U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
A. C. TRUE, Director.

IRRIGATION

IN THE

ROCKY MOUNTAIN STATES.

BY

J. C. ULRICH.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1899.

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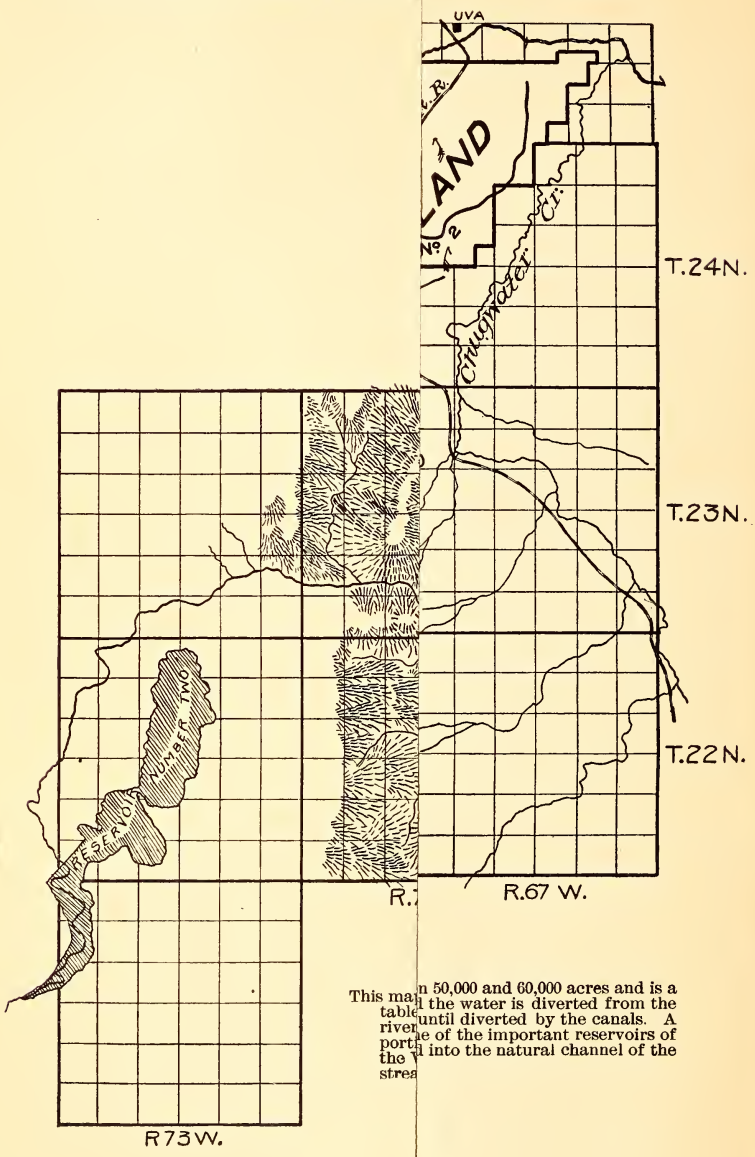

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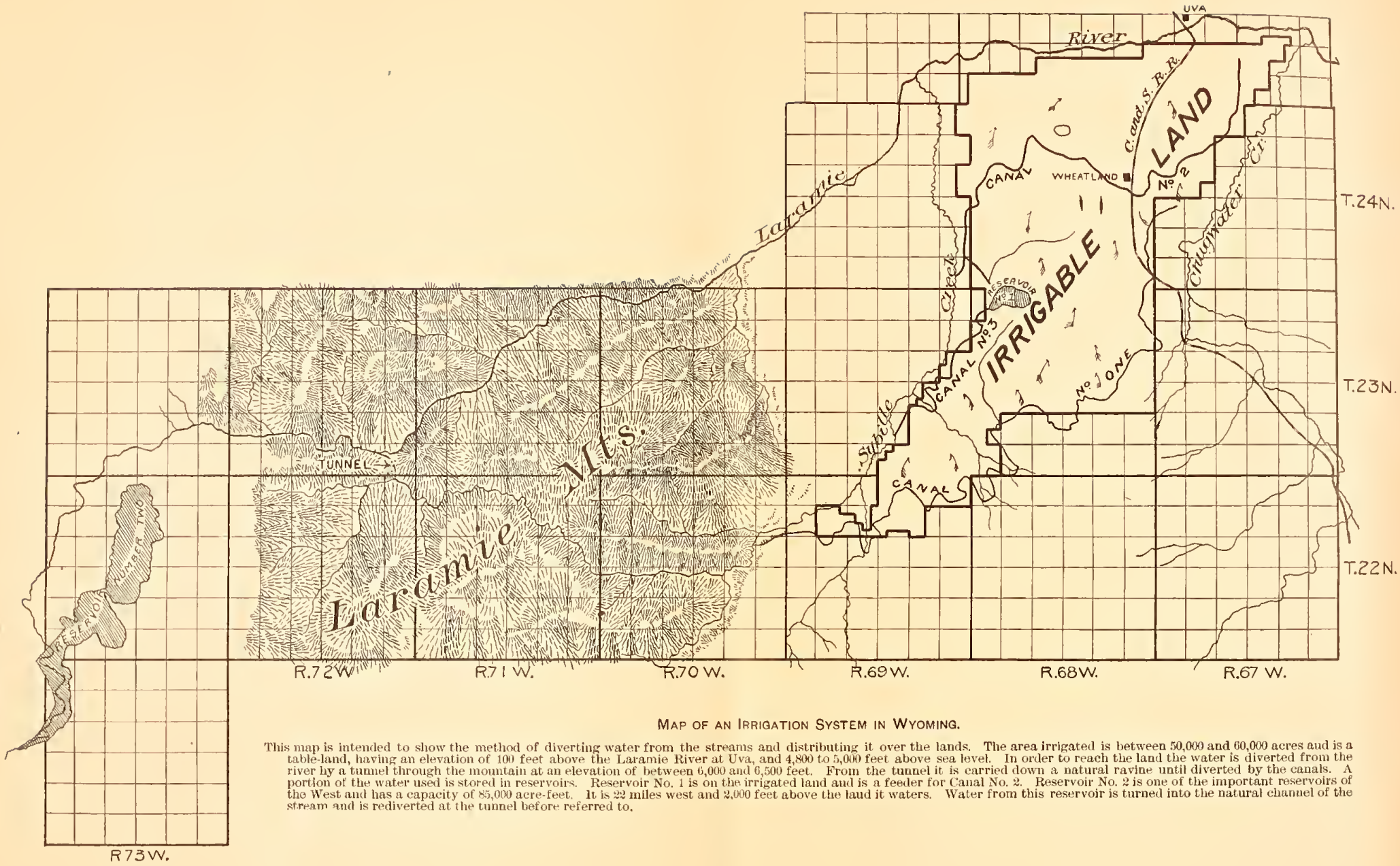

MAP OF AN IRRIGATION SYSTEM IN WYOMING.

This map is intended to show the method of diverting water from the streams and distributing it over the lands. The area irrigated is between 50,000 and 60,000 acres and is a table-land, having an elevation of 100 feet above the Laramie River at Uva, and 4,800 to 5,000 feet above sea level. In order to reach the land the water is diverted from the river by a tunnel through the mountain at an elevation of between 6,000 and 6,500 feet. From the tunnel it is carried down a natural ravine until diverted by the canals. A portion of the water used is stored in reservoirs. Reservoir No. 1 is on the irrigated land and is a feeder for Canal No. 2. Reservoir No. 2 is one of the important reservoirs of the West and has a capacity of 85,000 acre-feet. It is 22 miles west and 2,000 feet above the land it waters. Water from this reservoir is turned into the natural channel of the stream and is rediverted at the tunnel before referred to.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., November 22, 1899.

SIR: I have the honor to transmit herewith a paper by J. C. Ulrich on irrigation in the Rocky Mountain States and to recommend its publication as Bulletin No. 73 of this Office.

Settlers from the East, familiar only with agriculture under humid conditions, frequently make costly mistakes when they attempt to farm under the widely different conditions which prevail in arid regions—mistakes in locating claims, securing water rights, and in using the water. This bulletin is intended to explain the agricultural conditions prevailing and the methods of acquiring and using water for irrigation practiced in that portion of the arid region covered more particularly by the States of Colorado, Wyoming, Utah, Idaho, and Montana, in which the conditions and methods are somewhat similar, the main purpose being to instruct those to whom the subject is new and strange. For this reason, the subject is treated in an elementary manner.

Respectfully,

A. C. TRUE,
Director.

Hon. JAMES WILSON,
Secretary of Agriculture.

LETTER OF SUBMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Irrigation Investigations,
Cheyenne, Wyo., June 15, 1899.

Sir: I have the honor to submit for publication a paper entitled "Irrigation in the Rocky Mountain States," by J. C. Ulrich, C. E., who has had a long and varied experience in building and operating irrigation works.

The marvelous growth of the western half of the United States is more largely due to irrigation than to any other single agency. This has been almost wholly the work of men who at the outset knew nothing of either the methods of watering crops employed in other irrigated lands, or of the laws and customs by which rights to rivers are acquired and enforced.

At first there was little need of such knowledge. The beginnings in each State were simple. It required less skill and experience to plow the furrow and water the Mormon field from City Creek in Utah than it does for an Iowa farmer to drain the water off his land. The first ditches were little more than plow furrows. Many were built without surveys or records of rights. Diverting water raised no question of priority or interference with vested rights. The problems of the first settlers in each arid State were far easier of solution than those which beset the farmer under irrigation to-day, no matter whether he is a newcomer or has the experience of years behind him. The first settler on a stream thought of nothing except to find a place where he could get public land and secure a bend in the stream where the banks were low and the fall rapid. To-day he is beset by complications growing out of streams already having more ditches than their water supply will serve, by claims to more water than the ditches will carry, by complications growing out of the divided authority over land and water, and by legal and engineering questions whose solution in all irrigated lands has taxed the wisdom and patience of the ablest minds.

Success to the early irrigator involved only the right use of the plow and shovel. When there was only one ditch from a river the priority of its right did not need to be looked after, but when there are fifty the number of the priority and the laws for its protection determine not only the value of the ditch but of all the land it waters.

A break in the individual ditch of the pioneer could be repaired at the expense of a few hours' labor, and without injury to the crop it watered; but in the great aqueducts which have succeeded them, which require massive head gates to withstand the floods which beat against them, and which stretch away for scores of miles from the source of supply, a single break may mean the expenditure of thousands of dollars in repairs, the loss of the year's work to many farmers, and widespread disaster to the community. Under the pioneer ditches success in irrigation was as much a matter of individual effort as it is under rainfall, but under many of the large canals now in existence the returns of the farmer depend on many things besides his own labor. There must be wise and effective division of the stream, while the watchfulness, honesty, and skill of the inspector or "ditch rider" are as important as a fertile soil. A just water-right contract can make a contented community, while an unfair or unwise one is an effective promoter of discord.

The material development of irrigation has outrun its organization. To bring the conflicting interests which have already been created into harmony is a perplexing problem to those who have given years of study to the question. It is not difficult to understand how confusing it must be to the newcomer who learns of these complications for the first time. Every irrigator of experience knows that the title to the water is more important than the deed to the land it fertilizes, but the beginner, unfortunately, often learns this after it is too late for the knowledge to be of any benefit.

It is to the irrigated land that the home seeker must look hereafter in his effort to secure industrial independence. The vacant lands and unused rivers of the West offer the greatest inducements to those who have energy and self-reliance and but little else out of which to create a home. But the dangers and problems which confront them are greater than those which beset the settlers of a quarter of a century ago, and they ought to be enabled to learn what these dangers are in some less costly school than that of experience.

Respectfully,

ELWOOD MEAD,
Irrigation Expert in Charge.

Mr. A. C. TRUE,
Director.

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IRRIGATION IN THE ROCKY MOUNTAIN STATES.

INTRODUCTION.

The differences between agriculture under irrigation and that in regions of abundant rainfall are as marked as those between the appearance of a landscape in Arizona and one in Illinois. The home seeker from a humid region finds that his past experience as a farmer is of little service in choosing a location upon the arid lands of the West. The soil and climate are different and the conditions which farmers discuss are strange. As a result he usually follows the advice of those who settled before him, and the final result of his efforts depends in large measure on the kind of company he falls in with at the outset.

If he is a practical farmer he has been accustomed to consider the fertility of the soil, its drainage, the proximity to market, and the social advantages of a community the leading factors in making a location desirable; but when he casts his lot in an irrigated district he finds that all the unirrigated land looks alike and all apparently worthless. He frequently finds that lands conveniently located, close to market, and with a contour and slope suited to irrigation, are yet unoccupied and for sale at small price. If he seeks for the cause from a disinterested source he will probably learn that it is lack of a water right—that other lands absorbed the stream before ditches to water the land in question were built, and that when streams run low no water is left for its use. If he is not so informed at the outset, he may learn of this through unhappy experience.

The significance of a water right, and the importance of having both an adequate supply and adequate provision for its just distribution, are matters which the home seeker is most apt to overlook, as they were the last things to be properly appreciated by the early settlers.

Nor are the beginners the only ones who make mistakes in locations or feel themselves perplexed by the problems growing out of the distribution of the water of rivers among those dependent thereon. Old and capable irrigators find it hard to discriminate between the merits of widely differing ditch contracts for the supplying of water or to understand what rights farmers have in streams under the conflicting court decisions growing out of the litigation over water rights. They are learning that farming under irrigation requires a study of other things besides

the application of water, and are to-day studying the broader questions with an earnestness and alertness which must in time result in important changes in present laws.

Two causes explain the rapid extension of irrigation in the arid West. One is the inability to raise crops without it; the other is the ease and cheapness with which the first ditches were built. To the New England hill farmers the distribution of a layer of water over every inch of a wheat field seems a labor of great magnitude and difficulty; but when one has seen the gently sloping table-lands of Colorado, Kansas, and Nebraska he realizes that spreading water over the surface is as simple as plowing corn in Iowa. The dweller along the sluggish, deeply sunken rivers of the middle West marvels at the methods by which the irrigator gets his water supply above the surface; but when he looks at the mountain torrents, which have scarcely any banks and have a fall so great that the ditches which leave them seem to be running up hill, this mystery is also explained.

The first steps in practical irrigation are surprisingly simple, easily understood, and as easily carried out. Many ditches have been built by men who knew nothing of either irrigation or engineering. A few days' instruction and experience will make any man of ordinary intelligence able to irrigate most farm crops without any further direction or oversight. This does not mean that he knows all there is to be learned, or that further time will not enable him to do his work with greater ease or with increased economy in the use of water. The requirements of different crops and the time when water should be applied vary greatly, and the experienced irrigator has a great advantage over the novice; but this does not prevent beginners, without either experience or direction, raising good crops the first year. On land reclaimed, and with an ample water supply, success with beginners is the rule rather than the exception.

The primary purpose of this bulletin is to describe agricultural conditions in the Rocky Mountain region, to give the methods by which the waters of streams are appropriated, diverted, and used, and to point out some of the difficulties which may confront those to whom the whole subject is new and strange. The discussion is confined to that territory in which conditions are somewhat similar. The great diversity in conditions and methods in different parts of the arid region makes such a limitation necessary. The territory considered in this bulletin embraces particularly the States of Colorado, Wyoming, Utah, Idaho, and Montana, and includes the country which slopes east and west from the summit of the Rocky Mountains. In these States the waters of streams are under more or less strict public control and there is also a practical uniformity in irrigation methods, while the general character of the water supply, climate, and soil is not so very dissimilar. This territory also includes all of the States which have by constitution and statute abrogated the common-law doctrine of riparian rights.

GENERAL CHARACTERISTICS OF THE ROCKY MOUNTAIN STATES.

The region under consideration embraces about one-sixth of the total area of the United States. The different portions of this vast extent of country present every conceivable feature of variety and contrast. There is, however, one characteristic common to all localities within its limits, which establishes a condition which necessitates a radical departure from the practices under which agriculture is conducted in the more densely populated humid region, which definitely affects the customs of its people, raises new issues of national importance, places its indelible stamp on the very face of the landscape, and fixes a definite limit to the population which this region will support. This characteristic is that aridity of climate which makes the artificial application of water necessary to successful agriculture. This climatic condition necessitates methods of procedure in the conduct of farming operations which are unknown to the eastern farmer.

CLIMATE.

It would be useless to attempt a detailed description of the climate of this region, both because of the enormous extent of territory involved and the almost limitless variety due to local topographic conditions. Extending from Canada on the north to New Mexico on the south, it has a wide range of climatic variation due to latitude alone. There is found, also, the widest diversity in climate and temperature at points in close proximity, due to their great difference in elevation. An unusual percentage of bright, sunny days, an invigorating, bracing atmosphere, and that aridity from which the region gets its name are characteristics, however, which are common to all parts of the arid region and prevail to a greater or less degree in all latitudes and at all elevations.

The precipitation, like the temperature, is characterized by marked differences between points in close proximity. It is usually much greater upon the mountains than in the valleys, and generally increases with the altitude. At all points where the elevation is not such as to prohibit successful farming operations it is less than that characterizing the humid regions east of the one hundredth meridian of longitude, and is generally insufficient to guarantee successful results in agriculture without the aid of irrigation. In parts of southern Utah it does not average more than 6 inches per annum. In the farming regions of Idaho and Colorado it is from 12 to 15. It may be stated, generally, that it varies in different parts of the territory under consideration between the extremes of 6 and 24 inches per annum, except in a few restricted localities where the proximity of high mountains causes a rainfall sufficient for agricultural operations.

We thus see that the line of demarcation between the strictly arid and the strictly humid sections is not a clearly defined one. In some

localities within the arid region, particularly in western Kansas and Nebraska, in the valley of the Great Salt Lake, and in parts of southeastern Idaho, considerable "dry farming" is carried on. The results, however, with few exceptions, are not satisfactory. In years during which the precipitation is above the average, and its distribution with reference to the farming season is fortunate, bountiful crops are sometimes matured, but no reliance can be placed upon a continuance of those conditions. One or two seasons of good crops may be and generally are followed by a series of years of partial or complete failure. The farmers in such localities are never continuously prosperous. It requires all the proceeds of a series of good crops to carry them through the succeeding years of drought. It is therefore a serious mistake for people to settle in such localities with the intention of farming without irrigation.

