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Bulletin No. 181 - Duty-of-Water Investigations on Coal Creek, Utah

Arthur Fife

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Duty-of-Water Investigations on Coal Creek, Utah

By

ARTHUR FIFE

BULLETIN NO. 181

Utah Agricultural College
EXPERIMENT STATION

Logan, Utah August, 1922
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IN CHARGE OF COOPERATIVE INVESTIGATIONS WITH
THE U. S. DEPARTMENT OF AGRICULTURE

L. M. WINSOR, B. S., ........................................Irrigation Engineer

*On leave.
DUTY-OF-WATER INVESTIGATIONS ON
COAL CREEK, UTAH

By
ARTHUR FIFE

Coal Creek flows from the west slope of the part of the Wasatch Mountain range which is located in the southeast part of Iron County, Utah. Its drainage area is almost 100 square miles.

Seasonal and daily stream-flow fluctuations are very pronounced. During the high water of spring the flow has reached more than 600 second-feet. At the time of high water, the daily fluctuations are the greatest. During the low water season in July and August, the flow has dropped as low as 12 second-feet since 1917, when accurate records were first kept; and, from the accounts of early settlers, there have been times when the stream was too low to be of any service for irrigation.

Storage of spring and winter waters would greatly benefit the valley, but there are no promising locations for reservoirs on Coal Creek. Despite the lack of storage facilities, most of the high water is used for irrigation and is not wasted as with many Utah streams. Usually, the owners of the bottom lands are able to handle the entire high-water flow of the stream. However, if the water were available when it is most needed, the benefits would be much greater.

SOIL PROPERTIES

On the whole, the soil and subsoil of the lands under Coal Creek have a high moisture-holding capacity.

Most of the primary lands are situated on the bench or semi-bench area. The depth to the water-table is so great that there is no apparent danger of the rise of ground water. There is consequently little incentive to stimulate the irrigator to a careful and economical use of the water.

The work reported herein is based on experiments conducted cooperatively by the Utah Experiment Station, the Irrigation Division, Bureau of Public Roads of the U. S. Department of Agriculture, and the water users under Coal Creek. O. W. Israelsen, Irrigation Engineer, Utah Experiment Station, and L. M. Winsor, Irrigation Engineer, Irrigation Division, Bureau of Public Roads of the U. S. Department of Agriculture, have directed the work and have also assisted in preparing the report for publication.
DUTY OF WATER

The wide variation in the duty of water in different localities that are geographically somewhat similar emphasizes the fact that irrigation practice in many places is not based on the actual needs for water. Practice seems to be based on precedent established when water was plentiful and when there was no apparent need of determining the proper duty of water. Because the duty of water is influenced by a large number of variable factors, it is necessary that water-right allotments be based on the most complete information obtainable by painstaking observation and experiment.

Experiments on irrigation may be grouped under two heads: (1) those conducted on a purely scientific basis, in which all the factors affecting the fundamental requirements for water are controlled and measured; and (2) those conducted under actual field conditions to determine how nearly the irrigators in any locality under certain practical conditions can approach the use of only those amounts of water inherently necessary for crop growth.

The experiments here reported were conducted in average fields under ordinary farming conditions, and, therefore, concern practical water needs.

INCEPTION OF THE WORK

In 1915, L. M. Winsor, acting for the Utah Experiment Station and the Irrigation Division of the U. S. Department of Agriculture, outlined some irrigation experiments to be conducted until 1917, at which time new interests were involved in duty-of-water work on Coal Creek, and the work on the Branch Agricultural College farm became a part of the new work.

This new work was the outgrowth of a water-right decree rendered by Judge Greenwood in 1901, in which the rights on Coal Creek were divided into several classes. The quantity decreed in each class of rights was to be based on the requirements of the land, as determined by a water commissioner and his assistants. However, nothing was done to determine the water requirements until early in 1917, when the pressure of new water filings forced the question to an issue.

At a mass meeting of the water users on Coal Creek, a plan was adopted whereby the necessary investigations would be conducted cooperatively by the Utah Experiment Station, the Irrigation Division of the United States Department of Agriculture, and the water users. A representative of the first two cooperators was appointed court commissioner, who in turn,
selected two assistants for the field work, one to distribute the water, and the other to conduct experiments on the duty of water under the various classes of water-rights. This bulletin considers only the experimental work.

