3.0498−	4.6754+	6.3011−	7.9268−	9.5524+	11.1781−	12.8038−	14.4294+	16.0551−
.63	....	2.2879+	3.1205+	4.7857−	6.4508+	8.1160−	9.7811+	11.4463−	13.1114+	14.7766−	16.4418−
.64	....	2.3392+	3.1917−	4.8966+	6.6016+	8.3066−	10.0115+	11.7165−	13.4214+	15.1264+	16.8314−
.65	....	2.3908−	3.2633−	5.0084−	6.7534+	8.4985+	10.2436−	11.9887−	13.7337+	15.4788+	17.2239−
.66	....	2.4426−	3.3353+	5.1208+	6.9063+	8.6918+	10.4773+	12.2628+	14.0483+	15.8338+	17.6193+
.67	....	2.4946+	3.4078−	5.2340−	7.0602+	8.8865−	10.7127−	12.5389+	14.3652−	16.1914−	18.0176+
.68	....	2.5470−	3.4806−	5.3479−	7.2151+	9.0824+	10.9497−	12.8170−	14.6842+	16.5515−	18.4188−
.69	....	2.5995+	3.5538+	5.4625−	7.3711−	9.2797−	11.1883−	13.0969+	15.0055+	16.9141+	18.8227+
.70	....	2.6523+	3.6275−	5.5777+	7.5280−	9.4782+	11.4285−	13.3787+	15.3290+	17.2793−	19.2295+
.71	....	2.7054+	3.7015−	5.6937−	7.6859−	9.6781−	11.6703−	13.6625−	15.6547−	17.6469−	19.6391−
.72	....	2.7587−	3.7759+	5.8103+	7.8448−	9.8792−	11.9136+	13.9481−	15.9825−	18.0169+	20.0514−

TABLE 5.—*Discharges, in cubic feet per second for two-hour periods, of rectangular weirs from 1 to 10 feet long, with two end contractions, computed from the formula* $Q=3.33\ (L-.2H)\ h^{\frac{3}{2}}$—Continued.

Depth of water on crest.	1-foot weir.	1½-foot weir.	2-foot weir.	3-foot weir.	4-foot weir.	5-foot weir.	6-foot weir.	7-foot weir.	8-foot weir.	9-foot weir.	10-foot weir.
Feet.	Cu. ft. per sec.	Cu. ft. per sec.	Cu. ft. per sec.	Cu. ft. per sec.	Cu. ft. per sec.	Cu. ft. per sec.	Cu. ft. per sec.	Cu. ft. per sec.	Cu. ft. per sec.	Cu. ft. per sec.	Cu. ft. per sec.
0.73	....	2.8122+	3.8507−	5.9276+	8.0046+	10.0816−	12.1585+	14.2355−	16.3125−	18.3894+	20.4664−
.74	....	2.8659+	3.9258+	6.0456+	8.1654+	10.2852−	12.4050−	14.5248−	16.6446−	18.7643+	20.8841+
.75	....	2.9199+	4.0014−	6.1643−	8.3272−	10.4901−	12.6530−	14.8159−	16.9788−	19.1417−	21.3045+
.76	....	....	4.0772+	6.2835+	8.4898+	10.6961+	12.9024+	15.1087+	17.3150+	19.5213+	21.7276+
.77	....	....	4.1535−	6.4035−	8.6535−	10.9034+	13.1534+	15.4034+	17.6534+	19.9034−	22.1534−
.78	....	....	4.2301−	6.5240+	8.8180−	11.1119+	13.4059+	15.6999−	17.9938+	20.2878−	22.5818−
.79	....	....	4.3070−	6.6452+	8.9834+	11.3216+	13.6599−	15.9981−	18.3363+	20.6745+	23.0127+
.80	....	....	4.3843−	6.7670+	9.1498−	11.5325+	13.9153−	16.2980+	18.6808−	21.0635+	23.4463−
.81	....	....	4.4619−	6.8894+	9.3170+	11.7446−	14.1722−	16.5997+	19.0273−	21.4549−	23.8824+
.82	....	....	4.5398+	7.0125−	9.4851+	11.9578+	14.4305−	16.9031+	19.3758−	21.8485−	24.3211+
.83	....	....	4.6181−	7.1361+	9.6541+	12.1722−	14.6902+	17.2082+	19.7263−	22.2443+	24.7623+
.84	....	....	4.6967−	7.2603+	9.8240+	12.3877−	14.9514−	17.5150+	20.0787+	22.6424−	25.2061−
.85	....	....	4.7756−	7.3851+	9.9947+	12.6043+	15.2139+	17.8235+	20.4331+	23.0427−	25.6523−
.86	....	....	4.8548−	7.5105+	10.1663+	12.8221+	15.4779−	18.1337−	20.7894+	23.4452+	26.1010−
.87	....	....	4.9343−	7.6365+	10.3388−	13.0410−	15.7432+	18.4455−	21.1477−	23.8499+	26.5522−
.82	....	....	5.0141+	7.7631−	10.5120+	13.2610−	16.0099+	18.7589−	21.5079−	24.2568+	27.0058−
.89	....	....	5.0942+	7.8902−	10.6861+	13.4821−	16.2780+	19.0740−	21.8699+	24.6659−	27.4618+
.90	....	....	5.1746+	8.0178+	10.8610+	13.7042+	16.5474+	19.3907−	22.2339−	25.0771−	27.9203−
.91	....	....	5.2553+	8.1461−	11.0368−	13.9275−	16.8182+	19.7089+	22.5997−	25.4904−	28.3811+
.92	....	....	5.3363+	8.2748+	11.2133+	14.1518+	17.0903+	20.0288+	22.9673+	25.9058+	28.8443+
.93	....	....	5.4176−	8.4041+	11.3907−	14.3772+	17.3638−	20.3503−	23.3368+	26.3234−	29.3099+
.94	....	....	5.4991+	8.5340−	11.5688+	14.6037−	17.6385−	20.6733+	23.7082−	26.7430+	29.7779−
.95	....	....	3.5810−	8.6643+	11.7477+	14.8311+	17.9145+	20.9979+	24.0813+	27.1647+	30.2481+
.96	....	....	5.6630+	8.7953−	11.9275−	15.0597−	18.1919−	21.3241−	24.4563+	27.5885+	30.7207+
.97	....	....	5.7454−	8.9267−	12.1080−	15.2892+	18.4705+	21.6518−	24.8331−	28.0143+	31.1956+
.98	....	....	5.8280+	9.0586+	12.2892+	15.5198+	18.7504+	21.9810+	25.2116+	28.4422+	31.6728+
.99	....	....	5.9109−	9.1911−	12.4712+	15.7514+	19.0316−	22.3118−	25.5919+	28.8721+	32.1523−
1.00	....	....	5.9940	9.3240	12.6540	15.9840	19.3140	22.6440	25.9740	29.3040	32.6340
1.01	....	....	....	....	....	....	19.5977−	22.9777+	26.3578+	29.7379−	33.1180−
1.02	....	....	....	....	....	....	19.8826−	23.3130−	26.7434−	30.1738−	33.6042−
1.03	....	....	....	....	....	....	20.1687+	23.6497−	27.1307−	30.6116+	34.0926+
1.04	....	....	....	....	....	....	20.4561−	23.9879−	27.5197−	31.0515−	34.5832+
1.05	....	....	....	....	....	....	20.7447−	24.3275+	27.9104−	31.4932+	35.0761−
1.06	....	....	....	....	....	....	21.0345−	24.6686+	28.3028−	31.9369+	35.5711−
1.07	....	....	....	....	....	....	21.3255−	25.0112−	28.6969−	32.3826−	36.0683−
1.08	....	....	....	....	....	....	21.6176+	25.3551+	29.0926+	32.8301−	36.5676−
1.09	....	....	....	....	....	....	21.9110−	25.7005+	29.4900+	33.2795+	37.0691−
1.10	....	....	....	....	....	....	22.2055+	26.0473+	29.8891+	33.7309−	37.5727−
1.11	....	....	....	....	....	....	22.5012+	26.3955+	30.2898+	34.1841+	38.0784+
1.12	....	....	....	....	....	....	22.7981−	26.7451+	30.6922−	34.6392+	38.5862+
1.13	....	....	....	....	....	....	23.0961+	27.0961+	31.0961+	35.0962−	39.0962−
1.14	....	....	....	....	....	....	23.3953−	27.4485−	31.5017+	35.5550−	39.6082−
1.15	....	....	....	....	....	....	23.6956−	27.8022+	31.9089+	36.0156−	40.1223−
1.16	....	....	....	....	....	....	23.9970−	28.1573+	32.3177−	36.4781−	40.6384+
1.17	....	....	....	....	....	....	24.2995+	28.5138−	32.7281−	36.9423+	41.1566+
1.18	....	....	....	....	....	....	24.6032−	28.8716−	33.1400+	37.4084+	41.6769−
1.19	....	....	....	....	....	....	24.9079+	29.2307+	33.5535+	37.8763+	42.1991+
1.20	....	....	....	....	....	....	25.2138+	29.5912+	33.9686+	38.3460+	42.7234+
1.21	....	....	....	....	....	....	....	29.9530+	34.3852+	38.8175−	43.2497+
1.22	....	....	....	....	....	....	....	30.3161+	34.8034+	39.2907−	43.7780−
1.23	....	....	....	....	....	....	....	30.6805+	35.2231+	39.7657−	44.3083−
1.24	....	....	....	....	....	....	....	31.0463−	35.6443+	40.2424+	44.8405+
1.25	....	....	....	....	....	....	....	31.4133−	36.0671−	40.7209−	45.3747+
1.26	....	....	....	....	....	....	....	31.7816−	36.4913+	41.2011+	45.9109−
1.27	....	....	....	....	....	....	....	32.1511+	36.9171−	41.6830+	46.4490−
1.28	....	....	....	....	....	....	....	32.5220−	37.3443+	42.1667−	46.9890+
1.29	....	....	....	....	....	....	....	32.8941−	37.7730+	42.6520+	47.5310−
1.30	....	....	....	....	....	....	....	33.2674+	38.2032+	43.1391−	48.0749−
1.31	....	....	....	....	....	....	....	33.6420+	38.6349+	43.6278−	48.6207−
1.32	....	....	....	....	....	....	....	34.0179−	39.0680+	44.1182−	49.1684−
1.33	....	....	....	....	....	....	....	34.3950−	39.5026+	44.6103−	49.7179+
1.34	....	....	....	....	....	....	....	34.7733−	39.9386+	45.1040+	50.2694−
1.35	....	....	....	....	....	....	....	35.1528+	40.3761+	45.5994+	50.8227−
1.36	....	....	....	....	....	....	....	35.5335+	40.8150−	46.0964+	51.3779−
1.37	....	....	....	....	....	....	....	35.9155+	41.2553+	46.5951+	51.9349+
1.38	....	....	....	....	....	....	....	36.2987−	41.6970+	47.0954+	52.4938−
1.39	....	....	....	....	....	....	....	36.6830+	42.1402−	47.5973+	53.0545−
1.40	....	....	....	....	....	....	....	37.0685+	42.5847−	48.1009−	53.6170+
1.41	....	....	....	....	....	....	....	....	43.0306+	48.6060−	54.1813+
1.42	....	....	....	....	....	....	....	....	43.4779+	49.1127+	54.7475−
1.43	....	....	....	....	....	....	....	....	43.9266+	49.6210+	55.3154+
1.44	....	....	....	....	....	....	....	....	44.3767−	50.1309+	55.8852−
1.45	....	....	....	....	....	....	....	....	44.8281+	50.6424+	56.4567−

TABLE 5.—*Discharges, in cubic feet per second for two-hour periods, of rectangular weirs from 1 to 10 feet long, with two end contractions, computed from the formula* $Q=3.33 (L.-.2H) h^{\frac{3}{2}}$—Continued.

Depth of water on crest.	1-foot weir.	1½-foot weir.	2-foot weir.	3-foot weir.	4-foot weir.	5-foot weir.	6-foot weir.	7-foot weir.	8-foot weir.	9-foot weir.	10-foot weir.
Feet.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*
1.46									45.2809+	51.1555–	57.0300–
1.47									45.7351–	51.6701–	57.6050+
1.48									46.1905+	52.1862+	58.1819–
1.49									46.6474–	52.7039–	58.7604+
1.50									47.1055+	53.2231+	59.3407+
1.51									47.5650+	53.7439–	59.9228–
1.52									48.0258+	54.2662–	60.5065+
1.53									48.4879+	54.7900–	61.0920+
1.54									48.9513+	55.3153–	61.6792–
1.55									49.4161–	55.8421–	62.2681–
1.56									49.8821–	56.3704–	62.8587–
1.57									50.3494–	56.9002–	63.4510–
1.58									50.8180–	57.4314+	64.0449+
1.59									51.2878+	57.9642–	64.6405+
1.60									51.7589+	58.4984–	65.2378+
1.61										59.0341–	65.8368–
1.62										59.5712–	66.4374–
1.63										60.1098–	67.0396+
1.64										60.6498–	67.6435+
1.65										61.1912+	68.2491–
1.66										61.7341+	68.8562–
1.67										62.2784+	69.4650–
1.68										62.8241+	70.0753+
1.69										63.3713–	70.6873–
1.70										63.9198+	71.3009–
1.71										64.4697+	71.9160+
1.72										65.0211–	72.5328–
1.73										65.5738–	73.1511–
1.74										66.1279–	73.7710–
1.75										66.6834–	74.3924+
1.76										67.2402–	75.0154+
1.77										67.7984–	75.6400–
1.78										68.3579+	76.2661–
1.79										68.9189–	76.8937+
1.80										69.4811+	77.5229+
1.81											78.1536+
1.82											78.7858+
1.83											79.4196–
1.84											80.0548+
1.85											80.6916–
1.86											81.3298+
1.87											81.9695+
1.88											82.6108–
1.89											83.2535–
1.90											83.8976+
1.91											84.5433–
1.92											85.1904–
1.93											85.8389+
1.94											86.4889+
1.95											87.1404–
1.96											87.7933–
1.97											88.4476+
1.98											89.1034–
1.99											89.7606–
2.00											90.4192–

TABLE 6.—*Discharges, in acre-feet for two-hour periods, of rectangular weirs from 1 to 10 feet long, with two end contractions, computed from the formula* $Q=3.33\ (L-.2H)\ H^{\frac{3}{2}}$.

Depth of water on crest.	1-foot weir.	1½-foot weir.	2-foot weir.	3-foot weir.	4-foot weir.	5-foot weir.	6-foot weir.	7-foot weir.	8-foot weir.	9-foot weir.	10-foot weir.
Feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
0.01	0.00055−	0.0008+	0.0011−	0.0017−	0.0022+	0.0028−	0.0033+	0.0039−	0.0044+	0.0050−	0.0055+
.02	.00155+	.0023+	.0031+	.0047−	.0062+	.0078−	.0093+	.0109−	.0125−	.0140+	.0156−
.03	.0028 +	.0043−	.0057+	.0086−	.0114+	.0143−	.0171+	.0200+	.0229−	.0257+	.0286−
.04	.0044 −	.0066−	.0088−	.0132−	.0176−	.0220−	.0264−	.0308−	.0352−	.0396−	.0440−
.05	.0061 −	.0092−	.0122+	.0184−	.0246−	.0307+	.0369−	.0430+	.0492−	.0553+	.0615−
.06	.0080 −	.0120+	.0161−	.0242−	.0323−	.0403+	.0484+	.0565+	.0646+	.0727+	.0808−
.07	.0101 −	.0151+	.0202+	.0304+	.0406+	.0508+	.0610+	.0712+	.0814+	.0916+	.1018−
.08	.0123 −	.0185−	.0247+	.0372−	.0496+	.0621−	.0745+	.0870−	.0994+	.1119−	.1243+
.09	.0146 −	.0220+	.0295−	.0443+	.0592−	.0740+	.0889−	.1038−	.1186+	.1335−	.1483+
.10	.0171 −	.0258−	.0345−	.0519−	.0693−	.0867−	.1041−	.1215−	.1389−	.1563+	.1737+
.11	.0196 +	.0297−	.0397+	.0598+	.0799−	.1000−	.1200+	.1401+	.1602+	.1803−	.2004−
.12	.0223 +	.0338−	.0452+	.0681−	.0910−	.1139−	.1367+	.1596+	.1825−	.2054−	.2283−
.13	.0251 +	.0380+	.0509+	.0767+	.1025+	.1283+	.1541+	.1799+	.2057+	.2315+	.2573+
.14	.0280 +	.0424+	.0569−	.0857−	.1145+	.1434−	.1722−	.2010+	.2299−	.2587 −	.2875+
.15	.0310 +	.0470+	.0630−	.0950−	.1269+	.1589+	.1909−	.2229−	.2548+	.2868+	.3188+
.16	.0341 −	.0517+	.0693+	.1046−	.1398−	.1750+	.2102+	.2455−	.2807−	.3159+	.3511+
.17	.0373 −	.0566−	.0758+	.1144+	.1530+	.1916−	.2302−	.2687+	.3073+	.3459+	.3845−
.18	.0405 +	.0615+	.0826−	.1246−	.1666+	.2087−	.2507−	.2927+	.3348−	.3768−	.4188+
.19	.0439 −	.0666+	.0894+	.1350+	.1806+	.2262−	.2718−	.3174−	.3629+	.4085+	.4541+
.20	.0473 −	.0719−	.0965−	.1457+	.1950−	.2442−	.2934+	.3426+	.3919−	.4411+	.4903+
.21	.0507 +	.0772+	.1037+	.1567−	.2096+	.2626+	.3156−	.3686−	.4215+	.4745−	.5275−
.22	.0543 −	.0827−	.1111−	.1679−	.2247−	.2815−	.3383−	.3951−	.4519−	.5087−	.5655−
.23	.0579 +	.0883−	.1186+	.1793+	.2401−	.3008−	.3615−	.4222−	.4829+	.5436+	.6043+
.24	.0616 +	.0940−	.1263+	.1910+	.2558−	.3205−	.3852−	.4499−	.5146+	.5793+	.6440+
.25	.0654 −	.0998−	.1342−	.2030−	.2718−	.3406−	.4094−	.4782−	.5470−	.6158−	.6846−
.26	.0692 −	.1057−	.1421+	.2151+	.2881−	.3611−	.4340+	.5070+	.5800−	.6529+	.7259+
.27	.0731 −	.1117−	.1503−	.2275−	.3047+	.3819+	.4592−	.5364−	.6136−	.6908+	.7680+
.28	.0770 −	.1178−	.1585+	.2401−	.3216+	.4032−	.4847+	.5663−	.6478+	.7294−	.8109+
.29	.0810 −	.1240−	.1669+	.2529−	.3388+	.4248+	.5108−	.5967+	.6827−	.7686+	.8546 −
.30	.0850 +	.1302+	.1755−	.2659−	.3563+	.4468−	.5372+	.6277−	.7181+	.8086−	.8990−
.31	.0891 +	.1366+	.1841+	.2791+	.3741+	.4691+	.5641+	.6591+	.7541+	.8491+	.9441+
.32	.0933 −	.1431−	.1929−	.2925+	.3922−	.4918+	5914+	.6911−	.7907+	.8903+	.9900−
.33	.0975 −	.1496+	.2018−	.3061+	.4105−	.5148+	.6192−	.7235+	.8279−	.9322−	1.0365+
.34	.1017 +	.1563−	.2108+	.3199+	.4291−	.5382−	.6473+	.7564+	.8655+	.9747−	1.0838−
.35	.1060 −	.1630−	.2200−	.3339+	.4479+	.5619−	.6758+	.7898+	.9038−	1.0178−	1.1317+
.36	.1103 +	.1698−	.2292+	.3481+	.4670−	.5859−	.7048−	.8237−	.9426−	1.0614+	1.1803+
.37	.1147 +	.1766+	.2386−	.3625−	.4863+	.6102+	.7341−	.8580−	.9819−	1.1057+	1.2296+
.38	.1191 +	.1836+	.2481−	.3770+	.5059+	.6349−	.7638−	.8927+	1.0217−	1.1506−	1.2795+
.39	.1236 −	.1906+	.2577−	.3917+	.5258−	.6598+	.7939−	.9279+	1.0620−	1.1960+	1.3301+
.40	.1281 +	.1977+	.2673+	.4066−	.5458+	.6851−	.8243+	.9636−	1.1028+	1.2421−	1.3813+
.41	.1327 −	.2049−	.2771+	.4216+	.5661+	.7106+	.8551+	.9996+	1.1441+	1.2886+	1.4331+
.42	.1372 +	.2121+	.2871−	.4369−	.5867−	.7365+	.8863+	1.0361+	1.1860−	1.3358−	1.4856−
.43	.1419 −	.2195−	.2971−	.4523−	.6075−	.7627−	.9179−	1.0731−	1.2283−	1.3835−	1.5387 −
.44	.1465 +	.2268+	.3072−	.4678−	.6284+	.7891−	.9497+	1.1104−	1.2710+	1.4317−	1.5923+
.45	.1512 −	.2343−	.3174−	.4835+	.6497−	.8158+	.9820−	1.1481+	1.3143−	1.4804+	1.6466−
.46	.1559 +	.2418−	.3276+	.4994−	.6711−	.8428+	1.0145+	1.1863−	1.3580−	1.5297−	1.7014+
.47	.1607 −	.2494−	.3380+	.5154−	.6927+	.8701−	1.0474+	1.2248−	1.4021+	1.5795−	1.7568+
.48	.1655 −	.2570−	.3485+	.5316−	.7146−	.8976+	1.0807−	1.2637+	1.4468−	1.6298+	1.8128+
.49	.1703 −	.2647−	.3591−	.5479−	.7367−	.9255−	1,1142+	1.3030+	1.4918+	1.6806+	1.8694+
.50	.1751 +	.2724+	.3697+	.5643+	.7589+	.9535+	1.1481+	1.3427+	1.5373+	1.7319+	1.9265+
.51	....	.2803−	.3805−	.5810−	.7814+	.9819−	1.1824−	1.3828+	1.5833−	1.7838−	1.9842+
.52	....	.2881+	.3913+	.5977+	.8041+	1.0105−	1.2169−	1.4233−	1.6297−	1.8361−	2.0425−
.53	....	.2961−	.4022+	.6146+	.8270−	1.0394−	1.2517+	1.4641+	1.6765−	1.8889−	2.1012+
.54	....	.3040+	.4132+	.6317−	.8501−	1.0685−	1.2869−	1.5053+	1.7237+	1.9421+	2.1605+
.55	....	.3121−	.4243+	.6488+	.8733+	1.0978+	1.3224−	1.5469−	1.7714−	1.9959−	2.2204−
.56	....	.3202−	.4355−	.6661+	.8968+	1.1275−	1.3581+	1.5888−	1.8194+	2.0501−	2.2808−
.57	....	.3283−	.4467+	.6836−	.9205−	1.1573+	1.3942−	1.6311−	1.8679+	2.1048−	2.3416+
.58	....	.3365−	.4580+	.7012−	.9443+	1.1874+	1.4306−	1.6737−	1.9168+	2.1599+	2.4031−
.59	....	.3447+	.4694+	.7189−	.9683+	1.2178−	1.4672+	1.7166+	1.9661−	2.2155+	2.4650−
.60	....	.3530+	.4809+	.7367+	.9925+	1.2483+	1.5042−	1.7600−	2.0158−	2.2716−	2.5274−
.61	....	.3614−	.4925−	.7547+	1.0169+	1.2792−	1.5414−	1.8036+	2.0659−	2.3281−	2.5903+
.62	....	.3697+	.5041−	.7728−	1.0415+	1.3102+	1.5789+	1.8476+	2.1163+	2.3850+	2.6537+
.63	....	.3782−	.5158−	.7910+	1.0663−	1.3415−	1.6167+	1.8919+	2.1672−	2.4424+	2.7176+
.64	....	.3866+	.5276−	.8094−	1.0912−	1.3730−	1.6548−	1.9366+	2.2184+	2.5002+	2.7820+
.65	....	.3952−	.5394−	.8278−	1.1163−	1.4047+	1.6932−	1.9816−	2.2700+	2.5585−	2.8469+
.66	....	.4037+	.5513−	.8464+	1.1415+	1.4367−	1.7318−	2.0269+	2.3220+	2.6172−	2.9123−
.67	....	.4123+	.5633−	.8651+	1.1670−	1.4688+	1.7707−	2.0725+	2.3744+	2.6763−	2.9781+
.68	....	.4210−	.5753+	.8839+	1.1926−	1.5012+	1.8099−	2.1185+	2.4271+	2.7358−	3.0444+
.69	....	.4297−	.5874+	.9029−	1.2184−	1.5338+	1.8493+	2.1648−	2.4803−	2.7957+	3.1112−
.70	....	.4384+	.5996−	.9219+	1.2443−	1.5667−	1.8890+	2.2114−	2.5337+	2.8561−	3.1784+
.71	....	.4472−	.6118+	.9411+	1.2704−	1.5997−	1.9290−	2.2583−	2.5875+	2.9168+	3.2461+
.72	....	.4560−	.6241+	.9604−	1.2967−	1.6329+	1.9692−	2.3055−	2.6417+	2.9780+	3.3143−
.73	....	.4648+	.6365−	.9798−	1.3231−	1.6664−	2.0097−	2.3530−	2.6963−	3.0396−	3.3829−
.74	....	.4737+	.6489−	.9993−	1.3497−	1.7000+	2.0504+	2.4008−	2.7512−	3.1015+	3.4519+
.75	....	.4826+	.6614−	1.0189−	1.3764−	1.7339−	2.0914−	2.4489+	2.8064+	3.1639+	3.5214+

TABLE 6.—*Discharges, in acre-feet for two-hour periods, of rectangular weirs from 1 to 10 feet long, with two end contractions, computed from the formula* $Q=3.33\ (L-.2H)\ H^{\frac{3}{2}}$—Continued.

Depth of water on crest.	1-foot weir.	1½-foot weir.	2-foot weir.	3-foot weir.	4-foot weir.	5-foot weir.	6-foot weir.	7-foot weir.	8-foot weir.	9-foot weir.	10-foot weir.
Feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
0.76	....	....	0.6739+	1.0386+	1.4033−	1.7680−	2.1326+	2.4973+	2.8620−	3.2267+	3.5913+
.77	....	....	.6865+	1.0584+	1.4303+	1.8022+	2.1741+	2.5460+	2.9179+	3.2898+	3.6617+
.78	....	....	.6992−	1.0784−	1.4575+	1.8367−	2.2159−	2.5950+	2.9742−	3.3534−	3.7325+
.79	....	....	.7119+	1.0984−	1.4849−	1.8713+	2.2578+	2.6443+	3.0308−	3.4173−	3.8038−
.80	....	....	.7247−	1.1185+	1.5124−	1.9062+	2.3000+	2.6939−	3.0877+	3.4816−	3.8754+
.81	....	....	.7375−	1.1388−	1.5400+	1.9413−	2.3425+	2.7438−	3.1450+	3.5463−	3.9475+
.82	....	....	.7504−	1.1591−	1.5678−	1.9765−	2.3852−	2.7939+	3.2026+	3.6113+	4.0200+
.83	....	....	.7633+	1.1795+	1.5957+	2.0119+	2.4281+	2.8443+	3.2605+	3.6767+	4.0929+
.84	....	....	.7763+	1.2001−	1.6238+	2.0476−	2.4713−	2.8950+	3.3188−	3.7425+	4.1663−
.85	....	....	.7893+	1.2207−	1.6520+	2.0834−	2.5147−	2.9460+	3.3774−	3.8087+	4.2400+
.86	....	....	.8024+	1.2414+	1.6804−	2.1194−	2.5583+	2.9973−	3.4363−	3.8752+	4.3142+
.87	....	....	.8156−	1.2622+	1.7089−	2.1555+	2.6022−	3.0488+	3.4955−	3.9421+	4.3888−
.88	....	....	.8288−	1.2832−	1.7375+	2.1919−	2.6463−	3.1006+	3.5550+	4.0094−	4.4638−
.89	....	....	.8420+	1.3042−	1.7663+	2.2284+	2.6906−	3.1527+	3.6149−	4.0770+	4.5391+
.90	....	....	.8553+	1.3253−	1.7952+	2.2652−	2.7351+	3.2051−	3.6750+	4.1450−	4.6149+
.91	....	....	.8687−	1.3465−	1.8243−	2.3021−	2.7799−	3.2577−	3.7355−	4.2133+	4.6911+
.92	....	....	.8820+	1.3677+	1.8534+	2.3391+	2.8248+	3.3106−	3.7963−	4.2820−	4.7677−
.93	....	....	.8955−	1.3891+	1.8828−	2.3764−	2.8700+	3.3637−	3.8573+	4.3510−	4.8446+
.94	....	....	.9089+	1.4106−	1.9122+	2.4138+	2.9155−	3.4171−	3.9187+	4.4203−	4.9220−
.95	....	....	.9225−	1.4321+	1.9418−	2.4514+	2.9611−	3.4707+	3.9804−	4.4900+	4.9997−
.96	....	....	.9360+	1.4538−	1.9715−	2.4892+	3.0069+	3.5246+	4.0424−	4.5601−	5.0778+
.97	....	....	.9497−	1.4755−	2.0013+	2.5271+	3.0530−	3.5788+	4.1046+	4.6305−	5.1563+
.98	....	....	.9633+	1.4973−	2.0313−	2.5653−	3.0992+	3.6332+	4.1672+	4.7012−	5.2352−
.99	....	....	.9770+	1.5192−	2.0614−	2.6035+	3.1457+	3.6879−	4.2301−	4.7722+	5.3144+
1.00	....	....	.9907+	1.5412−	2.0916−	2.6420−	3.1924−	3.7428+	4.2932+	4.8436+	5.3940+
1.01	....	....	....	....	....	....	3.2393−	3.7980−	4.3567−	4.9154−	5.4740+
1.02	....	....	....	....	....	....	3.2864−	3.8534−	4.4204−	4.9874+	5.5544+
1.03	....	....	....	....	....	....	3.3337−	3.9090+	4.4844+	5.0598−	5.6351+
1.04	....	....	....	....	....	....	3.3812−	3.9649+	4.5487+	5.1325−	5.7162+
1.05	....	....	....	....	....	....	3.4289−	4.0211−	4.6133−	5.2055−	5.7977−
1.06	....	....	....	....	....	....	3.4768−	4.0775−	4.6781+	5.2788+	5.8795+
1.07	....	....	....	....	....	....	3.5249−	4.1341−	4.7433−	5.3525−	5.9617−
1.08	....	....	....	....	....	....	3.5732−	4.1909+	4.8087−	5.4265−	6.0442+
1.09	....	....	....	....	....	....	3.6217−	4.2480+	4.8744−	5.5008−	6.1271+
1.10	....	....	....	....	....	....	3.6703+	4.3053+	4.9403+	5.5754−	6.2104−
1.11	....	....	....	....	....	....	3.7192+	4.3629−	5.0066−	5.6503−	6.2940−
1.12	....	....	....	....	....	....	3.7683−	4.4207−	5.0731−	5.7255−	6.3779−
1.13	....	....	....	....	....	....	3.8175+	4.4787−	5.1399−	5.8010+	6.4622−
1.14	....	....	....	....	....	....	3.8670−	4.5369+	5.2069−	5.8769−	6.5468+
1.15	....	....	....	....	....	....	3.9167+	4.5954+	5.2742+	5.9530−	6.6318−
1.16	....	....	....	....	....	....	3.9664+	4.6541+	5.3418−	6.0294+	6.7171−
1.17	....	....	....	....	....	....	4.0164+	4.7130+	5.4096−	6.1062−	6.8027+
1.18	....	....	....	....	....	....	4.0666+	4.7722−	5.4777−	6.1832+	6.8887+
1.19	....	....	....	....	....	....	4.1170+	4.8315+	5.5460+	6.2606−	6.9751−
1.20	....	....	....	....	....	....	4.1676−	4.8911+	5.6146+	6.3382−	7.0617+
1.21	....	....	....	....	....	....	....	4.9509+	5.6835+	6.4161+	7.1487+
1.22	....	....	....	....	....	....	....	5.0109+	5.7526+	6.4943+	7.2360+
1.23	....	....	....	....	....	....	....	5.0712−	5.8220+	6.5728+	7.3237−
1.24	....	....	....	....	....	....	....	5.1316+	5.8916+	6.6516+	7.4117−
1.25	....	....	....	....	....	....	....	5.1923−	5.9615+	6.7307+	7.5000−
1.26	....	....	....	....	....	....	....	5.2531+	6.0316+	6.8101−	7.5886−
1.27	....	....	....	....	....	....	....	5.3142+	6.1020−	6.8898−	7.6775+
1.28	....	....	....	....	....	....	....	5.3755+	6.1726+	6.9697−	7.7668−
1.29	....	....	....	....	....	....	....	5.4370+	6.2435−	7.0499+	7.8564−
1.30	....	....	....	....	....	....	....	5.4987+	6.3146−	7.1304+	7.9463−
1.31	....	....	....	....	....	....	....	5.5607−	6.3859+	7.2112+	8.0365−
1.32	....	....	....	....	....	....	....	5.6228−	6.4575+	7.2923−	8.1270+
1.33	....	....	....	....	....	....	....	5.6851+	6.5294−	7.3736−	8.2178+
1.34	....	....	....	....	....	....	....	5.7476+	6.6014+	7.4552+	8.3090−
1.35	....	....	....	....	....	....	....	5.8104−	6.6737+	7.5371−	8.4004+
1.36	....	....	....	....	....	....	....	5.8733+	6.7463−	7.6192+	8.4922+
1.37	....	....	....	....	....	....	....	5.9364+	6.8191−	7.7017−	8.5843−
1.38	....	....	....	....	....	....	....	5.9998−	6.8921−	7.7844−	8.6767−
1.39	....	....	....	....	....	....	....	6.0633+	6.9653+	7.8673+	8.7693+
1.40	....	....	....	....	....	....	....	6.1270+	7.0388−	7.9506−	8.8623+
1.41	....	....	....	....	....	....	....	....	7.1125+	8.0340+	8.9556−
1.42	....	....	....	....	....	....	....	....	7.1864+	8.1178+	9.0492−
1.43	....	....	....	....	....	....	....	....	7.2606+	8.2018+	9.1430+
1.44	....	....	....	....	....	....	....	....	7.3350−	8.2861+	9.2372+
1.45	....	....	....	....	....	....	....	....	7.4096+	8.3706+	9.3317−
1.46	....	....	....	....	....	....	....	....	7.4844+	8.4554+	9.4264+
1.47	....	....	....	....	....	....	....	....	7.5595+	8.5405+	9.5215−
1.48	....	....	....	....	....	....	....	....	7.6348+	8.6258+	9.6168+

TABLE 6.—*Discharges, in acre-feet for two-hour periods, of rectangular weirs from 1 to 10 feet long, with two end contractions, computed from the formula* $Q=3.33\ (L-.2H)\ H^{\frac{3}{2}}$—Continued.

Depth of water on crest.	1-foot wier.	1½-foot weir.	2-foot weir.	3-foot weir.	4-foot weir.	5-foot weir.	6-foot weir.	7-foot weir.	8-foot weir.	9-foot weir.	10-foot weir.
Feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1.49	....	....	....	....	....	....	....	....	7.7103+	8.7114−	9.7125−
1.50	....	....	....	....	....	....	....	....	7.7860+	8.7972+	9.8084−
1.51	....	....	....	....	....	....	....	....	7.8620−	8.8833−	9.9046−
1.52	....	....	....	....	....	....	....	....	7.9381+	8.9696+	10.0011−
1.53	....	....	....	....	....	....	....	....	8.0145+	9.0562−	10.0979−
1.54	....	....	....	....	....	....	....	....	8.0911+	9.1430+	10.1949−
1.55	....	....	....	....	....	....	....	....	8.1679+	9.2301−	10.2922+
1.56	....	....	....	....	....	....	....	....	8.2450−	9.3174+	10.3899−
1.57	....	....	....	....	....	....	....	....	8.3222+	9.4050−	10.4878−
1.58	....	....	....	....	....	....	....	....	8.3997−	9.4928−	10.5859+
1.59	....	....	....	....	....	....	....	....	8.4773+	9.5809−	10.6844−
1.60	....	....	....	....	....	....	....	....	8.5552−	9.6692−	10.7831+
1.61	....	....	....	....	....	....	....	....	....	9.7577−	10.8821+
1.62	....	....	....	....	....	....	....	....	....	9.8465−	10.9814−
1.63	....	....	....	....	....	....	....	....	....	9.9355−	11.0809+
1.64	....	....	....	....	....	....	....	....	....	10.0248−	11.1807+
1.65	....	....	....	....	....	....	....	....	....	10.1143−	11.2808+
1.66	....	....	....	....	....	....	....	....	....	10.2040−	11.3812−
1.67	....	....	....	....	....	....	....	....	....	10.2940−	11.4818−
1.68	....	....	....	....	....	....	....	....	....	10.3842−	11.5827−
1.69	....	....	....	....	....	....	....	....	....	10.4746−	11.6838+
1.70	....	....	....	....	....	....	....	....	....	10.5653−	11.7853−
1.71	....	....	....	....	....	....	....	....	....	10.6562−	11.8869+
1.72	....	....	....	....	....	....	....	....	....	10.7473−	11.9889−
1.73	....	....	....	....	....	....	....	....	....	10.8386+	12.0911−
1.74	....	....	....	....	....	....	....	....	....	10.9302+	12.1935+
1.75	....	....	....	....	....	....	....	....	....	11.0220+	12.2963−
1.76	....	....	....	....	....	....	....	....	....	11.1141−	12.3992+
1.77	....	....	....	....	....	....	....	....	....	11.2063+	12.5025−
1.78	....	....	....	....	....	....	....	....	....	11.2988+	12.6060−
1.79	....	....	....	....	....	....	....	....	....	11.3915+	12.7097+
1.80	....	....	....	....	....	....	....	....	....	11.4845−	12.8137+
1.81	....	....	....	....	....	....	....	....	....	....	12.9180−
1.82	....	....	....	....	....	....	....	....	....	....	13.0225−
1.83	....	....	....	....	....	....	....	....	....	....	13.1272+
1.84	....	....	....	....	....	....	....	....	....	....	13.2322+
1.85	....	....	....	....	....	....	....	....	....	....	13.3374+
1.86	....	....	....	....	....	....	....	....	....	....	13.4429+
1.87	....	....	....	....	....	....	....	....	....	....	13.5487−
1.88	....	....	....	....	....	....	....	....	....	....	13.6547−
1.89	....	....	....	....	....	....	....	....	....	....	13.7609+
1.90	....	....	....	....	....	....	....	....	....	....	13.8674−
1.91	....	....	....	....	....	....	....	....	....	....	13.9741−
1.92	....	....	....	....	....	....	....	....	....	....	14.0811−
1.93	....	....	....	....	....	....	....	....	....	....	14.1883−
1.94	....	....	....	....	....	....	....	....	....	....	14.2957−
1.95	....	....	....	....	....	....	....	....	....	....	14.4034−
1.96	....	....	....	....	....	....	....	....	....	....	14.5113−
1.97	....	....	....	....	....	....	....	....	....	....	14.6194+
1.98	....	....	....	....	....	....	....	....	....	....	14.7278+
1.99	....	....	....	....	....	....	....	....	....	....	14.8365−
2.00	....	....	....	....	....	....	....	....	....	....	14.9453+

TABLE 7.[1]—*Discharges in cubic feet per second and acre-feet of rectangular weirs without end contractions and corrections for end contractions.*

Discharges for each foot in width of a rectangular weir without end contractions.			Number to be subtracted from cubic feet per second when weir of any width has two end contractions. (Half as much for each one of any number of such contractions.)	Discharges for each foot in width of a rectangular weir without end contractions.			Number to be subtracted from cubic feet per second when weir of any width has two end contractions. (Half as much for each one of any number of such contractions.)
Depth in feet.	Cubic feet per second.	Acre-feet.		Depth in feet.	Cubic feet per second.	Acre-feet.	
0.01	0.00333000	0.0005504+	0.0000067	0.71	1.99219459	0.3292884−	0.2828916
.02	.00941866	.0015568+	.0000377	.72	2.03443106	.3362696−	.2929580
.03	.01730319	.0028600+	.0001038	.73	2.07696187	.3432995−	.3032364
.04	.02664000	.0044033+	.0002131	.74	2.11978499	.3503777−	.3137282
.05	.03723053	.0061538+	.0003723	.75	2.16289845	.3575039−	.3244348
.06	.04894080	.0080894−	.0005873	.76	2.20630029	.3646777+	.3353577
.07	.06167229	.0101938−	.0008634	.77	2.24998862	.3718989+	.3464983
.08	.07534931	.0124544+	.0012056	.78	2.29396157	.3791672+	.3578581
.09	.08991000	.0148612−	.0016184	.79	2.33821731	.3864822−	.3694384
.10	.10530384	.0174056−	.0021061	.80	2.38275404	.3938436+	.3812407
.11	.12148797	.0200807−	.0026727	.81	2.42757000	.4012512+	.3932664
.12	.13842550	.0228802+	.0033222	.82	2.47266347	.4087047+	.4055169
.13	.15608431	.0257990+	.0040582	.83	2.51803274	.4162038−	.4179935
.14	.17443607	.0288324+	.0048842	.84	2.56367615	.4237481+	.4306976
.15	.19345552	.0319761+	.0058037	.85	2.60959206	.4313375+	.4436307
.16	.21312000	.0352264+	.0068199	.86	2.65577886	.4389717+	.4567941
.17	.23340901	.0385800+	.0079359	.87	2.70223499	.4466504+	.4701890
.18	.25430388	.0420337−	.0091549	.88	2.74895887	.4543734−	.4838169
.19	.27578754	.0455847+	.0104799	.89	2.79594899	.4621403+	.4976790
.20	.29784425	.0492305−	.0119138	.90	2.84320384	.4699510+	.5117768
.21	.32045952	.0529685+	.0134593	.91	2.89072196	.4778053−	.5261114
.22	.34361986	.0567967−	.0151193	.92	2.93850189	.4857028−	.5406843
.23	.36731274	.0607128+	.0168964	.93	2.98654220	.4936433+	.5554968
.24	.39152644	.0647151+	.0187932	.94	3.03484150	.5016267−	.5705501
.25	.41625000	.0688017−	.0208125	.95	3.08339839	.5096526+	.5858456
.26	.44147311	.0729708−	.0229566	.96	3.13221152	.5177209+	.6013845
.27	.46718606	.0772208+	.0252281	.97	3.18127956	.5258313+	.6171681
.28	.49337970	.0815504−	.0276293	.98	3.23060118	.5339837−	.6331978
.29	.52004537	.0859579+	.0301627	.99	3.28017508	.5421777−	.6494746
.30	.54717483	.0904421+	.0328305	1.00	3.33000000	.5504132+	.6660000
.31	.57476032	.0950017+	.0356351	1.01	3.38007467	.5586900+	.6827751
.32	.60279439	.0996354+	.0385788	1.02	3.43039785	.5670079+	.6998012
.33	.63126999	.1043421+	.0416638	1.03	3.48096832	.5753667−	.7170796
.34	.66018037	.1091207+	.0448923	1.04	3.53178488	.5837661−	.7346114
.35	.68951910	.1139701−	.0482663	1.05	3.58284634	.5922060+	.7523979
.36	.71928000	.1188893−	.0517881	1.06	3.63415153	.6006862+	.7704403
.37	.74945717	.1238772+	.0554598	1.07	3.68569930	.6092065−	.7887398
.38	.78004495	.1289330+	.0592834	1.08	3.73748851	.6177667−	.8072977
.39	.81103789	.1340558+	.0632610	1.09	3.78951805	.6263666+	.8261151
.40	.84243077	.1392448−	.0673945	1.10	3.84178681	.6350061−	.8451932
.41	.87421855	.1444989+	.0716859	1.11	3.89429370	.6436849+	.8645333
.42	.90639640	.1498176−	.0761373	1.12	3.94703764	.6524029+	.8841365
.43	.93895962	.1551999+	.0807505	1.13	4.00001757	.6611599+	.9040041
.44	.97190373	.1606452+	.0855275	1.14	4.05323245	.6699558−	.9241371
.45	1.00522436	.1661528−	.0904702	1.15	4.10668124	.6787903−	.9445368
.46	1.03891731	.1717219−	.0955803	1.16	4.16036292	.6876633−	.9652043
.47	1.07297850	.1773518+	.1008599	1.17	4.21427650	.6965746+	.9861408
.48	1.10740400	.1830420−	.1063107	1.18	4.26842097	.7055241+	1.0073475
.49	1.14219000	.1887917+	.1119346	1.19	4.32279535	.7145116+	1.0288254
.50	1.17733279	.1946005−	.1177333	1.20	4.37739868	.7235370−	1.0505758
.51	1.21282879	.2004676−	.1237086	1.21	4.43223000	.7326000	1.0725997
.52	1.24867452	.2063925−	.1298622	1.22	4.48728837	.7417006−	1.0948984
.53	1.28486659	.2123746+	.1361959	1.23	4.54257285	.7508385−	1.1174730
.54	1.32140174	.2184135+	.1427114	1.24	4.59808252	.7600136+	1.1403245
.55	1.35827675	.2245086−	.1494105	1.25	4.65381648	.7692259−	1.1634541
.56	1.39548854	.2306593−	.1562947	1.26	4.70977382	.7784750+	1.1868629
.57	1.43303407	.2368651+	.1633659	1.27	4.76595366	.7877609+	1.2105521
.58	1.47091042	.2431257−	.1706256	1.28	4.82235511	.7970835−	1.2345228
.59	1.50911471	.2494404+	.1780755	1.29	4.87897732	.8064425+	1.2587760
.60	1.54764415	.2558089+	.1857173	1.30	4.93581942	.8158379+	1.2833128
.61	1.58649602	.2622307+	.1935525	1.31	4.99288056	.8252695+	1.3081344
.62	1.62566767	.2687054−	.2015828	1.32	5.05015991	.8347372−	1.3332419
.63	1.66515650	.2752325−	.2098097	1.33	5.10765665	.8442408−	1.3586364
.64	1.70496000	.2818116−	.2182349	1.34	5.16536994	.8537802−	1.3843188
.65	1.74507569	.2884423−	.2268599	1.35	5.22329899	.8633552+	1.4102904
.66	1.78550116	.2951242−	.2356862	1.36	5.28144299	.8729658−	1.4365522
.67	1.82623406	.3018569−	.2447154	1.37	5.33980115	.8826118−	1.4631053
.68	1.86727208	.3086400+	.2539490	1.38	5.39837268	.8922930+	1.4899507
.69	1.90861296	.3154732+	.2633886	1.39	5.45715682	.9020094−	1.5170894
.70	1.95025452	.3223561+	.2730356	1.40	5.51615279	.9117608−	1.5445226

[1] Tables 3, 4, 5, and 6 were computed from Table 7.

TABLE 7.—*Discharges in cubic feet per second and acre-feet of rectangular weirs without end contractions and corrections for end contractions*—Continued.

Discharges for each foot in width of a rectangular weir without end contractions.			Number to be subtracted from cubic feet per second when weir of any width has two end contractions. (Half as much for each one of any number of such contractions.)	Discharges for each foot in width of a rectangular weir without end contractions.			Number to be subtracted from cubic feet per second when weir of any width has two end contractions. (Half as much for each one of any number of such contractions.)
Depth in feet.	Cubic feet per second.	Acre-feet.		Depth in feet.	Cubic feet per second.	Acre-feet.	
1.41	5.57535984	.9215471−	1.5722513	1.71	7.44626348	1.2307874−	2.5466215
1.42	5.63477722	.9313681+	1.6002766	1.72	7.51167698	1.2415995+	2.5840162
1.43	5.69440418	.9412238+	1.6285995	1.73	7.57728091	1.2524431+	2.6217385
1.44	5.75424000	.9511140+	1.6572210	1.74	7.64307473	1.2633181+	2.6597893
1.45	5.81428394	.9610387−	1.6861423	1.75	7.70905788	1.2742244+	2.6981695
1.46	5.87453529	.9709976−	1.7153642	1.76	7.77522983	1.2851620−	2.7368802
1.47	5.93499334	.9809906+	1.7448880	1.77	7.84159003	1.2961306−	2.7759223
1.48	5.99565737	.9910177+	1.7747146	1.78	7.90813796	1.3071302+	2.8152967
1.49	6.05652670	1.0010788−	1.8048450	1.79	7.97487308	1.3181608+	2.8550043
1.50	6.11760063	1.0111737−	1.8352803	1.80	8.04179487	1.3292223−	2.8950461
1.51	6.17887849	1.0213022+	1.8660214	1.81	8.10890282	1.3403145+	2.9354230
1.52	6.24035958	1.0314644−	1.8970695	1.82	8.17619641	1.3514374+	2.9761357
1.53	6.30204326	1.0416600+	1.9284255	1.83	8.24367512	1.3625909+	3.0171853
1.54	6.36392884	1.0518891−	1.9600904	1.84	8.31133845	1.3737750−	3.0585726
1.55	6.42601568	1.0621514−	1.9920652	1.85	8.37918591	1.3849894+	3.1002986
1.56	6.48830312	1.0724468−	2.0243509	1.86	8.44721698	1.3962342+	3.1423643
1.57	6.55079052	1.0827753−	2.0569486	1.87	8.51543118	1.4075093−	3.1847707
1.58	6.61347725	1.0931367+	2.0898592	1.88	8.58382801	1.4188145+	3.2275187
1.59	6.67636267	1.1035310+	2.1230837	1.89	8.65240700	1.4301499+	3.2706092
1.60	6.73944615	1.1139580+	2.1566231	1.90	8.72116765	1.4415153+	3.3140431
1.61	6.80272708	1.1244177−	2.1904784	1.91	8.79010948	1.4529107−	3.3578213
1.62	6.86620484	1.1349099−	2.2246506	1.92	8.85923203	1.4643359−	3.4019447
1.63	6.92987882	1.1454345+	2.2591407	1.93	8.92853483	1.4757909−	3.4464141
1.64	6.99374842	1.1559915−	2.2939496	1.94	8.99801739	1.4872757−	3.4912305
1.65	7.05781304	1.1665807−	2.3290783	1.95	9.06767927	1.4987900−	3.5363948
1.66	7.12207209	1.1772020−	2.3645278	1.96	9.13752000	1.5103339−	3.5819079
1.67	7.18652499	1.1878554−	2.4002991	1.97	9.20753912	1.5219073−	3.6277705
1.68	7.25117115	1.1985407−	2.4363932	1.98	9.27773618	1.5335101+	3.6739837
1.69	7.31601000	1.2092579−	2.4728110	1.99	9.34811073	1.5451423−	3.7205481
1.70	7.38104096	1.2200068−	2.5095534	2.00	9.41866233	1.5568037−	3.7674647

MEASURING FLUMES.

During the spring and summer of 1899 considerable time was occupied in rating flumes. Sufficient gagings were made of each flume to cover the variations in depths and discharges. In a number of the flumes rated it was found that the floor of the structure was below the grade of the ditch. Hence dead water existed in the flume when the discharge was zero. After the gagings were made, the notes giving the width of a cross section and the depths along it, together with the meter readings, were either computed in the field or sent to the Cheyenne office. Each gaging gives a depth and a corresponding discharge which define approximately a point on the rating curve when platted in rectangular coördinates. For convenience, the various depths of water are assumed to be the ordinates and the corresponding discharges the abscissas of the curve. If the points when platted on a convenient scale do not lie along or near a straight line or curve, it either shows inaccuracies in the gagings or faults in the construction of the flume. With the coordinates of the points observation equations can be written, and from these a mean mathematical curve can be computed.

The following method of reduction assumes that the general equation of a conic,

$$aq^2+2kqh+bh^2+2gq+2fh+c=0,$$

represents the relation between the depths h and the corresponding discharges q. The equation contains six constants, a, k, b, g, f, and c. Since it can be divided by any one of the constants without affecting the relation between q and h, there are only five conditions to be satisfied to determine the nature of the curve. Hence the results of the gagings, i. e., the depths and corresponding discharges, can be substituted for h and q in the general equation and the observation equation thus formed. The number of gagings, and consequently the number of such equations, generally exceeds six, the number of constants to be determined. They must therefore be reduced, preferably by the method of least squares, to six normal equations, which can be solved for the desired constants.

The resulting curve is usually hyperbolic. Owing to the fact that only a small portion of the curve is used, it is generally possible to find a parabola which will approximate it. Accordingly, a number of curves have been computed, using for the form of the observation equation

$$Q=ah^2+bh+c,$$

in which a, b, and c are constants. As this equation is the fundamental form of the parabola, the resulting curves are always parabolas. The computations are much simplified by making the approximation.

From the mathematical curve rating tables have been made which give the depths, with their corresponding discharges, from 0.01 of a foot to the greatest depth the flume will carry.

To show the method of rating flumes and preparing the rating tables, the results obtained at Mesa, Ariz., are given. Mr. W. H. Code had charge of the gagings. He sent the notes of his work to the office, where the rating curve was computed and a rating table was prepared.

Depths and corresponding discharges obtained from gagings of the Mesa Canal.

Depths.	Discharges per second.	Depth.	Discharges per second.
Feet.	*Cubic feet.*	*Feet.*	*Cubic feet.*
0.59	7.50	1.25	33.75
.66	9.38	1.31	36.56
.72	11.60	1.38	39.80
.79	13.80	1.44	43.80
.85	16.30	1.51	48.30
.92	19.07	1.57	53.60
.98	22.07	1.64	59.58
1.05	25.25	1.97	85.00
1.12	28.25	2.29	115.00
1.18	31.00	2.62	145.00

From these coordinates, the equation $Q=21.256h^2+.8502h+.0004$ was computed. Q and h have the same values as before given in the general equation for the discharge of measuring flumes. The third term in the second member can be omitted, as it is too small to affect the results. It represents the discharge when h is zero, and indicates that leakage around the flume was small. From this equation a rating table was computed for depths ranging from 0.01 of a foot to the maximum depth carried by the canal. A table was first prepared giving the results in cubic feet per second. It was afterwards reduced, as in the case of weir tables, to corresponding discharges in acre-feet for periods of two hours. The accompanying diagram (fig. 11) indicates how closely the gagings made by Mr. Code agree with the computed curve.

As tables of this character have no value except with reference to the flume to which they relate, they are not given in this report. However, when it is considered that about one-half of the stations maintained during the season of 1899 employed measuring flumes, the work of preparing the rating tables can be appreciated. The results obtained from flume ratings have served to show that but few points are needed to determine the nature of the discharge curve. For this

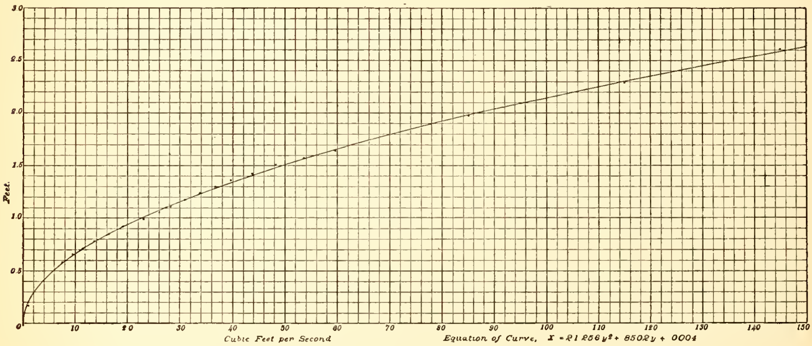


FIG. 11.—Discharge curve for the Mesa Canal, Mesa, Ariz.

reason it is better to make gagings which will accurately fix five or six points in the curve, rather than to have a great many gagings scattered along for various depths. If, while the depth is the same, the flume is gaged three or four times, each result checks the others, and the point on the curve for that depth is accurately located. In a number of flumes the discharge was zero when the depth was as great as a foot. In others there was a discharge when the depth was zero. As the radius of curvature of the discharge curve is short for small depths, it is important that a number of points be determined there.

REDUCTION OF REGISTER SHEETS.

After the rating tables and weir tables had been prepared, the register sheets were taken up for computation. The sheets show the depths on a natural scale, and the mean depth for two-hour periods can be seen at a glance. Noting the depth for each of these periods, the tables give the corresponding discharge in either cubic feet per second or acre-feet for that period. The discharges for each two-hour period of each day were added, and this sum was written on the sheet. After the season had been completed for each station, the sheets were again taken up and a table was prepared giving the discharge for each day during the irrigation season. This finished the first step in the determination of the duty of water for the canal or lateral in question. It was only necessary to find the area of land irrigated, and secure a record of the rainfall, to be able to prepare diagrams showing the results of the work graphically.

DIAGRAMS.

While the tables give all the information obtained relative to the volume of water used from canals and laterals, yet they require considerable study before they can be comprehended. It is almost impossible to understand the fluctuations as shown by the figures of the tables, or to compare the volume of water discharged during different days. unless it is all placed so that it can be understood at a glance. It was also desired to show the rainfall for each month, and if possible to determine the effect it has on the depth to which land is covered by irrigation during the same period. Diagrams were therefore drawn to show the tables graphically and the depth of water applied to the land each month by irrigation and rainfall. As the drawings have to conform to the dimensions of the printed page, the information which the diagrams are intended to show is not exhibited to the best advantage. Another factor which had to be taken into consideration in preparing the drawings was that the irrigation season varies at almost every station. At the southern stations, including New Mexico, Arizona, and California, irrigation is practiced throughout the year; hence the diagrams have been drawn to include a twelve-month period. The irrigation season in Northern States varies greatly, but to make the diagrams uniform a six-months period, beginning April 1, has been assumed. It only needs a glance at the diagrams to show that the season when water is used in the Northern States does not cover the periods allowed for them. Time divisions are measured by horizontal lines, and divisions showing the volume of water used or delivered in acre-feet are measured on vertical lines. For the southern stations a day space is equal to 3/160 of an inch, and for northern stations a day space is 3/80 of an inch. The months are designated by name at the top of the diagram, and under them are the numbers 10 and 20 in the Southern and 5, 10, 15, 20, 25, and sometimes 30, in the Northern States. Any intervening day can be easily located. The vertical or volume scale varies in every case. This fact should be borne in mind when comparing the quantity of water used in different localities, and the scale of acre-feet at the left of the drawing should be examined before the study of the diagram is begun. In each day space during the irrigation season is a column which stands vertically at a height on the acre-foot scale equal to the discharge for that day. The sum of the columns for each day of the irrigation period gives the total volume discharged by the ditch or canal in acre-feet.

When this volume in acre-feet is divided by the number of acres irrigated, the result is the equivalent depth to which the land would be covered in feet. Add the precipitation in feet to this, and the result is the total equivalent depth to which the land would be covered. This summary is shown in the column at the right of the discharge diagram. The depth supplied by irrigation is represented by black areas, while the rainfall is designated by hatched areas. A special scale is made for this column, and it should not be confused with the acre-feet scale at the left of the diagram.

The diagrams show that there is a great fluctuation in the daily discharges at each station. The register sheets show more. The discharge not only varies for different days, but it changes more or less each hour. A diagram made up of the discharges for each two-hour period would represent a curved instead of an irregular appearance. Many of the diagrams have special features which need explanation. Some unusual fluctuations occurred which were evidently brought about by the demands made upon the volume by the irrigators. Each station will be taken up, therefore, and the important features as exhibited by the discharge diagrams will be briefly described.

DIAGRAMS SHOWING USE OF WATER NEAR CARLSBAD, N. MEX.

(Plates IV and V.)

Plate IV shows the volume of water used from the Pecos Canal, New Mexico. This station keeps a continuous record of all water used from the canal on the west side of the river. Some irrigation was accomplished before the station was installed, and irrigation was necessary when the season's report was made. However, the diagram shows approximately the volume of water necessary for the growth and maturity of the crops. The discharge of the canal was regulated so as to provide only the water delivered to the irrigators, so that but little ran to waste at its lower terminus.

The register was installed on April 16. The discharge for that day corresponding to the record of depths furnished by it was 181 acre-feet. The volume decreased each day after that date until the 22d, when the discharge began to increase. On the 3d of May the discharge increased from 181 to over 299 acre-feet. From this date until the 9th of July the demand for water was steady and the volume flowing in the canal had no important fluctuations. Water was turned out of

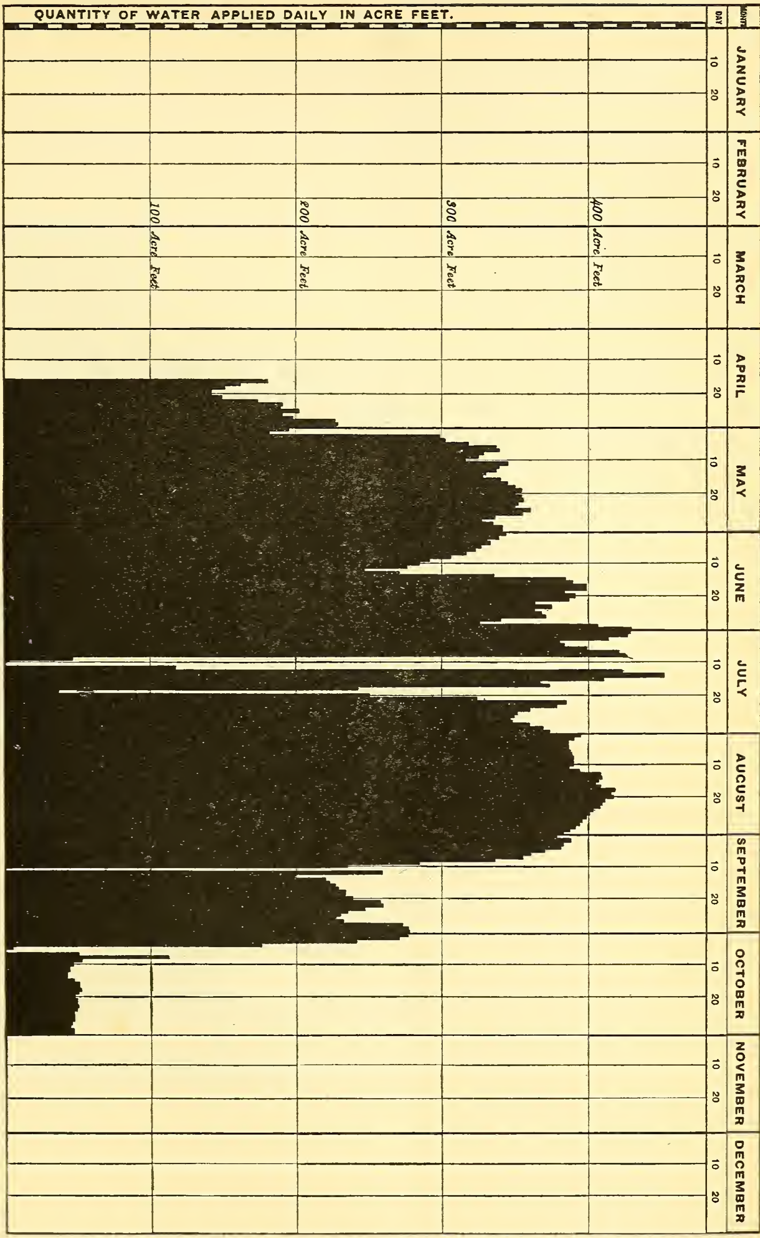


DIAGRAM SHOWING TIME OF IRRIGATION AND DEPTH OF WATER USED FROM CANAL OF THE PECOS IRRIGATION & IMPROVEMENT CO., CARLSBAD, N. MEX.

DIAGRAM SHOWING TOTAL DEPTH OF WATER APPLIED EACH MONTH

HATCHED AREA REPRESENTS RAINFALL. SOLID AREA REPRESENTS IRRIGATION.

DIAGRAM SHOWING THE USE OF WATER NEAR CARLSBAD, N. MEX.

DIAGRAM SHOWING THE TIME OF IRRIGATION AND THE DEPTH OF WATER USED ON THE FARM OF J. J. HAGERMAN, CARLSBAD, NEW MEXICO.

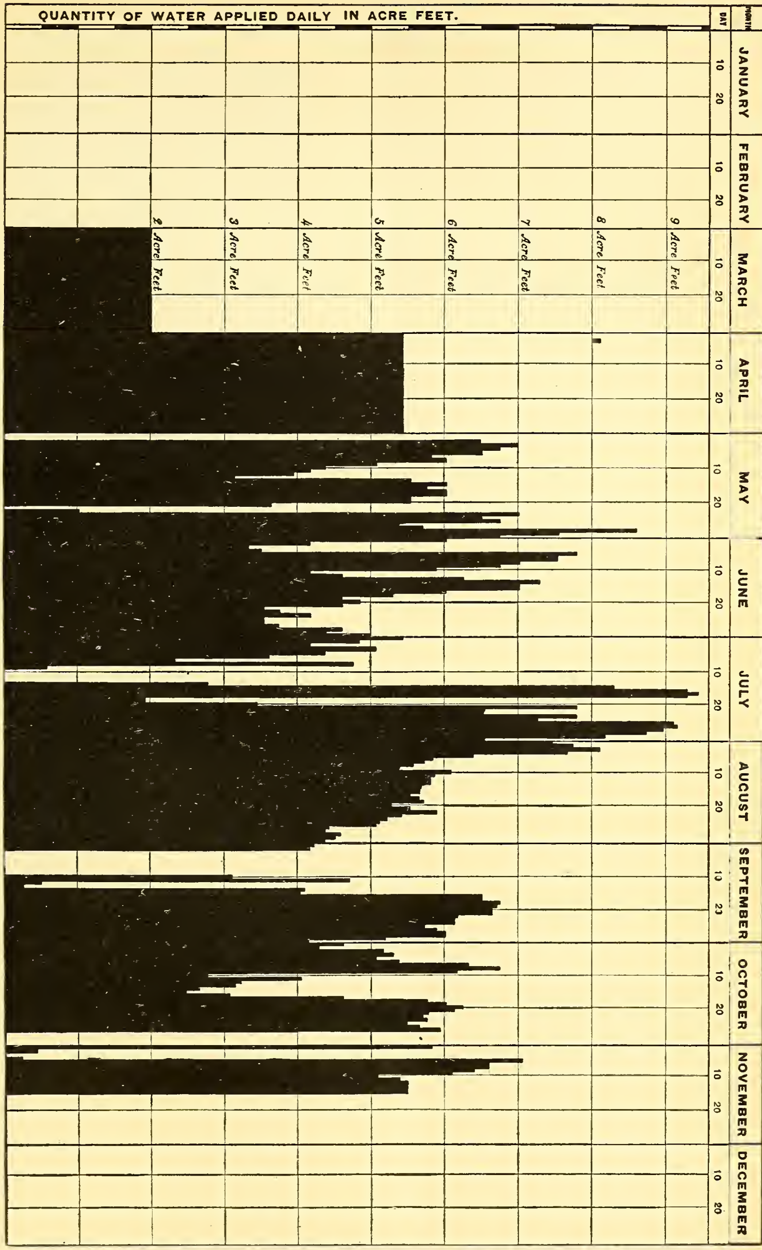


DIAGRAM SHOWING TOTAL DEPTH OF WATER APPLIED EACH MONTH.
HATCHED AREA REPRESENTS RAINFALL. SOLID AREA REPRESENTS IRRIGATION.

DIAGRAM SHOWING THE USE OF WATER ON HAGERMAN FARM, NEAR CARLSBAD, N. MEX.

Diagram Showing the Use of Water near Mesa, Ariz.

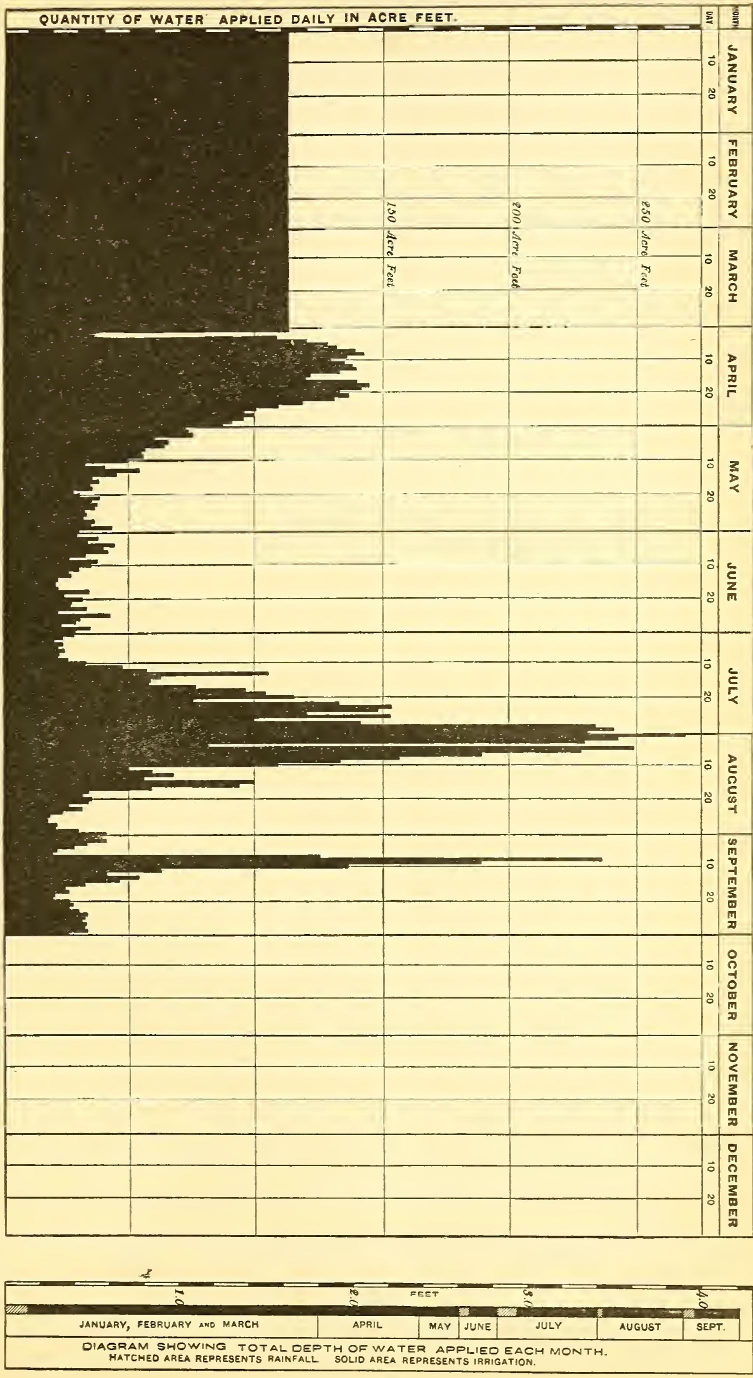


Diagram Showing the Time of Irrigation and Depth of Water Used from the Mesa Canal at Mesa, Arizona.

the canal then so that the channel might be repaired. Water was again turned into the canal on the 12th, and on the 14th the canal carried the maximum volume for any day of the irrigation season. After being deprived of water for several days, the irrigators demanded a large volume. The low points shown in the discharge diagram generally follow rains.

It will be noticed in the column to the right that enough water passed the measuring station, including rainfall, to cover the entire area on the west side of the river to a depth of 7 feet. No rainfall occurred during May and August, and but little during June or July. By referring to the first portion of the diagram it can be seen that the volume of the water used was affected by precipitation, and the column at the right shows that the quantity of water needed each month is about the same when rainfall is included.

The water used during the season of 1899 at this station was in excess of the normal volume needed. The driest season ever known in the valley occurred during that year; the river was lower, and the reservoirs were not filled when irrigation began.

The second station at Carlsbad was installed for the purpose of determining the quantity of water required in irrigation when the loss in transportation was eliminated. Plate V shows the volumes used each day, and the equivalent depth to which the land was covered by water. The farm selected is located near Carlsbad, on the east side of the river. The land is high, the soil is sandy, and owing to the scarcity of vegetation the water receives the direct rays of the sun throughout the day. In addition, the ditch is crooked and of considerable length. For these reasons the loss from seepage and evaporation is excessive, and the soil needs almost constant irrigation to produce crops. The ditch is only 4 or 5 feet wide and about a foot deep. Hence the fluctuations in its discharge are greater than those of the main canal. Yet the two diagrams are somewhat similar. Both show that August is the month when the greatest demand for water is felt, and many of the important fluctuations in the discharge of the canal can be seen in the diagram of this lateral. During the early part of September the ditch broke above the weir, and the channel was dry for a short time. During March and April the record was kept only close enough to form an estimate of the volume of water used. Hence the total volume is inserted for these two months, and no attempt is made to show the fluctuations which occurred each day.

DIAGRAM SHOWING USE OF WATER NEAR MESA, ARIZ.

(Plate VI.)

The diagram is similar to that for the Pecos Canal, inasmuch as it begins and ends abruptly, showing that water was used before and after the measurements were made. However, the greatest demand was felt during the months covered by the measurements. The record from January 1 to March 31, inclusive, was kept by daily gage-rod readings. The total discharge is shown for that period regardless of the daily fluctuations. The small discharge shown in May, June, and a portion of July is due to a shortage of water in the Salt River, from which the canal is taken. As the river increased its discharge the canal received more water, until on the 1st day of August it carried 268.2975 acre-feet. Later the discharge of the canal receded with that of the river, only to rise again in September when rains furnished an additional supply. The great fluctuations shown by this diagram are unusual in canals of the dimensions of the Mesa Canal, and can be explained only by the fact that its supply varied with the volume carried by the river. The column to the right shows the variation in the use of water for different months. It will be seen that the depth to which the land is covered during May and June together is about two-thirds of that for April. A comparison of the discharge diagram of the Mesa Canal and that of the Pecos Canal will serve to show the difference in use when the supply is ample and when it is insufficient. The conditions at the two places are quite similar, and yet, while the Pecos Canal afforded a supply sufficient to cover the land irrigated by it to a depth of 7 feet, the Mesa Canal furnished only enough to cover the land lying below it to a depth of 4.2 feet. The depth of the rainfall is included in both.

DIAGRAMS SHOWING USE OF WATER NEAR RIVERSIDE, CAL.

(Plates VII, VIII, and IX.)

Three stations were maintained on the Gage Canal near Riverside, Cal. It receives its water supply from the Santa Ana River, and the irrigated land was divided into three districts and a station installed where the canal enters each district. All of the water furnished by the canal was measured at station No. 1. At station No. 2 the water left after deducting that needed for the irrigation of district No. 1 was measured, and the remaining discharge of the canal after supplying district No. 2 was measured at station No. 3. The fluctuations in discharge of large and small volumes of water are shown clearly by these three diagrams. It will be seen that as the discharge decreases the fluctuations increase. As the canal is cemented, all the loss between the stations is due to evaporation. The rainy season in this locality occurs in December, January, and February. An examination of the diagrams will show that during this period the demand for water is at a minimum. The vertical or volume scales for stations No. 1 and No. 2 are nearly the same, while for station No. 3 the scale is seven times as great. A comparison between these diagrams and the one furnished by the measurements made in New Mexico shows the difference between

DIAGRAM SHOWING THE TIME OF IRRIGATION AND DEPTH OF WATER USED FROM THE GAGE CANAL IN DISTRICT NUMBER ONE, RIVERSIDE, CALIFORNIA.