Along the eastern border of the arid region is a strip of country, embracing portions of Kansas, Nebraska, the Dakotas, and a part of northwestern Texas, which is sometimes designated as the "rain belt." It derives its name from a theory that there is a progressive movement of the boundary of the humid region westward. This theory is based upon the assumption that the extension of railroad tracks and telegraph wires into the arid region is effecting a change in climatic conditions resulting in an increased rainfall, and that the settlement of the country, with its subsequent cultivation of the soil, assists in bringing about this result. That thorough cultivation materially modifies the effects of a given degree of aridity is not open to reasonable doubt, but that any perceptible change in the climate is brought about by the agencies mentioned, is a proposition that to the writer does not appear worthy of serious discussion.

There are, however, annually a considerable number of settlers who locate in such localities and practically test the rain-belt theory, and the periodical exodus of a like number who have thus wasted several years of time and labor attests the completeness of the demonstration so far as these are concerned. Under an efficient system of irrigation, however, the problem assumes a different aspect. The soil of the rain-belt country, like that in other parts of the arid region, is fertile and productive when water is applied in sufficient quantities. Without this adjunct it will not produce satisfactory crops, and its value must be limited by its availability as a stock range, for which purpose it is in many places well adapted.

APPEARANCE AND INDUSTRIES OF THE REGION.

To the visitor from the East the appearance of the arid region and the conditions under which farming is carried on are sources of constant surprise. He notes the absence of continuous stretches of cultivated fields and human habitations and is impressed with the vast extent of barren plains between the comparatively small productive

areas. Often the cultivated land is confined to a narrow strip of green along some small water course; sometimes it is of greater extent, reaching for a considerable distance back from some large river; but it is always bounded by the line of the irrigation canal, and is always of small extent compared with the barren areas beyond. The extent and number of the irrigated tracts are constantly increasing, but the available water supply and the topographic and climatic features of the country unite in limiting their extension, and they will always remain but a small fraction of the total area of this region.

Within this domain three great industries principally engage the attention of the people, viz, mining, agriculture, and stock raising. Of these, mining was until recently the most prominent and important, but at present the value of the products of agriculture largely exceeds that which results from mining. The principal mineral products are gold, silver, lead, iron, copper, and coal. The agricultural products include nearly everything which can be produced within the limits of the United States, the great variety and diversity in soil, climate, and elevation presenting the conditions necessary for the development of every form of farm product known to the latitudes embraced within its limits. By making possible a cheap food supply in this region, agriculture by irrigation has rendered mining more profitable, while the markets created by the latter industry have certainly been of the very greatest benefit and importance to the former.

Agriculture and stock raising are of course closely related, and in many localities largely dependent upon each other for success. The practice of running large herds on the range without adequate provision for their winter feeding is rapidly passing away throughout this entire region, resulting in the gradual establishment of the cattle industry upon a firmer and more permanent basis, and in the promotion and encouragement of actual settlement and cultivation of the soil. There will always be a very great preponderance of grazing lands over those which can be reclaimed by irrigation, and this fact gives the stock grower of this region a decided advantage over his eastern competitor; and the consequent demand for forage and grain furnishes in many localities a profitable market for the products of the irrigated farm, while the full utilization of the vast range will demand in many sections a large extension of the irrigated area and product. The combination of these two industries of farming and stock raising seems to be the ideal arrangement, and very many localities in the arid region offer exceptional advantages for such combination.

In the more mountainous localities agriculture does not assume a very prominent position, because large areas of land suitable for farming are not to be found, and it is only in the small valleys immediately adjacent to the streams that agriculture is attempted or can be followed with profit. Even these valleys can not all be successfully farmed on account of their great elevation, since farming, as a rule, can not be

conducted with success at altitudes exceeding 7,000 or 8,000 feet above sea level, and even at those elevations only the very hardiest products can be grown. These small valleys in the mountains, when favorably located at elevations ranging from 4,000 to 6,000 feet, present in many respects the most favorable conditions for successful agriculture under irrigation. The climate is often superior to that of localities remote from the mountains. They thus furnish more desirable locations for homes, and where the elevations do not exceed 4,000 or 5,000 feet they are often found to be superior to other localities for the production of deciduous fruits, which, under the favorable conditions of soil and climate here presented, respond with a bountiful yield, and the quality of the product is unsurpassed by that of any other part of the United States. These mountain valleys are also often contiguous to the public grazing lands, and thus afford especially good locations for stock raising. Generally speaking, however, the bulk of the irrigated area is on the extensive plains, the best land and facilities for marketing the produce being generally found in such localities.

CONDITIONS FAVORABLE AND UNFAVORABLE TO IRRIGATION.

Irrigation, in the region dealt with in this bulletin, is almost wholly a matter of gravity. The stream is tapped at a point where its channel is higher than the field to be watered. Thence the water is carried down hill in the ditch to the highest point to be covered. In spreading it over the field the laterals run on the ridges, and the shovel of the irrigator manipulates its distribution along or across the slopes below. When it has thus been brought to a level with the most elevated points upon the tract to be irrigated, it can be made to flow out over the land by the force of gravity alone, without any assistance from the irrigator beyond such manipulation as may be required to effect its uniform distribution over the minor irregularities of surface, which are eliminated as far as possible by careful leveling and preparation of the ground before irrigation is attempted.

Sometimes the water supply lies at a lower level than the land to be irrigated, and has to be raised. This occurs where the water supply comes from wells or other subterranean sources. In such cases it is raised to the required elevation by pumping, or by any other method which is found most convenient and economical. Pumping water for irrigation, because of the large volume required, is attended with great expense and can not usually be employed with profit except for the reclamation of land devoted to the cultivation of crops which represent great value per unit of area devoted to their production. In the cultivation of oranges, lemons, and other fruits which yield a product whose value is several hundred dollars per acre, and where the amount of water required is relatively small, pumping may be resorted to with profit; but in the growing of cereals and the ordinary farm products of the temperate regions, the cost of the pumping plant and its operation is often prohibitory.

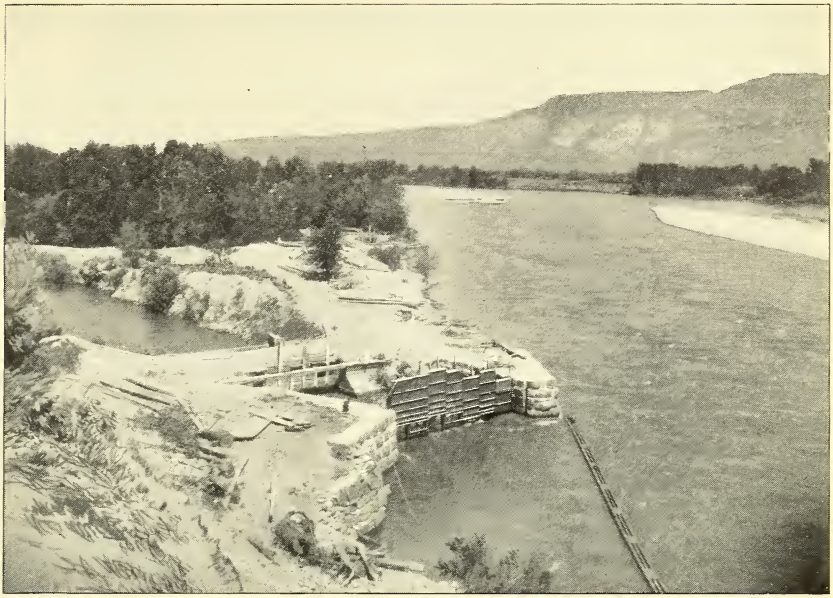


FIG. 1.—HEAD GATE OF RIDENBAUGH CANAL, BOISE RIVER, IDAHO.

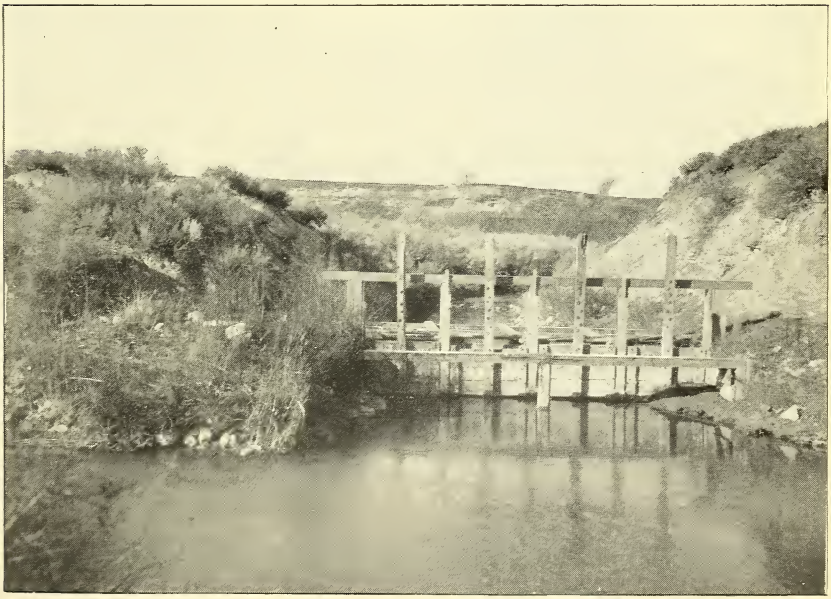


FIG. 2.—HEAD GATE OF JORDAN AND SALT LAKE CITY CANAL, UTAH.

FIG 1.—AMITY CANAL, ARKANSAS VALLEY, COLORADO.

FIG. 2.—CANAL NEAR BILLINGS, MONT.

In most cases, however (in all where irrigation is conducted upon an extensive scale), the water supply is obtained from running streams, which in the arid region generally have very high gradients, thus rendering their diversion upon the adjoining lands comparatively easy. Where the land to be irrigated lies along the immediate border of the stream and is but little elevated above the latter a dam may be constructed which will serve to elevate the water to the required level. This is a practice very frequently adopted in irrigating low bottoms, but is applicable only where the land is but slightly elevated above the stream; as where its elevation is very considerable the height of dam thus required would, in most cases, involve an expense prohibiting its building.

Frequently the lands to be reclaimed occupy positions remote from the stream whose waters are to accomplish their irrigation, and are elevated several hundred feet above it. In such cases neither pumping nor damming the stream would be feasible, on account of the expense involved. If the stream had but a slight fall, land so situated could not be irrigated from it at all. One of the characteristics of the streams of the arid region, however, as noted above, is the excessive declivity of their slopes. There are few whose fall is less than 4 or 5 feet per mile, and 40 feet is not unusual, especially in the case of the smaller streams in the vicinity of the mountains. When, therefore, it is desired to irrigate a body of land which occupies a position of great elevation above the stream selected as its source of supply, the elevation of the latter does not necessarily prohibit the enterprise, because, while at all contiguous points along the stream the water is much below the land, the excessive fall characteristic of these water courses permits of the selection of some point further upstream, whose elevation exceeds that of the land whose irrigation is desired, and from this point its waters may be conducted by means of a gravity canal to the lands to be reclaimed. This point of diversion may be, and frequently is, many miles up the river from the lands to be watered. (See Pls. II and III.)

The lands irrigated usually lie between the ditch or canal and the stream furnishing the supply, and below the former. The water is drawn off by letting it out of the artificial conduit and permitting it to run over the lands below.

It is evident, however, that under some conditions irrigation can not be thus accomplished. If, for example, the irrigation of a body of elevated lands were contemplated from a stream whose rate of fall does not exceed that required by the canal through which the waters are to be conveyed to the land, the latter could not be covered. It would also be impracticable to irrigate an elevated body of land from a stream whose fall exceeded but slightly that required for the canal through which the water is to be conveyed to the land. If a canal whose slope must be 6 inches per mile is designed for the irrigation of land lying 150 feet above a stream whose slope is 1 foot per mile, its point of diversion would have to be located 300 miles up the stream from the lands

to be irrigated, and the enterprise would consequently be impracticable. For these reasons much of the land in the humid region could not be irrigated by gravity canals, even if the necessity existed, since the streams, while affording an abundant supply, have generally such low gradients that the diversion of their waters through gravity canals could not be successfully accomplished.

HOW CANALS AND DITCHES HAVE BEEN BUILT.

It is not so very long since the settlement of the arid portion of the United States, and especially the carrying on of agricultural operations within its limits, was pretty generally regarded as impracticable if not impossible. Its actual development is already far beyond the dreams of half a century ago, and we do not yet realize its ultimate possibilities. As a consequence the importance of irrigation and the various problems connected therewith have not been generally realized or understood. In the older irrigated countries the construction and operation of canals, as well as the distribution of water, is under the most strict government supervision and control, if not ownership. The wisdom of the system of operation measures in a large degree the prosperity of the people who live under it. Our system is yet in a primitive condition. The development thus far reached has not been under any comprehensive public policy, but is rather a natural outgrowth of conditions.

THE SMALL DITCH OF THE PIONEER IRRIGATOR.

During the earlier period of the settlement of the arid region, before the possibilities of irrigation had come to be generally recognized, and prior to the advent of a population sufficient to warrant definite efforts toward organization in the development of its resources, irrigation was limited to the individual enterprise of pioneer settlers who formed the advance guard of civilization upon the frontier. These pioneers, having selected suitable locations for farming and ranching operations, constructed each his own ditch for the irrigation of his individual lands, and operated it independently in the manner best suited to his interests.

The individual ditch appeals to the inherited prejudices and habits which the settler brings with him. Even if it costs more, he often prefers it to the enforced submission to regulations which dependence on partnership ditches or canals involves; hence on each stream the locations for such ditches are early sought out. When those in the main valley are gone, locators look higher up in the mountain valleys and along the rivulets which go to make up the main stream. These opportunities still exist in some parts of the country, but they are rare and hard to find. The pioneer makes use of all such opportunities, and they are now to be found only along water courses remote from the centers of population, where all the drawbacks of the frontier must

be encountered. The gain in first cost is thus counterbalanced by the attendant disadvantages of location. The building of individual ditches is, therefore, largely a thing of the past.

EVOLUTION OF THE COMMUNITY DITCH.

The evolution of irrigation on the majority of streams has followed the same successive steps. Frequently the ditch of the pioneer was so located as to be conveniently and economically enlarged and extended to cover the lands of subsequent settlers. In such cases arrangements were often made with the original owner by which such enlargements and extensions were made and the later settlers became part owners in the ditch, which has often been enlarged and extended many times and thus grown from the small ditch constructed and owned by the first settler to a large partnership or community canal, in which each owner of lands irrigated by it has purchased or worked out an interest, and contributes to its annual maintenance in proportion to the amount of water used by him.

After the available lower lands near the stream have been taken up and rendered irrigable by the individual or partnership ditches, larger and longer canals are often projected to cover the mesas and benches above. These also are often built, owned, and operated by the owners of the lands to be reclaimed by them, the principal outlay being their own labor. These partnership or community canals have generally proven successful and satisfactory, and have been a most important factor in the development of the agricultural resources of the arid region. Their construction and operation are usually simple, and their value represents wealth created by the people who live under them. The operation and maintenance of such canals is generally satisfactorily accomplished through mutual agreement, by proportionate assessments of labor or money upon the various owners. The annual expense of operation is generally very small, and the value of land under such canals (which usually includes a proportionate ownership in the canal itself) is usually greater than that of similarly situated land under corporation canals. In many respects, where it is applicable, this individual or partnership system of canal ownership is an ideal one.

Although partnership and community canals, especially those which have grown up by the enlargement and extension of smaller individual ditches, are usually unincorporated mutual associations as above described, yet it often happens that a closer and stronger organization than one dependent upon mutual agreement is desired by the irrigators, and the result is the formation of the community irrigation stock company. In such a corporation the stockholders, as a general rule, are the farmers who expect to use the water thus made available. It generally originates and is organized in the following manner:

A body of lands suitable for farming purposes, and so situated with reference to a river or other satisfactory source of supply that it can be

irrigated with a reasonable degree of economy, is located and acquired by different individuals. If Government land, it is secured through the regular homestead or desert-land filings. If belonging to the State or a railroad company, it is acquired through purchase. Sometimes both State and Government lands are available, of which the alternate sections belong to each, respectively. In the case of Government lands, many of the filings may have been made long before the irrigation proposition in question had assumed definite form, the same having been made upon the assumption that irrigation was possible and would sooner or later become an accomplished fact.

For the purpose of specifically illustrating the method of organizing and conducting the affairs of such a community irrigation enterprise, it will be assumed that a number of individuals have made filings upon different tracts of Government land, comprising in the aggregate an area of 8,000 acres, or that they have acquired the same area through purchase from the State or from a railroad company. This land is, of course, arid and unproductive without water, and before its irrigation can be effected a canal or other conduit must be constructed for conveying thereto the waters of some adjacent stream. A meeting of the owners or claimants is therefore held, and the necessary plant is agreed upon; the amount of water required, the size of canal needed, and the approximate cost of the undertaking are determined; and a board of directors is elected, who appoint the executive officers for conducting the affairs of the company. It will be assumed that the probable cost of the works has been determined to be $50,000. The capital stock is then fixed at this amount, and is divided into 500 shares at a par value of $100 each. It will be assumed that the canal is to carry 100 cubic feet of water per second of time. Under this assumption each cubic foot of proposed capacity is represented by a capitalization of $500, and, as there are 500 shares, each of the latter would represent one-fifth of a cubic foot of water. If 1 cubic foot be considered as the amount required for 80 acres of land, each of those who desires to irrigate this area should subscribe for five shares of stock, and for larger areas in the same proportion. There would, however, be no condition specifying the number of shares which any purchaser must acquire, though it would be advisable that each landholder purchase the number necessary to accomplish the satisfactory irrigation of the area proposed to be cultivated, since the number of shares held will determine the amount of water which he will receive. Each landowner or other person desiring water shares now enters his name upon the subscription or stock book of the association, and the secretary enters opposite thereto the number of shares for which he has subscribed, opening at the same time an account with the subscriber, upon which he is charged with the value of the stock contracted for, and given credit, under the proper dates, for any payments made thereon.