**Scope of Work.**—The duty-of-water experiments were conducted during the years 1915 to 1919, inclusive. The purpose of the experiments was to find how the yields of staple crops were influenced by the application of different quantities of water to representative soils. The crops experimented with were alfalfa, spring wheat, barley, oats, potatoes, and corn. Not all of these crops were represented every year.

The experiments, it is believed, deal with a sufficient number of crop and soil conditions to be of value in assisting the court to understand the situation with reference to a water-rights adjudication.

However, limitations imposed by lack of funds made it necessary to confine the investigations to the more essential and fundamental features in duty-of-water studies. Many interesting and important problems that arose in the progress of the work could therefore be given only passing attention.

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**Fig. 1.**—Monthly precipitation during irrigation season, 1917, 1918, and 1919 at Cedar City.

**Records of Precipitation.**—Figures 1, 2, and 3, presenting precipitation comparisons, show that both extremes in rainfall are represented during the time the experiments were conducted. For 1917, the rainfall for the six months beginning with April was 131 per cent of the mean rainfall for that period, whereas in 1918 and 1919 it decreased to 82 per cent and 80 per cent, respectively.

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1 Precipitation records were secured from Parley Dalley, cooperator with the U. S. Weather Bureau at Cedar City.
For the crop-year\textsuperscript{1} 1917, the rainfall was 126 per cent of the mean decreasing in 1918 and 1919 to 72 per cent and 83 per cent, respectively.

A consideration of the precipitation at once raises the question as to the effect of the seasonal rainfall and other weather conditions on the duty of water. The weather factor is beyond the irrigator's control. It is very complex because it is influenced by a great many elements such as temperature, wind, and distribution of rainfall. The important effect of the weather on the duty of water and its wide range of variation clearly shows that no definite figure can represent the true irrigation requirements. Further consideration of the many other natural factors that influence irrigation confirms the assertion that the duty of water is necessarily variable.

It is interesting to note what an important factor the spring weather is in the distribution of the high water to lands under the several classes of water-rights. If the spring opens early and gradually, the high-water flow is extended through a long period of relatively small flow, in which case the largest part of it is turned into the canals representing the prior water-rights. But, if the spring opens suddenly and remains warm, the high water comes down in a gush, in which case, the first canals can hold only a small part of the flow, and the high-water lands are abundantly supplied.

**EXPERIMENTS**

**Selection of Farms:**—Farms on which to conduct the experiments were selected in different sections with the idea of having the typical soils represented. Uniformity of soil within each field is desirable and was given considerable attention in the selection of the farms. However, as will be noted later, some of the results were influenced by a lack of uniformity in the soil.

In 1917, each experimental field except field K was divided into four plats\textsuperscript{2} and each plat given a different amount of water.

\textsuperscript{1}Crop-year, October 1 to September 30 following.

\textsuperscript{2}Five plats in case of potatoes, Field E.
Field K (See Fig. 4) was divided into three plats. During the other years, three different amounts of water were given each field.

It was the original plan to depend largely upon the farm owners for the labor of applying the water to the land. However, experience proved that the variation planned could not be followed under this system, because in too many cases the problem of getting a uniform distribution of water on the field, one of the big factors in making the experiments significant, was not given enough attention by the farm owners. In other words, the farmer wanted to keep the water running till all parts of the field were watered, which action is justifiable, but he did not recognize the relationship which should exist between a proper irrigation and the amount of water necessary to obtain it. Consequently, he did not use the required diligence when it was difficult to obtain uniform lateral distribution. This situation made it necessary for the representative in charge of the work to take part in the actual work of applying the water.

Submerged orifices and trapezoidal weirs were used to measure the irrigation streams applied to the farms, and the runoff measurements were made with triangular weirs.

**ALFALFA**

The relative importance of alfalfa among the crops grown under Coal Creek demands that its water requirements be given the most weight in determining the duty of water. A rough survey of one typical section showed that 85 per cent of the farming land was in alfalfa.

The alfalfa experiments are considered in two groups: (1)
those on lands that have primary water-rights and (2) those on lands that have secondary water-rights.

Primary Lands.—In Figures 4 and 5 are shown graphically the yields produced by different quantities of water for the five years of the experiments on lands with primary water-rights. The amounts of water applied to the various plats are indicated by the length of the black solid columns below the middle horizontal line and are given in acre-inches an acre, or simply inches depth over the surface as shown on the left side of the figures.