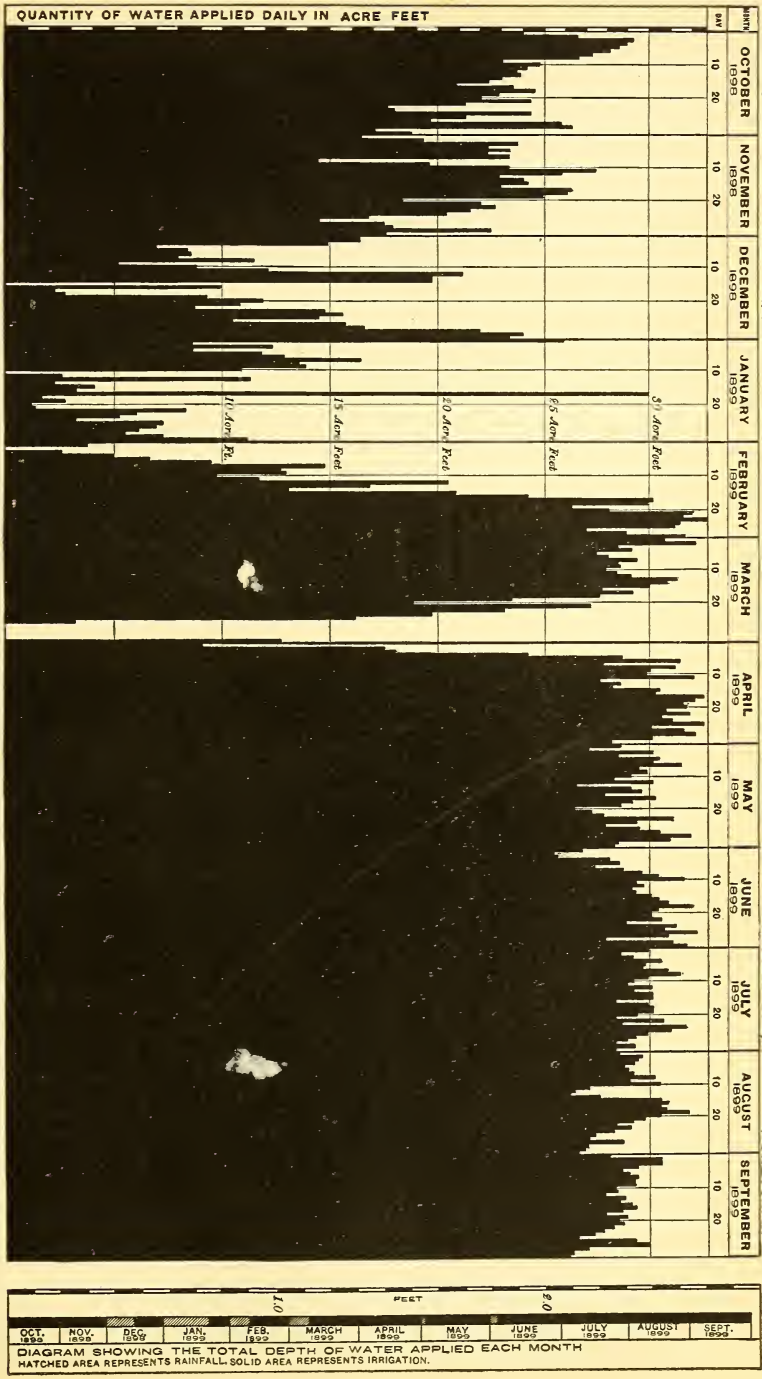
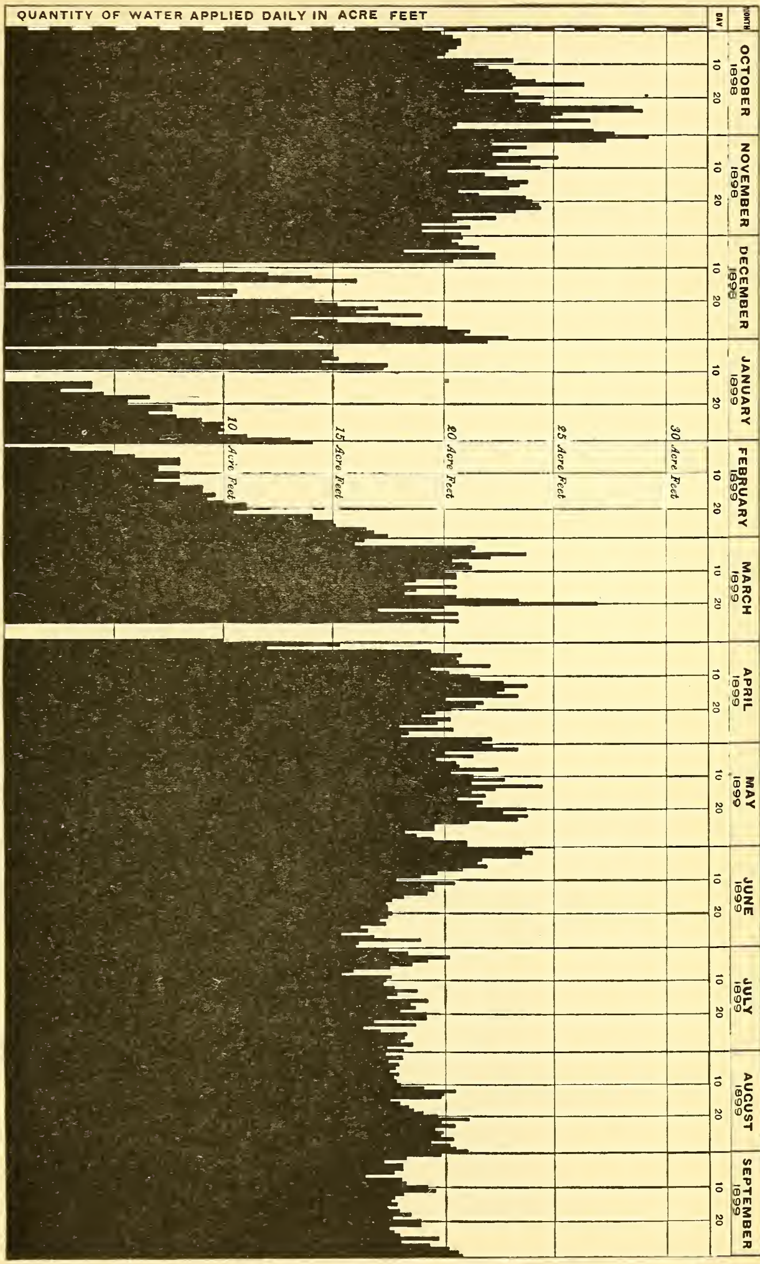


DIAGRAM SHOWING THE USE OF WATER NEAR RIVERSIDE, CAL., DISTRICT NO. 1.

Diagram Showing the Time of Irrigation and Depth of Water Used from the Gage Canal in District Number Two, Riverside, California.



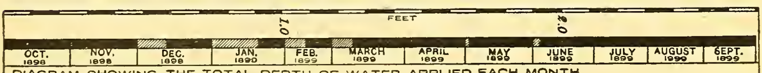


DIAGRAM SHOWING THE TOTAL DEPTH OF WATER APPLIED EACH MONTH
HATCHED AREA REPRESENTS RAINFALL. SOLID AREA REPRESENTS IRRIGATION.

Diagram Showing the use of Water near Riverside, Cal., District No. 2.

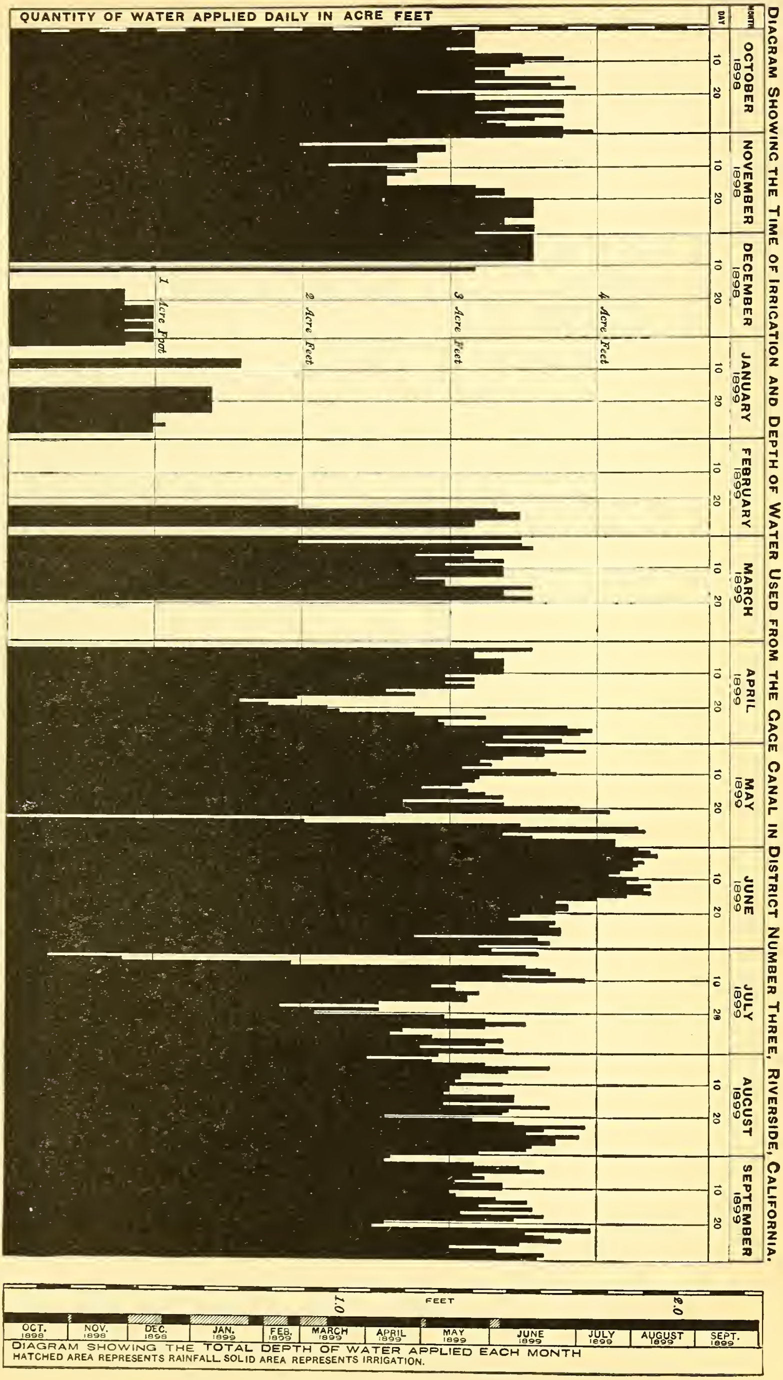


DIAGRAM SHOWING THE USE OF WATER NEAR RIVERSIDE, CAL., DISTRICT NO. 3.

DIAGRAM SHOWING THE TIME OF IRRIGATION AND DEPTH OF WATER USED FROM THE UPPER CANAL, SALT LAKE CITY, UTAH.

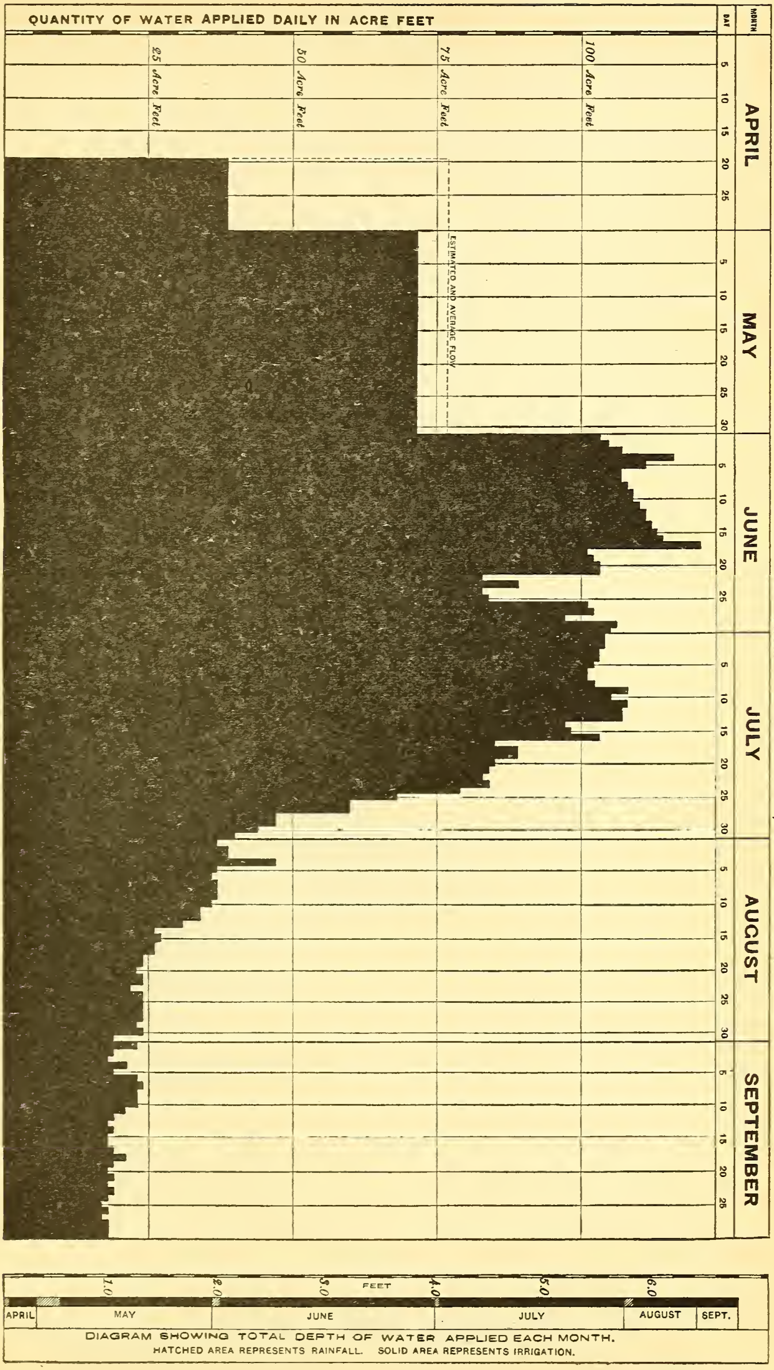
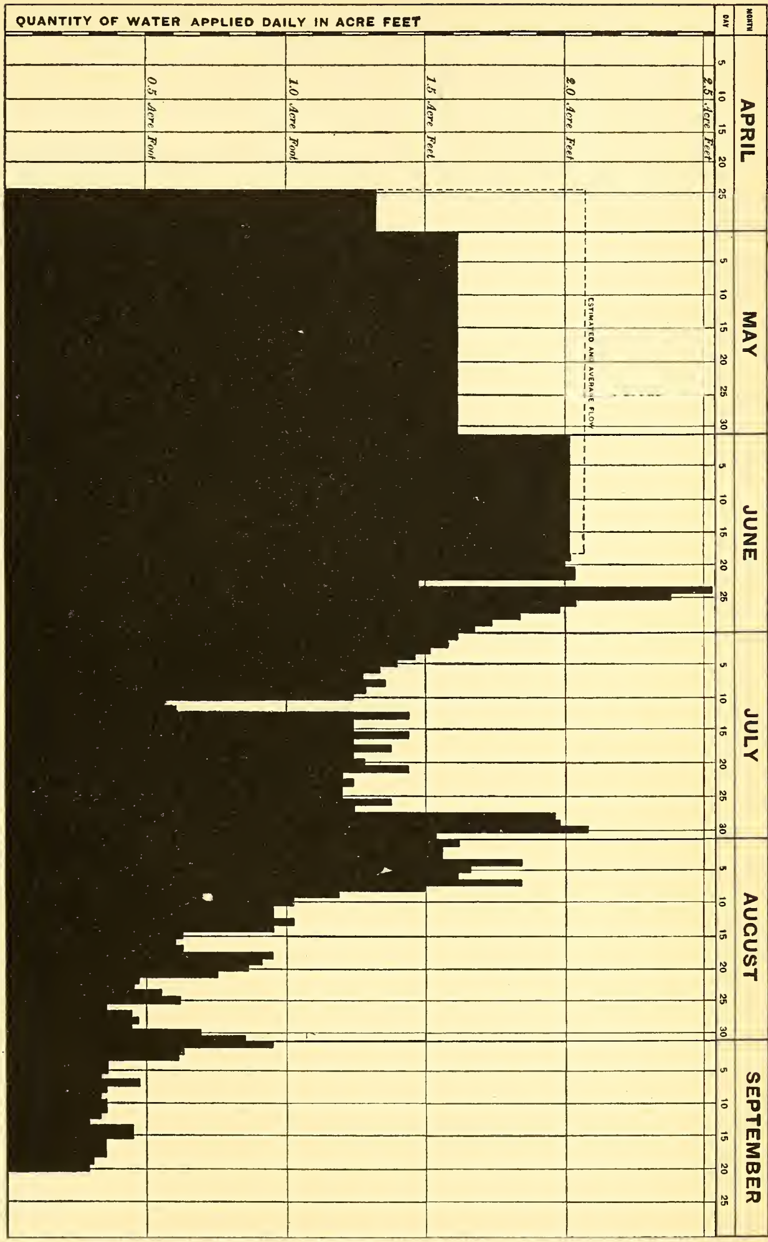


DIAGRAM SHOWING THE USE OF WATER UNDER THE UPPER CANAL, SALT LAKE CITY, UTAH.

Diagram Showing the Time of Irrigation and Depth of Water Used from the Lower Canal, Salt Lake City, Utah.



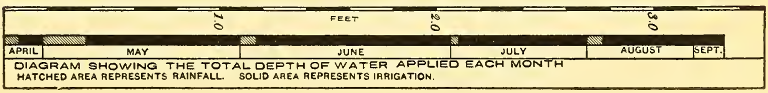


Diagram Showing the use of Water under the Lower Canal, Salt Lake City, Utah.

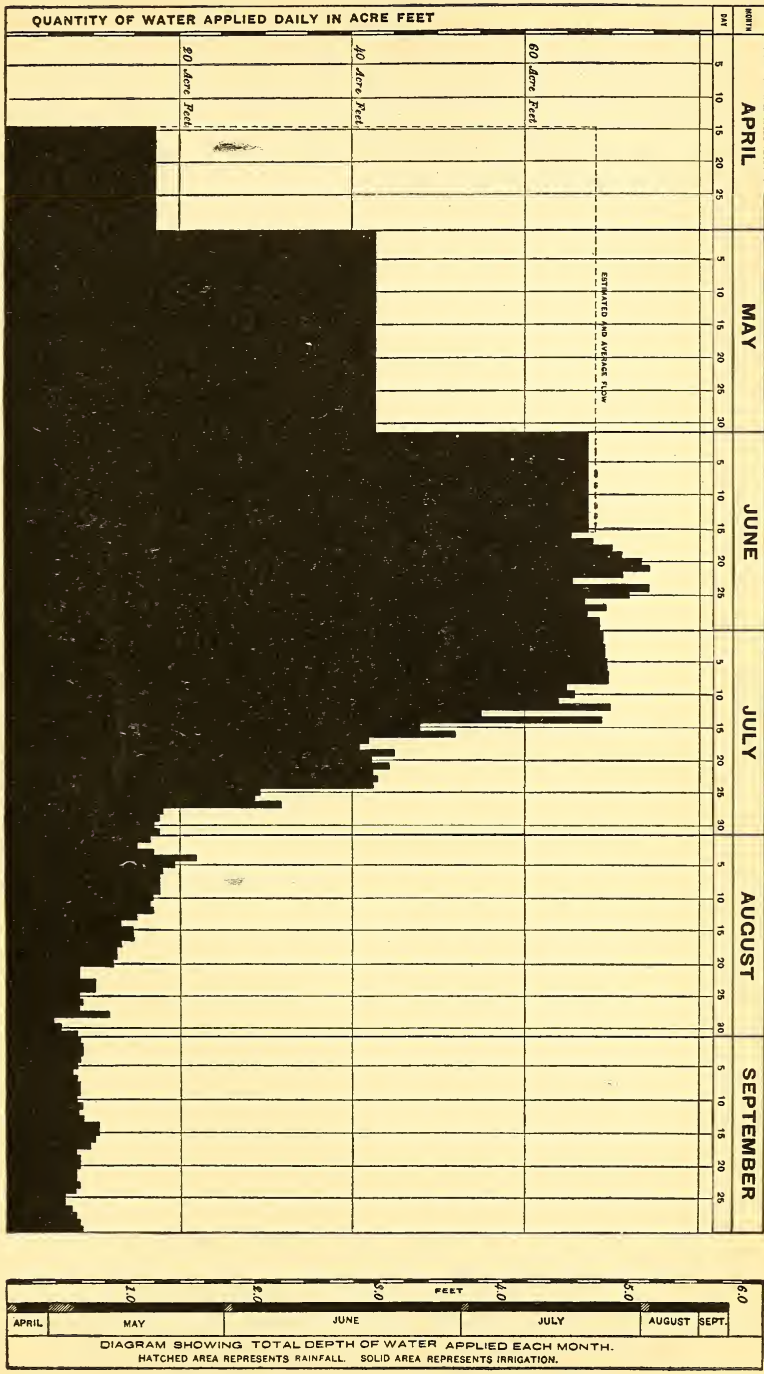


DIAGRAM SHOWING THE TIME OF IRRIGATION AND DEPTH OF WATER USED FROM THE BROWN & SANFORD DITCH, SALT LAKE CITY, UTAH.

DIAGRAM SHOWING TOTAL DEPTH OF WATER APPLIED EACH MONTH.
HATCHED AREA REPRESENTS RAINFALL. SOLID AREA REPRESENTS IRRIGATION.

DIAGRAM SHOWING THE USE OF WATER UNDER THE BROWN AND SANFORD DITCH, SALT LAKE CITY, UTAH.

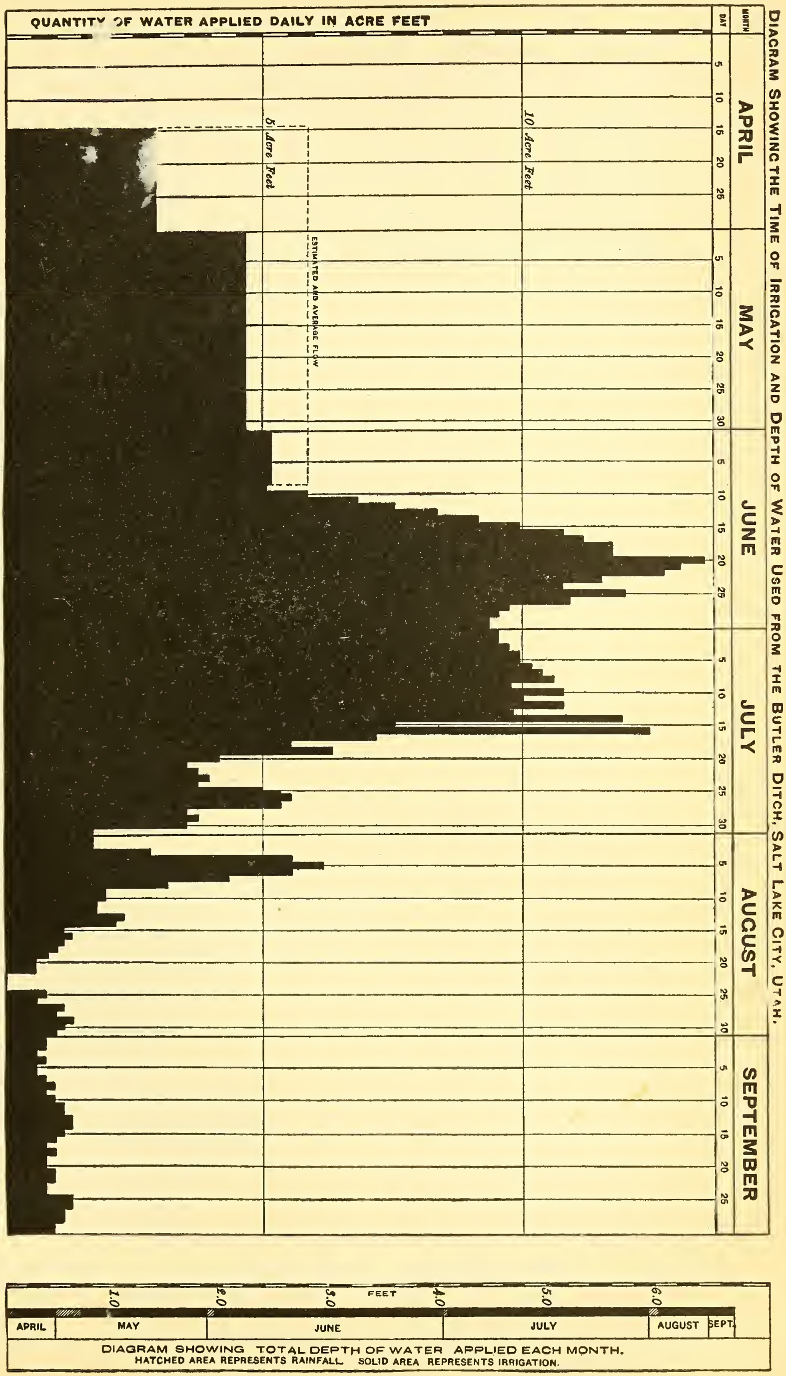


Diagram Showing the use of Water under the Butler Ditch, Salt Lake City, Utah.

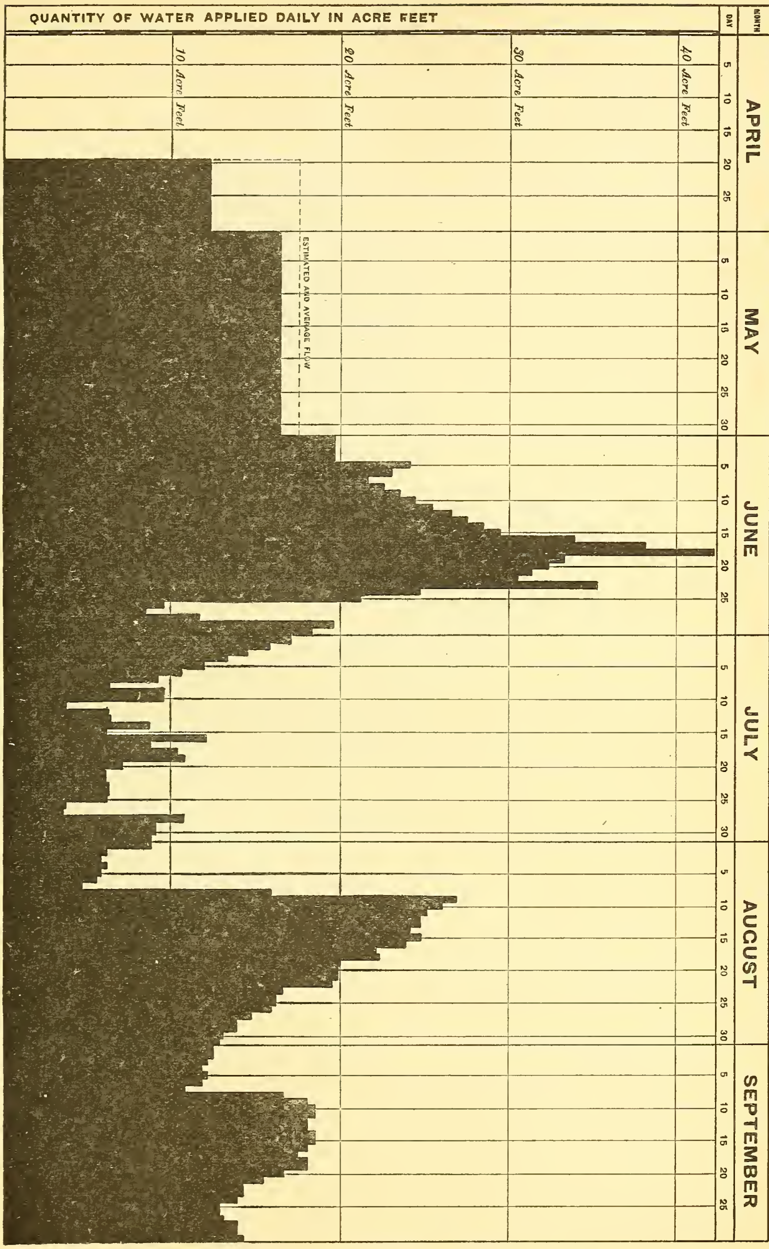


DIAGRAM SHOWING THE TIME OF IRRIGATION AND DEPTH OF WATER USED FROM THE GREEN DITCH, SALT LAKE CITY, UTAH.

DIAGRAM SHOWING TOTAL DEPTH OF WATER APPLIED EACH MONTH.
HATCHED AREA REPRESENTS RAINFALL. SOLID AREA REPRESENTS IRRIGATION.

DIAGRAM SHOWING THE USE OF WATER UNDER THE GREEN DITCH, SALT LAKE CITY, UTAH.

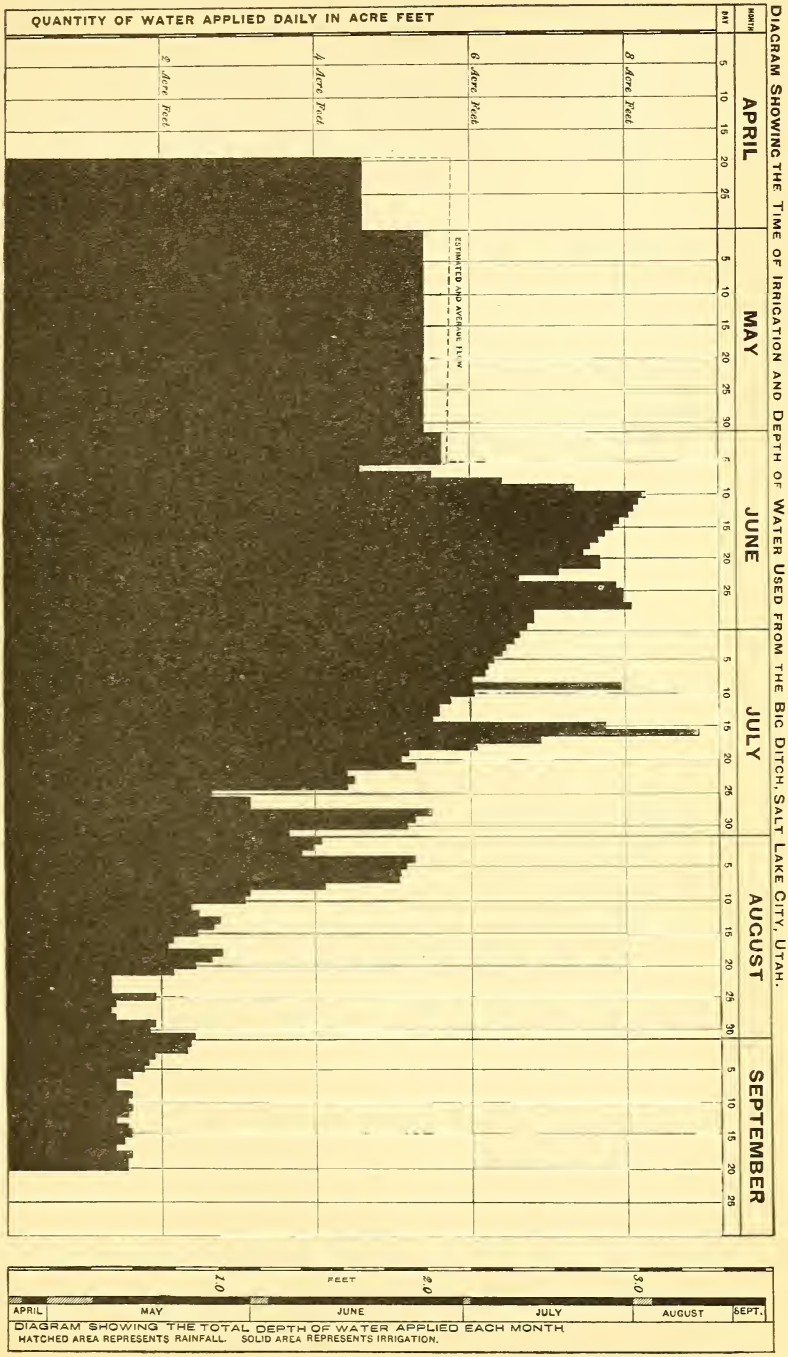


DIAGRAM SHOWING THE USE OF WATER UNDER THE BIG DITCH, SALT LAKE CITY, UTAH.

the economical and wasteful use of water. The climatic conditions are somewhat similar, yet the same quantity of water in California is spread over three times as much land as it was made to cover in New Mexico. When canals are cemented and a large portion of the water is delivered therefrom in pipes, losses are in a large measure prevented. If all localities, regardless of climatic conditions, were to adopt the same precautions for preventing waste as have been installed on the Gage Canal, there is no reason to predict a great variation in the duty of water aside from that which results from the different demands made by various crops and soils. At present the supply furnished by the Pecos River is ample, while in California there is a demand for every available cubic foot of water. The Gage Canal discharged sufficient water to cover the land under it to an equivalent depth of 2.71 feet, including rainfall. The record runs from October, 1898, to September, 1899. During a period of less than six months, beginning with April 15 and ending September 30, the Pecos Canal furnished enough water to cover the land under it to a depth of 7 feet, including rainfall. It is interesting to note that the volume of water needed each month from the Gage Canal is practically the same. The rainfall during the winter months, added to the volume of irrigation, makes the depth during that season equal to that for each of the remaining nine months.

DIAGRAMS SHOWING USE OF WATER FROM BIG COTTONWOOD CREEK, UTAH.

(Plates X, XI, XII, XIII, XIV, and XV.)

The diagrams for each locality where measurements have been kept exhibit special features. The diagrams showing the discharge of canals taking water from Big Cottonwood Creek in Utah are characteristic for that State. The irrigation season covers the same period on each, and the demand for water varies uniformly in all but one. The exception is the Green Ditch, which experienced a shortage of water during the latter part of June and throughout July. It used more water proportionally later in the season than any of the others.

Weirs were used exclusively in all of these canals, and readings of the depth of water flowing over them were made as often as possible by the water masters. The record for April and May has been estimated. The columns at the right of each diagram show that the equivalent depths that the various canals would have covered the land under them varies from 3.32 feet to 6.79 feet. The land on which the greatest depth of water was applied is supplied by the largest canal.

A comparison between these diagrams and those for the southern stations shows that the demand for water is much different during the irrigation season. June and July are the months of maximum use.

April, August, and September are the months when only small quantities are needed, and if the records were carried throughout the year the remaining six months, beginning with October 1, would show practically no discharge.

DIAGRAMS SHOWING USE OF WATER NEAR LOGAN, UTAH.

(PLATES XVI AND XVII.)

Plate XVI shows the results of the measurements made of the discharge of the Logan and Richmond Canal. It has the same general form as have all the diagrams for northern stations, and it is very much like those showing the discharge of the canals taking water from Big Cottonwood Creek, Utah. Water was turned into the canal early in June. The volume was gradually increased until the middle of July, when the demand was at its maximum. By the middle of August the discharge of the canal was small. The demand increased toward the end of August for the irrigation of late crops and meadow land.

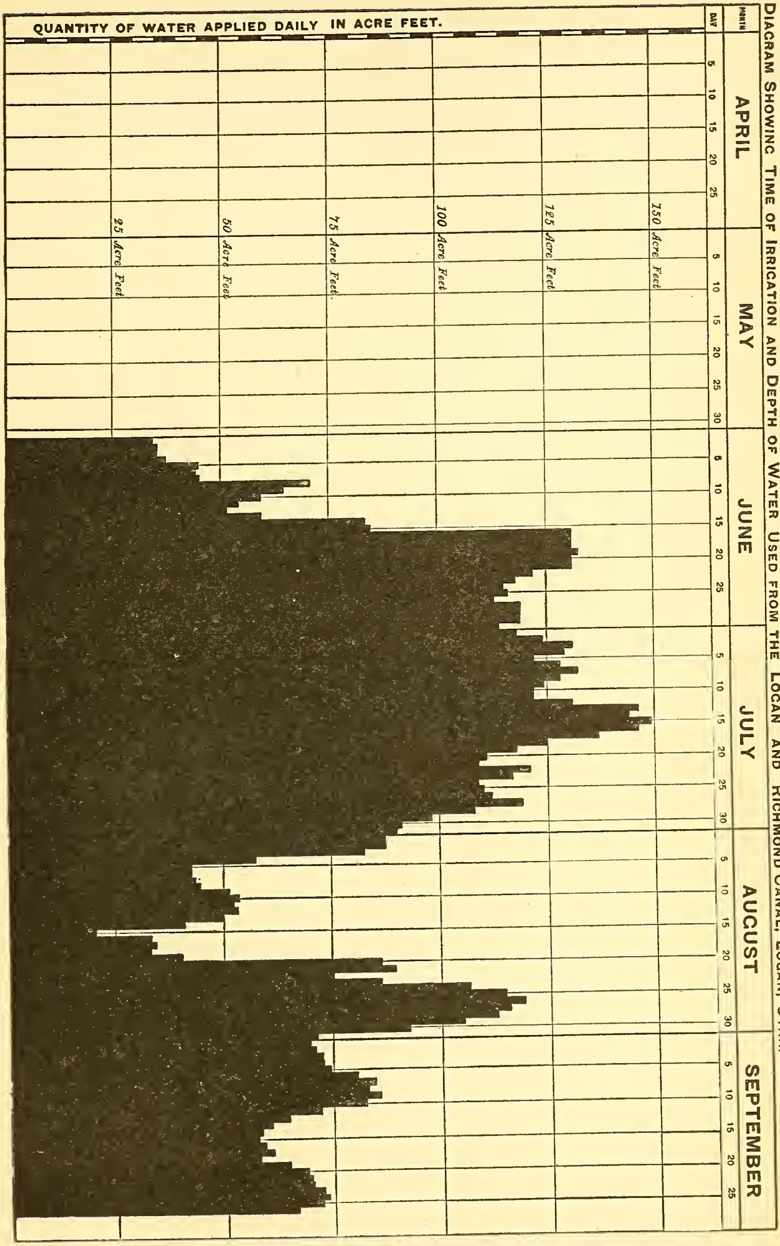
In studying the discharge diagram of a main canal there is a tendency to believe that each irrigator used water continuously and that the quantity of water used fluctuated with the precipitation and the crop irrigated. That this is not the case is shown by Plate XVII, which indicates the volume of water needed and the time when irrigation was necessary for a farm under a lateral from the main canal. Irrigation began on June 20 and was carried on until June 23. No water was used after that until July 9, when irrigation was commenced and continued until the 15th. From that date until August 17 no water was used. The third irrigation occurred between August 16 and August 22.

DIAGRAMS SHOWING USE OF WATER NEAR LAMAR, COLO.

(PLATES XVIII AND XIX.)

The investigation to determine the duty of water in Colorado has been carried on under the irrigation system of the Great Plains Water Company, which takes its supply of water from the Arkansas River. The Amity Canal, whose headgate is near the town of Lamar, was selected for the measurements. While the canal is one of the longest in Colorado, yet the fluctuations in its discharge, as shown by Plate XVIII, are rapid. This can be explained by the scanty supply furnished by the river. The diagram for Amity Canal is similar to that for the Mesa Canal in Arizona in this respect. The demands of the irrigators were in excess of the volume of water available throughout the season. If the reservoirs belonging to this system had been filled, the diagram would have had a much different appearance and would have represented the volume of water needed rather than the volume flowing in the river at the canal's headgate. During the latter part of July no water was available.

Diagram Showing Time of Irrigation and Depth of Water Used from the Logan and Richmond Canal, Logan, Utah.



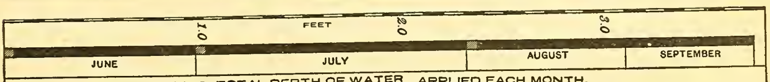


DIAGRAM SHOWING TOTAL DEPTH OF WATER APPLIED EACH MONTH.
HATCHED AREA REPRESENTS RAINFALL. SOLID AREA REPRESENTS IRRIGATION.

Diagram Showing the use of Water at Logan, Utah.

Diagram Showing the Time of Irrigation and the Depth of Water Used on the Farm of Olef Cronquist, Logan, Utah.

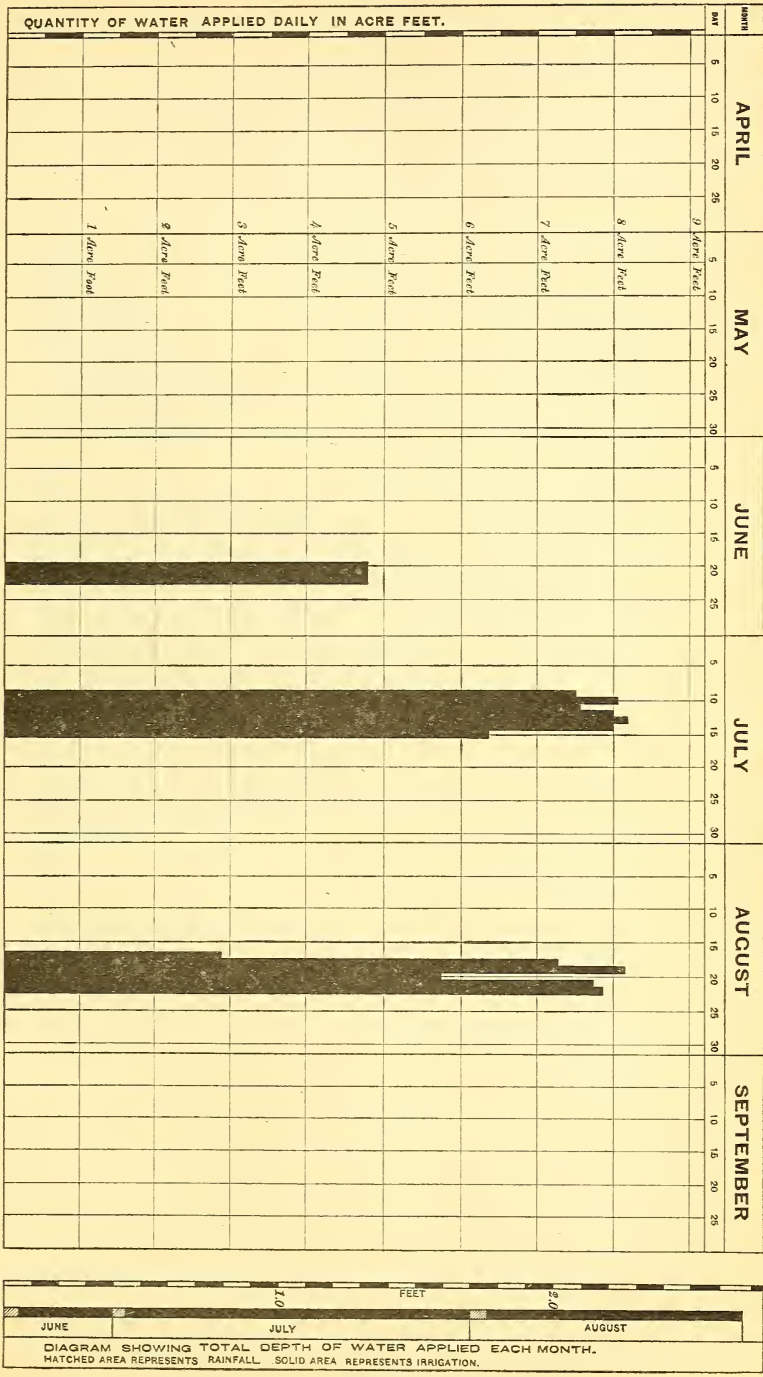
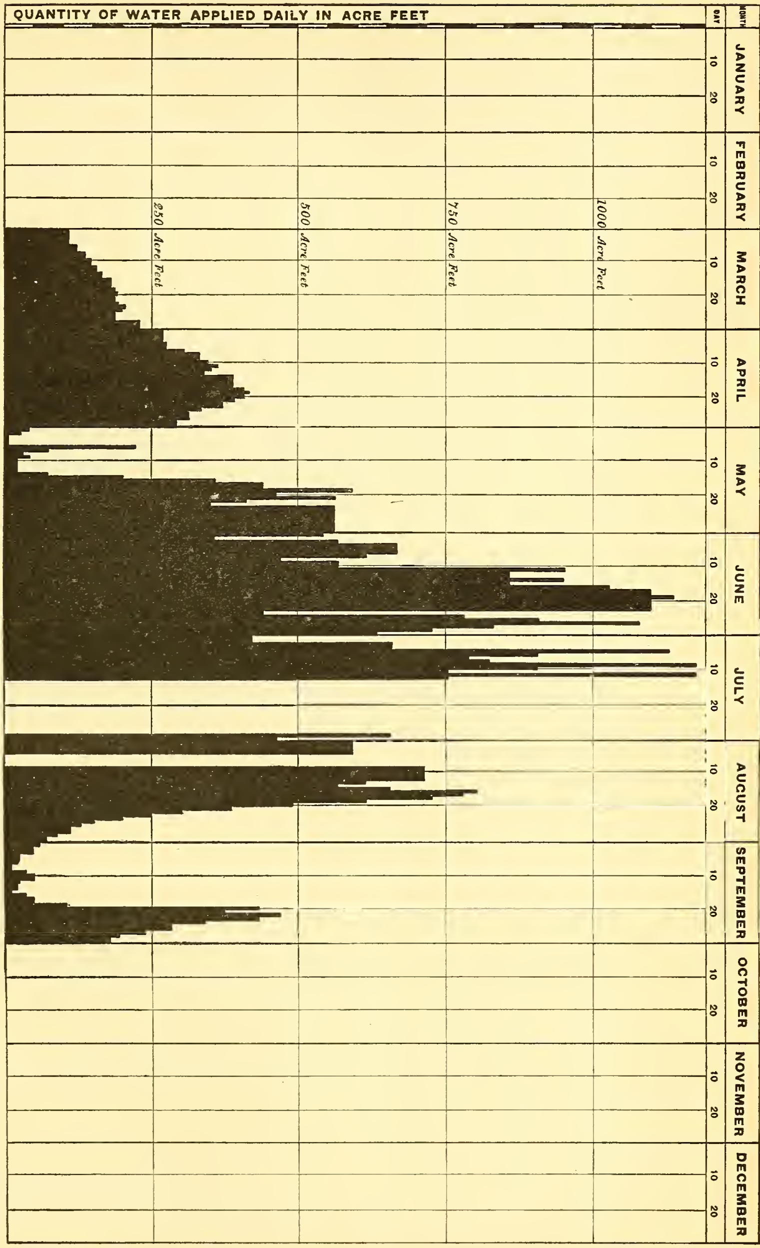


Diagram Showing the use of Water on Farm near Logan, Utah.

DIAGRAM SHOWING THE USE OF WATER NEAR LAMAR, COLO.

DIAGRAM SHOWING THE TIME OF IRRIGATION AND DEPTH OF WATER USED FROM THE AMITY CANAL NEAR LAMAR, COLORADO.



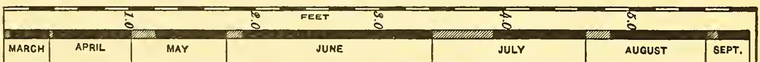


DIAGRAM SHOWING TOTAL DEPTH OF WATER APPLIED EACH MONTH.
HATCHED AREA REPRESENTS RAINFALL. SOLID AREA REPRESENTS IRRIGATION.

Diagram Showing Time of Irrigation and Depth of Water Used from the Biles Lateral of the Amity Canal, Lamar, Prowers Co., Col.

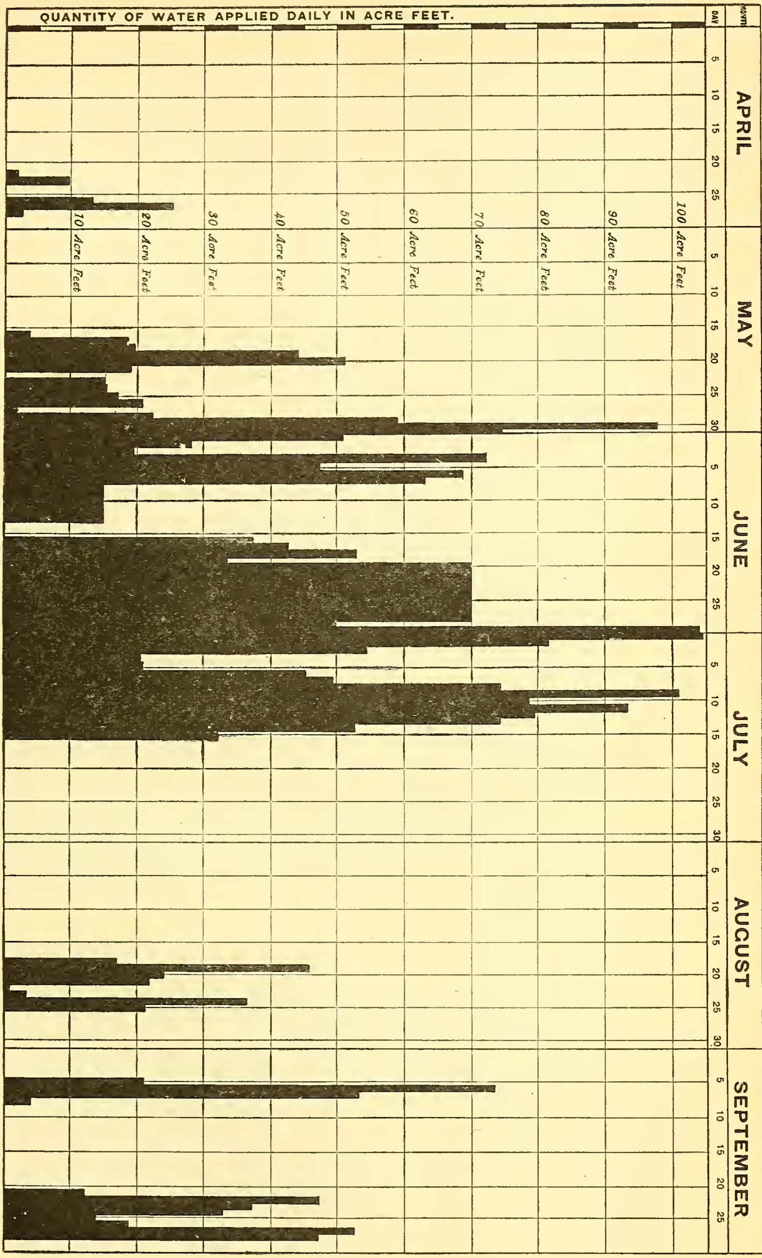


DIAGRAM SHOWING TOTAL DEPTH OF WATER APPLIED EACH MONTH.
HATCHED AREA REPRESENTS RAINFALL. SOLID AREA REPRESENTS IRRIGATION.

Diagram Showing the use of Water under Biles Lateral, near Lamar, Colo.

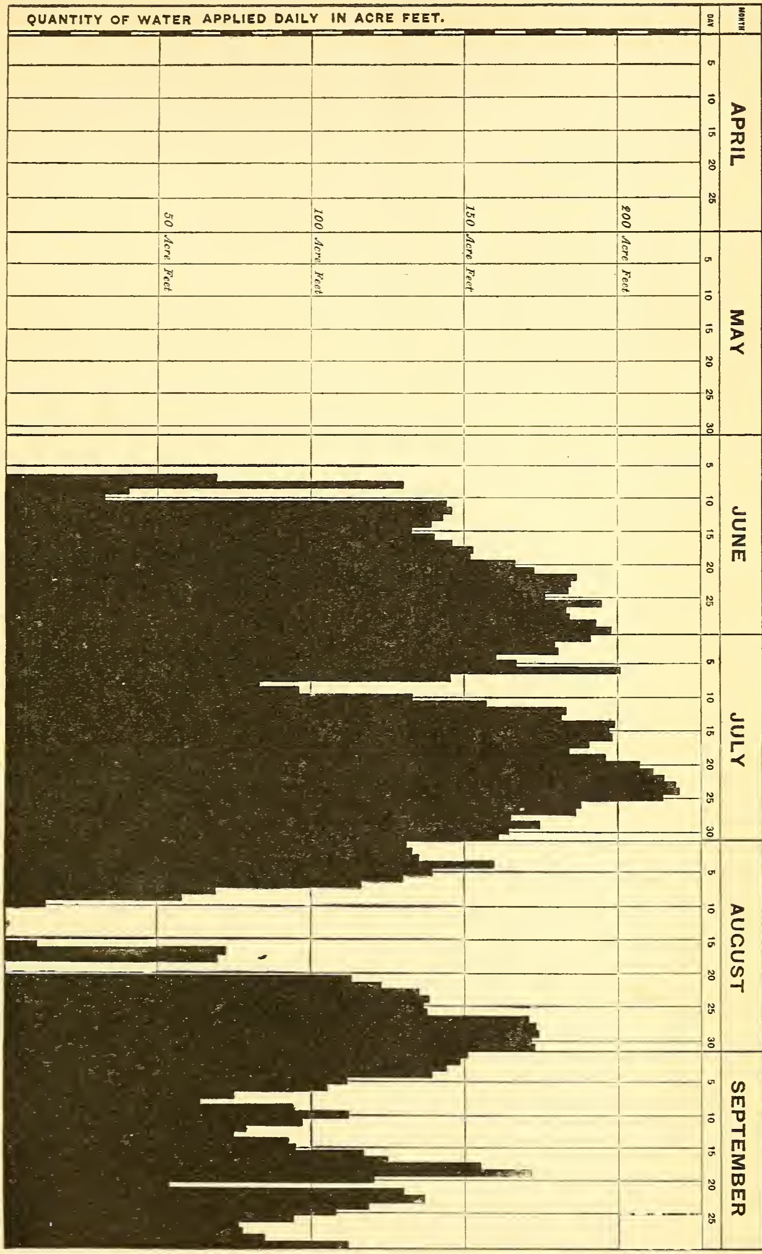


DIAGRAM SHOWING TIME OF IRRIGATION AND DEPTH OF WATER USED FROM THE CANAL OF THE GOTHENBURG POWER & IRRIGATION CO., GOTHENBURG, NEB.

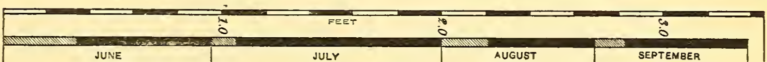


DIAGRAM SHOWING TOTAL DEPTH OF WATER APPLIED EACH MONTH.
HATCHED AREA REPRESENTS RAINFALL. SOLID AREA REPRESENTS IRRIGATION.

DIAGRAM SHOWING THE USE OF WATER NEAR GOTHENBURG, NEBR.

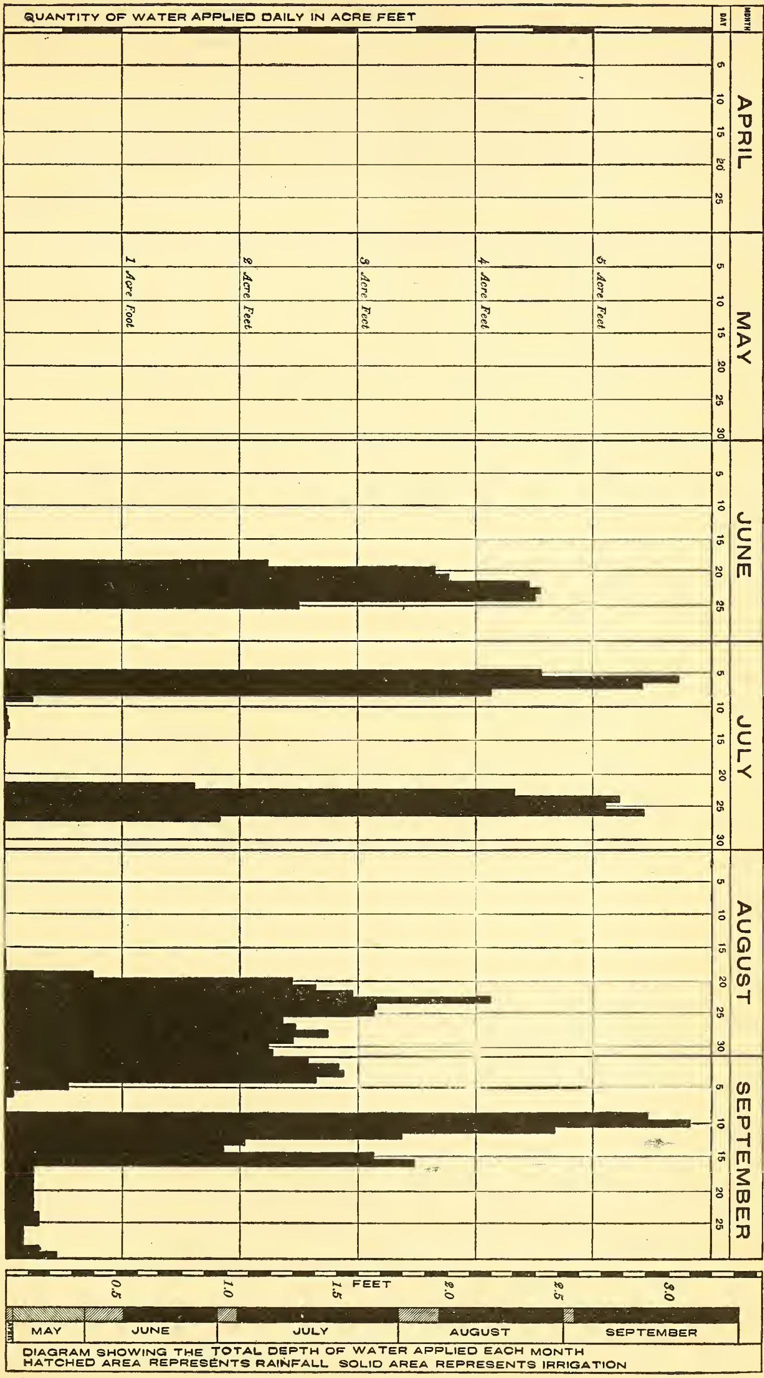


DIAGRAM SHOWING THE TIME OF IRRIGATION AND THE DEPTH OF WATER USED ON THE FARM OF D. W. DAGGETT, GOTHENBURG, NEBRASKA.

DIAGRAM SHOWING THE USE OF WATER ON DAGGETT'S FARM, NEAR GOTHENBURG, NEBR.

Plate XIX shows how intermittent was the supply furnished the Biles Lateral. This lateral leaves the main canal over 40 miles below the headgate; hence the length of the periods of scanty supply are increased by loss of water through seepage and evaporation. The diversity of crops under the Biles Lateral would require an almost constant volume of water to be provided; yet during a month beginning July 17 no water was used. It is difficult to follow the fluctuations of the discharge of the main canal to the lateral. The supply furnished by the river, the volume used between the headgate and the point of diversion of the lateral, and the extent of loss through seepage and evaporation all served to complicate the diagram.

DIAGRAMS SHOWING USE OF WATER NEAR GOTHENBURG, NEBR.

(Plates XX and XXI.)

Two stations were maintained during the season of 1899 on the irrigation system of the Gothenburg Power and Irrigation Company, at Gothenburg, Nebr. One station was installed on the Gothenburg Canal and another on a lateral some 6 miles east of the town of Gothenburg. The effect of the grade given to the Gothenburg Canal is almost totally destroyed by a system of checks along it, put in for the purpose of raising water so that laterals may be taken from the channel. These structures made it impossible to put in measuring flumes or independent weirs. The conditions being suitable, one of the checks was utilized as a rectangular weir.

The irrigation period proper is shown on Plate XX, giving the discharge of the canal, and is included between June 7 and August 10. Water was used later than August 10, but it was not needed for the growth and maturity of crops. The ground was irrigated in some cases after the crops had been harvested, so that the land could be plowed. During the irrigation season the flow of the canal was regulated as the use varied, and but little water ran to waste either at the lower terminus of the canal or through laterals. At Gothenburg is located a reservoir of considerable area, through which the canal runs. This body of water serves to furnish a steady discharge for the canal when such is desired. However, as the demand for water changed each day the volume flowing in the canal varied to meet it, so that the diagram is somewhat irregular in appearance.

The measurements made to determine the duty of water utilized were kept on the farm of D. W. Daggett near Gothenburg. The length of the lateral from the main canal to his land was only a few feet, so that the measuring weir was installed in the bank of the canal. The diagram (Pl. XXI) shows the volume of water used on his farm, and indicates the time when irrigation was necessary and the period required for the same. It will be noticed that water ran in the main canal before any was used for irrigation on the farm. The same fact would be shown if measurements had been kept on every lateral diverting water from the canal. As is generally true of uncemented canals, the discharge was lost by percolation during the first few days of the season. Only corn and wheat were raised and served by the volume of water shown on the diagram. The times when irrigation was necessary are plainly indicated. No water was needed for these crops after July. The discharge shown for August and September either ran to waste or was used to moisten the ground for plowing.

DIAGRAMS SHOWING USE OF WATER NEAR WHEATLAND, WYO.

(Plate XXII and Figures 12 and 13.)

The irrigation system of the Wyoming Development Company is the largest in that State. Two stations were installed under this system during May, 1899; one on Canal No. 2 and another on a lateral taking water from it. Water was turned into the canal on June 11, but little was utilized for irrigation before the 20th. Not only the channel of the main canal, but the entire distribution system had to be saturated. The diagram showing the discharge of water in the main canal indicates that the season began and ended abruptly. It has the appearance of an incomplete record, as though the station had been installed after the use of water began, and that irrigation was continued after the record was concluded. However, such is not the case. The canal is supplied by a reservoir, in addition to diverting water directly from Sybille Creek. The discharge from the reservoir can be varied at will; hence the canal carries the amount of water needed for irrigation under it each day. The crop which requires the greatest volume of water is alfalfa. The steady discharge of the main canal, as shown by the diagram, is largely due to the use of water on areas devoted to this crop. From the 12th of June to the 7th of August the alfalfa was irrigated three times or more.

The land under the lateral was devoted to raising corn and oats. The diagrams showing the volume of water needed for these crops indicate the difference in the irrigation season for the two. As shown by fig. 12, it was necessary to irrigate the oats three times. The rainfall which occurred in June doubtless served as another irrigation. The area of the field was small, hence it was irrigated in from three to five days. Figure 13 shows the time when corn needs water at Wheatland. Irrigation began on July 24 and ended on the 29th.

The rainfall which occurred in September came after all irrigation had ceased and all crops had been harvested; hence it does not in any way affect the volume of water used. Unless the precipitation which occurred in August fell during the early part of the month it had no value as an aid to growing crops.

DIAGRAM SHOWING TIME OF IRRIGATION AND DEPTH OF WATER USED FROM CANAL No. 2 OF THE WYOMING DEVELOPMENT CO., WHEATLAND, WYO.

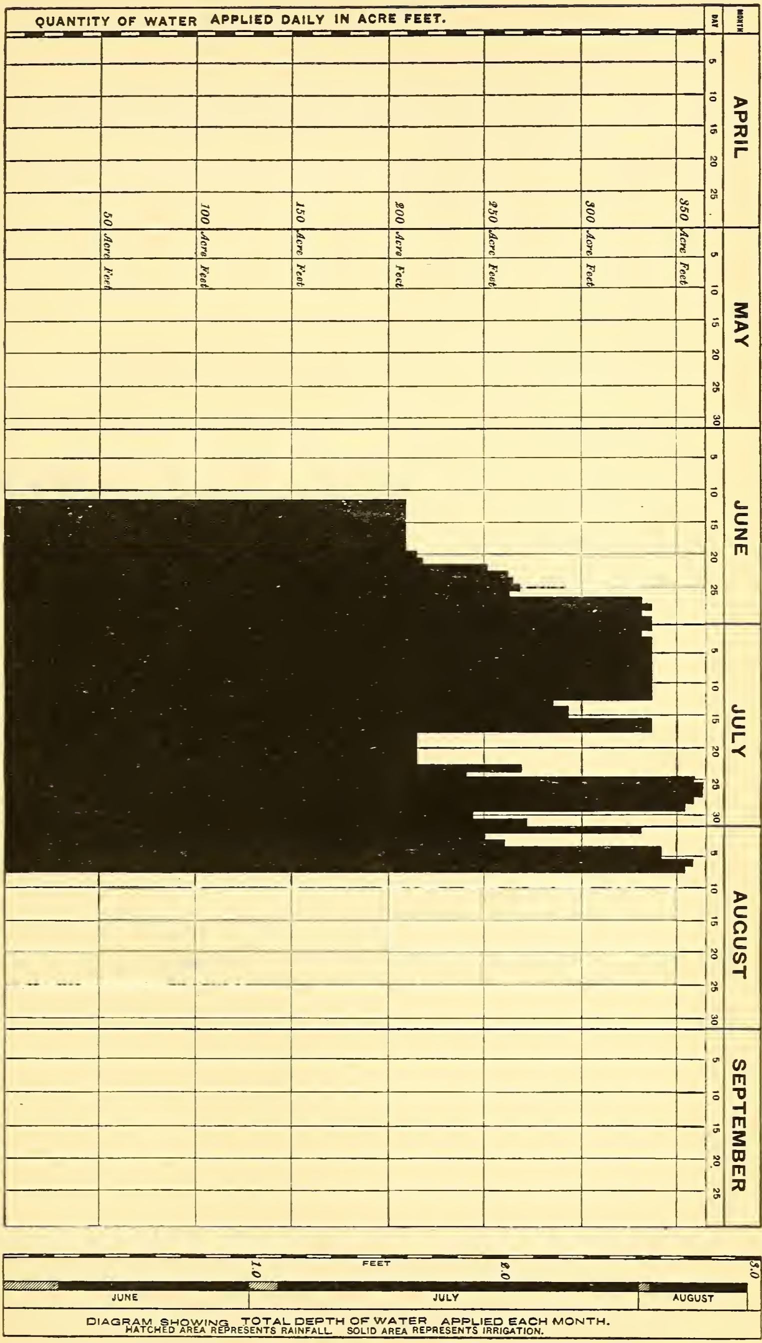


DIAGRAM SHOWING THE USE OF WATER NEAR WHEATLAND, WYO.

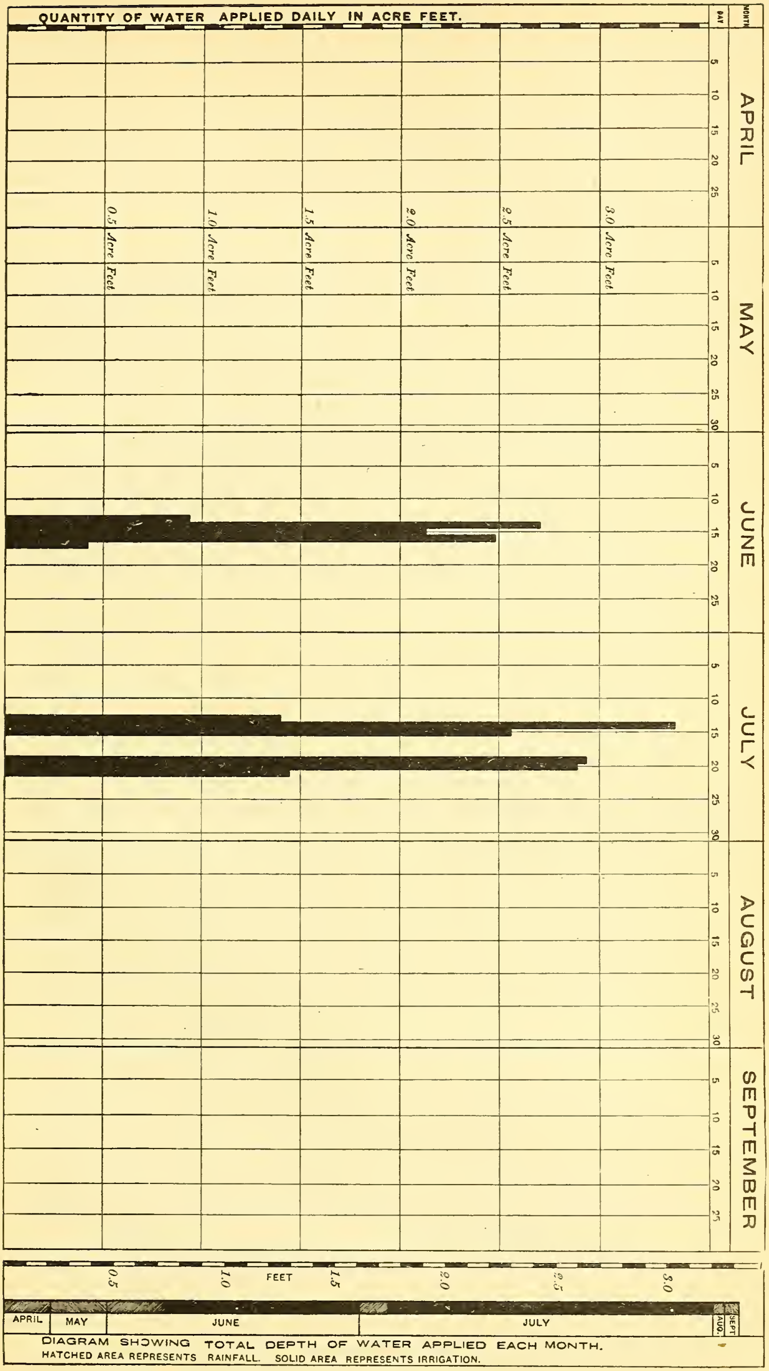


FIG. 12.—Diagram showing the use of water on oats at Wheatland, Wyo.

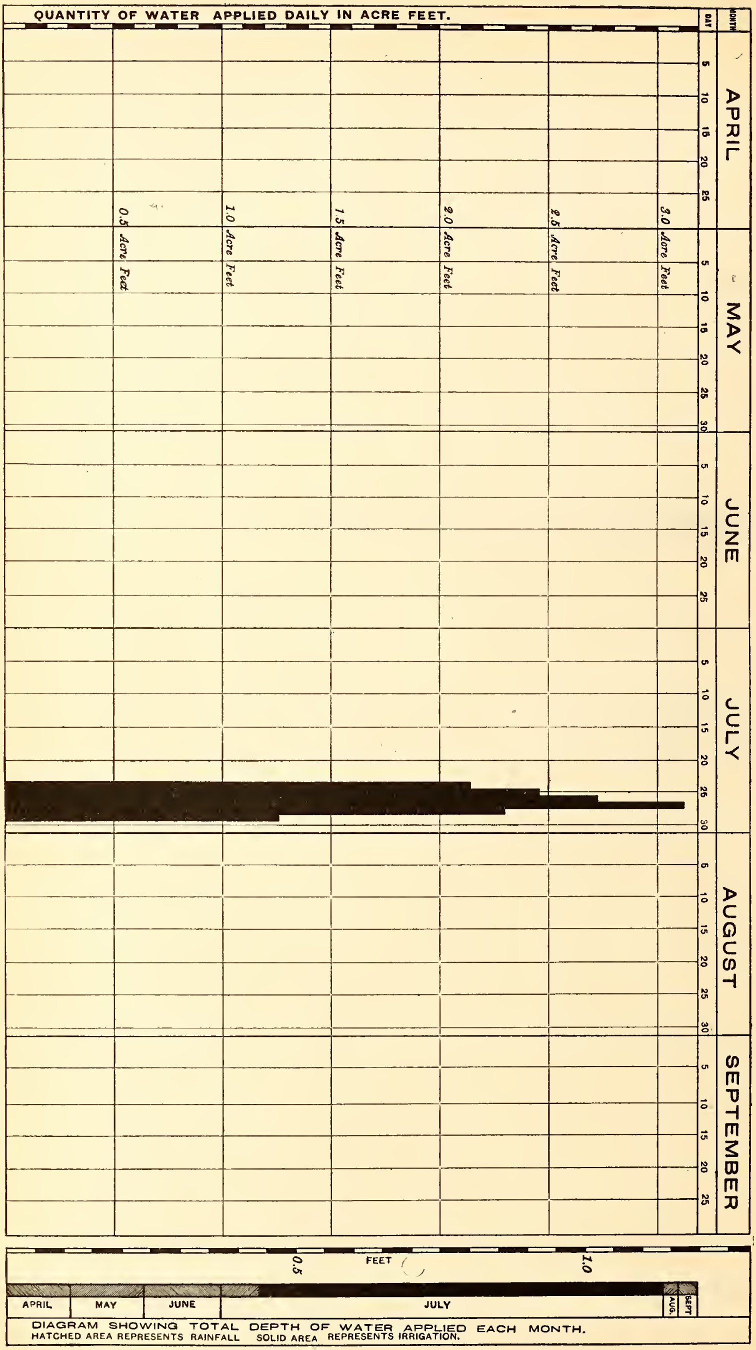


FIG. 13.—Diagram showing the use of water on corn at Wheatland, Wyo.

DIAGRAM SHOWING TIME OF IRRIGATION AND DEPTH OF WATER USED FROM THE RUST LATERAL OF THE BOISE AND NAMPA CANAL, BOISE, IDAHO.

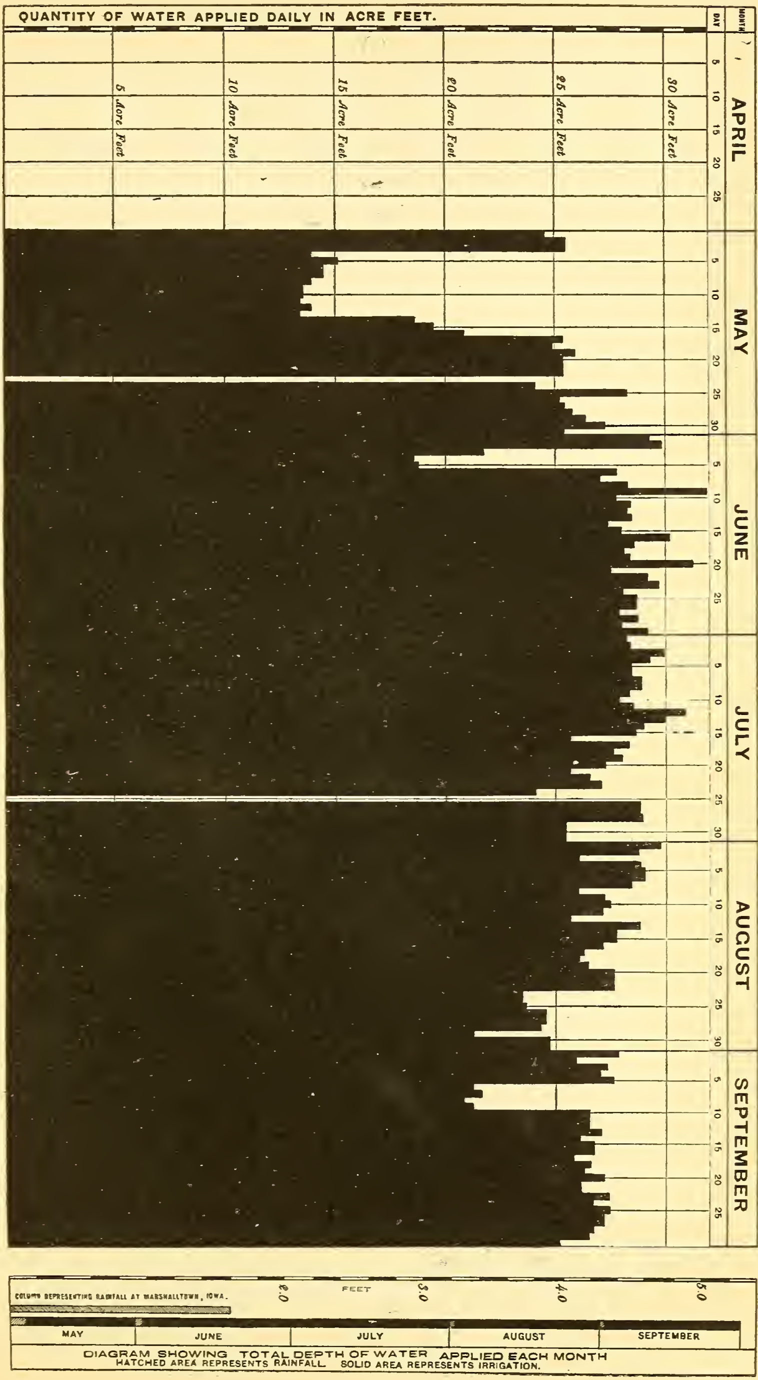


DIAGRAM SHOWING THE USE OF WATER AT BOISE, IDAHO.

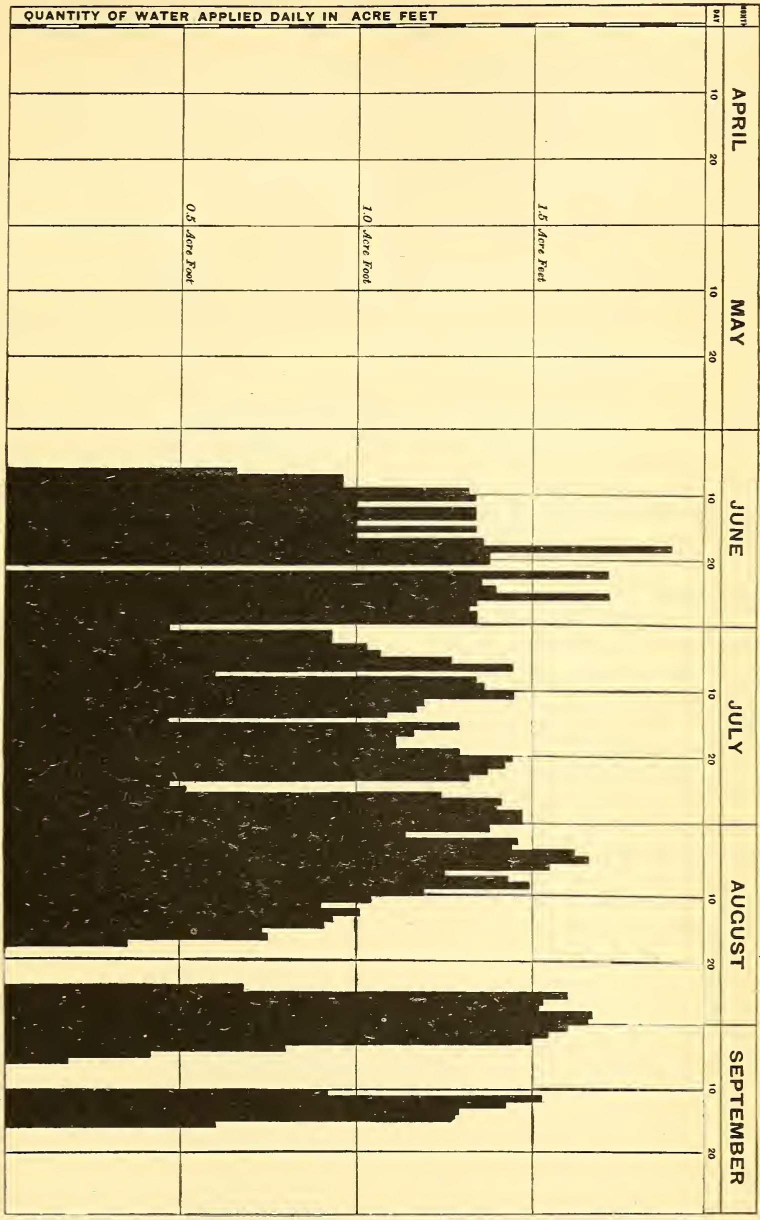


DIAGRAM SHOWING THE TIME OF IRRIGATION AND DEPTH OF WATER USED ON THE FARM OF EDGAR WILSON, NEAR BOISE, IDAHO.