While it is generally a fact that a majority of the holders of stock in

these concerns are actual farmers who propose to live upon and themselves farm the land to which the water thus acquired is to be applied, this is not a necessary requirement, and frequently a number subscribe for stock who do not own any land, but acquire the water either with the intention of selling it to others or because they intend subsequently to acquire land to which it may be applied. There are others, still, who, while owning land capable of irrigation from the proposed system, do not subscribe, because they do not intend to farm the land, but expect to sell it at an advanced figure, after the works are in operation, to those who already own or may subsequently acquire stock, either from the company direct or from other stockholders who may, for any reason, desire to reduce their holdings.

Each subscriber now becomes nominally a stockholder, though certificates of stock may never be issued, and he may proceed to work in the construction of the plant at a price for labor which has been fixed and scheduled by the board of directors, which, through the president of the association, has appointed a foreman and timekeeper to supervise the details of the work and keep the time of the operators engaged thereon. At the end of each month the foreman or timekeeper turns in to the secretary a statement setting forth the amount and value of the work contributed by each subscriber, and these amounts are by the secretary credited upon the accounts of the several stockholders in partial liquidation of their indebtedness to the association, incurred through the purchase of stock.

When the construction of the plant has been completed, the various accounts are made out and certificates of paid-up stock are issued to those who are found to have worked out the full amount due therefor. Those who are found not to have contributed the amount of work necessary to liquidate their indebtedness are given credits representing the amounts paid, and their accounts remain charged with the balance yet due, the adjustment of which may be required in the form of a cash payment, or may be permitted to stand on the books until an opportunity arises for working it out at a future date. Where stockholders at the completion of the construction have contributed work in excess of their stock subscriptions, the amount thus overpaid may be refunded in cash or allowed to stand as a credit upon the books of the association and subsequently applied in liquidation of assessment liabilities arising through expenditures incident to operation and maintenance of the plant.

If it should be found, upon the completion of the works, that the expense of construction was less than the amount realized through the sale of stock, the difference may be distributed to the stockholders in the form of a dividend, to each in proportion to the amount of his stock, or it may be permitted to remain in the treasury and applied to the liquidation of subsequent indebtedness incurred in operation and maintenance. It more frequently occurs, however, that the actual cost

of the works exceeds the estimate upon which the capitalization was based, and that additional funds are required to complete the enterprise. These may be realized by the levy of a pro-rata assessment upon the outstanding stock, or through the issue and sale of additional stock to the amount required. The general method of organization and procedure is similar in the case of unincorporated community associations.

When the works have been completed and actual operations inaugurated, certain expenses incident thereto are encountered. These consist, in the main, of salaries and expenses of officers, wages of ditch riders or patrolmen, repairs necessary to structures, and other incidental expenditures that need not be enumerated in detail. These liabilities are usually provided for through pro-rata assessments against the stockholders.

As noted above, the essential features of this kind of stock irrigation company and of the unincorporated community canal are not dissimilar. The works of both are created, owned, and operated by local capital and labor, and their inception and organization are brought about by similar causes and carried out along similar lines. Both depend for their success largely upon local ownership, economical management, and the lack of necessity for any great cash outlay in their construction and operation. Communities with little capital except pluck and muscle have, under these methods, created canal systems that are among the best and most successful in the whole arid region, and which, from modest beginnings, have ultimately resulted in the growing up of thriving towns and populous and prosperous farming districts under them. This is the system of construction and management common in Utah under the operation of the district irrigation law formerly in effect in that State. The districts formed under this law are in effect voluntary mutual associations or companies for the purpose of construction and operation of canals, the cost of which is raised by assessments on the various owners in proportion to their respective interests in the works and quantity of water to be used by them.

The farmers in many localities are prejudiced against stock corporations and prefer to operate their canals under mutual agreement. In Wyoming, for example, it is doubtful if one in fifty of the community ditches are incorporated. As trouble sometimes arises in regard to collection of assessments, a law has been enacted in that State the object of which is to compel the payment of such assessments in case of unincorporated community canals. The same aversion to corporations in connection with irrigation is noticeable in greater or less degree in the other States.

Although opportunities for participation in the development of new enterprises under the community system still exist throughout many parts of the arid region, they are becoming more rare with the advance of time. This is particularly true with reference to those localities in

convenient proximity to the more important towns and cities, where lands and water rights under such organizations can now generally be acquired only through purchase.

THE CORPORATION CANAL.

Throughout all parts of the arid region there are found areas of superior land in the form of high plateaus or mesas, located sometimes at considerable distances from the more important streams, usually occupying positions of great elevation above the latter, and frequently separated therefrom by high rocky bluffs or ranges of hills and mountains. The exceptional fertility of many of these lands, together with their wonderful uniformity of surface, render them especially attractive to the irrigator. They are the best lands, but their location is frequently such that to secure the proper elevation dams have to be built to raise the water at the head, and the canal must wind its way for many miles through rocky canyons and along precipitous cliffs, and be carried across ravines and chasms in pipes or flumes, whose design and construction require the best engineering talent and experience. The expense thus incident to the construction of the works is frequently so great that neither the individual nor the community can successfully undertake its execution; hence they await the coming of corporate capital or State aid. The agency through which many of these comprehensive, difficult, and expensive works of irrigation have been accomplished is the institution known as the land and irrigation corporation, which has been the successor to the individual and community enterprises in the development of the agricultural resources of the arid West. The latter successfully held the field so long as the propositions open to consideration were simple, inexpensive, and readily available. In the development of these they proved to be admirably adapted to the requirements of the situation, but as the simpler problems were solved first, operations became more difficult and expensive with the increasing magnitude and complexity of the undertakings, and finally a point was reached where progress must cease unless the assistance of some more powerful factor could be enlisted which might successfully grapple with the greater issues presented.

It was at this juncture that the irrigation corporation came to the rescue, and it has since become a prime factor in the development of the agricultural resources of the arid region. The individual and community efforts, however, had paved the way toward the new departure, and the substantial results achieved by them made it possible for this powerful agency to become a factor in the work. It was their successful efforts that had first subdued the implacable desert and demonstrated the fertility of its lands and the possibility of creating prosperous agricultural homes and communities in a land which had long been regarded as a suitable dwelling place for only the buffalo, the coyote, and the Indian. These pioneers had demonstrated that the so-called

desert lands of the arid region, whose acquisition from the Government could be accomplished practically without cost, assumed a value under the practice of irrigation equal to that of the very choicest farming regions of the Eastern and Middle States, and the uniform success which crowned their efforts in this field attracted the attention of capitalists to these enterprises as presenting unusual opportunities for profitable investment.

Under the individual and community régimes the prime incentive was the transformation of certain desert lands into productive farms, which were to serve as the permanent homes of the individuals who inaugurated and executed this work of reclamation, and they expected their profits through the actual farming of the lands so reclaimed.

With the corporation, however, it was different. The opportunity thus presented for investment was with it the prime consideration. It was no part of its programme to actually improve and farm these lands; none of the individuals composing its personnel ever expected to make a home thereon. In most cases they were all nonresidents, whose homes were not even within the limits of the arid region. The object of their operations was the acquisition of large bodies of lands and valuable water franchises, which were to be sold at a profit, after the development of their proposed irrigation plant, to people who might desire to improve and actually farm the lands. The actual relation of the real owners of these enterprises to the properties themselves is usually even more remote than this. The financial interests are generally represented by the bondholders, who through the purchase of bonds have advanced the money for the building of works.

The stock of the corporation irrigation systems is not, as in the case of the community stock organization, in the hands of the farmers and actual water consumers under the system; it is held and controlled by the promoters and organizers of the enterprise. Its affairs are also controlled by a board of directors, who are elected by a vote of the stockholders. The executive officers are the president, secretary, and treasurer, but the details of the executive management usually devolve upon an officer appointed by the board, who is called the manager (sometimes the general manager), who lives, or should live, within easy access to the works. The manager has the appointing of and directs the operations of all the employees beneath him in rank, and is in fact the local dictator of the policy and management of the concern.

In most cases these corporations own and handle lands as well as water, the land feature being frequently the more important of the two. Where they own lands the latter are generally sold in connection with water, at a price which includes both. The land is rarely sold alone, since it has no value except in connection with the water, which usually can not be secured except from the irrigation company.

Under this corporation régime water is not represented by shares of stock, as it is in the community organizations hereinbefore described,

but by a "water right," which is a right to a certain specified quantity of water, or to the amount necessary to irrigate a certain tract of land, the amount given for this purpose varying with different companies. The quantity of water really necessary to irrigate an acre varies widely in different localities, and again materially with the crop under consideration. While in Colorado and Idaho a flow of 1 cubic foot per second is usually furnished and applied to 50 acres of alfalfa, the same volume will supply the necessities of 500 acres of citrus fruits in southern California.

The irrigation corporation constructs, operates, and maintains the main line of canal or other conduit by which the water is diverted from the river and conveyed to or within easy access to the land to be reclaimed; and in addition thereto, and particularly where these lands belong to the corporation, it usually constructs a number of large lateral branches, which are diverted from the main line at convenient points and traverse the principal bodies of lands. These are designed for the purpose of bringing the water within reasonable proximity to such lands as are located at considerable distances from the main works. The main canal or conduit necessarily occupies a position outside and above all the area to be reclaimed. Without these branches a decided hardship upon some of the water consumers would be involved in the necessary construction of private ditches of great length for conveying their water from the main works, a condition which would tend to place an embargo upon the sale of water. By means of this arrangement is also avoided the necessity, which would otherwise exist, for tapping the main line at a great number of points for the diversion of water for individual consumers, as well as the objectionable feature involved in the great multiplicity of private lateral ditches across the entire body of lands.

The main canal and these principal branches are operated, maintained, and controlled by the corporation, and are patrolled and regulated by ditch riders in its employ.

The settler or farmer who has purchased water rights from the corporation is generally permitted to divert the water from any point on the main canal or any of the laterals found to be most convenient, subject, however, to the approval of the general manager or local superintendent. In either case a head gate or regulating structure is placed at the point selected, for the purpose of regulating the amount diverted. This structure is the private property of the individual for whose use it is erected, though it is designed and placed in position by the company, and is controlled and regulated by the ditch rider, who keeps it locked at the required degree of opening and himself carries the key. The ditch conveying the water from this structure to the land to be irrigated is most frequently constructed, maintained, and operated by the owner of the land at his own expense. It is, however, not usually of very great length, and is comparatively simple and inexpensive. In some cases the company contracts to deliver the water at some conven-

ient point on the tract of land to be irrigated by it, in which cases all the lateral ditches are constructed and controlled by the company. This method involves a great additional expense of management and operation, and is not usually followed.

The practical results from operations conducted under the corporation régime do not materially differ, so far as the actual user of water is concerned, from those realized under the auspices of the community organization. The farmer's success is measured and determined almost entirely by the certainty and permanence of a satisfactory supply of water at a reasonable price. When these conditions are fulfilled it makes little difference under what character of organization he operates, the advantage of one system over the other being measured by the relative certainty of supply and the expense of getting it.

That the annual cost of water from a large corporation system is in most cases greater than from the smaller partnership or community canals is inevitable for several reasons. The latter are nearly always constructed first and occupy the best locations for cheap diversion and economical construction and do not usually require such extensive and costly headworks nor such a long line of expensive canal to be constructed and maintained before the irrigable area can be reached. These are advantages which the earlier enterprises have secured. In addition to more expensive construction and maintenance in the case of the larger canals, the salaries of general officers often materially increase the fixed charges, while the interest on the investment during the period between the construction of the canal and the settlement of the lands and consequent sale of water rights and the expense incident to securing such settlement are always very large items of expense which do not figure in the community systems. Many individual and community canals involve scarcely greater expense in construction and maintenance than do some of the individual and community lateral ditches which have to be constructed by the irrigators to convey their water from the company's main canal to their lands. So if the completed main canal systems should be turned over free to the landowners under them, they would have but similar advantages for irrigating their lands to those which many of the earlier settlers secured from the natural streams. To offset this added cost of irrigation which often prevails under these extensive corporate canals, the quality of the lands covered by them is often superior to that of the lands along the river bottom and adjacent which were settled upon and irrigated by the cheaper and more easily constructed ditches of the earlier settlers.

This plan of conducting the business of irrigation development has its good and its bad features. Through its agency great volumes of capital have been invested in the development of the agricultural possibilities of the arid region, much of which if dependent upon individual or community resources would have remained unproductive for many years. It is the corporation enterprises which enlist the interest

of a majority of intending immigrants. It is usually a part of their business to effect the sale and settlement of the lands under them, and their magnitude usually warrants the expenditure of large sums in advertising for this purpose. In some cases the results achieved under these systems not only prove satisfactory to the farmers, but prove them to be safe and profitable investments for capital. In many respects these large canals are the best and most economical systems for the distribution of water to the lands covered by them. These lands are usually in a large and compact body, which gives many social and industrial advantages to the settlers upon them. A greater area can be irrigated with a given volume of water than by means of a multiplicity of scattered individual and community ditches. Taken altogether, these large systems have many things to recommend them and have materially advanced irrigation development and benefited the landowners under them.

In most instances, however, the investors in these enterprises have not met with the success they deserve. Many causes have contributed to this result, some of which have already been indicated. The systems have almost uniformly cost much more than the first estimates, while the area of irrigable land under them, the irrigating capacity of the canals, and the rapidity with which their settlement and the consequent use of the water could be accomplished have all been almost as uniformly overestimated. Many years often elapse before the total discharge of the canal is utilized and before the income from water sold even meets the fixed charges for management and operation. Their location is sometimes distant from railway lines, cities, and local markets, which increases the expense and difficulties of securing settlers. If they follow individual and community ditches near settlements and markets already established they have later water rights than the earlier and smaller ditches. This inferiority of priority lessens the value of the property and is often a source of annoyance and expensive litigation with the earlier ditch owners and with their own consumers, who may have their water supply reduced or cut off in time of scarcity. Unless those charged with the design and construction of the works have made a special and very careful study of the lands, water supply, and prior rights thereto before beginning work, they have little positive information as to the real elements of value in their investment, and they have not always done this. The capitalists whose millions have been thus invested have naturally been more ignorant of the principles involved than the promoters and have often been deluded into believing that fabulous profits were to be realized through such investments.

In this manner a few irrigation works have been created throughout the arid region for whose existence there was no warrant whatever, whose priority rights to the use of water are practically worthless, either for the reason that the supply never existed, or because the available water had been appropriated long before the propositions

under consideration had been conceived and executed. These schemes not only work a permanent injury to the interests of legitimate enterprises in this field and to irrigation development in general, but are a menace to the future prosperity of the immigrant to the arid region, who, being unacquainted with irrigation practice and unfamiliar with the principles involved, can not intelligently determine the relative merits of the different propositions presented for his consideration, and thus frequently falls a victim to the misrepresentations of colonization agents, who, through the agency of elaborate and beautifully executed prospectuses, present the most alluring descriptions of the wonderful opportunities which await the settler who will purchase a quarter section of land and a water right from their companies—whose canal may, in fact, be perfectly dry for ten months in the year. Those who have been thus induced to invest their savings in these arid lands and worthless water rights may lose not only their money, but frequently many years of time wrestling with the adverse conditions growing out of their efforts to farm arid lands without a sufficient supply of water. They may succeed in eking out a precarious existence for several years, but are likely to find themselves becoming poorer with the advance of time, until at last, convinced of the futility of their efforts and the hopelessness of the prospect before them, they give up in despair, and, moving to some other locality, begin anew under more favorable conditions, with less money but with a vastly increased fund of information concerning the importance and necessity of a safe and certain water right in order to profitably conduct agricultural operations in the arid region.

THE DISTRICT SYSTEM.

Another method of constructing or otherwise obtaining a system of works for the irrigation of a given area of land is what is known as the "district irrigation system." The law under which this system is carried out originated in California, and although its general features have been copied, with greater or less modification of details, into the statutes of some other States, notably Idaho and Nebraska, the operations under the system have been almost wholly confined to the first-mentioned State. This district law is designed to secure the ownership and control of the water rights and canal systems by the people of the districts organized under its provisions. A district may be organized by a vote of two-thirds of its residents, upon an order of the board of county commissioners, which acts upon petition of a certain number or a certain proportion of the residents of the territory proposed thus to be organized as a district. After the organization, bonds for the construction or purchase of the works or property necessary to the object in view may be voted, which bonds become a lien upon the real property within the district. The interest is paid by assessments, similar to other public taxes, and the operating expenses are raised either by assessments, by valuation or acreage, or by tolls for the use of the water.

This system has many theoretical advantages, but its operation in California has not justified the prophecies of its advocates, and new districts are not being formed under it. The powers granted the districts seem to have been exercised in many cases with poor judgment, and heavy bonded indebtedness was incurred without corresponding advantages to the landowner in the form of water for his needs. In some instances the provisions of the law seem to have been taken advantage of for the purpose of turning unremunerative existing property and water rights into interest-bearing district bonds. Like other business enterprises, it depends for its success upon the judgment and honesty of those intrusted with the management of the business of the districts thus organized.

Each system and locality has its own peculiar features, and the best location and system is therefore a matter for careful investigation as to relative advantages, always having in mind, however, the certainty of the water supply, which is often the most difficult matter for the newcomer to get reliable information about. As this condition is the principal factor in successful farming operations, when it is satisfied such operations intelligently conducted will generally prove certain and remunerative under any of the plans herein described.

OPERATION OF CANALS.

The owner of an individual ditch operates it as he pleases, subject only to the State laws governing the diversion and use of water. But when several persons are interested in the same ditch, the necessity for some system of control arises. In the case of unincorporated community canals this control is secured by the selection of a water master, who is usually one of the owners, to have charge of the operation and maintenance of the system and the distribution of its water to those entitled to its use. It is on the large corporation canals, however, that the necessity for a careful system of operation and management is most apparent. Many of these canals are more than 50 miles long, and number their water users by hundreds. The Ridenbaugh Canal (see Pl. II), in the Boise Valley, Idaho, furnishes water to more than 500 farmers. The High Line Canal, in Colorado, has 433 consumers under it; the Loveland and Greeley has 257, and many other systems are as large or larger. It can thus be readily seen that the proper operation of such canals involves a very thorough business organization and careful attention to many important details.