1The decree of 1901 divides the water-rights into seven priority classes. Primary lands are those in the first class. Secondary lands are those in subsequent classes.

2See explanation in heavy type, page 22.
The alfalfa produced with the different amounts of water is indicated by the dotted columns above the middle horizontal line, the yields being reported in tons to the acre. The letters, A, M, K, etc., indicate the particular field on which the work was done. The plan of presentation of the alfalfa yields is followed in reporting the yields of other crops; the alfalfa charts are, therefore, typical of all the charts used.

From 1915 to 1917, inclusive, it is apparent, by examination of Figure 4, that the range of variation in the amount of water applied was not high enough to satisfy the demands for maximum yields. In 1918 and 1919 this range was increased considerably.

In 1915, the irrigation treatments for field K consisted of an early, unmeasured irrigation for all plats, followed by two
3-inch irrigations to plat 2, and three 3-inch irrigations for plat 3.

In 1916, plat 1 was not irrigated, but a flood in August which covered it increased the yield of the third crop. Plat 2 was given three and plat 3 six irrigations, in which totals of 12 and 25 inches, respectively, were applied.

In 1917, the first group was unirrigated, the second was given one 5-inch irrigation for each cutting, and the third was given two five-inch irrigations for each cutting.

In 1918, nine irrigations were given to all plats of field M, in average amounts of $3\frac{1}{2}$ inches, $5\frac{1}{2}$ inches, and 7 inches, respectively. On field K, all irrigations were of a uniform size of about 5 inches, given in 3, 6, and 9 irrigations, respectively. Late in 1918 it was discovered that field K had been inadvertently flooded for several days during the winter before. This reduced the accuracy of the 1918 results.

In 1919 on field M, five 6-inch, seven 7-inch, and eight $9\frac{1}{2}$-inch irrigations were given to each of the three groups, respectively. The three groups represented on field K were given 3, 6, and 8 irrigations, the size of which ranged from 6 to 7 inches.

During the whole period, the total amount of water used ranged from 0 to 75 inches, with the maximum yield of more than 7 tons an acre from the land receiving the most water. This response to large quantities of water is quite typical of alfalfa under conditions similar to those existing on the lands that have primary water-rights on Coal Creek. Excellent under-drainage, combined with the high moisture retentive capacity of this deep soil, favors large alfalfa yields.

Different interpretations of the results, in relation to duty of water and water-rights, will be made, depending upon the interests concerned. The economical requirements, from the standpoint of the farmer who is having a measure placed on his water-right, will be greater than that deduced from a strict analysis of what constitutes economical use. From the standpoint of the public it is desirable to have the water distributed and used according to the truly economical duty. Just what policy to follow toward accomplishing economy in use is a question.

Table I shows the profits to the acre for different irrigation treatments on field M for 1918 and fields M and K for 1919. These profits are based on an economical solution in which the water investment is proportional to the amount used.
TABLE I. PROFITS TO THE ACRE. ALFALFA 1918, 1919.

<table>
<thead>
<tr>
<th>Year</th>
<th>Yield</th>
<th>Yield in Tons</th>
<th>Inches of Water Applied</th>
<th>Profit to the Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>1918</td>
<td>M</td>
<td>4.4</td>
<td>31</td>
<td>$7.31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.1</td>
<td>48</td>
<td>6.85</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.3</td>
<td>66</td>
<td>1.35</td>
</tr>
<tr>
<td>1919</td>
<td>M</td>
<td>5.6</td>
<td>28</td>
<td>18.30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.3</td>
<td>48</td>
<td>16.85</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.3</td>
<td>77</td>
<td>13.75</td>
</tr>
<tr>
<td>1919</td>
<td>K</td>
<td>5.4</td>
<td>21</td>
<td>20.17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.9</td>
<td>38</td>
<td>16.80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.2</td>
<td>52</td>
<td>13.50</td>
</tr>
</tbody>
</table>

An itemized statement of the values and costs used in the profit analysis follows:

1. Manure ........................................ $4.00 an acre
2. Interest and taxes.............................. 8 per cent of investment
3. Rent on machinery............................ 1.00 an acre
4. Labor of harvesting.......................... 1.70 a ton
5. Labor of irrigating......................... 0.60 an acre for each irrigation
6. Other labor items............................ 2.85 an acre
7. Value of land investment.................... 100.00 an acre
8. Value of water investment................... 50.00 an acre-foot
9. Hay in the stack was valued at............. 10.00 a ton

Table I shows in each case the smallest amount of water produced the maximum profit an acre. The economical solution differs from that made by a water-right owner, who is endeavoring to determine and obtain a quantitative measure of his water-right, in that the investment in the water-right is variable and increases directly with an increase in water, while the farmer considers his investment as constant even though the amount of water he actually gets varies greatly. If the profit figures in Table I are adjusted to comply with a constant or uniform water investment equal to the average price for a water-right, the maximum profit in each case was produced with the largest amount of water.