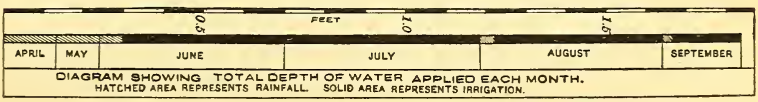


DIAGRAM SHOWING THE USE OF WATER ON ORCHARDS AT BOISE, IDAHO.

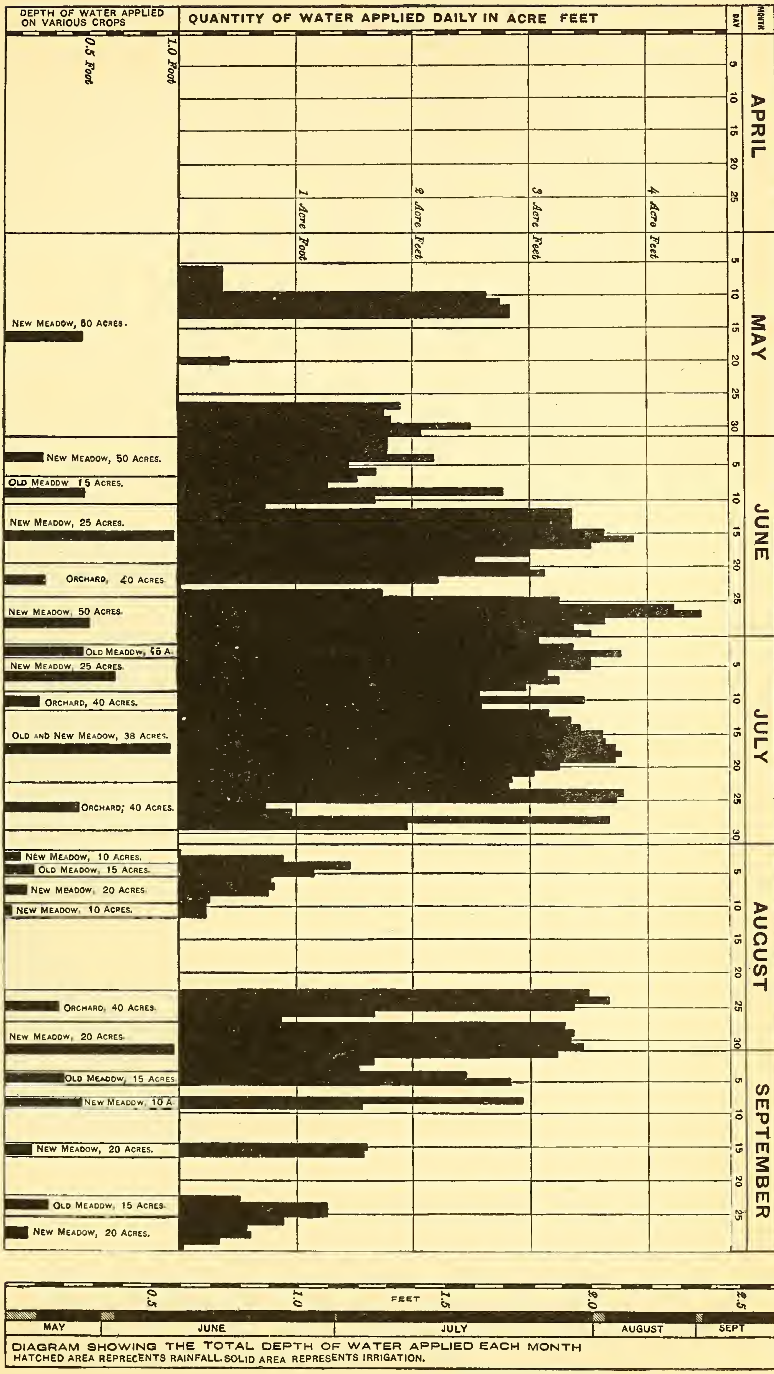


Diagram Showing the Time of Irrigation and Depth of Water Used on the Farm of A. F. Long, near Nampa, Idaho.

Diagram Showing the Use of Water on a Farm near Nampa, Idaho.

DIAGRAM SHOWING THE TIME OF IRRIGATION AND THE DEPTH OF WATER USED FROM THE MIDDLE CREEK CANAL, BOZEMAN, MONTANA.

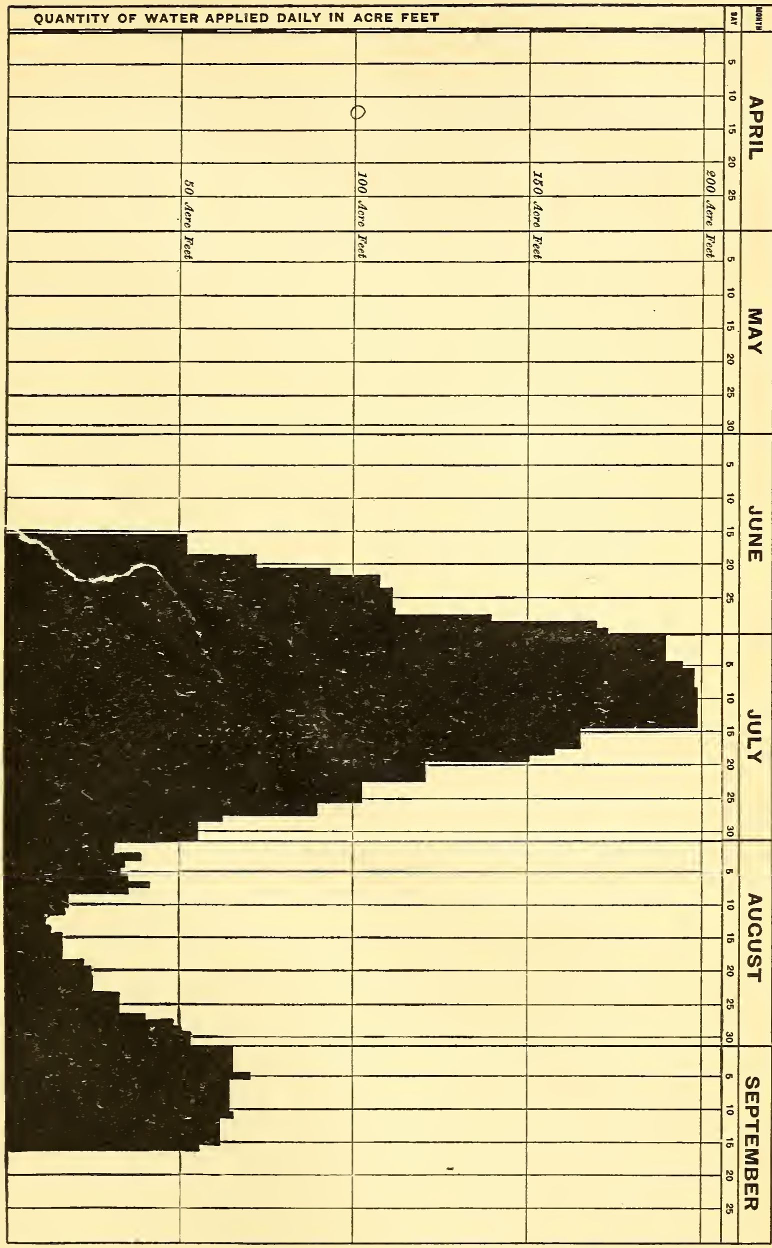


DIAGRAM SHOWING TOTAL DEPTH OF WATER APPLIED EACH MONTH.
HATCHED AREA REPRESENTS RAINFALL. SOLID AREA REPRESENTS IRRIGATION.

DIAGRAM SHOWING THE USE OF WATER NEAR BOZEMAN, MONT.

DIAGRAMS SHOWING USE OF WATER NEAR BOISE, IDAHO

(Plates XXIII, XXIV, and XXV.)

The investigations in Idaho were confined to canals taking water from the Boise River. The entire work deals with the use of water on farms and from laterals. No measurements were made of the water used from canals, but the investigations carried on relative to the use under the Rust Lateral, as shown by Plate XXIII, were quite similar to the record obtained from canals elsewhere. The season begins abruptly, showing that irrigation was practiced by a number of farmers as soon as a supply was afforded. The diagram shows that no great fluctuations took place in the discharge of the lateral. This can be explained in several ways. A large number of users generally have to irrigate a variety of crops. Each man is his own judge as to when to plant and when to irrigate. If in addition the irrigators are inclined to waste water, the volume consumed becomes more uniform.

The diagram (Pl. XXIV) showing the volume of water used for the irrigation of the orchard of Mr. Wilson, near Boise, indicates a much more economical use. From June 7 to August 14, inclusive, irrigation was practiced constantly, but the flow was so regulated that the entire volume of water received by the land, including the rainfall during the irrigation season, would cover it to a depth of only 1.8 feet.

Plate XXV is the most interesting diagram from Idaho. It shows the volume used on the farm of Mr. A. F. Long, near Nampa. Irrigation was begun in May and continued until late in September. The unusual length of the irrigation season is due to a large acreage of meadow. The land devoted to orchards was irrigated during practically the same season as covered by the irrigation of Mr. Wilson's orchard. Both the old and new meadow were irrigated at intervals throughout the season. The third portion of the diagram under the discharge diagram shows the dates when the various crops were irrigated, and the depths to which the land was covered each time. Mr. Wilson's orchards required steady irrigation for over two months. Corn and oats at Wheatland required an irrigation period of six days and eleven days, respectively, while Mr. Long's new meadow was irrigated often during a period of five months, beginning with May. The length of the season for irrigating grains and fruits in the Boise Valley is shown by the records furnished from the farms of Mr. Wilson and Mr. Long. The season practically begins on the 1st of June and ends at about the middle of August. The water used before and after these dates plays no important part in the total volume of water applied to the land.

DIAGRAM SHOWING USE OF WATER NEAR BOZEMAN, MONT.

(Plate XXVI.)

Plate XXVI shows the results of the measurements of the discharge of the Middle Creek ditch, near Bozeman, Mont. The total discharge of the Middle Creek ditch, as shown by the diagram, was 8,074 acre-feet, or enough including rainfall to cover the land irrigated to a depth of 2.56 feet. The use of water after August 15 is rather unusual, and the irrigation season for Bozeman really lies between the middle of June and that date. The time when irrigation is necessary at Bozeman is practically the same as at Wheatland, Wyo. The diagrams for different places, however, are not similar. The use at Bozeman begins on the 16th and gradually increases until the 1st of July. This gradual increase and decrease in the volume used, while partially due to a short season, can, in a measure, be ascribed to a large area of the irrigated land being sown to grains and garden produce.

REPORTS OF SPECIAL AGENTS AND OBSERVERS.

The stations included in this report fall naturally into two groups, the first including the States and Territories in which the use of water may be continuous; the second those in which it is interrupted during the winter months. The first includes Texas, New Mexico, Arizona, and California; the second, Nebraska, Colorado, Wyoming, Montana, Utah, and Idaho. The reports follow in the order in which these States are here named:

TEXAS.

The distance from the eastern boundary of Texas to its western limit at El Paso is 700 miles. The variation in annual rainfall between the two extremes is 37.6 inches, being 48.7 inches at Texarkana and 11.1 inches at El Paso. Eastern Texas therefore is humid, western Texas is arid, while the north central portion is debatable ground.

In the arid section of the State the use of water in irrigation extends from the Gulf of Mexico to the northern limit, a range of 10 degrees of latitude. In the southern end of this portion of the State irrigation in winter is practical to some extent; in the north it is restricted to the spring and summer months. A comprehensive study of the methods of irrigation in this State is therefore an undertaking of considerable magnitude, and the work done in 1899 was only a beginning.

The observations on the duty of water in 1899 were made at Beeville on the Gulf coast near the southern extremity of the State. This place was chosen because it is in the section between the regions where irrigation is necessary and where it is simply advantageous. In climate and products it is in some respects different from all other stations at which observations were made.

No measurements were made in northwestern Texas because those made at Carlsbad, N. Mex., were regarded as applying fairly well to this region. The measurements in Texas are being made by S. A. McHenry, superintendent of the Beeville substation of the Texas Agricultural Experiment Station. The use of water at this place being continuous, no report can be made at this time of the annual duty. The only crop irrigated during the summer was watermelons. A patch of watermelons was irrigated on June 1 and the water used was equal to a layer 1 inch in depth over the surface irrigated. It was estimated that the yield of the irrigated land was about 25 per cent greater than that of an adjacent patch not irrigated. The summer rainfall this year was ample for most crops, being nearly 12 inches for the six months from May to October.

All the streams of Texas carry more or less sediment in suspension. This fact has delayed the construction of many large irrigation works, and the solution of the problems relative to the effect of silt on ditches and cultivated fields must be brought about before the irrigated area in Texas is greatly increased. When water containing this silt is applied to a field, a deposit is left on the surface. Whether this has been beneficial or otherwise has long been a disputed question. It is at present the most important question connected with irrigation in the Southwestern States. Those most interested in the agricultural interests of those States have asked for a careful study of the problems connected with the depositions of silt in canals and on fields by some disinterested party.

With this end in view, arrangements have been made with Prof. J. C. Nagle, of the Agricultural and Mechanical College at College Station, Texas, for the collection and analysis of samples of water from important streams of Texas. He is to be aided by the chemist of the State experiment station in the analysis of the samples. He has already collected a large number of samples from various streams during floods and during seasons of low water. These have all been forwarded to College Station, where the work of analysis is being carried on. The work of collecting the samples from the rivers has raised problems of its own. A special instrument has been designed and constructed which permits samples to be collected at any depth between the surface and the bed of the stream.

The report on the results of this investigation will be prepared by Professor Nagle and published in bulletin form.

NEW MEXICO.

There are two important irrigation districts in New Mexico: The valleys of the Rio Grande and of the Pecos. Measurements of the duty of water were made in both. The records on the Rio Grande were kept by Profs. Charles A. Keffer and J. D. Tinsley, of the New Mexico Agricultural Experiment Station; those on the Pecos by Mr. W. M. Reed, chief engineer of the Pecos Irrigation and Improvement Company.

The work in this Territory at the experiment station was conducted for the purpose of information rather than for pecuniary profit, and had the further drawback of an insufficient water supply during part of the year. The results were so unsatisfactory that they are not given.

USE OF WATER IN IRRIGATION IN THE PECOS VALLEY.

By Special Agent W. M. Reed,

Chief Engineer of the Pecos Irrigation and Improvement Company.

BEGINNING OF AGRICULTURE IN THE PECOS VALLEY.

Previous to 1888 the Pecos Valley was known only to range stockmen and a few farmers who had settled on the small streams and springs where it was easy to divert water for irrigation purposes. The success of these few farmers demonstrated that the soil, water, and climate of the valley were adapted to successful farming, and this knowledge led Mr. Charles B. Eddy and Mr. Charles W. Greene to attempt reclaiming the valley upon a large scale. Others were interested and companies with strong financial backing were organized to carry out the ideas of Messrs. Eddy and Greene. Work was begun on a canal from the Rio Hondo, 5 miles east of Roswell, and also on a canal from the Pecos River 6 miles north of Eddy. From March, 1889, the work was carried on with vigor until the system was in working order.

As this report is to cover only the investigations in Eddy County, nothing will be said about the canal in Chaves County, taken from the Rio Hondo, more than that it was carried to completion and farming was begun under it in the summer of 1891. At the present time there are about 4,000 acres in cultivation under the system.

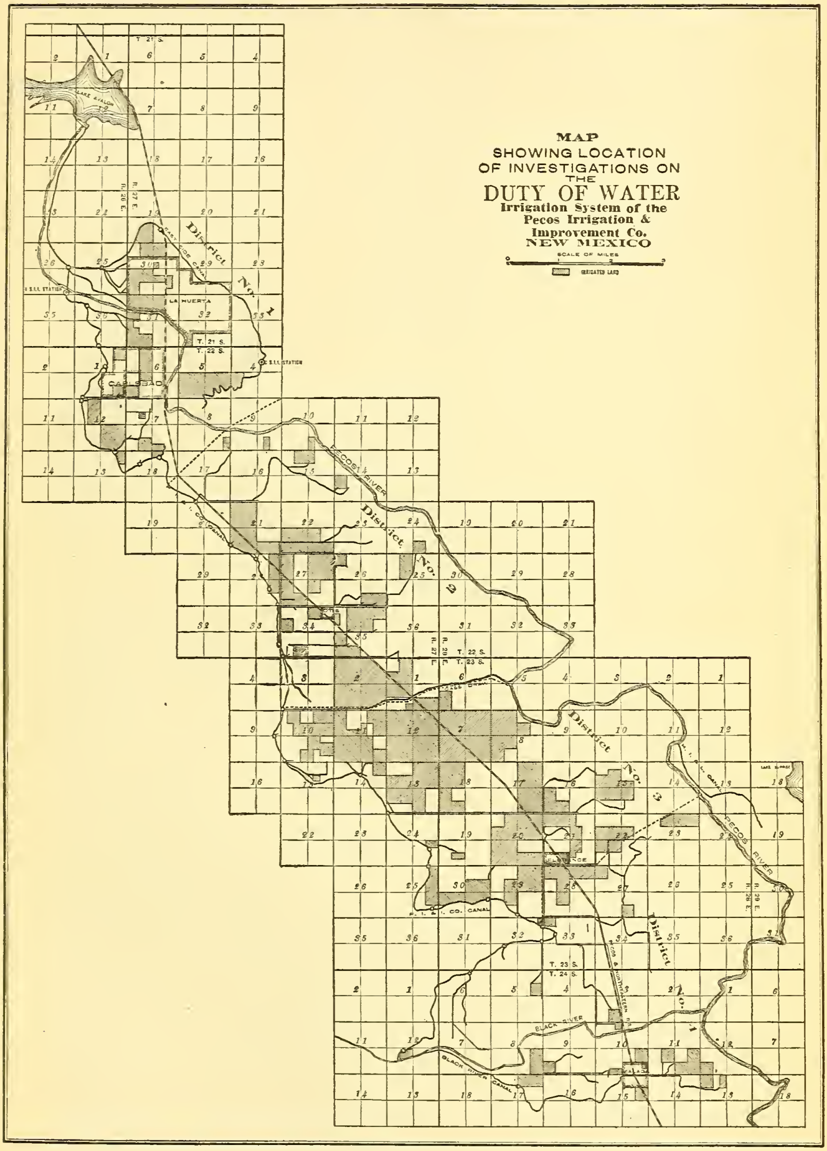
THE IRRIGATION SYSTEM OF THE PECOS IRRIGATION AND IMPROVEMENT COMPANY.

(Map, Plate XXVII.)

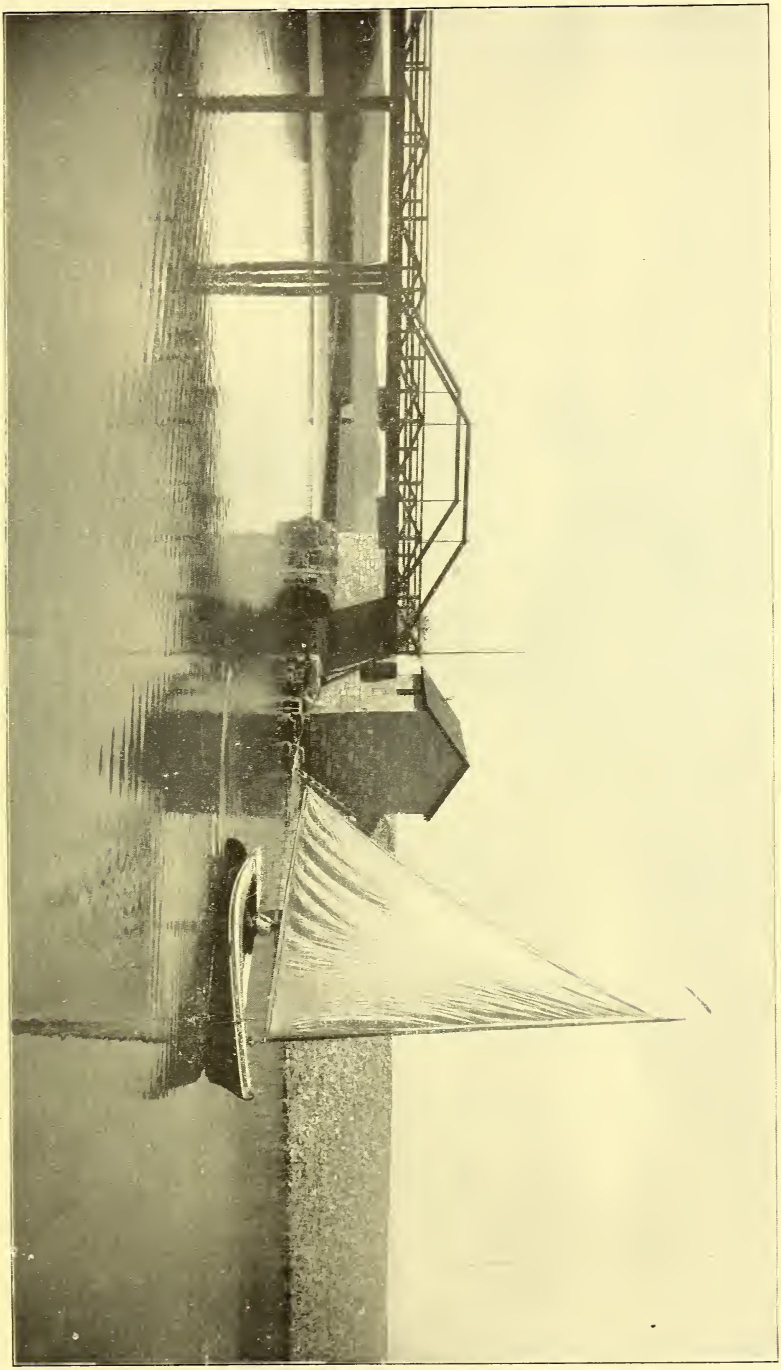
RESERVOIRS.

The total annual flow of the Pecos is sufficient to supply all the water for irrigation that the canals now built will ever be called upon to supply, but the discharge is very irregular. There are floods in midsummer, but often in the spring and early summer months the flow of the river is not sufficient to supply one-half the amount of water required; therefore from the inception of the project storage reservoirs were considered necessary and were provided for in the plans of the system. Several sites were selected and surveys and estimates made, but up to the present time it has been found necessary to construct but two. These are Lake Avalon, known as the distributing reservoir, and Lake McMillan, the storage reservoir (Pl. XXVIII). The general plan of construction is the same in both. In each case the reservoir is formed by a dam directly across the Pecos River. Nature had done much toward making these reservoirs possible. In each case the limestone bluffs approach the river on each side, making it only necessary to connect the two with a strong embankment. In the case of Lake Avalon it required an embankment 1,380 feet in length, maximum height 50 feet; at McMillan an embankment 1,686 feet long, and maximum height 52 feet. In each case the dam is constructed of a wall of loose rock, slopes 1.5 horizontal to 1 vertical on the downstream side and a dry-laid wall on the upstream side, slope one-half horizontal to 1 vertical, with a crown of 6 feet at McMillan and 10 feet at Avalon. In front of this is an apron of earth, crown 14 feet at McMillan and 10 feet at Avalon, and slope 3.5 horizontal to 1 vertical. The earth was laid in layers of about 2 feet in thickness and was kept moistened with pump and hose. On the face of the earth is 18 inches of rock, laid by hand and sledged firmly. That portion of the slope that is under the water all or a part of the time has flattened out and now slopes about 5 horizontal to 1 vertical. The riprap followed the change of slope without a break, and now the dams have reached a point of great stability, and will undoubtedly become stronger each year.

Lake McMillan when full submerges 8,331 acres and has a capacity of 80,000 acre-feet. In order to bring it up to this capacity an embankment 5,200 feet in length, maximum height 18.8 feet, was constructed across a low piece of ground to the west of the main dam. The reservoir is provided with an outlet canal on the east side 2,000 feet in length, cut through the solid rock, and leading back into the river at a point about 300 feet below the dam. The water is regulated through this canal by means of wooden gates raised by iron screws, opening through bulkheads. These gates are six in number, 8 feet high and 4 feet wide, with the openings 3 feet in the clear. A spillway was made between the east end of the dam and outlet canal. The water



Map of the Irrigation System of the Pecos Irrigation and Improvement Company, New Mexico.



Lake McMillan Reservoir.

from this spillway returned to the river bed at a point very close to the slope of the dam. As this was considered a danger to the construction, the spillway was abandoned and blocked. The spillway that is used is an opening about 400 feet wide through the embankment before mentioned, and about 1 mile west of the dam. The water from the spillway follows a shallow arroyo (ravine), and is returned to the river about 2 miles below the dam. The water began cutting back at the discharge end, and has continued toward the reservoir until now it is within 1,100 feet of the reservoir proper. Owing to there being less water in the Pecos, and therefore only two days of spill during the present year, there has been no further erosion in that time. At this point protective works must be installed soon, or the water will cut back into the reservoir and lessen the storage capacity. There is probably little danger here of a great disaster, as the natural slope of the reservoir bottom toward the center is but slight, and more than a mile would have to be cut back before the channel would reach deep water.

Lake Avalon, the distributing reservoir, submerges 1,980 acres, and has a storage capacity of 6,300 acre-feet. The construction of the dam has already been described. There are three spillways from the reservoir proper and one in the canal just below the outlet gates. Spillway No. 1 is situated between the headgate in the canal and the dam proper. There are 31 gates, 5 feet in width, which can be used after the water reaches the height of 12 feet 4 inches on the headgates. The gates to this spillway are on hinges and are secured by a latch when closed. A blow from a hammer will release the latches and allow the gates to open. One man can open all the gates in less than five minutes. The water pours over solid rock ledges and no signs of wearing away are visible. Spillway No. 2 is just beyond the west end of the dam. It is an open cut through solid rock 250 feet in width, and delivers the water back to the river about 600 feet below the dam. The rock is limestone, with occasional streaks of soft material toward the lower end that show some erosion, but it will be many years at the present rate of wear before any protection work will be required. Spillway No. 3 is still farther west one-half mile. It is in the same kind of material, and is 400 feet in width. The water from this spillway follows an arroyo and enters the river at the same point as that from Spillway No. 2.

Spillway No. 1, and 100 feet of No. 2, were constructed at the same time as the dam in 1889. These proved insufficient for the floods of 1893, when the estimated flow of the Pecos was 41,000 cubic feet per second, and the dam was destroyed. The reconstruction of the dam was immediately undertaken, and the additional spillway was constructed at this time. Since that time no trouble has been experienced in passing the flood waters.

The spillway in the main southern canal is below the headgates about 200 feet. It is a masonry wall, set on solid rock, with top of wall just below the level of the canal grade. On the top of the wall it is arranged for slash boards. When the slash boards are out a stream of water 70 feet in width and 4 feet in depth can be returned over the spillway directly into the river. This spillway is a precaution against damage from waters coming down some small arroyos near the head of the canal, but can be used in connection with the headgates of the canal in passing flood waters of the river.

CANALS.

The canal when it first leaves the reservoir has a bottom width of 45 feet, a side slope of 1 vertical to 1.5 horizontal, with a berm of 5 feet between excavation and embankment and 8 feet between grade line and top of embankment. The canal has a fall of 18 inches to 5,000 feet. It has but one bank, the upper side being left open for the avowed purpose of receiving storm waters without damage to the embankments. Open spillways are put in the lower embankment at intervals, for the purpose of disposing of the surplus water. Experience has taught that the single bank is not best adapted to the soil and climate. Remarks upon seepage and evaporation will appear later in this report, in explanation of the above statement.

The canal divides at 3 miles, one branch continuing on the east side of the river and watering the suburban property, La Huerta and Hagerman Heights. This branch has a bottom width of 20 feet. The other branch, 25 feet in width, crosses the river and serves the west side, watering the greater part of the land now under cultivation. The river is crossed by means of a wooden flume 528 feet in length and 25 feet wide in the clear (Pl. XXIX). This flume has been a source of much trouble. It has broken three times and caused a large expenditure of money as well as damage to growing crops. Its construction is simply a wooden trough carried on framed bents. The river bottom is solid rock and the bent sills are bolted to the rock. At the ends of the flume the bents now rest on piles, but up to a year ago they rested on mudsills with small cross pieces for additional support, and as the bank is almost pure sand at both approaches there was always trouble. Both floor and sides of the flume are double, but as there is no means of adjusting for expansion or shrinkage, leaks are frequent and numerous, and much calking is needed. The action of water upon iron is so great that nails become useless and renailing of the flooring and the sides below the water level is necessary about once in two years. The flume was built ten years ago and has since been nearly all replaced, a portion at a time.

From the flume to Dark Canyon, about 3 miles, the material through which the canal passes is sandy loam and lime rock. There is some loss here due to seepage, indicated by additional water in some of the springs along the river and by saturated land in the west part

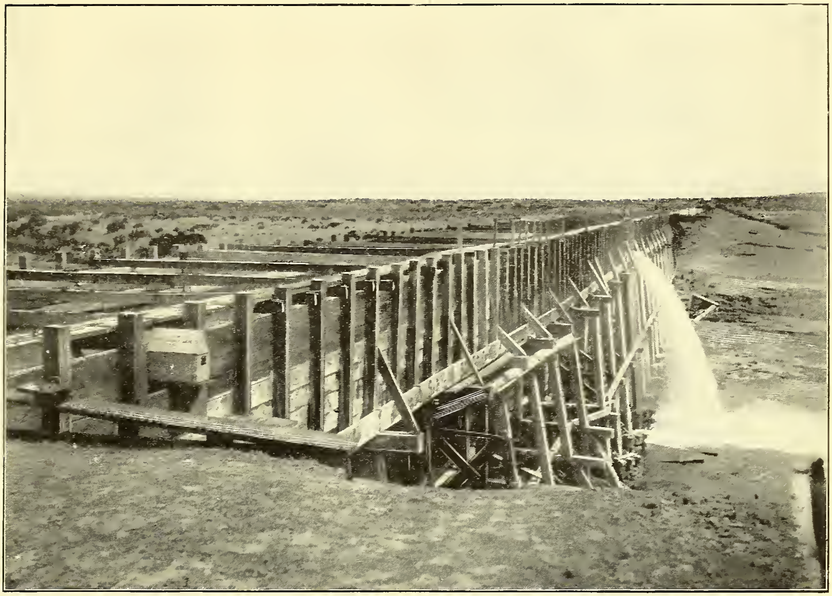


FIG. 1.—FLUME ACROSS PECOS RIVER.

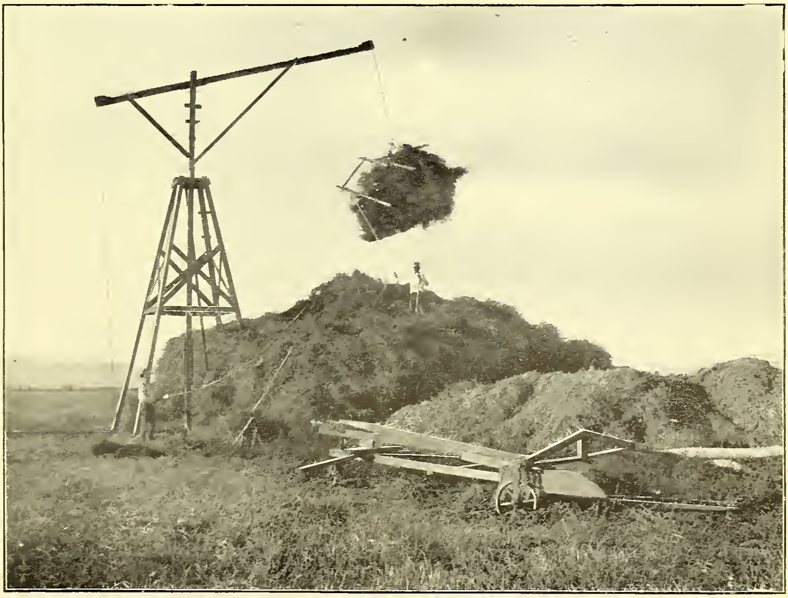


FIG. 2.—STACKING ALFALFA.

of the town of Carlsbad. The bottom of Dark Canyon where the canal crosses is a mass of coarse gravel and round bowlders. The crossing is made by an embankment on the lower side of the canal line provided with timber spillways so arranged that the flood waters of the canyon will pass over without damage. A bulkhead in the canal at the lower side of the canyon prevents the floods from overloading the canal below this point. There is considerable loss at this point. A large area is submerged by the backwater of the canal, and much water finds its way under the embankment through the gravel. At times, when the canal is carrying the most water, as much as 5 cubic feet per second is flowing on the surface in the canyon below the crossing, and undoubtedly a much larger quantity is flowing through the gravel.

From Dark Canyon for a distance of about 20 miles the soil through which the canal passes is mostly clay loam, and no large amount of water is lost by seepage. At the end of this distance for a mile the material is mostly gypsum, and the loss is enormous, ranging from 20 to 75 per cent of the water flowing in the canal in this distance of 1 mile. Much labor and expense have been incurred in various ways for overcoming this difficulty. Sheet piling, refilling trenches, and lining portions of the canal with good material have given only temporary relief. The most economical way of overcoming this difficulty would be to change the location of the canal. This would throw out some land now subject to irrigation, but it would be much better to do this than to give poor service to all lands below this point.

Three miles below this place the canal crosses Black River, and previous to this year the crossing was made by means of a flume of similar construction to the one crossing the Pecos. During the season of 1898 this flume gave trouble, and it was evident that it had about served its usefulness. The bents rested on mudsills, and the heavy leakage through the decaying timber and joints made a disaster probable at any time. To avoid this difficulty a low masonry dam, length 70 feet, height 4 feet, was constructed one-half mile farther down the stream, and from this dam a new canal 3 miles in length was constructed, intercepting the already constructed laterals. The water is now dropped into the river at the point where the flume formerly crossed and is again taken out at the dam by the new canal. By this means 9 cubic feet per second of water are obtained from the Black River during the irrigating season. The remainder of the flow of Black River is appropriated by private parties farther upstream. By the abandoning of the flume some land was thrown out of the irrigation district, but this seems economical when taking into consideration the better service rendered to the other lands. While the canal was built for some 10 miles south of Black River, it has never been used for irrigation purposes and might as well be abandoned for several years to come, there being plenty of land north of Black River to make a most prosperous section when all is in cultivation.

In the earlier days the management, without consultation with the engineer, sold water rights on land that was too high to be irrigated from the canal as planned and constructed. To deliver water to this land checks were placed in the canal, often 3 feet in height and at intervals so close that the canal, instead of having a uniform grade, is for miles a series of planes with perpendicular drops at distances varying from 1 to 2 miles. This has proved to be a great nuisance. It has constantly maintained the water at a high level, even if a small amount of water only is needed. Necessarily, with the single bank, a large area was exposed to evaporation and seepage. The current is reduced to a minimum, and the aquatic growth, which flourishes so luxuriantly in still, clear water, here becomes a great source of trouble, necessitating considerable expense in removing it, often twice during the irrigating season. It reduces the carrying capacity of the canal at least 75 per cent, and thus when the demand for water was greatest it was almost impossible to get the required amount of water through the canal to the consumers. Arrangements have now been made upon a satisfactory basis with the owners of this high land to abandon the use of water upon it, and the checks will be removed during this coming winter. When these checks are removed and the location of the canal changed so as to avoid the gypsum, the operation of the canal will be much more satisfactory.

LATERALS.

The topography of the country is such that the majority of the main laterals are run on section or subdivision lines, taking the natural slope of the surface as their grade lines. In a few instances drops of either lumber or rock have been put in to prevent erosion where the grade was too heavy. A few laterals with supported grade have been run, using a fall of from 2 to 5 feet per mile. In nearly all cases the flow through the laterals is satisfactory.

THE SALE AND DISTRIBUTION OF WATER TO IRRIGATORS.

Before entering on a history of the measurements of water used it is necessary to describe the terms and conditions under which the canal company supplies it to farmers. There are several forms of contract in use depending on whether the water right is paid for in cash or in a series of payments. Only the essential features taken from a copy of the cash form are given:

Deed and contract No.——

This indenture and agreement witnesseth that the first party has bargained, sold, assigned, granted, and conveyed, and hereby does bargain, sell, assign, grant, and convey, unto the said second party, as a member of the "irrigation" class of consumers under said first party's water rights in said canal as hereinafter limited and defined, to be used in accordance with and subject to the conditions, limitations, rules, and regulations hereinafter laid down and to be hereafter established.

The said water rights are and each one thereof is hereby applied and attached to, and is to be used in connection with, the certain tract or parcel of land the description of which is set opposite the number of such water right, as follows, to wit: * * * all of which real estate is situate in the county of ———, Territory of New Mexico; the intention of the above conveyance being that each of said water rights shall be and remain a right to receive and use during each year, from said canal upon the land named in connection therewith, the amount of water hereinafter specified, and that each of said water rights shall be and remain, so long as the conditions herein reserved are complied with, a right incident and appurtenant to said land so named in connection therewith, and that the whole of each water right shall always remain attached to the whole of said land mentioned in connection therewith and not be divisible so as to convey any right as against the first party to a part purchaser thereof.

Provided, however, and this grant and contract is made upon the express condition and agreement, That the said second party, or the legal representatives thereof, shall and will (in event the same now remains undone) truly and in good faith, comply with all laws and regulations of the United States governing the entry and lawful acquirement of all said land above described, and duly make and perfect final proof of said compliance and acquire full right thereto; and it is herein and hereby expressly reserved by the first party, that in case the foregoing condition and agreement with reference to a compliance with said United States laws and regulations be broken by the second party, or legal representative, then this deed shall become null and void, and all the rights, title, and claim of the second party in and to the water rights hereby conveyed shall revert to the first party, its successors or assigns: *And provided, also*, That no assignment, conveyance, or sale of said water rights, or either thereof, or any part of any such right, or any part of any tract covered by any such right, except in connection with the sale and transfer of the whole of the real estate to which said particular water right applies, shall convey any separate right to the purchaser thereof as against the first party, and that no assignment, conveyance, or sale of the whole of any tract of land covered by a water right shall convey any right to receive and use water therefrom, or be binding hereunder against the first party, until the same shall have been executed in writing, and duly acknowledged and presented for inspection to the first party, at its office at ———, New Mexico, and all amounts due thereupon, hereunder, be paid.

And the first party hereby contracts and agrees, to and with the second party, that it will permanently maintain the said canal and the flow of water therethrough, and that it has not sold, and will not sell, water rights in the same in excess of the carrying capacity thereof.

The amount of water which the first party shall deliver and the second party shall be entitled to receive under each of said water rights is, and shall be, 43,560 cubic feet per annum for each acre of land covered thereby, to be delivered at such times and in such quantities as may be necessary for the production of good average crops, as near the times required by the second party as the first party may reasonably be able, after notice of the requirement as to time and amount of delivery having been given the first party a reasonable length of time in advance, or so much of said amount of water per acre as may be necessary for the production of good average crops, under skillful irrigation, said water to be measured by the method prescribed by the first party; and the right to receive said water being, in addition to the conditions hereinbefore mentioned, under and subject to the following conditions and agreements:

(1) That the second party, and the heirs, assigns, and successors thereof in the ownership of said land, shall pay to the first party, for each year, as compensation for the furnishing of water for irrigating purposes above mentioned, the sum of ——— dollars for each acre of the above-described land embraced in a water right, said amount to be paid at the office of the first party at ———, New Mexico, in two equal payments, one-half on or before the 1st day of June and one-half on or before the 1st day of December subsequent thereto, in this and each succeeding year, in advance.

(2) Said water shall be used only to irrigate the lands above described and for domestic purposes, and stock kept thereon, and under no circumstances shall the same, or any part thereof, be used for mining, milling, or mechanical power, or any other purpose not directly connected with, or incidental to, the purposes first herein mentioned.

(3) The first party shall not be required to furnish a greater amount of water limited to each water right above stated than may be reasonably necessary for the production of good average crops under skillful irrigation and cultivation, and the other uses above allowed.

(4) The second party shall not permit said water to be furnished as aforesaid to run to waste, but as soon as a sufficient quantity shall have been used, for the time being, for the purposes herein allowed, shall, in such manner as the first party may prescribe, notify said first party that the said water may be shut off.

(5) The said water shall be delivered by the first party into a lateral ditch or subsidiary canal provided by the second party and connected with the said main canal, or with a lateral or subsidiary canal of the first party; and the manner of delivering, measuring, and regulating the supply of water to the second party shall be prescribed by the first party and at all times under its control; and if the second party shall in any manner change, open, or shut any measuring box, or by any means increase or diminish the aperture thereof, without the consent of the first party; or, in case the second party shall use a supply of water for any other lands, or shall allow any person to use it, except for the purposes herein allowed, upon the above-described premises, or shall in any way whatever take water from any ditch, canal, lateral, or sublateral supplied with water by the first party, except as delivered by the first party, then the second party shall, at the option of the board of directors of the first party, forfeit all right to receive water from the first party for the then current year, and also all moneys paid as compensation for furnishing water for said year.

(6) It is further agreed that if, by reason of any cause, the supply of water shall be insufficient to fill and flow through said main canal according to its estimated capacity, or insufficient to furnish the amount which all the consumers may be entitled to, then the first party shall have the right to distribute such water as may flow through said canal, pro rata, to all persons entitled thereto, and for the purpose of so doing may establish and enforce such rules and regulations as it may deem necessary or expedient; but in case of such pro rata distribution credit shall be given the owner or owners of the water rights hereby granted at a proportionate rate of annual water rental for the amount of water less than 43,560 cubic feet per acre which may have been needed and required by the owner of such water right for purposes herein recognized, but which the first party, on account of such pro rata distribution, may not have furnished; which credit shall be given upon the amount due as compensation for furnishing water to the party who is the owner of the water right upon which the credit is due, at the next semiannual period for the payment of said compensation. And the first party shall have the right to turn the water out of said main canal, and shut the water out of the lateral and service ditches, at any time for the purpose of cleaning or repairing said main canal, its dam or reservoir, or for repairing or putting in new or other wasteweirs, headgates, wastegates, service gates, bridges, or any of the appurtenances of said canal, and during the time occupied thereby the right of the second party to demand and receive water hereunder shall be suspended.

(7) It is hereby distinctly understood and agreed by and between the parties hereto that in case the canals of said first party through which the water rights herein granted are furnished water shall be unable to carry and distribute a volume of water equal to their estimated capacity, either from casual, unforeseen, or unavoidable accident, or the act of God, or if the volume of water proves insufficient from drought, or from any other cause beyond the control of said first party, the first party

shall not be liable in any way for the shortness or insufficiency of supply occasioned by any of said causes.

(8) And the second party agrees, in consideration aforesaid, to waive, and hereby does waive, any and all claims for loss or damage by reason of any leakage, seepage, or overflow from any canal or ditches, or from any reservoirs, lakes, or laterals of the first party, either upon the land aforesaid or any other tract belonging to said party, anything in any statute, law, or custom to the contrary notwithstanding.

(9) The second party shall construct and maintain in good order and repair a ditch upon said land, of such size and grade and at such point and location as shall be prescribed by the first party, to catch and conduct to some main lateral ditch of the first party all waste water flowing upon said tract of land.

The regular field force of this system during the irrigating season consists of a watchman at each reservoir whose duty it is to keep records of the height of water in the reservoir, the amount discharged through the canals and spillways, note condition of the works and keep everything in order, and regulate the flow into the canal as directed from the engineer's office; and four ditch riders, each in charge of a certain portion of the main canal and the laterals from it. Their duties are to deliver the water to the consumers and keep a record of all such deliveries. For this purpose they are provided with a book of slips, two to the page, one detachable. At the end of each delivery the two slips are filled out in duplicate, one detached and sent to the engineer's office, the other remaining as a stub in the book and sent in when the book is filled. The following is a copy of this slip:

Pecos Irrigation and Improvement Company.

Department of chief engineer. Record of water delivery.

Division No., ——, ———. Name of owner, ———, ———. Water right No., ——. Weir, ——. Width, ——. Depth, ——. Date, ——, from ——, —. m. to ——, —. m. Time in hours, ——. Acres irrigated, ——. Variety of crops, ———. Method of irrigation, ———. Nature of soil, ———. Condition of owner's laterals, ———. Remarks, ———. Total, acre-feet, ———.

The measurements are made over weirs, and are not absolutely accurate, as at present there are no automatic registers for determining the head. But as the whole system is connected by telephone, and all water is drawn from or returned to the canal under instructions from the engineer's office, the heads can be kept very uniform, except the variation due to evaporation, and as the measurements are taken twice daily, the results are at least approximate, and will certainly be of great aid in determining the duty of water.

This is the third season that any attempt has been made here to determine the amount of water actually used, and while it is known that the results are not absolutely accurate they give a comparative record, and, when the necessity of selling water by measurement becomes as apparent to both the seller and the consumer as it is to many engineers, methods of accurate measurement will be adopted, although involving considerable expense.

INVESTIGATIONS IN 1899.

The tabulated results of the season's work up to October 1 are divided into four parts, each representing a division, as shown on the map (Pl. XXVII, p. 86). These divisions vary much as to soil, subsoil, etc.

DIVISION NO. 1.

The soil of division No. 1 is nearly all pure sand. The only natural growth before irrigation was mesquite and cat claw—no grass or weeds. The soil varies in depth, but in nearly all instances has a porous subsoil, and while this division has had the most water per acre of the whole system, there is hardly a sign of water-logged land in it. For the division the average duty is about 6.5 acre-feet per acre. Such an amount with heavier land and less natural drainage would create a marsh. That this quantity of water is not needed can be easily understood from this year's record, for those who have used the least water have obtained equally as good crops as others who have used enormous quantities. A great drawback to the economical use of water in this division is the large number of users who farm more as a pastime than as a means of making a living. For instance, sixteen of those whose names are on the list as users have other business besides farming, and give no study to the matter. Every time the surface looks a little dry they demand water, never thinking that perhaps cultivation would do more good. Thus the water is wasted and the land injured, and such will continue to be the case until everyone pays for every drop of water he gets. In this way the waste of water, land, and labor can be curtailed.

The crop yield is much less than in the other divisions. This is partially due to the soil, but more to the bad farming, which includes lack of careful cultivation and a reckless, wasteful handling of the water. A special instance is that of the farm on which one of the Department registers was used. The owner does not farm. It is a beautiful place; thousands of trees grow along the ditches and drives. Water running in the ditches adds beauty to the scene; therefore water is always in them. The cultivation is mostly done by Mexicans and after Mexican fashion. The land is leased to them, so they are their own bosses. Cultivation is generally omitted, and pouring on large amounts of water substituted. It is also thought by those in charge that trees must have a constant stream of water at their roots, yet there are several trees living, probably not growing rapidly, not far from this land, on the same kind of soil, which have not been irrigated in two years. A large portion of the water used on this place during the season just past can be charged to maintenance of beautiful drives and the Mexican style of farming. This farm consists of 80 acres, and during the past season was planted as follows: Alfalfa, 40 acres; corn, 15 acres; orchard, 20 acres; trees, 5 acres. The quantity of water used on this land in March and April, previous to putting in the register, was, in March, 62.45 acre-feet; in April, 168 acre-feet. The daily use of water from May 3 to November 15 is given in the following table:

Water used on farm of J. J. Hagerman, near Carlsbad, N. Mex., May 3 to October 31, 1899.

[See diagram (Pl. V).]

Day.	May.	June.	July.	August.	September.	October.	November.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1	....	6.0115	5.4131	7.4464	4.2258	4.6104	5.8087
2	....	4.1714	4.8351	7.7522	4.1712	4.2804	.4793
3	6.4757	3.3408	4.1714	8.1080	....	5.1651	....
4	7.0124	3.5266	5.0636	7.6754	....	5.2956	.2706
5	6.7573	7.7958	4.3700	6.3846	....	5.0640	7.0539
6	6.5056	7.5316	3.6104	5.8306	....	5.3766	6.6102
7	5.8150	7.5316	2.3324	5.7298	....	6.3305	6.6102
8	6.0115	7.0124	4.7650	5.5712	....	6.7578	6.5052
9	5.0636	6.7573	.5795	5.3740	....	6.1616	6.1364
10	4.3890	5.8905	....	6.0026	2.1009	2.7755	5.1412
11	4.1714	4.1714	....	5.8706	4.7036	4.0524	5.4524
12	3.9574	4.6104	....	5.8100	.5072	3.2257	5.5308
13	3.1404	6.2569	....	5.8100	.2619	3.1404	5.5308
14	5.5307	7.2704	2.7869	5.6900	5.0841	2.6371	5.5308
15	6.0115	7.0124	8.3102	5.6701	5.0353	2.4798	1.5838
16	5.7695	7.0124	9.3030	5.5706	6.5052	3.0682	....
17	6.0115	6.0115	9.4440	5.5308	6.5052	4.6236	....
18	6.0115	5.2955	9.3089	5.6640	6.7572	5.7696	....
19	5.5307	4.6104	1.9353	5.7108	6.7153	6.0124	....
20	5.5307	4.8351	3.4357	5.2956	6.6312	6.2568	....
21	3.6417	4.6104	7.7964	5.5308	6.6312	6.1140	....
22	....	3.5411	6.5418	5.8908	6.1752	5.7898	....
23	1.0241	3.7474	6.5310	5.4132	6.1344	5.7099	....
24	7.0124	4.1714	7.7964	5.1991	6.1344	5.7696	....
25	6.5056	3.5411	7.2737	5.1026	5.7298	5.6502	....
26	6.7573	3.5411	9.1154	5.0640	5.8908	5.6502	....
27	5.2955	3.7474	9.1620	4.4264	6.0120	5.9312	....
28	5.7000	4.6104	8.9756	4.3896	6.0120	6.1548	....
29	8.6067	4.3890	8.7444	4.5736	5.1816	6.2160	....
30	7.5316	5.2955	8.1898	4.5184	4.4816	6.0732	....
31	6.7573	....	6.5484	4.3714	....	5.9113	....
Total	158.5276	157.8507	166.3394	177.0682	118.5954	158.0537	68.2443

This gives a total for the season of 1,235.1393 acre-feet used on 80 acres, or a layer of water 15.44 feet deep over the entire surface.

The small size of the holdings in this division also tends to the use of a large quantity of water. It has been the observation here that the man with 640 acres of land uses water with less waste than the man with 40 acres. This is due to the fact that any waste of water from one tract can be caught up in ditches and used beneficially on others where one man controls a large number of tracts. The custom of running small streams constantly to consumers for stock and domestic puposes has caused much loss of water and has done a great deal toward the "subbing" (water logging) of the land. In one instance in particular, in division No. 2, where a small stream of water has been run constantly during former years along high ground, a small valley below had to be abandoned on account of excess of water. This year the stream was run only during actual irrigation, and the effect can be plainly seen in the valley below in the disappearance of the water from the surface.

The following table gives the area irrigated and the water used during the past season in division No. 1:

Acreage of crops, and water delivered, for the year ended October 1, 1899, division No. 1, Pecos Irrigation and Improvement Company.

[Yield, where given, estimated.]

Name.	Location.	Soil.	Acreage of crops.										Waterdelivered.								Depth of irrigation.	Remarks.
			Alfalfa.	Corn.	Beets.	Cane.	Orchard.	Vines.	Garden.	Beans.	Trees.	Total.	March.	April.	May.	June.	July.	August.	September.	Total.		
													Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Feet.*	
Anderson, W. R	La Huerta, lot 1 in block 9.	Sandy	5									5	4.46	2.97	3.96	5.01		5.64	8.72	30.76	6.15	Pasture.
Bisa (Eddy)	La Huerta, lots 5 and 6 in block 9.	do	12									12	21.84	41.63	16.85	.55	1.04	41.97	18.82	142.70	11.89	Alfalfa yield, 3 tons.
Bryant, F. E	SE. ¼ SW. ¼ and SW. ¼ SE. ¼ sec. 19, T. 21, R. 27 E.	do	35	12		12	5					64	72.84	68.39	122.92	83.62	78.39	154.87	103.64	684.67	10.69	Alfalfa yield, 3 tons. Canc good.
Crawford, A. J	N. ½ NE. ¼ sec. 12, T. 22, R. 26 E.	Adobe	50			18						68	6.20	20.23	29.14	34.63	36.22	5.70	.81	132.93	1.95	Cane good. Alfalfa pastured.
Carlsbad (town)	Sec. 6, T. 22, R. 27 E	Sandy									100	100	22.74	58.82	70.88	53.67	47.40	68.81	54.67	376.99	3.76	
Cameron, J. O	La Huerta, lot 5 in block 11.	do	4				1					5		7.13	.74	2.92	5.87	4.84	5.18	26.68	5.33	
Draper, E. F	La Huerta, lot 11 in block 7.	do	2				1					3				7.30	2.22		1.87	11.39	3.76	
Freeman, A. A	La Huerta, lots 1 and 3 in block 11.	do	9				2		1			12	26.14	16.23	15.11	23.28	15.37	40.19	18.64	154.96	12.91	Alfalfa yield, 3 tons.
Hagerman, J. J	S. ½ sec. 5, T. 22, R. 27 E	do	40	15			20				5	80	62.45	168.00	147.99	131.43	149.07	157.32	109.47	925.73	11.57	Poor crop.
La Huerta	S. ½ and S. ½ N. ½ sec. 30, T. 21, R. 27 E.	do									20	20						22.67	95.05	117.72	5.88	Cottonwood trees.
Linington, C. G	SW. ¼ SW. ¼ sec. 6, T. 22, R. 27 E.	Adobe	38				2					40	38.70	27.24	32.65	26.30		10.53	25.22	160.64	4.00	Poor crop.
Love, R. P	La Huerta, lot 6 in block 12.	Sandy	1				5					6	3.46	4.45	1.99	1.21	1.38	5.83	5.03	23.35	3.89	Fair peach crop.
Lynne, E. C. (Tansill).	La Huerta, block 6	do		5			30	3	1	4		43	1.48		17.55		8.72	15.75		43.50	1.01	Poor crop.
McLenathen, C. H.	La Huerta, lot 1 in block 5.	do	4						1			5	8.42	1.99	.50	8.21	6.14	6.90	2.73	34.89	6.97	
Do	SE. ¼ SW. ¼ sec. 7, T. 22, R. 27 E.	do	10	20		10				5		45	12.97	34.02	26.87	53.19	25.84	67.31	48.41	268.61	5.98	Alfalfa yield, 2.5 tons. Good corn and cane.
McElvain, T. N	La Huerta, lots 2 and 4 in block 12.	do						15				15		52.29		28.46				80.75	5.38	
Miller, M. D	La Huerta, lots 5 and 7 in block 12.	do		8			1	1				10	5.20		10.15	1.95		29.59	1.01	47.90	4.79	Good corn and cane.

Motter, E. S	La Huerta, lot 1 in block 8.	....do					5					5	4.95	5.29	16.99	10.25				37.48	7.49	Good peach crop.
Osborne, I. S	N. ½ NW. ¼ sec. 7, T. 22, R. 27 E.	Adobe	60	20								80	26.93	58.39	69.55	88.81	63.92	104.04	61.47	473.11	5.91	Good alfalfa. Corn yield, 25 bushels.
Quiñones	Phœnix, lot 6	Sandy							1			1		2.33						2.33	2.33	
Rayoux, A	La Huerta, lot 10 in block 10.	....do	5	2		5			1			13	11.40	9.42	13.75	33.77	28.22	23.48	13.22	133.26	10.25	Good cane.
Reding, M. (Eddy)	NE. ¼ NW. ¼ and NW. ¼ NE. ¼ sec. 19, T. 21, R. 27 E.	....do	17	14			5		2			38	26.06	37.20	51.06	90.15	9.75	69.41	13.49	297.12	7.81	Do.
Rio Vista	NW. ¼ SW. ¼ sec. 31, T. 21, R. 27 E.	....do	2				2		1			5	9.87	12.33	12.38	13.24	11.92	15.86	3.45	79.05	15.81	
Rogers, I. W	La Huerta, lot 6 in block 8.	....do	4									4		5.60	3.22	8.87		6.50		24.19	6.04	Pasture.
San Jose	NW. ¼ SE. ¼ NW. ¼ sec. 7, T. 22, R. 27 E.	....do		6					3			9	1.98	5.94	13.87	20.79	17.21	34.08	11.79	105.69	11.74	
Sharpe, M	La Huerta, lots 1 to 6 in block 14.	....do		8		4	18		1			31	11.89		26.16	27.74	35.73	27.66	41.00	170.18	5.49	Heavy peach crop.
Swanson (Eddy)	E. ½ SW. ¼ and W. ½ SE. ¼ sec. 31, T. 21, R. 27 E.	....do	40	15	5		2		1			63	70.49	91.42	92.70	90.65	71.75	94.60	184.26	695.87	11.05	Corn poor. Alfalfa pastured.
Tansill, R. W	La Huerta, lots 3, 5, and 7 in block 8.	....do	15									15	11.56	23.05	13.62	19.00	22.70	49.87	33.72	173.52	11.56	Poor alfalfa (new seeding).
Thomas, Mrs. R	La Huerta, lot 8 in block 10.	....do					2					2	5.20		2.23		9.10	3.06	2.40	21.99	10.99	
Tracy, F. G	La Huerta, lot 2 in block 8.	....do	4									4	2.72	2.15	4.24	1.44	3.12	10.16	1.06	24.89	6.22	
Tucker	NE. ¼ NE. ¼ sec. 13, T. 22, R. 26 E.	....do	1			1	1					3	2.31	.98		1.38			.47	5.14	1.71	
Wardman, Geo	La Huerta, lots 9 and 11 in block 4.	....do	12			3	1					16	18.34	5.57	23.92	26.81	24.17	27.90	28.48	155.19	9.64	
Watkins, W. A	SW. ¼ SW. ¼ sec. 1, T. 22, R. 26 E.	....do	20									20	16.69	8.77	26.11	19.65	59.66		37.91	168.79	8.43	Fair alfalfa.
Wersell (Eddy)	SW. ¼ SW. ¼ and SW. ¼ NE. ¼ sec. 30, T. 21, R. 27 E.	....do	34	8	5		10		1	1		59	44.35	7.18	87.05	61.34	94.96	78.11	30.42	403.41	6.82	Alfalfa pastured.
Webster, G. H	SE. ¼ sec. 12, T. 22, R. 26 E.	Adobe	39	45	20	15				10		129		23.87	113.81	141.24	102.26	118.14	61.78	564.10	4.37	Beets fair. Corn yield, 20 bushels.
Wilson	La Huerta, lot 6 in block 11.	Sandy	4									4	.25	.99	1.49	1.86		13.51		18.10	4.52	
Wolfrom, L	SW. ¼ SE. ¼ sec. 7, T. 22, R. 27 E.	....do	17									17	21.36				1.77	28.88	29.26	81.27	4.78	Fair alfalfa (new seeding).
Yturaldi, Reyes	NE. ¼ NE. ¼ sec. 1, T. 22, R. 26 E.	....do		20								20		26.65		8.24	18.07	13.41	11.12	77.49	3.87	Corn yield, 30 bushels.
Total			484	198	30	68	113	19	14	20	125	1,071	573.25	830.52	1,069.45	1,126.96	952.00	1,356.59	1,067.57	6,976.34	6.51	

DIVISION NO. 2.

In division No. 2 the soil is nearly all sandy loam, and in many instances is very shallow. It is underlaid with limestone and drains well. There is some land along the river bottom that has been slightly "subbed," but drainage by means of open drains is overcoming this difficulty. Where the soil is shallow it requires frequent irrigation, the subsoil furnishing a drain. Such land will always need considerable water, but in many instances this need could be materially lessened by proper cultivation and better methods of irrigation. Flooding is the method of irrigation practiced almost entirely throughout the valley, and in many instances the "lands," as the areas irrigated from a single lateral are called, are laid out so broad and long that great loss takes place from evaporation. On the farm of R. J. Bolles, in this division, the "lands" were 75 feet wide and some of them 2,000 feet in length. It is easy to imagine the great loss of water from a small stream spreading out over an area of nearly 2 acres of land, heated almost to the burning point by a blazing summer sun, when evaporation from a body of water 3 feet deep ran up as high as three-fourths of an inch. In the hot summer days it took a constant flow of nearly 2 cubic feet of water per second twelve hours to cross one of these "lands." The present manager of this farm has cut some of these areas into smaller tracts, and intends making further improvements along this line. The soil naturally requires less water than much land elsewhere in the district, yet during the season more was used. The improvements now contemplated by the manager will undoubtedly change its place from the head of the list as a water user to a position near the bottom.

This division seems very well suited to fruit culture. Beets did not do well in former years, and very few were planted during 1899. The condition of alfalfa varies; it does well on soil of good depth, but not on the shallow soil. Indian corn does fairly well, but the head corns—Kafir, Egyptian, and millo maize—do exceedingly well.

The results of the measurements in this division for the past season are given in the following table:

Acreage of crops and water delivered for the year ended October 1, 1899, division No. 2, Pecos Irrigation and Improvement Company.

Name.	Location.	Soil.	Acreage of crops.										Water delivered.									Remarks.
			Alfalfa.	Corn.	Beets.	Cane.	Orchard.	Vines.	Garden.	Beans.	Trees.	Total.	March.	April.	May.	June.	July.	August.	September.	Total.	Depth of irrigation.	
													Acre-feet.	Acre-feet.	Acre-feet.	Acre-feet.	Acre-feet.	Acre-feet.	Acre-feet.	Acre-feet.	Feet.	
Bolles, R. J	Sec. 2, T. 23, R. 27 E.	Adobe	300							25	5	330	11.02	361.87	285.32	352.67	266.46	188.56	299.07	2,064.97	6.25	Alfalfa yield, 2 tons (estimated).
Do	S. ½ and NW. ¼ SW. ¼ sec. 35, T. 22, R. 27 E.	do	60									60	195.66	36.06	29.82	19.47	69.48	6.52	65.97	422.98	7.05	
Bradley, J. D	NE. ¼ NW. ¼ sec. 35, T. 22, R. 27 E.	do	16	16		6						38			24.42	35.21	23.24	60.71	7.22	150.80	3.96	Poor crop.
Brenis, K	SE. ¼ NW. ¼ sec. 35, T. 22, R. 27 E.	do	9	27		1						37		7.05	35.20	12.50	35.73		10.35	100.83	2.72	Good crop.
Crawford, A. J	S. ½ SE. ¼ and N. ½ SW ¼ sec. 22, T. 22, R. 27 E.	do	135									135	63.74	59.92	114.31	89.43	81.91	20.46	53.71	483.48	3.58	Alfalfa pastured.
Daugherty, W. F	SW. ¼ NW. ¼ sec. 27, T. 22, R. 27 E.	do	23	12		1						36	27.38	.01	51.63	41.68	18.45	34.31	28.63	202.09	5.61	Fair crop.
Do	NE. ¼ NE. ¼ sec 35, T. 22, R. 27 E.	do	20									20			42.82	.07	36.28			79.17	3.95	Pasture.
Demorest, C. J	SW. ¼ SW. ¼ sec. 27, T. 22, R. 27 E.	Sandy	28	1			2			1		32	25.06	42.45	31.05	34.29	32.95	62.27		228.07	7.12	Poor crop.
Do	SW. ¼ NW. ¼ NW. ¼ sec. 35, T. 22, R. 27 E.	Adobe	3	2								5					3.63	.83		4.46	.89	Alfalfa fair.
Galton, H. E	NW. ¼ NE. ¼ sec. 35, T. 22, R. 27 E.	do	29	9								38	10.14	9.02	41.84	26.37	10.78	53.25	65.78	217.18	5.71	Do.
Kayser, S. G	NE. ¼ sec. 27, T. 22, R. 27 E.	do	130	17		45						192	304.82	69.88	72.00	143.32	113.15	153.29	263.73	1,120.19	5.83	Alfalfa good.
Love, R. P	E. ½ SE. ¼ SE. ¼ sec. 8, T. 22, R. 27 E.	Sandy	14	3								17	11.27	.31	16.72		11.65	13.71	9.99	63.65	3.74	Do.
McKenzie, E. D	SE. ¼ SW. ¼ sec. 27, T. 22, R. 27 E.	Adobe	12	22						6		40	13.17	20.30	29.80	45.82	28.62	49.13		186.84	4.67	Fair crops.
Do	NW. ¼ SW. ¼ sec. 27, T. 22, R. 27 E.	do	17	20						1		38	29.84	7.70	33.96	11.16		12.18	38.70	133.54	3.51	Do.
Do	NW. ¼ NE. ¼ sec. 34, T. 22, R. 27 E.	do	12	22								34		16.89	2.37	52.51	35.64	46.23	14.47	168.11	4.94	Do.
Do	SE. ¼ SW. ¼ sec. 34, T. 22, R. 27 E.	do	22									22			29.70	26.16		41.83	6.60	104.29	4.51	Do.
McGinnis	S. ½ SE. ¼ sec. 9, T. 22, R. 27 E.	Sandy	20									20							66.90	66.90	3.34	Just sown.
Menoud, E	NE. ¼ NW. ¼ sec. 1, T. 23, R. 27 E.	do	25	10		2				1		38		23.65	40.07		24.97	24.44	24.80	137.93	3.62	Fair crops

Acreage of crops and water delivered for the year ended October 1, 1899, division No. 2, Pecos Irrigation and Improvement Company—Continued.

Name.	Location.	Soil.	Acreage of crops.										Water delivered.									Remarks.
			Alfalfa.	Corn.	Beets.	Cane.	Orchard.	Vines.	Garden.	Beans.	Trees.	Total.	March.	April.	May.	June.	July.	August.	September.	Total.	Depth of irrigation.	
													Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Feet.*	
Mihlferd, John	NW. $\frac{1}{4}$ SW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 35, T. 22, R. 27 E.	Adobe	.....	5	..	4	..	..	..	..	..	9	......	....	2.39	2.49	4.78	8.58	....	18.24	2.02	Good crops.
Mullane, W. H.	NE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 33, T. 22, R. 27 E.	do	1	2	4	..	1	..	..	..	..	8	......	....	6.52	12.14	3.84	2.56	15.04	40.10	5.01	Failure.
Rarey, J. F.	E. $\frac{1}{2}$ NE. $\frac{1}{4}$ and NE. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 28, T. 22, R. 27 E.	do	15	105	..	14	5	..	..	..	..	139	19.03	69.33	43.52	87.93	86.76	143.76	132.14	582.47	4.19	Alfalfa poor; corn fair.
Do.	S. $\frac{1}{2}$ SW. $\frac{1}{4}$ sec. 22, T. 22, R. 27 E.	do	10	70	..	..	..	..	..	..	..	80	32.90	....	69.23	89.12	....	38.72	21.71	251.68	3.14	Do.
Scoggins, Ed.	SW. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 35, T. 22, R. 27 E.	do	3	28	..	4	..	..	..	..	..	35	......	17.51	13.20	17.72	29.40	57.09	....	134.92	3.85	Good corn.
Stokes, J. W.	SW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 24, T. 22, R. 27 E.	Sandy	25	20	..	2	12	..	..	..	..	59	......	23.59	46.73	14.79	11.61	22.76	46.10	165.58	2.80	Good corn and alfalfa.
Tedford, Jack	NW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 27, T. 22, R. 27 E.	do	.....	40	..	..	..	..	..	..	..	40	......	42.24	8.53	....	....	34.73	....	85.50	2.13	Good corn.
Toone, J. B.	SW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 34, T. 22, R. 27 E.	Adobe	25	11	..	..	..	..	2	..	..	38	38.61	6.41	37.68	16.03	38.59	65.54	44.54	247.40	6.51	Fair corn.
Tracy, F. G.	SW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 10, T. 22, R. 27 E.	Sandy	14	20	20	5	17	..	1	..	..	77	......	43.96	44.39	54.02	22.45	50.08	20.35	235.25	3.05	Fair crop; heavy peach crop.
Webster, G. H.	Sec. 21, T. 22, R. 27 E.	Adobe	208	75	..	..	..	30	2	..	..	315	106.51	364.70	259.39	37.84	95.35	186.86	140.82	1,191.47	3.78	Alfalfa fair (new seeding); corn good.
Wilson, W. A.	SE. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 26, T. 22, R. 27 E.	do	20	7	..	10	..	..	..	..	..	37	......	5.39	19.29	9.05	10.36	36.61	22.31	103.01	2.78	Corn fair; alfalfa new seeding.
Wilson, W. B.	SW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 26, T. 22, R. 27 E.	do	30	8	3	..	3	..	..	..	..	44	.79	.69	14.50	28.05	11.40	7.48	16.48	79.39	1.80	Corn fair; alfalfa pastured.
Wright, C. H.	NW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 27, T. 22, R. 27 E.	do	5	7	..	..	5	..	..	..	..	17	17.41	.02	12.72	8.71	13.29	32.83	....	84.98	4.99	
Wright, C. W.	do	do	5	..	..	..	..	..	..	..	..	5	6.23	....	....	10.67	.18	9.69	6.38	33.15	6.63	Good alfalfa.
Yturaldi, S. A.	S. $\frac{1}{2}$ NE. $\frac{1}{4}$ and N. $\frac{1}{2}$ SW. $\frac{1}{4}$, sec. 1, T. 23, R. 27 E.	do	50	35	..	..	..	..	..	10	..	95	......	67.29	62.61	49.62	18.32	107.85	157.57	463.26	4.87	Poor alfalfa; good corn and beans.
Total			1,286	594	27	94	45	30	5	44	5	2,130	913.58	1,296.24	1,521.73	1,328.84	1,139.27	1,872.86	1,579.36	9,651.88	4.53	

DIVISION NO. 3.

This is a division of the greatest successes and worst failures. The soil is a heavy clay loam and has a greater depth than that of divisions No. 1 and No. 2. It is here that the best alfalfa, beets, and head corns have been raised, while on the other hand the same crops have been complete failures upon the same land. The soil is heavy and capable of producing good crops under a proper system of irrigation, but handled as a great deal of it has been it becomes a marsh. The soil does not drain naturally, and the large amounts of water that have been applied have literally submerged it until now some of it is bare of vegetation. The general fall is amply sufficient for a good system of underdrainage, and when such drainage is provided and intelligent care exercised in future applications of water it will make the most productive section under this system.

The area irrigated and the water used in this division is shown by the following table:

Acreage of crops and water delivered for the year ended October 1, 1899, division No. 3, Pecos Irrigation and Improvement Company.

[Yield, where given, estimated.]

Name.	Location.	Soil.	Acreage of crops.										Water delivered.									Remarks.
			Alfalfa.	Corn.	Beets.	Cane.	Orchard.	Vines.	Garden.	Beans.	Trees.	Total.	March.	April.	May.	June.	July.	August.	September.	Total.	Depth of irrigation.	
													Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Ft.*	
Abalos, B	SW. ¼ sec. 18, T. 23, R. 28.	Adobe	15	80	30	4	....	....	1	....	....	130	....	72.43	96.61	39.05	58.33	51.23	20.71	338.36	2.60	Failure; land subbed.
Anderson, W. W.	SW. ¼ NE. ¼ sec. 22, T. 23, R. 28.	Sandy	15	10	10	....	....	....	....	....	....	35	....	54.07	22.07	33.52	2.71	31.44	4.03	147.84	4.22	Failure.
Becerra, S. P.	NW. ¼ NE. ¼ and SW. ¼ NE. ¼ sec. 17, T. 23, R. 28.	Adobe	2	15	10	5	....	....	1	10	....	43	....	....	13.95	20.99	88.93	40.31	23.19	187.37	4.35	Failure; Mexican cultivator.
Benson, R. S.	Sec. 7, T. 23, R. 28.	...do...	520	80	....	....	20	5	1	....	....	626	72.07	337.80	328.61	243.92	127.85	203.77	164.86	1,478.88	2.38	Alfalfa yield 4 tons.
Do.	N. ½ NW. ¼ sec. 21, T. 23, R. 28.	...do...	....	....	....	80	....	....	....	....	....	80	....	37.77	....	1.06	62.07	31.26	....	132.16	1.65	
Bustamante, M.	SW. ¼ NE. ¼ sec. 12, T. 23, R. 27.	...do...	....	....	12	....	....	....	1	....	....	13	....	....	....	9.94	....	11.18	5.21	26.33	2.02	Beets yield 6 tons.
Calvani, T.	N. ½ SW. ¼ sec. 15, T. 23, R. 28.	Sandy	6	18	19	6	....	....	1	3	....	53	51.77	67.89	37.95	25.55	36.44	12.25	25.46	257.31	4.85	Fair crop.
Corrales, P.	N. ½ SE. ¼ sec. 17, T. 23, R. 28.	Adobe	12	14	40	....	....	....	1	2	....	69	5.72	66.87	41.55	41.55	41.68	37.00	25.49	259.86	3.76	Fair corn crop; beets a failure.
Dishman, C.	SE. ¼ NE. ¼ SW. ¼ sec. 21, T. 23, R. 28.	...do...	....	9	....	....	....	....	1	....	....	10	....	....	11.12	8.39	9.48	12.18	....	41.17	4.11	Corn yield 40 bushels.
Dearsley, Dick.	NW. ¼ sec. 12, T. 23, R. 27.	...do...	22	60	31	3	....	....	1	....	2	119	39.74	17.87	26.21	63.02	30.49	66.16	63.10	306.59	2.52	
Dunaway, J. F.	SW. ¼ sec. 16, T. 23, R. 28.	Sandy	50	20	30	....	....	....	1	5	....	106	23.99	81.67	98.81	89.24	100.64	15.02	76.84	481.21	4.54	Corn good; alfalfa pastured; beets yield 4.5 tons.
Galton, W. W.	SW. ¼ SW. ¼ sec. 6, T. 23, R. 28.	...do...	35	3	....	5	1	....	....	....	....	44	9.91	12.91	15.08	27.96	21.43	30.40	....	117.69	2.67	Cane good; alfalfa yield 4 tons.
Garza, E. (Bolles)	N. ½ and NW. ¼ sec. 20, T. 23, R. 28.	Adobe	24	218	150	....	....	....	....	20	....	412	5.86	147.20	123.57	159.82	157.30	158.58	72.85	825.18	2.00	Failure.
Do.	N. ½ NW. ¼ and SE. ¼ NW. ¼ sec. 18, T. 23, R. 28.	...do...	35	12	40	3	....	....	....	....	....	90	23.81	65.90	27.29	99.92	19.67	29.28	44.75	310.62	3.45	Do.
Gomes, C.	S. ½ SE. ¼ sec. 17, T. 23, R. 28.	...do...	33	6	33	....	....	....	1	....	....	73	23.33	53.37	10.78	29.44	33.95	40.98	9.82	201.67	2.76	Alfalfa poor; beets yield 6 tons.
Grandi, A.	SE. ¼ sec. 1, T. 23, R. 27.	...do...	20	12	35	3	....	....	1	2	....	73	6.99	73.55	64.20	40.17	18.32	54.96	14.75	282.94	3.87	Beets poor; corn yield 30 bushels.