The practical operation of corporation canal systems is, like their construction, under the control of the executive officer or officers of the company, but the representative with whom the farmer and irrigator comes into most frequent and intimate contact is the ditch rider, who is generally appointed by the manager or president. His duties consist in patrolling the ditch throughout the season of actual operation,

for the purpose of seeing that the works are in good repair, and to superintend the proper distribution of water to the various stockholders or irrigators from the system, and are somewhat similar to those of the water commissioner hereafter described, the main canal in this case taking the place of the stream, and the contracts or stock the place of the priority decree. In order to properly distribute the water the ditch rider is provided with a list of the persons having water rights from the canal, showing the amount to which each is entitled under his contract; or, in case of community stock companies, with a list of the stockholders and the amount of stock owned by each. Such a list furnishes the necessary data to enable him to distribute the water according to the quantity or proportion called for by these respective interests.

The larger irrigation systems generally have several distributary canals leading from the main one and following as nearly as possible the ridges or highest ground of the areas designed to be watered from them. Such distributaries obviate the necessity for such long and expensive individual lateral ditches as would be necessary if all such laterals diverted directly from the main canal. The expense of individual diverting works, as well as the danger attendant upon a multitude of diversions from the main canal, is also much reduced. The distributaries also generally follow the slopes of the ridges, and do not have a uniform light grade, as is the case with the main canals. Sometimes, also, natural drainage channels are followed, thus materially reducing their cost of construction.

At various points along the main canal or distributary lateral branches are diverted for conveying the water to the land of the individual consumers. As the amount to which each user is entitled is limited, it becomes necessary to place regulating structures at the points of diversion for the purpose of regulating the flow into these laterals. These consist of wooden, box-like structures in which sliding gates are placed, by which the size of aperture from the main canal is regulated and the flow of water therefrom controlled. (See Pl. IV.) Where considerable accuracy of results is attempted, there is also placed in the lateral ditch below the regulating gates a weir whose flow for all depths is computed and tabulated, and for the purpose of determining the depth at any time a graduated scale is so placed with reference to the weir that the depth can be conveniently and accurately read off. (See Pls. V and VI.) When it is desired to deliver into a lateral, so arranged, a given volume of water, it is merely necessary for the ditch rider to consult his weir tables and find the depth over this weir necessary to discharge the required amount. He then increases or lessens the opening from the main canal by moving the sliding gate in the regulating structure until the required depth over the weir is realized. This is the most important duty of the ditch rider, and for its proper execution he is expected to make a trip daily over the entire canal, or his division of it, and to examine and regulate the gate of every con-

FIG. 1.—DIVISION GATE ON IRRIGATION LATERAL, NEAR ROSWELL, N. MEX.

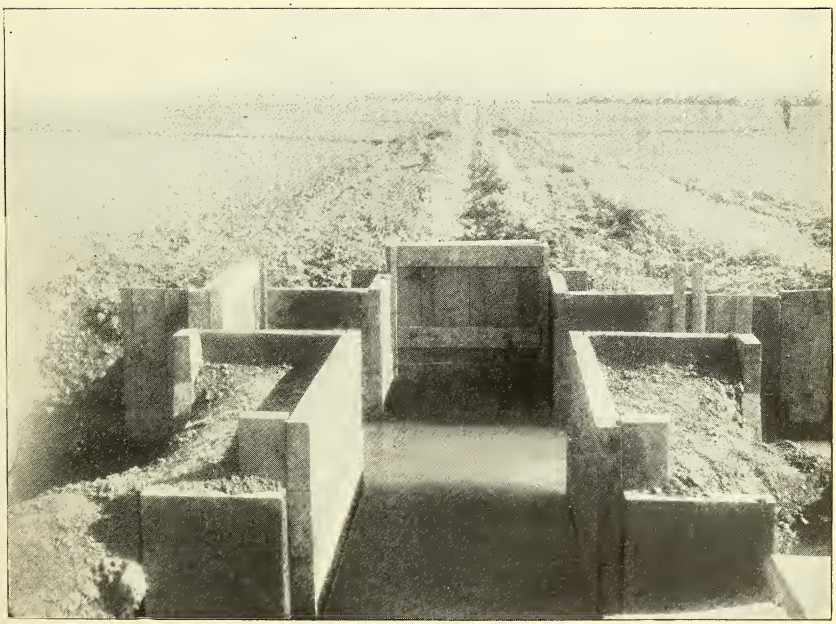


FIG. 2.—DIVISION BOX ON IRRIGATION LATERAL, MONTANA EXPERIMENT STATION.

FIG. 1.—SPILL MEASURING WEIR.

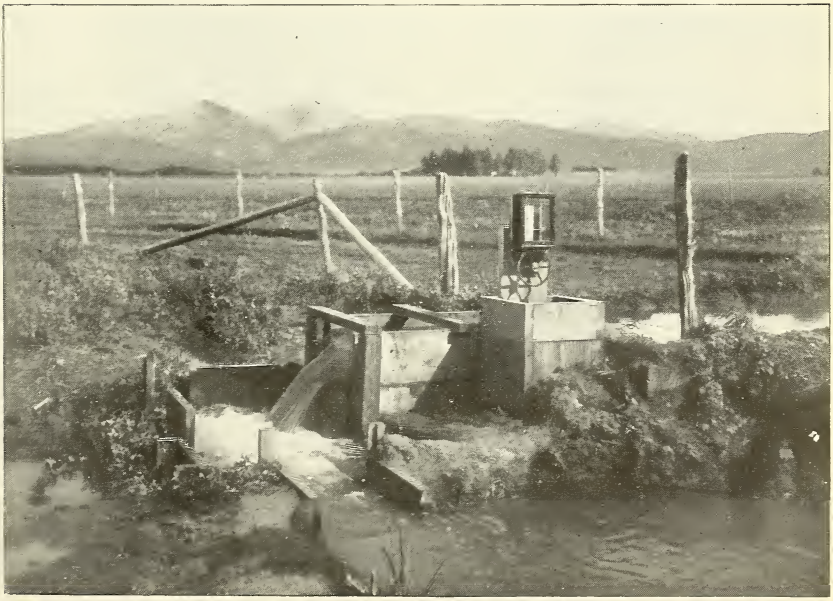


FIG. 2.—MEASURING WEIR WITH RECORDING INSTRUMENT.

CIPPOLETTI WEIR, JORDAN AND SALT LAKE CITY CANAL, UTAH.

sumer. He usually travels on horseback or in a two-wheeled cart, and carries a shovel, a hatchet, a small sharp-pointed bar, and frequently a number of empty sacks. The hatchet is used to repair structures and nail on boards which may have become loosened; the bar is for raising gates which may be difficult to move by hand; and the shovel and sacks are frequently required for the repair of banks and the stoppage of holes caused by the work of gophers, muskrats, and other burrowing animals, whose depredations frequently result in serious and expensive breaks in the embankments. The holes thus made are usually small and insignificant at first, but become rapidly enlarged through the erosion of the escaping waters, and if not stopped eventually result in a breach carrying away a portion of the embankment. The ditch rider, however, is expected to inspect the whole works under his charge daily, and usually detects the leaks by means of the escaping waters before serious results ensue. Upon the discovery of a leak thus caused, his first efforts are directed to the location of the point on the inside of the bank at which the water enters the hole. This is frequently detected through the eddy or vortex appearing at or near the opening. Having located this point, the orifice, if small, can be closed by pushing into the hole one or two empty sacks; if already too large to be closed in this manner, it can usually be accomplished by first filling a few sacks a half or a third full of loose earth and ramming them into the mouth of the opening into which the water from the ditch is passing. In this manner holes of considerable size can usually be effectually stopped in a few minutes.

The regulating gates before mentioned are frequently kept locked, as already stated, and the key thereto carried by the ditch rider. When, as frequently occurs, a water consumer has completed his irrigation and has for the time being no use for water, he may desire that it be shut out from his lateral. In such cases he leaves a note tacked to his head gate, requesting the ditch rider to shut it off at a specified time, and in the same manner notifies him to turn it on when he again needs it. The ditch rider gets these messages when he makes his daily round over the ditch.

Where a ditch does not exceed 12 or 15 miles in length one ditch rider is expected to patrol its entire length, but upon more extensive systems several may be required to perform these duties. Where there are several required the canal is divided into divisions, each of which is patrolled by a separate rider. In such cases the length of a division ridden by one man depends upon the character of the duties, varying materially with the amount of repairs, the danger of breaks and leaks, and the number of regulating gates to look after. The average length of a division is, however, from 12 to 15 miles, and the average compensation for the work ranges from $50 to $75 per month, out of which he must pay his own board and furnish and maintain his own horse and cart.

METHODS OF APPLYING WATER TO THE LAND.

Where an irrigator's land is contiguous to the main canal or distributary, he may have independent diverting works or lateral ditches. When, however, as usually happens, their position and the topography of the ground is such that a number of farms can be served by the construction of a single lateral, such is usually the method adopted. These laterals are usually constructed as partnership or community ditches, and are frequently extended and enlarged to meet the necessities of increased acreage and additional farms. Each irrigator is usually required to contribute in money or labor to the cost and maintenance of such ditches such a proportion of their whole cost as his water bears to the whole quantity of water carried, although sometimes the assessments are made also somewhat proportionate to distance from the head of the lateral. On most systems the company's responsibility ceases after turning into the head of such individual or community laterals a quantity of water equal to the aggregate amount to which all the users from it are entitled, the operation of the lateral and the distribution of water among the various consumers being left to be arranged by the interested parties. Where there are many users from a common lateral they usually select one of their number to take charge of the distribution of the water, whose duty it is to see that sufficient water is turned into the lateral by the company's ditch rider, and that it is equitably distributed among those entitled to its use. The proper location of these laterals is a matter of very great importance to economical and successful irrigation, and too great care can not be exercised in planning them, both to obviate the necessity for a multiplicity of ditches and to secure the best possible advantages for diverting the water over the lands to be irrigated.

FARMERS' DITCHES.

Individual farmer's ditches are required to convey the water from these community laterals to the places on the area to be irrigated from which it can be most advantageously spread over the ground for the irrigation of the various crops. These ditches should generally follow the ridges and higher contour of the area to be watered, and great care should be exercised in their location, so that all the land can be covered. Large areas of crops are frequently burned up through the careless and faulty location of these small ditches. Experience gained in such a manner is expensive, and too much care can not be exercised to secure their proper location in the first instance. The diverting works on these lateral and individual ditches are usually reduced copies of those used on the main canal, being in this country most often wooden boxes with sliding regulating gates. In the case of uneven and rolling ground it is frequently found necessary to divert water from several places on the main lateral to secure the proper irrigation of a single farm. The proper location of all distributing

ditches is possible only after a very careful study of the topography of the ground in each particular case.

The irrigator, having his stream of water in his own lateral, which is constructed across the highest part of the field to be covered, is now ready for its actual application to the growing crops. If his land is very favorably located, with comparatively uniform slopes, his lateral is probably in a straight line across the upper end or side of his field, with the greatest slope of the land at right angles to it. If his land has not so uniform a surface, his lateral may follow its irregular contour or be kept straight by diking it across the low places. In general the lateral ditches, from which actual application of the water to the crop is accomplished, should follow the line of least descent from the highest point of the field, the greatest slopes being perpendicular to them. There are several methods of applying the water to the land to be irrigated. Of these the two most common and generally used are the "flooding" and "furrow" systems.

FLOODING SYSTEM.

Under the flooding system small parallel ditches are constructed every hundred feet or so, according to the slope of the ground. Where the surface is broken they will be irregular and will follow along the ridges. These ditches should also have a slight fall, the steepest slope being at right angles to them. Such ditches are usually simply furrows made with a heavy moldboard plow, and, where the crop is grain, they are filled back by the plow before harvesting. These ditches, being cut at convenient points, allow the water to run out and spread over the adjacent land. The water thus released at once begins to follow the lines of quickest descent, and in so doing spreads out over the ground as it proceeds, dividing into numerous branches or rills as it increases its distance from the opening in the ditch. For the purpose of facilitating its spreading and to insure its thorough application to every portion of the surface, the irrigator follows its course, and by means of a long-handled shovel guides it to every portion of the field. This guiding is done by moving a few shovelfuls of earth here and there, and thus separating the various small rills and starting the branches in different directions. In this way the irrigator follows the water through the field and prevents its collecting in the depressions, leading it out upon such points as would without his assistance be missed by the water. Where only one operator is at work it is usually advisable not to make very many openings in the ditch at one time, since to do so may result not only in a waste of water through its concentration into larger streams which rapidly escape to lower ground where it may not be needed, but its concentration for long periods in the depressions of the surface is likely, through oversaturation, to damage the crop at those places. When the area which can be most conveniently irrigated from the openings thus made has been suffi-

ciently moistened, the latter are closed by throwing in a few shovelfuls of earth, and similar openings are made at other points, the same process being there repeated, and so on until the irrigation of the whole area has been completed.

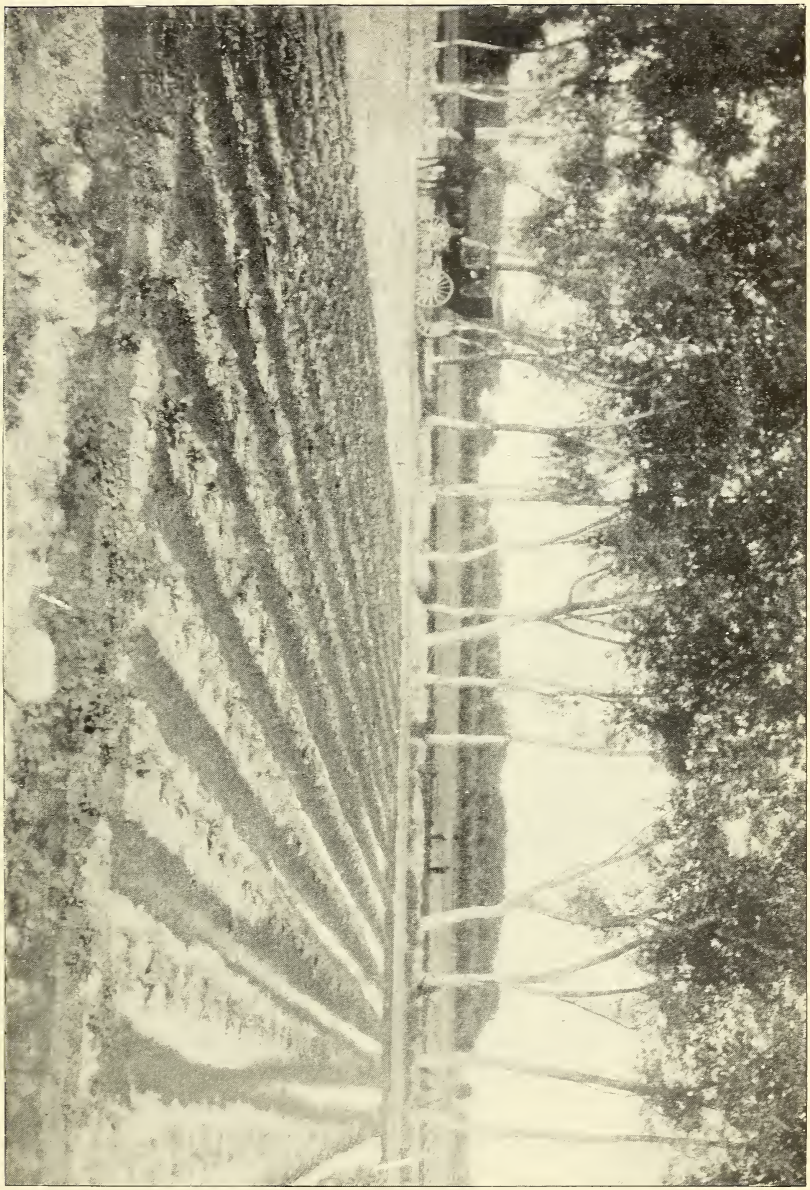
The entire operation is characterized by much greater simplicity than would be supposed by one unfamiliar with the practice of irrigation, only presenting features of serious inconvenience when the surface to which the water is applied is very irregular and broken, the slopes steep, and the soil loose and friable to such an extent as to be easily eroded. Even under those circumstances no real difficulty is presented, though the work is thereby rendered slower and more tedious through the greater care required in handling the water, and because a large volume can not be handled at one time on account of the greater liability of washing away the top soil and thereby injuring the land. Fortunately, however, most of the farming land in the arid region has a comparatively uniform surface, and this difficulty is therefore not frequently encountered. The land so preponderates over the available water supply in most localities that neither the necessity nor the inducement exists for developing and improving lands of great irregularity of surface, and it is not generally nor frequently done.

Under this system an experienced irrigator can cover from 10 to 20 acres a day, the area depending upon the character of the land surface and the volume of water at his disposal. For such crops as grain, alfalfa, clover, and the various grasses—for everything, in fact, which is sown broadcast and is distributed uniformly over the surface—the flooding system is employed, and furnishes the best, in some cases the only, practicable method of applying the water; but for many other crops this plan is neither the most convenient nor the best method.

FURROW METHOD.

Under this method parallel furrows are plowed, leading from the ditch through the field between the rows of the crop to be irrigated. (See Pl. VII.) A small opening is made in the ditch to let the water into each furrow. A dam of canvas or earth is placed in the ditch just below the lowest furrow into which water is being run at the time, thus holding the water nearly level in that part of the ditch from which it is being drawn. Where the slope of the ground is excessive, these furrows must be run diagonally, or irregularly, in order to reduce their grade and thus prevent erosion of the soil.