As was stated before, it is highly desirable from the standpoint of agricultural expansion and growth to have the water used according to a truly economical duty. For several reasons this is not within immediate attainment. Adjustment of methods of irrigation to suit the different soil and topographical conditions must be made before it will be physically possible to reach this duty. The organization of distribution must also be greatly

1As a basis for the determination of labor costs for the production of alfalfa, figures were used from Utah Experiment Station Bulletin 165, by L. G. Connor. Small modifications in some of Mr. Connor's figures were necessary to make these figures apply to the Coal Creek section.
improved. Then last and of the most importance, some policy must be developed which will make this practice agreeable and satisfactory to the primary water users.

**Secondary Lands.**—Figure 6 shows a summary of the three-years' results on land with secondary water-rights. Inasmuch as some primary water was used, the results do not show the true

<table>
<thead>
<tr>
<th>Year</th>
<th>1st Cutting</th>
<th>2nd Cutting</th>
<th>3rd Cutting</th>
</tr>
</thead>
<tbody>
<tr>
<td>1917</td>
<td><img src="image1.png" alt="Graph" /></td>
<td><img src="image2.png" alt="Graph" /></td>
<td><img src="image3.png" alt="Graph" /></td>
</tr>
<tr>
<td>1918</td>
<td><img src="image4.png" alt="Graph" /></td>
<td><img src="image5.png" alt="Graph" /></td>
<td><img src="image6.png" alt="Graph" /></td>
</tr>
<tr>
<td>1919</td>
<td><img src="image7.png" alt="Graph" /></td>
<td><img src="image8.png" alt="Graph" /></td>
<td><img src="image9.png" alt="Graph" /></td>
</tr>
</tbody>
</table>

*Fig. 6—Alfalfa yields with various quantities of water on secondary lands.*
condition under secondary rights only. However, a careful analysis will give a fair conception of the true secondary conditions. Naturally the yields are less from lands with the secondary rights than from those with primary rights.

The total yield during the season of 1917 from field C is shown with the corresponding amount of water used for each treatment. The field used in 1917 proved to be unsuitable for the experiments. A great many impervious spots caused a like number of "burnt" spots in the alfalfa field. Only the action of winter weather can get moisture into these bad places when once they become dry.

As an introduction to the results of 1918 and 1919, a word is necessary regarding the general situation of the experiments under secondary rights. Where the water supply is limited to a short period in the spring and early summer, the type of soil plays a more important part in the economical use of water than when the supply is constant throughout the season. Therefore, it is evident that the results on a single farm representing secondary lands must be more limited in application than the results from a single field under primary rights. Observations of general results on other fields in the section are very helpful in learning the economical needs for water on these secondary lands.

The results for 1918 and 1919 are arranged by cuttings. Due partly to the use of primary water, the second cuttings were not appreciably different from the first in the respective groups. However, under strictly secondary conditions very little water is available for lands with secondary rights after the first cutting. Consequently, the second and third crops depend on the retentive capacity of the soil to hold in reserve moisture for the late-season growth, in which case the yields for these cuttings are proportional to this retentive capacity. Observations of different fields in the section show that this capacity varies from the maximum, where good second and third cuttings are produced, to the minimum, where a second crop will hardly start without a renewal of soil moisture. As much as two feet of water each month during the limited irrigation season may be used quite economically by the good land, but this would result in a very significant percolation loss if applied to the less retentive soil. A soil survey is needed to determine the area and distribution of the several soil types.

This situation, in the light of the discussion above, means that a definite allotment to all lands with secondary rights will not coincide with the economical requirements for all types of
soil as nearly as it will coincide to the requirements of lands with primary rights. In other words, the true duty of water under secondary rights is subject to a much greater variation than under primary rights.