Gray, E. McQ	SE. ¼ NE. ¼ and NE. ¼ SE. ¼ sec. 29, T. 23, R. 28.	...do	23	15			40				2	80		33.53	33.20	26.63	29.85	58.57	21.01	202.79	2.53	Good crops.
Hughes, S	E. ½ and SW. ¼ NE. ¼ sec. 25, T. 23, R. 28.	...do	28	13	32	2	3			1		79	12.66	61.29	41.74	52.05	42.00	5.89	24.26	239.89	2.27	Poor crops; Mexican farming.
Krull, A	N. ½ SE. ¼ and SE. ¼ NE. ¼ sec. 10, T. 23, R. 27.	...do	70	45		2						117	47.01	99.79	98.08	55.78	66.48	82.47	15.06	464.67	3.97	Fair crops.
Louis, G	SW. ¼ NW. ¼ sec. 8, T. 23, R. 28.	...do		5	30					2		37			32.00	21.61	12.07	25.50	16.33	107.51	2.90	Beets a failure.
Lockhart, J. H	N. ½ SE. ¼ SW. ¼ sec. 19, T. 23, R. 28.	...do				8						8					6.50	10.89	8.15	25.54	2.19	Cane good.
McLendon, W	SW. ¼ NE. ¼ sec. 15, T. 23, R. 28.	Sandy		25		2						27		16.17	30.94	13.12	34.17	1.14		95.54	3.53	Corn good.
Molino, A	SW. ¼ SE. ¼ sec. 12, T. 23, R. 27.	Adobe			25				1	8		34			61.56	35.75	27.49	44.41	14.22	183.43	5.39	Beets yield 5 tons.
Niemeyer, F. H	NE. ¼ SE. ¼ sec. 24, T. 23, R. 27.	Sandy	8	5	6	1	2					22	1.03	6.40	14.65	3.26	2.73	8.85	3.10	40.02	1.81	Corn good; land subbed.
Nolty, Chris	NW. ¼ NW. ¼ and SW. ¼ SE. ¼ sec. 15, T. 23, R. 28.	...do	15	27	9					1		52		35.95	32.21	53.97	10.47	34.95	27.23	194.78	3.74	
Nymeyer, J. O	SE. ¼ sec. 20, T. 23, R. 28.	Adobe		40	40							80		11.15	27.04	51.87	21.75	62.14	42.29	216.24	2.70	Corn good.
Onsures, F	E. ½ SE. ¼ sec. 12, T. 23, R. 27.	...do			70				1	6		77			6.24	54.38	25.89	61.49		148.00	1.89	Beets yield 6 tons.
Ocon, C	NW. ¼ SE. ¼ sec. 21 and NW. ¼ SW. ¼ sec. 22, T. 23, R. 28.	Sandy	5	25	40	7			1	2		80		21.05	25.38	70.27	56.70	44.97	30.16	248.53	3.11	Corn fair; beets light.
Pompa, F	N. ½ SW. ¼ and SE. ¼ NW. ¼ sec. 8, T. 23, R. 28.	...do	20	50	41	2						103	8.25	43.42	56.82	77.12	59.37	34.59	49.47	329.04	3.18	Corn fair.
P. V. B. S. Co	NE. ¼ sec. 29, T. 23, R. 28.	...do			145							145			79.00	109.09	99.14	66.12	261.86	615.21	4.24	Beets light.
Rascoe, J. J	Sections 10, 11, and 13, T. 23, R. 27.	Adobe	125	235	252	65			4	20		1,011	238.25	200.71	492.85	471.40	495.94	486.09	290.43	2,675.67	2.64	Alfalfa yield 4 tons.
Ramuz, A	S. ½ NW. ¼ sec. 15, T. 23, R. 28.	Sandy	25	30	12		2		1	1		71	4.39	80.24	71.31	42.57	18.82	75.85	8.37	301.55	4.27	Alfalfa nearly all pastured; beets and corn light.
Roark, S	S. ½ NW. ¼ sec. 22, T. 23, R. 28.	...do	15	54		4				1		74	27.00	47.82	34.96	41.48	20.30	74.97	17.35	263.88	3.56	Alfalfa pastured; cane good; corn yield 40 bushels.
Salgado, B	SW. ¼ SW. ¼ and SW. ¼ NW. ¼ sec. 8, T. 23, R. 28.	Adobe		13	47				1	5		66		14.38	14.96	74.70	54.94	67.15	34.90	261.03	3.96	Failure; no cultivation; land subbed.
Sillem, P. O	E. ½ SE. ¼ sec. 11, T. 23, R. 27.	...do	20	5	15	15	12					67	34.48	9.04	25.22	29.40	38.87	24.87	29.57	191.45	2.85	Failure; land badly subbed.
Singleton, Mrs. J.	SE. ¼ SW. ¼ sec. 1, T. 23, R. 27.	Sandy		7								7				7.50	10.55			18.05	2.57	Corn good.

Acreage of crops and water delivered for the year ended October 1, 1899, division No. 3, Pecos Irrigation and Improvement Company—Continued.

[Yield, where given, estimated.]

Name.	Location.	Soil.	Acreage of crops.										Water delivered.									Remarks.
			Alfalfa.	Corn.	Beets.	Cane.	Orchard.	Vines.	Garden.	Beans.	Trees.	Total.	March.	April.	May.	June.	July.	August.	September.	Total.	Depth of irrigation.	
													Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Ft.*	
Smith, G. W	N. $\frac{1}{2}$ SW. $\frac{1}{4}$ sec. 30, T. 23, R. 28.	Adobe	15	32	3		5					55		11.42	4.11	20.02	12.73	14.35	12.93	75.56	1 37	Corn and alfalfa good.
Stone, M. T	NE. $\frac{1}{4}$ SE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 15, T. 23, R. 27.	do	8									8	12.16	4.85						17.01	2.12	Alfalfa pastured.
Townsite (Florence).	S. $\frac{1}{2}$ SW. $\frac{1}{4}$ sec. 21, T. 23, R. 28.	do									8	8					9.05			9.05	1.13	Cottonwood trees.
Valdes, M	SW. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 10 and W. $\frac{1}{2}$ NW. $\frac{1}{4}$ sec. 11, T. 23, R. 27.	do	45	45	5	4	10			3		112	70.52	50.75	48.32	62.29	52.63	141.88	18.74	445.13	3.97	Good crops.
Valles, G	SW. $\frac{1}{4}$ and E. $\frac{1}{2}$ NE. $\frac{1}{4}$ sec. 12, T. 23, R. 27.	Sandy	35	40	125				1	9		210		146.56	91.68	108.03	69.54	45.21	10.09	471.11	2.24	Good corn; beets yield 8 tons.
Valles, J	SW. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 21, T. 23, R. 28.	Adobe			40							40			21.15	63.18	39.91	45.77	50.40	220.41	5.51	Good beets.
Webster, G. H	S. $\frac{1}{2}$ NE. $\frac{1}{4}$ and N. $\frac{1}{2}$ SE. $\frac{1}{4}$ sec. 30, T. 23, R. 28.	do	40		20		40					100		54.89	47.04	69.10	24.75	40.62	32.19	268.59	2.68	Good beets; fair corn; alfalfa yield 3 tons.
Woodall, Geo	SE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 12, T. 23, R. 27.	do			40							40				36.61	21.75	41.56	13.74	113.66	2.84	Good beets.
Valles, C	E. $\frac{1}{2}$ NE. $\frac{1}{4}$ sec. 17, T. 23, R. 28.	Sandy	8	35	25	2				5		75		73.71	15.92	17.82	49.00	51.66		208.11	2.77	Good corn; beets a failure.
Total			1,594	1,303	1,462	223	135	5	21	106	12	4,757	718.94	2,112.42	2,324.18	2,602.54	2,222.68	2,477.96	1,582.91	14,046.63	2.95	

DIVISION NO. 4.

The part of this division north of Black River has characteristics very similar to those of division No. 3. Good crops are raised, but a part of the soil has also been ruined. In section 32, township 32 south, range 28 east, the subsoil is gypsum, and above this it is nearly impossible to avoid the use of large quantities of water. This is the section where leakage from the canal has given so much trouble. On the south side of Black River, where the soil is light and has better drainage, less damage has been done by careless irrigation. The crops look well in most instances. One orchard is badly over watered. The older trees are doing fairly well, but the land is in such a condition that young trees could not be made to live if set out. This piece of land could be easily drained, and with careful irrigation could be put in good condition. This is simply an example of the abuse of water, and there are many similar cases, but there are, at least, some hopeful signs. Some are beginning to realize the cause of the trouble, and it is gratifying to see the effort made by many to handle irrigating water with more care and to study the subject from a more scientific standpoint. The idea that as long as there is no limit put upon the use of water the more they use the more they are getting for their money is vanishing, and it is coming to be understood that just enough is what should be used, and that too much is as dangerous as too little.

The following table shows the area irrigated and the water used in division No. 4 during the season just closed:

Acreage of crops and water delivered for the year ended October 1, 1899, division No. 4, Pecos Irrigation and Improvement Company.

Name.	Location.	Soil.	Acreage of crops.								Water delivered.									Remarks.
			Alfalfa.	Corn.	Beets.	Cane.	Orchard.	Garden.	Trees.	Total.	March.	April.	May.	June.	July.	August.	September.	Total.	Depth of irrigation.	
											Ac.ft.	*Ac.ft.*	*Ac.ft.*	*Ac.ft.*	*Ac.ft.*	*Ac.ft.*	*Ac.ft.*	*Ac. ft.*	*Feet.*	
Anderwerth, C. M	N. ½ NW. ¼ sec. 28, T. 23, R. 28	Sandy	16	35	21	4				76		24.43	14.51	60.03	18.81	43.19	15.76	176.73	2.45	Good crops.
Anderwerth, F	N. ½ NW. ¼ NW. ¼ sec. 33, T. 23, R. 28.	do	2	18	8		3	1		32		12.52	15.32	17.22	5.06	12.43	1.12	63.67	1.99	Fair crops; land subbed.
Ayers, A. M	SE. ¼ SE. ¼ sec. 10, T. 24, R. 28	do		8				1		9			10.92	2.39		7.54		20.85	2.31	Fair crops.
Beeman, C. W	SE. ¼ SW. ¼ sec. 3, T. 24, R. 28	do	3	27			2			32		7.47	16.54	8.20	19.40	10.92	10.45	72.98	2.28	Poor crops.
Bowker, H. D	E. ½ SE. ¼ sec. 11, and SW. ¼ SW. ¼ sec. 12, T. 24, R. 28.	do	40	31			10			81		66.96	114.99	10.15	67.55	75.80	60.54	395.99	4.89	Corn fair; alfalfa pastured.
Cadwell, Edw	SE. ¼ SW. ¼ sec. 32, T. 23, R. 28	do	15							15	9.32		26.19			5.22		40.73	2.71	
Do	SW. ¼ NE. ¼ SW. ¼ sec. 10, T. 24, R. 28.	do		5						5				10.02		8.95		18.97	3.79	
Calderon, A	SE. ¼ NW. ¼ and NE. ¼ SW. ¼ sec. 28, T. 23, R. 28.	do			70	8				78		39.33	61.04	63.68	10.46	67.51	9.91	251.93	3.23	Beets fair.
Do	SW. ¼ SE. ¼ sec. 3, T. 24, R. 28	do		15						15		26.88	7.90	8.56	25.15	28.75	24.57	121.81	8.12	
Dishman, C. H	SW. ¼ SW. ¼ sec. 9, T. 24, R. 28	do	3	7	12		1			23			16.60	2.97	28.58	12.43	8.80	69.38	3.01	
Fletcher & Eakin	N. ½ NE. ¼ sec. 17, and E. ½ SE. ¼ sec. 8, T. 24, R. 28.	do	57			2			2	61		15.07	48.06	81.91	29.96	62.41	13.29	250.70	3.99	Alfalfa pastured.
Hakes, Eva	SW. ¼ SE. ¼ sec. 11, T. 24, R. 28	do	8	18			2	1	1	30		24.99	13.03	7.48	10.27	32.09	13.11	100.97	3.36	Fair crops.
Hare, W. H	S. ½ SE. ¼ SW. ¼ sec. 10, T. 24, R. 28	do					20			20		8.18	3.30	7.63	16.17	8.43	9.52	[illegible]	2.66	
Harkey, D. R	NE. ¼ SW. ¼ sec. 12, T. 24, R. 27	do	6	2			2			10		12.17	28.77	2.68	3.10	7.43		54.15	5.41	
Hays, J. W	E. ½ NE. ¼ NW. ¼ sec. 13, T. 24, R. 28	do	1	14		3		1		19			13.22	7.42	7.33	16.99	5.78	50.74	2.67	Good corn.
Hoag, L. N	NW. ¼ NW. ¼ sec. 13, T. 24, R. 28	do	15				23		2	40		24.20	1.86	24.11	1.56	33.25	2.73	87.71	2.19	Fair crops.
Humiston, H	SE. ¼ NE. ¼ sec. 15, T. 24, R. 28	do		10			2			12			11.73	14.88	9.12	29.16	8.41	73.30	6.10	Poor crops.
Kahman, A	SW. ¼ SE. ¼ sec. 27, T. 23, R. 28	do		2	5					7		14.67	26.71	5.95	6.01	14.57	6.36	74.27	10.61	Do.
Kemp, D. L	N. ½ NE. ¼ and NE. ¼ NW. ¼ sec. 23, T. 23, R. 28.	do	40	30	22			1		93	6.83	76.47	105.88	83.78	33.15	82.65	116.10	504.86	5.42	Good crops.
Mays, Mrs. J	NE. ¼ NE. ¼ NW. ¼ sec. 10, T. 24, R. 28.	do		8			2			10	3.02	4.67	9.77	10.04	5.69	7.49		40.68	4.06	
Montgomery, R. A	NE. ¼ SE. ¼ sec. 10, T. 24, R. 28	do	3	30		2	1			36			39.65	6.16	15.23	24.95	2.73	88.72	2.46	Fair crops.
Nolty, Cris	NW. ¼ NW. ¼ sec. 27, T. 23, R. 28	do			25					25			48.64	21.67		24.84	4.38	99.53	3.98	Failure; land subbed.
Pratt, A. N	NE. ¼ SW. ¼ sec. 22, T. 23, R. 28	do	6	30				1		37		26.03	54.00	18.18	48.65	56.05	13.98	216.89	5.86	Fair crops.
P. V. B. S. Co	N. ½ NE. ¼ sec. 28, T. 23, R. 28	do			70					70			49.58	33.12	22.89	11.87	55.10	172.56	2.46	Beets light.
Stamp, Mrs. M. S	NE. ¼ NE. ¼ sec. 32, T. 23, R. 28	do		7		3				10		.74	13.56	5.28		3.22		22.80	2.28	Poor crops.
Weaver, N. W	SE. ¼ NE. ¼ sec. 5, T. 24, R. 28	do		18	6	3	13			40			15.22	6.86	4.75		5.90	32.73	.82	Fair crops; some apples first year.
Valles, A	NE. ¼ NE. ¼ sec. 17, T. 24, R. 28	do	2	20	15					37		4.79	38.47	29.74	17.03	44.13	17.32	151.48	4.09	Poor crops; Mexican farming.
Total			217	335	254	25	81	6	5	923	19.17	389.57	805.46	530.11	405.92	732.27	405.86	3,288.36	3.56	

The rainfall at Carlsbad for the year 1899 was less than during any season since irrigation began in this valley. The monthly precipitation for the year is given below:

Monthly precipitation at Carlsbad, N. Mex., 1899.

Month	Inch.	Month	Inch.
January	0.00	July	0.08
February	.02	August	.00
March	.06	September	.08
April	.08	October	.03
May	.00	November	.18
June	.13		

The following table shows the depth of water received by the land in the four divisions from both irrigation and rainfall, from March to September, inclusive:

Duty of water under Pecos Canal, measuring water at heads of laterals.

	Div. No. 1.	Div. No. 2.	Div. No. 3.	Div. No. 4.
Area irrigated ... acres	1,071	2,130	4,757	923
Water used ... acre-feet	6,976.34	9,651.88	14,046.63	3,288.36
Depth of irrigation ... feet	6.51	4.53	2.95	3.56
Depth of rainfall ... do	.43	.43	.43	.43
Depth of irrigation and rainfall ... do	6.94	4.96	3.38	3.99

DUTY OF WATER UNDER SOUTHERN BRANCH OF PECOS CANAL.

Not all the water used in the four divisions is measured at the head of the canal, but a record is kept of that passing through the flume across the Pecos and watering the land on the west side of the river. This water irrigates 8,410 acres. The following table gives the results of these measurements:

Water discharged by flume across Pecos River, April 16 to October 31, 1899.

[See diagram, Pl. IV, p. 72.]

Day.	April.	May.	June.	July.	August.	September.	October.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1	....	195.0950	342.8513	429.7190	393.9339	378.2479	277.1727
2	....	181.5041	339.1571	427.6364	389.6364	387.7088	271.9180
3	....	299.1157	333.8596	413.9008	386.2975	382.6802	242.9520
4	....	301.7273	333.0000	381.3884	386.0248	380.5511	177.9687
5	....	318.8265	327.5703	384.5123	386.5702	370.0089	6.1846
6	....	336.8512	323.5703	400.0082	387.3885	359.5825	0
7	....	337.5620	317.6194	421.5374	388.1157	355.3024	50.8560
8	....	329.3058	305.8679	326.8512	389.1157	336.1610	113.4150
9	....	325.2975	291.4380	46.3636	389.7521	284.2470	53.5480
10	....	316.0413	284.9256	0	388.8430	234.5950	46.1660
11	....	345.2975	275.8512	0	387.3884	0	44.9800
12	....	339.4298	246.7769	118.0000	394.1901	25.9421	44.5080
13	....	337.3967	270.8512	424.5868	410.0000	198.8099	43.5640
14	....	330.4050	335.8760	447.0744	408.8760	219.9669	43.8000
15	....	327.8595	384.9093	408.7521	407.2397	222.7107	47.1240
16	181.0000	340.6860	389.9008	367.5371	405.7851	227.7190	51.4200
17	162.4298	345.7355	399.3719	374.3884	408.0496	229.4545	51.9030
18	145.9174	350.2727	379.3141	243.1653	418.4114	233.6529	52.3890
19	142.2808	354.2562	384.1983	37.8099	415.2397	234.0165	50.4600
20	143.4380	350.0992	390.4298	246.7768	416.1983	238.8678	48.7800
21	149.4711	354.0000	387.2314	323.9504	411.1736	258.4215	49.5000

Water discharged by flume across Pecos River, April 16 to October 31, 1899—Continued.

[See diagram, Pl. IV, p. 72.]

Day.	April.	May.	June.	July.	August.	September.	October.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
22	174.1612	355.5620	363.6281	385.4380	409.7851	260.6281	49.7400
23	190.7934	352.4628	375.2727	377.8763	407.3306	247.2945	50.4600
24	190.0950	350.4504	373.8512	359.4380	403.9504	235.1354	49.0200
25	202.4215	359.3058	369.5207	351.2727	401.0579	230.3874	47.8280
26	190.9422	355.1405	370.8678	348.6281	399.2727	227.6539	47.3520
27	197.9669	335.9109	340.8595	346.7107	396.8926	233.3504	47.1140
28	227.3554	326.6804	326.6694	349.0165	393.9174	273.8720	46.4000
29	229.4463	335.8512	407.4959	360.2562	391.5702	277.5922	45.9240
30	227.3058	344.5289	429.9174	369.1240	386.4793	278.3387	47.3520
31	....	341.5041	....	373.9504	382.7107	....	47.7280
Total	2,755.0248	10,174.1615	10,402.6531	9,845.6694	12,341.1966	7,822.8992	2,247.5270

Duty of water under southern branch of Pecos Canal, measuring water at the Pecos flume.

Area irrigated	acres..	8,410
Water used	acre-feet..	55,589.1316
Water used per acre	acre-feet..	6.61
Rainfall, April to October	feet..	.40
Total depth, irrigation and rainfall	do...	7.01

The duty of water as indicated by this year's investigations in the Pecos Valley is very low. The farmers have had all the water they wanted and in many instances much more than they needed. When the majority realize how much damage is done by the improper use of water, and when water becomes scarce enough to be sold by measure, the duty in this valley will be greatly increased.

LOSS OF WATER IN CANALS.

While farmers have had all the water they wanted and have used it wastefully, much has been lost from the canal before reaching the headgates of the laterals. There are no exact records of this loss, but it may be approximated by taking the difference between the flow of the canal at the flume and the quantity of water delivered to users below that place.

The two records are complete only for the months of May, June, July, August, and September. During these months the water delivered to the land under this canal, as shown by the tables for the several divisions, was as follows:

Water delivered to land under Southern Canal, May 1 to September 30, 1899.

	May.	June.	July.	August.	September.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
First division	487.95	551.79	456.05	561.36	533.62
Second division	1,521.73	1,328.84	1,139.27	1,872.86	1,579.36
Third division	2,324.18	2,602.54	2,222.68	2,477.96	1,582.91
Fourth division	805.46	530.11	405.92	732.27	405.86
Total	5,139.32	5,013.28	4,223.92	5,644.45	4,101.75

The following table shows the proportion of the water passing through the flume which was delivered to the land under the canal below the flume:

Percentage of water delivered.

Month.	Discharge of flume.	Water delivered.	Percentage.
	Acre-feet.	*Acre-feet.*	
May	10,174.16	5,139.32	50.8
June	10,402.65	5,013.28	48.2
July	9,845.67	4,223.92	42.9
August	12,341.20	5,664.45	45.8
September	7,822.90	4,101.75	52.4
Total	50,586.57	24,142.72	47.7

It will thus be seen that less than half the water entering the canal reached the land to be irrigated. This loss is due to evaporation and seepage and faulty construction. Under the present development this water is not needed, and hence the loss is not felt.

TEMPERATURE AND EVAPORATION.

The following table gives the temperature records at Carlsbad for the six months, May to October:

Temperature at Carlsbad, N. Mex., 1899.

Month.	Maximum.	Minimum.	Average maximum.	Average minimum.
	°F.	°F.	°F.	°F.
May	98	41	90.0	54.2
June	102	45	93.2	55.3
July	101	64	93.7	68.0
August	103	64	94.8	67.7
September	99	48	88.1	59.2
October	89	34	78.1	49.2

Records of evaporation were kept for the period from May 1 to November 11. The atmosphere was dry and evaporation was heavy. The table given below shows the evaporation for periods of one week:

Evaporation at Carlsbad, N. Mex., by weeks, 1899.

	Inches.		Inches.
May 1 to 7	1.13	August 13 to 19	2.00
May 8 to 14	2.50	August 20 to 26	1.75
May 15 to 21	4.25	August 27 to September 2	2.00
May 22 to 28	5.25	September 3 to 9	1.25
May 29 to June 3	5.88	September 10 to 16	1.25
June 4 to 10	2.50	September 17 to 23	1.25
June 11 to 17	2.85	September 24 to 30	1.25
June 18 to 24	2.00	October 1 to 7	1.00
June 25 to July 1	1.63	October 8 to 14	1.00
July 2 to 8	2.25	October 15 to 21	1.00
July 9 to 15	2.00	October 22 to 28	.88
July 16 to 22	1.00	October 29 to November 4	.75
July 23 to 29	2.00	November 5 to 11	.75
July 30 to August 5	1.75		
August 6 to 12	1.50	Total	54.62

LOSS OF WATER FROM EVAPORATION.

The loss by evaporation from reservoirs and canals was heavy, but the greatest loss from this source occurred in applying water to the land. Nearly all irrigation is by flooding, and often the lands to be flooded are laid out in such large sections that immense quantities of water are lost. Instances were noticed during the season where water was divided into small heads and applied to such large tracts that during the warmest part of the day no progress was made. In one or two instances the wetted line receded. This caused "scalding" of growing vegetation, and barren spots were often seen. And in the summer, when the water is low and contains the greatest amount of alkaline salts, this great evaporation is certainly an injury to the soil.

ARIZONA.

USE OF WATER IN IRRIGATION IN ARIZONA.

By Special Agent W. H. Code,
Chief Engineer of the Consolidated Canal Company.

BEGINNING OF IRRIGATION IN SALT RIVER VALLEY.

The Salt River Valley of Arizona embraces a large tract of wonderfully productive soil, a comparatively small portion of which has been brought under cultivation, but which produces most abundantly when water is applied to it.

This water is supplied from the Salt River and its tributaries and at certain seasons of the year is rich in sediment that continually fertilizes and enriches the irrigated soil.

The slope and uniformity of the valley lands is a source of surprise to even a casual observer. These features are especially appreciated by the engineer whose duty it is to build canals and laterals to supply the lands with water, and by the farmer, who, on receiving the water from the lateral, must spread it over every foot of his farm in order to render it productive.

The history of modern irrigation in this valley is of recent date. Irrigation was carried on, however, by a prehistoric people, whose canals covered a large portion of the present reclaimed area. The great mystery of the complete blotting out of these people is of exceeding interest to the archaeologist who contemplates the ruins of their villages. That they had some knowledge of engineering is evident from the manner in which they constructed their canals. The writer has had occasion to run careful levels over several miles of one of these. The result has been a source of wonder ever since, for not only was the grade fairly uniform, but it was a grade suited to a canal of such dimensions, and in accord with our present knowledge of hydraulics, safe velocities, and coefficients of friction.

CANALS DIVERTING WATER FROM SALT RIVER.

Modern irrigation in Salt River Valley dates back only thirty-two years. The first canal, known as the "Swilling Ditch," was built in 1867 and covered land in the immediate vicinity of what is now the city of Phœnix. This canal subsequently became known as the Salt River Canal. At a little later period the Maricopa Canal was constructed, and in 1878 the Grand Central was started, each reaching farther out into what was then desert. The large Arizona Canal was constructed between the years 1883 and 1887, and subsequently absorbed the older ditches, delivering them nearly all their water by means of a cross-cut canal. This system, now known as the Arizona Water Company, controls the delivery of water on the north side of the river, and is so situated that in the event of an increased water supply, it could bring under cultivation an additional area of over 100,000 acres.

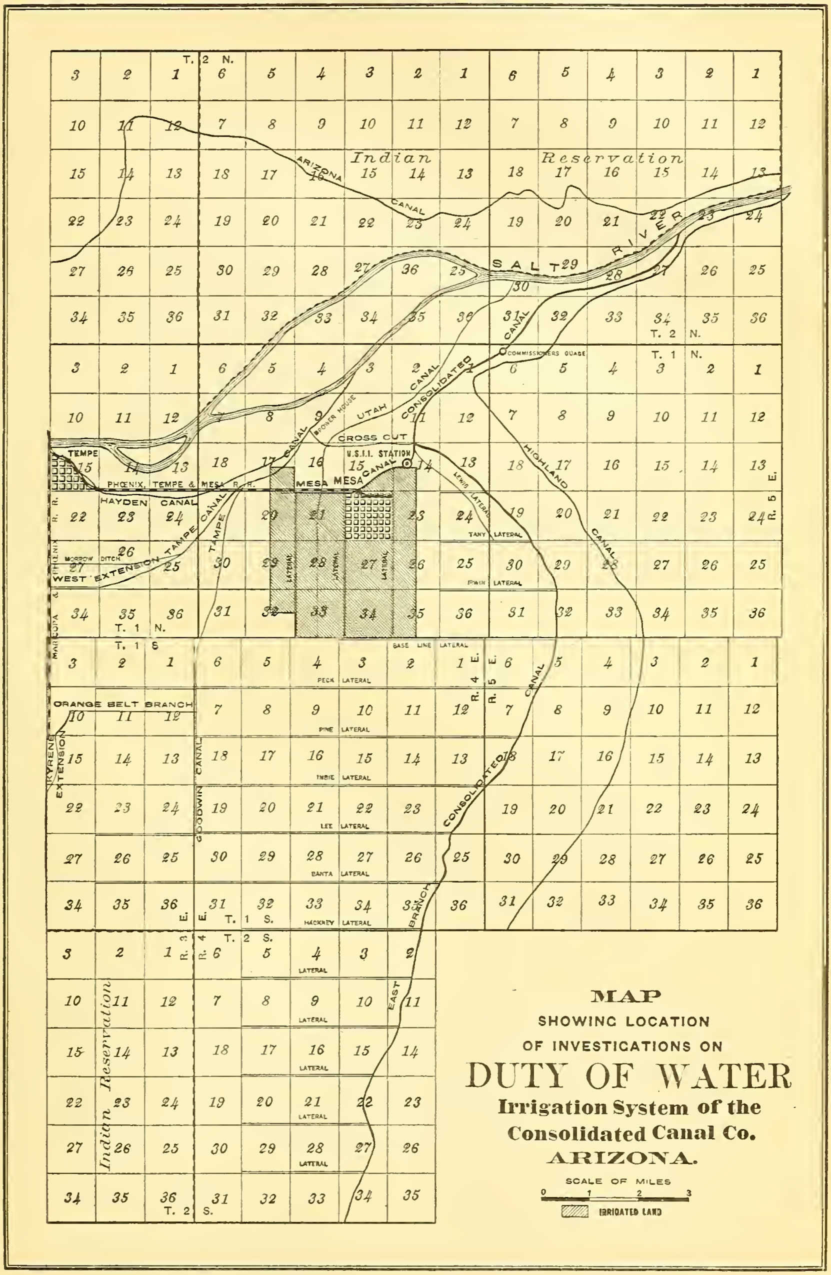
The canals on the south side of Salt River are the San Francisco, Tempe, Utah, Mesa, Consolidated, and Highland canals, the first four named being the oldest.

The "Consolidated" system (see Map, Pl. XXX) is the largest on the south side, taking its water out of the river near the original head of the Mesa Canal. The latter now receives its supply of water from the Consolidated Canal Company, this company having under a certain contract acquired the right and title to all franchises of the original Mesa Canal, enlarging the same for a distance of 8 miles, and delivering them their water at a point some 2½ miles northeast of the town of Mesa.

The Mesa Canal proper was taken out of the Salt River in the year 1878 by a small band of Mormon settlers, and was constructed under great difficulties and privations.

The work of enlarging the Consolidated Canal has been in progress for about nine years, and has been effected by means of dredges. This work is now complete. From the new head of this system (Pl. XXXI, fig. 1) the canal was excavated a distance of 2½ miles through a bluff, necessitating a cut from 16 to 24 feet in depth. The canal cross section is now 45 feet on bottom, slopes 1 to 1, and this cross section continues a distance of 8 miles, to a point known as Division Gates (Pl. XXXI, fig. 2), where the Mesa Canal water is delivered to the south, Tempe water to the west through the Consolidated crosscut, and Consolidated water to the east and south in what is known as the eastern branch of the Consolidated Canal system. This system in its entirety would furnish water for 100,000 acres of land.

The foregoing brief outline includes the canals which irrigate the section adjoining the land chosen for this year's investigations. There are several other important systems west of Phœnix, such as the Farmers' and Buckeye canals, and it is worthy of note that the latter system (the Buckeye) has the least variable water supply of any canal in the valley. It is taken out of the Gila River a few miles below the junction of the latter with the Salt River, and immediately below the mouth of the Agua Frio. The canal is, therefore, supplied



MAP OF THE IRRIGATION SYSTEM OF THE CONSOLIDATED CANAL COMPANY, ARIZONA.

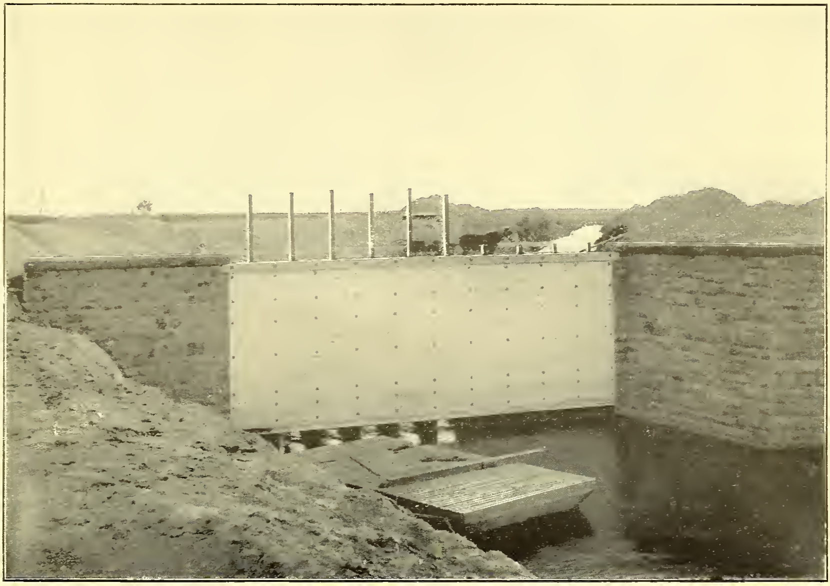


FIG. 1.—HEADGATE OF THE CONSOLIDATED CANAL COMPANY, ARIZONA.

FIG. 2.—DIVISION GATE OF THE CONSOLIDATED CANAL COMPANY, ARIZONA.

with return water from irrigated land under both the Salt and Gila rivers, in addition to the seepage water of the Agua Frio. This gives them a minimum supply of about 150 cubic feet per second (6,000 miner's inches) during the lowest stages of the river. The canal covers approximately 25,000 acres of land, only a small portion of which is yet under cultivation. The head works are located some 22 miles west of Phœnix.

The Mesa Canal, on which the observations of the duty of water in 1899 were made, was constructed and is maintained by a corporation of farmers whose land it irrigates. The stock of the canal is divided into 400 shares of a present value of $500 each. The annual cost per share is approximately $16, which, considering the excellence of their water system, is very reasonable. Their water supply is variable, depending on the stage of water in the river. This irregularity of supply is an unfortunate condition which can not be changed without a reservoir to impound flood waters. Under the present conditions the canals take all the water possible during floods and every user of water endeavors to spread his quota over as large an area as the limited time will allow. The result of this haste on the part of both the canal company and the farmer is generally a great waste of water, and the country roads after such a spurt are at times almost impassable. Again at a period of extreme low water the quantity in the canal is so small that the farmers in most cases simply use it for stock water and to irrigate such fruit or trees as they may have.

Observations of the duty of water under such conditions can not be considered as measuring the possible duty under the economical distribution which would be possible if storage reservoirs for floods were provided.

DIVISION OF THE WATER OF SALT RIVER AMONG CANALS.

The law controlling water distribution in the valley is known as the "Kibbey decision," which was rendered by Judge Joseph H. Kibbey in the year 1890, after long and tedious litigation. The fundamental principle of the decision is that the priority of actual application of the water to the land gives priority of right. This necessitated the determining of the date when water was actually applied on each and every parcel of land under the various canals named in the suit. The evidence thus deduced filled some 6,000 pages of type-written matter, and from it, under the direction of the court, was compiled a table showing the number of quarter sections irrigated in each year under each canal entitled to water from Salt River as per decree of court. The land area unit used in this table was one quarter section (160 acres). The duty of water as tentatively fixed was 64 miner's inches to the quarter section; the miner's inch being estimated as one-fortieth of a cubic foot per second. In the application of the Kibbey decision the above duty of water is not continually allowed to the lands having early rights to the exclusion of all others, the land and canal owners having for the most part pursued a "live and let live" policy, which has permitted of a development that could not otherwise have been effected. It is evident, however, that there is a limit to which this latter policy should be pursued.

There are periods of low water in summer when a duty of 64 inches per one quarter section would allow water to but 35,000 acres of land, a tract much smaller than the 82,640 acres given adjudicated rights for the year 1884. The table prepared as a result of the Kibbey decision is as follows:

Table showing for each year the number of quarter sections under each canal entitled to water from Salt River as per Kibbey decision.

Year.	Salt River Valley Canal.	Maricopa Canal.	Tempe Canal.	San Francisco or Wormser Canal.	Utah Canal.	Mesa Canal.	Grand Canal.	Arizona Canal.	Total number of quarter sections for each year.
1868	12.5	1	....	....	....	....	....	....	13.5
1869	22	6	....	....	....	....	....	....	28
1870	31.5	14.5	....	....	....	....	....	....	46
1871	48	24.5	5	8	....	....	....	....	85.2
1872	78.5	28.5	49	8	....	....	....	....	167
1873	90.5	29	57	12	....	....	....	....	188.5
1874	90.5	31	57	12	....	....	....	....	190.5
1875	90.5	32	57	12	....	....	....	....	191.5
1876	92.5	36	57	12	....	....	....	....	197.5
1877	95.5	41	57	22	7	....	....	....	222.5
1878	102	53	67	22	24	23	2	....	293
1879	104	65.5	70	22	24	30	15	....	330.5
1880	109	84.5	70	24	24	35	17.5	....	364
1881	116.5	102	72	24	24	43	18.5	....	400
1882	117.5	117.5	90	27	26	50	23.5	....	451.5
1883	118.5	124.5	90	28	38	59	43.5	....	501.5
1884	119.5	128.5	95	28	38	62	45.5	....	516.5
1885	120.5	133	98	28	38	73	46.5	43.5	580.5
1886	121.5	135	105	29	38	75	47.5	105.25	656.25
1887	122.5	134	113	31	40	82	47.5	192.75	765.75
1888	123.5	139	117	31	55	82	48.5	333.25	929.25
1889	123.5	139	117	31	55	82	48.5	350	946

With the above table as a guide, the court, through its officer, a duly appointed water commissioner, apportions the water among the canals entitled to receive it during the various stages of medium and low water. At periods of high water every canal carries as much as it can take in at its head.

Mr. Trott, the present water commissioner, has his office in Phœnix, making periodical trips over the various canals in the valley, in order that he may keep constantly informed of the quantity of water being delivered in each. He is allowed one assistant, a gage observer, who reads the gages in the various canals twice a day, reporting the readings after each trip to Mr. Trott by telephone. The latter then makes his calculations, and as he has telephone connections which enable him to reach the headgates of all the canals on short notice, he can have them regulated as he desires at any time. His responsibility ceases when he has apportioned the water to the various canals. After the water passes his gages it is handled by the canal company's zanjero, or water master, who distributes it to the different laterals under the system.

The water commissioner keeps a record of the water flowing in the canals under his jurisdiction, and at the end of the year compiles a table showing the amount received by each canal for each day of the year, also the monthly and yearly averages. The following table gives the average flow for each month of the year 1897 and the average for the year. The flow is given in miner's inches for local convenience, the inch, as before stated, being estimated at one-fortieth of a second-foot. This table is merely the summing up of the numerous pages giving the daily flow for each canal for the entire year. The Indians on the Maricopa Reservation are allowed a constant head of approximately 500 inches from Salt River, which is not included in the table.

Average flow of canals receiving water from the Salt River for the year 1897.

Month.	South side.				North side.		Total water diverted.
	Tempe, San Francisco, Broadway.	Mesa, Crismon, Consolidated.	Utah.	Highland.	Arizona.	Joint-head.	
	Miner's inches.	*Miner's inches.*	*Miner's inches.*	*Miner's inches.*	*Miner's inches.*	*Miner's inches.*	*Miner's inches.*
January	4,443	5,475	1,604	458	4,897	2,694	19,571
February	7,094	9,406	3,908	1,220	17,930	4,643	44,201
March	11,199	9,901	5,008	1,436	23,448	7,417	58,409
April	10,558	9,105	2,565	1,212	21,501	10,347	55,288
May	9,672	9,692	4,054	300	18,425	7,320	49,463
June	5,944	1,942	1,697	....	7,430	3,394	20,407
July	4,138	766	797	....	3,082	2,759	11,542
August	6,382	3,350	2,302	....	10,919	3,078	26,031
September	8,199	7,193	3,412	427	12,390	5,630	37,251
October	7,433	5,463	3,049	90	8,045	4,808	28,888
November	3,776	2,115	2,421	....	10,617	3,210	22,139
December	6,362	3,091	1,341	....	8,580	3,269	22,643
Average flow for the year.	7,100	5,600	2,672	422	12,218	4,874	32,886

The court's authority at present does not extend outside of this valley, and it is beginning to be felt that the law of priority needs to be exercised beyond these limits. Under the present method of operation there is no way of guarding the priority of rights of the Salt River Valley to the waters of the Upper Salt and Verde rivers. Any man who can raise the necessary funds to build a ditch and dam on either of these tributaries can do so, take what water he wants, establish a home, and acquire possessory rights, while the people in the valley are in ignorance of the entire matter. This is the case in the other parts of the Territory also.

In Wyoming and other States having special irrigation laws no man or company can thus appropriate water without permission of the State engineer, and this permission is not granted if the stream is already fully appropriated. If a permit is given, the whole transaction is recorded, giving size of ditch, capacity, location, date of appropriation, etc., so that there is no future trouble in adjudicating the rights of the ditch or canal. This system eliminates for the most part all the difficulties that would otherwise arise in endeavoring to adjudicate the claims of one county against another which was using water from the same stream or its tributaries.

METHOD OF DISTRIBUTION UNDER MESA CANAL.

As before stated, the Mesa Canal Company receives its supply at the division gates of the Consolidated Canal Company. Their zanjero, or water master, then assumes charge of it, turning the water out to the laterals in accordance with the number of shares each lateral represents. It is then taken charge of by the various water masters on the laterals, who control its distribution to the lands. The duties of the latter are simplified by the fact that, as a rule, they have but little dividing to do. The users of water under the laterals operate on the hour system, each share owned by any farmer entitling him to so many hours' run of the entire flow of the ditch. This rotation in use is the best and most economical method of distribution which they could adopt under present conditions.

DUTY OF WATER UNDER MESA CANAL FOR THE YEARS 1896, 1897, AND 1898.

The total area irrigated under the Mesa Canal approximates 12,000 acres of land especially well adapted to the growth of fruit and vegetables, as well as the more staple crops of grain, sorghum, alfalfa, etc. (Pls. XXXII and XXXIII.) This area is not all under a high state of cultivation, a considerable portion of it being farmed only for grain crops during the winter. These crops, being diversified, require different quantities of water, and such water at different seasons of the year. Grain is usually put in during October and November, and is irrigated periodically until the following May. Alfalfa is also irrigated more extensively during this season, though this is simply on account of the larger water supply. Fruit requires more water in the spring and summer months.

The tables show the flow in Mesa Canal for the years 1896, 1897, and 1898. It will be seen by observing the column of mean flow that the season of high water is between the months of January and May. This is invariably the rule, during which period immense volumes of water generally run to waste down the Salt River. At no place would the great advantage of a reservoir as an equalizer of flow be better appreciated than in this valley.

FIG. 1.—DRYING APRICOTS IN ARIZONA.

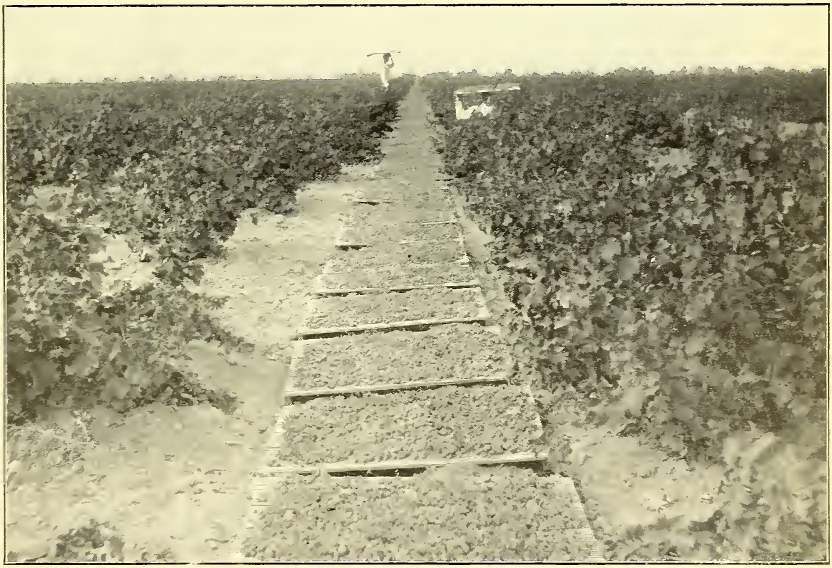


FIG. 2.—DRYING MUSCAT GRAPES IN ARIZONA.

FIG. 1.—VIEW OF A STOCK RANCH AT MESA, ARIZ.

FIG. 2.—AN ALMOND ORCHARD IN ARIZONA.

Flow of Mesa Canal for the years 1896, 1897, and 1898.

Month.	Maximum.	Minimum.	Mean.	Total.	Rainfall.
	Cubic feet per second.	*Cubic feet per second.*	*Cubic feet per second.*	*Acre-feet.*	*Inches.*
1896.					
January	175.0	75.0	117.25	7,209.4	0.15
February	132.5	18.75	79.05	4,547.0	.05
March	175.0	102.5	159.11	9,783.2	.46
April	210.25	117.05	165.50	9,848.0	.03
May	128.75	34.9	70.0	4,304.0	....
June	34.9	12.0	20.9	1,243.6	....
July	200.0	9.95	88.64	5,450.2	4.40
August	175.0	52.475	118.8	7,304.0	.26
September	175.0	54.425	107.31	6,385.3	.37
October	213.55	64.725	95.29	5,859.1	2.19
November	214.75	63.10	73.59	4,378.8	.85
December	115.3	50.8	76.57	4,708.0	.65
Total for the year	....	....	97.66	71,020.6	9.31
1897.					
January	150.0	56.6	76.10	4,750.4	3.67
February	169.55	150.0	159.62	8,864.8	.75
March	175.0	112.5	151.61	9,322.5	1.63
April	175.0	150.0	140.0	8,330.5	....
May	175.0	73.55	146.03	8,979.0	.16
June	90.7	16.75	42.02	2,500.3	1.00
July	41.875	4.4	15.21	935.2	.33
August	175.0	13.075	76.46	4,701.3	2.24
September	175.0	31.25	104.85	6,239.0	1.35
October	175.0	12.125	87.01	5,350.0	1.10
November	65.375	8.5	45.78	2,724.0	....
December	84.475	43.625	65.74	4,042.1	.30
Total for the year	....	....	92.56	66,739.1	12.53
1898.					
January	194.3	66.7	114.02	7,010.8	1.05
February	175.0	108.25	162.20	9,008.1	....
March	200.0	84.7	145.31	8,934.7	.44
April	194.9	90.25	138.0	8,211.5	.10
May	121.3	18.15	61.73	3,795.6	....
June	62.45	10.35	22.82	1,357.8	.12
July	175.0	8.025	93.46	5,746.6	.95
August	207.5	24.25	80.14	4,927.6	1.10
September	175.0	16.825	58.24	3,465.7	....
October	37.425	15.0	17.60	1,082.1	....
November	62.675	23.55	32.37	1,926.1	.70
December	175.0	40.0	84.76	5,211.7	2.39
Total for the year	....	....	84.22	60,678.3	6.85

The area irrigated under the canal in each of these three years is estimated at 12,000 acres. Upon that basis the preceding tables show the following duty of water:

Duty of water under Mesa Canal, 1896, 1897, 1898.

	1896.	1897.	1898.
Area irrigated ....acres..	12,000	12,000	12,000
Discharge of canal ....acre-feet..	71,020	66,739	60,678
Discharge per acre irrigated	5.91	5.55	5.01
Estimated loss from waste, seepage, and evaporation, 30 per cent	1.77	1.66	1.50
Depth of irrigation..........feet..	4.14	3.89	3.51
Rainfall ....do...	.78	1.04	.57
Total depth of water received by land..........do...	4.92	4.93	4.08
Acres served by a continuous flow of 1 cubic foot per second[1]	123	130	145
Acres served by a continuous flow of 1 miner's inch[1]	3.07	3.25	3.62

[1] For 365 days.

The results shown in the above table would be very satisfactory if the 12,000 acres were in a constant state of high cultivation, producing maximum crops at all periods. This is not the case, however, as but little water is used on alfalfa during low stages of the river, and the farmer thus loses from one to two crops that could be easily grown had he sufficient water during the summer season. This same state of affairs exists throughout the valley generally, but the great productiveness of the soil, in response to the few extra irrigations afforded by reason of our occasional summer floods, makes the showing far better than in many places where the water supply is more abundant. It is fair to assume that could the present annual discharge of the canal be evenly distributed throughout the different months of the year and be delivered in uniform heads under a system whereby the farmer would be obliged to practice economical irrigation, its duty would not only be increased, but maximum crops would be insured.

I have estimated the loss from percolation, evaporation, and waste to be fully 30 per cent of the amount shown at the gage. This seems very high, but in the opinion of the writer it is a fair estimate considering the degree of heat experienced during the summer months, the wasteful methods of irrigation practiced during periods of high water, and the great waste caused by furnishing water to stock during low stages of the river. Judge Kibbey, in his decision, expressed himself very forcibly on this latter practice. The following is an extract from his decision:

> No man has a right to waste a drop of water. Any excess of water that he diverts and wastes by carelessness, negligence, or ignorance of economic methods of cultivation or irrigation, or failure to adopt them, he unlawfully diverts.
>
> It appears from the evidence in this case that large quantities of water are allowed to flow in the various canals and ditches to supply stock with water. This necessarily involves a great waste of water. At a small estimate I should think the evidence discloses an amount of water wasted thus sufficient, if properly applied to irrigation, to make productive 10,000 acres of land. The amount of water actually consumed by stock is insignificant. The loss is that due to evaporation and seepage in its long passage through the various canals and the miles of subsidiary ditches. This seems to me to be an unreasonable use of water. I do not mean to deny the right of the use of water for stock, for it has always been a recognized use, like that for domestic purposes, but it can not, I think, be diverted from its original course for that purpose. It has always been the law that stock and the public could drink from a water course, but not to impede its flow or diminish its quantity for that purpose. Instead, I consider the law to be, of bringing the water from a natural water course a long distance by means necessarily involving an enormous proportionate waste to water stock, the stock must be taken to the natural water course to drink or otherwise provided for. If the water be in the ditches on a man's ranch in the course of application directly to irrigation, it might be permitted to allow stock to drink from it, but it is an unreasonable use of it to permit water to be in the ditches for that purpose alone.

This states the situation very clearly, but unfortunately this portion of the Kibbey decision is not enforced. That it should be is the opinion of all who have the best interests of the valley at heart. The cost of a well and pumping plant is not great, and each farmer should be supplied with one. The company with which the writer is connected furnished 1,000 head of stock with excellent water for several years with a well pump and horsepower that did not cost over $200. The lift was about 45 feet, but it only required four or five hours' work each day on the part of an inexpensive mule to keep the cattle well supplied with water even during the hottest weather. It is needless to say that the fresh water thus pumped daily was infinitely better for the cattle than that furnished from malaria-breeding mud tanks.

A few of our progressive farmers have put in windmills for stock purposes, and while the winds in this section are quite light, the results for the most part have been very satisfactory. Mons Ellingson, who has a cattle ranch several miles southwest of Mesa, states that he watered several hundred head of cattle by means of his windmill. A mill with horsepower attachment would perhaps be more desirable for those who could afford the outlay. The average monthly velocity of the wind, according to the records of the weather observer in Phœnix, will not exceed 5 miles per hour at a height of 57 feet above the ground; it would perhaps be higher on farms and ranches that present a considerable unobstructed area. It is essential to have a good storage tank of some kind, in event of either windmill or horsepower. Dr. A. J. Chandler has an excellent tank and watering trough combined on one of his ranches south of Mesa; it consists of a 100-foot section of a semicircular redwood stave flume with ends in, banded every few feet with iron hoops, which connect to cross pieces of 4 by 4 timber. The trough is 6 feet across and holds about 10,000 gallons. Fifty or more head of cattle can drink at once from the tank. As it is always kept wet, the lumber will last indefinitely.

Judge Kibbey also referred to the loss due to seepage and evaporation in the many miles of canals and laterals. This is one of the greatest sources of waste we have to contend with, as each canal and lateral while carrying small heads loses an amount of water by seepage out of proportion to the amount carried. Thus the Mesa Canal has a wetted perimeter of 17 feet when carrying only 500 inches; when carrying 5,000 inches the perimeter or surface exposed to seepage will not exceed 22 feet. The Arizona Canal, with a bottom width of 30 feet, loses by seepage and evaporation approximately 30 inches per mile when carrying the ordinary summer supply, notwithstanding that it has an excellent cross section and is lined with a coating of silt that is almost impervious to water. This loss would be increased but very little with double the amount of water in the canal, and what is true in this instance of course holds good for smaller canals and laterals. The efficiency of the summer supply would be largely increased if the respective canal owners could enter into arrangements whereby they might receive a larger supply of water for a shorter time by pursuing a system of rotation during stages of low water in the river.

OBSERVATIONS ON DUTY OF WATER IN 1899.

The observations as given above are close approximations for the years stated, but are more general in their character than those begun in 1899, under the direction of Professor Mead, irrigation expert in charge.

The purpose of the latter was to determine the actual volume of water used on a given area. Six thousand acres irrigated from the Mesa Canal was the area chosen. As canals vary in depth from day to day and sometimes from hour to hour, it was necessary to have a continuous record of the depth of water passing through the canal. This was secured by placing a self-recording register in the canal one-half mile below where its water supply is delivered by the Consolidated Canal. The instrument was started on April 2 of 1899, and accurately recorded the gauge readings from that date until October 1, the close of the observations for the year. It continues to record flow since that date, the data thus obtained to be used in future reports.

The following is the acreage of the different crops grown:

	Acres.
Alfalfa	4,102.00
Grain	806.50
Grain and alfalfa	443.75
Fruit, vineyards, orchards, etc	569.00
Vegetables	32.75
Total	5,954.00

In addition to the above acreage there were a number of trees, small lawns, and garden patches watered in the townsite of Mesa, which are not included in this report, but which would easily swell the total to 6,000 acres.

The amount of water for this tract that passed the rating station previous to putting in the register, according to daily records on file, was 10,032 acre-feet. The amount from April 2 to October 1, as per recording instrument, is tabulated as follows:

Discharge of Mesa Canal, January 1 to September 30, 1899.

[See diagram, Pl. VI, p. 72.]

Day.	April.	May.	June.	July.	August.	September.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1	....	72.2547	29.5917	28.1835	268.2975	39.0579
2	36.6876	73.3339	37.5967	23.2562	242.0081	40.5223
3	110.0446	74.7554	56.5421	20.3636	229.2942	33.1934
4	119.7696	60.2645	44.1736	23.5240	80.5983	28.3240
5	128.5091	65.0132	39.8314	21.8959	248.0149	21.5291
6	131.7355	64.5421	41.4744	24.4810	227.4149	19.5695
7	139.3202	56.3339	32.5240	22.1752	189.8628	124.9570
8	142.5769	54.7008	26.0050	21.7587	156.6215	235.1835
9	135.4661	55.3058	37.1818	25.7025	133.0149	187.7653
10	129.4475	49.3074	35.0099	32.7488	107.6397	135.8926
11	135.1851	32.4645	29.9934	47.6959	49.5058	62.2347
12	137.7620	40.8099	25.8347	57.2512	58.1488	41.0529
13	139.1405	54.3835	26.5008	104.7686	67.3554	53.4017
14	132.9769	45.0248	21.5902	62.6182	55.4017	45.7620
15	121.4876	35.5124	20.8050	58.5438	99.1851	32.3223
16	119.4612	37.9653	19.8909	57.6430	93.0810	24.4909
17	139.8066	34.5733	21.4083	75.8479	58.6264	25.7256
18	144.2496	35.2231	34.1636	95.9488	34.3025	20.6479
19	141.6446	27.5868	24.2975	103.3636	31.5653	20.0777
20	132.9488	30.8711	31.8843	114.2860	35.2678	26.4017
21	135.9074	38.4331	27.3669	75.1702	34.3521	27.6397
22	130.5306	35.2033	27.1721	133.0562	25.6661	26.3008
23	117.7124	37.3868	33.4479	153.0595	30.9256	30.4463
24	108.6628	36.4529	21.3521	147.3190	23.3256	32.2215
25	99.8446	32.5537	42.3273	119.6959	18.3669	32.6281
26	95.3388	32.7207	30.7471	152.8114	17.2760	31.1603
27	99.8298	31.9636	28.8182	98.8083	17.2760	33.1669
28	95.1355	36.6298	23.0413	141.1488	20.9603	32.4050
29	90.5570	35.2397	34.4463	233.1140	20.6678	33.3818
30	86.8760	42.9537	28.4182	240.5504	29.8926	25.6264
31	....	30.1818	....	253.0942	40.9769	....
Total	3,478.6149	1,389.9455	933.4367	2,769.8843	2,744.8925	1,523.0888

	Acre-feet.
Flow from January 1 to April 1 (from daily gauge readings)	10,032.0000
Flow from April 2 to September 30 (from register sheets)	12,839.8627
Total flow from January 1 to September 30, 1899	22,871.8627

The monthly precipitation at Mesa for the year 1899, as measured by the United States Weather Bureau, was as follows:

Month	Foot.	Month	Foot.
January	0.11	July	0.11
February	.03	August	.03
March	T	September	.06
April	T		
May	.00		.40
June	.06		

The data given above show the following duty of water for 1899:

Duty of water under Mesa Canal, 1899.

Area irrigated ....acres..	6,000
Discharge of canal ....acre-feet..	22,872
Discharge per acre irrigated ....do...	3.81
Estimated loss from seepage, waste, and evaporation, 25 per cent ....foot..	.95
Depth of irrigation ....feet..	2.86
Depth of rainfall ....do...	.40
Total depth of water received by land ....do...	3.26

It will be noted that the estimate of loss in the above table is but 25 per cent. This is because the rating station is several miles nearer the irrigated area than is the commissioner's gauge, from which the data previous to 1899 were obtained, the commissioner's gauge being about 8 miles from the center of the irrigated area.

The supply of water in Salt River for 1899 has been much below the average. Mr. Trott estimates that the combined daily flow in the canals of the valley for the present year to October 1 has been 10,000 miner's inches less than the average daily flow for the past five years, and the figures giving the daily flow show the variable water supply. The rainfall was also very small.

The total depth applied from January 1 to October 1 is 2.86 feet, and the yield from the 6,000 acres can be said to have been wholly produced by this amount of water plus the rainfall of 4.69 inches, although this does not include the entire year or the entire period in which water is used; but in a region where cultivation and production never end, and where there is no distinction between seedtime and harvest such as exists in Northern climates, there has to be some arbitrary point for beginning. The one chosen is as satisfactory as if it included the entire twelve months, because the value of the crops on January 1, when investigations began, did not differ largely from their value on October 1, when observations for this year closed, and in recording yields for the season just past the value of the crops on October 1 has not been taken into consideration.

The writer found it no easy task to obtain the acreage and yield of 6,000 acres of diversified crops. Many of the letters sent out were not answered, so that finally it became necessary to employ a canvasser, who personally interviewed all delinquents. This plan proved more expeditious and accurate, though more expensive.

The yields given can not be considered more than a close approximation, for the reason that few farmers keep a close record of their crops and pasturage.

Approximate yield from 6,000 acres under the Mesa Canal, January 1 to October 1, 1899.

Products.	Quantity.	Price.	Amount.
Alfalfa ....tons..	3,207	$4 per ton	$12,828.00
Alfalfa seed ....pounds..	27,650	$0.07 per pound	1,935.50
Barley ....do....	375,900	$1 per cwt	3,759.00
Wheat ....do....	437,275	.....do	4,372.75
Apples ....do....	4,900	$0.02 per pound	98.00
Apricots ....do....	151,000	$0.01 per pound	1,510.00
Almonds ....do....	41,500	$0.105 per pound	4,357.50
Grapes ....do....	159,500	$0.01 per pound	1,595.00
Figs ....do....	47,650	$0.02 per pound	953.00
Nectarines ....do....	600	.....do	12.00
Peaches ....do....	82,400	$0.01 per pound	824.00
Pears ....do....	33,000	$0.02 per pound	660.00
Plums ....do....	600	.....do	12.00
Prunus simoni ....do....	23,700	$0.03 per pound	711.00
Quinces ....do....	1,560	$0.02 per pound	31.20
Eggs (dealers' estimate) ....dozen..	42,332	$0.17 per dozen	7,196.44
Poultry (shippers' estimate)	....	....	4,000.00
Honey (shippers' estimate)	....	....	3,000.00
Milk (cash paid by creameries)	....	....	8,480.00
Stock, pastured for eight months..........head..	3,478	$0.75 per head per month...	20,868.00
Total	....	....	77,203.39

In making up the above statement of yields we have endeavored to make a conservative estimate. As before stated, but few of the farmers kept books, most of them depending largely on memory for estimate of yield. There was also a suspicion among a few of the farmers that the assessor would in some manner obtain the data thus given and use it to their future disadvantage. On the whole, however, it is as close an estimate of yield as it is possible to obtain, and the error, if any, is in placing the yield too low.

The gross income per acre for the first eight months of 1899 according to this statement would be $12.87. This is not large, owing to the returns from the skillfully farmed lands being merged with those from lands that were poorly taken care of. The return from Mesa lands is in proportion to the labor and skill exercised in their cultivation, and in examining these statistics it was a common thing to find tracts that produced double the amounts of the adjoining farms. Almond, peach, pear, and apricot orchards, vineyards, and gardeners' tracts when well handled produced yields per acre varying from $20 to over $100, though there were also a number of small, ill-kept orchards that were not worthy of the name. It must be borne in mind that these returns are for but eight months of the year and that the lands in the Salt River Valley produce to a greater or less extent throughout the entire twelve months.

APPROXIMATE VALUE OF EACH ACRE-FOOT OF WATER APPLIED.

The actual cash cost per acre-foot.—In various irrigated States and Territories the relation between the acre-foot of water and its actual cash value when properly applied to land is one of the most important factors in estimating either the probable return from canals or the benefits to come from the construction of storage reservoirs.

To irrigate the 6,000 acres of Mesa land from January 1 to October 1, 1899, required 22,872 acre-feet of water. Dividing the latter amount into the total value of yield in dollars and cents ($77,203.39) gives $3.37 as the return from each acre-foot used. It is evident that with a regular supply of water, which could be furnished by the construction of storage reservoirs, the value of an acre-foot would be much higher.

Many of the farmers in giving their yields affirmed that their products would have been double if the same amount of water could have been delivered to them in uniform heads, according to the wants of the crops. This approximate gross value per acre-foot will give some idea of what a source of potential wealth to the Salt River Valley exists in the "Tonto Basin Reservoir."

In individual instances the return was much in excess of that above given for common diversified farming. The returns from the Trippell almond orchard gave over $30 per acre-foot applied, and in gardening and melon culture the value was even higher, though, unfortunately, tracts of land so utilized did not come under the field of this year's investigations. The returns from the orange orchards are not included in this report, since they are not on the market until late in November. This branch of horticulture on the Mesa lands being still in its infancy, the yield and the consequent profit from the same is not yet large, but orchardists are looking with confidence for a brighter future. The valley produces an excellent orange, and the fact that they can be sent to market several weeks earlier than other oranges, gives promise of a value per acre-foot for water far in excess of any product mentioned in this report.

APPROXIMATE COST OF WATER PER ACRE-FOOT.

The number of shares in the Mesa Canal represented on the 6,000 acres of land was 234. These shares have a par value of $250 each, and at present are selling at $500. Estimating the investment at the latter enhanced valuation, the cost per share for eight months, including interest, would be as follows:

Ten per cent on value of share	$33.32
Operating canal	12.00
Maintenance of laterals	4.00
Total cost	49.32

This gives a total charge for the 234 shares of $11,540.88, or a cost for the 22,872 acre-feet of 50 cents per acre-foot of water applied. This is reasonable, and is made so especially because of a favorable contract with the Consolidated Canal Company, whereby the Mesa farmers are relieved of the burden of maintaining an unstable dam and headgate.

DUTY OF WATER ON GRAIN FIELD AND YIELD FROM SAME.

A careful calculation was made of the water furnished certain land under a lateral supplied with a rating station. The farmer, Mr. John Vance, of Mesa, sowed 123 acres of barley and alfalfa together in November, 1898, sowing, approximately, 70 pounds of barley to the acre. He commenced irrigating November 20, 1898, rotating with other shareholders in his circuit, thus getting large streams for short periods. He finished his last irrigation on May 14, 1899, making a total irrigating season of 175 days.

The amount of water which his shares represented at the commissioner's gage would have covered his land to a depth of 2.82 feet. Estimating that 30 per cent of the water passing the gage was lost in seepage, evaporation, and waste, it leaves a total depth applied of 1.98 feet. In addition to this there was a rainfall during the period of 4.39 inches. The water was well handled and properly applied, and from the showing made there was evidently enough of it, though the farmer would probably have used more could he have obtained it.

The harvesting was finished early in June. His yield was 2,703 sacks of barley, averaging 95 pounds per sack, making a total of 256,785 pounds, or 2,087.68 pounds per acre. The value of barley at harvest time approximated 95 cents per hundred pounds, giving a return per acre of $19.83.

The farm was virgin soil, never having been irrigated before, unless it was by a prehistoric race. The soil is light alluvial and not considered by many farmers as being so well adapted to grain raising as the heavier soils in other sections of the Mesa country. The net profit, after allowing for wages and paying for all harvesting, will closely approximate $1,400, and in addition an excellent stand of alfalfa is on the ground.

The gross income from the above 123 acres was at the rate of $19.83 per acre, and this return was reaped in about six months. The amount of water used was 344.86 acre-feet, giving an approximate gross value of $7 per acre-foot applied. The difference in this value per acre-foot and the one previously given is more than 100 per cent, and illustrates the point before made that some lands produced double the amount of adjoining farms, for the simple reason that they were properly handled.

The above is a larger yield than is usually secured on virgin soil, but not so large as the average yield of grain sown on old alfalfa land, which frequently averages over 3,000 pounds per acre. The rainfall during this period was very light, necessitating more irrigation than would have been necessary if there had been the usual precipitation. There are instances when the rainfall has been sufficient to mature grain crops with the aid of one or two irrigations, but these instances are so rare that they are not to be counted upon. During seasons of high water there are also many instances where the farmer, in his anxiety to "soak up" while the water lasts, has nearly or quite ruined his crops by an oversupply.

METHODS OF HANDLING WATER TO OBTAIN GREATEST EFFICIENCY.

As regards the best methods of handling water to increase its efficiency on the crops above tabulated, the writer has tried to obtain the views of practical and successful irrigators of experience in their various lines.

FRUIT.

As regards horticulture (almonds), the following letter from Mr. J. E. Bettler, who has charge of the fine Trippell almond orchard near Mesa (Pl. XXXIII, fig. 2, p. 116), is submitted:

Mesa, Ariz., *October 12, 1899.*

Mr. W. H. Code.

Dear Sir: In reply to your request, would state that I could only make an approximate estimate of the amount of water used under the present system of distribution. This system is made in the interest of the alfalfa and grain growers, consequently an average of fifty per cent of water for orchards is lost. To obtain the best results, I would prefer to have water as follows: 120 inches 18 hours twice a month, or the same amount 36 hours once a month. I use the furrow system in irrigation, and allow just sufficient water to flow in each furrow so that there will be no waste water. The smaller the flow the deeper the penetration into the soil, consequently less waste.

The short and frequent irrigations so commonly in vogue in this valley cause a loss of at least 50 per cent of the practical utility of the water, and, furthermore, make the orchards short lived. The condition of the soil is of much importance. Where the furrows are made in hard and compact soil, water is of little value to the trees. The ground should be well broken, so that the water can enter deeply into it. Following the furrow with a subsoiler would be beneficial.

From September to May irrigation should be followed by plowing or cultivation. The most thorough irrigations are made in the winter, in order to use the land as a reservoir to supplement the short supply in the river in May and June, also to keep the roots from coming to the surface for moisture, and hold them deep in the ground and so avoid check growth. It is also beneficial in conjunction with "smudging" (the building of smoldering fires) for protection from frost, and is essential to successful almond culture.

It would seem that winter irrigation is as essential to the production of certain kinds of fruit as it is to growing alfalfa. The owner of a Thompson Seedless grape vineyard near Mesa states that he depends largely on winter irrigation. He gives his vines two or three good waterings during this period, and in the spring and early summer keeps the surface as moist as possible with his decreased water supply, cultivating thoroughly during the latter period.

It would be interesting to know to what depth these copious winter irrigations saturate the soil. The general practice seems to be to fill the ground during this period, in this way providing a reservoir to tide over the months of limited supply.

GRAIN.

Mr. H. S. Phelps, a practical farmer of Mesa, has supplied the following description of his methods of irrigating grain:

> The ground should be irrigated thoroughly by the middle of October, then plowed; early in November irrigate it again thoroughly, and follow up as soon as possible with seeding, this in turn to be directly followed with peg-tooth harrow. Two subsequent irrigations will then make a fine grain crop.
>
> If there is alfalfa ground in addition to grain land, use the water provided by the ditches on it after the grain is sown, and allow it to soak in thoroughly; then when the time comes for irrigating grain, the alfalfa has had plenty of water to last it until the grain crop is taken care of.

Mr. Phelps states that by this irrigation the efficiency of water is largely increased, and that one water share in the Mesa Canal will irrigate in ordinary seasons 25 acres of grain and a like tract of alfalfa. This plan might be further improved by the use of a press drill seeder.

ALFALFA.

In irrigating alfalfa, the borders should be solidly built and from 4 to 6 rods apart, depending on the intervening fall of land and the head of water available. The head ditches should be from three-eighths to one-half mile apart, also depending on slope of country, and should be well constructed, having uniform cross section.

In irrigating, it is desirable, when possible, to turn good heads of water between each set of borders, so that the quantity may be sufficient to spread quickly and uniformly over the intervening area. It is a common condition for the "lands" to have poor and weak borders, so that the water which should be confined between them breaks through into adjoining lands, and a large portion is wasted in indiscriminate flooding. It is of course primarily important that the land should be well leveled, but the construction of substantial borders enables the farmer to force the water over irregularities in the surface that would otherwise receive no irrigation. This manner of confining the water is especially necessary in the summer season, since when the supply is limited it enables the irrigator to spread it over the surface more rapidly, moistens a greater area, and reduces the chances of scalding alfalfa to a minimum. Also during summer floods it enables farmers to push the water rapidly over the surface and prevents the heavy deposit of silt that would otherwise smother out closely cropped alfalfa.

PASTURES.

In collecting statistics of yields from the 6,000 acres, the canvasser obtained the average number of stock pastured each month from January 1 to October 1, 1899. One farmer, Mr. C. S. Steward, made the remarkable showing of pasturing an average of 450 head of cattle in addition to cutting a crop of 310 tons of alfalfa from 240 acres of land. He states that in handling water to the best advantage in pasturing stock, it is advisable to have four or five pastures, so that one may, by changing cattle from one to another, irrigate continuously. In the winter and spring months he soaks his fields thoroughly, allowing the water to run continuously in small heads. If the water supply allows him a late spring irrigation, he can subsequently cut two crops of hay without further watering. He shifts his cattle from field to field while this irrigation is going on. After he begins haying he allows the cattle to follow behind, gleaning everything that is left. He states that the alfalfa is in no way injured by a very close cropping in dry weather. His subsequent summer supply of water (outside of flood periods) is pushed as rapidly as possible over the various fields to moisten the surface, which practice tends to retain the moisture under neath, and this tides over the intervals between more thorough irrigations. Mr. Steward could not have made such a record in pasturing cattle had he not been able to keep them all together. Had he been forced to divide them into several bunches, the showing would have been much smaller.

Mr. McQueen, who has charge of a ranch on which pure-bred Galloway cattle are grown (Pl. XXXIII, fig. 1, p. 116), says that in handling such cattle the showing in pasturage can not be made so great, owing to the necessity of keeping the stock separated in different fields, and that dividing the fields into pastures of 40 acres is the best plan, not only for the cattle, but in order to utilize a low water supply to best advantage.

There are other portions of the valley where a larger water supply gives extraordinary results in pasturage and alfalfa raising. This is notably the case on the lands under the Tempe Canal, which has one of the largest appropriations of water of any system in the valley.

CORN.

The writer is indebted to Mr. George Schornick, a successful corn raiser, for the following data:

Select good strong soil and flood it thoroughly about the middle of July. As soon as practicable, usually the first or second day subsequent to irrigation, begin operations with a combined lister and drill, running the same a depth of between 4 and 5 inches, and using Eastern corn for seed. Corn will come up in three or four days. When it is about 6 inches high, run a tooth harrow down each row, which will pulverize the surface of the ridges and rake or cultivate sufficient fine soil around the young corn for the first time. Then follow with an irrigation about twelve days from time of planting, running water down furrows between rows; follow irrigation with a two-horse cultivator, giving the corn a thorough cultivation, and throwing the dirt to the corn. Go through the same process every twelve days until the corn is too large to cultivate. It will be found that corn can be harrowed once and cultivated about three times before it is too large.

It will be noted that the time for seeding is about July 15, which allows corn to be taken care of during periods of low water. There were times when Mr. Schornick's supply was very limited indeed, but small as it was he always made some progress, owing to the plan of furrow irrigation, which greatly increases the efficiency of the water.

The methods of furrow or subirrigation should be followed whenever possible, not only on account of the great saving of water, but also for the more profitable yields assured. Even alfalfa grows better on top of the borders.

MELONS.

Mr. J. Holdren, of Mesa, has attained great success in growing the Georgia watermelon and the Rockyford canteloupe. He shipped the latter to many portions of the United States, including New York City.

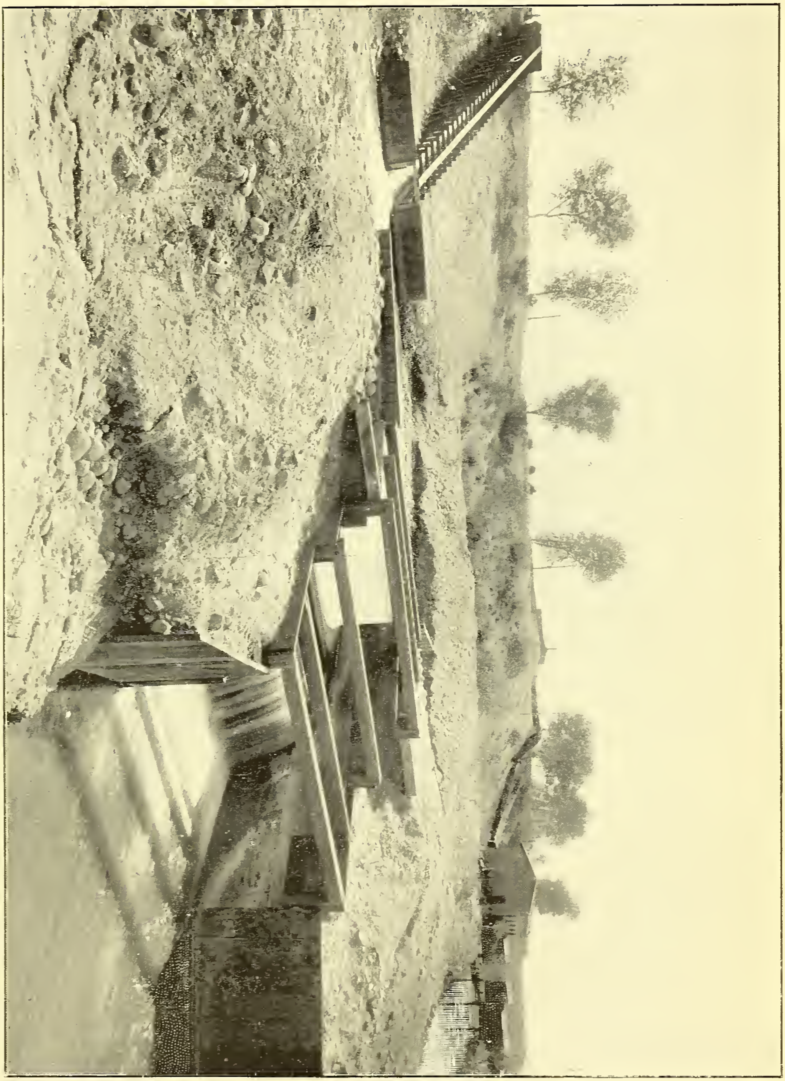
The Mesa farmers have not entered into melon culture on the scale of the farmers in the vicinity of Phœnix, but the showing this year has been so satisfactory that their culture is likely to increase.

Mr. Holdren states that in gardening and melon culture the principal factor for economical irrigation is thorough cultivation at just the time when the soil is in proper condition. This latter knowledge can be gained only by experience, on account of the great variety of soils. He further states that careful preparation of the ground before planting is the foundation of success. Use the furrow method of irrigation, water every ten or twelve days until melons are growing, then every five or six days if possible, cultivate after each irrigation until vines cover the ground, and never flood the soil after planting.

For successful gardening and melon culture it is essential to use water according to the demands of the crop. Fortunately, owing to the system of furrow irrigation employed, it is possible to make considerable progress during "a turn," even in periods of low water, but the greatest difficulty is in obtaining the water with sufficient frequency during the summer months. Under some of the Mesa laterals, where there are a large number of shares, the "turns" are ten or twelve days apart during the low-water period, and crops often suffer between turns. It will be noted that Mr. Holdren recommends irrigating melons every five or six days, if possible, after they have reached a certain stage.

PUMPING WATER.

If the gardener could afford a small gasoline pumping plant, to provide a supplemental supply from wells, it would remove the element of uncertainty above mentioned. A pumping plant of this character could also be used to good advantage as a supplemental supply to vineyards and for orange and almond orchards. There is an abundance of underground water in this vicinity which could be developed. The Consolidated Canal Company has a well at their power house (Pl. XXXIV) from which they pump 150 inches of water for irrigating purposes for lands in the vicinity. The well is 8 by 16 feet, horizontal cross section, and is 30 feet deep. Surface water was found at a depth of only 8 feet below ground level. This well is situated at the foot of the Mesa bluff, an exceptionally good location. On top of the bluff water is found at depths varying from 20 to 40 feet below the surface, depending on the location, fall of the country, and formation of the subsoils. If gravel, coarse sand, or quicksand are encountered when excavating a well, an exceptionally good flow can be calculated upon. A flow of 50 to 60 inches can be obtained by a small outlay, but when a discharge of 150 inches is desired the cost increases out of all proportion to the depth of the well, owing to the expense of keeping the water out of the way of the well diggers.



POWER HOUSE AND WASTEWAY OF THE CONSOLIDATED CANAL COMPANY, ARIZONA.

CALIFORNIA.

DUTY OF WATER UNDER GAGE CANAL, RIVERSIDE, CAL.

By Special Agent W. Irving, C. E.,
Chief Engineer Gage Canal.

LOCATION.

The Gage Canal system, including water sources, canals, and land capable of irrigation from said system, is situated in the counties of San Bernardino and Riverside.

The water supply is obtained from within the boundaries of the San Bernardino Rancho, comprising 2,831 acres, the lots and blocks of which rancho are shown on the accompanying map (Pl. XXXV). The Santa Ana River runs through the above-described property for a distance of about 4.25 miles, as measured along its channel.