In the case of fruit trees it is generally found desirable during very hot weather to prevent the water from coming into actual contact with the trees, because of the danger of scalding. Flooding the surface also results, in some soils, in baking and compacting the earth about the trunks and roots of the trees. To avoid these consequences the furrow system is employed, one or two furrows being plowed along each side of a row of trees, at a distance of two or three feet therefrom, and the water is turned from the ditch into these furrows and



FURROW IRRIGATION.

permitted to traverse them slowly from end to end, thoroughly soaking the ground as it progresses, and reaching in to the roots without coming in contact with the stems above the surface. The necessary moisture is thus imparted without the wetting and subsequent baking of the surface which might result from flooding. When the trees are sufficiently irrigated, the water is turned out of these furrows and into others, the process being thus continued until the whole area has been served. The furrows are then filled in with a plow, the whole surface worked over with a cultivator, and no trace left of either the furrows or the application of water.

This method also requires the attention of an irrigator, to see that the proper amount of water is kept in each furrow, and that it does not break out and flood the surface in places, leaving the furrow beyond the break without water. One man can take care of a considerable number of these furrows at once, and under favorable conditions of surface and water supply can accomplish the irrigation of as great an area in a given time as by the flooding system.

This method is also applicable to the irrigation of corn, and in fact of any crop whatever which is planted regularly in rows, a single furrow between each two rows being generally used for such crops. When applicable it is the favorite method, both for its convenience and the economy of water thereby effected. But where the ground is very irregular this plan is often inconvenient, for the reason that the furrows paralleling the rows of crop would, upon such surfaces, be up and down hill, and would therefore not carry water. To make this method applicable in such cases it would be necessary that the rows follow approximately the contour of the ground, in order that the parallel furrows might carry water throughout their entire length. The irrigation of irregular surfaces, however, is generally conducted under the flooding system, except in localities where, as in parts of southern California, the value of the crop frequently warrants the expense of leveling off or terracing irregular surfaces, or the application of water through buried pipes, as it is arranged in the water supply of cities.

COMPARTMENT SYSTEM.

A modification of the flooding method is the compartment or check system of irrigation practiced in some localities, particularly in portions of Arizona. This consists in dividing the field to be irrigated into squares or compartments by levees or dikes of such height as to cause the water to stand over the entire area of the compartments at one time, the water being admitted to each compartment by means of a gate in the levee. The water is allowed to stand until the ground has become properly moistened, the time depending largely upon the character of the soil. The compartments or squares vary in size according to the slope of the ground, but are not usually more than an acre or so in area.

CHARACTER OF SUPPLY AND USE OF WATER.

SUPPLY.

Most of the streams of the arid region are comparatively small. This is the logical result of those climatic conditions which render the region arid. It is likewise a consequence of the proximity of their sources. More than half of the arid region is mountainous. Practically all its streams have their sources within its borders. They therefore consist of the headwaters of large rivers and a multitude of smaller tributaries. Most of the latter are short, and drain comparatively small areas before joining one of the larger streams.

All of the streams throughout this territory have rates of fall which are excessive in comparison with those found on the streams of the larger part of the humid region. The reason for this is found in the topography of the country. In the middle of the arid region are located the main ranges of the Rocky Mountains, which constitute the backbone of the continent, the divide between the Atlantic and the Pacific. The lands on both sides of this ridge slope rapidly, and the water courses, following generally along the lines of quickest descent, have corresponding declivities.

In the humid region the rivers are chiefly fed from rain, the highest water being generally experienced in February and March. Those in the arid region, as a rule, carry but little water at this season of the year, because there is little, if any, rainfall at this time. With few exceptions, there is no rainy season within the ordinary meaning of the term. The precipitation ordinarily occurs in the form of snow, and even this is not abundant except in the mountains. It is only in a few localities that streams in the arid region are appreciably and for considerable periods directly affected by the rainfall, such as southern California and parts of Arizona and New Mexico, where a more or less distinctly rainy season prevails and the streams usually carry their maximum volume in the winter and very early spring. But in the region under consideration in this bulletin, the source of supply and the cause of periodical high water is found in the fall of snow which occurs upon the mountain ranges during the fall, winter, and spring months. It is the melting of this snow with the advent of warm weather which causes the periodical rises, and it is therefore only during the spring and early summer that the water courses throughout the major portion of the arid region experience any considerable and permanent increase in volume of discharge, April, May, and June being the high-water months (see Pl. VIII). They always show high water at this time whether there has been any rain or not, the volume of flood depending upon the amount of snow to be melted, and its relative duration being determined by the warmth of the season and the consequent rapidity with which the snow disappears. Those streams taking their supply from the higher mountain ranges do not

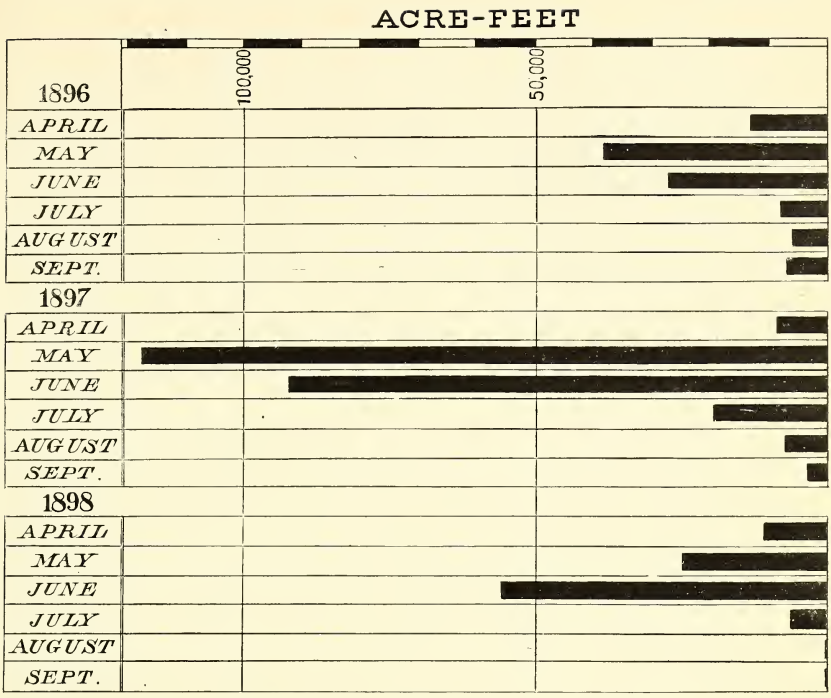


FIG. 1.—DIAGRAM SHOWING DISCHARGE OF LARAMIE RIVER.

FIG. 2.—DIAGRAM SHOWING DISCHARGE OF BOISE RIVER.

definitely respond to the effects of warm weather until about the middle or last of April; the maximum is reached about June 1, and the complete subsidence of the flood occurs from July 1 to July 15. When the winter's supply of snow has disappeared the streams again shrink to the normal volume which characterizes their flow for about nine months of the year, the source of which consists principally of springs in the mountains and the melting of perennial snow banks whose sheltered locations in the higher ranges, where the intense heat of summer never prevails, causes their melting to proceed more slowly and gradually than at lesser elevations.

USE.

The irrigation season, or the period during which the application of water is practiced, varies within wide limits. In the southern parts of Arizona and New Mexico water is used throughout the entire year. The conduits in these localities are kept running winter and summer, being closed down only when a break or accident occurs, or when it is necessary to clean out their channels, or when (in the case of those of recent priorities) the stage of water in the streams whence their supply is diverted does not entitle them to its use. In the more northerly regions the date upon which water is turned into the conduits varies between March 1 and May 1, and it is generally turned off for the season between November 1 and December 1, depending upon the climate and the character of crops produced. In Colorado and Idaho these dates are fixed by statute, and are April 1 and November 1, respectively, though water may be turned in as much earlier and kept running as much later as the weather will permit.

The irrigation season is, however, with reference to the necessities of the crops under cultivation (except in the southern territory named), of shorter duration than that indicated by the dates limiting the flow of water in canals. The latter may be considered the limits within which the flow of water is practicable throughout the more northerly parts of the territory under consideration. With the exception of the grasses, and perhaps alfalfa, few crops require irrigation earlier than May 1, nor do they often require it later than September 15.

The quantity of water necessary or used for irrigation fluctuates during the irrigating season, but unfortunately the period of maximum use does not coincide with the period of maximum flow of the streams. On some streams the low-water flow is reached before the end of the period of maximum demand for water, and, as the flow available at such time limits the irrigating efficiency of the stream, the flood waters are of no material benefit to the irrigator. On other streams the maximum use is over before the complete subsidence of the high-water flow, some of which is consequently not utilized. The time of greatest need for water varies somewhat in different localities, but generally there is very little water used in April, and the quantity used in May

is relatively unimportant. June and July are the months of maximum use, and the use in August is usually considerably greater than that in May. After September 1 the necessity is again relatively unimportant (see Pl. IX).

Considerable data bearing upon this subject has been collected during the present year. Some investigations have been previously made by the State engineers and experiment stations in Colorado, Wyoming, Utah, and Idaho. From these results the relative quantities of water used during the different months may be approximated as follows:

	Per cent.
May	10
June	30
July	30
August	20
September	10

The proportion of the total annual discharge carried by the streams during the different months may be roughly stated as below:

	Per cent.
April	10
May	25
June	25
July	10
August to March, inclusive (eight months)	30

From an inspection of the above figures we find that the August flow of streams is the flow which limits their irrigating capacity, and that not more than about 20 per cent of their total annual discharge can be made available for irrigation from their natural flow. Of course this is only an approximation, but it is believed, from the data at hand, that this proportion will be found substantially true of most of the streams in the region under consideration.

STORAGE OF WATER.

If rivers were highest at the time when irrigators had greatest need of water the problem of utilizing the entire water supply would be much simpler than it is. In that case the area irrigated could be extended until the demand on the stream exactly equaled its supply and the entire flow could be utilized by diverting it directly from the river onto the land. This coincidence, however, does not occur. It has been seen that most streams begin to rise about April 1 and reach their highest point on or before June 1. The period when irrigation begins varies in different States and different altitudes in the same States and with the end of the spring rains. In Montana, Idaho, and Wyoming it is later than in Utah and Colorado. In the States first named there is little irrigation before May 1 and fully one-half of the water used is needed after July 1. Hence it follows that one-half of the annual flow of most rivers has passed the irrigator's head gate before the time of greatest need is reached, and a large percentage is gone before irrigation begins.

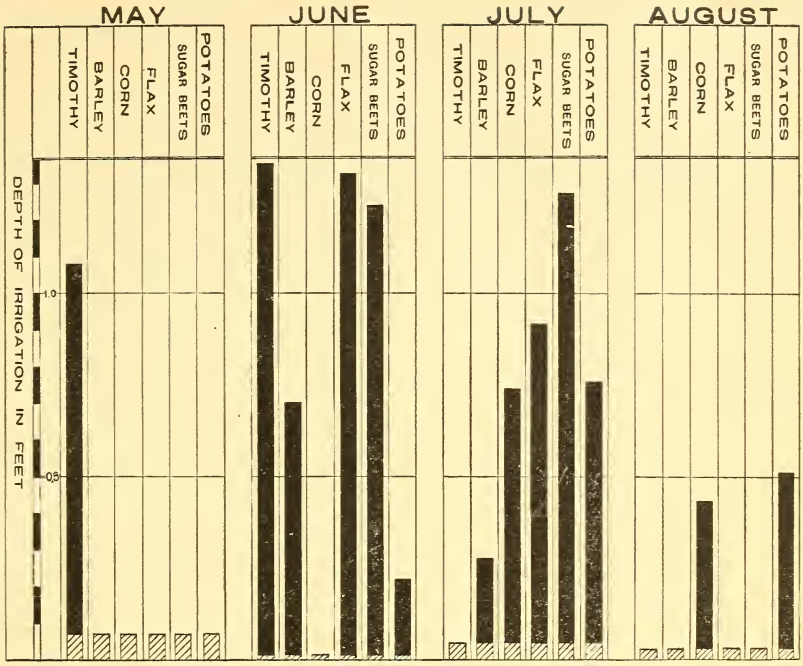


FIG. 1.—DIAGRAM SHOWING USE OF WATER AT WHEATLAND, WYO. (HATCHED PORTION REPRESENTS RAINFALL.)

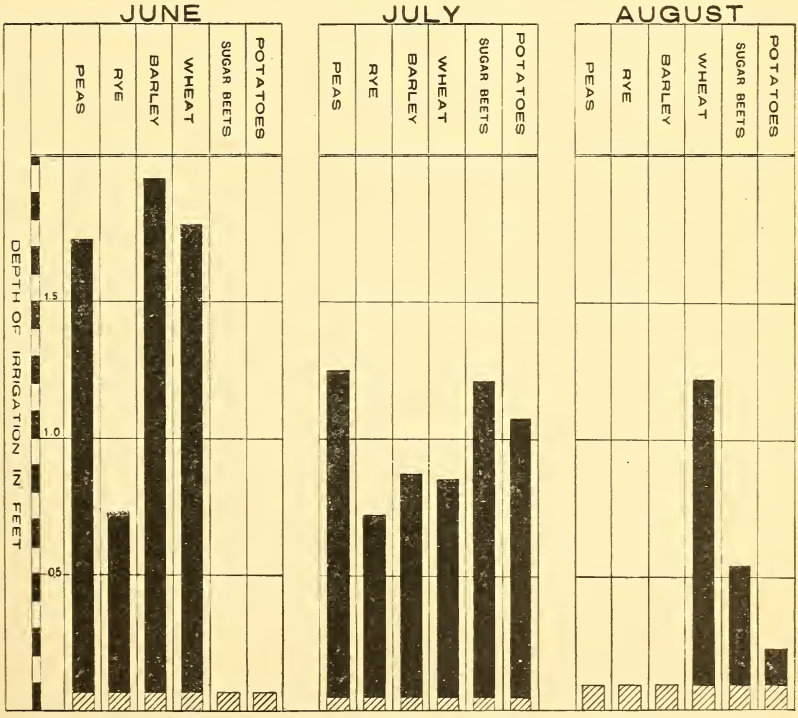
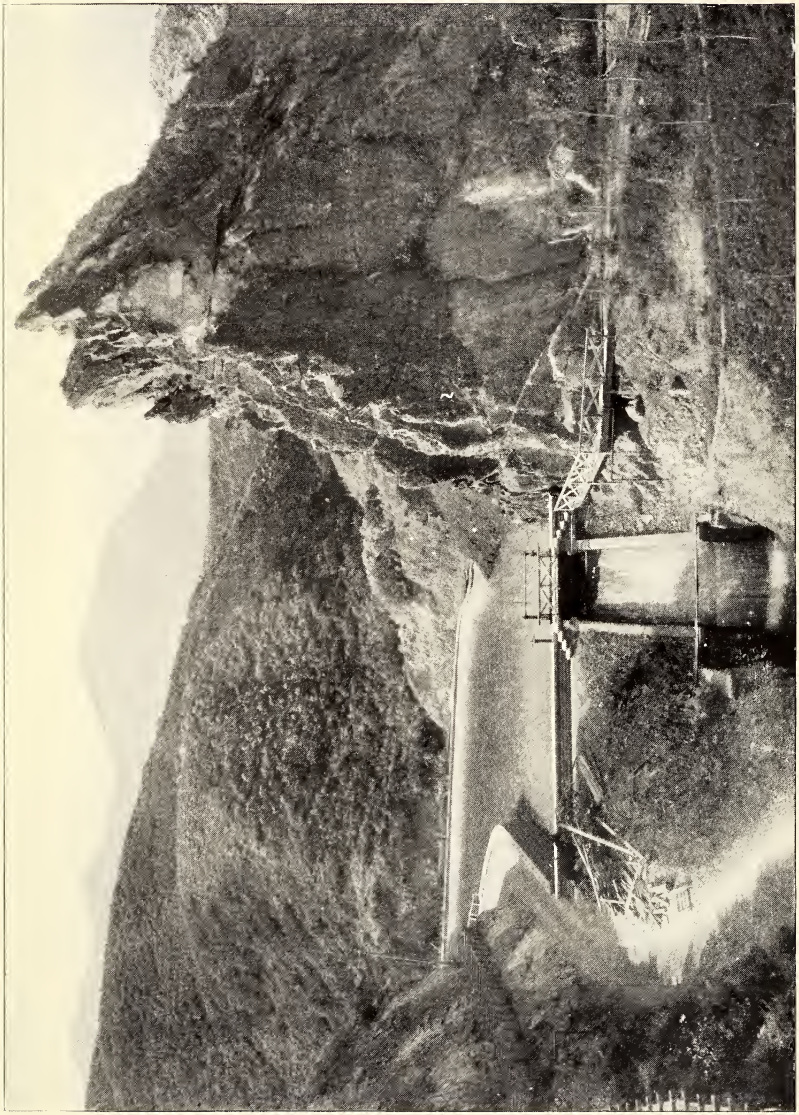


FIG. 2.—DIAGRAM SHOWING USE OF WATER AT LARAMIE, WYO. (HATCHED PORTION REPRESENTS RAINFALL.)



PARLEYS CREEK RESERVOIR, UTAH.

The effect of this, as shown above, is to restrict the area which can be profitably irrigated to that supplied by the July and August discharge of streams, rather than to their discharge in the flood season, and to cut down the area which can be irrigated by the natural flow alone to from one-half to one-fifth of what could be reclaimed if the floods which now run to waste could all be stored.

Where the topography of the country is favorable this loss of water may be prevented or greatly diminished through the construction of reservoirs for storing the surplus during the early part of the season for use in the later months. In order to accomplish this, lofty and expensive dams have been built across the canyons of mountain streams. (See Pl. X.) The greater number of storage sites which have been utilized, and those which give the largest return for a given expenditure of money, are the lakes often found near the heads of streams and the natural basins or depressions frequently found in the valleys which border them. In some localities these basins are quite numerous and extend for a long distance from the stream out into the plains which border them. Others are broad openings or valleys in the mountains which were doubtless formerly lakes, but which have been filled by sedimentation. The basins found on the plains are more desirable, both because they are nearer the place where water is to be used and are freer from floods, and because it usually requires a smaller outlay to improve them. To do this requires the construction of a canal to fill them, and of outlet works for drawing off the water and transporting it to the land to be irrigated. Many of these basins are in the form of a great bowl, completely inclosed on all sides, so that no dam or embankment is required; but, on the contrary, there has to be constructed either an open cut or a tunnel through the surrounding rim, through which a pipe or some other form of conduit is placed for drawing off the water whenever it is required. In other cases the surrounding rim of the basin may not be continuous, low places existing which require the construction of embankments to retain the water.