Without exception, the largest yields for any cutting were produced on the plats receiving the most water. Explanation of the methods of irrigation will assist in interpreting these results. The difficulty of securing a uniform lateral distribution causes excessive single applications. Lateral distribution is the final operation of the irrigator in getting water into the soil. Under the ordinary methods of irrigation in this district, by the time the lower parts of the fields are properly watered, the upper parts have absorbed excessive amounts of water. This partly accounts for the larger yields being produced with the most water, inasmuch as these yields were produced on the only plats which were really given a thorough application over their entire area. Additional care and expenditure in the preparation of land for irrigation and in the application of the water will greatly increase the efficiency in the use of water. The problem of adjusting methods of irrigation to suit the particular soil and other conditions on each farm will have to be given careful attention. A high duty of water never can be attained until this adjustment is made, and the necessary adjustment will require a number of years.

Fig. 7.—Wheat yields with various quantities of water.
GRAINS

Most of the irrigated grain grown under Coal Creek is spring planted. The two big variable factors in the duty of water for grain on the ordinary soil under Coal Creek are: (1) the moisture condition of the soil as it emerges from winter; and (2) the practical size of single irrigations. The practice of irrigating the grain land just before planting has given excellent results in this locality because so often without this early irrigation, there is not sufficient moisture in the soil to give the plant the proper growth early in the season. In other words, it is more desirable to irrigate before planting than soon after planting. However, when the winter precipitation has been abundant and cultivation has held it in the soil, this early irrigation is unnecessary.

The practical size of single irrigations can well be given considerable attention. To overcome the necessity of excessive single applications, it is first important to plant on fall-plowed land. Spring plowing increases evaporation losses and also greatly increases the porosity of the soil. Then the length of run must be considered. Attention later will be called to the use of cross ditches in saving water. Adjustment in length of run of the water on the land applies to alfalfa as well as to grains.

In the final allotment of water to the land, the weight given the requirements of each crop should be in proportion to the relative acreage of each one. For example, if alfalfa constitutes 85 per cent of the acreage grown, then 85 per cent of the allotment should be based on alfalfa requirements.

Wheat.—Figure 7 shows two years' results on wheat. In 1917 the crop was grown on run-down land and the yields were light. The damage by grasshoppers in 1919 greatly reduced the yields.

The 1917 wheat crop received 4 irrigations in average sizes of 3½, 5, 6½, and 8 inches, respectively, for the four variation groups. In 1919 three 3-inch, three 4-inch, and four 5-inch irrigations were given.

Wheat will need from 2 to 4 irrigations, depending on the winter precipitation and on other weather conditions. The factors governing the sizes of irrigations have been mentioned. For one experiment, not recorded in the figure, 18 inches of water were used in one irrigation before the lower part of the field was watered. In this experiment the water was run in furrows 40 rods long. Two men were employed in the work, and the condition cannot be materially changed until there are introduced one or two cross-ditches in this 40-rod length. A run of 40 rods is a fairly standard length in this section.
If a reasonably uniform lateral distribution can be accomplished 5- or 6-inch applications will be sufficient for all grain crops. A reasonably satisfactory lateral distribution may be obtained with these amounts of water on fall-plowed land, but may not be possible on spring-plowed land. The actual duty of water for wheat under present conditions ranges from 18 inches to 40 inches. The success in reducing consistently the size of single irrigations will determine the possibility of greatly increasing the duty of water for wheat. A truly economical analysis of the results given in figure 7 shows that the largest application of water each year produced the maximum profit.

Barley.—The practical duty of water for barley is not greatly different from that of wheat. From 2 to 4 irrigations are necessary, depending on the moisture content at the beginning of the season and on the weather conditions during the growth. Experiments indicated that a shortage of soil moisture during the early growth caused a more permanent injury to barley than to wheat.

Figure 8 shows the results of two years' experiments on barley. In 1918, on field M, a normal yield was taken only from the plat that received nearly 40 inches of water. This was ap-

1Cost figures, with small modifications, from Utah Exp. Sta. Bul. 165, were used in all the analyses reported.
plied in 3 irrigations the first two being about 15 inches each. These large single irrigations, as above pointed out, are the result of the standard but wasteful practice of 40-rod runs. The other two plats of this field received 3 excessive applications, which were largely ineffective because of the long runs. The general discussion on this question applies to all grain crops.