The headgates of the Gage Canal (Pl. XXXVI, fig. 1) are located at a point on the south bank of the Santa Ana in lot 3, block 69, of the San Bernardino Rancho, or in sec. 13, T. 1 S., R. 4 W., San Bernardino base and meridian. From thence the canal runs generally in a southwesterly direction over the bottom lands of the Santa Ana Valley, a distance of about 2 miles; thence, skirting the sloping bench land for 1 mile, its channel is carried along the face of a high bluff by means of tunnels and trestle work until it emerges on the Riverside plains, across which it continues to its termination in the SE. ¼ sec. 19, T. 3 S., R. 5 W., San Bernardino meridian, a total distance from the place of beginning of 20.16 miles.

The lands capable of irrigation from the Gage Canal system, both below and above the height of the 100-foot contour, are particularly well fitted for the culture of citrus fruits. They are situated mainly in Riverside County, ranging from sec. 5, T. 2 S., R. 4 W., San Bernardino meridian, in San Bernardino County, to sec. 26, T. 3 S., R. 4 W., San Bernardino meridian, in Riverside County, comprising a total acreage of 11,469.08 acres.

WATER RIGHTS.

The form of water right prevailing in the valley of the Santa Ana is mainly that provided under the State laws, and is known and designated as "right by appropriation." This form of right, of course, applies to the waters of natural streams, and is therefore subject to limitation by the application of the law affecting riparian rights.

The sections of the civil code of California, under which rights by appropriation can be acquired, read as follows:

SEC. 1410. The right to the use of running water flowing in a river or stream, or down a canyon or ravine may be acquired by appropriation.

SEC. 1411. The appropriation must be for some useful and beneficial purpose, and when the appropriator, or his successor in interest, ceases to use it for such a purpose the right ceases.

SEC. 1414. As between appropriators, the one first in time is the first in right.

SEC. 1415. A person desiring to appropriate water must post a notice, in writing, in a conspicuous place at the point of intended diversion, stating therein:

I. That he claims the water flowing to the extent of (giving the number) inches, measured under a 4-inch pressure.

II. The purposes for which he claims it and the place of intended use.

III. The means by which he intends to divert it and the size of the flume, ditch, pipe, or aqueduct in which he intends to divert it.

A copy of the notice must, within ten days after it is posted, be recorded in the office of the recorder of the county in which it is posted.

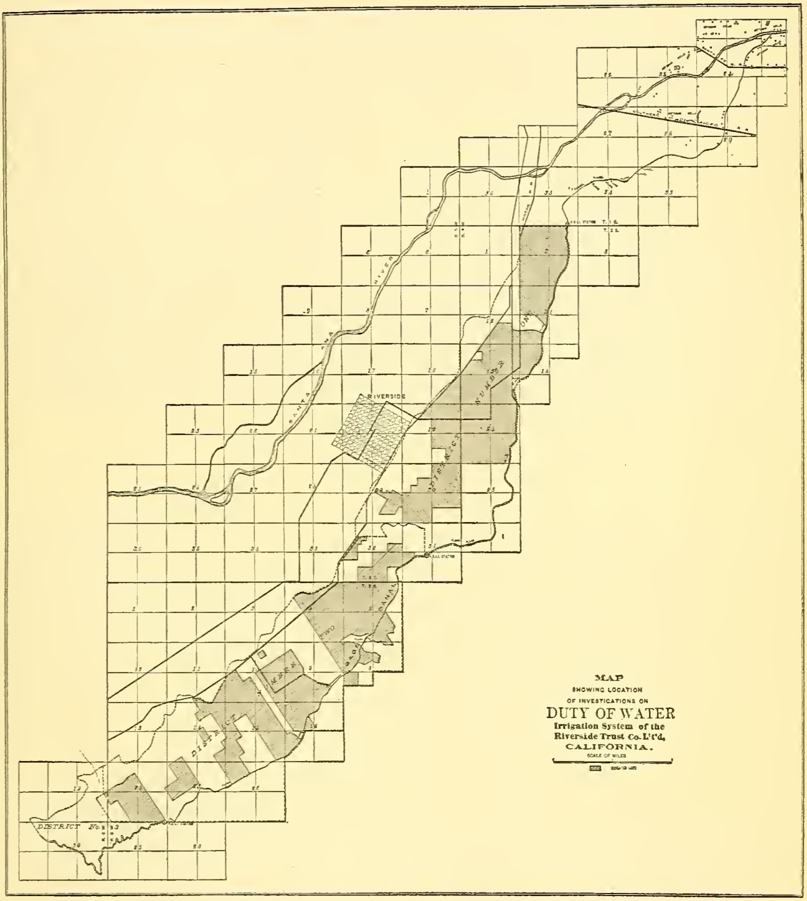
SEC. 1422. The rights of riparian proprietors are not affected by the provisions of this title.

WATER SOURCES.

It may be taken without question that all the water used under the different irrigation systems in the Santa Ana Valley has its origin primarily in the San Bernardino Mountains, whether it is eventually diverted from surface-flowing streams or from subterranean channels. The drainage from this range of mountains manifests itself in the valley in three ways, namely: Surface-flowing streams direct from the canyons; subterranean waters coming to the surface in the form of springs; and again by artificial springs created by means of artesian wells tapping the underground streams and thus developing a flow of water from that source.

Upon these sources, then, the irrigation systems of the Santa Ana Valley depend for their supply of water, and the Gage Canal system depends on all three, although at the present time most of the water is received from artesian wells (Pl. XXXVII), now sixty-five in number, including three not yet fully completed.

The right of this canal to divert water from the Santa Ana is based on the claims of the following ditches which had established legal rights to do so: The "Hunt & Cooley" ditch had a right of diversion from the river at a point now occupied by the Gage Canal, and from that point the water from the river was carried in a ditch to the land south and below the flow of the canal as now constructed. This right was transferred to the Gage Canal by an agreement entered into between the owners of the Hunt & Cooley ditch and Mr. M. Gage, whereby the latter agreed to supply the above ditch with 130 inches



MAP OF THE IRRIGATION SYSTEM OF THE RIVERSIDE TRUST COMPANY, LIMITED, CALIFORNIA.

FIG. 1.—HEAD OF GAGE CANAL, CALIFORNIA.

FIG. 2.—DIVISION BULKHEAD OF GAGE CANAL, CALIFORNIA.

ARTESIAN WELLS, HEAD OF GAGE CANAL, CALIFORNIA.

of water from other sources in lieu of its original rights of diversion from the river. The "Wells & Long" right, by appropriation, to divert water from the river, and the "Spring," or "Parish ditch" right to water rising on lands now forming part of the water sources of the Gage Canal are the two remaining claims on which the Gage system bases its right to divert water for irrigation.

The right of an owner to use the water developed by means of artesian wells excavated on his own property has been, so far, undisturbed.

THE GAGE CANAL.

The Gage Canal was constructed in two divisions, the first extending to the Terquisquite arroyo, a distance of 11.9 miles from the headgates, and the second division, built sometime later, extending to the terminal point previously mentioned, a distance of 8.26 miles from said arroyo.

The capacity of the canal for about 6 miles from the head is on the average 4,500 inches; for the remaining part of the first section the average is 3,500 inches, and the second section has an average capacity of 3,000 inches. The cross-sectional dimensions vary only in bottom width—that is, from a width of 10 feet to that of 5 feet; the other dimensions—a depth of 4 feet, with slope of banks 4 feet perpendicular and 3 feet horizontal—remaining the same throughout, while the grade is, in general, for the total length, 2.5 feet per mile.

Up to the present time about 15 miles of canal have been coated with a ¾-inch thickness of cement. Along the line of the canal, where its course crosses the natural depressions, there have been constructed thirteen flumes, the total length being 4,170 feet, the longest being 1,100 feet, with a height of 65 feet; also fourteen tunnels, which, where driven through soft earth, soft sandstone, or cemented sand, were lined on the bottom and on the sides as high as 4.5 feet, with an average thickness of concrete of 6 inches, giving a waterway 6 feet in width, the top being kept in place by a timbered arch. The tunnels in rock are 6.5 feet in width and 6.5 feet in height to center of arch. The aggregate length of these tunnels is 6,178 feet, the longest being 2,320 feet, and the shortest 110 feet. Heavy fills were used, instead of flumes, in four cases, to bridge arroyos, averaging about 6,000 cubic yards of earth each. In every case, in fills, the channel of the canal was lined with cemented masonry to the thickness of 6 inches. Masonry culverts have been constructed through said fills for the purpose of discharging the storm waters drained by these arroyos from the neighboring hills. That these storm waters may be utilized, the discharge through the culverts is regulated by means of gates, retaining just the amount of water that the fills can safely control and permitting the remainder to pass through. This is also accomplished by the use of an L-shaped culvert, the perpendicular shaft being built on the upper side of the fill and up to the height necessary to control a certain depth of water, any surplus being discharged into it and then on through the horizontal culvert.

The remaining portions of the canal were constructed through surfaces which offered no special difficulties in carrying on the work.

NATURE OF IRRIGABLE LANDS.

Starting from an average elevation of 1,005 feet above sea level, on line of canal, the slope of the irrigable lands below the flow of the canal is generally on a grade of 100 feet to the mile, and in most cases requires little or no grading before planting. Where arroyos intersect the plains the sides, or bluffs, are generally made capable of cultivation by means of a system of terracing. The land above the canal is not of the same general evenness, but it can be prepared without much difficulty for planting.

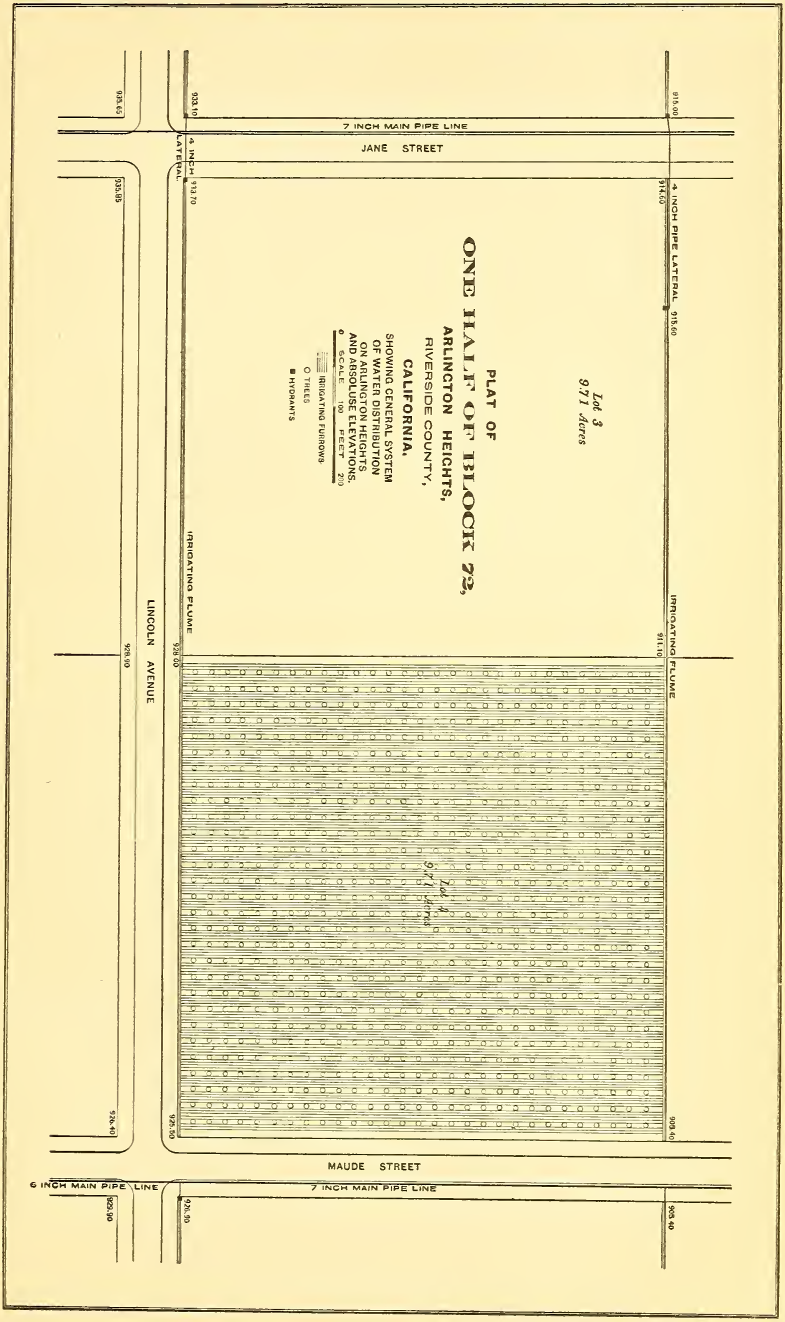
The soil of the above lands is of granite origin, varying from a light loam on the higher levels to a medium adobe on the lower, and concerning all of said soils it has been determined, both by experiment and analysis, that they contain the necessary elements for the production of citrus fruits.

SYSTEM OF DISTRIBUTION.

On the line of canal at points where it is intersected by streets, usually at intervals of one-fourth of a mile, masonry bulkheads (Pl. XXXVI, fig. 2) are built for the diversion and measurement of the water into the different main pipe lines laid in the streets. The diversion of the water is effected by means of bulkhead boards inserted across the flow of water in the canal, and kept in place by grooves in the masonry of the bulkhead. The water, being thus obstructed, passes from the canal through a pipe into the bottom of a measuring box, situated in said bulkhead, and then up over a weir, thus registering the total amount of water used for irrigation of the lands depending on that particular pipe for their supply.

At distances of about 650 feet, lateral pipe lines are inserted into the mains (these points being opposite the upper line of each subdivision fronting the street), and from thence are carried to the highest point of each subdivision, except where more than one subdivision can be conveniently irrigated from one hydrant. At the end of each lateral a hydrant and measuring box are attached, and the amount of water used for the irrigation of each parcel of land is measured as it discharges into the flume over a weir built in the measuring box for that purpose.

The system may be better understood from the accompanying map (Pl. XXXVIII) of block 72, Arlington Heights, showing the acreage



PLAT SHOWING SYSTEM OF WATER DISTRIBUTION UNDER GAGE CANAL, CALIFORNIA.

and elevation of lots, water distribution, and system of irrigation. The lands of Arlington Heights, generally, are subdivided into about 40-acre blocks by streets and avenues; and said blocks are resubdivided into lots of about 10 acres each. The width of streets and avenues, with one exception, is 80 feet. Victoria avenue, which runs throughout the whole length of the tract, is 120 feet wide, divided into two roadways. All roadbeds are 33 feet wide, and the remainder of width, in each case, is devoted to sidewalks and margins for shade trees. The acreage indicated on maps is strictly exclusive of streets and avenues, hence a purchaser of these lands pays only for the acreage within the boundaries of the lots proper, as indicated on map. On each street there is a main pipe line of riveted sheet steel, leading from the canal, and from which are taken lateral pipes of the same material to the highest point in each lot, or where two lots are in one ownership, as in this case, the distribution of water is made from one point only. These lateral pipes terminate at hydrant boxes situated at the highest point in the upper line of each lot or lots, and in said hydrant box is fixed a "low down" shut-off valve to control the discharge of water. In the side of each hydrant box is fixed a measuring weir 10 inches wide, and of sufficient height to measure at least 40 inches of water passing from hydrant box to "flume." There is placed along the upper line of each lot or lots a line of "distributing flumes" from which, at intervals of about 3.5 feet, the water is discharged into furrows made in the soil for the purpose of irrigation. The trees are planted at intervals of about 21 feet in both directions, and between each row of trees there are five furrows indicated as terminating at "flume," which furrows receive the finely subdivided water discharged from small controllable gates in the flume. As a matter of fact the number of furrows varies from three to six, depending on the age of trees. The elevation above sea level is indicated at the corner of each lot, and from this the direction of the flow of water from hydrants can be inferred. All the lots indicated on accompanying map are now planted, and assumed to be represented on map as indicated on lot 4. (Pl. XXXVIII.)

In the further distribution of the water to the lands there are two systems of irrigation employed. The basin system has been used to some extent in the planting and irrigation of young trees. This is done by forming basins around the roots of the young trees and then filling the basins with water at regular intervals of time during the first year after planting. It has been found that only one-twentieth part of the water is used in this system that is used by the furrow system under the same conditions.

The furrow system (Pl. XXXIX) is the more common method, by means of which all parts of the soil are irrigated, which is absolutely necessary when the trees reach maturity and are in full bearing. To carry out this latter system a flume leading from the hydrant box is carried across the lot just within its upper boundary line and parallel to it, and into the said flume the water from the hydrant is discharged. These flumes are usually made of redwood, but the cement flume is largely superseding the wood. The size varies with the grade and amount of water to be used, and ranges from 8 to 12 inches in width, and from 6 to 10 inches in depth. In the side of the flume from which the water is to be discharged 1-inch holes are bored at intervals of from 2 to 3 feet. Furrows are made in the soil by means of a marker or shovel plow, from two to six between the tree rows down to the lower end of the lot. The amount of water discharged into the furrows is regulated by small gates placed at the outlets in the flume. When the stream of water reaches the lower end it is regulated so as to prevent waste, and is kept thus till the expiration of the time allowed the irrigator.

The opinions of irrigators are various with reference to the duty of water, the variations extending from a duty of 1 inch to 3 acres to a duty of 1 inch to 10 acres. The duty of water for lands under the Gage Canal system is considered to be properly placed at 1 inch to 5 acres, 1 miner's inch being equivalent to one-fiftieth of a cubic foot per second, and equal to a precipitation of rain of nearly 3 inches per month.

The owner of a 10-acre ranch has a water right of 2 inches continuous flow on the basis of the duty of water above mentioned, but as it would be impossible to irrigate with that amount "in continuous flow" his allowance is permitted to accumulate, and at the end of varying periods he receives the equivalent of his water right at such times as he for himself determines, but subject to the by-laws of the Gage Canal Company, which provide "that the users of water must give four days' notice of their desire for a supply of water and to accept the same on any day or days that the company may be able to arrange for the supply thereof."

In the same article it is provided that thirty days is the limit beyond which water can not be accumulated, but this has been amended to read "forty-five days," as some irrigators prefer a longer interval between irrigations—one user applying water to his land three times only during the irrigation season. Whatever interval of time between irrigations may be adopted by the user it is understood that he will have delivered to him his full equivalent amount of water due at the time the service is given him, so that the same amount of water in any case is discharged onto the land during the season.

THE GAGE CANAL COMPANY.

In order that all the users of water under the Gage system of canals might be represented under one organization, so far as their interests in the water for irrigation were concerned, it was determined to incorporate under the State laws the Gage Canal Company.

This company is incorporated for no other purpose than to manage the affairs of its stockholders, and such affairs are confined solely to the maintenance of the general water supply and the distribution and delivery of it onto the lands of the shareholders. It is further provided that neither profit nor loss can arise to the shareholders, as such, from the operations of the company, as all disbursements for the maintenance of the above-described works and services are provided for by an annual assessment on the shareholders in the ratio of shares held by each, and for such sums only as are required to meet their obligations in the above behalf.

The constitution of the company provides for the election of a board of directors by the shareholders, the voting power depending on the number of shares held and each share representing one-tenth of an inch of water.

The board of directors elect a president, secretary-treasurer, and zanjero—the two latter being the executive officers of the company. The zanjero has full and undisputed charge of the water distribution, and no water can be run onto the lands of any stockholder until the discharge hydrant is opened by the zanjero or one of his agents. This system of noninterference by the users of water was adopted from the first, and being universal in its application it has worked with great satisfaction.

The stock of the company consists at present of ten thousand shares, representing 1,000 miner's inches of water. This amount of water was developed and owned by the Riverside Trust Company, Limited, and by it transferred to the canal company, water stock being taken in payment.

The Riverside Trust Company, Limited, to whom Mr. M. Gage transferred all his interests in the above-described estate, was originally, so far as the Gage Canal Company is concerned, the owner of the land and water. In transferring the water to the canal company and taking water stock in lieu thereof, the trust company is required to issue to each purchaser of its lands such number of shares as represents the water to which the lands are entitled on the basis of 1 inch to 5 acres.

The contracts entered into by the purchasers of land under said system provide explicitly that the water once attached to a particular piece of land becomes appurtenant thereto, and can not be transferred to other lands.

In connection with the routine work of the canal company's office there are certain forms and records which are used to facilitate the work and to keep the record of its working. Among these is a blank form of "water order" which is given to each user of water, and which he fills up and serves upon the zanjero at the company's office. The following is a blank "water order:"

Water order.] Riverside, Cal., ——, 189—.

THE GAGE CANAL COMPANY.

Please deliver —— inches of water for use on lots —— block —— commencing on the morning of —— the —— day of ——, 189— for —— days.

Signature —— ——.

The company will not undertake to deliver water unless this form, properly filled up and signed, is left at its Camp Arlington office, at least four (4) days before the water is required. Water will be delivered to shareholders in accordance with Section II of Article IX of the company's by-laws, each order having precedence according to the date of its delivery at the company's office as above.

N. B.—Anyone found tampering with the hydrants, measuring boxes, or any of the company's property will be prosecuted under sections 499, 592, 625, of the penal code.

In the same office is kept a "water book" in which is entered daily the total flow of water and the particular lands to which it is distributed. From such a record a complete history of the water service from day to day and from year to year can be determined.

SPECIAL INVESTIGATIONS IN 1899.

For the purpose of more accurately determining the amount of water used in the irrigation of lands under the Gage Canal system during the year 1899, the total area was divided into three districts. (See Map, Pl. XXXV. p. 132). These districts lie one below the other along the course of the canal. Measuring weirs have been placed at the upper boundaries of the districts, to determine the flow of the canal at those points. All the water passes weir No. 1. What water is not used in district No. 1 passes weir No. 2, and that left after district No. 2 has been supplied flows through weir No. 3 to district No. 3.

These lands require a practically constant supply of moisture throughout the year, except that in winter evaporation from the ground and trees is less. When this moisture is not supplied by rainfall it must be supplied by irrigation, so that the canal is in operation throughout the entire year. The crop year for citrus fruits does not coincide with the calendar year, but may be considered to extend from October to October, for which period the measurements are given.

All measurements made under the Gage Canal are in miner's inches, 50 inches being considered equal to 1 cubic foot per second. The daily records are given in miner's inches continuous flow for twenty-four hours, as this unit is used almost exclusively in California.

The rainfall for the period from October 1, 1898, to September 30, 1899, was as follows:

Rainfall as measured at Camp Arlington, from October 1, 1898, to September 30, 1899.[1]

Month.	Rainfall.	Month.	Rainfall.
1898.	*Inches.*	1899.	*Inches.*
November 20	0.01	March 9	0.03
		March 16	.19
December 9	.96	March 17	.31
December 15	.42	March 20	.31
		March 21	.03
	1.38	March 28	.03
1899.			.90
January 2	.38		
January 3	.07	May 6	.03
January 8	.14	May 7	.10
January 10	1.02		
January 11	.33		.13
January 12	.15		
		June 1	.24
	2.09	June 2	.04
		June 3	.02
February 1	.16		
February 2	.60		.30
February 5	.02		
February 24	.11	Total rainfall	5.70
	.89		

[1] There was no rainfall from June 4 to October 6, 1899.

DISTRICT NO. 1.

District No. 1 includes the lands known as the East Riverside Devel opment, and extends from the north boundary of T. 2 S., R. 4 W., San Bernardino meridian, at a distance of 5.68 miles from the head gates to the Terquisquite arroyo, or No. 9 flume, a distance of 11.90 miles from the headgates, and contains 3,595 acres now under irriga tion, all planted to citrus fruits. The planting in this district commenced in the year 1887, and from year to year additional planting has been done up to the year 1896. The following tables show the water used in this district from October 1. 1898. to September 30. 1899:

Water used daily on lands in district No. 1 under Gage Canal, October 1, 1898, to September 30, 1899.

[See diagram, Pl. VII, p. 74. Measurements in miner's inches.]

Day.	October, 1898.	November, 1898.	December, 1898.	January, 1899.	February, 1899.	March, 1899.	April, 1899.	May, 1899.	June, 1899.	July, 1899.	August, 1899.	September, 1899.
1	671	408	406	636	96	750	224	700	652	730	696	687
2	655	477	406	[1] 212	([1])	791	431	660	626	701	728	747
3	660	583	368	304	66	699	443	737	628	716	724	745
4	636	550	172	217	124	717	591	698	692	748	716	720
5	645	574	209	293	164	672	704	748	700	728	701	703
6	655	550	212	319	234	688	776	734	676	726	705	710
7	655	513	199	404	363	722	682	771	706	754	710	716
8	650	357	286	337	315	698	768	722	727	770	739	714
9	566	486	130	342	320	701	736	728	747	730	709	712
10	609	576	218	270	242	682	732	711	775	714	694	690

Water used daily on lands in district No. 1 under Gage Canal, October 1, 1898, to September 30, 1899—Continued.

[See diagram, Pl. VII, p. 74. Measurements in miner's inches.]

Day.	October, 1898.	November, 1898.	December, 1898.	January, 1899.	February, 1899.	March, 1899.	April, 1899.	May, 1899.	June, 1899.	July, 1899.	August, 1899.	September, 1899.
11	593	676	300	([1])	290	698	790	697	722	734	662	696
12	582	634	521	65	505	713	679	740	731	737	644	687
13	584	564	487	280	417	778	701	652	717	717	639	704
14	565	591	488	58	324	768	692	717	721	738	677	699
15	550	594	([1])	102	513	739	745	727	737	738	744	710
16	511	566	246	81	597	678	741	683	747	691	751	713
17	579	649	59	737	746	713	815	742	756	731	743	700
18	602	644	70	44	742	675	791	716	783	739	749	684
19	561	613	230	69	646	576	775	704	744	738	775	705
20	541	451	293	32	691	463	778	648	739	718	743	695
21	598	542	268	36	799	666	752	670	739	691	724	702
22	522	559	218	204	788	567	783	682	746	750	706	691
23	435	530	366	150	846	484	748	758	708	697	688	682
24	441	503	386	131	781	399	762	718	766	774	703	674
25	481	414	359	83	771	80	817	683	752	759	687	654
26	524	358	260	180	660	([2])	736	725	790	727	670	718
27	484	432	389	173	713	....	773	747	750	716	664	732
28	634	442	410	154	788	....	788	784	686	704	695	663
29	644	553	541	139	....	....	733	755	760	690	658	643
30	422	436	590	180	....	....	690	697	779	715	653	642
31	461	....	575	275	....	316	....	692	....	693	640	....
Total	17,716	15,825	9,662	6,507	13,541	16,433	21,176	22,146	21,802	22,514	21,737	20,938
Acre-feet	702.78	627.77	383.29	258.13	537.16	651.89	840.04	878.52	864.87	893.12	862.29	830.60

[1] Rain. [2] Water out for repairs.

Duty of water in district No. 1 under Gage Canal, 1898 and 1899.

Month.	Area.	Water used.		Depth.	Area per miner's inch.[1]
	Acres.	*Miner's inches.*	*Acre-feet.*	*Feet.*	*Acres.*
1898.					
October	3,595	17,716	702.78	0.1955	....
November	3,595	15,825	627.77	.1746	....
December	3,595	9,662	383.29	.1066	....
1899.					
January	3,595	6,507	258.13	.0718	....
February	3,595	13,541	537.16	.1494	....
March	3,595	16,433	651.89	.1813	....
April	3,595	21,176	840.04	.2337	....
May	3,595	22,146	878.52	.2444	....
June	3,595	21,802	864.87	.2405	....
July	3,595	22,514	893.12	.2491	....
August	3,595	21,737	862.29	.2399	....
September	3,595	20,938	830.60	.2310	....
Total irrigation	3,595	209,997	8,330.46	2.3178	6.25
Rainfall	....	....	....	.475	....
Total water received during year	....	....	....	2.7928	....

[1] Continuous flow for the year.

DISTRICT NO. 2.

District No. 2 includes all the lands of Arlington Heights and some adjacent territory, extending from the Terquisquite arroyo to the end of the canal, a distance of 20.16 miles from the headgates, and contains 2,871 acres now under irrigation.

Some of the land in this district lies above the flow of the canal. About 150 acres of these lands have been planted to citrus fruit trees, and as the higher planted boundary of said lands is at an elevation of 100 feet above the canal, and the supply of water needed for their cultivation is taken from the canal, a pumping company has been organized for the purpose of distributing the water to these higher levels. The users of water on these lands are related, in the first instance, to the Gage Canal in every respect as those using water on lands below the canal, but in addition they have to pay the cost of pumping in the ratio of the shares they hold in the Gage Canal Company.

In order to form correct estimates of results it will be necessary to give details of the time of planting of the portions of district No. 2 which are under our immediate care, and the particulars of which we have in our own keeping. These particulars, however, with reference to a part will serve fairly well to form estimates of the whole.

It will be kept in view that the orange or lemon tree can hardly be said to yield fruit until after the third year from time of planting in orchard form, and that the yearly increase in product continues at least to the fifteenth year.

The following are the times of planting of said portions of district No. 2:

Date of planting trees in district No. 2.

	Acres.		Acres.
1891	690.10	1896	14.31
1892	130.04	1897	58.86
1893	667.57	1898	16.66
1894	79.80		
1895	10.00	Total	1,666.84

The total product from the 1,666.84 acres above tabulated can not be given for this present year, but is estimated as follows:

	Packed boxes.
Oranges, all varieties	174,813
Lemons, all varieties	46,173
Total	220,986

The remaining acreage in district No. 2, amounting to 1,205 acres, excepting 120 acres planted between 1896 and the present year, were planted in the year 1891, and will exceed in average product the acreage above shown. The water used upon the above acreage is shown in the following table:

Water used daily on lands in district No. 2 under Gage Canal, October 1, 1898, to September 30, 1899.

[See diagram, Pl. VIII, p. 74. Measurements in miner's inches.]

Day.	October, 1898.	November, 1898.	December, 1898.	January, 1899.	February, 1899.	March, 1899.	April, 1899.	May, 1899.	June, 1899.	July, 1899.	August, 1899.	September, 1899.
1	499	730	522	550	350	412	383	556	592	438	432	493
2	510	685	510	172	([1])	400	300	586	601	459	451	453
3	520	553	517	([1])	75	537	485	501	589	508	434	430
4	520	597	540	375	125	535	520	533	543	482	447	451
5	516	573	455	375	150	595	514	490	538	463	442	451
6	506	555	560	380	200	555	515	513	549	436	436	441
7	501	630	560	360	200	510	551	517	520	399	448	409
8	493	600	510	435	175	530	485	562	496	382	410	450
9	580	560	200	430	175	532	507	507	473	440	445	453
10	544	610	([1])	([1])	200	502	530	533	445	433	448	480
11	557	505	220	([1])	200	515	541	569	514	430	474	488
12	574	549	300	([1])	170	515	569	532	487	446	511	452
13	577	573	350	([1])	200	470	596	612	487	470	498	443
14	591	595	400	100	225	455	570	559	482	445	496	438
15	605	587	([1])	100	225	515	562	531	455	434	434	445
16	660	576	([1])	65	240	540	585	548	440	481	418	433
17	579	517	265	115	230	490	502	515	433	461	457	448
18	523	540	260	165	250	515	545	544	434	465	463	460
19	586	595	220	140	275	585	537	539	434	449	473	439
20	615	602	355	140	275	675	509	592	441	480	490	471
21	581	608	380	190	260	500	490	569	437	480	527	471
22	610	610	425	190	350	425	475	595	427	423	496	435
23	716	582	400	165	350	517	508	584	434	469	511	441
24	725	510	475	195	376	487	492	529	405	403	488	446
25	635	560	325	225	377	519	450	489	422	428	498	491
26	622	515	380	250	412	([2])	510	489	382	458	497	449
27	667	475	440	248	420	......	460	452	421	457	511	481
28	515	531	505	250	345	......	452	468	474	452	481	503
29	512	475	530	245	......	......	553	487	402	464	503	515
30	671	520	525	275	......	......	543	526	400	436	513	517
31	690	......	575	325	......	250	......	526	......	453	525	......
Total	18,000	17,118	11,704	6,460	6,830	13,081	15,239	16,553	14,157	13,924	14,687	13,777
Acre-feet	714.05	679.06	464.29	256.26	270.94	518.92	604.52	656.65	561.60	552.36	582.62	546.53

[1] Rain. [2] Water out for repairs.

Duty of water in district No. 2 under Gage Canal, 1898 and 1899.

Month.	Area.	Water used.		Depth.	Area per miner's inch.[1]
	Acres.	Miner's inches.	Acre-feet.	Feet.	Acres.
1898.					
October	2,871	18,000	714.05	0.2487	....
November	2,871	17,118	679.06	.2369	....
December	2,871	11,704	464.29	.1617	....
1899.					
January	2,871	6,460	256.26	.0892	....
February	2,871	6,830	270.94	.0944	....
March	2,871	13,081	518.92	.1807	....
April	2,871	15,239	604.52	.2106	....
May	2,871	16,553	656.65	.2287	....
June	2,871	14,157	561.60	.1956	....
July	2,871	13,924	552.36	.1924	....
August	2,871	14,687	582.62	.2029	....
September	2,871	13,777	546.53	.1904	....
Total irrigation	2,871	161,530	6,407.80	2.2319	6.49
Rainfall	....	....	....	.475	....
Total water received during year	....	....	....	2.7069	....

[1] Continuous flow for the year.

DISTRICT NO. 3.

District No. 3 includes lands lying beyond the terminus of the Gage Canal. This territory is known as the San Jacinto estate. The water for said lands is taken from the Gage Canal and distributed by means of small cemented ditches and pipe lines at the expense of the San Jacinto Company. The total acreage now under irrigation in district No. 3 is 530 acres. The first planting was done in the year 1895, and the company has added to the planted area each year since. The water used in this district is shown by the following table:

Water used daily on lands in district No. 3 under Gage Canal, October 1, 1898, to September 30, 1899.

[See diagram, Pl. IX. p. 74. Measurements in miner's inches.]

Day.	October, 1898.	November, 1898.	December, 1898.	January, 1899.	February, 1899.	March, 1899.	April, 1899.	May, 1899.	June, 1899.	July, 1899.	August, 1899.	September, 1899.
1	80	95	90	25	......	88	......	82	108	83	74	66
2	80	65	90	20	......	50	......	92	110	91	62	65
3	80	50	90	......	......	88	90	99	111	7	73	80
4	80	75	90	......	......	90	80	92	107	20	82	98
5	80	75	90	......	......	80	80	85	109	49	93	92
6	75	70	90	......	......	70	85	81	108	89	86	80
7	80	70	90	40	......	80	85	83	107	93	78	82
8	88	70	90	40	......	85	85	78	105	94	78	77
9	95	55	(1)	40	......	75	85	93	103	85	77	85
10	88	65	(1)	......	......	85	85	94	108	99	85	85
11	86	70	80	......	......	85	75	81	106	77	76	76
12	80	68	......	......	......	85	80	80	110	73	76	77
13	85	65	......	......	......	70	75	78	109	77	75	84
14	85	65	......	......	......	75	80	71	110	81	87	89
15	95	65	......	......	......	75	65	79	106	79	87	81
16	80	80	......	35	......	90	70	82	101	79	75	90
17	93	85	20	35	......	85	50	85	94	64	93	78
18	97	85	20	35	......	85	40	68	96	47	86	92
19	70	80	20	35	......	90	45	85	96	64	85	87
20	80	90	20	35	......	......	55	98	94	53	65	65
21	80	90	20	35	......	......	57	103	88	75	80	63
22	95	90	25	35	......	......	70	65	86	82	87	100
23	95	90	25	35	50	......	82	......	94	89	99	89
24	85	90	25	25	84	......	74	51	93	82	92	92
25	80	90	25	25	88	......	75	88	95	68	89	95
26	95	85	20	25	88	......	96	108	95	66	98	88
27	90	85	25	27	80	......	100	109	70	73	94	76
28	82	90	25	25	80	......	98	85	91	85	94	84
29	85	90	20	25	......	......	85	90	93	82	90	92
30	95	80	25	......	......	......	95	104	81	71	89	91
31	100	......	25	......	......	......	......	104	......	85	81	......
Total	2,659	2,323	1,140	597	470	1,531	2,142	2,593	2,984	2,262	2,586	2,499
Acre-feet	105.48	92.15	45.22	23.68	18.64	60.73	84.97	102.86	118.37	89.73	102.59	99.13

[1] Rain.

Duty of water in district No. 3 under Gage Canal, 1898 and 1899.

Month.	Area.	Water used.		Depth.	Area per miner's inch.[1]
	Acres.	*Miner's inches.*	*Acre-feet.*	*Feet.*	*Acres.*
1898.					
October	530	2,659	105.48	0.1990	....
November	530	2,323	92.15	.1738	....
December	530	1,140	45.22	.0853	....
1899.					
January	530	597	23.68	.0447	....
February	530	470	18.64	.0352	....
March	530	1,531	60.73	.1146	....
April	530	2,142	84.97	.1603	....
May	530	2,593	102.86	.1941	....
June	530	2,984	118.37	.2233	....
July	530	2,262	89.73	.1693	....
August	530	2,586	102.59	.1936	....
September	530	2,499	99.13	.1870	....
Total irrigation	530	23,786	943.55	1.7802	8.14
Rainfall	....	....	....	.475	....
Total water received during year	....	....	....	2.2552	....

[1] Continuous flow for the year.

The following table gives the duty of water under the Gage Canal as a whole. No allowances are made in any of the tables for losses from seepage and evaporation. Seepage is practically eliminated, as most of the canal is cemented, and measurements of evaporation show a loss of only about 1 per cent, so that losses from these sources need not be considered. The duty for the whole canal is as follows:

Duty of water under Gage Canal, 1898 and 1899.

Month.	Area.	Water used.		Depth.	Area per miner's inch.[1]
	Acres.	*Miner's inches.*	*Acre-feet.*	*Feet.*	*Acres.*
1898.					
October	6,996	38,375	1,522.31	0.2176	....
November	6,996	35,266	1,398.98	.2000	....
December	6,996	22,506	892.80	.1276	....
1899.					
January	6,996	13,564	538.08	.0769	....
February	6,996	20,841	826.75	.1182	....
March	6,996	31,045	1,231.54	.1760	....
April	6,996	38,557	1,529.53	.2186	....
May	6,996	41,292	1,638.03	.2341	....
June	6,996	38,943	1,544.85	.2208	....
July	6,996	38,700	1,535.21	.2194	....
August	6,996	39,010	1,547.50	.2212	....
September	6,996	37,214	1,476.26	.2110	....
Total irrigation	6,996	395,313	15,681.84	2.2414	6.46
Rainfall	....	....	....	.475	....
Total water received	....	....	....	2.7164	....

[1] Continuous flow for the year.

The preceding tables show the averages for the several districts and for the canal as a whole. There are wide differences in the practices of individuals, which are brought out in the tables which follow. These tables, in addition to showing the quantities of water used, illustrate the system used in delivering water (see page 134), and show the periods between irrigations and the quantities used at each irrigation.

Water used by N. P. Cayley on lots 3 and 4, block 72, October 1, 1898, to September 30, 1899.

[See map, Pl. XXXVIII, p. 134.]

Ordered.					Received.		
Date.	Amount.	Time for which ordered.		Place.	Date.	Amount.	Remarks.
		Date.	No. of days.				
	Miner's inches.					*Miner's inches.*	
Oct. 12, 1898	30	Oct. 15–17	2	Lot 3	Oct. 16–19	120	30 inches for 4 days.
Oct. 12, 1898	20	Oct. 17–20	3	Lot 4			
Nov. 11, 1898	30	Nov. 12–16	4	Lots 3 and 4	Nov. 12	35	
					Nov. 13–15	90	30 inches for 3 days.
Feb. 3, 1899	30	Feb. 8–12	4	Lots 3 and 4	Feb. 8, 9	60	30 inches for 2 days.
					Feb. 10	25	
					Feb. 11	30	
Mar. 4, 1899	20	Mar. 4–7	3	Lot 3	Mar. 9–12	80	20 inches for 4 days.
Mar. 10, 1899	20	Mar. 11–14	3	Lot 4	Mar. 19–21	60	20 inches for 3 days.
Apr. 16, 1899	30	Apr. 21–25	4	Lots 3 and 4	Apr. 23–26	120	30 inches for 4 days.
May 8, 1899	30	May 23–27	4	Lots 3 and 4	May 22–25	120	Do.
June 19, 1899	30	June 23–27	4		July 2–6	150	30 inches for 5 days.
Aug. 26, 1899	30	Sept. 1–5	4		Sept. 8–10	84	28 inches for 3 days.
					Sept. 11	25	
Total						999	

Summary.

Area irrigated	acres	20.00
Water used	acre-feet	39.63
Depth of irrigation	feet	1.98
Depth of rainfall	do	.47
Total depth of water received by land	do	2.45

Water used by J. D. Carscaden on lot 2, block 39, October 1, 1898, to September 30, 1899.

Ordered.				Received.		
Date.	Amount.	Time for which ordered.		Date.	Amount.	Remarks.
		Date.	No. of days.			
	Miner's inches.				*Miner's inches.*	
Nov. 17, 1898	20	Nov. 22–25	3	Nov. 22–24	60	20 inches for 3 days.
Apr. 27, 1899	20	May 3–6	3	May 3–5	60	Do.
				May 6	15	
July 10, 1899	20	July 17–20	3	July 17	17	
				July 18, 19	40	20 inches for 2 days.
				July 20	25	
				July 21	10	
Sept. 11, 1899	20	Sept. 18–21	3	Sept. 18	25	
				Sept. 19	30	
				Sept. 20	20	
Total					302	

Summary.

Area irrigated	acres..	10.00
Water used	acre-feet..	11.98
Depth of irrigation	feet..	1.20
Depth of rainfall	do...	.47
Total depth of water received by land	do...	1.67

Water used by Gulick Brothers on block 64, October 1, 1898, to September 30, 1899.

Ordered.				Received.		
Date.	Amount.	Time for which ordered. Date.	Time for which ordered. No. of days.	Date.	Amount.	Remarks.
	Miner's inches.				*Miner's inches.*	
				Oct. 1	20	
				Oct. 2	25	
				Oct. 3–6	120	30 inches for 4 days.
				Oct. 7	40	
Sept. 29, 1898	30	Oct. 3–13	10	Oct. 8	45	
				Oct. 9–11	90	30 inches for 3 days.
				Oct. 12, 13	30	15 inches for 2 days.
				Oct. 14, 15	40	20 inches for 2 days.
				Oct. 16	15	
				Nov. 1	22	
				Nov. 2, 3	50	25 inches for 2 days.
Oct. 31, 1898	30	Nov. 3–13	10	Nov. 4–10	210	30 inches for 7 days.
				Nov. 11	15	
				Nov. 12	20	
				Nov. 13	10	
				Dec. 27–31	150	30 inches for 5 days.
Dec. 10, 1898	30	Dec. 14–24	10	Jan. 1–5, 1899	120	30 inches for 4 days.
				Jan. 6–8	60	20 inches for 3 days.
				Jan. 9	15	
Feb. 22, 1899	30	Feb. 25–Mar. 7	10	Feb. 25–Mar. 7	330	30 inches for 11 days.
				Mar. 8, 9	20	10 inches for 2 days.
Apr. 8, 1899	30	Apr. 13–23	10	Apr. 13–23	330	30 inches for 11 days.
				Apr. 24–26	45	15 inches for 3 days.
				May 17–23	210	30 inches for 7 days.
May 12, 1899	30	May 17–27	10	May 26–31	150	30 inches for 5 days.
				June 3, 4	20	10 inches for 2 days.
				June 19, 20	60	30 inches for 2 days.
				June 21, 22	50	25 inches for 2 days.
				June 23	27	
June 12, 1899	30	June 19–29	10	June 27	30	
				June 28, 29	50	Do.
				June 30	22	
				July 1	22	
				July 6, 7	20	10 inches for 2 days.
				July 25–31	210	30 inches for 7 days.
July 10, 1899	30	July 17–27	10	Aug. 3, 4	60	30 inches for 2 days.
				Aug. 5, 6	20	10 inches for 2 days.
				Aug. 28–31	120	30 inches for 4 days.
Aug. 18, 1899	30	Aug. 24–Sept. 3	....	Sept. 1–6	180	30 inches for 6 days.
				Sept. 10	10	
Total	....	....	....	....	3,083	

Summary.

Area irrigated	acres..	51.30
Water used	acre-feet..	122.30
Depth of irrigation	feet..	2.38
Depth of rainfall	do...	.47
Total depth of water received by land	do...	2.85

Water used by C. C. Quinn on lot 4, block 73, October 1, 1898, to September 30, 1899.

Ordered.				Received.		
Date.	Amount.	Time for which ordered.		Date.	Amount.	Remarks.
		Date.	No. of days.			
	Miner's inches.				*Miner's inches.*	
No order				Oct. 13–15	60	20 inches for 3 days.
Nov. 2, 1898	20	Nov. 14–17	3	Nov. 14–16	60	Do.
Dec. 10, 1898	20	Dec. 14–17	3			Rain on the 14th.
Feb. 16, 1899	20	Feb. 22–25	3	Mar. 6, 7	20	10 inches for 2 days.
Apr. 9, 1899	20	Apr. 12–15	3	Apr. 13–15	60	20 inches for 3 days.
May 7, 1899	20	May 13–16	3	May 13–15	60	Do.
June 7, 1899	20	June 13–16	3	June 17–19	60	Do.
July 12, 1899	20	July 17–20	3	July 22–24	60	Do.
No order				Aug. 27–29	60	Do.
Sept. 18, 1899	20	Sept. 27–30	3	Sept. 30–Oct. 2	60	Do.
Total					500	

Summary.

Area irrigated	acres	10.00
Water used	acre-feet	19.83
Depth of irrigation	feet	1.98
Depth of rainfall	do	.47
Total depth of water received by land	do	2.45

Water used by C. E. Kennedy on block 82, October 1, 1898, to September 30, 1899.

Ordered.				Received.		
Date.	Amount.	Time for which ordered.		Date.	Amount.	Remarks.
		Date.	No. of days.			
	Miner's inches.				*Miner's inches.*	
Oct. 4, 1898	35	Oct. 10–13	3	Oct. 7–10	120	30 inches for 4 days.
Nov. 11, 1898	21	Nov. 14–19	5	Nov. 15–20	120	20 inches for 6 days.
Jan. 6, 1899	21	Jan. 9–14	5	Jan. 7–9	60	20 inches for 3 days. Rain.
Feb. 14, 1899	35	Feb. 17–20	3	Feb. 17–21	200	40 inches for 5 days.
Apr. 13, 1899	35	Apr. 17–20	3	Apr. 26–28	105	35 inches for 3 days.
May 25, 1899	35	May 31–June 3	3	June 3–5	105	Do.
June 27, 1899	35	July 7–10	3	July 9–10. July 11	70 25	35 inches for 2 days.
No order				Aug. 20–23 Aug. 24	140 15	35 inches for 4 days.
Sept. 25, 1899	35	Sept. 26–29	3	Sept. 26–28	105	35 inches for 3 days.
Total					1,065	

Summary.

Area irrigated	acres	17.00
Water used	acre-feet	42.28
Depth of irrigation	feet	2.48
Depth of rainfall	do	.47
Total depth of water received by land	do	2.95

The preceding tables afford a good illustration of the workings of the system of delivering water to irrigators as demanded. The tables showing the use of water by individuals show that as a rule they received water at the time for which it was ordered; and the tables for the three districts show that, taken as a whole, a fairly uniform flow was required to supply these demands, showing that such a system of delivery can be carried out on a canal depending on the natural flow of streams or wells, and without storage facilities.

As was said, the duty assumed in the contracts of the Gage Canal Company is 1 inch to 5 acres. This would allow for the use of water to a depth of 0.24 foot per month, or 2.89 feet for the year, if the water was used constantly, but there is in practice a great falling off in the use during the rainy season. The measurements for this year show an average depth of 2.24 feet for the whole canal. In no month has the water used come up to the assumed duty, but the greater part of the shortage occurred in the months of greatest rainfall. The drought of the past three years has rendered economy necessary, and it is possible that irrigators have not used so much water as they would have, had a larger supply been available.

NEBRASKA.

DUTY OF WATER IN NEBRASKA.

By Special Agent O. V. P. Stout,
Professor of Civil Engineering, University of Nebraska.

GAGINGS OF THE NORTH PLATTE RIVER.

Gaging stations have been maintained for several years by the United States Geological Survey at Gering and at Camp Clarke on the North Platte River in Nebraska. From the records of these stations the daily mean discharge of the river at those points during the open season of each year has been estimated. In the spring of 1899 it seemed that a comparatively small amount of work in addition to that of the Geological Survey would secure results which would be of value as bearing upon the practice of irrigation under the canals which divert water from the river at points between the two gaging stations. The plan was to obtain the area of land irrigated by water diverted between these two stations and to obtain from the discharge records of the river the approximate quantity of water used on this land. The work would be simplified by the total absence of surface tributaries entering on this length of the river.

Soon after the work was commenced it was arranged that the expense should be borne by the Agricultural Experiment Station of the University of Nebraska. In view of the limited sum available, it was decided that an effort should be made to secure only general results covering the considerable territory involved. It is a matter of regret that the results, in addition to being general in their nature, are uncertain in value to an extent greater than was anticipated when the work was undertaken.

With a view to securing increased precision in the records of the discharge of the river, it was determined that the number of measurements of discharge should be increased by about 25 per cent. This has been done, and, although certain peculiarities to which attention will be invited appear in the report, there is no reason to suspect that the results have been less accurate than the best which can be obtained in streams whose beds are of the shifting, changeable character of the North Platte.

The following table gives the discharge of the river at the two gaging stations:

Discharge of North Platte River at gaging stations in Nebraska in 1899.

Date.	Mean discharge.		Gering in excess of Camp Clarke.	Camp Clarke in excess of Gering.
	Gering.	Camp Clarke.		
	Cubic feet per second.	*Cubic feet per second.*	*Acre-feet.*	*Acre-feet.*
April 11-20	9,228	7,735	29,700	....
April 21-30	9,689	7,782	37,820	....
May 1-10	8,020	6,505	30,050	....
May 11-20	9,412	8,902	10,110	....
May 21-31	11,344	14,900	....	77,600
June 1-10	12,065	14,119	....	40,730
June 11-20	15,706	14,423	25,440	....
June 21-30	20,304	20,911	....	12,030
July 1-10	15,543	19,236	....	73,260
July 11-20	11,081	11,839	....	15,030
July 21-31	6,287	6,110	3,860	....
August 1-10	4,199	3,974	4,470	....
August 11-20	2,895	2,977	....	1,625
August 21-31	1,904	1,668	5,140	....
September 1-10	995	909	1,706	....
September 11-20	718	995	....	5,496
September 21-30	808	1,323	....	10,215
October 1-10	893	1,264	....	7,359
October 11-20	1,366	1,471	....	2,082

Crops irrigated in 1899 by diversion between Gering, Nebr., and Camp Clarke, Nebr.

Name of canal.	Corn.	Alfalfa.	Oats.	Wheat.	Hay.	Garden.	Barley.	Trees.	Millet.	Total.
	Acres.	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*
Minatare	222	339	287	294	3,297	48	20	35	......	4,542
Steamboat	35	260	15	10	......	......	......	......	......	320
Castle Rock	507	964	264	401	1,280	36	15	20	......	3,487
Nine Mile, or Bayard	253	302.5	116	253	2,216	32	9	......	9	3,190.5
Short Line	67	20	54	77	450	10	......	......	......	678
Chimney Rock	122	200	66	44	715	11	8	......	10	1,176
Alliance	107	210	53	49	141	7.5	......	......	0.5	568
Belmont	55	25	10	13	......	......	......	......	......	103
Total	1,368	2,320.5	865	1,141	8,099	144.5	52	55	19.5	14,064.5

NOTE.—Empire, Schermerhorn, and H. T. Clarke ditches are small, and no account was taken of the land irrigated under them.

As shown by the table of crops irrigated, the total area to which water was applied was only a little in excess of 14,000 acres. The amount by which the discharge at Gering exceeded that at Camp Clarke during the ten days from April 11 to April 20, noted in the foregoing table as 29,700 acre-feet, is enough to cover this area to a depth greater than 2 feet. The corresponding excess for the period from April 11 to May 20 is sufficient to cover the irrigated area with more than 7½ feet of water. If these figures are accepted as even approximately correct, it is clear that something other than the diversion of water for irrigation exerts a preponderating influence to cause this difference. If we undertake to allow in some way for the effect of contributions to the river from underground sources between Gering and Camp Clarke, or from the immediate run-off of storms, added emphasis will accrue to the statement which has just been made.

Examination and analysis of the discharge record at the two river stations for the balance of the season only confirm the conclusion which the facts already pointed out would justify, namely, that even general approximate conclusions respecting the quantity of water used for irrigation from a stream of the size and character of the one under discussion can be based only on direct observation of the amount of water carried in the canals.

GAGINGS OF CANALS.

Aside from the extra gagings of the river, it was proposed to secure as full data as practicable in regard to operations under the irrigation canals. To secure an estimate of the amount of water diverted into each of the several canals the following plan was relied upon:

The hydrographer was instructed to the effect that opportunity to gage canals was to be sought as he traveled up and down the river between Gering and Camp Clarke. Gage rods were set in the canals at some point above the first diversion of water, the ditch riders agreeing to make and report daily observations of the height of canal water on the rods. The adoption of this method, at best lacking in precision, presupposes a considerable number of gagings distributed throughout the season and that the records of voluntary observers will be fairly complete. Reasonable certainty attaches to the results which are submitted about in proportion as these suppositions have been found correct.

The hydrographer was depended upon to determine also, as closely as possible without actual survey, the acreage and kind of crops under each canal. He was also to endeavor to collect the information necessary to a reliable estimate of the yield of different crops and as to the effect of irrigation upon the soil, especially in regard to alkali, raising of the level of ground water, and as to whether drainage is necessary or advisable in certain cases.

MINATARE CANAL.

Taking the canals in their order downstream, the Minatare Canal is the first to be considered. This is the oldest of the canals embraced in the present discussion, having been first used in 1888.

Measurements of discharge were made as follows:

Date.	Gage.	Mean velocity.	Area of cross section.	Discharge.
	Feet.	*Feet per second.*	*Square feet.*	*Cubic feet per second.*
May 25	2.15	0.96	43.6	41.8
June 21	2.65	1.77	36.4	64.1

The fact that the less area of cross section occurs in connection with the greater discharge and height of water surface indicates that the canal has silted up considerably at the gaging section during the brief period between gagings. This is a feature which seriously impairs the value of the record of gage heights as a basis for the estimation of the amount of water which flowed in the canal during the season. The record of gage heights covers the periods from May 25 to August 8, at which latter date the canal was shut down for the season. It was also shut down from June 30 to July 16. The record lacks six days of being complete. The gage heights ranged much of the time from 2.40 to 2.70 feet, the extreme range reported being from 1.85 to 2.80 feet.

On the basis of measurements and observations which have been collected it is estimated that 6,700 acre-feet flowed in the canal during the period from May 25 to August 8. The accompanying table (p. 150) shows that this canal supplied water for 4,542 acres of crops. The duty of water as measured at the gaging section corresponds, therefore, to the depth of 1.475 feet upon the land irrigated. It is worthy of note that nearly three-fourths of the acreage irrigated under this canal was in hay.

STEAMBOAT CANAL.

A gaging of this canal on June 6 showed that it was carrying 12.53 cubic feet per second. On September 21 the hydrographer noted that there was no discharge. The record of gage heights is too brief to be of any value. There are indications that the canal was shut down during much of the season. As noted in the table (p. 150), it carried water for only 320 acres of crops, more than three-fourths of which was alfalfa.

CASTLE ROCK CANAL.

This is also one of the oldest canals in the valley. Its dimensions just below the head gate are as follows: Depth, 2½ feet; width on bottom, 20 feet; grade, 2 feet per mile. It is intended to irrigate 5,780 acres of land. Measurements of discharge were made as follows:

Date.	Gage.	Mean velocity.	Area of cross section.	Discharge.
	Feet.	*Feet per second.*	*Square feet.*	*Cubic feet per second.*
June 6	2.8	1.75	19.7	34.39
August 23	1.9	1.16	21.2	24.6
September 21	2.45	....	....	[1] 37.2

[1] By floats.

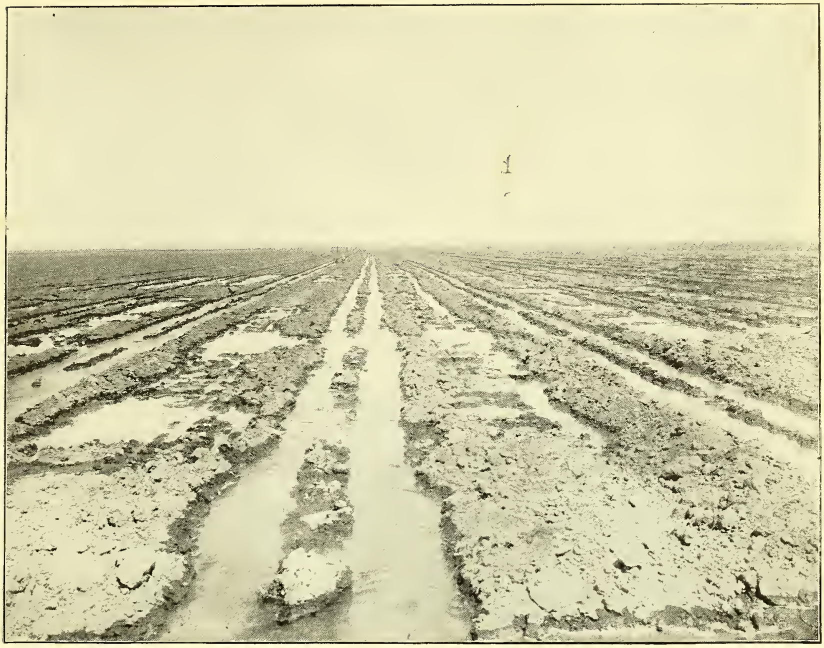


FIG. 1.—A CRUDE METHOD OF FURROW IRRIGATION.

FIG. 2.—AN IMPROVED METHOD OF FURROW IRRIGATION.

It is to be noted that in the case of the two gagings by meter the less area of cross section occurs in connection with the earlier or greater discharge, this indicating that the canal had washed out to some extent during the summer. As noted in the case of the Minatare Canal, the effect of this is to impair the value of the record of gage heights for the purposes intended. The record of gage heights was one of the most faithful which was secured. It extends from June 6 to September 21. There is no record of the canal having been shut down during that period. Taking the record of gage heights in connection with the measured discharges, it is estimated that 6,600 acre-feet of water were carried in the canal during the period of record. As this was applied to 3,487 acres of crops, it indicates a duty of water corresponding to a depth of 1.89 feet over the irrigated area. The general tendency in the variation in the use of water seems to have been in the direction of using a uniformly decreasing amount as the season advanced, the rate of use in September being about half that in June.

NINE-MILE OR BAYARD CANAL.

The following tabulation sets forth the measurements of discharge which were made:

Date.	Gage.	Mean velocity.	Area of cross section.	Discharge.
	Feet.	*Feet per second.*	*Square feet.*	*Cubic feet per second.*
May 25	1.15	0.50	18.7	9.35
July 7	2.30	1.54	60.0	92.10
August 11	No rod.			34.69

There is no indication from these gagings that there was any material change in the bed of the canal during the interval between them. The record of gage heights was begun on May 25 and does not extend beyond July 17. It is estimated that 4,090 acre-feet of water flowed in the canal during this period. Three thousand one hundred and ninety acres were irrigated. This indicates that sufficient water flowed past the gaging section to cover the irrigated land to the depth of 1.28 feet. The actual amount which flowed during the season is, of course, considerably in excess of this, since the record is incomplete, as noted. The canal at a distance of 1,000 feet below the headgate has a nominal depth of 1½ feet, is 20 feet wide on the bottom, and has a grade of 2 feet per mile.

CHIMNEY ROCK CANAL.

Gagings were made as follows:

Date.	Gage.	Mean velocity.	Area of cross section.	Discharge.
	Feet.	*Feet per second.*	*Square feet.*	*Cubic feet per second.*
West branch:				
June 7	1.95	0.79	14.6	11.5
August 22	2.40	2.49	17.2	17.2
East branch:				
June 7	.50	....	....	....
August 22	2.70	.70	....	4.48

Both of these sets of gagings show evidence of the canal being silted up at the gage to such an extent that a rating is out of the question. An estimate, however, based on these gagings and on the somewhat insufficient record of gage heights has been attempted with the following results:

About 6,000 acre-feet flowed in the canal between the dates June 7 and October 10, and was applied to 1,176 acres of crops. This would mean between 5 and 6 feet in depth of water on the area irrigated. This seems excessive, and, in view of the scantiness of the data on which it is based, can not be accepted as conclusive. The fact, however, that the period of time covered is longer than in some of the canals already discussed will account for some of the excess above the figures noted in connection with those canals.

ALLIANCE CANAL.

The hydrographer reports gagings as follows:

Date.	Gage.	Mean velocity.	Area of cross section.	Discharge.
	Feet.	*Feet per second.*	*Square feet.*	*Cubic feet per second.*
May 24	0.67	1.29	7.2	9.25
July 27	1.50	1.34	11.4	15.37
September 13	1.70	....	....	18.40

Here again it seems clear that the canal silted up to some extent during the period of record, and that a rating for direct application can not be entirely relied upon. However, it has been used, and results will be presented for later confirmation or disproof. In the case of this canal we have what would seem to be a complete and faithful record of gage heights from the beginning of the work on May 24 until August 24. From this record, in connection with the measurements of discharge, it is estimated that between the dates May 24 and October 1, 2,200 acre-feet of water passed the gaging section. Five hundred and sixty-eight acres were irrigated. This corresponds to an amount which would cover the irrigated area nearly 4 feet deep.

BELMONT CANAL.

While this is the largest canal among those under consideration, very little irrigation was attempted last year on the lands under it. Only 103 acres have been reported. Of course, an amount of water considerably in excess of that required to water this land passed down the ditch, but as the record book was lost by the observer, there is no basis for an estimate.

Empire, Schermerhorn, and H. T. Clarke are simply minor ditches, the small operations under which the hydrographer could not find it convenient to make note of.

The rainfall for the year 1899, as measured at the two gaging stations by the United States Weather Bureau observers, was as follows:

Precipitation at Gering and Camp Clarke, Nebr., 1899.

Month.	Gering.	Camp Clarke.	Month.	Gering.	Camp Clarke.
	Inches.	*Inches.*		*Inches.*	*Inches.*
January	[1] 0.80	0.80	August	2.24	2.12
February	1.04	.80	September	.19	Trace.
March	1.92	1.40	October	1.19	.74
April	.41	.53	November	.10	.30
May	7.72	2.75	December	.13	.15
June	1.77	1.53			
July	1.90	2.26	Total	19.41	13.38

[1] Record incomplete for this month.

The total precipitation for the months April to September, inclusive, at Gering was 14.23 inches. At Camp Clarke it was 9.19 inches.

The results of measurements of the canals are brought together in the following table:

Duty of water under canals from the North Platte River in Nebraska.

Canal.	Area irrigated.	Depth of water received.		
		Irrigation.	Rainfall.[1]	Total.
	Acres.	*Feet.*	*Feet.*	*Feet.*
Minatare Canal	4,542	1.475	0.98	2.455
Castle Rock Canal	3,487	1.89	.98	2.87
Nine Mile or Bayard Canal	3,190.5	1.28	.98	2.26
Chimney Rock Canal	1,176	5.10	.98	6.08
Alliance Canal	568	3.87	.98	4.85

[1] Mean of two stations from April to September, inclusive.

While it can not be claimed that the element of precision attaches to the work which has been discussed in the foregoing paragraphs, it seems that it may serve as a basis for a positive statement on one point. It has been a common custom in dealing with estimates of water supply and the duty of water in Nebraska to assume that, on the average, after the art of irrigation has been learned and the subsoil has absorbed its complement of water, a depth of 12 inches over the land, together with the rainfall, will raise a crop. It is evident that this stage of practice has not been reached under these canals.

DUTY OF WATER UNDER GOTHENBURG CANAL.

(Map, Plate XL.)

Early in the season of 1899 it was arranged as a part of the regular work of the investigation[1] that records should be kept in connection with operations under the Gothenburg Canal in Dawson County, Nebr. By means of the standard apparatus of the investigation a record was obtained of the total amount of water entering the canal from June 7 to September 30, and of the amount applied on the farm of Mr. D. W. Daggett from June 19 to September 30. The main facts of interest relating to the plant are noted in the following letter, which was written under date of October 2, 1899, by Mr. C. A. Edwards, engineer of the canal:

The Gothenburg Water Power and Irrigation Company's canal is situated in the western part of Dawson County, and crosses the one hundredth meridian about 20 miles from its head. It was partly built in 1890 and 1891 and was completed in 1895, and is now 30 miles in length, with about 40 miles of laterals. The capacity of the irrigation portion is for 14,000 acres of land; the grade is 1 foot in 5,000 feet. We have watered this season a little over 6,000 acres of land, 2,400 being small grain, 3,400 corn, and about 200 acres of alfalfa, and the remainder grain, etc.

The yield under the ditch has run from 7 to 30 bushels of wheat this season. Where the wheat was a poor crop I would say that it was damaged by the Hessian fly. The corn crop will average from 50 to 70 bushels per acre.

The amount of water delivered from the main canal is shown by the register sheets which we have sent you weekly. At Mr. Daggett's the register did not work satisfactorily, but we have missed only one week while the water was running—September 16 to 23—and the amount that week was equal to the amount from the 23d to the 30th, which we have given you in miner's inches.

Mr. Daggett had in 35 acres of winter wheat, the yield of which was 25 bushels per acre, and 25 acres of corn, the yield of which was 65 bushels per acre. This was all the crop that was watered by water running through the measuring weir.

There was one party who sowed 7 acres of buckwheat and thrashed out 154 bushels of grain, for which he received 75 cents per bushel.

Alfalfa does very well here, cutting 1½ to 2 tons at each cutting and three to four cuttings per season. Corn is the staple crop. Wheat is worth here in the market from 50 to 55 cents per bushel, and corn from 15 to 20 cents per bushel.

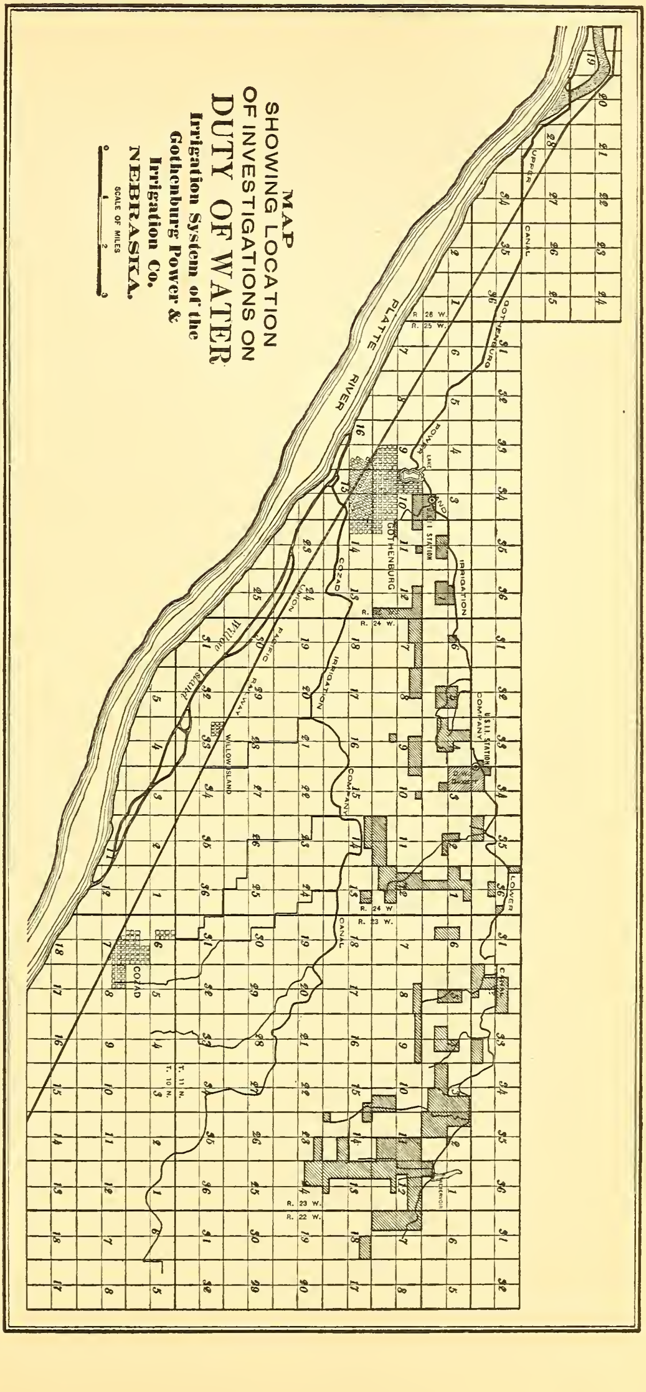
The people under our canal seem to be very well satisfied with the water furnished them. We deliver about 2 cubic feet per second of water to each patron and not less, whether he has a small water right or not, limiting the time rather than the flow of water. We find this a great deal more satisfactory than to deliver one-half cubic foot per second on 40 acres. It is better for the farmer and the ditch company also, as a large stream will cover more ground than a small stream running full time.

The subjoined tabulations set forth the results obtained:

Monthly precipitation at Gothenburg, Nebr., 1899.

	Inches.		Inches.
April	0.41	August	1.93
May	4.01	September	.60
June	2.16		
July	1.08	Total	10.19

[1] Office of Experiment Stations, United States Department of Agriculture.



Map of the Irrigation System of the Gothenburg Power and Irrigation Company, Nebraska.

Water discharged by the Gothenburg Canal, June 7 to September 30, 1899.

[See diagram, Pl. XX, p. 76.]

Day.	June.	July.	August.	September.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1		193.2618	133.2049	153.1667
2		181.9910	112.2315	150.0804
3		182.5689	137.3816	145.9771
4		162.3893	161.4043	140.8587
5		169.2397	142.2251	112.5981
6		204.2938	127.9279	107.2158
7	70.0753	147.3078	118.5133	75.6788
8	131.2460	84.8298	70.0714	64.4591
9	41.1236	97.5966	59.4027	95.3960
10	32.8073	134.2545	12.8339	113.3629
11	145.8275	159.1402		98.6471
12	147.9195	185.1098		80.2601
13	145.1559	184.5293		75.9543
14	141.4441	201.4008		94.2995
15	134.8146	199.7245		95.7359
16	142.6964	200.3585	- 10.7671	117.7786
17	148.0958	192.3830	73.3322	125.8655
18	155.5624	185.7055	70.0954	156.3031
19	155.0055	197.7352		173.0666
20	167.0403	209.0522		121.3553
21	173.2836	213.5207	116.9668	53.7272
22	186.9791	216.9674	126.6240	131.2451
23	185.9046	220.8303	138.8584	138.2376
24	185.6171	221.7937	142.4916	119.9843
25	179.1158	216.1476	140.8279	109.1212
26	198.2978	189.9424	142.2493	95.4941
27	187.0730	188.7925	171.5542	77.3916
28	188.4005	167.0458	173.0200	77.8337
29	197.3041	176.0797	173.5845	85.2397
30	202.0668	166.7813	170.6236	113.0327
31		162.6209	149.9008	
Total	3,642.8566	5,613.3945	2,876.0924	3,299.3668

Duty of water under Gothenburg Canal.

Area irrigated	acres	6,000
Water used	acre-feet	15,431.7103
Depth of irrigation	feet	2.57
Depth of rainfall	do	.85
Total depth of water received by land	do	3.42

Water used on the farm of D. W. Daggett, near Gothenburg, Nebr., June 19 to September 30, 1899.

[See diagram, Pl. XXI, p. 76.]

Day.	June.	July.	August.	September.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1		0	0	2.5825
2		0	0	2.8419
3		0	0	2.8971
4		0	0	2.6415
5		4.5804	0	.5206
6		5.7468	0	.0750
7		5.4480	0	0
8		4.1520	0	0
9		.2563	0	5.4742
10		.0044	0	5.8137
11		.0432	0	4.6743
12		.0521	0	3.3601
13		.0684	0	2.0284
14		.0476	0	1.8311
15		.0135	0	3.1128
16		0	0	3.4700

Water used on the farm of D. W. Daggett, near Gothenburg, Nebr., June 19 to September 30, 1899—Continued.

[See diagram, Pl. XXI, p. 76.]

Day.	June.	July.	August.	September.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
17	....	0	0	*a* 0.2597
18	....	0	0	*a* .2597
19	2.2206	0	0.7719	*a* .2597
20	3.6348	0	2.4595	*a* .2597
21	3.7656	0	2.6423	*a* .2597
22	4.4412	1.6240	2.9529	*a* .2597
23	4.5804	4.3934	4.1149	*a* .2597
24	4.5126	5.2359	3.1427	.2975
25	2.5038	5.1190	3.1214	.2975
26	0	5.4325	2.3696	.1653
27	0	1.8531	2.4707	.1653
28	0	0	2.7273	.1653
29	0	0	2.4410	.2975
30	0	0	2.2239	.4297
31	....	0	2.2764	....
Total	25.6590	44.0706	33.7145	44.9592

a Estimated. See letter of October 2, 1899, from C. A. Edwards.

Duty of water on farm of D. W. Daggett.

Area irrigated	acres..	60
Water used	acre-feet..	148.4033
Depth of irrigation	feet..	2.47
Depth of rainfall	do...	.85
Total depth of water received by land	do...	3.32

It is to be noted that there was little difference between the amount of water applied on the Daggett farm and the average amount applied to all lands under the canal. This slight difference is somewhat surprising when it is remembered that the duty of water as noted for the canal is what may be termed the headgate duty, and included losses by seepage and evaporation from the canal, together with such waste as there may be from the lower ends of the laterals. It indicates that the losses from seepage are much less than frequently exist.

The work in the North Platte Valley viewed in the light of this more precise work seems to present no especially abnormal features.

COLORADO.

DUTY OF WATER UNDER THE AMITY CANAL.

By Special Agent Thomas Berry,
Chief Engineer of the Great Plains Water Company.

LOCATION AND DESCRIPTION OF CANAL SYSTEM.

The use of water described in this report occurred under the canal system of the Great Plains Water Company, located in the Arkansas Valley, on the north side of the river in Otero, Bent, Kiowa, and Prowers counties, Colorado, and in Hamilton County, Kansas. It comprises the Amity and Buffalo canals, and a storage system from which a supplementary supply for these canals is derived and lands above them may be irrigated. The accompanying map (Pl. XLI) shows the extent of the system in Colorado.

The development of the reservoir system is a result of the uncertainty that the river will provide an adequate direct supply for the Amity Canal, and may be considered an independent project.

AMITY CANAL.

In Colorado the service of the Amity Canal is confined to Prowers County, and in Kansas to Hamilton County. It has a capacity of 740 cubic feet per second at the headgates and 177 cubic feet per second at the State line. The maximum and minimum grades are, respectively, 1.584 feet per mile and 1.056 feet per mile.

The width of the bottom varies from 32 feet at the headgates to 16 feet at the State line and 14 feet at the terminus, and the heights above grade to which water is run at these points are 6 feet, 3.5 feet, and 3 feet, respectively. The slopes of the standard embankment throughout are 1 on 2 on the water side, and 1 on 1.5 on the outer side; the minimum width on the top is 8 feet, and the height above high-water mark is 1.5 feet. All embankments over 6 feet in height at crossings of "draws" (dry ravines), creeks, and arroyos have slopes of 1 on 3 on the water side and 1 on 1.5 on the outer side, and are not less than 12 feet wide on the top, which is 3 feet above high-water mark. The excavation on the upper side is cut down to a slope of 1 on 1.

The construction of the canal was commenced in the spring of 1886, but the work which brought the property to its present state of development did not begin until the spring of 1893. Until the latter year the canal depended altogether upon sand and brush dams for the diversion of its supply from the river, a condition which in itself was sufficient to hinder the progress of agricultural improvement and advancement. That year a pile and frame dam and new headgates were built, and early in 1895 work on the enlargement and extension of the canal was commenced.

