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# METHODS OF IRRIGATION FOR MONTANA

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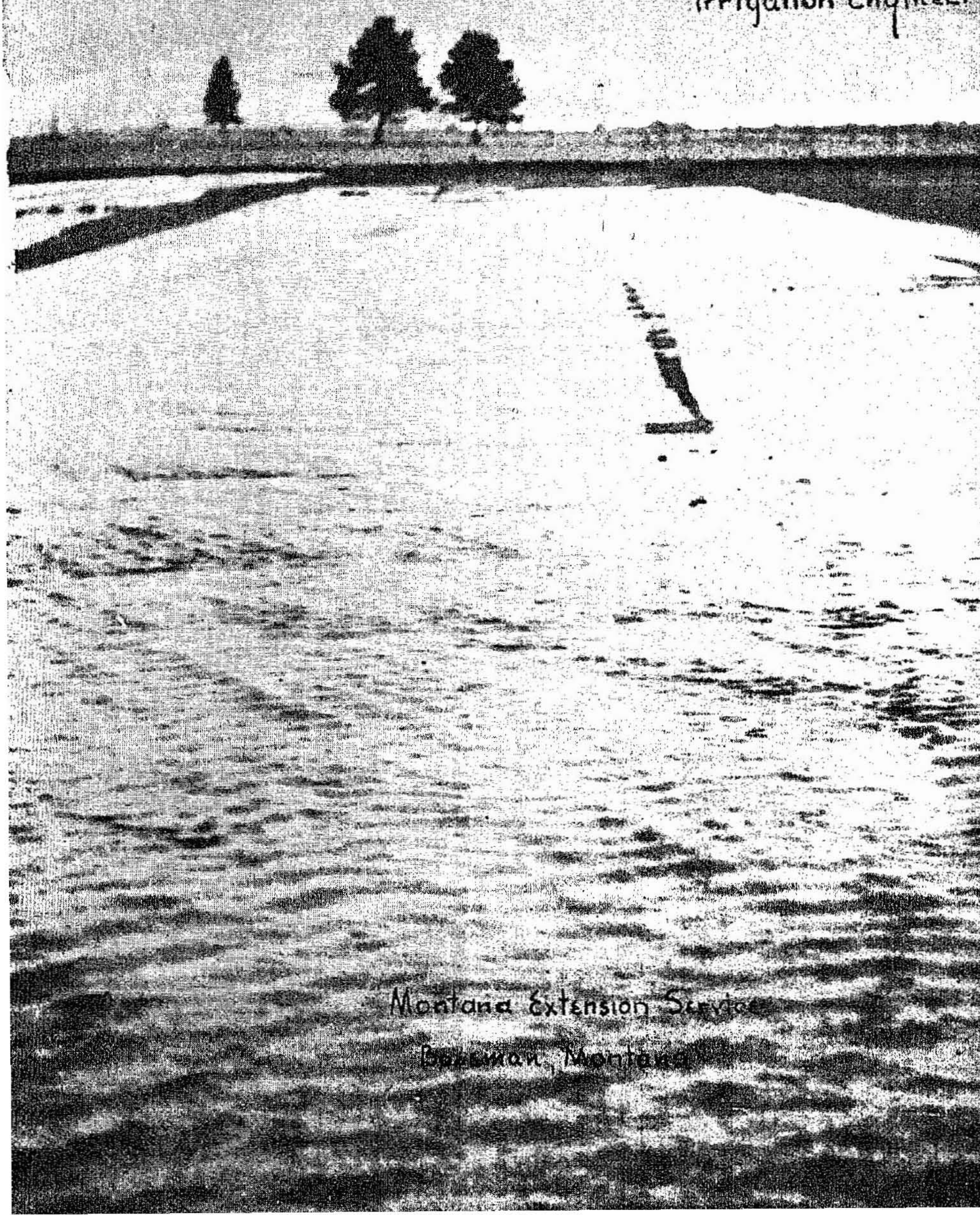

Montana Extension Service
Bozeman, Montana

## Introduction

Flowing water is measured in cubic feet per second, in miner's inches, or in gallons per minute. A cubic foot per second is a stream sufficient to fill a box one foot square and one foot deep in one second. This is equal to about 7½ gallons per second or 450 gallons per minute. A miner's inch is 1/40 of a cubic foot per second or 11.1 gallons per minute.

An acre foot of water is enough to cover an acre of land one foot deep. In volume it amounts to 43,560 cubic feet. To deliver this amount a one second-foot stream would require 12.1 hours. An acre inch is 1/12 of an acre foot and would be supplied in about 1 hour with 1 second foot. So it becomes convenient to think of a cubic foot per second as also equal to an acre inch per hour. These units of measurements are helpful to the irrigator in regulating the amount of water applied to a crop. For convenience they are given in tabular form below.