The yields on the different plats of Field O were not satisfactory. Wild oats and other weeds came up so thickly that on some parts of the field the yield was very low. Thirty inches of water gave the best yield, although less than 24 inches produced almost as much. One irrigation was given each plat before planting and 3 irrigations were given each plat after planting.

In 1919, the barley crop as well as the wheat crop was greatly damaged by the grasshoppers. A maximum of 25 inches of water was applied in 5 irrigations. The land was spring-plowed, and the first irrigation was given before this plowing. Observations indicated that no suffering for moisture occurred on the land receiving 25 inches of water. Special preparation in the form of two cross-ditches made it possible to accomplish a thorough irrigation with a reasonable amount of water. If the water had been run the entire length, as it was during 1918, it is safe to say that the requirements would have been as great as for Field M in 1918.

![Fig. 9.—Yields of oats with various quantities of water.](image-url)
Oats.—Figure 9 shows two years' results for oats. In 1917 21 inches given in four irrigations produced the maximum yield, but the net profit was practically the same as for the yield with 17 inches of water. The nature of the land and the preparation for irrigation made it possible to apply single irrigations with reasonable amounts of water. Where this is possible, the economical duty of water is relatively high.

In 1918 only two of the plats were carried to completion. Difficulty in applying single irrigations with reasonable amounts of water made the total for the maximum yield more than 30 inches, while the highest profit was made with about 23 inches. Each plat was given 4 irrigations.

Potatoes.—As a rule, potatoes can be irrigated by using from 4 inches to 6 inches of water in each irrigation. This then makes the duty of water for potatoes vary less than with alfalfa and small grains. The maximum profits from the results shown in figure 10 were realized with about 2 feet of water both years.

Fig. 10.—Potatoes, yield with various quantities of water.
Duty-of-Water Investigations on Coal Creek, Utah

Corn.—Figure 11 bears out the oft-repeated remark that corn adjusts itself well to the moisture conditions. Good corn can be grown under Coal Creek without any irrigation water, but the response in yield to irrigation water up to 24 inches is significant.

Surface Run-off Losses.—On small farms, the surface run-off at time of irrigation is an important factor in the gross irrigation requirements. The primary lands are made up of small farm units. Table II shows the run-off percentages of gross applications for alfalfa, grain, and potatoes for three years.

The percentage for alfalfa from year to year does not vary much. For grain and potatoes, the variation is more pronounced.

During 1918 and 1919 the average run-off percentages for grain and potatoes are much lower than the community average, because extra precautions were taken to reduce these losses on the experiment plats.

In all cases, the run-off has been deducted from the gross application in the figures showing the amount of irrigation water used. Thus, as an example, if a net allotment of 36 inches were made for alfalfa, an additional 3 or 4 inches may be necessary to allow for unavoidable run-off.

Losses in Canals.—All losses of water in the canals should be determined and considered in making water allotments. These net-duty-of-water investigations above reported give very little consideration to conveyance and distribution losses.

Table III shows the only work conducted on canal seepage losses. The seepage loss percentages recorded are high because the canals were running at a very low stage. The small streams spread over wide-bottom canals caused excessive percentage losses. These streams were running in canals, the capacities of which were from five to ten times greater than the discharge at the time of these measurements.
TABLE II.—RUN-OFF PERCENTAGES FOR THE DIFFERENT CROPS FOR THREE YEARS.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Number of Irrigations</th>
<th>Run-off in Per cent of Water Applied</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Maximum</td>
</tr>
<tr>
<td>1917 Alfalfa</td>
<td>42</td>
<td>34</td>
</tr>
<tr>
<td>1917 Grain</td>
<td>47</td>
<td>43</td>
</tr>
<tr>
<td>1917 Potatoes</td>
<td>32</td>
<td>63</td>
</tr>
<tr>
<td>1918 Alfalfa</td>
<td>134</td>
<td>46</td>
</tr>
<tr>
<td>1918 Potatoes</td>
<td>44</td>
<td>47</td>
</tr>
<tr>
<td>1919 Alfalfa</td>
<td>123</td>
<td>53</td>
</tr>
<tr>
<td>1919 Grain</td>
<td>24</td>
<td>24</td>
</tr>
</tbody>
</table>

As soon as the system is properly equipped with measuring devices for water distribution, the regular hydrographic records will furnish data for determining more fully the seepage losses in the main canals.

TABLE III.—CONVEYANCE LOSSES IN TYPICAL CANALS.