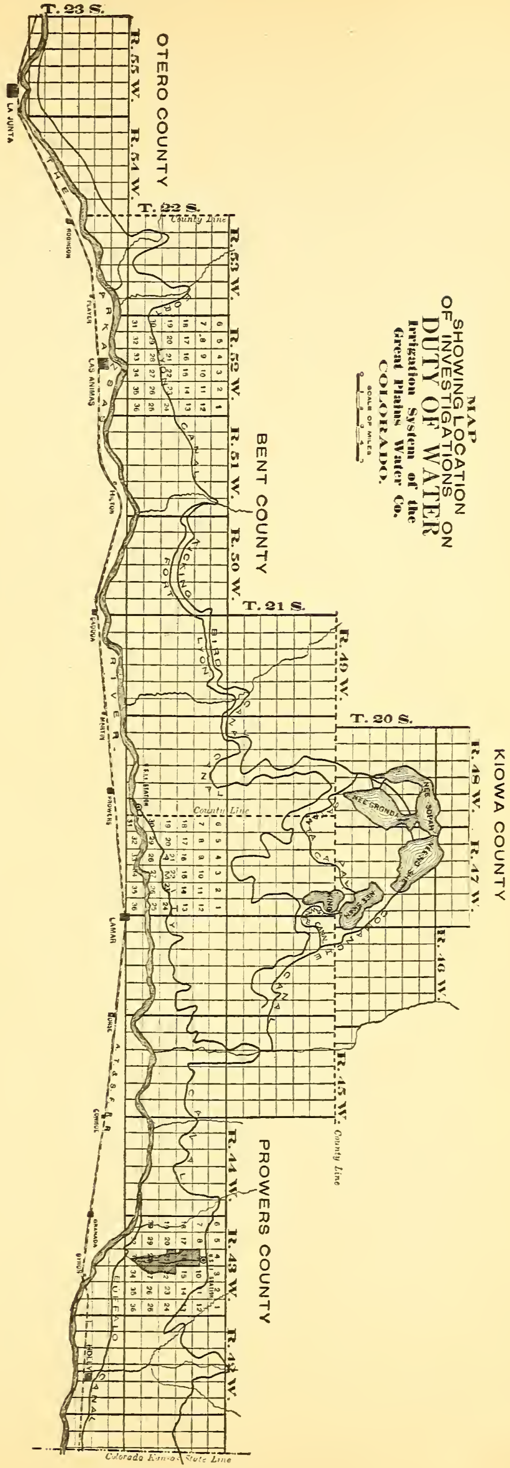
Sand traps in combination with check and waste gates are built in the canal at a point 3,000 feet from the headgates. To maintain the priorities of the canals lower on the river, there is always sufficient water turned out at this point to carry the sand coming in at the headgates back to the river, so that no trouble is experienced with it in the canal.

Other structures and appurtenances of the canal are a measuring flume; check and waste gates at Big Sandy Creek; waste gates at Buffalo Creek; and check and waste gates at Cheyenne Creek; and lateral gates and bridges.

All lateral gates are constructed of lumber, and those for individual water rights are furnished with double valves arranged so that the water can be cut off by the user, but increased, the head remaining constant, only by the patrolman.

There is not a flume in the length of the Amity Canal, the waterways all being crossed by means of fills. Spillways are generally provided in favorable locations at each end of the embankment and at a safe distance therefrom by keeping construction down to the high-water line of the canal. This, of course, can be only a partial remedy of the danger at such points, and while the method of construction may be economical at those creeks which are crossed nearly on a level, it is very doubtful, everything considered, if it is so at the deeper crossings. Usually the cost per cubic yard of moving material at such times as breaks occur is very high; in fact it may always be considered a maximum one, and each succeding break is more expensive to repair than its predecessor, from the fact that the point from which material can be obtained keeps receding.

Except for the creeks and their "breaks," which are confined to narrow margins on either side, the surface of the country watered by the Amity Canal is smooth and unbroken. The high land between the main drainage ways as a general rule slopes unbrokenly and uniformly either way to the drainage, while the slope to the south on the summit is always irregular, one or more points inaccessible to water intervening between the canal and the "bluffs" which bound the river bottom lands. The slope of the country from the north toward the river is about 20 feet per mile.



Map of the Irrigation System of the Great Plains Water Company, Colorado.

The main laterals are constructed by the company and afterwards incorporated and turned over, for management, operation, and maintenance, to the owners of the lands which are watered from them. Their capacities run from 3 cubic feet per second for individual rights to 67 cubic feet per second for the larger laterals. The same care that governed the construction of the main canal was and is being used in the construction of the main laterals. They are all built on uniform grades, and where the country is steep, excess slope is overcome by the introduction of wooden drops.

The Amity Canal is in irrigation district No. 67 and has an appropriation of 283.5 cubic feet per second, dating from February 21, 1887.

BUFFALO CANAL.

The Buffalo Canal heads north of the town of Granada, and is located along the base of the steep slopes which divide the "bench" land from the bottom land, having a length of 16 miles in the State line. It has a grade of 5.28 feet per mile and a capacity of 215 cubic feet per second. By reason of its location accidents to this canal are numerous during the rainy season, and the cost of maintaining it is very high.

It is in irrigation district No. 67 and has an appropriation of 67.5 cubic feet per second, dating from January 29, 1885.

RESERVOIR SYSTEM.

The reservoir system consists of the King, Neeskah (Queen), Neenoshe, Neegronda, and Neesopah reservoirs; a right of way through the Fort Lyon Canal from the headgates to Gageby Arroyo (Pl. XLII, fig. 1), a distance of 42 miles; Kicking Bird, Satanta, and Lone Wolf, all supply canals; and the Comanche and Pawnee, both outlet canals. The Fort Lyon Canal and the Kicking Bird Canal are the main feeders, and their capacities are, respectively, 1,700 and 1,000 cubic feet per second. The grade of the former varies from 1.584 feet per mile to 2.112 feet per mile, and for a short distance through rock on the west side of Horse Creek it has a fall of 5.28 feet per mile. The Kicking Bird Canal has a uniform grade of 1.056 feet per mile, except on 2.5 miles, which fall at the rate of 0.75 feet per mile.

The Lone Wolf and Satanta canals are independent feeders to Neenoshe and Neeskah reservoirs, and are diverted from the main canal 0.75 mile and 1.5 miles, respectively, from its terminus.

The Lone Wolf Canal is 4 miles long and has a capacity of 700 cubic feet per second. Check gates are constructed at its head across the Kicking Bird Canal for the better control of the division of the water for all three canals.

The Satanta Canal is 14.5 miles long and has a capacity of 350 cubic feet per second.

The reservoirs are five in number, with capacities as follows:

Capacities of reservoirs.

Name.	Area at high-water mark.	Capacity.
	Acres.	*Acre-feet.*
No. 1, King	1,332	18,279
No. 2, Queen (Neeskah)	1,930	23,046
No. 3, Neenoshe	3,777	60,636
No. 4, Neegronda	3,490	57,209
No. 5, Neesopah	3,600	23,464
	14,129	182,634

INVESTIGATIONS IN 1899.

The plans for the observation of the duty of water under the Amity Canal during the past season have been only partially carried out, owing to the failure of one of the instruments for measuring the flow of water. One of the instruments was placed in Biles Lateral and has worked successfully. A record was also kept of the land irrigated under this lateral, so that the returns from that station are complete. Some difficulty was experienced in finding a suitable location for the other instrument. Finally an 80-acre tract was found, the owner of which was very much interested in the work and anxious to do all he could to further the investigations. A flume and register were put in his lateral, but for some reason the clock would not work. It was taken out and repaired, but again failed to work, so that there are no returns for that lateral.

DUTY OF WATER UNDER AMITY CANAL.

A record is kept by the company of the water entering the Amity Canal at its headgate, and also of the acreage irrigated under the whole system. These measurements are less accurate than those kept for the smaller area under Biles Lateral, and the distance from the headgate to the land irrigated introduces another element of uncertainty, since there are no records of the losses from the canal from seepage and evaporation. The results of these measurements are given below.

FIG. 1.—WASTEWAY AND GAGEBY ARROYO, GREAT PLAINS WATER COMPANY.

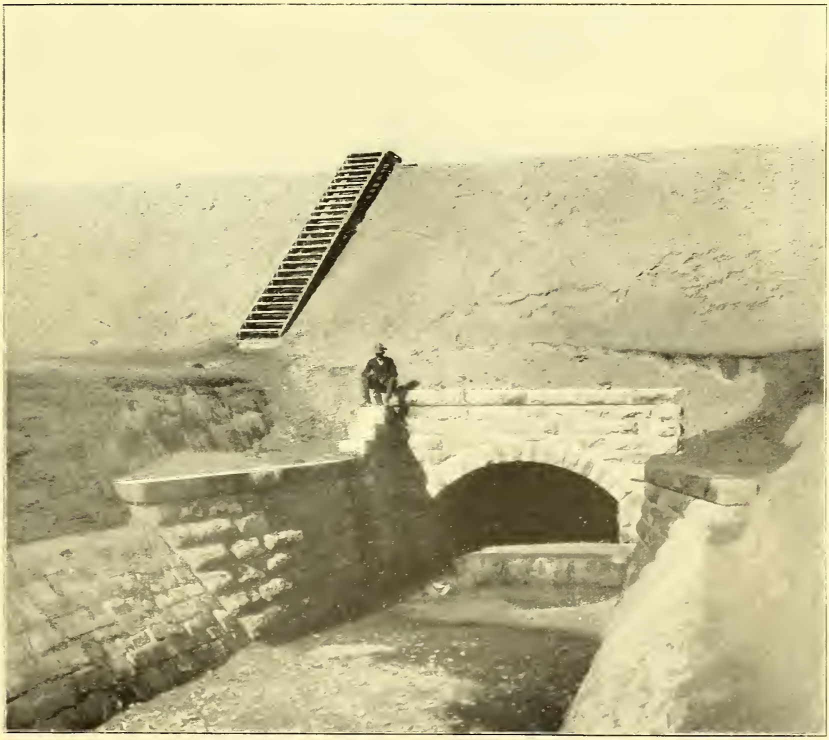


FIG. 2.—OUTLET CONDUIT NO. 2, GREAT PLAINS WATER COMPANY.

The following tables give the record of the water received by the Amity Canal at its headgate during the irrigating season of 1899:

Water received by Amity Canal at headgate, May 1 to September 30, 1899.

[See diagram, Pl. XVIII, p. 76.]

Day.	May.	June.	July.	August.	September.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1	46	544	422	590	62
2	34	358	422	590	50
3	10	568	656	590	50
4	10	668	656	590	28
5	10	668	1,132	0	28
6	224	668	904	0	20
7	76	612	790	0	14
8	34	468	826	0	14
9	46	568	1,180	414	38
10	22	568	904	414	50
11	22	950	756	414	50
12	22	668	1,180	414	28
13	22	668	756	612	20
14	76	950	0	568	20
15	200	860	0	656	14
16	358	1,030	0	806	38
17	440	1,100	0	780	50
18	440	1,100	0	728	50
19	590	1,140	0	612	104
20	468	1,100	0	494	432
21	568	1,100	0	386	370
22	414	1,100	0	302	466
23	358	1,100	0	250	432
24	568	440	0	200	340
25	568	780	0	152	284
26	568	910	0	132	284
27	568	1,080	0	112	238
28	568	830	0	112	198
29	568	728	0	92	178
30	568	634	656	76	178
31	568	....	468	76	....
Total	9,034	23,958	11,708	11,162	4,128

The total for five months was 59,990 acre-feet. The percentage of this water entering the canal each month is as follows:

	Per cent.
May	15
June	40
July	19
August	19
September	7
Total	100

The total discharge of the Amity Canal for the year ended October 1, 1899, is given in the following table. No water ran from December 11, 1898, to March 20, 1899, and in July, 1899, the water was turned out from the 14th to the 30th.

Discharge of Amity Canal from October 1, 1898, to October 1, 1899.

[See diagram, Pl. XVIII, p. 76.]

	Acre-feet.
October, 1898	3,318
November, 1898	8,874
December, 1898	4,233
March, 1899	4,924
April, 1899	9,851
May, 1899	9,034
June, 1899	23,958
July, 1899	11,708
August, 1899	11,162
September, 1899	4,128
September, 1899, reservoir water	3,000
Total	94,190
Total during season of 1899	77,765

The acreage of the various crops cultivated under the Amity Canal during the season of 1899 was as follows:

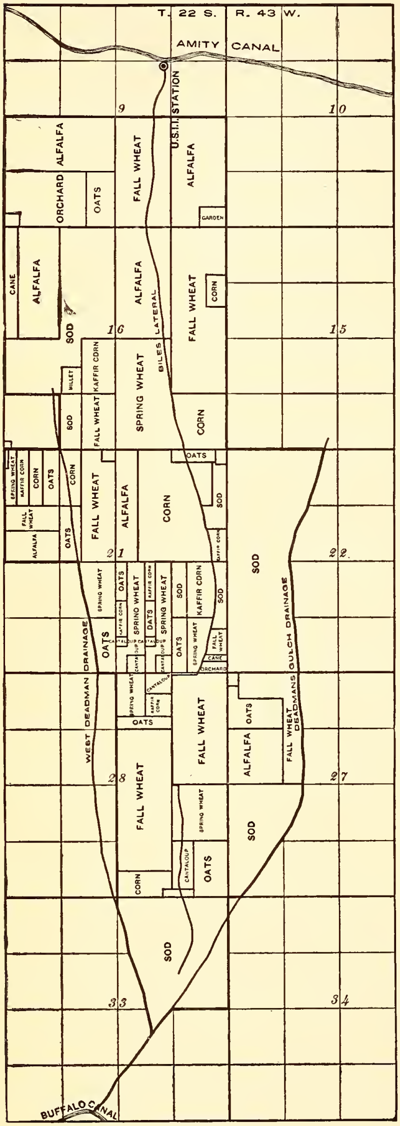


FIG. 14.—Map of Biles Lateral.

Acreage irrigated under Amity Canal, 1899.

	Acres.
Fall wheat	3, 111
Spring wheat	1, 153
Oats	2, 071
Barley	279
Corn	1, 979
Cane, etc	993
Alfalfa	4, 755
Flax	355
Broom corn	175
Cantaloupes	376
Orchard	271
Millet	207
Garden	71
Total	15, 796

From the above tables we have the following summary showing the duty of water under the Amity Canal for the season of 1899:

Duty of water under Amity Canal, 1899.

Total discharge of canal, 1899, to October 1 ....acre-feet..	77, 765
Acreage irrigated ....acres..	15, 796
Depth of irrigation ....feet..	4. 92
Depth of rainfall at Lamar..do...	. 91
Total depth of water received by land....feet..	5. 83

This, of course, makes no allowance for loss of water between the headgates and the place of use. In a canal having as great length as the Amity Canal the loss from both seepage and evaporation is necessarily large, so that the land received much less water than is indicated in the table.

Expressed in the usual way, the above results show a duty of about 80 acres per cubic foot per second for the season of 194 days from March 20 to October 1, during which the water ran.

DUTY OF WATER UNDER BILES LATERAL.

The results of the measurements on Biles Lateral (see Map, fig. 14) are given in the tables which follow. Construction on this lateral was in progress up to the end of May, which, of course, kept the application of water to the lands under it much lower than it would otherwise have been and lower than it was under the canal as a whole. The following table shows the water used on the land under this lateral:

Discharge of Biles Lateral, 1899.

[See diagram, Pl. XIX, p. 76.]

Day.	April.	May.	June.	July.	August.	September.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1			50.9	104.8		
2			28.1	81.6		
3			19.4	54.7		
4			72.2	20.5		
5			47.8	20.8		[1]21.0
6			68.8	45.5		73.3
7			63.1	49.5		53.2
8			15.0	23.6		4.2
9			15.0	101.0		
10			15.0	78.6		
11			15.0	93.7		
12			15.0	79.6		
13			15.0	74.6		
14				52.5		
15				32.2		
16		3.7	37.6			
17		18.6	42.7			
18		19.6	53.0		17.0	
19		44.1	33.7		46.0	
20		51.2	70.0		24.0	
21		19.0	70.0		22.0	12.2
22	1.9		70.0		.7	47.5
23	9.8	15.3	70.0		3.5	37.3
24		15.6	70.0		36.8	32.9
25		17.3	70.0		21.2	10.4
26	13.3	20.8	70.0		18.7	18.7
27	25.1	1.9	70.0			62.5
28	2.5	22.6	70.0			47.3
29		58.8	50.1			
30		97.9	104.2			
31		74.7				
Total	52.6	481.1	1,391.6	913.2	171.2	420.5

[1] From September 5 to 8, inclusive, is reservoir water.

The total discharge for the season was 3,430.2 acre-feet. The percentage of this water used in each month during the season is as follows:

	Per cent.
April	1
May	14
June	41
July	27
August	5
September	12
Total	100

A very careful record was kept of all the land irrigated under this lateral. The areas devoted to the various crops are shown on the map (fig. 14). The following table gives the acreage:

Acreage irrigated under Biles Lateral, 1899.

	Acres.		Acres.
Fall wheat	518	Garden	31
Spring wheat	211	Orchard	79
Alfalfa	387	Millet	6
Oats	152	Cantaloupes	21
Kafir corn	70.5	Sod	204
Indian corn	141		
Cane	56.5	Total	1,884

From the above tables the following summary of duty under Biles lateral is obtained:

Duty of water under Biles Lateral, 1899.

Discharge of lateral	acre-feet	3,430.2
Area irrigated	acres	1,884
Depth of irrigation	feet	1.8207
Depth of rainfall	do	.6850
Total depth of water received by land	do	2.5057

The length of season from the first to the last irrigation is 160 days. For that length of season the duty of 1 cubic foot per second is about 175 acres.

LOSS OF WATER.

The preceding tables show that the water discharged by the Amity Canal at its headgates would cover the land irrigated to a depth of 4.92 feet, provided it all reached the land. The depth of irrigation under Biles Lateral is 1.82, showing a loss of 63 per cent of the water between the headgates and the laterals, supposing that Biles Lateral correctly represents the whole system.

However, this lateral does not fairly represent an average of the whole system, so that the loss is something less than the 63 per cent shown by comparing the quantity of water passing the headgates and that used under Biles Lateral.

The tables given indicate a low duty under the Amity Canal. No doubt the duty this year is much lower than it has been in previous years on account of weather conditions alone. The seepage in the early part of the season all along the canal was much greater than has ever before been observed, a result, no doubt, of the excessive frosts of last winter. While the high winds usually blow during the months of March, April, and May, they commenced this year a month later and continued on through June. The comparative effect of this alone upon evaporation was very apparent.

As a whole, the character of the soil and the configuration of the land under the Amity Canal are favorable to a high duty. The temporary conditions which are unfavorable to a high duty are the short time the land has been irrigated, the inexperience of the irrigators, and to some extent the manner in which the water is conveyed to the land. It is safe to say that 75 per cent of the land has been under cultivation not more than three years, and 50 per cent of the whole not over two years. Our settlers are mostly Eastern people who never saw irrigation until they came to Colorado.

In so far as an economical delivery of the water is concerned, we are doing all we can to eliminate the individual lateral and discouraging the desire for such among farmers. The company builds the main laterals and turns them over, for operation and maintenance, to the communities owning the land which they cover. These laterals are very carefully aligned and constructed, and the conveyance of water through them and its distribution are perhaps as economical as they could well be under the circumstances.

It is expected that measuring flumes will be put in at the heads of all main laterals between now and next season. This will not be done with the intention of limiting the farmer to the amount of water he is actually entitled to, but because it will have a tendency toward careful application and economy on his part, and generally because it will be an aid in the transition from the extravagant use of as much as he can handle to the established duty of 2 acre-feet delivered at the head-gates of the main laterals.

CROP YIELDS.

The following table, showing the yields of crops under the Amity Canal, was very carefully compiled and may be considered thoroughly reliable. As shown by this table this season's crops were not a success, and the value of the returns of duty of water is somewhat lessened by this fact. The yields were as follows:

Acreage irrigated and crop yields under Amity Canal, 1899.

Crop.	Acreage.	Total yield.	Yield per acre.
	Acres.		
Fall wheat	3,111	20,895 bushels	6.75 bushels.
Spring wheat	1,153	6,259 bushels	5.50 bushels.
Oats	2,071	34,569 bushels	16.75 bushels.
Barley	279	3,042 bushels	11 bushels.
Corn	1,979	12,110 bushels	6 bushels.
Cane, etc	993	1,386 tons	1.50 tons.
Alfalfa	4,755	11,686 tons	2.50 tons.
Flax	355	2,232 bushels	6 bushels.
Broom corn	175	43 tons	0.25 tons.
Cantaloupes	376	12,567 crates	33 crates.
Orchard	271		
Millet	207		
Garden	71		
Total	15,796		

PRECIPITATION, EVAPORATION, AND TEMPERATURE.

The following tables give the precipitation at two points in the Arkansas Valley, on the Amity Canal, and the evaporation and temperature each at one station:

Precipitation, Lamar Station, 1899.

Day.	May.	June.	July.	August.	September.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1					
2					
3					
4					
5	1.17			1.60	
6				.50	
7				.10	
8					
9	.34	0.08			0.72
10					
11					
12					
13			0.09	.20	
14			2.30		.30
15			.10		.10
16		.80			.10
17					
18	.36				
19			2.27		
20					
21					
22		.35			
23		.30	.76		
24					
25	.52				
26					
27					
28			} .45		
29			}		
30					
31					
Total	2.39	1.53	5.97	2.40	1.22

There were high winds at Lamar on May 1, 2, 12, 13, 14, 15, 17, 18, 20, 24, 25, and 29, and on September 4, 5, 13, and 27. Thunderstorms occurred on May 18 and 25.

Precipitation and evaporation, Holly Station, 1899.

Day.	June.		July.		August.		September.	
	Precipitation.	Evaporation.[1]	Precipitation.	Evaporation.	Precipitation.	Evaporation.	Precipitation.	Evaporation.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1								
2			0.03					
3			.15					
4			.03	1.89	2.15	1.98		1.32
5					.19			
6					.12			
7	0.04							
8	.45							
9	.02						0.80	
10								
11				1.57	.02	1.44		.83
12			.05					
13			.20					
14					.10			
15			.53				.03	
16		2.28					.30	
17					.37			
18						1.57		.90
19			.16	1.84				
20								
21	.05							
22	.80							
23	.07	2.10	.15					
24	.10							
25								
26						2.04		1.68
27								
28		1.08	.15	1.63				
29			.08					
30			.08					
31								
Total	1.53	5.46	2.61	6.93	2.95	7.03	1.13	4.73

[1] Evaporation measurements not begun until June 13.

There were high winds at Holly from August 15 to 22, and some heavy dews from September 8 to 15.

Temperature at Lamar, 1899.

	May.	June.	July.	August.	September.
	°F.	°F.	°F.	°F.	°F.
Maximum	95.0	106.0	105.0	106.0	106.0
Minimum	31.0	45.0	55.0	49.0	38.0
Mean maximum	81.7	91.0	90.0	95.7	88.4
Mean minimum	48.0	57.0	62.0	62.0	51.5
Mean	65.0	74.0	76.0	79.0	70.0

DISCHARGE OF THE ARKANSAS RIVER AT PUEBLO, COLO.

Comparative table of discharge of the Arkansas River at Pueblo, Colo., for the irrigation seasons of 1895, 1896, 1897, and 1898.

Month.	Stage of water.	1895.	1896.	1897.	1898.
		Cubic feet per second.	*Cubic feet per second.*	*Cubic feet per second.*	*Cubic feet per second.*
April	Maximum	1,790	1,172	616	620
	Mean	744	470	235	370
	Minimum	301	276	146	232
May	Maximum	2,490	2,352	3,470	1,258
	Mean	1,561	1,097	1,631	841
	Minimum	601	472	578	470
June	Maximum	3,564	2,096	3,750	3,290
	Mean	2,152	895	2,214	2,202
	Minimum	1,455	412	1,218	1,258
July	Maximum	5,000	2,835	1,848	5,385
	Mean	1,900	633	1,036	1,605
	Minimum	1,044	301	474	470
August	Maximum	3,112	3,438	1,170	948
	Mean	1,275	489	470	306
	Minimum	568	203	180	123
September	Maximum	888	441	436	266
	Mean	494	309	272	125
	Minimum	383	219	146	46

WYOMING.

DUTY OF WATER IN WYOMING.

By C. T. Johnston.
Assistant in Irrigation Investigations.

The investigation of the duty of water in Wyoming for the season of 1899 was limited to the lands of the Wyoming Development Company, at Wheatland.[1] The irrigable land under this system has a total area of 60,000 acres, and is located 90 miles north of the southern boundary of Wyoming and 35 west of the eastern boundary of that State. It is east of the Laramie Mountains, and has a mean elevation of 4,800 feet. The soil is a sandy loam and quite uniform. Water is obtained from the Laramie River, and the supply is made secure by a complete reservoir system under construction having a total capacity of 90,000 acre-feet. Irrigation seldom begins before June 20, and the greatest demand for water is felt between that date and July 15. Unfortunately, the flood discharge of the Laramie River takes place between May 15 and June 10, while the transition from high water to low water is often rapid, taking place at times in a week or ten days; hence the necessity for storage. The distributing system is shown on the accompanying map (Pl. XLIII).

In the investigation for the season of 1899, a continuous record was kept of the depth of the water flowing in Canal No. 2 by means of a Wyoming nilometer. The use of a weir being impossible, a flume at the sand gate, a short distance below the headgate, was rated, and the register installed at this place. Canal No. 2 is supplied during low water by a ditch which carries water from Reservoir No. 2. This ditch joins the canal just above the sand gate, hence all the water used passed through that structure.

The duty of water as determined by these measurements is about half what would have been obtained if the water wasted through laterals and at the end of the canal could be taken into account, and if the loss due to evaporation and seepage could be eliminated. The

[1] For a fuller discussion of the use of water in irrigation in Wyoming, see U. S. Dept. Agr., Office of Experiment Stations Bul. 81.

following table gives the discharge of Canal No. 2 during the time that irrigation was necessary:

Flow of Canal No. 2, Wyoming Development Company, Wheatland, Wyo., season of 1899.

[See diagram, Pl. XXII, p. 78.]

Day.	June.	July.	August.	Day.	June.	July.	August.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*		*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1		331.06	348.01	18	210.67	287.69	
2		331.06	351.28	19	210.67	264.13	
3		326.70	348.01	20	210.67	236.01	
4		331.06	325.51	21	210.67	210.67	
5		331.06	244.76	22	214.52	210.67	
6		331.06	255.40	23	246.71	210.67	
7		331.06	335.49	24	258.19	210.67	
8		331.06	335.49	25	260.16	210.67	
9		331.06		26	264.13	239.56	
10		331.06		27	258.19	266.33	
11		331.06		28	326.70	351.28	
12	210.67	331.06		29	331.06	357.91	
13	210.67	331.06		30	326.70	357.91	
14	210.67	331.06		31		351.28	
15	210.67	331.06					
16	210.67	280.66		Total	4,593.06	9,295.34	2,543.95
17	210.67	287.69					

Monthly precipitation at Wheatland, Wyo., 1899.

	Inches.
June	2.63
July	1.28
August	.49
	4.40

The facts obtained are shown as follows in tabular form:

Duty of water under Canal No. 2, 1899.

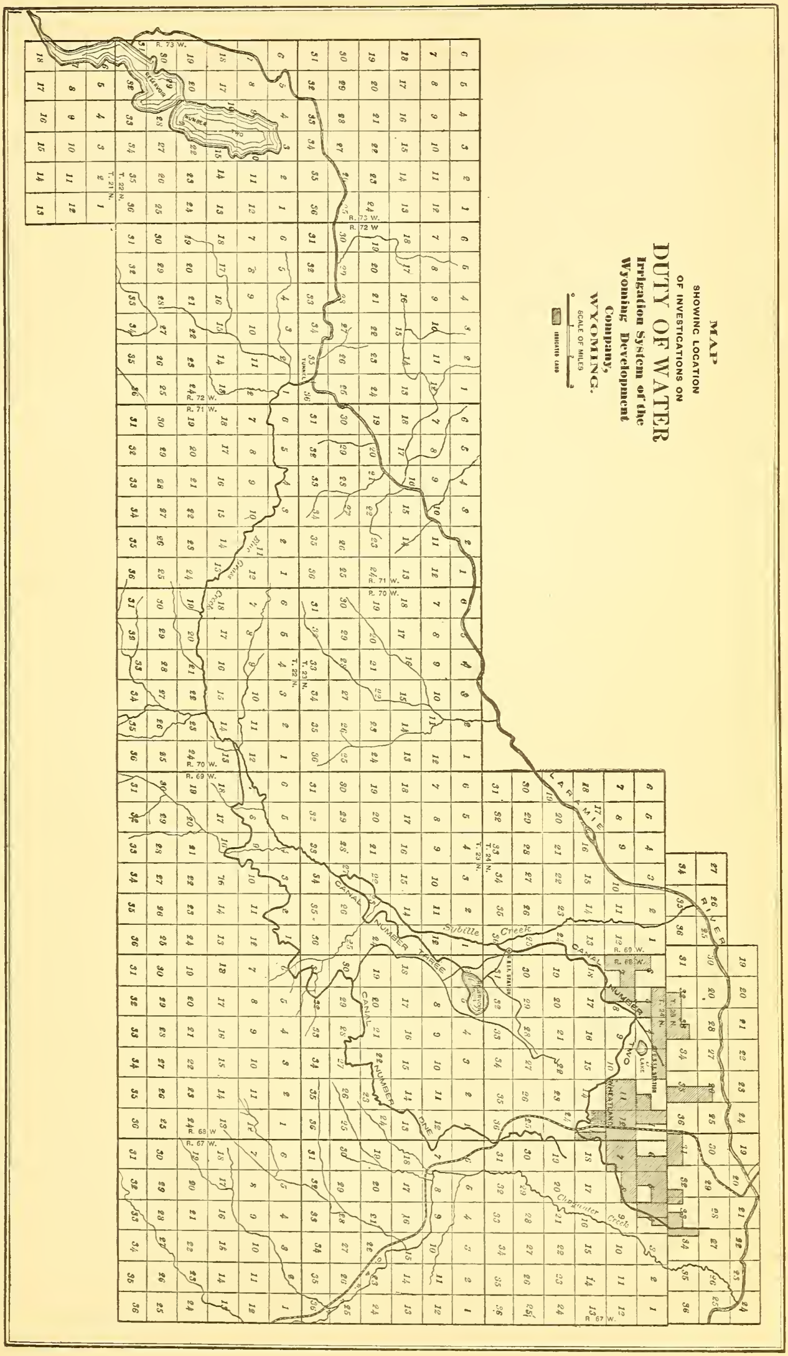
Area irrigated	acres	6,502.00
Water used	acre-feet	16,432.35
Depth of irrigation	feet	2.53
Rainfall for June, July, and August	do	.37
Total depth of water received	do	2.90

Table showing acreage and yields of each crop.

Crop.	Acres.	Total yield.	Yield per acre.
Wheat	2,292	49,000 bushels.	21.4 bushels.
Oats	1,398	51,500 bushels.	41.1 bushels.
Corn	800	20,000 bushels.	25 bushels.
Potatoes	350	24,500 bushels.	70 bushels.
Hay	1,662	6,975 tons.	4.2 tons.

A second investigation was carried on to determine the quantity of water needed for different crops. Only corn and oats were grown on the area included in this work.

During the first week of June, 1899, two weirs were constructed to measure the water used on a farm a few miles west of the town of



MAP OF IRRIGATION SYSTEM OF WYOMING DEVELOPMENT COMPANY, WYOMING.

Wheatland. As the two crops were irrigated at different times, one register served for both, being shifted from one weir to the other as water was used. The oats had an area of 15 acres, and the ground on which they were grown was not broken until the spring of that year. The field of corn had an area of 20 acres. Both of these crops were carefully irrigated, only the water needed being used.

The following tables show the quantity of water used and the dates when irrigation took place:

Table showing volume of water used in irrigation of oats.

[See diagram, fig. 12, p. 79.]

	Acre-feet.		Acre-feet.
June 13	0.94	July 14	3.38
June 14	2.70	July 15	2.56
June 15	2.13	July 19	2.93
June 16	2.48	July 20	2.89
June 17	.42	July 21	1.44
	8.67		14.60
July 13	1.40	Total	23.27

Table showing the volume of water used in irrigation of corn.

[See diagram, fig. 13, p. 80.]

	Acre-feet.		Acre-feet.
July 24	2.14	July 28	2.30
July 25	2.46	July 29	1.26
July 26	2.73		
July 27	3.12	Total	14.01

From these two tables the duty of water for each crop has been computed.

Duty of water on oats and corn at Wheatland, Wyo., 1899.

	Oats.	Corn.
Area irrigated ... acres	15	20
Water used ... acre-feet	23.27	14.01
Depth of irrigation ... feet	1.55	.70
Rainfall for June, July, and August ... foot	.37	.37
Total depth of water received ... feet	1.92	1.07

It will be noticed that the general duty of water under the canal is much less than that under the lateral. The difference is almost entirely due to the loss of water from the canal through seepage and evaporation.

The total length of the canal is 22 miles and the mean length between the point where the measurements are kept and the extreme eastern tract irrigated is about 10 miles. The loss of water due to seepage in the first 2 miles of the canal below the sand gates is excessive. The canal follows a steep sidehill for that distance and the material forming its channel is porous. The loss due to both seepage and evaporation decreases as the canal is followed eastwardly after leaving this sidehill. The soil not only becomes more impervious to water, but the section of the canal is reduced as laterals decrease its discharge.

The total value of the crops grown under Canal No. 2 in 1899 was $126,500. This value was produced by the application of 16,432.35 acre-feet of water; hence the return from the use of each acre-foot as measured at the headgates of the canal was $7.69.

The return from an acre-foot of water varies with the crops grown. As an illustration of this, corn raised under the J lateral yielded 25 bushels per acre and sold for 30 cents per bushel, making a return of $7.50 per acre. To produce this 0.7 of an acre-foot of water was used on each acre of land, or the return for each acre-foot of water used was $10.71.

The return for the oats was $13.15 per acre; 1.55 acre-feet of water was used in its irrigation, making a return from each acre-foot of water used of $8.40. If a comparison were made with potatoes the difference would be much more striking. From this crop a return of $35 an acre was received. As but little more water was used in its cultivation than was used on the corn, the return for each acre-foot of water used was approximately $50.

MONTANA.

DUTY OF WATER IN THE GALLATIN VALLEY.

Samuel Fortier, C. E.,
Professor of Irrigation Engineering, Montana Agricultural College.

INTRODUCTION.

In outlining a plan for the carrying on of investigations to determine the average quantity of water used on the irrigated farms of Montana, it was deemed best to begin the work in the Gallatin Valley.

This valley is justly termed the granary of the State, since it produces annually more than one-fourth of the cereals and contains within its boundaries more than one-eighth of the total irrigated area of Montana. The valley is 28 miles long and about 14 miles wide. It is traversed in a northwesterly direction by the Northern Pacific Railroad, and the elevations of the track at the towns of Bozeman, Manhattan, and Gallatin are 4,754 feet, 4,292 feet, and 4,032 feet, respectively.

To the south of the valley are to be found the sharp-pointed, snow-covered peaks of the Gallatin Mountains; on the east the steep incline lying between the East Gallatin River and the foot of the Bridger Range is thickly dotted with dry farms, which produce average yields of wheat without irrigation; a low range separates it from the Missouri Valley on the northwest and a plateau forms the divide between it and the Madison Valley on the west.

The area that may be brought under ditch in the Gallatin Valley is about 150,000 acres, and deducting 25 per cent for waste lands and tracts that are not susceptible of irrigation, there remains 112,500 acres of arable and irrigable land. A trifle less than one-half of this area is now irrigated.

The water supply for this entire tract of exceedingly fertile farming land may be obtained from the following sources in the quantities stated, which indicate approximately the average flow for June and July of each year, as determined by the engineers of the United States Geological Survey:

	Cubic feet per second.
West Gallatin River	1,000
Middle Creek	150
Cottonwood Creek	60
Other streams	250
Total	1,460

Since little irrigating water is used after August 1, each cubic foot per second is ample for 80 acres of land. One thousand four hundred and sixty cubic feet per second would thus irrigate 116,800 acres, or all of the good land in the valley.

EVAPORATION AND PRECIPITATION.

It was late in June before a decision was reached to ascertain the amount of evaporation during the crop-growing season, and there was then no time to procure a permanent steel tank. In the way of a substitute, a wooden box was made and lined with zinc. This box was made in the form of a cube, and contained when full a cubic yard of water. It was set in a grass plat at a considerable distance from any buildings, with its top edge but slightly raised above the surface of the ground, and filled to within 2 inches of the top with water. A woven-wire fence 12 by 12 feet and 3 feet high, supported by light pine posts and painted green, inclosed the tank.

The rate of evaporation was determined by taking measurements from a gage on the top of the tank to the water surface. As the water in the tank was evaporated, more was added. The following table shows the results of these measurements:

Evaporation at Bozeman, Mont., July 6 to September 30, 1899.

	Temperature in tank, 6 inches below surface.	Evaporation.
	° *F.*	*Inches.*
July 6 to 31, 1899	70	5.48
August, 1899	63	8.70
September, 1899	58	6.75

The following table shows the precipitation at the Montana Experiment Station for the calendar year 1899:

Precipitation on the Montana Experiment Station farm, Bozeman, for 1899. (Prof. R. S. Shaw, observer.)

	Inches.		Inches.
January	[1] 0.78	August	0.80
February	[1] 3.14	September	.56
March	1.93	October	1.12
April	.58	November	.61
May	1.82	December	.74
June	2.04		
July	.34	Total	14.46

[1] Approximate equivalent of water from snow fall.

EXPERIMENTS ON THE DUTY OF WATER IN 1899.

EXPERIMENT NO. 1.

In the southwest corner of the Montana Experiment Station farm there is a field of red clover containing nearly 31 acres. About half

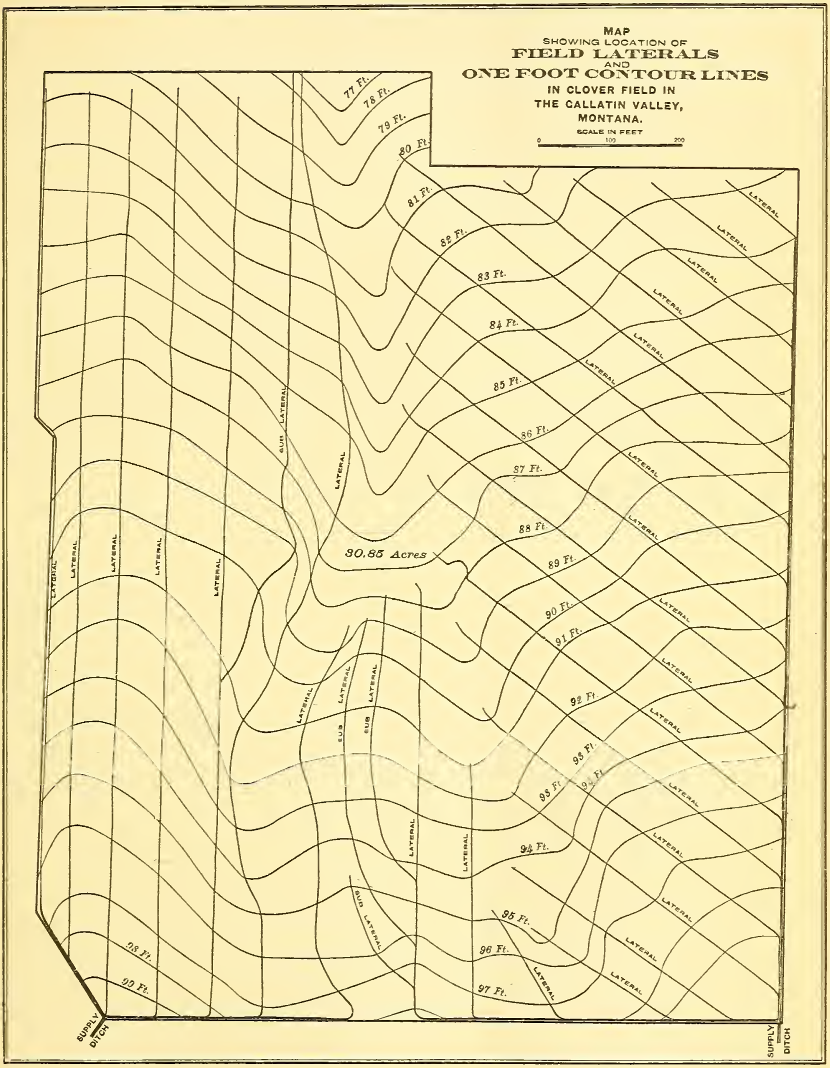


FIG. 15.—Map showing location of field laterals and contour lines in clover fields in Gallatin Valley, Montana.

of this field was seeded to clover in the spring of 1897 and the remainder was seeded to barley and clover in the spring of 1898. Two crops were obtained during the past season, but owing to the late spring the second cutting was light. The total yield of cured hay was about 90 tons, or 3 tons per acre, and the prices per ton for clover hay delivered in Bozeman, one and one-half miles distant, have varied from $6 to $8.

Two supply ditches enter the field at the southwest and southeast corners, respectively. In June last a trapezoidal weir was placed in each supply ditch, and by means of automatic registering machines the depths of water over the weirs during the time of irrigation were recorded. The field slopes toward the north at the rate of nearly 80 feet to the mile, and also to a lesser degree toward a central ravine which traverses the field from south to north. With the exception of the area occupied by the ravine, which is formed of cobblestone overlaid with a shallow soil, the field is of average fertility. The best portions consist of 6 inches vegetable loam, 20 inches clay loam, 40 inches clay marl, and an unknown depth of gravel and cobblestone. The field laterals were made in 1897 and 1898 and were spaced from 60 to 90 feet apart, but averaged 80 feet. The accompanying diagram (fig. 15) shows the arrangement of field laterals.

In applying the water there was practically none wasted, and at each irrigation the main object sought was to wet the soil uniformly to a depth of 1 foot.

The following table contains the data pertaining to this experiment:

Duty of water on clover, as shown by experiment No. 1.

	First irrigation.	Second irrigation.	Total.
Date of irrigation	June 17–22	July 26–Aug. 2	....
Duration of irrigation .... hours..	104	115	....
Area irrigated .... acres..	27.44	27.44	27.44
Water used .... acre-feet..	13.35	14.57	27.92
Average depth of water applied .... feet..	.49	.53	1.02
Rainfall during growth .... do...	....	....	.44
Total depth of water received during growth .... do...	....	....	1.46
Number of irrigators	2	2	....
Average head of water used .... cubic feet per second..	1.55	1.53	....
Average distance between field laterals .... feet..	....	....	80

The table shows that a trifle less than 6 inches of water, if applied uniformly over the field, was used during the first watering, and a trifle more than this quantity was used during the second watering—that is to say, the depth of water used during the season was about 1 foot, there being 27.44 acres of land included in the experiment and 27.86 acre-feet of water applied. In addition to this, this crop received during its growth 5.28 inches of rainfall.

The average flow used by the irrigators was 1.54 cubic feet per second, or 61.6 Montana statutory inches, a somewhat smaller quantity than is usually preferred in this section of the State.

EXPERIMENT NO. 2.

The second experiment on the duty of water was conducted on a field of peas of the Mummy variety, 4.23 acres in extent, located near the southwest corner of the experiment station farm.

This field has been cropped continuously since 1893. It produced potatoes in 1894, barley in 1895, oats in 1896, peas in 1897, barley in 1898, and peas in 1899. The yield for the past season was 132.25 bushels on 4.23 acres, or 31.25 bushels per acre. The price at the experiment station granary has remained stationary since the harvest time at $1 per bushel.

The peas were sowed May 8, irrigated for the first time June 28, when the crop was about 9 inches high, irrigated a second time July 11 and 12, and harvested September 7.

The soil is somewhat richer than that described in experiment No. 1. There is more vegetable mold in the top layer and the depth to the porous stratum of gravel and cobblestone is fully 6 feet.

The field was irrigated in the usual manner with but a small percentage of waste. The following table shows the results of this experiment:

Duty of water on peas, as shown by experiment No. 2.

	First irrigation.	Second irrigation.	Total.
Date of irrigation	June 28	July 11–12	....
Duration of irrigation .... hours..	22	22	....
Area irrigated .... acres..	4.23	4.23	4.23
Water used .... acre-feet..	2.93	1.75	4.68
Average depth of water applied .... feet..	.69	.41	1.10
Rainfall, May 8 to September 7 .... do...	....	....	.41
Total depth of water received during growth .... do...	....	....	1.51
Number of irrigators	1	1	....
Average head of water used .... cubic feet per second..	1.61	.95	....
Average distance between field laterals .... feet..	....	....	60

EXPERIMENT NO. 3.

The quantity of water used on a grain field of 11.27 acres, located on the experiment farm west of the pea field, was also determined.

In this field there were 5.25 acres of barley and 6.02 acres of wheat; but since it was impossible to irrigate them at different times, the entire field was included in the experiment. The field slopes to the north at the rate of about 90 feet to the mile, and also to the east in a like degree. The steep inclines, coupled with the fact that the irrigators allowed a diminished flow to run all night without attention, caused considerable waste. The table shows that nearly 2 feet of water was run over this tract in the two irrigations, but it is safe to assert that if the water had been applied during the hours of daylight and carefully attended to a much smaller quantity would have sufficed.

The waste of water had no apparent effect on the yield, which was for the wheat slightly above the average, being 348½ bushels on 6.02 acres, or 57.89 bushels per acre. The barley averaged 45 bushels per acre.

The soil and subsoil of this grain field are similar to that described in experiment No. 2. It was seeded to oats in 1893, peas in 1894, and to barley in 1895. It was in clover for three years from 1896 to 1898, inclusive.

In regard to last year's crops, the barley was sowed May 9, irrigated June 25, when it was about 6 inches high, and again July 13, and harvested September 12 and 13.

The wheat was sowed May 8, irrigated at the same time as the barley, and harvested September 23.

The price of barley in Bozeman, Mont., during the past autumn has varied from 90 to 95 cents per bushel, and wheat has averaged about 75 cents per bushel.

The following table gives the result of experiment No. 3:

Duty of water on grain, as shown by experiment No. 3.

	First irrigation.	Second irrigation.	Total.
Date of irrigation	June 23–27	July 12–14	....
Duration of irrigation ....hours..	96	56	....
Area irrigated ....acres..	11.27	11.27	11.27
Water used ....acre-feet..	14.34	7.96	22.30
Average depth of water applied ....feet..	1.27	.71	1.98
Rainfall, May 8 to September 18 ....do...	....	....	.42
Total depth of water received during growth ....do...	....	....	2.40
Number of irrigators	2	2	....
Average head of water used ....cubic feet per second..	1.81	1.72	....
Average distance between field laterals ....feet..	....	....	90

EXPERIMENT NO. 4.

The quantity of water applied to a large field of barley belonging to the Hon. James E. Martin, and situated in the southeastern part of Gallatin Valley, was ascertained by means of a rating flume and recording register. A weir would have been preferred, but the requisite fall could not be obtained. The field was not watered until quite late, and then only one irrigation was given.

The greatest slope of the field was about 80 feet to the mile, or 3 inches to the rod, and the field laterals were parallel and ran diagonally through the field on a grade of about 1.5 inches to the rod. The distance between the laterals varied from 56 to 93 feet and averaged 69 feet. The soil consists of a clay loam, with a porous stratum of gravel wash beneath.

The barley field, after being summer fallowed in 1897, was seeded to barley and oats in the following year, and produced at the rate of 73 bushels per acre of barley and 50 bushels of oats.

The following table shows the quantity of water used on this field:

Duty of water on barley, as shown by experiment No. 4.

Date of irrigation	July 5–13
Duration of irrigation ... hours	196
Area irrigated ... acres	66. 39
Water used ... acre-feet	65. 37
Average depth of water applied ... feet	.98
Rainfall during period of growth ... do	.41
Total depth of water received during growth ... do	1. 39
Number of irrigators	2
Average head of water used ... cubic feet per second	4. 04
Average distance between laterals ... feet	69

EXPERIMENT NO. 5.

The quantity of water used on a field of oats 23.41 acres in extent, situated below the barley field described in experiment No. 4, and likewise owned by Mr. Martin, was determined. In this case considerable water was wasted. The topography of the field was irregular, and it was difficult to irrigate. In addition to this a slough extended along the west and north sides into which a large percentage of the water applied found its way. Under favorable conditions and having as even a surface this field should have required less water in proportion to its area than that used in experiment No. 4.

The yield was 1,200 bushels of oats, or 51 bushels per acre.

The following table gives the data of this experiment:

Duty of water on oats, as shown by experiment No. 5.

Date of irrigation	July 13–18
Duration of irrigation ... hours	122
Area irrigated ... acres	23. 41
Water used ... acre-feet	35. 73
Average depth of water applied ... feet	1. 53
Rainfall during period of growth ... do	.38
Total depth of water received during growth ... do	1. 91
Number of irrigators	2
Average head of water used ... cubic feet per second	3. 54
Average distance between field laterals ... feet	85

EXPERIMENT NO. 6.

Experiment No. 6 was made on a field of oats situated on the south side of the experiment station farm containing 7.26 acres. This field has been cropped continuously since the establishment of the experiment farm. Barley was raised on this field in 1894, potatoes and peas in 1895, barley in 1896, peas and grain in small plats in 1897, and barley and other grains in small plats in 1898.

The oat crop of the past summer was seeded May 19, irrigated July 6 and 7, irrigated again July 22 to 24, and reaped September 18.

The average yield of all the oats raised last season on the experiment farm was 72.75 bushels per acre, and the price has increased from 95 cents at threshing time to $1.15 per hundred pounds in February.

Duty of water on oats, as shown by experiment No. 6.

	First irrigation.	Second irrigation.	Total.
Date of irrigation	July 6–7	July 22–24	....
Duration of irrigation ... hours	24	48.25	....
Area irrigated ... acres	7.26	7.26	7.26
Water used ... acre-feet	2.63	7.11	9.74
Average depth of water applied ... feet	.36	.98	1.34
Rainfall from May 19 to September 18 ... do	....	....	.36
Total depth of water received during growth ... do	....	....	1.70
Number of irrigators	1	1	....
Average head of water used ... cubic feet per second	1.33	1.78	....
Average distance between field laterals ... feet	....	....	75

EXPERIMENT NO. 7.

This experiment was tried on a small field of oats on the station farm. It was seeded May 23 and cut September 18, thus taking 119 days to mature. The yield was at the rate of 72.75 bushels per acre.

In irrigating it was found impracticable to prevent part of the water from flowing on adjacent fields. Hence the flow over the weir did not accurately represent the quantity actually applied to the land at the first irrigation. At the second watering more accurate results were obtained. The following table shows the quantity of water passing over the weir:

Duty of water on oats, as shown by experiment No. 7.

	First irrigation.	Second irrigation.	Total.
Date of irrigation	July 7–8	July 25	....
Duration of irrigation ... hours	23.25	10	....
Area irrigated ... acres	2.48	2.48	2.48
Water used ... acre-feet	3.70	1.66	5.36
Average depth of water applied ... feet	1.49	.67	2.16
Rainfall from May 23 to September 18 ... do	....	....	.36
Total depth of water received during growth ... do	....	....	2.52
Number of irrigators	1	1	....
Average head of water used ... cubic feet per second	1.92	2.01	....

EXPERIMENT NO. 8.

This test was made on a field of oats containing a trifle over 25 acres, owned by Mr. J. L. Patterson, county commissioner of Gallatin County.

The water was measured over two trapezoidal weirs placed side by side at the same elevation, the depth of water over the crest of each being recorded by one Gurley register.

This field received a thorough watering, and if part was wasted it must have been due to percolation through the soil, which is shallow in places, and not to run off from the field. The results of this experiment are shown in the following table:

Duty of water on oats, as shown by experiment No. 8.

Date of irrigation	July 20–26
Duration of irrigation ...hours..	123.5
Area irrigated ...acres..	25.09
Water used ...acre-feet..	32.00
Average depth of water applied ...feet..	1.28
Rainfall during period of growth ...do...	.44
Total depth of water received during growth...do...	1.72
Number of irrigators	1
Average head of water used ...cubic feet per second..	3.13
Average distance between field laterals ...feet..	85

CONCLUSIONS.

(1) The average of the eight experiments shows approximately 1.2 acre-feet of water used for each acre irrigated.

(2) Irrigating with insufficient help is wasteful of water.

(3) Much more water is required when the irrigating streams are allowed to run all night without attention.

(4) Irrigating late in the season retards the ripening of grain, and on account of the prevalence of early frosts it is not advisable to apply water on grain lands after August 1.

(5) Little water is used before June 15 in this locality. The so-called irrigation period is therefore only 45 days.

DUTY OF WATER FLOWING IN MIDDLE CREEK CANAL.

In ascertaining the duty of water for a field of known area, when the flow is measured as it enters the highest corner of the field, all losses due to conveyance are excluded. In the eight experiments previously described the loss of water due to seepage and percolation from the bottom and sides of the main canal and supply ditches and from evaporation was not considered. The quantity of water which flowed onto the field selected for an experiment, together with the incidental losses due to the character of the soil and the lack of skill or negligence on the part of the irrigator, was taken to compute the duty in that particular case.

We have now to consider the duty of water under entirely different conditions. It must now be debited with all the losses and waste which occur from the time the water leaves its natural source until it forms part of the mechanical constituents of the irrigated farms. A momentary reflection will convince the observer that a much larger quantity will now be required. In other words, the so-called duty will be lessened. Particularly is this true in a season like last summer, when there was an abundance of water in Middle Creek and little occasion to economize in its use.

In order to determine the flow of Middle Creek Canal during the irrigation period, a rating flume 16 feet long and 10 feet wide was inserted near the point of diversion. A self-registering instrument, made by Richard Brothers, of Paris, recorded continuously the height of the surface of the water in the flume.

The following tables give the dates and flow in acre-feet for stated periods of time. The same results are also shown in diagram (Pl. XXVI, p. 80).

Discharge of Middle Creek Canal, June 16 to September 16, 1899.

Day.	June.	July.	August.	September.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1	....	188.9256	31.3007	65.9616
2	....	188.9256	31.2472	65.9616
3	....	188.9256	39.2328	65.9616
4	....	188.9256	34.3399	65.9616
5	....	194.4146	33.2616	70.7834
6	....	197.1777	35.4090	64.3416
7	....	197.1777	41.8512	64.3416
8	....	197.1777	35.2231	64.3416
9	....	198.6442	18.0888	64.3416
10	....	198.6442	18.0888	64.3416
11	....	198.6442	17.1372	65.4298
12	....	198.6442	11.4817	61.0896
13	....	198.6442	11.4817	61.0896
14	....	198.6442	13.4479	61.0896
15	....	164.3282	16.1852	61.0896
16	52.4032	164.3282	16.1852	55.9988
17	52.4032	164.3282	16.1852	....
18	52.4032	157.7896	16.1852	....
19	72.4752	150.0388	22.8499	....
20	72.4752	120.0923	24.8520	....
21	93.8195	120.0923	24.8520	....
22	107.6220	120.0923	24.8520	....
23	107.6220	102.9547	24.8520	....
24	111.0864	102.9547	32.8489	....
25	111.0864	102.9547	32.2104	....
26	111.0864	89.1522	32.2104	....
27	112.2636	89.1522	40.1350	....
28	139.3385	62.8590	48.0596	....
29	169.8862	55.2984	50.9554	....
30	172.6632	55.2984	53.8512	....
31	....	55.2984	53.8512	....
Total	1,538.6342	4,610.5279	902.7124	1,022.1248

It appears from the foregoing figures that the total diversion from Middle Creek, through this canal, from June 16 to September 16, 1899, amounted to 8,074 acre-feet. Assuming that 1½ acre-feet are sufficient for 1 acre, the volume diverted would irrigate 5,383 acres. As will be seen later, this area, owing to excessive losses, is far greater than that actually irrigated.

The land actually watered under this canal during the summer of 1899 was obtained by visiting each irrigator in person and ascertaining from him as accurately as he could determine the acreage of each crop, the extent of fallow land, and the portions that had been watered twice. The following table shows the results of this canvass:

Acreage of irrigated crops under Middle Creek Canal, 1899.

	Acres.
Barley	1,438
Oats	597
Wheat	118
Timothy and clover	1,405
Clover and alfalfa	147
Other crops	148
Total	3,853

SUMMARY.

Total area of farms	6,476
Total area irrigated in 1899	3,853
Area watered twice in 1899	2,036
Area summer fallowed in 1899	1,135

Duty of water under Middle Creek Canal, 1899.

Area irrigated	acres	3,853
Discharge of canal	acre-feet	8,074
Depth of irrigation	feet	2.10
Depth of rainfall, May 1 to September 30	do	.46
Total depth of water received by crops	do	2.56

The data given in connection with the eight field experiments showed that the average duty was 1.2 acre-feet. Considering the entire canal, the duty is 2.1 acre-feet. The reason for this difference will be better understood after noting in what follows the excessive loss due to seepage in the main canal.

LOSS DUE TO SEEPAGE IN MIDDLE CREEK CANAL.

This canal was located by means of the pioneer ditch level shown in fig. 16 and built without competent supervision. In working with so crude an instrument anything approaching accuracy was impossible, and since too little fall was considered fatal to the canal, the errors were usually placed on the side of safety. So one often finds that a ditch which was intended to be laid out on a grade of ½ inch to the rod, or 13.5 feet to the mile, approaches more nearly 1 inch to the rod, or 26⅔ feet per mile.

Whether intentionally or not, Middle Creek Canal, like most of those of an early date, was built with too great a fall. The grade near the head is about 1 foot per hundred, or 52 feet per mile. No levels were taken of the lower portion, but it is believed that the average grade of the main canal—4 miles in length—is 35 feet to the mile, or about four times greater than it should be in a properly located and constructed canal of the same carrying capacity.

The formation for a mile or more below the headgates consists of sand, gravel, cobblestone, and bowlders. On a proper grade, sufficient to create a mean velocity of 2.75 feet per second, the sediment borne by the rapidly moving water in Middle Creek would have been deposited on the bottom of the canal and rendered it in time nearly impervious. Under existing conditions the deposition of sediment is impossible owing to the high velocity, and practically the same conditions have existed during the life of the canal, a period of twenty-eight years.

Soon after the canal was excavated the finer particles of soil, sand, and gravel within the water area of the channel were carried away, leaving a bed of cleanly washed cobblestones. This is true of the upper portion of the canal, but the formation changes in the second mile to a clay soil and subsoil with gravel and cobblestone beneath. In the lower 2 miles the seepage is small, except at gravel bars and

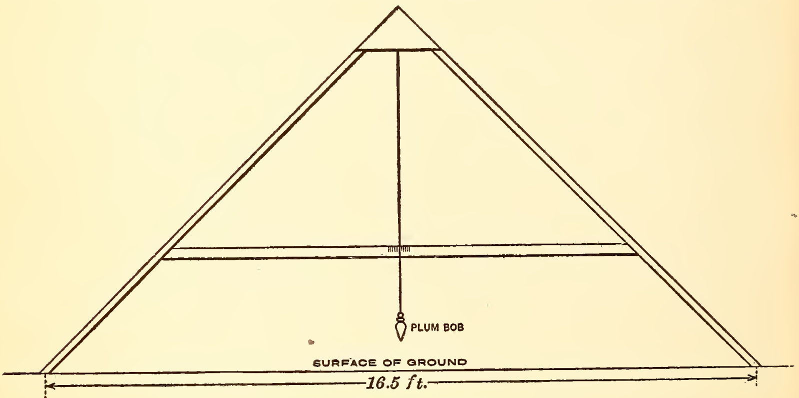


FIG. 16.—The pioneer ditch level.

where the high velocity has eroded the clay subsoil, thus exposing the rocky and porous substratum.

On July 10, 1899, when the flow of the canal was nearly at its highest point, the writer, aided by his assistant, Mr. Stanley Koch, determined by means of a complete series of ditch and canal measurements the loss due to seepage throughout the length of the main canal, a distance of 4 miles. The main canal was measured below the head-gate at the rating flume on the morning of July 10, and during the day a complete series of measurements was made of all the laterals and branches diverting water therefrom. The results are summarized in the accompanying table.

Losses due to seepage in Middle Creek Canal.

	Discharge.	Discharge.
	Cubic feet per second.	*Cubic feet per second.*
Main canal at rating flume		98.90
No. 1 lateral	3.72	
No. 2 lateral	Dry.	
No. 3 lateral	2.46	
No. 4 lateral	1.75	
No. 5 lateral	5.26	
No. 6 lateral	.52	
No. 7 lateral	6.06	
No. 8 lateral	4.85	
No. 9 lateral	9.98	
No. 10 lateral	.41	
No. 11 lateral	1.77	
No. 12 lateral	11.52	
No. 13 lateral	2.11	
No. 14 lateral	4.83	
No. 15 lateral	9.95	
No. 16 lateral	12.21	77.40
Loss in seepage in 4 miles		21.50

An examination of the table shows that 98.9 cubic feet per second passed through the rating flume, and that the aggregate flow of all the laterals and branches amounted to only 77.4 cubic feet per second, thus leaving 21.5 cubic feet per second unaccounted for. Since the loss due to evaporation would be quite small, probably not more than the one-hundredth part of a cubic foot per second, it is safe to assert that 21.5 cubic feet per second seeped through the porous channel of the canal.

In a canal of like capacity located and built under the direction of a competent hydraulic engineer the loss due to percolation after 28 years of operation should not exceed 1.5 cubic feet per second. In the case under consideration, therefore, the penalty annually paid for faulty design and bad construction is the loss of 20 per cent of the entire water supply.

This waste water if utilized would not only increase the irrigated area under Middle Creek Canal 20 per cent, but it would also redeem extensive tracts that are being made unproductive on account of too much water. Seepage water from canals invariably rises in places where it is not needed and results either in reducing fertile tracts of arable land to alkaline wastes or compels the proprietor to expend the greater part of the price of good land in providing drainage.

The cost of fluming the upper portion of the canal would be prohibitory. Cement or other lining in this region of severe frost and winter thaws would be impracticable. Clay puddle would be washed out by the rapidly moving water. About the only feasible remedy is either a new canal, well puddled with clay and gravel, or the placing of combined checks and vertical falls in the present canal.

From a business standpoint it would pay the stockholders of the canal to expend a considerable sum in reducing, if not preventing, the present waste. The summer use of a cubic foot per second of water for irrigation purposes is worth at least $30; the damage to land by the same quantity of water being wasted may be roughly estimated at $20 more, or $50 in all. Now as there are 20 cubic feet per second wasted, the total loss is $1,000 per annum, or, considering money worth 8 per cent, the expenditure of $12,500 would be justifiable in preventing the loss of 20 cubic feet per second of water.

CONDITIONS AFFECTING THE DUTY OF WATER IN MONTANA.

METHOD OF DISTRIBUTION.

Throughout Montana the waters of a creek or canal are usually divided among the respective claimants or shareholders, in continuous streams, in proportion to the recognized rights of each owner. Were it not for the large farms of this State a division by constant flow would be impracticable. It is wasteful of water as it is, and if the distribution by time as practiced in Utah and southern California were better understood by the Montana irrigators it would be speedily adopted in many sections.

A Utah farmer who owns but 20 acres can not well irrigate his farm by means of a continuous stream. Only 10 miner's inches flowing through his division box may require as many days to flow over 20 acres. Whereas if he can get 50 inches for two days he will not only water his farm more uniformly but save the labor of eight days.

By the census of 1890 the average size of the Montana irrigated farm was 95 acres, or nearly four times as large as that of Utah. If the water supply be abundant, little objection can be raised to the use of a continuous stream for 160 acres, because the allotment for this area would be as much water as one man could handle. In seasons of scarcity, and for farms that are 80 acres or less, a constant flow is not economical of either water or labor. Under such circumstances the division should be made for stated periods, or by the time method, by which each irrigator would have a large flow, say, twice a week, instead of a small flow daily. The day is not far distant when the farms that are now 160, 240, and 320 acres in extent will be subdivided into 80-acre farms, and when that time comes the division of water by time will be the rule and not the exception.

DIVERSIFIED FARMING.

Water can not be economically used on farms that produce only grain crops. This is true of both large and small holdings. While irrigation lasts the volumes applied are large and the time limited. Ten days may suffice to water a grain crop. It is thus evident there is a great loss to him who can make use of his share of a creek or canal during only one-fourth or perhaps one-sixth of the irrigation period. So long as Montana irrigators continue to seed the greater part of their farms to barley, oats, and wheat, as is now done in the Gallatin

Valley, they can not hope to make the most of their available water supply. All the cereals named require to be irrigated at nearly the same time. In many cases seven days' delay after the right time has come will materially reduce the yield. A shareholder can not, therefore, without incurring damage, allow others to use all the water during the first two weeks of July for the privilege of having his share during the third week. The extent of land seeded to grains under any particular stream or canal must not exceed that which can be watered simultaneously.

The writer has no desire to attempt to instruct the farmers of this State in the kinds of crops to raise. That is their business. If, however, the same profits could be made from diversified farming, the area now watered in many parts might be increased by one-half.

On an 80-acre farm as now cultivated in the Gallatin Valley one may find 40 acres in grain, 10 acres in meadow, 20 acres summer fallowed, and the remainder in pasture, or occupied by buildings. In this case only 50 out of 70 arable acres are productive, and the bulk of the water required is used from July 4 to 15. Now, in more diversified farming the acreage and kinds of crops might be as follows: 22 in grain, 15 in red clover or alsike, 10 in alfalfa, 10 in timothy, 8 in potatoes, 3 in mangel-wurzels, and 2 acres in garden, or 70 acres in all.

In the latter case the value of the yield is easily double that of the former, and by exercising good judgment an equal allotment of water if used for a longer period would suffice. On the farm producing chiefly grain the irrigation period may be only twenty days, whereas on the diversified farm water may be used over a period of fifty days.

LOSS DUE TO SEEPAGE IN CONVEYING WATER.

We have just seen that the loss due to seepage in the upper four miles of Middle Creek Canal is nearly 22 per cent of the total flow. It is reasonable to conclude that the corresponding loss in the main branches and canal laterals is 15 per cent more, making 35 per cent in all. It is thus seen that the duty of water for a particular field or crop is not identical with that for a canal, since the amount of water applied depends on the place of measurement.

In regard to the percentage of loss, Middle Creek Canal and its branches are not different from hundreds of canals now being operated in this State. For every 100 cubic feet per second diverted, it is quite probable that not more than 60 cubic feet per second ever reach the fields of the irrigators. To corroborate this statement, the percentages of loss in the upper portions of a few canals in the State of Utah, as determined by the writer in 1893, are herewith given. In the case of the first named, the distance included the whole length of the main canal. Ten years prior to the time the test was made the loss was 50 per cent in the main canal, but owing to the deposition of sediment the seepage had decreased more than one-half in that period.

Losses by seepage from canals in Utah.

Name of canal.	Discharge.	Loss.	Distance.
	Cubic feet per second.	*Per cent.*	*Miles.*
Utah and Salt Lake Canal	185.0	22	28
Davis and Weber Counties Canal	105.5	26	10
Logan, Hyde Park and Smithfield Canal	48.0	44	1.5
Bear River Canal	71.2	6.7	5
Ogden Bench Canal	11.5	18	1.5

GRADING THE SURFACE OF THE FIELDS.

To irrigate land that has an uneven surface and an irregular grade results in a needless waste of water, additional labor, small crops, and eventually a deteriorated soil. In irrigating by flooding between small field laterals, a method commonly practiced in Rocky Mountain States, the surface of the land between any two laterals requires to be fairly even and of uniform grade; otherwise the water as it spreads from the higher lateral will run into the low places only and leave the high places untouched. The injurious effects of applying too much water to some portions of the field and none to other portions are soon apparent. To use the irrigator's expression, the crop of the high ground becomes "burnt," that on the low ground "water-logged."

In trying to prevent injury to the crop on fields that are uneven, the irrigator frequently performs double and treble the labor that would be required under more favorable conditions. With the utmost care, it is seldom possible to obtain a good crop. The yield on the dry places is not only lessened, but its time of ripening is hastened. In autumn it is not uncommon to see fields that look like a chessboard, yellow and green in alternate patches. The first to mature shells out in reaping, and the last, in the high altitudes of this State, is apt to be affected by frosts. In order to have a crop of uniform quality throughout, the irrigating water must be evenly applied over the entire surface, but this can not be done unless the surface is graded. Western farmers are beginning to realize that it pays to level the surface. This knowledge has been acquired by costly experience. It is to be hoped that the lesson thus taught will not soon be forgotten.

Until recent years, the implements used to grade the surface were either mere makeshifts, or else were designed for work of an entirely different character. The V-shaped leveler made of planks or timbers, and loaded with rocks in the center, serves the double purpose of crushing the sods and leveling the surface. It has, however, but one good feature to recommend it, and that is its low cost.

The ordinary scraper or railroad slip has also been extensively used. If the object to be attained were the removal of earth from one place to another less than 150 feet distant, the scraper would be effective. As a rule it is better adapted to digging holes than it is to making rough places smooth. These objections hold true for the ordinary two-wheeled scraper, as well as the Fresno scraper, although the latter, having a longer blade, is to be preferred. Many irrigators have also made use of the various kinds of road graders, but the larger implements are too unwieldy. The two-wheeled four-horse road grader is the most serviceable for grading land.

On the Montana Experiment Station farm considerable land leveling was formerly done with the Shuart grader. This device consists of a steel blade 5 feet 6 inches long and 15 inches deep, supported on a frame, and is raised and lowered by a lever. The frame, which is about 6 feet square, rests in front on a pair of short steel-shod runners and in the rear on two 20-inch iron wheels. Very effective work can be done with this small implement in the way of removing earth from the high to the low places. It has, however, two serious defects. The cutting blade is short, and the grader when in operation has often a rocking motion in the direction in which the team is moving, which leaves the surface undulated rather than level.

THOROUGH CULTIVATION.

Thorough cultivation is considered necessary in good farming in humid countries. The needs of the cultivated plants require a finely pulverized soil. To a greater extent is this true in an arid region like Western America. Here surface cultivation serves a double purpose. It not only renders the plant food of the soil available, but, by preventing evaporation, retains the moisture in the soil. To the Western irrigator a soil mulch two or three inches deep over his cultivated fields is as essential as asbestos covering on the steam pipes of the mechanical engineer. It is a grave mistake to conclude that the artificial application of water to soil can take the place of cultivation. In applying large quantities of water by the flooding system in a careless manner, one is apt to make a paste of the top soil. When this is done, in less than sixty hours the moisture in this top layer may be evaporated, leaving it hard and baked. Under such conditions it is astonishing how rapidly the soil moisture is converted into vapor. If this process is long continued there will be found little moisture within a foot of the surface, the crops begin to suffer for lack of moisture, and the unskilled irrigator, ignorant of the real cause, applies more water in the same careless manner. Now, in many cases this second watering following so closely after the first might have been wholly unnecessary if the proper means had been used to prevent the baking of the top layer of soil and the consequent excessive evaporation.

METHODS ADOPTED IN IRRIGATING.

The duty of water depends to a large extent on the skill and appliances of the irrigator. Attention has already been directed to the need of a covering of soil mulch to lessen the evaporation, as well as a smooth, well-graded surface over which water can readily flow. We have now to consider the equally important features of the location of the furrows, or field laterals, and the best manner of conducting the water flowing therein to the roots of the growing crops.

Much depends on the proper location of farm laterals. The intelligent farmer, who cultivates and irrigates for years the same 80 or 160 acre tract, learns by experience what he terms the "lay of the land." He has learned the right direction for his laterals, or ditches, their proper distances apart, and how to locate them so as to cover the high places with water. The beginner learns by the mistakes he makes. A common mistake is to run the laterals in the direction of the greatest slope and to have them too far apart. A better way, as a general rule, is to locate the laterals as near as practicable, consistent with a grade of from one-half to 1 inch to the rod, at right angles to the steepest slope, in which case the water will flow and spread without trouble from each lateral.

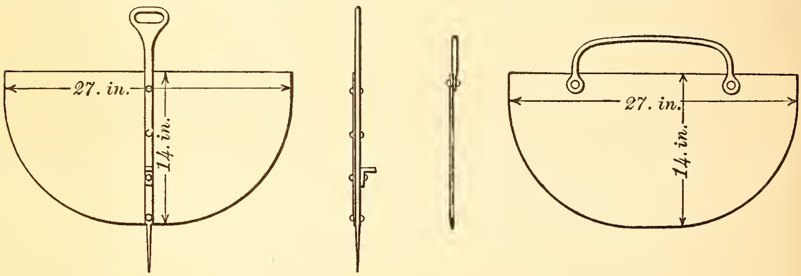


FIG. 17.—Two forms of the steel dam.

The inexperienced farmer also frequently attempts to force the water over too great distances. His plow furrows, or laterals, instead of being from 50 to 100 feet apart, may be three times those distances, and in irrigating with a small flow it is difficult to cover with water all the intervening space.

In this locality, when the laterals have been made in the grain fields with a ditch plow, it is customary to run over them with an implement called a "dammer" (Pl. XLIV, fig. 1) drawn by one horse. It consists of a large shovel attached to handles resembling those of a plow. As the horse travels, the shovel collects the loose dirt in the bottom of the double furrow and when the driver raises the handles it is deposited in a heap to form a dam. These dams are spaced from 40 to 75 feet apart, depending somewhat on the slope of the lateral. The object of these earth dams in laterals is to hold back the water and permit it to overflow the lower bank. This being accomplished, the dam is broken and the unused portion of the water, together with the flow of the irrigation stream, is temporarily checked by the next lower earth dam. In the clover and timothy fields of the Gallatin Valley little piles of manure are placed in the laterals for the same

FIG. 1.—USING THE DITCH PLOW IN MONTANA.

FIG. 2.—FURROW IRRIGATION OF SUGAR BEETS IN MONTANA.

purpose. These manure dams are not water-tight, but they are made so for a short time by covering their upstream face with about 2 inches of earth. The canvas dam, so much used in other States, is seldom seen in Montana. The irrigators here prefer the steel dams shown in fig. 17.

In the judgment of the writer much water is allowed to run to waste in this State by locating the field laterals on inclines too steep. In the sketch of a clover field shown in fig. 15, p. 177, the grade of some of the laterals as shown by the contour lines is about 80 feet per mile. Nor is this an extreme case. The conditions in this case are representative of the best practice in this locality at the present time. The farm ditches under the West Gallatin Irrigation Company's Canal frequently have a fall of 150 feet per mile. In irrigating from steep laterals more dams are required and the water is all distributed from one point, whereas, on medium slopes, it may be distributed from several points between dams.

THE PERIOD OF GREATEST RAINFALL IN MONTANA.

In this State the heavy rains of May and June are a good substitute for one artificial watering. This precipitation, coming as it does at the beginning of the crop-growing season, increases the duty of water by lessening the quantity required. In the States of Nevada, Utah, Idaho, and Arizona little rain falls between the times of seeding and harvesting, and this deficiency must be made up by irrigation. Colorado, Montana, and Wyoming are more favored, in that a large percentage of the annual precipitation of these States falls during the months of May, June, July, and August.

The normal or average precipitation up to and including the year 1897, for the months of May and June, as compared to the normal yearly precipitation, is herewith given, as found at some of the principal Weather Bureau stations of this State.

Proportion of rainfall in May and June at Montana stations.

Station.	Precipitation for May and June.	Yearly precipitation.
	Inches.	*Inches.*
Virginia City, Mont	5.27	15.12
Fort Logan, Mont	4.69	13.83
Helena, Mont	4.00	13.46
Bozeman, Mont	5.25	20.05

FARM CROPS UNDER IRRIGATION IN GALLATIN VALLEY.

Gallatin Valley has long been recognized as one of the most productive sections in the United States. It is true the average yields are greater in other localities, but this fact is readily accounted for.

The Gallatin Valley farms are large. From statistics collected by the Montana Experiment Station in 1893 the average size of farms in Gallatin County was 196 acres. It is not uncommon, therefore, for one farmer to cultivate and irrigate 200 acres of land. Such being the case, it is impossible to give that close attention to details in properly cultivating and irrigating the soil that one would look for on a well-tilled farm of 20 acres.

The low average yield on a big farm is chiefly due to careless and overhasty irrigation. There is often a difficulty and sometimes a disinclination on the part of the proprietor to engage a sufficient number of irrigators. Experienced irrigators are also a necessity. Even with skilled help results are not always satisfactory.

The prevalent custom throughout the Gallatin Valley during the time of irrigating is to control and guide the course of the irrigating stream during daylight and permit it to run "wild," or without attention, during the night. This slovenly custom is a direct result of large farms and insufficient help and has been practiced so long that it is now difficult to abandon it.

Many a farmer has the yield reduced one-third through carelessness, or inattention, in not applying water at the right time, or in the proper manner. In this way the average yield is not only decreased, but a large percentage of the land is being rendered unproductive by the presence of too much water. It is unreasonable to suppose that each farmer may allow 80 miner's inches of water to flow at random over his field every night, while water is being used, and not damage either his own or his neighbor's land.

On good soil, where the defects named are remedied, the returns are unusually large. Last fall a Mr. Arnold obtained on an average 84 bushels of barley for each acre seeded. Another year a Mr. Gouch's large field of oats averaged over 100 bushels per acre. Sixty-five bushels of wheat to the acre are not uncommon. And so numerous other examples might be cited of large yields, but as there is seldom any opportunity given to investigators to verify the reports, they are of comparatively little value.

Herewith is presented, however, reliable statistics obtained through the courtesy of Prof. R. S. Shaw, agriculturist of the Montana Experiment Station, of crops raised under his direction and supervision during the past season. It is questionable if Professor Shaw's results can be duplicated east of the Missouri River. The straw and grain were accurately weighed, and the areas were obtained not by measuring the actual surface of each plat, but by ascertaining its area as a part of a large field.

The dates of applying water are given in each case, as well as those of seedtime and harvest time, an important consideration in an irrigated region located so far north:

Barleys grown at the Montana Experiment Station, 1899.