The improvement of mountain reservoirs is essentially the same as that of those found on the plains, but the utilization of the water supply involves some problems not presented by those which exist on the plains. In the plains reservoirs the water is usually conducted directly to the lands, but in those of the mountains it has to be first turned back into the river and carried with the natural flow of the stream to the headgates of the ditches or canals through which it is to be diverted and used. This is necessary because of their distance from and their great elevation above the lands on which it is to be used. The Chambers Lake reservoir, at the head of the Poudre River, is 75 miles from the head of the ditch which is entitled to divert the stored water. The projected reservoirs at the head of Piney Creek, in the Big Horn Mountains, are from 15 to 40 miles from the ditches which are to utilize the water they will hold, and the construction of a complete storage system

for the utilization of the floods of almost any stream would require that some of the stored water be carried in the natural channel for long distances.

In many localities it is difficult or impossible to operate canals during the winter months. In such cases it is impossible to store the winter flow in reservoirs which lie outside of the channel of the stream and which have to be filled by means of ditches. It is only by means of lakes at the heads of streams, or the reservoirs created by dams along their channel, that the winter flow of these streams can be stored and utilized. Such reservoirs must be so constructed that the surplus water shall pass over the top of the dam or through a wasteweir provided for that purpose, as in no other way could the rights of prior claimants to the natural flow of the stream be protected. Whenever the stored water is needed it is turned out through large gates in the bottom of the dam. This lowers the water surface of the reservoir and ends the discharge of the natural flow over its surface or through the wasteweir provided. The question then comes as to the division of the natural flow and of the volume released from the reservoir, and this requires that measurements be made to determine the amount of each. This is usually accomplished by means of a weir or measuring flume placed immediately below the reservoir through which the water passes and by the construction of a similar measuring device to measure the natural flow of the stream above the reservoir. Where the stored water is diverted another measurement is required, the second gauging being for the purpose of determining that the amount taken out shall not exceed the amount of the stored water turned from the reservoir above.

Within the past ten years many of these basins have been improved and water has been stored with the most satisfactory and profitable results. Many irrigation enterprises with inferior priorities whose patrons prior to the enjoyment of this supplemented supply seldom were able to irrigate later than the 15th of June, have, since the construction of these storage works, been placed in a position of equality with those having the oldest and best priority rights.

With these benefits there are also complications. If a comprehensive system of storage is to be adopted it will doubtless greatly increase the difficulty of dividing water among the different claimants to a common supply and make it necessary to have additional legislation to define the character of the rights to these stored waters.

The benefits which have already come from the construction of reservoirs have been of the most substantial character, but their improvement and operation has also added largely to the annual cost of water and a canal with an early priority right which gives a definite and abundant water supply without their aid is much to be preferred. Reservoirs are simply a secondary means of utilizing waters which otherwise run to waste and they are the only safeguard of irrigators

on streams in which the natural flow has been overappropriated. Those familiar with irrigation know that this situation of affairs is of frequent occurrence and that there are few streams on which irrigation has assumed considerable importance in which late appropriators do not suffer as much from drought in July and August as do farmers dependent upon rainfall. In seasons where the winter snows have been heavy they can have an assured supply, but there are also years dependent upon rainfall when there is no lack of moisture. The discharge of rivers in the arid region varies more from year to year than the rainfall does in the section of country where crops are cultivated wholly through its aid. The discharge of the Laramie River in 1899 was five times as great as it was in 1889. An adequate system of storage will not only protect irrigators from the variation in supply from month to month, but will assist in reducing the fluctuations from year to year. It will enable the floods of years of large discharge to be held back for use during years of drought.

DUTY OF WATER.

No definite estimate that would apply generally to different localities and conditions can be made of the quantity of water required for the irrigation of crops. The amount varies with the locality; in a given locality it varies in different seasons, and at the same place and during the same season it varies with the nature of the soil, the method of application, the degree of skill exercised by the irrigator, and the kind of crop irrigated. Grain requires less water than alfalfa, potatoes need less than grain, and fruit trees less than any of them. For the ordinary farm products of the temperate regions—in Colorado, Wyoming, Utah, Idaho, and Montana—two or three irrigations or applications are usually required for the production of a satisfactory crop. The amount required for each irrigation will vary, within the States named, between 5 and 9 inches over the land.

These figures represent the results of the writer's observations during a long period of service in the distribution of water under many different systems of irrigation. This takes into account the losses due to seepage and evaporation from canals between the source of supply and the lands served, that resulting from the wasteful and unskillful handling of the water by careless or inexperienced irrigators, and various incidental sources of loss and waste; but as these factors of loss are generally to be found and are apparently inevitable under most of the existing systems of distribution within the States named, they constitute factors which can not be ignored in the proper consideration of the duty of water. That the service which water could be made to perform under the most favorable conditions of land preparation and skill in application would be much greater is a well recognized and conceded fact; and that improved practice in the design and construction of irrigation canals, increased intelligence and economy in the use of water, and more frequent and thorough cultivation of the soil will

eventually produce a marked effect in this direction are propositions that do not admit of reasonable doubt.

Then, too, the duty obtained from water depends very largely upon the method of its distribution. Under some canals compensation is made dependent entirely upon acreage cultivated rather than quantity used. Such a method is likely to promote wasteful use. In those cases where compensation is made to depend upon quantity of water used, the quantity is usually designated by a unit of continuous flow. This method also tends to promote waste during that part of the irrigation season when the maximum flow is not required. Neither of these methods will result in the fullest possible use of the water. In cases where a high duty and great economy in the use of water is necessary (especially where reservoir supplies are involved) the quantity should be expressed in terms of duration as well as volume of flow, as a cubic foot per second for twenty-four hours. This kind of a system and an equitable rotation in use among different users is the one best designed to promote the fullest possible use of the water.

This system of rotation is now practiced on many of the smaller streams and canals in time of scarcity, and will doubtless gradually become more general. The principle is that of periodical use of a certain irrigating stream by each owner in turn for a time corresponding to his proportionate ownership, and the periods of rotation are so arranged as to best promote the cultivation of the crops upon which the water is used. It is unfortunate that so many water-right contracts have established the more wasteful method. The time has come on many streams, and is certainly coming on most of them, when the highest possible duty of water will be necessary to the fullest development of farming operations. The method of distribution by rotation of use is quite generally practiced in Utah, where a very high duty, especially during the latter part of the irrigation season, is obtained under its operation. When there is a scarcity of water, the water master, instead of cutting down the size of the stream allowed to each irrigator, limits the time during which the stream may be used by him, thus giving him a stream large enough for economical irrigation for a length of time proportionate to his ownership of water or acreage to be watered. The length of time allowed each irrigator will, of course, decrease with the decreasing available supply from the stream, and the periods of rotation are arranged so as to give each user a fair proportion of night and day use.

This method is a very beneficial modification of the rigid doctrine of priority of right. Under it people are encouraged to irrigate liberally when there is a plentiful supply in the stream, and to exercise the greatest possible economy and skill in their operations when there is a scarcity. In Utah, where this commendable system is so generally employed, the doctrine of priority of right is modified by the division of rights into two classes, primary and secondary. The former class

includes all of the older rights on the stream to the extent of the usual low-water flow, and in times of scarcity all who hold such rights suffer equally, which is certainly more equitable than to allow a few of the earliest appropriators to control all of the flow at such times, to the ruin of the others. The necessity for careful measurements of the flow of streams through a series of years before the division of appropriators into classes can be made is of course apparent, and the lack of such reliable information may lead to errors of classification, but the plan has certainly many elements of justice not found in the rigid adherence to the doctrine of priority, and under its operation a greater beneficial use of the available water supply will result. To secure this fullest use of the water supply not only necessitates proper laws, but a careful and efficient system of administration and control of water distribution.

HOW WATER RIGHTS ARE ACQUIRED AND MAINTAINED.[1]

THE DOCTRINE OF PRIORITY.

The best lands, the best markets, and the most genial climate are generally found in the valleys, rather than at the headwaters of rivers. The first settlements are usually made on these valley lands. The first settler on a stream does not concern himself greatly about his right to its waters. He takes all he needs, or all there is, and in either case is neither helped nor hindered by wise or unjust laws governing its ownership. But the first settler is followed by the second, and as ditches multiply and the reclaimed area broadens there finally comes a time when there are more ditches than the stream will supply.

We have already seen that the streams of the arid region are small in most cases, carrying throughout most of the year a volume of water that is comparatively insignificant and often insufficient for the demand; and when the vast area is contemplated over which the condition of aridity prevails, and it is considered that scarcely any of it has any agricultural value without irrigation, and that the insignificant streams here found constitute the only source of supply, it requires no elaborate argument to prove that much the greater portion of this area can never be successfully or profitably cultivated—that most of it can in fact never be farmed at all. If the available water were equally distributed over all the lands of this vast territory, the amount would prove so slight as not to appreciably affect its aridity, and the whole would be wasted without producing any beneficial effect. In order, therefore, that the greatest good may be accomplished, its use must be restricted to such an area as it can reclaim in the best and most satisfactory manner. In practice this result can not, for many reasons, be perfectly attained, but it may, within reasonable limits, be approximated. If the streams of the arid region carried at all times sufficient

[1] See also Appendix, p. 58.

water for the requirements of all the lands susceptible of irrigation from them, there would be no question raised concerning the right of priority to its use. All users would then be at liberty to divert and use as much as they desired, and one of the most fruitful sources of perplexity and controversy would be eliminated from the irrigation problem. But the preponderance of land within the arid region over the water available for its irrigation has naturally resulted in the attempt to reclaim many times the area which the meager streams can accommodate, resulting in conflicts of interest. Without some sort of general regulation and control the ditches farthest up the stream would take what they need, those lower down would take what was left, and on many streams the land first settled would have to go without water, and homes already established would be destroyed to create less desirable ones. Position would count for everything.

There are many reasons why such a condition of affairs has not been permitted in irrigated districts. As land is valuable only when it has an assured supply of water, respect for vested rights has led to the enactment of laws for the protection of the rights of those who first made use of the water. These laws are based upon the principle of priority of right, which decrees that of the various users and claimants of water those have the prior and best right who have first diverted and appropriated it to a beneficial use, and that rights descend to other claimants in the order of the dates of their respective appropriations. Without some such adjudication of these questions it is evident that agricultural development could not proceed; property rights in irrigated lands and reclamation works would not be secure, and the latter would therefore not be created. It would not be safe to invest labor and capital in the development and improvement of lands if the water rights upon which their value depends were not guaranteed the necessary protection.

The principle of prior appropriation appears to furnish the most satisfactory solution of the problems arising through the inadequacy of the water supply, and it is the one universally accepted and applied. Under the regulations based thereon no advantage is gained through position upon a uniformly-flowing stream, nor does the magnitude or relative importance of the improvements affect the right. A consumer near the headwaters of such a stream must yield to the prior appropriator who diverts his water at a point a hundred miles below. The powerful corporation which has spent millions in the construction of its works must close its headgates and permit the precious fluid to pass on to the humble individual who constructed his ditch first, and thereby acquired the prior right to its use. Few streams, however, have anything like a uniform flow through their entire course. Seepage water from irrigated lands above, as well as surface and subterranean flows, are often of great importance on the longer streams and of material

benefit to the lower appropriators. Streams can not, therefore, be generally considered as channels of uniform flow where each appropriation is valuable according to its priority number; but conditions are often much complicated by losses and gains in different portions of their course, and the determination of priorities and the fair and just distribution of the water under them is consequently often rendered difficult and perplexing.

Priority rights to the use of water, however, are most important and far-reaching in their connection with agriculture in the arid region and merit the closest investigation, not merely on the part of the capitalist who contemplates the investment of his millions in works of reclamation, but by the individual settler and farmer who proposes to locate in this region and devote his energies to farming under the practice of irrigation.

In order that prior rights may receive the respect and protection to which they are entitled, and for the purpose of furnishing information concerning the unappropriated water supply of the different streams for the benefit of those who may contemplate availing themselves of its use, it is necessary that the facts concerning the water supply of all streams, and the effective appropriations therefrom, be made matters of public record, readily accessible to the general public and to those who may be interested in this question. It is the absence of such a record that has led to many of the abuses and evils from which irrigators suffer at the present time. For this the early settlers are probably more responsible than anyone else. The old settler, as a rule, has resisted legislation for the definite enforcement of rights. He has done this for two reasons. As a rule, he claimed more water than he used or needed, and he feared that any adequate control would deny him the title to all he claimed. The next reason was his antagonism and jealousy of the larger and later ditch companies. The second obstacle to proper laws for the recording or enforcement of rights is the opposition of the later appropriators. The corporation ditch owners are not, as a rule, users of water. They build canals to sell water. When their work began there was a chaotic condition of law and of public sentiment regarding what constitutes an appropriation. It seemed to be in the interest of the larger companies to claim that the size of the canal determined the amount of the right, no matter whether the water was used or not. In many cases not even the size of the canal has been the standard, but the flexible and expansive "intent" of its owner. The fact that the large corporation, the small individual ditch, and the farmers who use water from both are all claimants for a common supply, having interests that are more or less antagonistic, has led in every State to more or less indefinite declarations, and in some of the States prevented any legislation whatever.

METHOD OF APPROPRIATION.

The laws of most States require that any individual, association, or corporation desiring to appropriate any of the public water of the State must file for record with some public officer (generally the county recorder of the county in which the diversion is proposed to be made) a statement setting forth the quantity of water claimed and more or less definite information in regard to the location and character of the proposed use. If within a reasonable period, the limits of which are usually fixed by law, the actual diversion has been accomplished and the water applied to a beneficial use, the claim becomes definite and effective and the steps taken to acquire the water right becomes a matter of record, which is designed to furnish specific information as to the volume so appropriated and date of its appropriation.

As a matter of fact, however, many such recorded claims are purely speculative and have never been perfected at all. Few have been perfected for more than a small proportion of the quantity claimed in the record. So an examination of the recorded claims to the waters of any stream really gives very little actual information in regard to appropriations from it. With the exception of Wyoming and Nebraska, the State exercises no control over the perfecting of an appropriation, and the determination of the priority and volume of an appropriation can be had only by a suit at law resulting in a court decree establishing them. Such suits generally result when the water of a stream is insufficient to satisfy the demands of those who claim rights to its use. These court decrees are based upon the testimony of the interested parties as to the quantity of their appropriations, and have often been rendered under a misapprehension of the facts and in ignorance of the actual conditions. Many of the earlier decrees were rendered before the very great importance of the questions involved was realized. The results have not generally been satisfactory, and have usually been the giving of excessive quantities of water to the various claimants, resulting on many streams in a few of the earlier priorities controlling all of the low-water flow. That a strict State supervision, and examination of ditches and area irrigated is necessary to a just determination of rights and a proper protection of public interests in the water, is now apparent to all students of the subject. Existing methods are leading to much litigation on the overappropriated streams, efforts being made in some cases to overturn existing decrees. The conditions may be best shown by a few brief quotations. Hon. V. A. Elliott, formerly a district judge in Colorado, in a brief in the supreme court of that State, says:

> In the earlier adjudication of priorities, there was little or no contention between rival claimants. People seemed to think all they needed to do was to "prove up" their appropriations and get decrees for as large quantities of water as possible, * * * notwithstanding the fact that the amount of the appropriations decreed from some of our natural streams was four times as much as the ordinary flow of the water in such streams.

In another case in the same court he says:

> Excess priority decrees are a crying evil in this State. From every quarter the demand for their correction is strong and loud. * * * Their continuance is such a hardship that litigated cases will be continually pressed upon the attention of the courts until such controversies are heard and settled, *and settled right.*

The State engineer of Idaho, in his biennial report for 1895–96, states:

> The tendency toward excessive decrees has certainly retarded settlement and cultivation in some cases on account of the waters of the stream not being so decreed and distributed as to serve the greatest possible area of land.

Similar conditions exist in the other States where the determination of these important questions are left to the ordinary process of the courts, almost endless litigation and enormous expense to the litigants resulting. Sometimes, too, the decrees are indefinite, the method of measurement prescribed by the courts being often incorrect or uncertain, still further complicating the decrees.

On the other hand, in those States (Wyoming and Nebraska) which have a board of control for the settlement of these questions, there has not only been very little litigation, but the adjudication of rights has been comparatively inexpensive, as well as fair and equitable, as shown by the very few appeals from the decisions of the board. This is shown by the following quotation from the latest report of the secretary of the Wyoming board of control:

> In other States irrigation matters have proved a fruitful and vexatious source of litigation. Not so in our State. Whenever tested the courts have upheld the actions and decisions of the board of control. It is a source of great satisfaction to the members of the board that the irrigation litigation that other Western States are burdened with does not exist in Wyoming.

In this State the water is decreed to certain described land, and is by law forever inseparable from it. Speculation in water rights apart from the land is therefore prevented.

HOW RIGHTS ARE ENFORCED.

These court decrees, or (in Wyoming and Nebraska) the orders of the boards of control, as to priority of the various water rights and the volume of water of a stream furnish the basis for a distribution of the water in times of scarcity. The enforcement of these rights of priority and the distribution of water under them is accomplished by water commissioners or water masters. In some States, as Colorado and Wyoming, these commissioners are appointed by the governor and are under the general direction of the State engineer. In others, as Idaho and Montana, they are appointed by the judge of the court rendering the decree, and are responsible for the proper performance of their duty to no other authority.