UNITS OF MEASUREMENT FOR IRRIGATION WATER

| | Sec. Feet | Miners Inches | Gal. per Minute | Acre in. per hour | Acre feet per day (24 hrs.) |
|---|---|---|---|---|---|
| 1 cubic ft. per second = | 1 | 40 | 450 approx. | 1 | 2 |
| Miners inch = | 1/40 | 1 | 11.1 | 1/40 | 1/20 |

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# Methods of Irrigation for Montana

By

**O. W. Monson, Irrigation Engineer**

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## Purpose of Irrigation

A proper balance of moisture in the soil is necessary for the healthy growth of plants. This balance varies from complete saturation for water loving plants as tules, swamp grass and rice etc., to almost a dry condition for such plants as cactus, sagebrush, and bunch grass. The requirements for most farm crops are met about half way between these two extremes. When the natural precipitation during the growing season is insufficient, a supplementary amount must be added through irrigation.

The amount which must be supplied varies with the kind of season and crop. An early maturing crop, such as grain, benefits from the spring rains as well as the accumulated moisture in the soil from the melting snows. It needs but a small amount of supplemental water because growth is completed early in the season. Late crops such as alfalfa, sugar beets, and potatoes require more water because their growing season extends into the dry months of July, August, and September. Irrigation in effect, extends the growing season by making possible the raising of crops which could not otherwise mature.

The relation between the amount of water applied and the yield of any crop is more or less indefinite because yield is dependent upon many other factors such as variety of crop, preparation of seed bed, time of planting, cultivation, competition with weeds, temperature, rainfall, fertility of the soil, the time of irrigation and other factors. In general, however, the yield increases with, but not in direct proportion to the amount of water applied. After a certain limit is reached, additional irrigation may actually reduce the yield. Water logging of the soil through excessive irrigation is harmful to most farm crops.

Hay, especially the grasses, will tolerate rather liberal applications of water, but grain, potatoes, beans, peas, and corn are sensitive to over irrigation.[1] Maximum yields of alfalfa have been obtained in Montana with applications of from 18 inches[2] to 36 inches of irrigation, wheat, oats and potatoes with 6 to 12 inches, and sugar beets with 10 to 20 inches.

## Moisture Holding Capacity of Soil

The amount of water which should be applied at one time depends upon the amount the soil will absorb and make available for the growing crop.

Favorable growing conditions require a considerable amount of air to be present in the soil because numerous bacteria which help break down minerals in the soil and make them soluble, require air in which to live. Water logging excludes the air from the soil, destroys the proper balance between air, water, and soil, and interferes with the activity of these useful bacteria.

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[1] Tech. Bulletin 36—Irrigation requirements of the arid and semi-arid lands of the Missouri and Arkansas River Basins—Fortier.

[2] Inches of irrigation refers to acre inches per acre. An inch of irrigation is the equivalent of an inch of rain.

The approximate proportions of air, water, and solids for good growing conditions are shown in figure 1. It shows the soil to be made up of small grains of materials loosely held together. Each grain of soil is normally covered with a thin film of water held so tightly that it doesn't drain out with the force of gravity. Between the wet soil grains are numerous small air pockets as shown in (a) of figure 1. If the soil particles were compressed into a solid mass, leaving the water and air in separate parts above the soil, the proportions would be about as shown in (b) of figure 1.

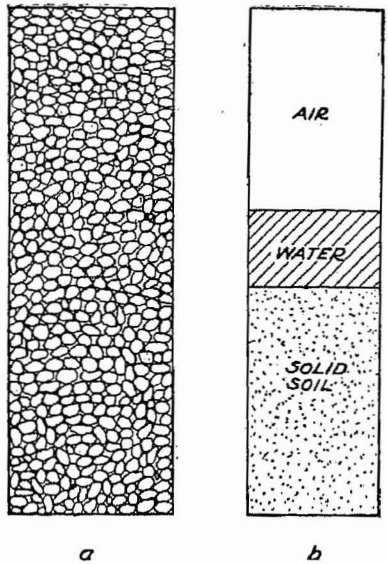


Fig. 1—Proportions of air, water and solids in ordinary soil.

These proportions vary somewhat with the texture of the soil. In general the coarser soils have the smallest proportion of exposed surface and consequently the smallest area to be covered with the moisture film, while the finer soils have a large surface exposed upon which the moisture may cling.

The water holding capacity of the soil varies with the soil texture. Medium sandy soils are capable of storing from 1 to 1½ inches of water per foot of soil in a form available to plants. Loam will store from 1 to 3 inches; silt loam from 1½ to 3 inches; clay loam from 1 to 2 inches; and sandy clay from 1 to 2 inches. [1]

Amounts in excess of these should not be applied unless there is free drainage in the subsoil, otherwise a water logged condition will result. Even though free drainage exists it is undesirable to add excessive amounts of water because in passing through the soil, this excess water will leach out valuable plant foods and carry them away.