No.	Name of variety.	Period of growth.			Date irrigated.		Yield per acre.	
		Seeded.	Harvested.	Days to mature.	First irrigation.	Second irrigation.	Straw.	Grain.
							Pounds.	*Bushels.*
1	Goldenthorpe	May 19	Sept. 15	119	July 3	July 25	3,030	68.1
2	Black Hulless	....do...	Aug. 28	101	....do...	....do...	2,580	62.5
3	Highland Scotch	....do...	Sept. 8	112	....do...	....do...	3,930	60.6
4	Guy Male	....do...	Aug. 28	101	....do...	....do...	2,610	60.6
5	Manshury	....do...	....do...	101	....do...	....do...	4,500	58.7
6	New Zealand	....do...	Sept. 15	119	....do...	....do...	3,660	58.7
7	Manshury	....do...	Sept. 8	112	....do...	....do...	3,150	56.8
8	Italian	....do...	Sept. 2	106	....do...	....do...	3,360	56.2
9	Smooth Hulless	....do...	Aug. 28	101	....do...	....do...	3,090	55.6
10	New White Hulless	....do...	Sept. 1	105	....do...	....do...	2,940	55.0
11	Winnipeg	....do...	Aug. 28	101	....do...	....do...	2,940	53.7
12	Imp. Cheyenne	....do...	Sept. 6	110	....do...	....do...	4,110	53.1
13	King 9-10	....do...	Aug. 28	101	....do...	....do...	3,270	57.8
14	Manhattan	....do...	Sept. 4	108	....do...	....do...	4,770	50.6
15	Chevalier	....do...	Sept. 1	105	....do...	....do...	3,420	48.7

NOTE.—First fifteen out of a list of twenty-five.

Oats grown at the Montana Experiment Station, 1899.

No.	Name of variety.	Period of growth.			Date irrigated.		Yield per acre.	
		Seeded.	Harvested.	Days to mature.	First irrigation.	Second irrigation.	Straw.	Grain.
							Pounds.	*Bushels.*
1	Russian 2788	May 18	Sept. 15	120	July 3	July 25	4,740	107.6
2	Canadian White	May 17	Sept. 17	123	....do...	....do...	5,190	92.6
3	White Swede	....do...	....do...	123	....do...	....do...	3,300	91.7
4	American Beauty	May 18	Sept. 15	120	....do...	....do...	3,780	86.4
5	Archangel	May 17	....do...	121	....do...	....do...	4,050	85.5
6	Great Northern	....do...	....do...	121	....do...	....do...	4,470	85.5
7	Nameless Beauty	....do...	Sept. 14	120	....do...	....do...	3,360	84.7
8	Giant Yellow	....do...	Sept. 18	124	....do...	....do...	4,080	84.7
9	White Danish	May 18	Sept. 15	120	....do...	....do...	3,450	83.8
10	Siberian (15)	May 17	....do...	121	....do...	....do...	3,480	82.9
11	Black Tartarian	....do...	Sept. 17	123	....do...	....do...	3,780	82.9
12	Victoria	May 16	Sept. 10	117	....do...	....do...	3,660	79.4
13	Poland White	....do...	Sept. 9	123	....do...	....do...	3,000	79.4
14	Giant Yellow	May 18	Sept. 15	120	....do...	....do...	3,570	78.5
15	Nebraska	May 16	....do...	122	....do...	....do...	....	77.6

NOTE.—First fifteen out of a list of forty-eight.

Spring wheats grown at the Montana Experiment Station, 1899.

No.	Name of variety.	Period of growth.			Date irrigated.		Yield per acre.	
		Seeded.	Harvested.	Days to mature.	First irrigation.	Second irrigation.	Straw.	Grain.
							Pounds.	*Bushels.*
1	Onyx	May 12	Sept. 22	133	July 5	July 26	4,650	74.5
2	Opal	....do...	....do...	133	....do...	....do...	4,440	73.0
3	Amethyst	....do...	....do...	133	....do...	....do...	6,870	67.5
4	Bordeau N. M. 472	....do...	....do...	133	....do...	....do...	7,680	64.0
5	Black-Bearded Centennial.	....do...	....do...	133	....do...	....do...	5,040	64.0
6	Gneiss	....do...	....do...	133	....do...	....do...	4,710	63.5
7	Nose B	....do...	....do...	133	....do...	....do...	5,400	59.0
8	Gypsum	....do...	....do...	133	....do...	....do...	5,490	58.0
9	Chili	....do...	....do...	133	....do...	....do...	4,260	56.0
10	Ladoga	May 13	Sept. 5	116	....do...	....do...	3,570	53.5
11	Glyndous 676	May 12	Sept. 22	133	....do...	....do...	4,980	49.0
12	Glyndous 661	....do...	....do...	133	....do...	....do...	5,460	49.0
13	Imp. Russian R 6, P 1	May 13	Sept. 15	126	....do...	....do...	5,460	49.0
14	Glyndous 692	May 12	Sept. 22	133	....do...	....do...	5,100	48.0
15	Hungarian Mountain	May 13	Sept. 16	127	....do...	....do...	3,180	48.0

NOTE.—First fifteen out of a list of sixty-seven.

Results of potato experiments, Montana Experiment Station, 1899.

No.	Name of variety.	Period of growth.		Date irrigated.		Yield per acre.	
		Planted.	Harvested.	First irrigation.	Second irrigation.	Total.	Marketable.
						Bushels.	*Per cent.*
1	Montana Beauty	May 25	Oct. 6 and 7	July 5	July 22	699.3	80.4
2	Rural New Yorker No. 2	do	do	do	do	698.4	90.8
3	Beauty of Hebron	do	do	do	do	961.8	70.2
4	Winters White	do	do	do	do	860.3	79.7
5	Rural Blush	do	do	do	do	821.6	98.4
6	White Elephant	do	do	do	do	821.6	63.5
7	Irish Daisy	do	do	do	do	792.6	78.6
8	White Star	do	do	do	do	773.3	68.7
9	Charles Downing	do	do	do	do	768.5	74.8
10	New Queen	do	do	do	do	758.8	77.0
11	Unknown	do	do	do	do	739.5	90.6
12	Jennie	do	do	do	do	729.8	70.8
13	Lee Favorite	do	do	do	do	729.8	93.0
14	Early Telephone	do	do	do	do	705.6	77.6
15	Crown Jewel	do	do	do	do	696.0	45.1

NOTE.—First fifteen out of a list of sixty-four.

UTAH.

DUTY OF WATER ON BIG COTTONWOOD CREEK.

By Special Agent R. C. Gemmell,
State Engineer of Utah.

Big Cottonwood Creek is a beautiful mountain stream, rising in the heart of the Wasatch Mountains, about 20 miles southeast of Salt Lake City, and having a drainage area of about 48.5 square miles. At its head are a number of small picturesque lakes, situated at an elevation of from 8,500 to 10,000 feet above sea level. Some of these lakes have been segregated by the United States for reservoir sites, viz, Silver Lake, Twin Lakes, and Marys Lake. From its source this stream flows about 12 miles in a general westerly direction, through a rugged, magnificent canyon, at the mouth of which the first irrigation ditches are taken out; thence it flows in a general northwesterly direction about 10 miles to its junction with the Jordan River. The lands irrigated by the water diverted from this stream are at an elevation of from 4,250 to 5,000 feet above sea level.

CANALS AND DITCHES.

The location of canals and ditches diverting water from Big Cottonwood Creek, and of the lands irrigated, is shown on map accompanying this report. (Pl. XLV.) Cross sections and grades of the various canals and ditches are shown on Plate XLVI. None of these canals and ditches, except the Upper Canal, were surveyed or constructed by an engineer, and there is no regularity or uniformity in their cross sections or grades. Frequently the principal instrument used in laying out the ditches was a plow. Starting at the stream, a furrow would be plowed, following as nearly as possible a grade contour. After a short length of furrow had been plowed, water would be turned in from the creek. If the water ran to the lower end of the furrow it was assumed that the grade was all right, and the furrow was continued. If the water would not run the full length of the furrow, it was easy to locate and cut down the high points. In some instances an attempt to have a uniform grade line was made by setting grade pegs with a triangle and plumb bob, or with a carpenter's level and straightedge, and the ditches were supposed to have certain bottom widths. As a matter of fact, however, the cross section and grade of any given ditch varies between rather wide limits, as may readily be imagined from the methods of construction.

HISTORY OF ARBITRATION.

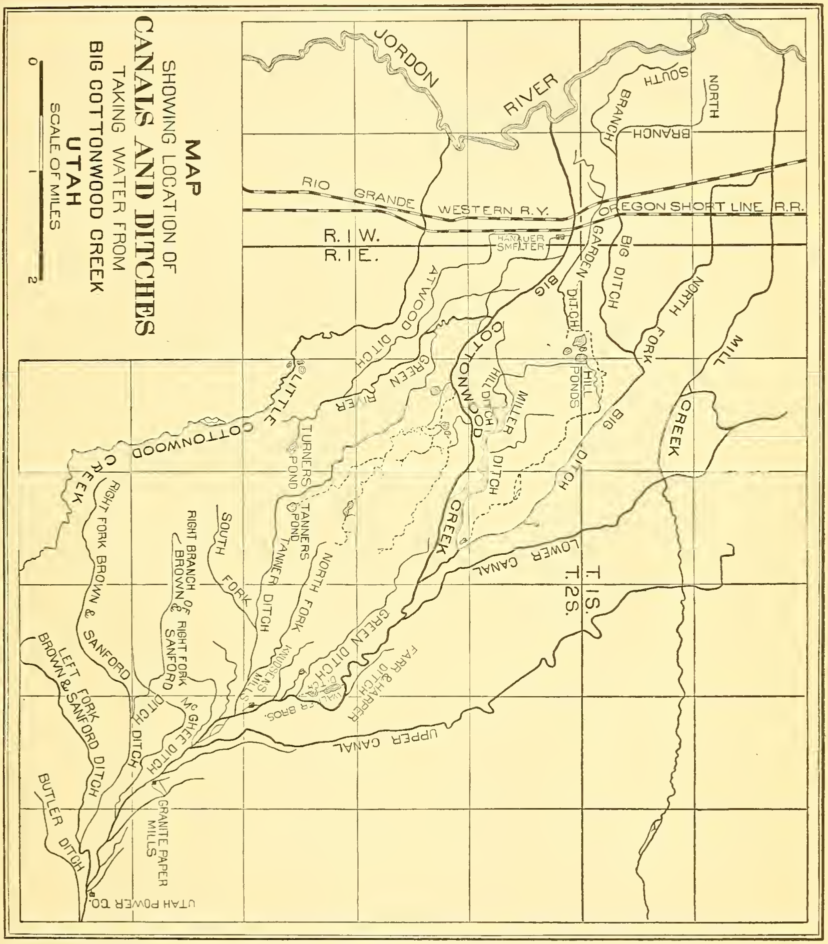
On September 13, 1879, the district court of the Territory of Utah appointed Joseph S. Rawlins, Reuben Miller, and D. B. Brinton, after they had previously been chosen by the water owners of Big Cottonwood Creek, a board of arbitrators to adjust all claims to the water of said creek and report its findings to said district court. This board, for convenience, divided the creek into 60 parts. One part would entitle its owner to irrigate 127.25 acres during time of low water. Each part, or share, was taken to mean one-sixtieth of the waters flowing in the creek at the highest point thereon where water is diverted by any of the canals or ditches mentioned in said agreement for arbitration. Only those holding primary rights were allotted shares during low-water season. The board classified the different canals and ditches, and parts, or shares, were allotted as follows:

Division of the water of Big Cottonwood Creek.

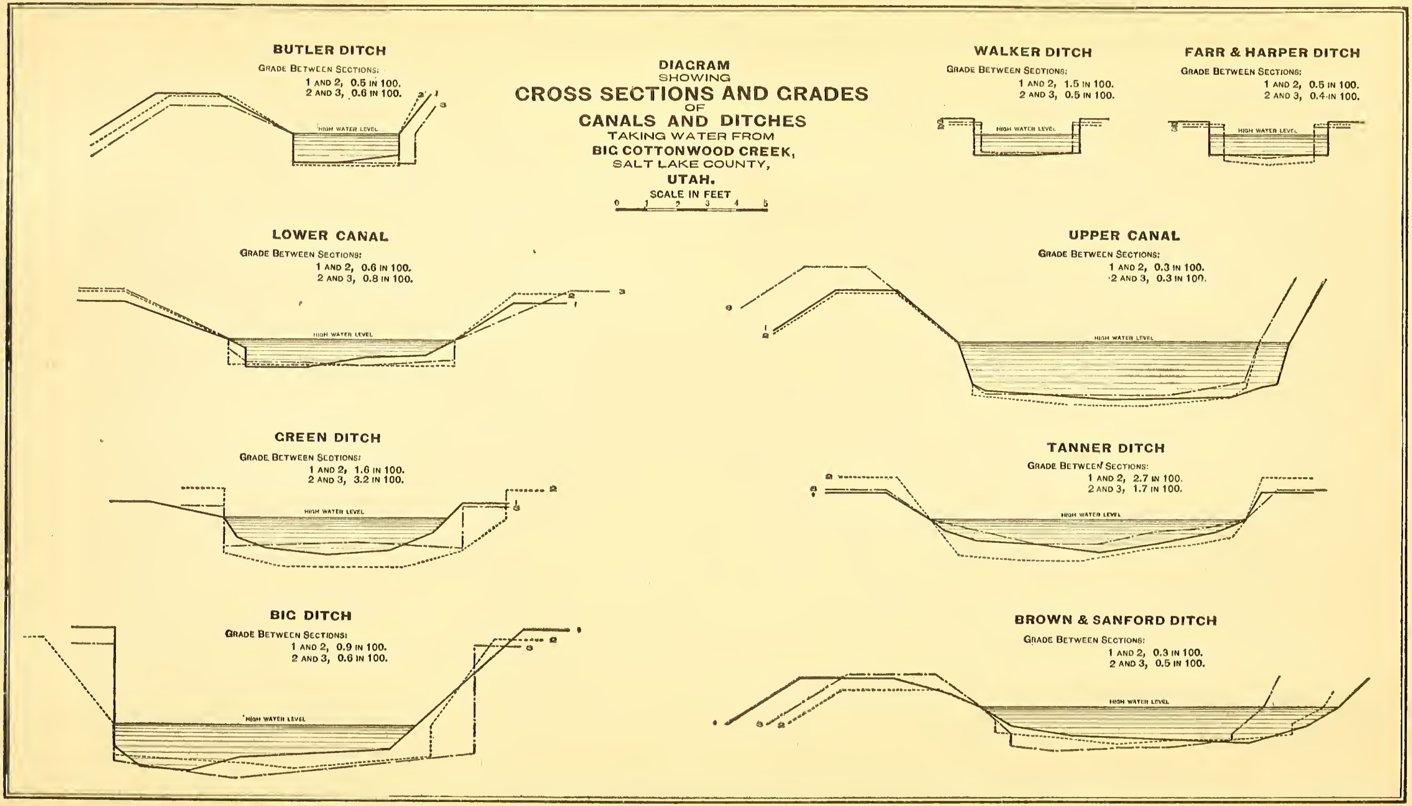
Class.	Name of ditch.	Number of parts.	
		January 1 to July 1.	July 1 to January 1.
1	Butler Ditch	0.5	0.2
2	Brown & Sanford Ditch	4.5	2.1
3	Upper Canal	10.5	10.2
4	Tanner Ditch	12.6	12.9
5	Green Ditch	3.5	3.8
6	Farr & Harper Ditch	.6	.6
7	Lower Canal	5.6	6.1
8	Big Ditch	19.6	21.3
9	Hill Ditch	2.6	2.8
	Total	60.0	60.0

A formal printed report showing the results of the action of the board of arbitration was made to the district court, and was properly filed. Each owner of a primary right in the stream was served with a written or printed notice of the arbitration, and a time was set by the court for hearing objections to said arbitration. No one appeared or objected, and the judgment of the court was rendered in accordance with the terms of the arbitration.

Nearly all of the owners of primary water rights appeared before the board of arbitrators and signed, under oath, an agreement to accept the division made by the board as binding and final. This agreement was properly filed with the district court, but has since disappeared and can not now be found. There were a few who did not sign this agreement, notably the Walker Brothers and a few owners on the Green Ditch. Others now claim that they did not sign the agreement,



MAP SHOWING THE LOCATION OF CANALS AND DITCHES TAKING WATER FROM BIG COTTONWOOD CREEK, UTAH.



CROSS SECTIONS OF CANALS TAKING WATER FROM BIG COTTONWOOD CREEK, UTAH.

but the records of the proceedings of the board of arbitrators show that they did.

The division made by this board of arbitrators is supposed to be the basis upon which the water is divided, and is considered binding by all of the owners of primary rights, although those on the Green Ditch and part of the Tanner Ditch claim more water than was allotted to them by the board. As a matter of fact, the upper canals have always had more than their allotments and some of the lower canals less.

The following table shows the quantities of water actually diverted by six of the canals and ditches, together with the quantity that would have been diverted by each canal if the total quantity of water had been divided in accordance with the allotments of the board of arbitrators. During the season of 1899 there was an unusually large amount of water flowing in the creek, and, as there was an abundance of water for all, very little attention was paid to the manner of dividing it.

Table showing the quantity of water actually diverted by each canal during the irrigating season of 1899, together with the quantity that would have been diverted if the water had been divided in accordance with the allotments of the board of arbitrators.

[Flow given in cubic feet per second.]

Month.	Butler Ditch.		Brown & Sanford.		Upper Canal.		Green Ditch.		Lower Canal.		Big Ditch.	
	Allotted.	Diverted.	Allotted.	Diverted.	Allotted.	Diverted.	Allotted.	Diverted.	Allotted.	Diverted.	Allotted.	Diverted.
April	0.75	1.50	6.68	8.60	15.59	19.60	5.20	6.28	8.32	6.72	29.11	22.95
May	1.17	2.35	10.57	21.65	24.67	36.00	8.22	8.30	13.16	8.20	46.06	26.85
June	1.67	4.39	15.00	34.62	35.00	52.87	11.66	12.41	18.67	10.72	65.33	35.24
July	.51	3.73	5.31	25.24	25.77	44.08	9.60	4.45	15.41	6.91	53.83	28.02
August	.23	.93	2.40	6.84	11.72	15.13	4.36	8.38	7.00	4.90	24.48	14.01
September	.15	.49	1.58	4.32	7.70	10.06	2.87	7.63	4.60	2.11	16.07	8.36

The Big Ditch. Lower Canal, and Hill Ditch, being the last on the creek, claim that they have never received the amounts allotted by arbitration. As a water master on one of the upper canals naively remarked: "In high water they can't take it, and in low water they never get it. We take what we want and let them have the balance."

This division by arbitration was contested by suit in the third district court in 1891 and 1892 by the owners of the Green Ditch. In this suit they got judgment for enough water to irrigate 400 acres. Under this judgment they have usually taken all the water they needed, except at short intervals when the owners of the Big Ditch would shut off part of the water flowing into the Green Ditch and turn it down the creek.

It would seem that the root of all the trouble was the method pursued by the board of arbitration in making the division. It appears that the board did not make any measurements of lands irrigated under each ditch. It simply called upon owners of primary rights to state under oath for how many acres they claimed water rights. The acreage was footed up for each ditch and the division made upon that basis. People owning primary rights turned in the acreage they thought they had. Afterwards, when surveyed, it was found in some cases that they had not turned in enough. For instance, the people on the Upper Canal now claim that their allotment was about 100 acres short. In the case of the Big Ditch, other canals claim that the stockholders in the Big Ditch, in order that they might receive a large allotment of water by the arbitration, turned in all the land they had in the district, whether it had been irrigated or not. In that way much wet pasture land is said to have been listed, which they did not irrigate before and have not since. Again, it is claimed that much of the land turned in by owners on the Big Ditch was, and always has been, irrigated from springs.

The whole matter of division of the water seems to be in a very unsatisfactory condition. So much so that the troubles will probably culminate in a lawsuit involving all of the rights on the creek.

WATER RIGHTS.

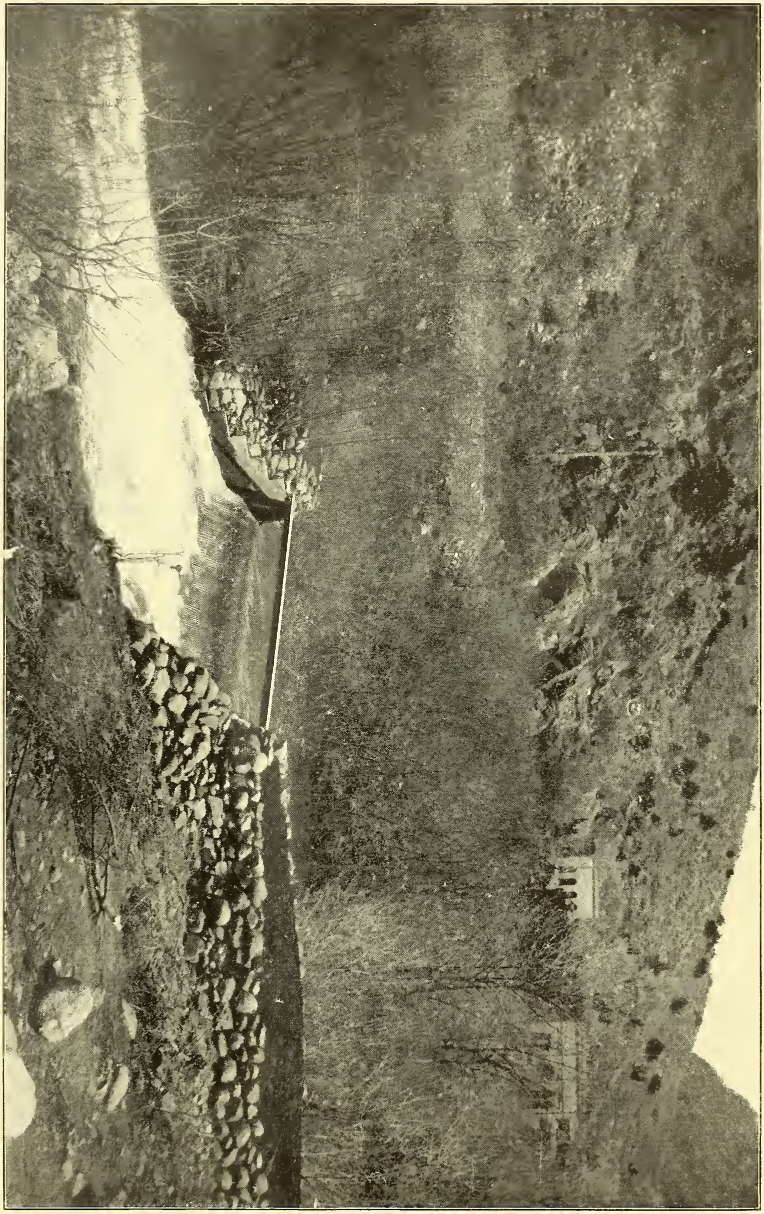
The records used in making distribution of the water are those kept by the water masters. The water master of each ditch keeps a record of all the rights under his ditch, which is generally conceded to be correct by the owners on that particular ditch, but not necessarily so by the owners on other ditches.

The water master on a ditch is elected by the owners of water rights in the ditch, who hold a meeting annually for that purpose. The county commissioners used to appoint the water masters, but the district court ruled that they should be elected annually by the farmers themselves.

The ownership of water rights is based mainly upon the records of the water masters, each owner being supposed to have a right to water a certain number of acres. A right does not mean any certain quantity of water, nor does it mean any certain portion of the water flowing in the creek. This is owing to the manner in which the water is divided.

In the spring when the creek rises the upper ditches are filled full, and kept full as long as possible. If they do not take too much no objection is made, but if they take so much that the lower ditches do not get all they want, then the owners of the latter call for a division. Some seasons when there is a wet spring a division of the water is not necessary until July 1. Other years when there is a dry spring it may be necessary to have a division as early as in April. Users of surplus water are generally shut off on July 1, but it depends upon the season—that is, when the water in the creek gets low.

When the division is made the water masters of all the canals and ditches owning primary rights meet at the lowest point on the creek



WEIR AT THE HEAD OF BIG COTTONWOOD CREEK, UTAH.

where water is diverted, and proceed upstream, measuring the width and depth of water flowing at the head of each canal as they go. In this way the number of "square inches" flowing into each canal is obtained. These are added together to obtain the total number of "square inches" diverted. Then the water masters usually proceed downstream, regulating the quantities of water diverted, so that each canal will have its proper number of "square inches," according to the shares allotted by the arbitration, although this rule is not always closely followed. This regulation of the water holds good until another division is called for. They realize that there is nothing accurate about this method of measurement, but have always made it in that way. The measurement was usually made over a board at the head of the canal. This year it was made over Cippoletti weirs (Pl. XLVII). A stream 100 inches wide and 5 inches deep would be 500 "inches," according to their method, and a stream 50 inches wide and 10 inches deep would also be 500 "inches." No allowance is made for differences in velocity in the various canals. The upper ditches take out their full number of "inches," and the lower ditches take what they can get.

The division of the water among the owners of any ditch is made by the water master. A description of the ownership and method of dividing the water on the Brown & Sanford Ditch will serve as an illustration.

Ownership in the water goes by shares or "rods," each rod representing that length of the main ditch built by the first owners. The water master kept track of the construction work, calculated the acreage to which different ones were entitled according to such work, and made out certificates for the same. Usually the farmers do not form a regular company, but simply club together and furnish labor for the construction of the main ditch. Water enters all the main branches by self-dividing gates, the widths being proportioned to the shares, no attempt being made to attain accuracy. During low water these branches usually take turn about in carrying the full flow allowed to the main ditch, as the water will go much farther by thus using a large head.

For the individual owners on each main branch there is an allotment to each of the full flow for a certain number of hours, beginning at the one nearest the head and following down in regular order. Usually seven and one-half days or one hundred and eighty hours is the period for one rotation, the watering then beginning at the head again. Each owner's gate is fixed so that he can take the full flow, and his water ticket shows the date and number of hours he is entitled to all of the water, so that he can at once divert it when his time begins, at which time the one above is to cease diverting it. Where there is harmony among the owners, all this is done without need of superintendence on the part of the water master, his main work being in making out the tickets of time for such distribution. The "rods" or shares are sometimes divided into quarters, and even smaller fractions, to suit the various holdings.

From what has been said it will be noted that it would not be easy to obtain a legally defined title to water on this stream, and that it would be impossible to determine how much water any given right represents.

STUDIES OF DUTY OF WATER IN 1899.

Instructions to measure the water diverted from Big Cottonwood Creek by canals and ditches were not received until about June 1, 1899. As soon as possible thereafter, Cippoletti trapezoidal weirs were put in the canals and ditches at points near the headgates, and the measurements were begun. It required considerable persuasion in some instances to obtain permission to put in the weirs. There has been more or less friction among the owners of the various canals and ditches, and some of them did not want the water measured at all. The owners of the Tanner Ditch would not allow a weir to be put in where all of the water they diverted could be measured. During part of the season they ran water from the creek through a small branch, turning it into their ditch at a point about 50 yards below the weir. At the time the weir was put in owners of other ditches said they would shut off this branch, claiming that the Tanner Ditch had no right to take water through it; but this was not done until the creek had fallen to low-water stage. The measurements made in the Tanner Ditch are, therefore, of little or no value. The weir on the Farr & Harper Ditch was torn out by the ditch owners after being in only one day, and arrangements were not completed for replacing it until early in July. Most of the water measured in the Walker Ditch was merely run through a fish pond, only a small portion of it being used for irrigating purposes.

The heads on the weirs were measured once a day with a hook gage. Probably the heads should have been measured at least twice a day, as there is generally a slight variation between morning and evening in the discharge of the creek. But as the weir measurements were made at all hours of the day, and not at any particular time for each ditch, it is believed that a fair average of the flow was obtained.

In order to calculate the duty of water it has been necessary to estimate the flow in the canals and ditches during April, May, and the early part of June. In doing this use has been made of gagings of the discharge of the creek. These gagings were made by Mr. F. C. Kelsey, city engineer of Salt Lake City, over a Cippoletti weir, the head being measured twice a day with a hook gage. The estimates of flow in canals and ditches during that part of the irrigating season when weir measurements were not taken have been thoughtfully and carefully made, and it is believed that they are pretty close to the truth. For reasons previously stated, no attempt has been made to calculate the duty of water under the Tanner, Farr & Harper, or Walker ditches.

The irrigating season usually begins about April 15 and ends about September 30. The date when irrigating is begun varies with the seasons; with a dry spring it may begin as early as April 1, and with a wet spring it may begin as late as May 1.

During the winter of 1898–99 there was an unusually heavy snowfall in the mountains on the drainage area tributary to this creek. For this reason there was an abundance of water for all ditches during the early part of the irrigating season, and it is believed that more water was taken out then than was needed, and that the duty of water was therefore lower than usual.

The following table shows the precipitation as recorded by the Weather Bureau at Salt Lake City:

Precipitation at Salt Lake City, Utah, October, 1898, to September, 1899.

Month.	Rainfall.	Above normal.	Below normal.
1898.	*Inches.*	*Inches.*	*Inches.*
October	1.57	0.03	
November	1.95	.59	
December	1.28		0.36
1899.			
January	.84		.60
February	2.98	1.70	
March	2.93	.90	
April	.81		1.40
May	2.59	.87	
June	.96	.17	
July	.42		.11
August	1.06	.34	
September			.23
Total	17.39	4.60	2.70

From the above table it will be noted that the precipitation from October, 1898, to March, 1899, inclusive, was 2.26 inches in excess of the normal; while during the irrigating season, from April to September, 1899, inclusive, it was 0.36 inch below the normal.

In order to make an intelligent comparison of the duty of water under the various canals it is necessary to know what kinds of lands were irrigated in each case. As a general statement it may be said that bench land requires about 50 per cent more water than bottom land.

BUTLER DITCH.

The acreage irrigated by the Butler Ditch is all sandy, gravelly bench land, requiring much water. The area irrigated under this ditch is 123.5 acres. The following table shows the daily use of water on lands under this ditch from April 15, when irrigation began, to

September 30, when irrigation closed. The flow from April 15 to June 8 is estimated, as previously explained:

Water used in irrigating lands under the Butler Ditch, 1899.

[See diagram, Pl. XIII, p. 74.]

Day.	April.	May.	June.	July.	August.	September.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1	....	4.6611	5.1570	9.5207	1.7851	0.7934
2	....	4.6611	5.1570	9.5207	1.7851	.7934
3	....	4.6611	5.1570	9.7190	2.7769	.5950
4	....	4.6611	5.1570	9.9174	5.5537	.7934
5	....	4.6611	5.1570	9.9174	6.1488	.5950
6	....	4.6611	5.1570	10.1157	5.5537	.5950
7	....	4.6611	5.1570	10.3140	4.3636	.7934
8	....	4.6611	5.1570	10.5124	3.1736	.9917
9	....	4.6611	5.1570	9.7190	1.9835	.7934
10	....	4.6611	5.9504	10.7107	1.9835	.9917
11	....	4.6611	6.7438	9.9174	1.7851	1.1901
12	....	4.6611	7.5372	10.7107	1.7851	1.1901
13	....	4.6611	8.3306	9.7190	2.3802	1.3884
14	....	4.6611	9.1240	11.9008	2.1818	1.3884
15	2.9752	4.6611	9.9174	7.5372	1.1901	1.1901
16	2.9752	4.6611	10.7107	12.4959	1.3884	.9917
17	2.9752	4.6611	11.1074	7.1405	1.1901	.7934
18	2.9752	4.6611	11.7025	5.5537	.9917	.9917
19	2.9752	4.6611	11.7025	6.3471	.7934	.7934
20	2.9752	4.6611	13.4876	4.1653	.5950	.7934
21	2.9752	4.6611	13.0909	3.5702	.5950	.9917
22	2.9752	4.6611	12.6942	3.7686	....	.9917
23	2.9752	4.6611	11.5041	3.9669	....	.7934
24	2.9752	4.6611	10.7107	3.7686	....	.7934
25	2.9752	4.6611	11.9008	5.3554	.7934	1.3884
26	2.9752	4.6611	10.9091	5.5537	.5950	1.3884
27	2.9752	4.6611	9.7190	5.3554	1.1901	1.1901
28	2.9752	4.6611	9.5207	3.5702	.9917	1.1901
29	2.9752	4.6611	9.3223	3.7686	1.3884	.9917
30	2.9752	4.6611	9.3223	3.5702	1.1901	.9917
31	....	4.6611	....	1.7851	.9917	....
Total	47.6032	144.4941	261.4212	229.4875	57.1238	29.1567

Duty of water under the Butler Ditch, 1899.

Month.	Area.[1]	Water used.		Area per cubic foot per second.[2]
		Quantity.	Depth.	
	Acres.	*Acre-feet.*	*Feet.*	*Acres.*
April	123.5	47.6032	0.39	....
May	123.5	144.4941	1.17	....
June	123.5	261.4212	2.12	....
July	123.5	229.4875	1.86	....
August	123.5	57.1238	.46	....
September	123.5	29.1567	.24	....
Total irrigation	....	769.2865	6.24	53.72
Rainfall	....	....	.49	....
Total water received	....	....	6.73	....

[1] It is impossible to tell just how much of the land under the canal is irrigated each month. For the purpose of computing the depth of water used, the whole area is assumed to have been irrigated each month.
[2] Continuous flow for 169 days.

BROWN & SANFORD DITCH.

The acreage under the Brown & Sanford Ditch is nearly all sandy, gravelly bench land, requiring much water. The area irrigated is 1,108.5 acres. The following table shows the daily flow of this ditch from April 15 to September 30, the period during which water was used in irrigation. The flow from April 15 to June 15 is estimated.

Water used in irrigating lands under the Brown & Sanford Ditch, 1899.

[See diagram, Pl. XII, p. 74.]

Day.	April.	May.	June.	July.	August.	September.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1	....	42.9421	67.3851	69.0248	16.8595	8.5289
2	....	42.9421	67.3851	69.0248	15.2727	8.9256
3	....	42.9421	67.3851	69.2231	17.2562	8.9256
4	....	42.9421	67.3851	69.2231	22.0165	8.5289
5	....	42.9421	67.3851	69.4215	19.8347	8.1322
6	....	42.9421	67.3851	69.4215	18.2479	7.7355
7	....	42.9421	67.3851	69.6198	17.8512	8.1322
8	....	42.9421	67.3851	69.6198	17.8512	8.5289
9	....	42.9421	67.3851	65.0578	17.8512	8.5289
10	....	42.9421	67.3851	66.4463	17.2562	8.1322
11	....	42.9421	67.3851	64.2645	16.8595	8.9256
12	....	42.9421	67.3851	70.4132	17.2562	8.5289
13	....	42.9421	67.3851	55.9339	15.2727	8.9256
14	....	42.9421	67.3851	69.6198	13.4876	10.7107
15	17.0579	42.9421	67.3851	48.5950	14.8760	10.7107
16	17.0579	42.9421	65.6529	52.1654	14.8760	10.3140
17	17.0579	42.9421	68.0301	42.4463	13.4876	9.9174
18	17.0579	42.9421	70.4132	41.0578	12.8926	8.1322
19	17.0579	42.9421	71.4050	45.0248	12.8926	8.5289
20	17.0579	42.9421	73.5868	42.4463	12.4957	8.5289
21	17.0579	42.9421	74.3802	44.4298	8.5289	8.1322
22	17.0579	42.9421	71.4050	42.4463	8.5289	8.1322
23	17.0579	42.9421	65.6529	43.0413	10.3140	8.5289
24	17.0579	42.9421	74.3802	42.4463	10.3140	8.1322
25	17.0579	42.9421	72.1983	29.5537	8.5289	6.7438
26	17.0579	42.9421	67.4380	28.9587	8.9256	6.7438
27	17.0579	42.9421	69.6198	31.9339	8.5289	7.7355
28	17.0579	42.9421	67.4380	18.2479	12.0992	8.1322
29	17.0579	42.9421	68.8264	17.8512	5.5537	8.5289
30	17.0579	42.9421	68.8264	17.2562	6.3471	8.9256
31	....	42.9421	....	17.8512	8.1322	....
Total	272.9264	1,331.2051	2,060.0297	1,552.0660	420.4952	257.0571

Duty of water under Brown & Sanford Ditch, 1899.

Month.	Area.[1]	Water used.		Area per cubic foot per second.[2]
		Quantity.	Depth.	
	Acres.	*Acre-feet.*	*Feet.*	*Acres.*
April	1,108.5	272.9264	0.25	....
May	1,108.5	1,331.2051	1.20	....
June	1,108.5	2,060.0297	1.86	....
July	1,108.5	1,552.0660	1.40	....
August	1,108.5	420.4952	.38	....
September	1,108.5	257.0571	.23	....
Total irrigation	....	5,893.7795	5.32	63.01
Rainfall		....	.49	....
Total water received	....	....	5.81	....

[1] For the purpose of estimating depth of water used, the whole area is assumed to have been irrigated each month.
[2] Continuous flow for 169 days.

UPPER CANAL.

Under the Upper Canal about 300 acres is sandy, gravelly bench land, about 1,200 acres is clayey bench land, not requiring quite so much water as the gravelly bench land, and about 90 acres is bottom land, requiring still less water than the clayey bench land. The total area is 1,590.5 acres. The following table shows the daily use of water on these lands. The flow of the canal from April 20 to June 3 is estimated.

Water used in irrigating lands under the Upper Canal, 1899.

[See diagram, Pl. X, p. 74.]

Day.	April.	May.	June.	July.	August.	September.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1	....	71.4050	103.1402	104.9256	37.8843	23.2066
2	....	71.4050	105.1237	104.3306	39.8678	19.2397
3	....	71.4050	107.1072	103.7355	39.2727	18.2479
4	....	71.4050	116.0331	103.1405	47.2066	21.0248
5	....	71.4050	111.4711	102.5455	37.0909	19.2397
6	....	71.4050	107.1074	101.9504	36.4959	23.2066
7	....	71.4050	107.7025	101.3554	37.8843	24.3967
8	....	71.4050	108.4959	102.3471	37.4876	23.8017
9	....	71.4050	109.0909	108.0992	37.0909	23.2066
10	....	71.4050	109.8843	105.1240	36.4959	23.8017
11	....	71.4050	110.4793	108.0992	34.5124	21.6198
12	....	71.4050	111.2727	107.1074	34.1157	19.2397
13	....	71.4050	111.8678	107.1074	31.1405	18.2479
14	....	71.4050	112.6612	97.5868	26.7769	19.2397
15	....	71.4050	113.4545	98.5785	27.3719	18.8430
16	....	71.4050	114.0496	103.3388	26.7769	18.2479
17	....	71.4050	121.9835	85.6859	26.7769	19.2397
18	....	71.4050	101.3554	89.2562	24.9917	21.6198
19	....	71.4050	102.3471	89.2562	24.3967	19.2397
20	38.8760	71.4050	103.3388	85.6859	23.8017	18.8430
21	38.8760	71.4050	103.3388	84.6942	24.9917	19.2397
22	38.8760	71.4050	83.9008	83.9008	24.3967	18.8430
23	38.8760	71.4050	89.2562	84.6942	22.2149	19.2397
24	38.8760	71.4050	83.9008	79.3388	24.9917	18.8430
25	38.8760	71.4050	84.6942	68.2314	24.9917	17.6529
26	38.8760	71.4050	101.3554	60.0992	24.3967	18.2479
27	38.8760	71.4050	102.3471	60.0992	24.9917	17.6529
28	38.8760	71.4050	97.5868	47.8017	24.9917	18.2479
29	38.8760	71.4050	106.1157	47.2066	23.2066	18.8430
30	38.8760	71.4050	105.5207	44.2314	24.3967	18.2479
31	....	71.4050	....	40.6612	19.2397	....
Total	427.6360	2,213.5550	3,145.9827	2,710.2148	930.2480	598.8101

Duty of water under the Upper Canal, 1899.

Month.	Area.[1]	Water used.		Area per cubic foot per second.[2]
		Quantity.	Depth.	
	Acres.	*Acre-feet.*	*Feet.*	*Acres.*
April	1,590.5	427.6360	0.27	....
May	1,590.5	2,213.5550	1.39	....
June	1,590.5	3,145.9827	1.98	....
July	1,590.5	2,710.2148	1.70	....
August	1,590.5	930.2480	.58	....
September	1,590.5	598.8101	.38	....
Total irrigation	....	10,026.4466	6.30	51.63
Rainfall	....	....	.49	....
Total water received	....	....	6.79	....

[1] For the purpose of computing the depth of water used, the whole area is assumed to have been irrigated each month.
[2] Continuous flow for 164 days.

GREEN DITCH.

The acreage under the Green Ditch is all bottom land. About 200 acres of it is gravelly land, requiring much water; the remainder is rich, loamy soil, requiring less water. The total area irrigated under this ditch is 586.25 acres. The daily use of water from this ditch is shown by the following table. The flow from April 20 to June 4 is estimated.

Water used in irrigating lands under the Green Ditch, 1899.

[See diagram, Pl. XIV, p. 74.]

Day.	April.	May.	June.	July.	August.	September.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1		16.4628	19.8347	17.0579	8.7273	12.4959
2		16.4628	19.8347	15.8678	6.1488	12.4959
3		16.4628	19.8347	14.4793	5.7521	12.0992
4		16.4628	19.8347	13.2893	6.1488	11.7025
5		16.4628	24.1983	11.9008	5.7521	12.0992
6		16.4628	23.0083	10.5124	5.5537	11.7025
7		16.4628	21.6198	9.1240	4.7603	10.7107
8		16.4628	22.6116	6.3471	15.8678	16.6612
9		16.4628	23.6033	9.5207	26.9752	17.8512
10		16.4628	24.5950	9.5207	26.1818	18.4463
11		16.4628	25.5868	3.7686	25.1901	18.4463
12		16.4628	26.5785	6.1488	24.7934	17.8512
13		16.4628	27.5702	6.3471	24.7934	17.8512
14		16.4628	28.5620	8.7273	24.1983	18.4463
15		16.4628	29.5537	6.1488	24.7934	18.4463
16		16.4628	33.9174	12.0992	23.8017	17.8512
17		16.4628	38.2810	8.7273	22.0165	17.4545
18		16.4628	42.4463	10.3140	21.0248	17.8512
19		16.4628	33.3213	10.7107	20.4298	17.8512
20	12.4562	16.4628	32.3306	7.1405	19.8347	16.6612
21	12.4562	16.4628	31.3388	6.1488	19.8347	15.4711
22	12.4562	16.4628	30.5455	6.1488	19.4380	14.2810
23	12.4562	16.4628	25.3884	6.3471	16.6612	14.2810
24	12.4562	16.4628	24.7934	6.3471	16.2645	13.8843
25	12.4562	16.4628	21.2231	6.1488	16.2645	12.8926
26	12.4562	16.4628	9.5207	3.7686	15.8678	12.8926
27	12.4562	16.4628	8.5289	3.5702	14.6777	13.0909
28	12.4562	16.4628	11.7025	10.7107	13.8843	13.8843
29	12.4562	16.4628	19.6364	9.1240	13.8843	13.8843
30	12.4562	16.4628	18.4462	9.1240	13.0909	14.2810
31		16.4628		8.7273	12.8926	
Total	137.0182	510.3468	754.5116	273.9177	515.5045	453.8183

Duty of water under the Green Ditch, 1899.

Month.	Area.[1]	Water used.		Area per cubic foot per second.[2]
		Quantity.	Depth.	
	Acres.	*Acre-feet.*	*Feet.*	*Acres.*
April	586.25	137.0182	0.23	
May	586.25	510.3468	.87	
June	586.25	754.5116	1.30	
July	586.25	273.9177	.47	
August	586.25	515.5045	.88	
September	586.25	453.8183	.77	
Total irrigation		2,645.1171	4.52	71.97
Rainfall			.49	
Total water received			5.01	

[1] For the purpose of estimating the depth of water used, the whole area is assumed to have been irrigated each month.
[2] Continuous flow for 164 days.

LOWER CANAL.

The acreage under the Lower Canal is all bottom land. It is all good, rich soil except that which has become swampy by irrigation above. The pasture land is watered only once or twice during the irrigating season. A number of small springs, caused by seepage from higher irrigated lands, rise on this land, and serve to slightly increase the calculated duty, as they were not taken into account in the water measurements. There are 717.25 acres irrigated from this canal. The following table shows the flow of the canal from April 25 to September 20, when irrigation closed. The flow from April 25 to June 19 is estimated:

Water used in irrigating lands under the Lower Canal, 1899.

[See diagram, Pl. XI, p. 74.]

Day.	April.	May.	June.	July.	August.	September.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1	....	16.2645	21.9852	16.2645	16.2645	9.5207
2	....	16.2645	21.9852	15.8678	15.6694	6.3471
3	....	16.2645	21.9852	15.2727	15.6694	6.1487
4	....	16.2645	21.9852	14.6777	18.4463	3.5702
5	....	16.2645	21.9852	14.0826	16.6612	3.5702
6	....	16.2645	21.9852	13.4876	16.2645	3.3719
7	....	16.2645	21.9852	12.8926	18.4463	4.7603
8	....	16.2645	21.9852	13.6859	15.0744	3.5702
9	....	16.2645	21.9852	12.8926	11.9008	3.3719
10	....	16.2645	21.9852	12.4959	10.3140	3.5702
11	....	16.2645	21.9852	5.7521	9.5207	3.5702
12	....	16.2645	21.9852	6.1488	9.5207	3.3719
13	....	16.2645	21.9852	14.4793	10.3140	2.9752
14	....	16.2645	21.9852	12.4959	9.5207	4.5620
15	....	16.2645	21.9852	12.4959	6.3471	4.5620
16	....	16.2645	21.9852	14.4793	6.1487	3.5702
17	....	16.2645	21.9852	12.4959	6.3471	3.5702
18	....	16.2645	21.9852	13.8843	9.5207	3.5702
19	....	16.2645	21.9852	12.4959	9.1240	3.1736
20	....	16.2645	22.0165	12.8926	8.7273	2.9752
21	....	16.2645	20.4298	14.4793	7.5372	....
22	....	16.2645	20.4298	12.0992	4.7603	....
23	....	16.2645	14.8760	12.4959	4.5620	....
24	....	16.2645	25.5868	12.0992	5.5537	....
25	13.3289	16.2645	23.8017	12.0992	6.1487	....
26	13.3289	16.2645	20.4298	13.8843	3.5702	....
27	13.3289	16.2645	19.8347	12.4959	4.5620	....
28	13.3289	16.2645	18.4463	19.6364	4.7603	....
29	13.3289	16.2645	17.4545	19.8347	4.5620	....
30	13.3289	16.2645	16.8595	20.8264	6.9421	....
31	....	16.2645	....	15.4711	8.5289	....
Total	79.9734	504.1995	637.8842	424.6615	301.2892	83.7021

Duty of water under the Lower Canal, 1899.

Month.	Area.[1]	Water used.		Area per cubic foot per second.[2]
		Quantity.	Depth.	
	Acres.	*Acre-feet.*	*Feet.*	*Acres.*
April	717.25	79.9734	0.11	....
May	717.25	504.1995	.70	....
June	717.25	637.8842	.89	....
July	717.25	424.6615	.59	....
August	717.25	301.2892	.42	....
September	717.25	83.7021	.12	....
Total irrigation	....	2,031.7099	2.83	104.43
Rainfall	....	....	.49	....
Total water received	....	....	3.32	....

[1] For the purpose of estimating the depth of water used, the whole area is assumed to have been irrigated each month.
[2] Continuous flow for 149 days.

BIG DITCH.

The acreage under the Big Ditch is all bottom land except about 250 acres of sandy bench land near the Jordan River. It is all good, rich soil except the pasture, which is wet land, requiring only one or two waterings during the irrigating season. A number of springs also rise on this land and serve to slightly increase the calculated duty, as in the case of the Lower Canal. The total area irrigated from this ditch is 2,243.13 acres.

The daily flow of the Big Ditch is given in the following table. The flow from April 25 to June 6 is estimated:

Water used in irrigating lands under the Big Ditch, 1899.

[See diagram, Pl. XV, p. 74.]

Day.	April.	May.	June.	July.	August.	September.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1		53.2562	55.5372	65.8512	40.6612	23.8017
2		53.2562	55.5372	65.0578	39.8678	23.2066
3		53.2562	55.5372	64.2645	37.8843	18.8430
4		53.2562	55.5372	63.4711	52.3636	18.2479
5		53.2562	55.5372	62.6777	51.5702	17.6529
6		53.2562	45.6198	62.0826	50.7769	16.0661
7		53.2562	54.5455	61.6859	50.7769	14.0826
8		53.2562	63.6694	59.3058	40.8595	14.0826
9		53.2562	72.5950	78.5455	31.1405	16.0661
10		53.2562	81.5207	60.0992	30.5455	15.6694
11		53.2562	80.7273	50.7769	23.8017	16.0661
12		53.2562	79.9339	55.3388	24.9917	15.6694
13		53.2562	79.1405	55.3388	27.3719	14.0826
14		53.2562	78.3471	54.7438	26.7769	15.6694
15		53.2562	77.3554	76.7603	24.3967	16.0661
16		53.2562	76.5620	88.2645	21.6198	15.0744
17		53.2562	75.7686	68.2314	21.0248	14.0826
18		53.2562	74.9752	60.0992	27.3719	16.0661
19		53.2562	74.1818	51.5702	26.7769	15.6694
20		53.2562	75.9669	50.7769	24.3967	15.6694
21		53.2562	75.9669	52.3636	21.6198	
22		53.2562	70.8099	43.4380	13.6859	
23		53.2562	65.8512	44.2314	13.6859	
24		53.2562	77.7521	43.4380	13.6859	
25	45.4807	53.2562	78.5455	26.7769	19.2397	
26	45.4807	53.2562	78.5455	31.1405	14.0826	
27	45.4807	53.2562	79.3388	31.1405	13.6859	
28	45.4807	53.2562	67.4380	54.7438	14.0826	
29	45.4807	53.2562	67.4380	52.3636	19.2397	
30	45.4807	53.2562	66.6446	51.5702	18.8430	
31		53.2562		36.4959	24.3967	
Total	272.8842	1,650.9422	2,096.9256	1,722.6445	861.2231	331.8344

Duty of water under the Big Ditch, 1899.

Month.	Area.[1]	Water used.		Area per cubic foot per second.[2]
		Quantity.	Depth.	
	Acres.	*Acre-feet.*	*Feet.*	*Acres.*
April	2,243.13	272.8842	0.12	
May	2,243.13	1,650.9422	.74	
June	2,243.13	2,096.9256	.93	
July	2,243.13	1,722.6445	.77	
August	2,243.13	861.2231	.38	
September	2,243.13	331.8344	.15	
Total irrigation		6,936.4540	3.09	95.64
Rainfall			.49	
Total water received			3.58	

[1] For the purpose of estimating the depth of water used the whole area is assumed to have been irrigated each month.
[2] Continuous flow for 149 days.

ACREAGE, CROPS, AND YIELD.

The following table shows the acreage and the yield for the lands under each canal and ditch:

Table showing the acreage and the yield for each canal and ditch. [1]

Crop.	Butler Ditch.		Brown & Sanford.		Upper Canal.		Green Ditch.		Lower Canal.		Big Ditch.	
	Acres.	Yield.	Acres.	Yield.	Acres.	Yield.	Acres.	Yield.	Acres.	Yield.	Acres.	Yield.
Wheat	30.00	385	155.50	3,645	174.88	5,668	44.75	1,013	107.25	3,428	313.00	10,028
Oats	......	......	6.50	150	37.00	1,395	6.50	265	18.00	776	129.75	5,285
Barley	......	......	......	......	1.50	40	6.00	190	2.50	196	7.50	384
Corn	2.50	85	37.00	940	97.00	3,157	46.50	2,525	76.25	3,050	143.50	5,150
Hay	85.00	255	747.00	2,187	1,049.25	3,840	221.50	672	314.25	1,182	829.00	2,538
Pasture	......	......	37.50	......	12.00	......	207.50	......	68.25	......	570.75	......
Small fruit	.50	1,428	4.25	5,499	19.62	28,223	3.00	4,415	10.62	15,825	4.25	4,478
Orchard	4.00	......	26.00	40	155.75	813	29.00	260	58.25	90	71.00	659
Vegetables	.25	$30	4.25	$230	3.75	$363	6.75	$330	6.25	$730	34.38	$2,166
Potatoes	1.25	150	20.50	3,640	39.75	6,964	14.75	2,700	55.63	10,215	140.00	25,688
Nursery	......	......	70.00	......	......	......	......	......	......	......	......	......
Total	123.50	......	1,108.50	......	1,590.50	......	586.25	......	717.25	......	2,243.13	......

[1] In this table the yields of wheat, oats, barley, corn, orchard, and potatoes are given in bushels; the yields of hay in tons; the yields of small fruit in quarts; the yields of vegetables in dollars. The pastures and nurseries were irrigated, and therefore their acreage is included in the total areas watered.

A period of warm weather late in the winter, followed by freezing weather, injured some of the crops. Large fruit was almost an entire failure. Small fruit was about three-fourths of the usual crop; alfalfa, about three-fourths; fall wheat and potatoes, about two-thirds of a crop. Other crops were not injured.

CONCLUSIONS.

From the information obtained by this investigation the following conclusions may be drawn:

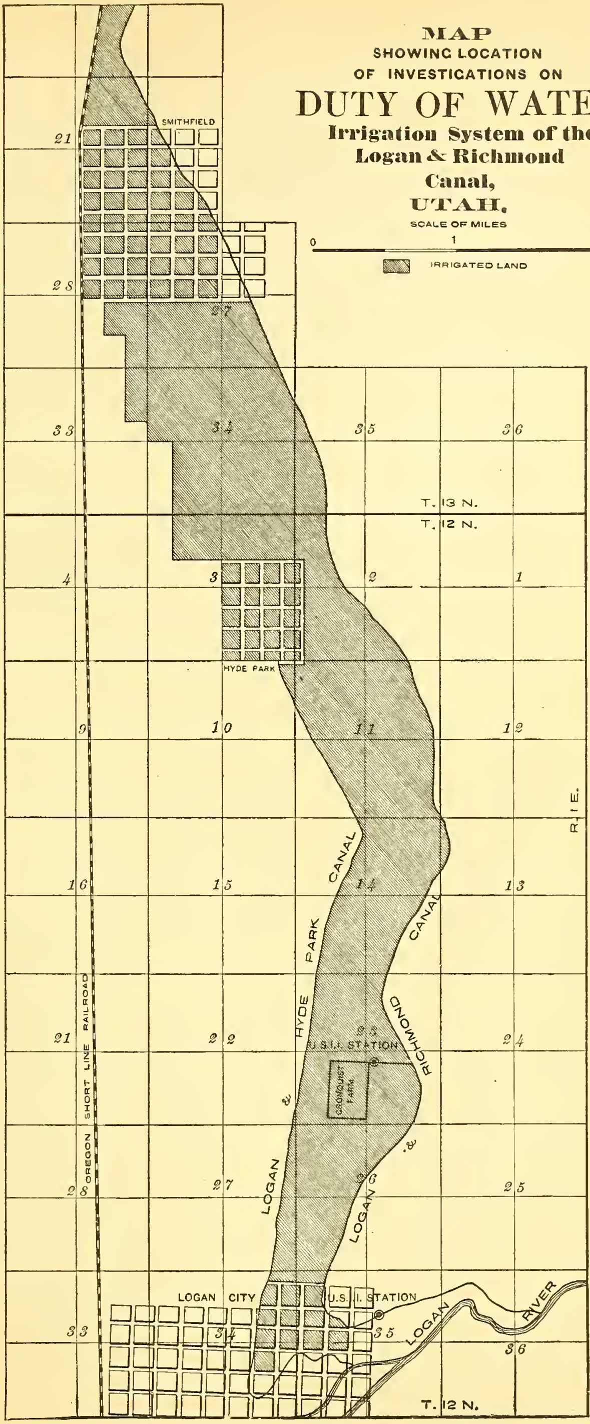
(1) The canals and ditches are improperly located and poorly con structed.

(2) The work of the board of arbitration was improperly done and its findings are not really considered binding by the water owners.

(3) The water rights are not properly recorded and such records as they have are not recognized by all as being correct.

(4) The water is improperly divided and distributed, and a right does not carry with it any certain quantity of water nor any certain portion of the water flowing in the creek.

(5) The duty of water for cultivated bench land should be at least 70 acres per cubic foot per second, and for cultivated bottom land at least 100 acres per cubic foot per second—pasture not being considered as cultivated land.



Map of the Irrigation System of the Logan and Richmond Canal, Utah.

DUTY OF WATER UNDER THE LOGAN AND RICHMOND CANAL.

Special Agent George L. Swendsen,
Professor Irrigation Engineering, Utah Agricultural College.

HISTORY AND DESCRIPTION OF THE CANAL.

Irrigation from the Logan River began in 1860. Four years later a high-line ditch was seen to be necessary. To the north of Logan were the towns of Hyde Park and Smithfield depending entirely on Logan River for water supply. Still farther north were the towns of Richmond and Franklin, both in need of additional supplies. All of these, together with the high lands around Logan, could be supplied from one canal from Logan River. (See Map, Pl. XLVIII.) The enterprise soon took definite form, and early in the autumn of 1864, at a meeting of the representatives from the above-named places, a committee of five—one each from the towns of Logan, Hyde Park, Smithfield, Richmond, and Franklin—was appointed to provide funds from the sale of wheat owned by the farmers interested, which was then worth $5 per bushel. The canal was begun at once and, although 300 farmers worked on it as early as 1865 and nearly $17,000 was expended on its construction during the first four years, water had been carried only about 4 miles at the end of that period; and it was 1877, or thirteen years after its beginning, before it was completed. The total cost of the canal up to 1878 was $34,481.34. It then irrigated 1,450 acres of farm land and 195 city lots, or an equivalent, counting city lots as needing a double supply, of 1,916 acres. The cost of the main canal, therefore, was an average of $18 for each acre irrigated. The canal was then only 9 feet wide at the head, although the original plan provided for a canal 20 feet wide. Subsequent enlargements made in 1879 and in 1880 made it capable of carrying water for 3,012 acres of land.

In 1894 the trustees found that the law had not been complied with in the organization of the irrigation district in 1875. A map of the district had not been filed, nor had the notice of the intention to organize been published as the law required. For twenty years water had been distributed, taxes levied and collected, and the canal managed in every detail under an irrigation-district organization before it was discovered that the organization was not legal. The errors were corrected before the irrigation season began in 1895.

CHARACTER OF WATER RIGHTS AND METHOD OF ACQUIREMENT.

The owners of water rights in this district have secured them in payment for services in constructing the canal, or bought them from the original owners. A few have been bought direct from the company, but such transactions are rare for the reason that the canal throughout its history has been just large enough to supply the water for those who had rights and any considerable increase in the acreage to be irrigated has required an enlargement of the canal. Such enlargement has usually been made by those desiring to acquire a right to water, as was the case in Logan City and Smithfield in 1880. Section 16 of the by-laws provides that the trustees shall not admit any person or persons as stockholders in the canal without the consent of the landholders by a two-thirds majority vote.

In some cases those who aided in the construction have not yet received the benefits due them because of the failure to carry out the original plan of construction. Under this head come the towns of Richmond and Franklin.

The cost per acre of the additional rights acquired by those who enlarged the canal in 1880 was $4. There is no provision in the by-laws of the company nor any action of the board of trustees to fix the price that shall be paid for water rights in the canals, except in one case, where a water right for a city lot in Logan City was granted by the board on payment of $10, which would be equivalent to $5 per acre.

Since 1896 there has been a chance to acquire rights by purchase at the delinquent-tax sales, but the number thus sold has always been small and thus far have been bought in by the company and generally redeemed by the delinquent owner. At such sales there is an upset price of $4 per acre, a standing offer of this sum having been made by the company.

The total cost of the canal to date is $38,118.08, including the construction and all enlargements. The average acreage irrigated each year of the past twenty has been 3,186, making the average cost of water-right shares $11.96 per acre.

Until the year 1891 the only record of these rights was on the books of the company, the individual owners holding no receipt, certificate, or written statement of any kind to show their interest. But in that year the issuance of a certificate to each owner of a water right was authorized.

The volume of water represented by a water right is variable, depending in most cases upon the needs of the land. The certificate of a stockholder is for a water right for a certain number of acres, and in general the only limit on the amount of water he may take is the volume which he can use on this area. Where exceptions to this rule are found the custom is to allow the use of an irrigating "stream" for a certain number of hours to the acre. In the city lots of Logan irrigated from this canal the custom at present is to use water six hours once each week. The water right for one city lot is counted equal to that for 2 acres of farm land, and is taxed accordingly.

DISTRIBUTION OF WATER.

The general distribution of water is in the hands of the head watermaster. He is aided by subwatermasters, who are assigned the management of certain parts of the district. The diversion gates all along the canal are of substantial construction, and each is provided with a lock, the key of which is kept by one of the watermasters.

For Logan and Hyde Park city lots the water is taken by turns on the various blocks, and each lot, generally about 1¼ acres, is entitled to water six hours each week. Each person is notified in the beginning of the irrigation season of the day of the week and the hours of that day during which he has the right to use of water on his lot.

In the case of the farm lands the custom is to allow a use of the water whenever and wherever it may be needed, up to the limit of the supply. Such is generally the practice around Logan and Hyde Park, but at Smithfield the time method of distribution is followed, each acre right entitling the person to the use of an irrigating stream for four hours each week. This difference is due to the fact that water in the northern portion of the district is much less plentiful, and the land requires a greater supply on account of its gravel subsoil.

COST OF OPERATION.

The following table gives the yearly cost of operation, delinquent taxes, and area irrigated by this canal during the twenty years preceding the present season. The heavy special taxes of 1891 to 1898 are due to the cost of constructing a large amount of fluming for those portions of the canal destroyed directly or indirectly by landslides. The legislature appropriated $5,000 for this purpose in 1898. The labor tax for those years is high for the same reason.

Annual maintenance taxes, Logan and Richmond Canal, 1879–1898.

Year.	Annual taxes paid.				Taxes delinquent.	Acres taxed.
	Labor.	Cash.	Special.	Total.		
1879	$1,457.62	$290.33	$309.69	$2,057.64	....	1,934
1880	557.70	199.85	....	757.55	$61.50	1,981
1881	[1] 3,674.74	282.15	....	[1] 3,956.89	53.34	3,016
1882	746.64	496.31	....	1,242.95	36.33	3,084
1883	787.15	453.05	....	1,240.20	41.65	3,315
1884	784.85	442.25	....	1,227.10	66.15	3,322
1885	482.85	376.35	....	859.20	162.35	3,341
1886	1,591.55	388.40	....	1,979.95	144.15	3,303
1887	796.47	264.18	....	1,060.65	234.59	3,163
1888	813.02	309.75	....	1,122.77	221.84	3,376
1889	819.20	466.06	....	1,285.26	41.84	3,248
1890	818.08	477.80	....	1,295.88	76.80	3,371
1891	818.10	528.20	1,636.15	2,982.45	306.75	3,272
1892	813.92	625.50	1,305.60	2,745.02	397.20	3,448
1893	1,145.75	491.90	404.90	2,042.55	292.47	3,374
1894	1,091.60	611.65	317.10	2,020.35	207.90	3,407
1895	1,242.40	617.90	....	1,860.30	111.10	3,570
1896	973.65	551.50	....	1,525.15	....	3,405
1897	972.21	462.03	....	1,434.24	....	3,402
1898	987.56	443.63	627.95	2,059.14	....	3,393
Total	21,375.06	8,778.79	4,601.39	34,755.24	....	63,725

[1] Including cost of enlarging canal.

Omitting the extra $3,000 tax for 1881 due to the enlargement made that year, and comparing the total cost of maintenance for twenty years ($31,755.24) with the total acres irrigated in that time (63,725), gives an average annual cost of maintenance and operation of 50 cents per acre irrigated. Of this cost one-third has been required in cash, the remainder in labor. The products of the land irrigated during the season of 1899 were worth nearly double the entire first cost of the whole main line of the canal. The wheat and alfalfa were worth $37,000.

INVESTIGATIONS IN 1899.

METHODS OF APPLYING WATER.

Two methods of applying water were used. Flooding the whole surface was the method followed in irrigating wheat, oats, alfalfa, and hay, and occasionally practiced in the irrigation of corn and orchards. Furrow distribution was employed in the irrigation of potatoes, gardens, sugar beets, and usually with orchards and corn.

The following table gives in detail the crops irrigated, the area of each, the water rights acquired, and the number of times each crop was irrigated during the season of 1899:

Areas of crops and number of times irrigated, under Logan and Richmond Canal, season of 1899.

Crop.	Times irrigated.										Total area of each crop.	Acres[1] of water-rights required.
	1	2	3	4	5	6	7	8	9	10		
	Acres.	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	
Wheat	140	923	......	......	......	......	......	......	......	......	1,063	1,063
Oats	......	53	......	......	......	......	......	......	......	......	53	53
Corn	7	38	15	......	......	......	......	......	......	......	60	60
Potatoes	......	2	34	20	2	......	......	......	......	......	58	62
Sugar beets	......	5	21	38	4	......	......	......	......	......	68	121
Alfalfa	1	88	509	367	22	39	......	33	6	......	1,065	1,065
Hay	......	106	......	......	......	......	......	......	......	......	106	106
Orchard	......	......	13	5	35	26	......	43	......	22	144	288
Garden	......	......	......	8	42	34	9	109	4	58	264	528
Miscellaneous	......	3	......	......	4	......	6	......	......	......	13	13
Total	148	1,218	592	438	109	99	15	185	10	80	2,894	3,359

[1] The term acres of water right arises from the fact that shares in the enterprise are based on acres of land rather than an interest in the canal. In ordinary use the owner of a water right for an acre is entitled to take water from the canal for an acre, but where that acre is a city lot two acre water rights are required before water for its irrigation is supplied. It was the cultivation of wheat on city lots which caused 3,359 acres of water rights to be required for 2,894 acres irrigated.

VOLUME OF WATER CONVEYED BY THE CANAL.

Measurements of the quantity of water used began on May 21 and ended October 1. Almost no water was used before June 1, and all irrigation was reported by the water master as concluded September 26. The point chosen for measurements of discharge is a few rods above the first point of diversion of water from the canal. At this point the canal is carried in a flume of rectangular section 12.73 feet wide and 3.5 feet deep. For more than 100 feet above the gaging station this flume is straight and it has a uniform grade and cross section. A part of the flume is lined with matched flooring so that the water passes through it with very slight lateral interference, and with a uniform and undisturbed current.

A continuous record of depths has been made by means of an automatic recorder furnished by this Department. The depths so recorded have been checked a number of times each week by actual measurements.

A table of velocities for 18 different depths was prepared from current-meter measurements. In 17 of these measurements the observations were checked by the use of a second current meter. The surface velocity was also taken by means of floats, to serve as a rough check.

The following tables give the total discharge for each day for June, July, August, and September in acre-feet, and the rainfall and evaporation at Logan for the same months:

Water discharged by Logan and Richmond Canal at Logan, Utah, June 1 to September 26, 1899.

[See diagram, Pl. XVI, p. 76.]

Day.	June.	July.	August.	September.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1	34.2888	118.2404	87.6531	69.4320
2	35.5236	124.1095	87.0684	70.5318
3	35.5236	131.0712	82.5796	72.2016
4	37.4880	129.2643	57.4714	72.4597
5	45.0276	122.1732	42.6720	74.2225
6	44.2056	128.4157	42.6060	80.4369
7	45.0276	132.0038	43.0020	84.0680
8	70.5240	128.1479	44.5919	82.9322
9	64.6644	124.9079	51.0656	85.1130
10	59.1852	122.0049	53.3362	82.2634
11	54.0864	122.8987	52.1532	71.7983
12	51.2088	131.9540	52.8774	64.1988
13	59.1852	146.0988	49.4478	60.5232
14	83.3808	144.6793	40.8680	58.6632
15	84.7500	149.6814	20.0741	57.7913
16	131.0712	146.5857	33.8063	58.8715
17	131.0712	137.1702	34.4450	60.9808
18	131.0712	125.8649	33.7598	57.7900
19	132.8964	118.7363	40.2238	64.9274
20	131.0712	111.6323	86.6688	68.9260
21	131.0712	109.1532	89.1102	69.4244
22	122.1732	121.4519	75.0684	69.9228
23	118.7196	117.5979	86.0233	72.5727
24	115.3272	109.5511	106.6515	73.4932
25	116.4606	110.0806	115.3439	71.9614
26	113.5400	112.6008	119.6142	66.4146
27	119.7227	119.0505	116.4528	....
28	119.8660	108.2635	113.5615	....
29	119.8686	98.3113	105.0133	....
30	114.2258	91.8252	92.3537	....
31	....	90.8744	71.1324	....
Total	2,652.2257	3,784.4008	2,126.6956	1,821.9277

Rainfall and evaporation[1] at Logan, Utah, 1899.

Day.	June.		July.		August.		September.	
	Rain.	Evaporation.	Rain.	Evaporation.	Rain.	Evaporation	Rain.	Evaporation.
	Inch.	*Inches.*	*Inch.*	*Inches.*	*Inch.*	*Inches.*	*Inch.*	*Inches.*
1	0.18			0.35				
2		0.50					0.02	0.52
3								
4					0.38			
5	.42				.18	1.48		
6								
7					.10			
8				2.02				
9					.04			1.83
10		1.68						
11			0.47					
12						1.83		
13								
14								
15			.05	1.78				
16								1.82
17		1.61						
18								
19						2.08		
20								
21								
22				2.22				
23								1.62
24		2.09						
25								
26			.03			2.06		
27			.05					
28								
29				2.30				
30		2.11						1.26
31				.90		1.32		
Total	.60	7.99	.60	9.57	.70	8.77	.02	7.05

[1] Evaporation is for the week ending on the date for which it is given.

The observed duty of water under the Logan and Richmond Canal is given in the following table:

Duty of water under the Logan and Richmond Canal, 1899.

Month.	Area irrigated.	Total discharge.	Depth of irrigation.	Average daily discharge.		Area irrigated from each cubic foot per second.
	Acres.	*Acre-feet.*	*Feet.*	*Acre-feet.*	*Sec.-feet.*	*Acres.*
June	2,894	2,652.2257	0.9165	88.4075	44.5721	64.93
July	2,894	3,784.4008	1.3077	122.0774	61.5474	47.02
August	2,894	2,126.6956	.7348	68.6030	34.5873	83.67
September (26 days)	2,894	1,821.9277	.6295	70.0741	35.3290	81.92
Season (118 days)	2,894	10,385.2498	3.5885	88.0106	44.3720	65.22

Summary.

Area irrigated	acres	2,894
Water used	acre-feet	10,385.2498
Depth of irrigation	feet	3.59
Depth of rainfall	do	.16
Total depth of water received by land	do	3.75

By referring to the table on page 214, it will be seen that 1,366 acres was irrigated less than three times, and that 1,528 acres was irrigated three or more times. The average number of irrigations was slightly more than three, and the average depth supplied at each irrigation 1.2 feet.

The demand for water was greatest during June and July. This was due to the fact that both alfalfa and wheat are irrigated during these months. The need in July was greater than in June, while the demand in August and September was largely owing to the irrigation of alfalfa. During the latter part of September much water ran to waste; hence the requirements for that month were less than the volume measured. An average flow of 44.37 cubic feet per second during the four principal irrigation months irrigated 2,894 acres, or a duty of 65.22 acres for each cubic foot per second.

This result includes losses from seepage and evaporation in the canal.

Alfalfa and wheat are grown on nearly three-fourths of the area irrigated; hence the result applies especially to those two crops. The lands irrigated were of nearly every quality except alkali lands; therefore the result obtained represents a fair average for the lands in this vicinity.

DUTY OF WATER ON THE CRONQUIST FARM.

The measurements of the water flowing through the main canal gave a duty which included the loss in distribution. In order to estimate, if possible, the influence of this loss, a measurement was made of the water actually applied to a definite tract, the location selected being a 60-acre farm situated near the heart of the irrigation district and irrigated from the canal. This was watered from two laterals, one entering the farm at the northeast and the other at the southeast corner. A Cippoletti weir was placed at the corner of the field where the main lateral entered, and one of the automatic recorders of the Department was arranged to record the depth of water passing over it. In one other supplying lateral, a small rectangular flume was placed, and during irrigation the depth of water was read at least three times a day, and the velocity at each observed depth was determined. By these means an accurate measurement of all water used was obtained. Whenever irrigation was in progress, daily visits were made to the farm and a record was kept of the progress made. The date and duration of each irrigation and the kinds of crops and acres devoted to each were noted. The orchard referred to in the following table is young, with a garden between the rows of trees, so that the irrigation of the two is necessarily considered together.

Irrigation of Cronquist farm, season of 1899.

[See diagram, Pl. XVII, p. 76.]

Crop.	Acres.	Date of irrigation.	Hours.	Acre-feet.	Depth.	Total depth.[1]	Method of distribution.	Cash value of product.
					Feet.	*Feet.*		
Wheat	15	June 19–22	59.08	14.64	0.97	0.97	Flooding	$162
Do	4	July 13, 14	18.00	3.76	.94	.94	do	41
Alfalfa	20	July 9–15	145.00	47.40	2.37	3.83	do	500
		August 17–22	110.00	29.20	1.46			
Do	2	July 14	18.00	2.68	1.34	3.19	do	50
		August 20	18.00	3.70	1.85			
Orchard and garden	1.5	June 20	16.00	2.10	1.40	5.95	Furrow	[2]197
		July 15	24.00	2.90	1.93			
		August 16	14.00	1.95	1.30			
		September 20	15.00	1.98	1.32			
Total	42.5		437.08	110.31				950

[1] Add 0.16 foot rainfall for total depth of water received by the land.
[2] Estimated.

In common with the usual practice, the water wasted over the lower side of the field was a large percentage of what was supplied at the upper. This, rather than the need of the crop, caused the application of enough water to cover the alfalfa to a depth of 3.77 feet and the 1.5 acres of garden to a depth of 5.95 feet.

The alfalfa produced three crops and averaged during the season 5 tons to the acre, or a total of 110 tons. The wheat crop was considerably below the average, but gave a return of 27 bushels to the acre, or a total of 513 bushels. The orchard and garden comprised a variety of products, among them 125 bushels of potatoes, a large quantity of fruit, and the ordinary garden products, besides a small amount of sugar cane. An estimate of the cash value of the products at the present market price gives a return from the 42.5 acres of $950.

The table shows that enough water was used to cover the 42.5 acres irrigated to a depth of 2.59 feet. The water flowing in the main canal was sufficient to cover the land irrigated to a depth of 3.59 feet. This indicates a loss of 28 per cent of the water flowing in the canal, assuming that the Cronquist farm fairly represents the farms under the canal.

IDAHO.

DUTY OF WATER AS RELATED TO THE IRRIGATION PROBLEMS OF THE BOISE VALLEY, IDAHO.

By Special Agent D. W. Ross,
State Engineer of Idaho.

BOISE VALLEY.

The total area of irrigable land in the Boise Valley is five times greater than the area now watered. The problem which confronts us is to so increase the duty of water that the entire area may be irrigated and become productive.

The Boise Valley (Map, Plate XLIX) might easily be regarded as a part of the great sagebrush plains of the Snake River, simply a widening out of that monotonous stretch of desert land which begins within sight of the Yellowstone National Park and extends westward without break for a distance of nearly 600 miles. There is the same great sweep of undulating bench land, the same gray ashy soil that filters through the closed double windows of the Pullman as it speeds through southern Idaho. To the eye of the topographer, however, one difference presents itself—the Boise River, running between low banks, may be easily diverted. The barriers left by nature are slight, and at reasonable expense its waters are transforming this once desert waste into a fit habitation for man.

The irrigable portion of the Boise Valley lies at an elevation of from 2,400 to 2,800 feet above sea level. On the north side of the river, beyond the valley proper, gently sloping terraces rise one above the other and merge gradually into the foothills. On the south a somewhat similar system of terraces, though much broader, ends finally in a broken ridge parallel to and about 3 miles distant from Snake River. Natural drainage courses run from east to west through this portion of the valley, emptying into the river near Caldwell. These were originally dry except during the spring freshets. They cause only slight undulations in the surface of the ground and now serve as distributary channels and waste ways in the irrigation system.

There are nearly 634 square miles of land lying under the canals and ditches already constructed or projected, and of this 484 square miles, or 310,000 acres, are susceptible of irrigation. About 40,000 acres is known as the first bottom or valley proper, which lies from 5 to 15 feet above the river. The bench lands rise to a height of nearly 125 feet above the river near the lower end of the valley.

WATER SUPPLY.

Rainfall.—The United States Weather Bureau reports an average rainfall for the year at Boise of nearly 14 inches. At Nampa, the center of the irrigable portion of the valley, it is but half that amount. Of this an average of 3.5 inches falls during the irrigation season and less than 1 inch falls during the hot months of June, July, and August. Thus it may be plainly seen that unless moisture is artificially applied to the soil, the country must always remain in a desert condition.