That this supervision of the distribution of the water may be effective in detail, it becomes necessary to police and patrol the streams from which it is diverted. To this end it is the duty of the water com-

missioners or water masters to examine and regulate the head gates of all ditches or other conduits by which water is diverted from the stream or streams under his charge, for the purpose of determining that each claimant receives the volume of water to which he is entitled under his decreed priority of right. During the spring season, when the streams are in flood and before the work of irrigation is in active operation, these duties are comparatively simple, since at this time there is generally enough water for all claimants, who may take all they want without interfering with the rights of others; but later in the season, when the floods have subsided, the streams have resumed their normal level, the weather has become hot, the soil parched with thirst, and the maximum area of crops is suffering for the want of moisture, his work becomes complicated and his lot is frequently not a happy one.

As there is not sufficient water for all, it now becomes necessary to consult his list of priorities, and, watching closely the gauge upon the stream which informs him of the quantity of water passing, he must shut off the supply from those whose priorities do not entitle them to its use at this stage of the water, permitting it to be diverted by those who have the earlier and prior rights. It is at this period that his troubles and hard work begin. It would be a comparatively simple matter to distribute properly the water in the order of prior appropriations if this order corresponded with that of the position of the various claimants upon the stream. This, however, is never the case. Priorities are numbered according to the dates under which the works were constructed and the appropriations made effective, while the position of the works along the stream are governed by other conditions entirely. That canal whose order or number of priority is 1, may be located near the lower end of the stream, while No. 100 may be diverted from a point 50 miles up the stream from the latter. When, for example, the stage of water requires that the head gates through which priority No. 80 is diverted be shut down, he may have to travel 20 miles to reach them. If the river by this time has fallen to an extent requiring that No. 79 be shut down, he may have to return up stream 10 or 15 miles to perform this duty, while No. 78, which is next in order of deprivation, may require him to return to the vicinity of No. 80, or perhaps travel even farther than this to close its gates. If the stream does not fluctuate, but continues to go steadily down, this closing of gates likewise continues until only those remain open whose priorities are the oldest and best, and the aggregate amount of which rights does not exceed the quantity of water flowing in the river at its lowest stage. These, of course, are never molested, and the farmers whose operations are conducted under these canals are fortunate. They are always prosperous, because they always get plenty of water and therefore invariably have good crops.

If the river fluctuates rapidly, sometimes rising and again falling, the water commissioner has an even more difficult task, for in addition

to the work of closing gates, he has, with each rise, to see that the gates of those thus becoming again entitled to water are raised, which is a matter of quite as much importance as that of closing those of the appropriators who have not the right to its use. In the time of scarcity he has in the discharge of his duties not only the right to close the head gates of those not entitled to water at the time, but the authority to lock them down. When this authority is exercised he usually posts a written notice upon the gates so closed, which gives notice that the same are under the control of the water commissioner and must not, under the penalty of the law, be opened or interfered with except by his authority. Such interference constitutes a misdemeanor for which, upon conviction, the offender may be punished by fine or imprisonment, or both.

Many irrigation enterprises have several priorities to the use of water, bearing different numbers and becoming effective under separate dates. This results through enlargement of the works subsequent to the date of original construction. When a canal or other irrigation enterprise is constructed, it receives a priority right bearing a given number and recorded under a date which is usually coincident with the beginning of construction of the works. If, upon any date subsequent thereto, the owners or operators of this enterprise enlarge the works so as to divert and use a larger volume of water it becomes necessary, in order to secure protection in the use of the additional right thus claimed, that a decree of the court be obtained establishing the priority right pertaining to the additional supply thus provided for. This priority will take its proper consecutive rank with relation to other prior appropriations, will be recorded under its appropriate number, and will bear a date registering the time when it became effective. This date will be, if the work of enlargement has been prosecuted with reasonable diligence and application has been made of the water to a beneficial use, coincident with the date upon which the work of enlargement was begun. If between the date of original construction and that of the enlargement no other appropriations have been made from this stream, the priority numbers of these two decrees will be consecutive, and the two priorities may be treated practically as one, though bearing different dates and numbers. When, however, between these dates of original construction and subsequent enlargement other appropriations intervened, these take precedence over that for the enlargement of the work under consideration, and, while junior and inferior to the original appropriation, are senior and superior to that secured by virtue of the enlargement. This enterprise will then have two separate priorities, bearing different numbers and dates, and having different degrees of effectiveness. As a result of this, at times when the water supply is deficient, one (the earlier) of its priorities may be effective, while that due to the enlargement is not recognized.

Some canals have several of these successive priorities with other

rights intervening. It thus becomes necessary that the water commissioner know not only the full carrying capacity of each conduit diverting water from the streams within his division, but that he also know the amount being carried at any given depth of water. The canals are usually rated or gauged by the State engineer's office, and the water commissioner is given a table of these ratings. For convenience in gauging each canal company is required to have placed in its canal, at or near its upper end, a flume or rating weir which is used by the State engineer in such gaugings, and his ratings or tables of discharge for given depths are based upon measurements made in this structure. By means of these tables the water commissioner can, by observing the depth of water within this structure, determine the amount passing at the time, and is thus enabled in times of scarcity to accurately shut off one or more of the junior appropriations without interfering with those of earlier dates which may be still effective.

NECESSITY FOR DEFINITE LAWS.

While the doctrine of priority of right is necessary to protect the appropriators and to make possible a system of distribution, the fullest beneficial use of the public waters, as well as the interests of the later appropriators, demands that such rights, on overappropriated streams, be subject to reasonable and careful restriction and public control to prevent an unnecessary use or waste of the water. A record of the flow of the different streams is very important in this connection, and one of the duties of the State engineer's office is to make and record the results of periodical or daily gaugings of the different streams of the State from which water is diverted for agricultural or other uses, the object of these measurements being the determination of the volume of their discharge at various depths, the amount generally available for use during the different months, and the total run-off for each year. Records of the results of these operations are preserved for future reference and furnish most valuable information concerning the water supply, of great service to those investigating the merits of irrigation enterprises already created, propositions under contemplation, construction of storage works, etc.

The laws and customs regarding appropriation and distribution of water are generally in an unsettled condition, and differ materially in different States. In some States, as Utah, water is clearly recognized by law as being personal property, subject to transfer and sale separate and apart from the land it irrigates. In others, as Wyoming, the directly opposite doctrine is laid down, land and the water used for its irrigation being inseparable. In still others, as Colorado, the question is not definitely settled by statute and the decisions of the courts have not been uniform, the later decisions seeming to treat water appropriated for irrigation as personal property. This important question ought to be definitely settled, and after that is determined it ought to be established so that everybody could know exactly how an appro-

priation is acquired and when it is completed. Every man who owns an irrigated farm or every settler who wishes to own one ought to be able to ascertain exactly what the water rights of a particular tract of land are. Where the ownership of the land, the ditch, and the appropriation are all centered in one individual, this is not of much importance, but when it is possible for one party to own the appropriation, another the canal, and still another the land, as it unquestionably now is in a number of the arid States, the uncertainties of the situation and the possibility for litigation are so great as to make those who expect to be farmers and nothing else hesitate to take their chances under them.

CONTRACTS BETWEEN CORPORATIONS AND IRRIGATORS.

We have explained (p. 18) the four general plans by which individuals, communities, corporations, or districts organize and operate to provide a water supply for irrigation. In three of these the individual irrigator has an interest of ownership in the water right and in the system of works for its distribution. Under the corporation plan, however, the water user has, as a rule, neither an ownership in the works nor in the appropriation of water. Where the irrigator is also the owner of the ditch by means of which the water is diverted from a public stream, the restrictions on his right to water are simply those imposed by the priority of his appropriation and the provisions of the State law for its enforcement. But under the corporation canal he is subject to the limitations of his contract and the regulations of that canal in addition to the limitations imposed by the irrigation laws. In the present chaotic state of legislation and of public sentiment it is difficult to make a positive statement in any State regarding the exact limitations of an appropriation, or to definitely describe and define the nature of the irrigator's rights under a water right contract with a canal company.

In the first place, outside of Wyoming and Nebraska the appropriations so far as made go to the ditch companies, not to the land reclaimed nor to the owner of the land irrigated by them, and each ditch company, subject to State laws, fixes the conditions under which the water so appropriated shall be disposed of. The rights of the individual settler or the rights of a particular tract of land are not, therefore, determined by the State irrigation laws, but by a corporation acting under those laws. In many cases the contracts of these corporations place restrictions on the use of water which they deny govern its appropriation. Some of these restrictions are wise and show a better appreciation of what the laws governing an appropriation should be than have either the courts or lawmakers in their efforts to define it. In other cases the conditions of these contracts are wholly one-sided, unfair to the irrigator, and a menace to agriculture. Their reform is necessary to either the stability of the irrigated farm or the peace and content of the user of water.

KINDS OF CONTRACTS.

When the corporation is the agency through which the water is diverted and conveyed to the land, it becomes necessary that the water user enter into a contract with the latter which defines the obligations and liabilities assumed by both parties thereto. Of these contracts there are two generic forms that are radically different and applicable to two distinct plans of procedure, designated respectively as the "perpetual" and the "annual" plans. Under the former the corporation agrees that upon the payment by the water user of a stipulated amount of money it will divert and deliver to a certain point a specified volume of water for the irrigation of certain lands, which service will be repeated in perpetuity throughout each irrigation season. These contracts frequently take the form of a deed for a perpetual right to water. The second plan is generally termed the rental system, as the corporation agrees to deliver and the settler to take and pay for water only during the irrigation season under consideration.

In the contract under the latter plan no provision is made for the delivery of water beyond the limit of the specific year and season for which it was made, and though the consumer will probably, and usually does, use the water every year, he must annually renew his lease or enter into a new and distinct contract at the beginning of each irrigation season for the water which he intends to use. The principal obligation assumed by the water user under this form of agreement is the payment to the irrigation company of its charge or rental price for its delivery. In return for this annual payment the corporation agrees to deliver the specified amount of water continuously through the irrigation season under consideration, or throughout that part of the season when a supply in excess of that required for the necessities of prior appropriators is found in the stream from which the diversion is made. For the result of a shortage in the stream the company assumes no liability, the individual consumer of water being expected to satisfy himself as to the sufficiency of its priority right before locating under the system, and being compelled to submit to the consequences of his failure to do so when it may have developed later that the supply is unsatisfactory. The company agrees, however, and under the terms of its contract is required, to maintain its conduits in good order and repair, and to be at all times prepared to deliver water whenever the supply is available.

Where the "perpetual water right" plan is followed a contract is issued in which there is no time limit to the obligations and liabilities assumed. It is contemplated that the water will be required and used every year and for all time. It provides that the irrigation company or its successors will maintain its conduits and other works in good order and repair for the carriage and delivery of water during each and every irrigation season, and that it will at all times be prepared to and will deliver to the lands specified in the contract the quantity therein stated, except when, through scarcity of the supply, the water is

required and taken by prior appropriators who have a superior right to its use, or when unforeseen and unavoidable accidents, resulting in injury to or destruction of parts of its works, make the performance of this service temporarily impossible. It is provided, however, that when unavoidable accidents of this nature occur the company must exercise every reasonable diligence in their repair in order that the delivery of water may be resumed with the least possible delay.

UNIT OF MEASUREMENT.

Some irrigation companies sell the right to the use of water by the cubic foot per second, or "second-foot;" others supply it by a unit designated as the "inch;" a few determine the quantity by a certain depth over the area irrigated, while the contracts of many companies guarantee the delivery of sufficient water to properly irrigate the described land, not exceeding a certain quantity per acre.

A cubic foot of water per second (second-foot) may be defined as the amount which would be delivered by a rectangular trough 1 foot wide and 1 foot deep, running level full, the water moving at a uniform velocity of 1 foot per second of time. Or, again, it is the quantity which, if flowing continuously and uniformly from a spout, would fill a cubical vessel 1 foot wide, 1 foot deep, and 1 foot long (7½ gallons) in exactly one second.

The "inch" has a widely different meaning in different localities, and is not, like the "second-foot," a definite quantity. It is measured through a square or rectangular opening, with the water in the source of supply standing a certain number of inches above the top of such opening. The number of inches being discharged is equivalent to the number of square inches in the area of the opening, the variation in different localities being due to the varying regulations governing the form and size of the opening, and the height or "head" of the standing water above it. That employed generally in the agricultural regions of Idaho and California (4-inch "head") is equivalent to one-fiftieth of a cubic foot per second. In Montana 40 statute inches are declared by law to equal 1 cubic foot per second. In Colorado also, the inch is defined by statute and is called the statutory inch, of which 38.4 are equivalent to 1 cubic foot per second.

LIMITATIONS OF CONTRACTS.

The consumer is limited to the use of a specified maximum volume of water, more than which the corporation is not under any circumstances required to deliver; which quantity, however, may be and on many streams frequently is materially reduced during the low-water period, except under those systems having the best and oldest priorities, whose patrons may enjoy the benefits of a full supply continuously throughout the irrigation season. These contracts usually stipulate that when, because of shortage in the stream, the supply is less than that called for by the outstanding contracts, the water available must

be prorated among the different contract holders in the proportion that each claim bears to the aggregate amount called for by all the contracts. For example, if a given irrigation canal has outstanding contract obligations calling for the delivery of 100 cubic feet of water per second, and the volume flowing in the stream from which the diversion is made is such that after the rights of prior appropriators have been honored only 50 feet remain available to the canal in question, each of the contract holders is given just half the maximum quantity of water for which his contract calls. In such cases no reduction is made in the amounts payable to the irrigation company, the latter assuming the position that its obligations have been carried out and performed when it has maintained its works in good order and condition, has been prepared at all times to convey water in the quantities contracted for, and has so conveyed it at all times when water, unappropriated by consumers having prior rights to its use, was available in the stream.

There is sometimes a provision in these contracts, under which the corporation agrees that when a specified percentage of the carrying capacity of the canal or other conduit has been disposed of through the sale of water rights, the enterprise will be reorganized, the paid-up water-right contracts outstanding will be taken up, and in lieu thereof certificates of stock will be issued to the former contract holders, to each in the proportion which the quantity of water called for under his contract bears to the total quantity represented by all of the contracts. The management of the affairs of the enterprise will then be turned over to these new stockholders. When this reorganization has been effected the enterprise assumes the form hereinbefore described, in which the stockholders are the actual users of the water. This is the usual provision in the contracts in those States (Wyoming and Nebraska) where the appropriation of public water is vested in the land irrigated by it, although it is often found in contracts issued in other States.

COST AND CONDITIONS OF RECLAMATION.

A serious mistake is involved in the assumption that the immigrant to the arid West has only to homestead or purchase a quarter section of land and at once become a prosperous and successful farmer. This would be possible if the land secured were at the time of its acquisition developed and highly improved. Lands of this description are available throughout this region, but in most cases they command prices equal to those prevailing in the humid States for lands of similar quality and equal productiveness and proximity to markets. They are, therefore, out of the reach of settlers of limited means. Those offered for sale by the various irrigation companies are almost without exception raw and unimproved prairie lands, upon which much development work must be done in the way of breaking and subduing the native

sod, leveling, erecting fences and buildings, constructing ditches, etc. These lands can usually be bought at very moderate figures, and upon very favorable terms. They are, as a rule, capable of being developed into farms of superior fertility and productiveness; but they can be brought into this condition only at the expense of great labor and a considerable investment of time.

Similar conditions prevail in those cases where the settler homesteads land from the Government and creates his own water-supply facilities under the individual plan described in previous pages (p.18). His land in this case, nominally, costs him nothing, and if he does the work of development and improvement himself he may get along without the expenditure of much actual money; but if he should figure up the cost, at its market price, of the labor and time which he has devoted to the work, he would discover that the farm thus acquired, practically without cash, had in reality involved an expenditure largely in excess of anything which he had anticipated at the outset, and he will then understand why well-improved farms in the arid regions, which originally cost nothing for the raw land, sell for as much as similar farms in the well-settled States of the humid region. Nor is there any good reason why they should not do so, since a fertile, well-improved, and well-located ranch in this region, which has a satisfactory supply of water for irrigation, will, under skillful and intelligent management, as a rule, yield a profitable return upon the investment represented by its cost; and this is especially true in those cases where the actual settler acquires raw lands and improves them himself through his own labor and without the expenditure of cash. The labor and the hardships involved may appear trying and burdensome for a while during the pioneer period, and before the development is completed, but past experience indicates that where the conditions are favorable, the results will, in the end, generally be satisfactory. Where failures and disappointments occur, they are usually the result of an insufficient or unreliable water supply.

The value of farming lands and water rights varies so greatly in different localities of the arid region that it is extremely difficult to give any average price that will not be misleading. The price of raw land with a perpetual water right under the larger enterprises is usually between the limits of $15 and $35 per acre, with the annual maintenance charge on the water right varying from 50 cents to $1.50 per acre. From 40 to 80 acres is generally regarded as the proper acreage for a person of limited means, and in ordinary farm crops can be farmed principally by his own labor. The payment for land and water right is usually extended over a period of five years or more, the time of the second payment being often two years after the first, thus enabling the farmer, under favorable conditions, to make his second as well as succeeding payments from the results of the cultivation of his land.

Taking $20 per acre as cost of land and water right, and $1 per

acre as the annual maintenance charge, the first year's expenses on an 80-acre tract of this kind of land will be likely to run something like this:

First year's expenses on an 80-acre irrigated farm.

First payment on land and water right (one-fifth of $1,600)	$320
Fencing materials	150
Buildings	300
Team, wagon, implements, etc	300
Annual assessment for ditch maintenance	80
Total cash outlay	1,150

To this must be added a year's living expenses. The above items will of course vary with the tastes and means of the settler, but they can not well be greatly reduced below these figures. Of course he may bring his team and implements with him from the East, thus cutting out those items. If he commences in the early fall he may be able, under ordinary circumstances, to do the necessary fencing, clearing, plowing, leveling, and ditching, so as to get 40 acres into crop the following spring. He can hardly hope to do better than that, and may have to have a little help with some of the work. Where this work is done by hired labor, its cost will usually be between $5 and $10 per acre so prepared for crop, depending very largely upon the amount of clearing and leveling required. It is always poor economy to slight this part of the work. Ground should not be put in crop without painstaking preparation for its easy and complete irrigation.