<table>
<thead>
<tr>
<th>Canal</th>
<th>Date</th>
<th>Upper Discharge</th>
<th>Lower Discharge</th>
<th>Difference</th>
<th>Length Considered</th>
<th>Loss Per Cent per mile</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>c.f.s.¹</td>
<td>c.f.s.</td>
<td></td>
<td>miles</td>
<td></td>
</tr>
<tr>
<td>1. Union Field</td>
<td>Sept. 27</td>
<td>1.59</td>
<td>1.36</td>
<td>.23</td>
<td>2.9</td>
<td>5.0</td>
</tr>
<tr>
<td>2. Union Field</td>
<td>Sept. 28</td>
<td>2.08</td>
<td>1.80</td>
<td>.28</td>
<td>2.9</td>
<td>4.6</td>
</tr>
</tbody>
</table>

¹c.f.s. means cubic feet per second.

OTHER DUTY-OF-WATER FACTORS

Spring High Water.—Efficiency in the use of high water is greatly reduced by the large amount of silt, sand, and gravel carried. The wide daily fluctuations, with the peak coming in the night, make the problem of properly handling the water a perplexing one.

Canal Structures.—There is an urgent need for well-constructed head gates, measuring devices, and dividers over a large part of the system. Proper irrigation structures are very essential to efficient water distribution.

Size of Irrigation Streams.—Late in the season as the water supply diminishes, irrigation streams should be maintained at proper sizes by making fewer streams, with shorter periods of use for each irrigator in the rotation. Rotation schedules should
be carefully arranged and adjustments should be made when needed as the season advances.

**Methods of Irrigation.**—Each farmer should sense his responsibility to adjust his methods of irrigation best to meet the topographical and soil conditions of his farm. The irrigator must make a conscientious study of the peculiarities of his farm in order to use water economically. As has been stated before, an efficient use of the water will not be possible until these adjustments are made; until single irrigations are reduced from 10 to 20 inches, the amounts often necessary under present methods; to 5 to 8 inches, the amounts which the soils can retain for use by the crops.

**SPECIAL CONTROVERSIES**

The North and Union fields present a situation which must be given very careful consideration. Until the court completely classifies the rights of all the land claiming water in these fields, water distribution will be subject to controversies on account of the indefiniteness of the water-right situation.

If this point is made clear, it will eliminate many controversies in which previously the water commissioner has unjustly been attacked. The real trouble has been indefiniteness of the water-right classification.

**SUMMARY AND RECOMMENDATIONS**

1. This bulletin contains the results of five years' irrigation investigations of the net duty of water under Coal Creek, Iron County, Utah.

2. The primary purpose of the work was to arrive at a scientific basis for the distribution of water to the various users.

3. Increasing the water to as high as 70 inches for alfalfa on land having primary water-rights increased the yields.

4. Under secondary rights, the capacity of the soil to hold moisture for late crop growth is the most important single factor in the determination of an economical use of water.

5. The net duty of water for grain ranged from 20 to 40 inches. Where uniform lateral distribution of water was difficult to obtain, the requirement was high.

6. The results indicate that little more than 24 inches of water are necessary for potatoes.

7. Improvements in land preparation and in methods of irrigation to obtain a uniform lateral distribution of water
offer the greatest opportunity for increasing efficiency in the use of water.

(8) It is very important to keep in mind that these investigations concern only the net duty of water. The gross allotment of water must provide, in addition to these net requirements, enough water to take care of run-off, seepage, and other unavoidable losses.

(9) An immediate limitation of water applications to the amounts shown by the experiments to be necessary is considered neither desirable nor feasible. The adoption of a water distribution policy that will reward skillful and intelligent use of water and penalize guess work, and careless irrigation methods is recommended as a proper procedure pending the attainment of the ultimate goal of having the water used on a truly economical basis.

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In order to fully understand the meaning of the expression “inches water applied” as used in the diagrams and throughout the pages of this bulletin, the reader should keep in mind the fact that a stream of one cubic foot per second (1 c. f. s. or 1 sec.-ft.) applied to one acre continuously for one hour is equivalent, if uniformly spread over the surface, to one inch rain fall or one inch depth of water over the acre. For example, a 5-second-foot stream applied continuously to one acre for one hour gives a 5-inch irrigation; likewise a 2 sec.-foot stream on one acre for 3 hours gives a 6-inch irrigation.