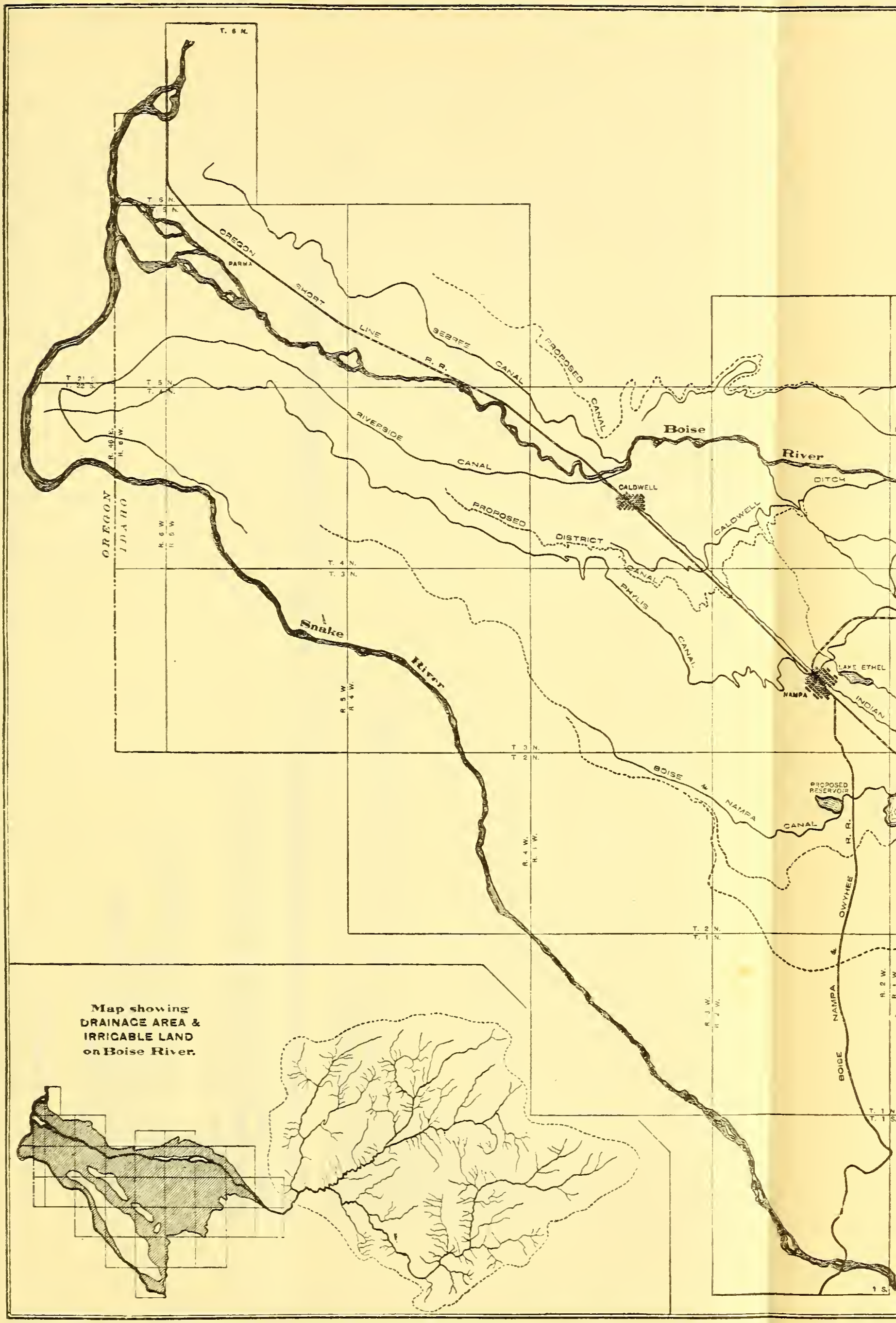
Boise River.—The Boise River rises in the Saw Tooth Mountains. The area of its drainage basin, which lies at an elevation of from 4,000 to 9,000 feet above the sea, is about 2,450 square miles. The greater portion of this is well timbered, and in the high elevations where this growth is plentiful the snow lies until well into June and July. In the lower elevations and foothills, or where there is but a sparse growth of timber, the snow disappears under normal conditions during the month of May; hence the flood-water season begins during that month, reaching its highest mark during the month of June, and lasts until near the middle of July.

Like all mountain streams whose chief source of supply is the melting snow, the Boise River quickly subsides after its highest stage is reached, and the period of low water soon follows.

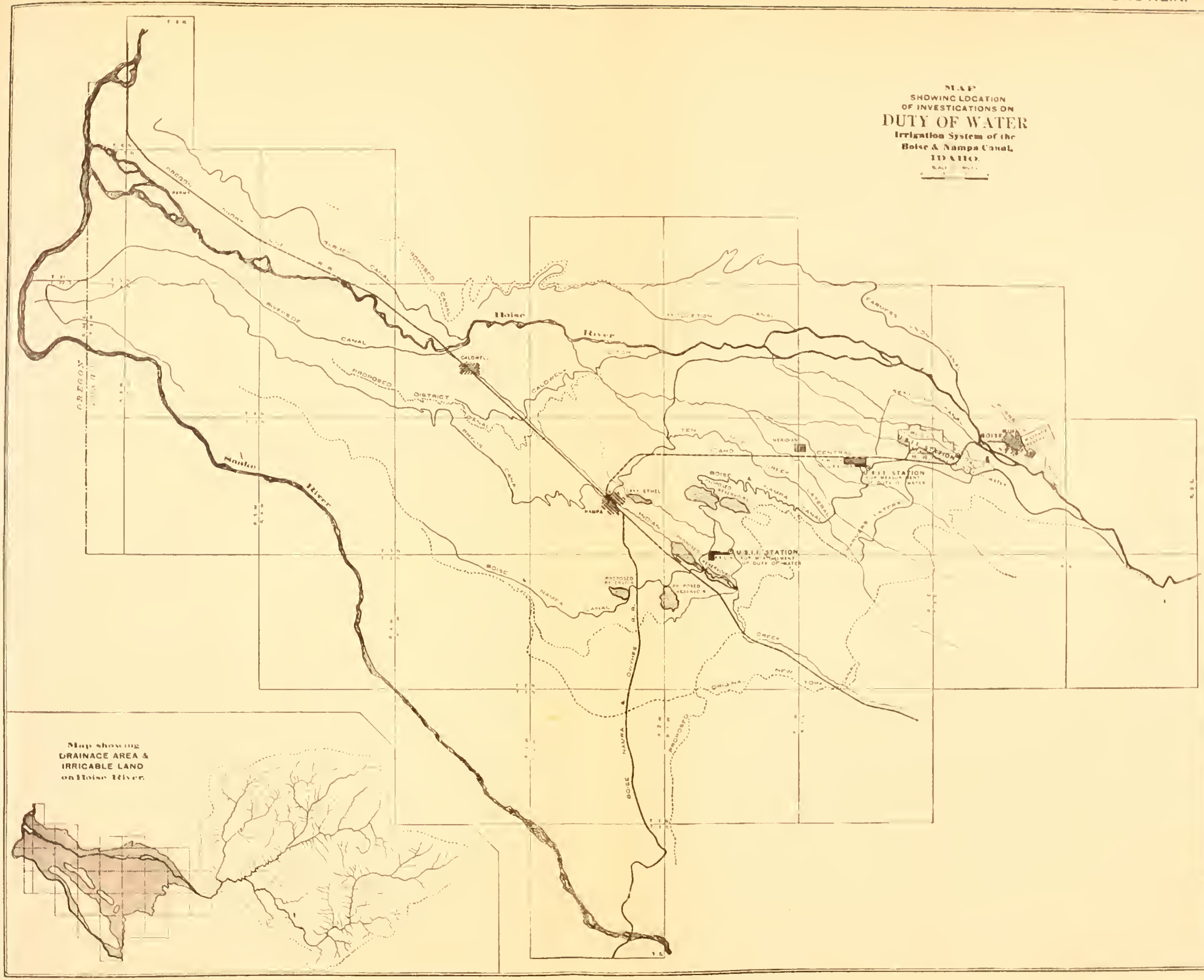
The mountain portion of the river channel has a fall of from 25 to 200 feet per mile, while from the Boise Canyon to its mouth, a distance of about 60 miles, its total fall is 600 feet, or an average fall of 10 feet per mile. After emerging from between the high walls of the Boise Canyon the stream winds about between low banks, seldom confined during high water to one channel. At one point in its course through the valley the high bench lands on both sides are joined by a lava dike through which the water has cut the Caldwell Canyon.

The diagram (fig. 18, p. 221) shows the discharge of the Boise River in acre-feet during the irrigating season from 1895 to 1899 inclusive.

This diagram discloses the fact that the low-water season of this period was in 1898, when, during the months of July, August, and September, the mean daily flow of the river was 1,917, 794, and 729 cubic feet per second, respectively. The greatest discharge of the river for any month during this period occurred in June, 1896, when the average daily flow was 22,112 cubic feet per second, the average discharge each day being more than one-third of the discharge during the entire month of July, 1898, or a quantity nearly equal to the total discharge during the month of August of that year. The high-water year for the irrigator, however, is the one during which the flood discharge is prolonged late into the irrigating season. This occurred during the year 1899. While the mean daily flow of the river during the month of June, 1899, was about one-half that during the same month in 1896, its average daily flow during the months of July, August, and September was greater than during the same months of 1896, the usual rush of



Map of the Irrigation System of the Boise



Map of the Irrigation System of the Boise and Nampa Canal, Idaho.

flood water having been checked by cool weather until late in the month of July. The diagram also indicates that a flood discharge of 40,000 cubic feet per second occurred in June, 1896. A subsidence to a flow of 2,000 cubic feet per second usually takes place during the

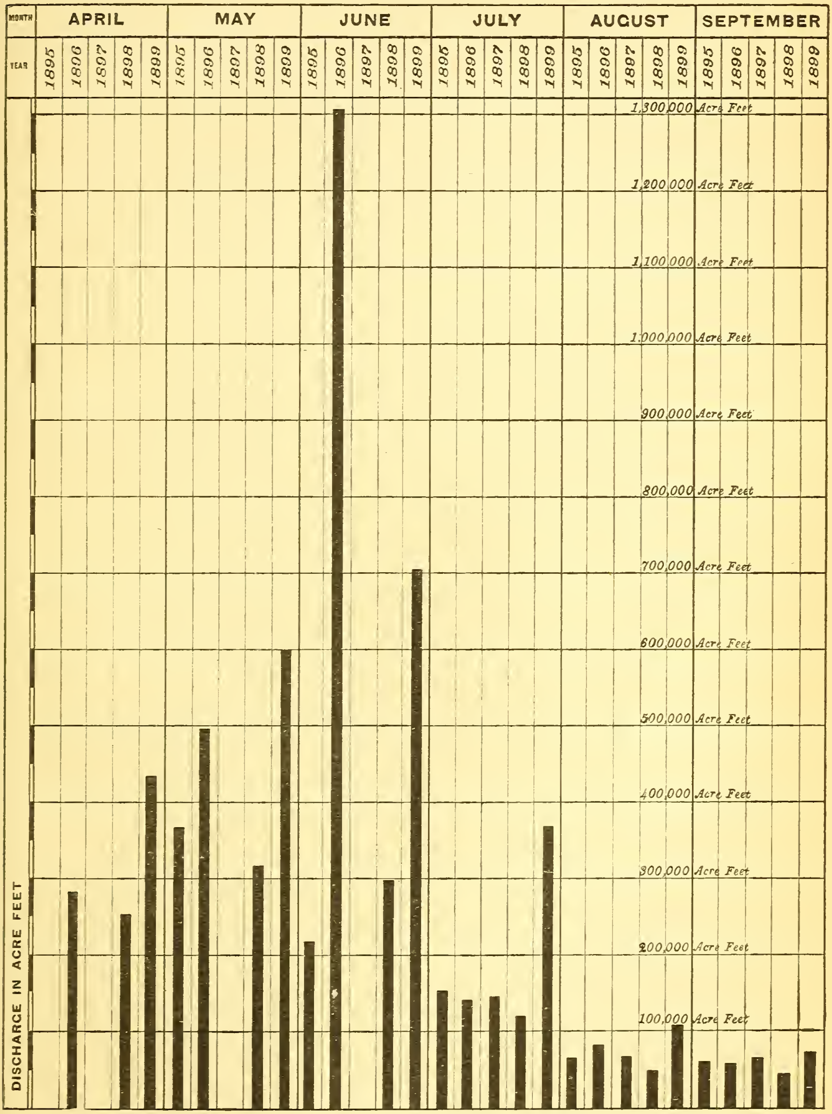


FIG. 18.—Diagram showing the discharge of the Boise River in acre-feet from 1895 to 1899, inclusive.

last week of July of each year. The average daily discharge during the months of August and September of the years from 1895 to 1899, inclusive, was 1,197 and 967 cubic feet per second, respectively, yet a greater volume than this is diverted from the river each day during these months and used for irrigation.

IRRIGATION INVESTIGATIONS IN THE BOISE VALLEY IN 1899.

AMOUNT OF WATER CLAIMED AND THE AMOUNT ACTUALLY DIVERTED.

In order that the investigation should embrace all of the factors which influence the duty of water in irrigation now obtained in this valley, it was thought desirable to secure a record of the claims to water from the stream and make such measurements as would show the location and capacity of the canals already built. Mr. Wiley, a civil engineer of Boise, Idaho, was employed to do this work. His reports give the abstract of the claims to water from the three counties through which the river flows. The abstracts of the records are omitted from this report because of the space they would occupy, and because of the fact that the claims of one county aggregate more than one hundred and sixty times the midsummer flow of the river. It would seem that the validity of such records would not be a matter of much practical importance.

Following the study of the water-right records, Mr. Wiley made surveys and gagings of the various canal systems. These canals now serve to irrigate about 50,000 acres of land, and have a total capacity of 1,741 cubic feet per second, and an estimated average discharge during the height of the irrigation season of 1,400 cubic feet per second. The results of Mr. Wiley's measurements are given in the following table. The diagram which follows the table shows graphically the difference between the amounts of water claimed by the several canals and the volumes they were actually diverting when measured.

Measurements of canals diverting water from the Boise River.

[Made by A. J. Wiley, June 25 to 30, 1899. See diagram, Pl. XLIX, p. 220.]

Name of canal.	Surface width.	Bottom width.	Average depth.	Discharge.
South side of river:	*Feet.*	*Feet.*	*Feet.*	*Cu. ft. per sec.*
Costons	9.0	6.0	0.87	7.526
Ridenbaugh	38.0	32.5	4.64	390.656
Payne	6.0	6.0	1.30	9.703
Rossi	16.0	16.0	2.50	52.930
Rossi waste	11.2	11.2	1.67	47.184
Lemp or Settlers	22.0	19.0	2.47	92.342
Davis	7.6	7.6	2.55	22.101
Catlin & Hart	5.3	5.3	0.94	4.667
Phyllis	18.0	12.0	2.96	85.996
Eureka	15.5	15.0	2.13	68.442
Caldwell (Strahorn)	13.0	10.0	2.44	74.972
Riverside	15.0	13.0	1.55	46.918
Keller	9.0	7.0	1.26	12.588
American	10.0	7.5	1.86	30.476
North side of river:				
Perrault (Walling)	9.3	6.0	1.86	23.333
Grove Street	8.5	7.0	1.52	14.798
Jacobs	11.6	10.0	2.42	46.443
Farmers' Union	26.6	21.0	2.07	94.994
Boise Valley	10.3	8.0	2.14	39.592
Dry Creek	18.0	12.0	2.47	53.199
Union	8.0	5.0	1.01	8.426
Ballentine	7.2	5.5	1.62	20.033
Cassiday	7.3	7.3	0.79	3.639
Middleton	18.0	14.0	3.58	141.979
Middleton Mill Slough	18.0	14.0	3.45	128.464
Swalley & McDowell	10.0	7.0	1.62	23.797
Middleton Water Company	22.0	20.0	1.87	31.104
Sebree	31.0	22.0	3.19	164.905
Total				1,741.207

Desert areas still exist in the Boise Valley. Irrigators are in constant strife over the division of water, yet the volume flowing in the river must serve to irrigate an area five times as great as that now under cultivation. One cause for this condition of affairs is that our plans in the beginning were too selfish and narrow. Each promoter thought only of his own scheme. He ignored entirely the efforts put forth at the same time by others similarly situated, and too often he introduced methods which were directly opposed to the general good. It has been left to his successor to save from ruin the enterprises sustained by the money of the capitalist and labor of the farmer; to bridge the gulf created between canal management and water users, and to show the necessity for the cooperation of every one from the landowner and land cultivator to the banker.

The extent to which the desert may be redeemed is measured by the amount of water at hand and the methods employed in its application. Therefore the policy pursued in the management of canals and the practice of the individual irrigator are the important factors in the problem of development and will, for that reason, be considered as part of the study of the duty of water.

DESCRIPTION OF THE PRINCIPAL CANAL SYSTEMS.

Boise and Nampa or Ridenbaugh Canal.—This canal, the highest and most important one in the Boise Valley, diverts its water supply from the south side of the Boise River at a point about 6 miles above Boise, and after crossing the first bottom of the river skirts the bluff and reaches the top of the first "bench" at a distance of about 8 miles from its head. From this point its course diverges rapidly from the river, being nearly 12 miles distant at a point south of Nampa. Four hundred and fifty feet below the headgate the canal is 38 feet wide at the surface of the water, 32.5 feet wide on the bottom, and 4.6 feet in depth, and diverts 390.6 cubic feet per second of water or 19,500 miner's inches, measured under a 4-inch pressure. Water is furnished for power for the Electric Light Company of Boise, being discharged just above the headgate of the Settlers' Canal. From 18 to 35 cubic feet per second are used for power purposes.

In order to avoid expensive construction on sidehill and broken ground, several vertical drops were introduced in the grade of the main canal, the land left on the upper side to be watered by means of laterals taken out above the drops and continued on the higher ground on the upper grade plane of the main canal. The accompanying map shows the system of upper laterals (Pl. XLIX, p. 220). Owing to the dropping of the ridge line between the Snake and Boise rivers, these upper laterals finally reached the level of the main canal at a point south of Nampa. By this location of the main canal a great saving was effected in the cost of its construction, and owing to the topographical condition all the land which lies below the upper level of its grade plane may still be watered.

The management of this property, fully realizing the necessity of providing against the time of great demands by the irrigator and shortage of water in the river, is providing a storage system as shown on the maps. Sites have been selected for seven reservoirs along the line of the main canal which will have a combined storage capacity of 26,000 acre-feet or enough water to give 50,000 acres one thorough irrigation, allowing for all loss in the lateral system. By this means it will be possible for the large district which will ultimately be served by this system to tide over the low-water period in the Boise River. The plans of the company contemplate the early enlargement of its main canal to keep the reservoirs filled until they are needed. They will be filled each season during the month of June.

Until 1899 this company charged for the delivery of water by the acre, and the duty has been low—about 47 acres for every cubic foot per second flowing in the main canal below the electric power plant. The loss from seepage and evaporation in the canal has never been determined, but owing to the length it must be very great.

Perrault Ditch.—The ditch heads on the north side of the Boise River about 3 miles above Boise. The first 2 miles is used for floating logs and for power purposes. The irrigation ditch proper begins at the lower end of the log pond below Goodwin's sawmill, where a small head of water—less than 25 feet—is diverted and used for the irrigation of lots in Boise and a few farms lying near the city. The portion of this ditch used for irrigation is 9.3 feet wide at water surface, 6 feet wide on the bottom, and 1.9 feet deep, and when measured on June 30, 1899, it carried 23.3 cubic feet per second. All portions of this ditch which were expensive to construct and maintain are embraced within the upper 2 miles. The remainder, about 3 miles, is maintained at but little cost.

The annual charge for water for farm irrigation is $4 per acre, and it is delivered for the irrigation of lots at the rate of $7.50 per 50-foot lot. Water is supplied to the city for flushing sewers at a cost of about $1,800 per annum. There has been considerable litigation over rates charged for the delivery of water from the ditch, which has resulted in a court decision that the rate of $4 per acre to be paid annually is just and reasonable. About 800 acres, including city lots, is watered from this ditch.

Settlers' or Lemp Ditch.—This ditch diverts water from the Boise River west of Boise. It is 22 feet wide at the water surface, 19 feet wide on the bottom, and 2.5 feet deep, and carried on June 28, 1899, 92.3 cubic feet per second. About 4 miles from the headgate it reaches the top of the first bench, where it turns to the south nearly at right angles to the course of the river and ends at the South Slough, 7 miles from the head. The owner of this canal charges by the acre for the delivery of water. The price paid is $1.50 per acre per year. No measuring boxes are provided, and the water users are forced to practice a system of rotation. Four thousand nine hundred and seventy acres were irrigated during the season of 1899, requiring a flow in the canal of over 92 cubic feet per second, or at the rate of 1 cubic foot per second for each 54 acres. The loss of water through seepage and evaporation is slight.

This canal was originally built by a company composed of the farmers whose lands are now watered by it, but owing to bad management the company became involved in debt and lost the property through foreclosure. The present owner then enlarged it to its present size, and is now deriving a handsome revenue on his outlay.

During the year 1896 the owners of the land lying below the level of this canal organized an irrigation district, for the purpose of purchasing and enlarging the canal to a capacity sufficient to water 21,000 acres of land. So favorable is the location, and so cheap would be the construction of the ditch that the plan had great merit, for by this arrangement the cost of water to irrigators might have been reduced to about one-third the present charge. For some unaccountable reason the plan has been abandoned.

Farmers' Union Ditch.—This canal is a community project, planned and built by farmers. It heads on the north side of the river about 2 miles below Boise, and will ultimately water all the land lying between the foothills and the first bottom of the river, a district about 12 miles long and of an average width of 1 mile. It is 26.6 feet wide at the water surface, 21 feet wide on the bottom, and 2 feet deep at a point 500 feet below the headgate. On June 21, 1899, it carried 95 cubic feet per second, and waters at present about 3,000 acres.

This company is organized under the corporation laws of the State, and has issued to its members shares of stock which entitle the owner to a certain amount of water. Both cash and labor assessments are levied to meet the expenses of operation. The stock held by each farmer represents a certain proportional interest in all rights and liabilities of the company, but from the nature of the enterprise there are no dividends, water being delivered at actual cost. In the absence of any law regulating the distribution of water from canals, the interest of each user presupposes a continuous flow of his share of the water, and as the needs of the people are not great at present (it being a new canal) the methods of distribution are wasteful, and water has a very low duty.

While believing in the ownership of canals by their users, I must admit that the method of distribution practiced under this one is ill advised. It is hoped that the good sense which was shown by these people while pushing their canal to completion will point out the necessity of promoting public welfare by economy in the use of the common water supply. This canal is operated without expensive management, the only salaried officer being the water master. All the measuring boxes are provided with locks, and so far as the internal management of the company is concerned it is satisfactory.

Middleton canals.—Two canals owned and controlled by community organizations divert water from the north side of the river about 13 miles below Boise. The water rights of these organizations are old, and until recently all the water was used on the first bottom of the river. The ditches head close together and after a distance of about one-half mile their water is emptied into an old high-water channel of the river, from which it is drawn according to the demands of the irrigators. No measuring gates are in use.

Water masters are appointed whose duties are to divide the water among the stockholders in the proper proportion. Usually the stockholders attend to this part of the work themselves, leaving those situated at the lower end of the canal to suffer from lack of water, while the upper country is flooded.

The irrigators from this system claim that their right is such an old one that no matter how much water is used they will not interfere with any prior rights. Because of this they believe they need not consider community regulations, and argue that the water wasted soon finds its way back into the river, and that appropriators lower down get the benefit. While the claim that appropriators lower down will not suffer because of seepage may be true, the damage to the land from overirrigation, the swamps created, and the general unsightly aspect of the country which has resulted from the indiscriminate wasting of water, call for better methods. The two ditches were diverting on June 23, 1899, a total of 270 cubic feet per second. This served to irrigate about 7,500 acres, or 28 acres to each cubic foot per second.

Phyllis Canal.—This canal delivers water on the south side of the Boise River, its point of diversion being opposite the lower end of Eagle Island, about 14 miles below Boise. It is 18 feet wide at the water surface, 12 feet wide on the bottom, and 3 feet deep at a point 300 feet below the headgate, and has a present capacity of 86 cubic feet per second. About 4 miles from its head it leaves the river at right angles. The canal was built in 1890 and has a total length of 55 miles, but is operated at present only to a point south of the town of Caldwell. It covers 30,000 acres, but irrigates only 3,000. In another place comment is made on the method of distribution.

Caldwell or Strahorn Ditch.—This ditch waters a few ranches on the south side of the river in the vicinity of Caldwell. The point of diversion is about 7 miles above Caldwell Canyon. The ditch is 13 feet wide at the water surface, 10 feet on the bottom, and 2.4 feet deep, and discharged, June 25, 1899, 75 cubic feet per second. The outcome of this project has been disappointing. It has not paid as an investment, and it irrigates only one-tenth of the land it covers.

The enterprising people of this community have now decided to organize an irrigation district, purchase this canal, and enlarge and improve it until it will water 12,300 acres. This will necessitate the construction of a canal 24 feet wide on the bottom. It will carry 223 cubic feet per second of water, or 1 cubic foot per second for each 55.1 acres irrigated. The estimated cost of the canal, when enlarged, is less than $55,000, and it is believed that water can be furnished by it for less than 40 cents per acre per annum. Under the provisions of the irrigation district law an acreage assessment must be levied for the payment of the interest on and redemption of the bonds, but tolls may be charged for the delivery of the water, to be based upon the quantity delivered. This latter charge will be for the payment of the cost of distributing the water. It is hoped in this way to distribute the charges equitably, holding all land in the district liable for the payment of the bonds, but placing a part or all of the expenses of maintenance upon the users of water. These expenses will be for the wages of one water-master and his assistants, the salary of a secretary, whose duties will be very light, the repairing of gates, and the occasional cleaning out of the canal. The plan is to build a canal of ample size and capacity, employing good methods in construction with a view of saving a large part of the annual maintenance expenses.

Owing to the location of the point of diversion of this canal it will be one of the first to profit from the return or seepage water to the river. It is thought that the seepage water which accumulates above this point will insure a steady and increased flow of the river during its low stage. The canal crosses Ten Mile and Indian creeks a short distance above their mouths, and it is intended that it shall catch the waste water flowing in these streams.[1]

Sebree Canal.—This canal heads in the Caldwell Canyon, and waters land lying on the north side of the river. At a quarter of a mile below its headgate it is 31 feet wide at the surface of the water, 22 feet wide on the bottom, 3.2 feet deep, and carried on June 24, 1899, 165 cubic feet per second. It irrigates about 6,000 acres of land.

The canal was first built by the Idaho Irrigation and Colonization Company. It has since been enlarged in accordance with an arrangement with the landowners. The original builders charge for the delivery of water by the quantity, but owing to its small capacity the

[1] Since the above was written the people living below the level of the Phyllis Canal have joined with those under the Caldwell ditch and are preparing to organize an irrigation district which will embrace all the land lying below the line of the two canals, about 33,000 acres. The project has great merit and will undoubtedly be a success.

property was never on a paying basis. After a great deal of disappointment on the part of both water users and investors, it was agreed to allow the farmers to "work out" an interest in the project, and the small ditch was accordingly enlarged to its present capacity.

It seemed to be the understanding of the landowners that water would be delivered to them at actual cost, but after the work had been performed a difference arose with the original company, which had not been dissolved. The company retained the control of the ditch and fixed the charges for maintenance according to its own ideas. The farmers claimed these were being arbitrarily increased from year to year and have finally taken the matter into court for settlement.

Riverside Canal.—The point of diversion of this canal is only a few feet above that of the Sebree ditch on the south side of the river in the Caldwell Canyon. From the headgates it runs along the first bottom of the river for a distance of nearly 10 miles, when it reaches the first bench, where the first delivery of water is made. It is 14 feet wide on the bottom and carries at present about 50 cubic feet per second of water.

The Boise Land and Water Company, the owner of this property, was organized in 1892, and a ditch was built and water delivered onto the land during the season of 1893. The original plan of this company contemplated the selling of "perpetual water rights" at the rate of $10 per acre with an annual maintenance charge of $1 per acre. Early in the year it was believed that this system would prove a failure, so a second company called the Riverside Irrigation District, Limited, was organized. This company bought the canal and issued to purchasers of water a proportionate amount of stock in the Riverside Irrigation District, Limited. The rights to the water are dedicated to described lands and the stock only represents the right to participate in the affairs of the company, the intention being to make the irrigators the managers of the property. It would seem by the arrangements made that it would be impossible to separate the water from the land even if the stock of a landowner were to be sold under an attachment. These shares sell for the uniform price of $10 each, one share to each acre of land.

While the owners of stock in the Riverside company do not at present possess a majority of shares, yet the management of the canal has been turned over to them entirely, and they now obtain their water at the actual cost of maintenance.

No one has suffered through the workings of this scheme. The builders of the canal are making a reasonable profit through the returns from the stock and land. By making a liberal contract for the use of water, the company has so strengthened its position that it has at all times received the hearty support of the settlers. This community is thrifty and peaceful and has had a steady growth. Water is at present delivered to 2,000 acres of land. Measuring gates are not used at present, although it is the intention to adopt them next season. The right is reserved in the by-laws of the company to establish a system of distribution by rotation whenever it shall be deemed necessary. While no fears are entertained regarding the water supply for this canal, yet a more orderly system for its distribution would be a great gain to the people. The first step in the reform would be to base assessments for maintenance on the amount actually used.

A better point of diversion for the Riverside and Sebree canals could not have been chosen. The lava dike which forms the Caldwell Canyon forces the seepage water to the surface near this place and insures a steady and increased supply in the river during its low stage. Nearly 15,000 acres of land will be ultimately served by the Riverside Canal, and about 20,000 acres of land will one day be watered by means of the Sebree Canal.

Smaller ditches.—All the canals just described conduct water onto the bench lands, although some serve land located on the first bottom. A great number of short ditches built by the landowners water the lands of the first bottom. Some of these ditches belong to associations of farmers, who work out the annual assessments levied for maintenance expenses. The construction of these canals has cost from $2 to $4 per acre for the land watered by them, and the annual cost for maintenance is from 15 to 50 cents per acre. The regulations governing the use of water from these ditches have had but little effect in promoting economy. A large body of valuable land is being ruined by overirrigation. Drain tiles are needed as badly on the first bottom of the river as irrigation canals on the bench lands. The cheapness with which water may be obtained in some localities is not without its drawbacks, as it leads to overirrigation and renders valuable fields unfit for cultivation.

A detailed description of the location and management of these canals has been given because the duty of water depends on other things than rainfall, soil, or the crops grown. Among the factors which determine the area which a cubic foot per second will irrigate are the nature of the water contract and the spirit of cooperation which exists among the irrigators. Until selfish irrigators at the head of the river or at the head of the ditch are compelled to regard the rights and interests of other users, those above will waste water and those below will have to take what is left.

In describing the defects of the system now in use it is hoped to create a public sentiment in favor of more economic distribution and secure a higher duty than an inch to the acre. It is believed that this is not only possible, but that the educational movement should be begun at once in order that it may influence the final adjustment of rights and limit appropriations to the quantity actually used. Those who favor the continuation of old methods, which disregard the right of the later and lower users, should remember the benefits which will come to the community and State through an economical administration which will permit of the reclamation of thousands of acres of desert land lying below the levels of the canals already built.

DUTY OF WATER.

If asked how much water is required to irrigate a given amount of land in the Boise Valley I should be compelled to answer, "I do not know."

The gathering of facts on which to base an answer to this inquiry was made in the season just closed. With this purpose in view three stations were established in the Boise Valley, all of which are on the Boise and Nampa Canal, as shown on the map (Pl. XLIX, p. 220). Water was used in the usual manner, being turned on and off according to the ideas of the irrigator, or allowed to flow continuously if thought necessary.

Station No. 1.—The Rust Lateral, which serves a large body of land situated in one of the oldest portions of the bench, was selected for this investigation. From a daily record of its flow the amount of water delivered to users was determined. The greater portion of the tract was devoted to old meadow (alfalfa, timothy, and clover), and the remainder was seeded to grain (oats and wheat). The discharge of the lateral was computed from daily reports of the water master on the main canal. He measured the head of water and the height of the opening in the gate twice each day, from which the volume of water flowing in the lateral was determined. These reports began on May 1 and ended September 30. Water was used after this date, but no record was kept of its flow. While occasionally the meadows are improved by irrigation during the month of October, rainfall usually supplies all needed moisture. The record covers the extreme limits of the usual irrigating season.

The lateral in question delivered water to 790 acres of land, the property of eighteen owners. Each owner ordered and paid for the quantity of water which, in his estimation, the crops would need. The lateral has a large fall and is short, hence the loss from seepage and evaporation is slight. The ground is favorably situated for irrigation, since a large head of water may be passed over the surface in a short time without any danger of washing or cutting. The surface could be easily prepared for irrigation by means of the check system. The following table shows the daily discharge of the lateral for the season:

Water delivered from the Boise and Nampa Canal through the Rust Lateral to eighteen users near Boise, Idaho, season of 1899.

[See diagram. Pl. XXIII, p. 80.]

Day.	May.	June.	July.	August.	September.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1	24.58	29.38	28.20	29.70	27.84
2	25.54	29.90	28.44	28.70	25.92
3	25.54	21.84	29.92	26.02	27.36
4	13.90	18.60	29.20	28.80	27.00
5	15.12	18.80	28.44	29.00	27.56
6	14.48	27.82	28.44	29.00	21.22
7	14.48	27.08	28.92	28.40	21.60
8	13.90	28.30	28.92	26.02	20.88
9	13.50	32.40	28.32	27.10	21.24
10	13.50	27.80	27.90	27.42	26.54
11	13.40	28.44	28.56	27.10	26.54
12	13.90	28.30	30.92	25.60	26.54
13	13.40	28.58	30.08	28.80	27.00
14	18.72	27.44	29.06	27.60	26.10
15	19.52	28.00	28.60	27.60	26.76
16	20.88	30.20	25.64	27.10	26.76
17	25.44	28.70	28.30	26.24	25.84
18	24.96	28.18	27.60	26.02	26.54
19	25.92	28.42	28.00	26.48	26.38
20	25.44	31.20	27.20	27.66	27.22
21	25.44	27.50	25.64	27.66	26.10
22	25.44	29.20	26.54	27.66	26.10
23	....	29.70	27.00	23.48	27.44
24	24.14	28.18	24.00	23.48	26.76
25	28.30	28.70	....	23.60	27.44
26	25.20	28.70	28.80	24.50	27.22
27	25.44	27.94	28.80	24.50	27.22
28	25.80	28.80	28.90	24.30	26.76
29	26.40	28.00	25.48	21.24	26.54
30	27.36	29.20	25.48	24.78	25.10
31	25.44	....	25.48	24.78	....
Total	635.08	855.30	906.78	820.34	779.52

As shown by the table, the total discharge for the season was 3,997.02 acre-feet. This gives the following duty for the water discharged by the lateral:

Duty of water under Rust Lateral.

Area irrigated	acres	790.00
Discharge of lateral	acre-feet	3,997.02
Depth of irrigation	feet	5.06
Depth of rainfall	do	.22
Total depth of water received by land	do	5.28
Area irrigated per cubic foot per second	acres	57.48

It will be observed that during the first half of May only about one-half the usual amount of water was used. After that period there was but little change in the flow until September 30, the end of the season. The average daily flow of the lateral for this period of 153 days was 13.1 cubic feet per second, or about 1 cubic foot per second for each 57.5 acres of land irrigated. This flow of water, if spread out evenly over the surface of the tract of 790 acres, is equivalent to an average daily rainfall of 0.033 foot, or nearly two-fifths of an inch.

Later on, attention will be called to a notice sent to the users of water under this canal, wherein they are advised to economize in the use of water by adopting a system of "rotation" or the use of a large irrigating head of water in turn. It is quite evident that this system of distribution was not adopted, for had it been, one-half the quantity of water which was turned through the headgate of the lateral would have sufficed. Still, the quantity of water turned into the lateral was ordered by the farmers in the spring, and paid for notwithstanding its waste. A comparison with the results secured at another point in the valley will show that a system of distribution might have been adopted which would have saved fully one-half of the water used.

Station No. 2.—The water used on the farm of Mr. A. F. Long was carefully measured over a trapezoidal weir, the depth being recorded by an automatic register from the 7th day of June to the 30th day of September. This land is situated about 5 miles southeast of Nampa, under one of the upper laterals of the Boise and Nampa Canal, and is marked on the map as Station No. 2 (Pl. XLIX, p. 220). The tract supplied with water is favorably situated for irrigation, and previous to seeding it was properly leveled, an effective system of laterals was constructed, and preparations were made for handling a large head of water at a minimum outlay of time and labor. The cultivated portion of the farm consists of 15 acres of alfalfa, seeded in 1898, 50 acres of alfalfa and clover, seeded in 1899, and a 40-acre prune orchard, planted in 1894, or 105 acres in all. In the spring Mr. Long contracted with the irrigation company for 100 inches or 2 cubic feet per second of water. For this he paid $150, with the understanding that he was to turn off the water when it was not needed on his land. The terms of this contract were the same as those entered into by the users of water from the Rust Lateral. One advantage enjoyed by the users of the Rust Lateral and not enjoyed by Mr. Long was that, owing to the great number of water users and the large head of water carried by their common lateral, every opportunity was afforded for a splendid system of rotation. Mr. Long, being the only user of water near this point of delivery on the canal, was obliged to order an irrigation head large enough for the greatest need at any one time, rotating from one tract to another on his own land, but receiving no credit when he turned the water back into the main canal. He paid for a continuous flow, fixed by the character of the crops grown and the area devoted to each, without regard to whether he used the water all the time or not. The following table shows the quantity of water used by Mr. Long and the time of its use:

Water used by A. F. Long, near Nampa, Idaho.

[See diagram, Pl. XXV, p. 80.]

Day.	May.	June.	July.	August.	September.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1	....	1.81	3.07	....	3.24
2	....	1.81	3.38	0.01	1.67
3	....	1.81	3.77	.90	1.54
4	....	2.20	3.51	1.49	2.47
5	....	1.47	3.51	1.17	2.83
6	0.38	2.70	3.13	.80	....
7	.38	1.53	3.25	.81	....
8	.38	1.29	2.98	.78	2.95
9	.38	2.79	2.57	.27	1.57
10	2.66	1.69	3.48	.25	....
11	2.75	.76	2.58	.25	....
12	2.84	3.38	3.17	....	....
13	2.84	3.38	3.35	....	....
14	....	3.38	3.42	....	....
15	....	3.64	3.63	....	1.61
16	....	3.90	3.64	....	1.57
17	....	3.53	3.74	....	....
18	....	3.01	3.77	....	....
19	....	2.53	3.74	....	....
20	.46	3.01	3.27	....	....
21	....	3.13	3.04	....	....
22	....	2.24	2.87	....	....
23	....	.01	3.85	3.51	.53
24	....	1.73	3.80	3.68	1.27
25	....	3.25	3.73	3.38	1.27
26	....	4.22	.75	1.69	.90
27	1.91	4.44	.99	.88	.59
28	1.79	3.64	3.69	3.31	.62
29	1.83	3.38	1.96	3.39	.36
30	2.50	3.51	....	3.38	.03
31	2.08	....	....	3.44	....
Total	23.18	79.17	91.64	33.39	25.02

Irrigation was begun on May 6, lasting for but a week, and did not begin again until the 27th, when only a small head was used until June 11. The exact record of the quantity of water used and the place of its use was begun on June 7, which record was kept to September 30. The head was reduced from June 7 to June 10 and was all used for the irrigation of a meadow of 15 acres, seeded in 1898, designated "old" meadow, as against "new" meadow, seeded in 1899. The amount delivered during this time was 7.29 acre-feet, which is sufficient to cover the land to a depth of 5.84 inches. The entire head, after being increased on the 11th, was turned onto 25 acres of new meadow, where it was used for nine days. The total volume furnished this tract was 27.49 acre-feet, or enough to cover it to a depth of 13.2 inches. The head was then reduced and turned on to the orchard tract of 40 acres, which required for its first irrigation 10.12 acre-feet, or a depth of about 3 inches. From the 25th of June until the 25th of July there was but little change made in the head of water drawn from the main canal; from the 26th to the 29th the head was reduced, and turned off entirely on the 30th. A small head of water was used in turn from August 2 to August 11 in the irrigation of old and new meadow tracts, and from that date until August 22 water was not used. Rain fell from August 14 to 25 to a total depth of 0.083 foot, or about 1 inch. Beginning with the 23d of August, water was applied to the orchard for five days, concluding its irrigation for the season. An increased head was then turned on to 20 acres of new meadow, and on September 3 it was changed to the old meadow. On the 6th and 7th of September a large head of water was allowed to run to waste. Small heads were intermittently used on meadow land during the remainder of the month of September. The following table shows the water used on the various crops, by months and for the season:

Water used on various crops during the season.

Crop.	Area.	Number of irrigations.	May.		June.		July.	
			Quantity.	Depth.	Quantity.	Depth.	Quantity.	Depth.
	Acres.		*Acre-feet.*	*Foot.*	*Acre-feet.*	*Feet.*	*Acre-feet.*	*Feet.*
Old meadow	15	6	....	....	7.30	0.49	17.37	1.16
New meadow	50	[1]	23.18	0.46	61.75	1.24	46.87	.84
Orchard	40	4	....	....	10.12	.25	27.40	.69
Total	105	....	23.18	.22	79.17	.75	91.64	.87

Crop.	Area.	Number of irrigations.	August.		September.		Total.	
			Quantity.	Depth.	Quantity.	Depth.	Quantity.	Depth.
	Acres.		*Acre-feet.*	*Foot.*	*Acre-feet.*	*Foot.*	*Acre-feet.*	*Feet.*
Old meadow	15	6	2.66	0.18	8.37	0.56	35.70	2.38
New meadow	50	[1]	17.59	.35	16.65	.33	166.04	3.32
Orchard	40	4	13.14	.33	....	....	50.66	1.27
Total	105	....	33.39	.32	25.02	.24	252.40	2.40

[1] Indeterminate.

We observe from the above table that the new meadow required the most water during the month of June, while the old meadow and the orchard demanded the most during the month of July. The period of greatest demand for all crops was during the month of July, when a depth of 0.87 foot was required, which was about one-third of the total amount used during the entire irrigating season. The orchard required a total depth of 1.27 feet, 54 per cent of which was applied during the month of July. The average depth used on the meadow was 3.09 feet, although the depth of 2.38 feet will perhaps be sufficient after the first year; 3.32 feet for the new meadow is excessive. A safe estimate of the quantity of water needed for the proper irrigation of alfalfa would be 2.5 acre-feet per acre, and the supply must be such that at least 1 per cent of it may be had each day during a period of thirty days in the months of July and August.

As before stated, 50 acres of this land was seeded in the spring of 1899 to clover and alfalfa. It is unusual to obtain a cutting from a meadow of this kind during the first season of its growth, yet in October of this year 50 tons of hay were cut from 40 acres. It is needless, therefore, to state that it had received sufficient water for its irrigation.

Mr. Long states that after the water had been running over the surface of his meadow for a few days nearly as great a quantity of waste water ran off at the lower end of the field as was turned on at the upper. The determination of the exact amount of such waste will, it is hoped, be undertaken next season.

Station No. 3.—Station No. 3 consists of an apple orchard of 74 acres, the property of Hon. Edgar Wilson. The ground was carefully prepared before the trees were planted, and the cultivation and care of these orchards has ever since been thorough. A portion of the orchard has been in bearing for two seasons past. Water has been applied with great care, and the best results as to quantity of fruit and growth of trees have been attained.

The first irrigation of the orchard began on the 7th of June, during which month 29.82 acre-feet of water was used. Quite a uniform flow was used during the month of July, a total of 35.42 acre-feet, and continued with but slight diminution until about the 15th of August, when the irrigation of the older and bearing portions was suspended for a time or until the fruit buds became properly set. In order to impart color and promote the healthy maturing and ripening of the apple crop, water was again turned onto the bearing portion of the orchard and allowed to run from August 26 until September 5, and again from the 11th to the 16th of September.

The following table shows the quantity of water in acre-feet used each day during the irrigating season. The depth given assumes that this amount had been spread evenly over the tract of 74 acres, thus affording means for a comparison with results at Stations 1 and 2:

Water used on the orchard of Hon. Edgar Wilson, near Boise, Idaho, season of 1899.

[See diagram, Pl. XXIV, p. 80.]

Day.	June.	July.	August.	September.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
1	....	0.47	1.38	1.60
2	....	.93	1.14	1.55
3	....	.93	1.46	1.50
4	....	1.03	1.44	.80
5	....	1.07	1.62	.42
6	....	1.27	1.66	.18
7	0.66	1.44	1.55	....
8	.96	.60	1.25	....
9	.96	1.31	1.43	....
10	1.32	1.36	1.49	....
11	1.34	1.45	1.19	.92
12	1.00	1.19	1.04	1.52
13	1.34	1.17	.90	1.42
14	1.34	1.09	1.01	1.29
15	1.00	.47	.93	1.26
16	1.34	1.29	.91	.60
17	1.00	1.16	.73	....
18	1.36	1.11	.75	....
19	1.90	1.11	.35	....
20	1.38	1.39	....	....
21	1.38	1.44	....	....
22	....	1.42	....	....
23	1.72	1.37	....	....
24	1.36	1.32	....	....
25	1.40	.47	....	....
26	1.72	.57	.68	....
27	1.34	1.24	1.60	....
28	1.32	1.41	1.53	....
29	1.34	1.40	1.52	....
30	1.34	1.47	1.67	....
31	....	1.47	1.66	....
Total	29.82	35.44	30.89	13.06

Duty of water at Station No. 3, Boise Valley.

Month.	Area.	Water used.	Depth.
	Acres.	*Acre-feet.*	*Feet.*
June	74	29.82	0.40
July	74	35.44	.48
August	74	30.89	.42
September	74	13.06	.18
Total	74	109.21	1.48

The maximum irrigating head used at any one time was 0.83 cubic foot per second or 41.5 inches, and the average head was 0.61 cubic foot per second or 30.5 inches. The orchard was divided into several tracts, which were irrigated by rotation in from four to eight days.

An automatic register made a continuous record of the depth of the water flowing in the supply lateral as it passed over a trapezoidal weir.

Duty on grain and miscellaneous crops.—No measurements were made this season for the determination of the amount of water used in the irrigation of grain in the Boise Valley. Four irrigations between seedtime and harvest will usually more than suffice. Assuming that 2 cubic feet per second are used in the irrigation of 40 acres of grain, and that three days are required for each application, the total volume employed is 47.6 acre-feet, or enough to cover the tract to a depth of 1.19 feet. Provision should be made for the application of one-half this amount during the hottest part of the growing season, which is usually during July. The last irrigation of grain usually occurs before the 1st of August, or before the river has reached its low-water stage. Potatoes require from one to three irrigations; corn and other crops planted in rows require water from two to four times during the growing season. When the surface is carefully prepared, crops planted in rows may be easily irrigated and do not require a large volume of water, as the irrigating head is divided into very fine threads, one being applied to each row to be watered. A safe estimate of the quantity needed for these and other miscellaneous crops whose growing season is short would be a depth of 1.25 feet, one-half of which should be provided for during thirty days of the hottest season, or from June 15 to August 15.

COST OF WATER.

The following table shows the amount paid per acre and per acre-foot for the delivery of water by irrigators whose methods have just been considered:

Cost of water at Stations 1, 2, and 3.

User.	Volume contracted for.	Price paid.	Acres.	Amount paid per acre.	Water used.	Amount paid per acre-foot.
	Cu. ft. per sec.				*Acre-feet.*	
Under Rust Lateral	13.02	$976.50	790	$1.23	3,997.02	$0.24
A. F. Long	2.00	150.00	105	1.43	252 40	.59
Wilson (orchard)	1.2	90.00	74	1.35	109.21	.82

Although Mr. Long used water with care, turning it back into the main canal when it was not needed, he paid more for it by the acre, and nearly two and one-half times as much per acre-foot used, as was paid by the irrigators under the Rust Lateral. Mr. Wilson, who required but a small volume or irrigating head for each irrigation of his orchard, paid a little more per acre, and nearly three and one-half times as much per acre-foot for the quantity of water actually delivered to him, as did the irrigators under the Rust Lateral. It might be well to state here that the maximum irrigating head used by Mr. Wilson did not exceed 0.8 cubic foot per second; therefore he was to blame for ordering more water than he needed. Had he paid for only the maximum head used, an acre-foot would still have cost him more than twice as much as was paid by the irrigators under the Rust Lateral. Had a reasonable charge been made for the delivery of this water by the acre-foot and a system of rotation in the use of serviceable irrigating heads been planned and enforced by the management, more than twice the area might have been irrigated from the Boise and Nampa Canal this season and the revenue of the company greatly increased. No industry demands as close cooperation on the part of those employed in it, as does farming by means of irrigation. The works which convey water to large bodies of land are necessarily expensive. The cost of maintaining and operating a canal varies but little after a certain capacity is reached. Whether water is sold by a fixed charge per acre irrigated or at so much per cubic foot per second, there is a tendency toward wasteful use. To encourage economy in irrigation water should be sold by the volume used, employing a definite unit, such as the cubic foot or the acre-foot. When a charge is based upon a certain volume flowing continuously during the season, delivering water by rotation can not be enforced by the management, and can only be entered into voluntarily by the users.

DISTRIBUTION OF WATER.

Often on small streams the area of land reclaimed is so great as to seem out of all proportion to the water supply. Harmony may prevail among the irrigators, while on a neighboring large stream the people may be in continual turmoil and litigation over water rights. On the streams first mentioned the irrigators regard the water supply as common property, no one claiming to have a superior right. The opposite of this equitable system may be established on streams having a water supply in excess of the needs of the first users. With only their present needs in mind, every irrigator claims the right to the continuous flow of a certain volume of water. Upon these claims a system of administration of canals and distribution of water is founded, which ignores entirely the fact that the public is as much benefited by the careful use of the water of a large as of a small stream.

It is of course necessary to maintain a continuous flow in the large canals diverting water from the Boise River, for the canal is to the many irrigators along its course what the smaller stream is to those who divert water from it by means of individual ditches. Being their only source of supply, cessation of its flow would be as damaging in its effect as the drying up of the stream.

CHARGING FOR THE DELIVERY OF WATER BY THE ACRE AND ITS EFFECT.

Until 1899 all the canals in the Boise Valley, which were operated for revenue, fixed a price for the delivery of water at a certain amount per acre. Then a change was made. In order to explain its character the methods which were abandoned must be described.

On some of these canals an attempt was made to measure the volume furnished, but most of the devices used were crude, and in many instances the amount was estimated. As a rule there was no orderly system of distribution adopted, the practice being to keep the main lateral filled if possible and to let the users from a common lateral "fight it out" among themselves. Near the lower end of long laterals supplying many users it became necessary for the irrigators to "rotate" in the use of the water reaching them, in order to save their crops. No reduction in price was made on this account, the water costing the same whether a scant or an abundant supply was furnished. It was not surprising, therefore, that every irrigator demanded the full allowance for his land, whether his crops needed it or not.

This practice led to many extravagant ideas regarding the duty of water. There is always an abundant supply during the flood season, but during the period of low water a shortage is liable to occur. As a preparation for this, irrigators were allowed to use all they wanted during the season of plenty. Many took advantage of this license and kept their ditches bank full, saturating the low places on their farms. If the Boise Valley received an annual rainfall of 60 inches or over, drainage would be necessary on all the low land along the river. The excessive use of water in irrigation has had the same result. Waste water has been allowed to flow down every drainage way and collect on every low piece of land lying along its course, and the only individual who has been thoroughly satisfied with the result is the sportsman—wild ducks having become more plentiful on this reclaimed land.

In justice it should be said that many farmers are pursuing better methods, constructing splendid lateral systems, properly leveling their fields, until many farms show the effect of the skill and good taste of their owners. But even this class of farmers have suffered from the wrong system of distribution, for the effort to guard against the selfishness of the slovenly irrigator has led to the building of numerous individual laterals from the main canal and a further loss by delivery of water through several channels, where one would have served better.

The practice of charging for water by the acre not only encouraged wasteful methods in irrigation, but was also, in addition, an inequitable proposition. It compelled the painstaking, thrifty farmer, who had leveled his fields in order to save water, to pay the same price per acre as the man who had not done so.

CHANGE IN STATE IRRIGATION LAW.

The legislature, in 1899, enacted a law to require payment for water by quantity and to secure a more equitable division in other respects. The section referred to is quoted:

SECTION 20. Any person or persons owning or controlling land which has or has not been irrigated from any such canal shall, on or before January 1 of any year, inform the owner or person in control of such canal whether or not he desires the water from said canal for the irrigation of land during the succeeding season, stating also the quantity of water needed. In distributing water from any such canal, ditch, or conduit during any season preference shall be given to those applications for water for land irrigated from said canal the preceding season, and a surplus of water, if any there be, shall be distributed to the lands in the numerical order of the applications for it. But no demand for the purchase of a so-called "perpetual water right," or any contract fixing the annual charges or the quantity of water to be used per acre, shall be imposed as a condition precedent to the delivery of water annually, as provided in this act, but the consumer of water shall be the judge of the amount and the duty of the water required for the irrigation of his land; and annual charges, to be made and to be fixed under the further provisions of this act, shall hereafter be based upon the quantity of water delivered to consumers, and shall not, in any case, depend upon the number of acres irrigated by means of such amount of water delivered.

With but few exceptions this practice of charging by the acre was confined to the Boise Valley when the above law was enacted, the Boise and Nampa, the Settlers, and the Phyllis canals having been operating under that system. As these canals must be depended upon for the irrigation of the greater portion of the reclaimable land in the valley, their management is of great importance to those who wish to promote the prosperity of this section.

The law compelling the delivery of water by quantity was designed to become operative during the season of 1900. The following notices, sent out to water users shortly after its enactment, show how it was viewed by ditch owners in the Boise Valley:

OFFICE OF ——— CANAL,
Boise, Idaho, March 1, 1899.

NOTICE TO CUSTOMERS:

The water rent for the irrigation season of 1899 will be at the rate of seventy-five dollars per cubic foot of water per second, payable November 1, 1899.

Positively no applications will be accepted nor water delivered for any land in arrears for water rent until such arrears are settled.

No water will be turned in any lateral used by two or more customers, nor will the canal company assume any responsibility, until a water master has been appointed and the canal company notified of such appointment.

Applications will first be taken, up to March 25, for land irrigated in 1898, after which date they will be taken in the order they are made, for any surplus water the canal company may safely contract to deliver.

All customers are requested to have their applications in on or before March 30.

Applications, made on the company's contract forms, will be required of all customers, whether claiming under water-right agreements or under general rental, and must be signed by the owner of the land or his authorized agent.

The suggestion is made to customers that under the present law it is very desirable, if not absolutely necessary, for customers under a common lateral, in order to use the water to the best advantage, to club together on a system of rotation; also that all laterals be kept thoroughly clean, and banks strengthened to prevent overflow and waste.

The law against unnecessary waste on the part of both canal and customers will be rigidly enforced.

Water will be turned into the canal as soon after April 1 as the necessary cleaning out and repairs can be made, and will be kept in until November 1, unforeseen and unavoidable accidents and conditions excepted.

OFFICE OF THE ——— CANAL,
Nampa, Idaho, March 20, 1899.

TO THE PATRONS OF THE ——— CANAL:

Water will be furnished for the irrigation season of 1899 at the rate of $225 per cubic foot per second, continuous flow for the season, or, upon applicant waiving the right to demand water by quantity, at the rate of $1.50 per acre, one-half of the amount to be due and payable on or before July 15 and the balance to be due and payable on or before November 1, 1899. No application will be received the amount of which is less than $5, except for town lots.

A discount of five per cent will be made on applications where the money accompanies the application. A discount of one per cent per month will be allowed on all payments made before due.

No water will be furnished to land in arrears for water rent until such arrears are paid in full. Water will not be delivered until the landowner has made a contract for the same.

Where water is delivered by the cubic foot per second, the flow shall be a continuous flow as far as possible, and the amount contracted for will be the maximum amount that will be delivered at any one time. The maximum amount of water to be delivered by the acre at any time will be at the rate of one cubic foot per second for fifty acres (or one miner's inch per acre), and the total maximum quantity allowed at $1.50 per acre will be sufficient to put two feet in depth on the land irrigated (equivalent to a continuous flow of one-half miner's inch per acre for 101 days). Any water used above said two acre-feet will be charged for at proportional rate.

No reduction will be made on any contract where there is less land than contracted for, unless written notice of such shortage be given on or before June 15, 1899. All laterals must be cleaned out and put in good repair and a water master for the same appointed before water for the same will be turned into the lateral.

The notice given first stated that the price charged for the delivery of water will be at the rate of $75 per cubic foot per second, without restrictions of any kind being placed on its delivery. As the law contemplated, the applicant was allowed to estimate the volume needed by his land. Practical suggestions were made as to the importance of cooperation among the irrigators on a common lateral. The price, which was fixed by the cubic foot per second, was designed to yield about the same revenue as the rate per acre formerly charged. As the canal has been carrying its full capacity for two years, the farmer only could profit by this arrangement. The company has tried to measure all the water delivered this season, and the new system has given general satisfaction. Immediate recovery from the effects of the injurious system under which the canal had been conducted for over eight years was not anticipated.

The second notice stated that the price for the delivery of water for the season of 1899 "will be at the rate of $225 per cubic foot per second, continuous flow for the season, or upon the applicant waiving the right to demand water by quantity, at the rate of $1.50 per acre."

The great importance attached to the condition of a continuous flow for the season does not seem warranted when it is further agreed that the water is to be used only when required. No one would be benefited by allowing valuable water to run to waste. The second rate, $1.50 per acre, is the minimum price which will be accepted. At this rate the irrigator can cover his field to a depth of 2 feet. If this is exceeded an additional payment must be made at a proportional rate. Under this arrangement one farmer might cover his land to a depth of 4 feet, which would cost $3 per acre. Another might cover his land to a depth of but one-half of a foot. The latter would have to pay $1.50 per acre, or four times as much for the same quantity as the former. This is manifestly unjust. When water is sold by the volume, the rate should be uniform.

The notice provides that "when water is delivered by the cubic foot per second the flow shall be continuous as far as possible, and the amount contracted for will be the maximum amount that will be delivered at any one time."

The most ignorant irrigator realizes that a continuous flow of water, like a continual downfall of rain, would be injurious. Under this arrangement the small farmer who might otherwise economize is discouraged. He is compelled to pay for the greatest quantity used at any one time, no matter how brief the duration of such use. He must therefore pay for enough to cause it to flow quickly over his field, otherwise the attempt to irrigate would be like a drizzling rainfall lasting from spring till autumn, but not heavy enough at any time to wet the soil.

It is galling to the irrigator who notifies the management at the beginning of the season that he will require the same amount of water he used in previous years for the irrigation of a larger area to have this acreage carefully measured at the close of the season and his bill for the delivery of water proportionately increased.

A careful analysis of this notice shows that the distribution of water based upon this system is diametrically opposed to every voluntary effort of the irrigator to secure a higher duty.

ADVANTAGES OF BASING CHARGES UPON THE QUANTITY DELIVERED.

A charge for the delivery of water by the acre-foot combined with a system of rotation will not only lead to the best methods in the application of water to the land, but is in itself equitable and just. An acre-foot is specific; its delivery presupposes the existence of proper measuring devices, and the number of acre-feet used determines the cost of each and every irrigation during the season. An effort to reduce the size of water bills will lead to a study of methods for the better preparation and cultivation of the soil. Taking water by turns leads to orderly habits and respect for the rights of others. The resulting increase in the duty of water leads to the reclamation of other lands to share in the burden of taxation and other assessments made by the community. In fixing charges for delivering water it would be an advantage to give a lower rate for the first part of the season. Prior to harvesting time the supply is ample, and the more water diverted onto the bench lands before this time the greater will be the return seepage during the months of minimum discharge.

DUTY OF BOISE RIVER.

In order to determine the duty of the Boise River we must know, first, its natural discharge at the head of the valley during the irrigation season; second, the amount of return seepage water, and third, the average quantity of water required to irrigate an acre of land during a certain portion of the irrigating season. The discharge of the river during the period of the greatest use measures the available supply for irrigation. This occurs during the last week of July and in the month of August. Occasionally it begins early in July, and though there may be a slight variation in the time of its occurrence, its duration is about the same each year—thirty to thirty-five days. In August, 1898, the mean flow of the river each day was 794 cubic feet per second, varying from 1,063 feet on August 2 to 698 feet on August 31. An examination of the diagram (fig. 18, p. 221) of the discharge of the river proves that that season was one of extreme low water. It will therefore be safe to assume that this amount is the average minimum flow of the river during the period of greatest use.

Influence of return or seepage water.—The volume of return or seepage water will undoubtedly increase from year to year and be in proportion to the amount diverted for irrigation. If the canals of the Boise Valley were each year made to utilize more of the flood flow of the river, the seepage water would without doubt continue to increase. Assuming that after the present canals have been sufficiently enlarged the available seepage flow amounts to but 500 cubic feet per second, we will then have a minimum supply in the river at our disposal during the period of greatest use of 1,294 cubic feet per second.

The irrigated area of the Boise Valley has increased from about 27,000 acres in 1895 to 50,000 acres in 1899. The increase of area has been chiefly on the upper or bench lands. The water conducted onto these benches (especially on the south side of the river) has been distributed to a great distance from the river, therefore the return of the water taken up by the underlying gravel was not noticed until within the last two or three years. The following incident illustrates the changed conditions resulting from this seepage.

In 1891, the promoters of the New York Canal proposed to divert nearly all the water of the Boise River at a point in the Boise Canyon and irrigate all the lands lying on the south side of the river below the level of that line. (See Map, Pl. XLIX, p. 220.) The following protest against the building of this canal, copied from the public records of Ada County, shows the apprehensions of those constructing canals and diverting water from the river in the Caldwell Canyon, 40 miles below:

Idaho Irrigation and Colonization Company to Idaho Mining and Irrigation Company.

The Idaho Irrigation and Colonization Company to the Idaho Mining and Irrigation Company and to whom it may concern, greeting:

Whereas it has come to our knowledge that a certain company, viz, The Idaho Mining and Irrigation Company, has projected and intends to the construction and enlargement of certain canals and ditches, viz, the so-called New York Canal and the Phyllis Canal, with the object of taking and diverting water from the Boise River in the State of Idaho for irrigating, mining, and other purposes; and whereas we believe that all the water running in said river in time of low-water has been filed upon and appropriated by individuals and companies whose priority of claims and appropriation must and will be guarded and protected; and

Whereas we believe that the great expense to which said Idaho Mining and Irrigation Company would be at in construction and enlargement of said canals would result in great loss to said company because of lack of water in the Boise River heretofore appropriated by prior claimants to supply said canals and ditches constructed and enlarged as intended:

Therefore said Idaho Mining and Irrigation Company will please take notice that we have appropriated 20,000 cubic inches, measured by the mining laws of the United States and State of Idaho prescribed, of water running in the said Boise River for irrigation and agricultural purposes; that in time of low water there is barely sufficient unappropriated water running in said river to supply our claim; that any diminution in this supply by appropriation subsequent to our own will be resisted; that we now warn said company that any taking or diverting of waters from said Boise River in canals and ditches constructed and enlarged as intended by said company will cause a diminution of water appropriated and used by us, and therefore that the proposed construction and enlargement of canals and ditches by said company is unwarranted and the taking and diverting of water as intended will be unlawful and the great expense incident to said work must result in great financial loss to said company.

IDAHO IRRIGATION AND COLONIZATION COMPANY.

This protest was filed in 1891. At that time not more than 4,000 acres of bench land were irrigated from the Boise River. The plans of the company referred to contemplated the construction of storage works on the head waters of the Boise. If the parties who protested were not cognizant of this fact their apprehensions of danger in the diversion of more water from the river might have been considered at that time well founded, for during the early years of the settlement of the country about Caldwell the Boise River had been entirely dry during a portion of the summer. Since the above protest was recorded the area of bench land irrigated has been increased tenfold. Instead of the water right of this canal being precarious it is regarded as the best on the river.

What is now being done.—The large canals maintain a constant flow throughout the irrigating season. It will be safe to estimate the average combined irrigating head of these canals at 1,400 cubic feet per second. This volume irrigated 50,000 acres during 1899. There was, of course, considerable loss from seepage and evaporation in the main canals and laterals during the hottest weather. This loss has not been determined, but from the nature of the soil loss from seepage could not have been very great. Assuming, however, that the combined loss is equal to 30 per cent of the volume diverted from the river, the net supply delivered at the fields for irrigation would be 980 cubic feet per second. This allows an average duty of 51 acres for each cubic foot per second of water diverted. Nine hundred and eighty cubic feet per second flowing onto 50,000 acres of land for thirty-one days will cover it to a depth of 1.21 feet. We find that the farmers under the Rust Lateral used during the month of July, 1899, a depth of 1.15 feet, which approximates the average duty obtained throughout the valley. In the case of Mr. Long, however, we find that a depth of 0.872 foot during the month of July was sufficient. Inasmuch as the methods employed by Mr. Long were not unusual, it is not unreasonable to insist that 32 per cent more land under the Rust Lateral could have been irrigated during that month with the same head of water. When the available supply in the river is only 1,294 cubic feet per second there should be sufficient water to properly irrigate 63,682 acres, after deducting 30 per cent due to loss from seepage and evaporation. This would require a duty of 70.5 acres for each cubic foot per second of water applied to the land. No account is taken here of the amount which runs off the land during its irrigation. If this were collected in drainage ditches and applied to the lower lands, this irrigated area might be increased by perhaps 30 per cent. The duty of water would increase to 64.1 acres for each cubic foot per second diverted from the river, or 91.6 acres for each cubic foot per second applied to the land, and the river would irrigate 83,000 acres at its minimum flow. This area is not, however, the limit of the ultimate service of the Boise River. Usually at the end of July the available supply, estimating the increase for seepage at 500 cubic feet per second, is about 2,000 cubic feet per second. Assuming that the irrigation of 83,000 acres will require at all times 1,294 cubic-feet per second, there will be left 706 cubic feet per second for the irrigation of grain, which will mature before the low-water stage is reached. Assuming that each cubic foot per second of this water will irrigate 64.1 acres, it will be sufficient for the growth of 45,254 acres of grain, making in all 128,254 acres which might be watered. This estimate will, perhaps, seem high to many irrigators in the valley, but this is because they have become accustomed to the waste which is now so prevalent.

The Boise and Nampa Canal delivered daily 700 acre-feet of water to only 17,100 acres, equivalent to a depth of 1.27 feet during both July and August, or to a daily rainfall of nearly one-half an inch.

The Settlers' Canal delivered 180 acre-feet daily on 5,000 acres. Being a short canal, the loss from seepage and evaporation was slight. This was equal to a layer 1.13 feet deep in both July and August.

Assuming that the Phyllis Canal discharged daily 160 acre-feet during both July and August, there was delivered to the 3,000 acres under it sufficient water to cover it to a depth of 1.65 feet, or an amount nearly equal to the rainfall in the State of Iowa from May 1 to September 30, 1899.

The Sebree Canal delivered 320 acre-feet daily. This volume would cover the 7,000 acres of land watered by it to a depth of 1.42 feet during the months of July and August. The canals and ditches on the first bottom delivered water at the rate of "1 inch to the acre," which would cover the land to a depth of 1.24 feet in thirty-one days.

In some portions of the State the duty of water is nearly twice as great as in the Boise Valley. If the farmers of this valley are disposed to continue the present system, then the duty of water will remain low, the cost of water per acre high, and storage works for sufficient water to irrigate more than one-half the area lying below the present canals must be provided. If economical methods are inaugurated the cost of reservoirs to provide water for the irrigation of the remainder of the land will be proportionately decreased.

RELATION OF DUTY OF WATER TO THE FUTURE OF THE VALLEY.

Of the land embraced within the boundaries of irrigation canals constructed and projected in the Boise Valley, 88,440 acres have been acquired under the homestead act, 59,440 acres by purchase, 53,000 acres under the desert-land laws, 65,840 acres have been selected by the State of Idaho, and 133,080 acres are vacant public lands. Of these lands, 96,000 acres are waste, or above the level of canals, leaving 310,000 acres susceptible of irrigation. Of the 262,920 acres of land which have passed from the public domain, 184,859 acres have been patented. The assessed valuation of property in the Boise Valley made in April, 1891, exclusive of the value of canals, and three-fourths the value of the realty in the city of Boise was $3,268,000, or a real value of over $6,000,000. This valuation does not include the stock interest, but only such property as properly pertains to agriculture. The products of the Boise Valley cover a wide range. In horticulture they range from peaches to winter apples, while in the garden and field they range from the cantaloupe of excellent quality to corn and hops. Prune and apple orchards are no more conspicuous than alfalfa fields. Therefore we might with safety claim a value for this land, after it has been properly developed, equal at least to the average value of the irrigated lands of Utah. This, according to the last census, was $84 per acre. When on this basis 280,000 acres of land are under a high state of cultivation, the farms of this valley will be worth more than $20,000,000; 100,000 people may find homes and be comfortably sustained, and they will produce more wealth than all of the gold mines of Idaho.

CHARACTER OF APPROPRIATIONS OF WATER IN IDAHO AND ITS INFLUENCE ON THE DUTY OBTAINED.

The water-right provisions of the constitution of Idaho constitute a foundation for equitable laws, but the laws for carrying this constitution into effect are so indefinite that there are about as many views regarding their meaning as there are users of water. This uncertainty has lowered the duty obtained, because in the absence of specific provision there has been a general feeling that the more water used the larger the right which could be subsequently established. If there had been a definite declaration that only the actual users of water would have a right to it, the public records of Idaho would not have been vitiated by the extravagant claims which now encumber them. Assuming that these claims give a right to a continuous flow from the Boise River, they amount to one hundred and sixty times the low-water discharge of the stream. (See Pl. L.) No one can scrutinize these records without realizing that an immense amount of work will be necessary to select from among the many who have claimed a right to water the few who have actually used it. The difficulty of making a just division of the water to the many users will increase as the irrigated area grows. The work should be taken up at once. The testimony necessary for making an equitable adjudication of the rights can only be given by the pioneers who constructed the ditches and used the water.

Measured by the duty now prevailing, canals to supply the reclaimable area of the valley will need a combined capacity of about 7,800 cubic feet per second. This will involve the enlargement and extension of the service of nearly every canal, and the question arises, What is to be the character of the rights to water growing out of these extensions? These canals now supply isolated farms scattered throughout the length and breadth of the valley, and are slowly enlarging the sphere of their usefulness as the oases now under cultivation are multiplied or

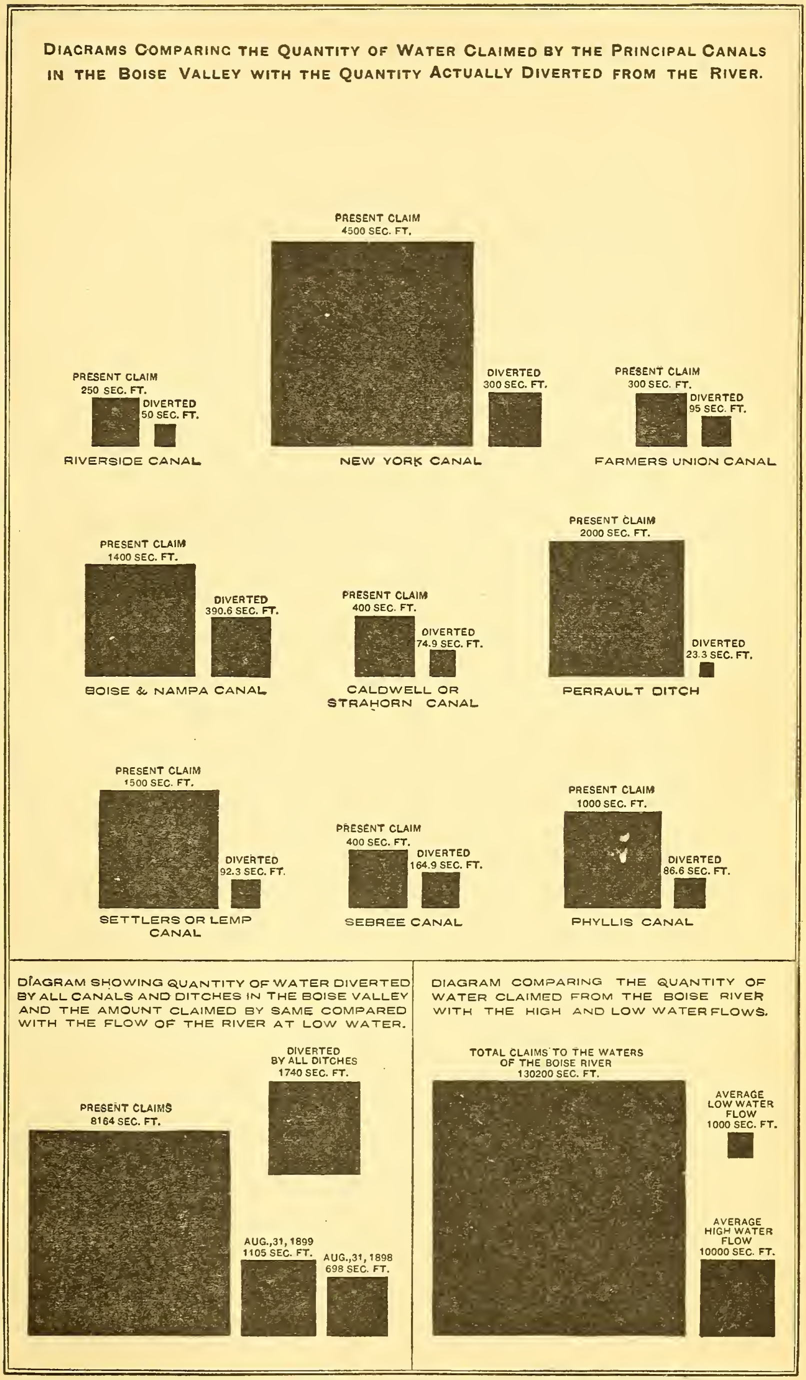


DIAGRAM COMPARING THE QUANTITY OF WATER CLAIMED AND ACTUALLY DIVERTED BY THE PRINCIPAL CANALS IN THE BOISE VALLEY.

extended. This progress in the beneficial use of water is going on at the same time under the ditches last built and those first constructed. The benefits to the State from the labors of a settler under a new ditch are as great as from those who settled under the earlier ones, and it is simply a matter of chance which has the older citizenship. Where settlers come to the State the same year, file on land the same season, and use water in the same fashion, it is not easy to understand why they have not an equal right to the use of the State's public water supply, but there are some to whom this doctrine is heresy. The latter hold that the earlier ditches have exclusive rights and that to protect these there should be an immediate adjudication, having for its purpose the determination of which ditch should be allowed to increase its usefulness and which denied the privilege.

CONCLUSIONS.

The investigations which form the basis of this report show that a knowledge of the conditions which influence the duty of water is a fundamental necessity in the improvement of irrigation methods. The most effective method of promoting economy is to show the loss produced by waste. This is what the studies of the duty of water now being carried on by the United States Department of Agriculture are doing. The results of the first year's measurements in this valley show that fully one-half of the water now diverted by canals is wasted. It also shows that it is possible to reclaim more than twice the area of land now watered without any enlargement of the canals now in use. The surest way to bring this about is to have water contracts provide that canal companies shall measure the volume delivered and farmers pay for only what they receive.

INFLUENCE OF THE CHARACTER OF WATER-RIGHT CONTRACTS ON THE DUTY OF WATER.

(1) When farmers are charged for water according to the number of acres they irrigate, the temptation is to use the largest volume afforded them rather than the quantity needed.

(2) This system requires a constant flow, and when no rebate is given for the time water is shut off the tendency is to permit it to run continuously. The volume wasted is often a large percentage of the volume supplied. Waste robs the canal company directly and the farmer indirectly by reducing the productiveness of his farm.

(3) Were the charge for water based on the volume used, the loss from waste would be borne wholly by the irrigator, as it should be.

(4) A charge for the volume employed would result in a more beneficial use of water. A larger area could then be irrigated and revenues derived from the sale of water would increase.

(5) Under such administration the farmer would carefully prepare the surface of his fields in order that the water might be applied in the shortest possible time. He would endeavor to determine the quantity of water actually required to produce the best results. Thus an interest would be encouraged in the more accurate and scientific features of farming, which are always of incalculable benefit to every community.

(6) The inauguration of a uniform system of rotation would tend to increase the duty of water and proportionately reduce the cost of irrigation. In order to properly carry this into effect, laterals and boxes should always be in good condition.

(7) When this system is established, irrigation on each tract is reduced to a routine, every farmer knowing in advance what sized head of water he is entitled to and the length of time it will flow onto his land. Under this plan he is also afforded an incentive to reduce the amount used by improving his methods of cultivation and of distributing the water after it enters his fields.

(8) The company should construct a drainage system throughout the entire district connecting all swampy places with natural waste ways, and the water thus drained from the land should be under its control for distribution.

INDEX.

O