If the farmer under consideration has a sufficient water supply and has fairly good luck with his 40-acre crop, its proceeds will pay his maintenance, assessment, taxes, and, as he has no further payment to make on his land the first year, keep him going for the succeeding year, when he will have his entire 80 acres in crop, and, with the aid of his year's experience, should have a full yield. With careful economy and hard work he will be able to meet his second and succeeding payments on his land from the proceeds of its cultivation, and at the end of five or six years, from an investment of from $1,000 to $1,500, he will become the owner of an 80-acre farm worth probably $50 an acre, and capable of making him a good living, besides, if in a favorable location, constantly increasing in value. This is the result under favorable conditions. If, however, he has been so unfortunate as to locate on poor soil (which is not likely to happen), or under a canal having an uncertain water supply, his case may be decidedly different. His best efforts will avail him nothing if he is not able to get the necessary water at the times needed. This is the most important, as it is sometimes the most perplexing, question to be settled before purchasing. The soil is almost certain to be of excellent quality, and there are few irrigated regions where there is not now a market for all products raised. Prices vary considerably in different localities, owing to local conditions which are largely temporary in their nature. The safest basis for estimating prices, however, is not upon such conditions, but,

especially for such products as hay, etc., upon their feeding value upon the farm. Farming throughout the arid region, except as regards such specialized products as fruit, hops, sugar beets, etc., is each year getting nearer that character which long experience has demonstrated as most generally successful and profitable, viz, that in which the bulk of the product is fed on the farm. Success in this kind of farming in the arid States does not necessarily depend upon nearness to railroads or large towns, but is quite largely influenced by other considerations, such as proximity to free grazing lands. Of course favored localities will demonstrate the great success of particular kinds of products, but still the great proportion of farming throughout this region will be of the diversified and general nature practiced elsewhere, and its success will be most largely dependent upon a good water supply. Much farming is done in the arid region under conditions of water supply which are not entirely satisfactory, but its success in all cases is directly proportional to the sufficiency and certainty of the supply. Entire success is only achieved when the water is sufficient in quantity and certain in its duration throughout the period when it is required. Where these conditions prevail the factor of uncertainty is as nearly eliminated from farming operations as can be predicated of any business, and its results are more certain and satisfactory than can be realized from farming in any part of the humid region.

The farmer in the humid States is always practically "between two fires." He may be either burned out by drought or seriously damaged by too much rainfall, and he is powerless to avert either of these evils. The ranchman in the arid region, who is operating under favorable conditions, is protected from the latter by the aridity of his climate, and from the former by his artificial water supply, whose assistance he can invoke at pleasure. He has the exact amount of moisture which he needs, just when he wants it, and at no other time. His operations are rarely delayed by weather conditions. He may plow when the crop needs it, nor is he hampered by either dry or wet weather. If his land is too dry to plow when the crop requires cultivation, he irrigates it to the proper degree of moisture. In most localities he will be able, so far as climatic conditions are concerned, to work on his farm nearly every day in the year. Under favorable conditions he is certain of a large crop, and will be able to harvest it in good condition. Taken altogether, the practice of irrigation furnishes the very ideal conditions for the conduct of agricultural operations.

APPENDIX.

METHODS OF ADMINISTRATION IN THE SEVERAL STATES.[1]

We have pointed out the necessity for careful investigation by intending settlers of the conditions of water supply, priority rights, methods of their enforcement, etc. It is the purpose of this chapter to discuss somewhat more in detail the systems of water administration prevailing in the different States, giving the names of the persons at present charged with these important duties.

For the purposes of this discussion the States under consideration may be divided into two general classes, each class having somewhat similar laws and customs in regard to water administration and distribution. In one grouping may be placed Nebraska, Colorado, and Wyoming; in the other, Idaho, Montana, and Utah. In the former three States the distribution of water from the natural streams to the various parties entitled to its use is vested by law in water commissioners appointed by the governor and acting under direction of the State engineer, who is the head of the irrigation department in each of those States. The methods of adjudicating the various rights to water (as a basis for its proper distribution by the water commissioners) are, however, essentially different in Nebraska and Wyoming from those prevailing in Colorado.

In the first-mentioned States, rights to the use of water are determined by a board of control, constituted by law for that purpose. Under the provisions of the law, the adjudication of the rights to the waters of any stream may be inaugurated by this board at its discretion. It is usually done upon petition of some of the water users. All claimants to the water of the stream are properly notified of the intended adjudication of their rights, and must present their respective claims and evidence to the board at the time and place fixed by it for the taking of such evidence, which place is selected with reference to the convenience of the claimants. After considering all the facts, the board makes a decree fixing the priority and value of each right to the waters of the stream under consideration. These decrees are based upon the records and testimony introduced by the claimants, and upon a very careful examination and survey, under the direction of the State engineer, of the stream, of all ditches diverting water therefrom, and of the areas

[1] See also U. S. Dept. Agr., Office of Experiment Stations Bul. 58.

of land upon which the water is used. The results of this survey are tabulated and mapped for the use of the board in its consideration of the case and determine the volume of water decreed to each claimant. The maps and evidence in each case are made public before the decree is finally entered, and a reasonable time is allowed for contesting any of the facts therein contained. These decrees always specify the land upon which the decreed water is to be used. It is forever inseparable from it, and the water right must always go with the title to the land. The actual beneficial use is made the basis for the decree in all cases. These decrees may be appealed from to the proper court within a certain time after being rendered, but so careful is the board in its examination and determination, and so complete the data submitted by the State engineer, that such right of appeal is very rarely taken advantage of and the determination of the board is very seldom reversed.

In Colorado, on the other hand, these decrees of water rights are rendered only by the district courts after trials under the ordinary rules of evidence as to the facts in each particular case. No special regulations exist governing the character, accuracy, and completeness of the evidence which must be submitted, and no provision is made for any examination or survey under authority of the State to obtain the exact facts as a basis for the determination of the volume of each acquired right. The whole matter is settled in a suit between the various claimants and upon whatever evidence may be introduced by them, while the interests of the State, the real owner of the water, are not represented in the case at all. Frequently there is no real contest in the suit, each claimant getting a decree for the full amount claimed by him. The lack of accurate, as well as the presence of inaccurate and untrue testimony, renders the issuance of a fair and just decree in such cases impossible. The necessity for a painstaking survey of the streams, ditches, and land is very apparent, both for the protection of the interests of the State in the water and those of the appropriators.

An investigation of the results of these two systems of water-right adjudication leaves no room for argument as to which is best suited to the accomplishment of the end in view, which is, or should be, the distribution of the water of the streams in such a manner as to secure its greatest possible beneficial use and the best possible protection of the interests of the actual users of it. The advantages of the system adopted in Wyoming and Nebraska are getting to be generally recognized by all parties interested in a just determination of water rights, and the prevention of costly and interminable litigation in regard to them, which is doing so much to retard settlement and irrigation development in some of the States.

The systems of administration and distribution of the water after the decrees fixing the priority and volume of rights are rendered are practically the same in Nebraska, Colorado, and Wyoming. Each State is divided into several water divisions, each as nearly as practicable em-

bracing a single drainage system. A commissioner or superintendent for each division, who has general supervision, under direction of the State engineer, of the distribution of water in his division, is appointed by the governor. Each division is subdivided into districts, each district having its water commissioner for the actual distribution of the water, among those entitled to its use, under the orders and general direction of his division superintendent. The decrees of the board of control, or of the courts, furnish the basis for such distribution. These water commissioners are vested with the power to arrest any person interfering with the execution of or failing to obey their orders in regard to the distribution of water, heavy penalties being provided for such offenses. They also have power to require the owners of the various ditches to construct and maintain the necessary and proper head gates and measuring devices for the proper distribution of the water.

In Utah, Idaho, and Montana (in fact, in all the arid States except Wyoming and Nebraska) water rights can be established only through lawsuits the same as in Colorado, and a similar condition of litigation and dissatisfaction exists. The distribution of the water under the decrees, however, is accomplished in a different manner.

In Idaho the judge of the district court from which the decree was issued is required by law to appoint, before May 1 of each year, a water master to take charge of the distribution of water under each decree for the ensuing season. He is charged by the court with the execution of the decree. He receives his instructions from the judge, and is responsible for the proper performance of his duties only to the court appointing him.

In Montana the law is similar to that of Idaho, with the exception that the judge can not appoint a water master except upon the petition of at least 25 per cent of the parties entitled to water under the decree. It would seem that under this provision injustice might be done to a small minority of the users from a stream, without their being able to get adequate relief. The compensation of the water masters in both these States is fixed by the judges who appoint them, and is collected by assessments against the parties entitled to the water, in proportion to the quantity distributed to each. Anyone dissatisfied with any action or order of the water master may of course appeal to the court for redress.

In Utah the water masters are chosen by the water users at an election held for that purpose, at which time their compensation is also fixed. This is collected by assessments levied as in the other States.

The water masters in Idaho, Montana, and Utah have similar powers and duties to those of the district water commissioners of Nebraska, Colorado, and Wyoming, already described. In both Utah and Idaho, on streams where no adjudication has been had and no decree fixing the priorities for the distribution of the water has been issued, but where a supervision of such distribution is deemed desirable by a

majority of the claimants, water masters are sometimes elected for that purpose, the basis for their distribution of the water in such cases being mutual agreements or local customs and recognized rights. In some cases also, especially in Utah, the earlier appropriators have in some instances secured injunctions from the courts against later ones, enjoining the latter from using the water claimed by the former. These injunctions have usually been obtained without a consideration of all the rights in the stream, and the results under their operation have not generally been satisfactory.

The United States has never attempted to exercise any supervision or control over the appropriation and use of the public water supply in the arid States, this having been left to the various States which have assumed the responsibility to a greater or less extent. The result has been the growing up of important State departments having this work in charge. A list of the officers charged with the administration of the water laws in the various States is given below. In addition to the duties which have been specified, these officers are directed by law to measure the flow of the various streams used for irrigation, to collect all possible information in regard to water supply, and irrigated and irrigable lands of the State, to examine dams, existing reservoirs and possible reservoir sites, to give information in regard to measurement of water, to examine all existing irrigation systems, and in general to become thoroughly familiar with the agricultural and irrigation conditions and possibilities in their respective States and districts. The results, in a general way, may be found in the reports of the various State engineers, and of the Montana Arid Land Grant Commission. These reports may often be obtained, and they embody the best and most reliable information in regard to the region under consideration. Special inquiries addressed to the irrigation officials in the different States will secure additional information. The irrigation officials in the several States are as follows:

COLORADO.

Addison J. McCune, State engineer.....Denver.
Rod. S. King, deputy State engineer.....Denver.

Water superintendents.

James J. Armstrong, superintendent, water division No. 1.....Denver.
E. R. Chew, superintendent, water division No. 2.....Pueblo.
J. F. Goad, superintendent, water division No. 3.....Monte Vista.
Harry C. Wheeler, superintendent, water division No. 4.....Durango.
A. F. Reeves, superintendent, water division No. 5.....Montrose.
C. S. Roberts, superintendent, water division No. 6.....Hayden.

Water commissioners.

D. W. McSween, commissioner, district No. 1.....Brush.
W. J. Southland, commissioner, district No. 2.....Room 10, Capitol, Denver.
Charles C. Hawley, commissioner, district No. 3.....Fort Collins.
J. M. Wolaver, commissioner, district No. 4.....Greeley.

L. A. Dickson, commissioner, district No. 5 ..... Longmont.
Thomas Kneale, commissioner, district No. 6 ..... Niwot.
William E. Cole, commissioner, district No. 7 ..... Golden.
A. D. Butterfield, commissioner, district No. 8 ..... 1082 Broadway, Denver.
C. B. Clark, commissioner, district No. 9 ..... Box 605, Denver.
T. B. Pyles, commissioner, district No. 10 ..... Colorado Springs.
D. M. Jones, commissioner, district No. 11 ..... Buena Vista.
T. H. Newkirk, commissioner, district No. 12 ..... Florence.
Louis Mueller, commissioner, district No. 13 ..... Silver Cliff.
T. J. Burrows, commissioner, district No. 14 ..... Pueblo.
C. E. Emery, commissioner, district No. 15 ..... Pueblo.
James K. Dempsey, commissioner, district No. 16 ..... Pueblo.
H. W. Forbes, commissioner, district No. 18 ..... Gulnare.
Felix Cordova, commissioner, district No. 19 ..... Trinidad.
Lou J. Mitchel, commissioner, district No. 20 ..... Alamosa.
David Martinez, commissioner, district No. 21 ..... Capulin.
John C. Dalton, commissioner, district No. 22 ..... Manassa.
E. E. De Coursey, commissioner, district No. 23 ..... Alma.
J. C. L. Valdez, commissioner, district No. 24 ..... San Luis.
Gus Peterson, commissioner, district No. 25 ..... Mirage.
C. A. Potts, commissioner, district No. 26 ..... Sagouche.
A. T. Scott, commissioner, district No. 27 ..... Del Norte.
T. P. Goodman, commissioner, district No. 28 ..... Sargents.
J. S. Hatcher, commissioner, district No. 29 ..... Pagosa Springs.
John T. Sleeth, commissioner, district No. 30 ..... Durango.
Frank H. Meyer, commissioner, district No. 33 ..... Durango.
D. H. Redmon, commissioner, district No. 34 ..... Maucos.
Howard W. Hill, commissioner, district No. 36 ..... Plains.
Andrew Kalquist, commissioner, district No. 37 ..... Gypsum.
George W. Hull, commissioner, district No. 38 ..... Basalt.
Frank D. Squires, commissioner, district No. 39 ..... Rifle.
M. H. Payne, commissioner, district No. 40 ..... Delta.
W. E. Obert, commissioner, district No. 41 ..... Delta.
George Hall, commissioner, district No. 42 ..... Collbrau.
J. D. Moog, commissioner, district No. 43 ..... Meeker.
William Chadwick, commissioner, district No. 45 ..... Rifle.
W. D. Beckwith, commissioner, district No. 47 ..... Fort Collins.
E. W. Johnson, commissioner, district No. 48 ..... Glen Eyre.
Burt Ragan, commissioner, district No. 49 ..... Landsman.
C. B. Rundell, commissioner, district No. 52 ..... Redcliff.
C. M. Morris, commissioner, district No. 53 ..... Eagle.
P. T. Mellon, commissioner, district No. 61 ..... Montrose.
J. W. Landrum, commissioner, district No. 64 ..... Sterling.
E. J. Picard, commissioner, district No. 65 ..... Yuma.
Jesse Tanner, commissioner, district No. 66 ..... Springfield.
J. B. Traxler, commissioner, district No. 67 ..... Lamar.
P. H. Shue, commissioner, district No. 68 ..... Ouray.
Albert E. Arms, commissioner, district No. 69 ..... Rico.

IDAHO.

Douglass W. Ross, State engineer ..... Boise.

MONTANA.

Arid land grant commission.

T. C. Marshall, chairman ..... Helena.
Donald Bradford, vice-chairman and general manager ..... Helena.

D. A. Corey, secretary.....Helena.
Joseph K. Toole.....Helena.
C. O. Reed.....Helena.
W. S. Fortiner, chief engineer.....Helena.

NEBRASKA.

Board of irrigation.

W. A. Poynter, governor (ex officio).....Lincoln.
C. J. Smyth, attorney-general (ex officio).....Lincoln.
J. V. Wolfe, commissioner public lands and buildings (ex officio)..Lincoln.
J. M. Wilson, State engineer (ex officio, secretary).....Lincoln.

Under secretaries.

E. D. Johnson, division No. 1.....Lexington.
T. J. O'Keefe, division No. 2.....Hemingford.

Under assistants.

James Dayley, water district No. 1, water division No. 1–A.....Lewellen.
R. H. Willis, water district No. 2, water division No. 1–A.....Camp Clarke.
I. A. Young, water district No. 3, water division No. 1–A.....Gothenburg.
C. J. Osborn, water district No. 1, water division No. 1–E.....Sidney.
Robert Busch, water district No. 1, water division No. 1–B.....Trenton.

UTAH.

Robert C. Gemmel, State engineer.....Salt Lake City.

WYOMING.

Fred Bond, State engineer.....Cheyenne.
A. J. Parshall, assistant engineer.....Cheyenne.

Division superintendents.

W. M. Gilcrest, secretary State board of control, and superintendent, water division No. 1.....Cheyenne.
F. S. Kellogg, superintendent, water division No. 2.....Sundance.
B. B. Morton, superintendent, water division No. 3.....Tensleep.
John Iredale, superintendent, water division No. 4.....Rock Springs.

Water commissioners—Division No. 1.

W. D. Pease, commissioner, district No. 1.....Cheyenne.
George W. Snow, commissioner, district No. 2.....Little Bear.
J. L. Jordan, commissioner, district No. 3.....Iron Mountain.
Price Jacobs, commissioner, district No. 4.....Laramie.
C. H. Jones, commissioner, district No. 5.....Laramie.
William Brauer, commissioner, district No. 6.....Saratoga.
Horace Nichols, commissioner, district No. 7.....Collins.
J. M. Calvert, commissioner, district No. 8.....Dixon.
Daniel Fitgar, commissioner, district No. 10.....Johnstown.
J. W. Price, commissioner, district No. 11.....Casper.
W. F. King, commissioner, district No. 12.....Rockcreek.
Price Martin, commissioner, district No. 13.....Glendo.
D. A. Wucherer, commissioner, district No. 14.....Lusk.

Division No. 2.

F. B. Fawcett, commissioner, district No. 1.....Newcastle.
John Ridley, commissioner, district No. 2.....Buffalo.

A. C. Warburton, commissioner, district No. 3.....Buffalo.
M. K. Wood, commissioner, district No. 4.....Sheridan.
Thomas T. Howd, commissioner, district No. 5.....Dayton.
Adolphus Yonkel, commissioner, district No. 6.....Slack.

Division No. 3.

A. P. Battrum, commissioner, district No. 1 .....Lander.
L. P. Hudson, commissioner, district No. 2 .....Lander.

Division No. 4.

Charles Rathburn, commissioner, district No. 1 .....Fontenelle.
M. Henderson, commissioner, district No. 2 .....Afton.
John Shirk, commissioner, district No. 3.....Robertson.

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