[1] Bulletin 7, Irrigation Practices and Water Requirements for Crops in Alberta.

## Mechanics of Irrigation

The problem of irrigating is principally one of distributing water uniformly over a field in the proper amount to supply the needs of the crop. This is accomplished through the use of ditches by which the water is conveyed to different parts of the field, allowed to spread over the surface and be absorbed by the soil. The more complete and well arranged the ditch system, the more uniformly can the field be irrigated. The amount of labor involved in irrigating a field will also vary with the convenience and efficiency of the ditch system.

The first requirement is a good head ditch, free from weeds, silt, rocks, or other obstructions, and of ample dimensions. A small head ditch or one which is choked with silt, debris, weeds or willows will carry only a small stream and will consequently limit the number of acres that may be irrigated per day. A head ditch therefore should have a large capacity so the farmer can use a large stream and irrigate his fields promptly and quickly. The need for a large stream is shown by the relation between the size of stream and the time required to irrigate a field which is given in the following equation:

$$T = \frac{D\ A}{Q} \text{ where:}$$

Q = Size of stream in cubic feet per second (or acre inches per hour)

T = Time required in hours

D = Depth applied in acre inches per acre

A = Number of acres irrigated

The number of hours per acre required to apply a given amount of water may be stated as $\frac{T}{A} = \frac{D}{Q}$ where $\frac{T}{A}$ = the hours per acre. It is very important to use rather large streams in cutting down the labor cost per acre of applying water. The economical size of stream to use is from three to eight second feet. Streams larger than eight second feet are difficult for one man to handle. If the absorptive rate of the soil is very great, it is almost impossible to do a good job of distributing water uniformly with a small stream.

TABLE I—CARRYING CAPACITY OF FARM DITCHES

| Depth in inches | Cross section —sq. ft. | Velocity—feet per second | | Discharge in cubic feet per second | |
|---|---|---|---|---|---|
| | | Grade .001 or .1 ft /100 | Grade .002 or .2 ft/100 | Grade .001 | Grade .002 |
| | | Bottom width of ditch 2 feet | | | |
| 9 | 2.06 | .80 | 1.15 | 1.65 | 2.36 |
| 12 | 3.00 | .96 | 1.38 | 2.88 | 4.14 |
| 15 | 4.06 | 1.10 | 1.57 | 4.46 | 6.38 |
| 18 | 5.25 | 1.24 | 1.75 | 6.50 | 9.20 |
| 21 | 6.56 | 1.35 | 1.92 | 8.85 | 12.60 |
| 24 | 8.00 | 1.46 | 2.03 | 11.70 | 16.20 |
| | | Bottom width of ditch 3 feet | | | |
| 9 | 2.81 | .88 | 1.24 | 2.47 | 3.48 |
| 12 | 4.00 | 1.06 | 1.47 | 4.25 | 5.88 |
| 15 | 5.31 | 1.20 | 1.70 | 6.36 | 9.02 |
| 18 | 6.75 | 1.34 | 1.90 | 9.05 | 12.82 |
| 21 | 8.31 | 1.44 | 2.04 | 11.98 | 16.92 |
| 24 | 10.00 | 1.58 | 2.26 | 15.80 | 22.60 |

Poor head ditches are wasteful of water. They are a common cause of overflowing and washing out of the ditch bank, as well as of excessive seepage losses. Table I shows the dimensions for satisfactory farm head ditches.

Ditches may be constructed with plow and scraper or with regular ditching equipment. Figure 2 shows a big ditcher in

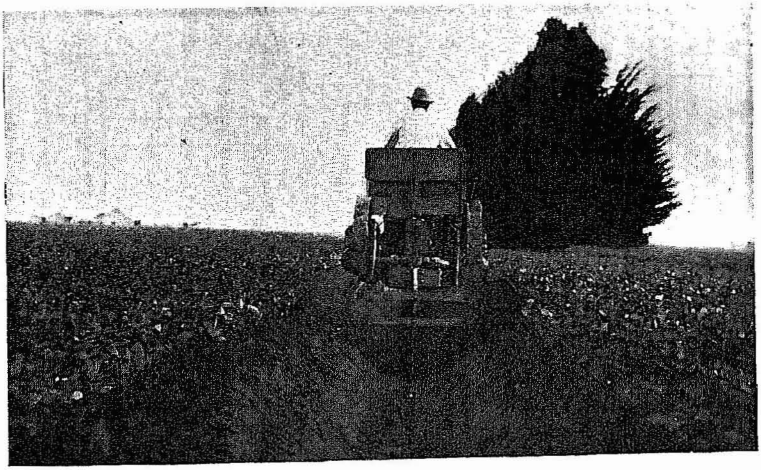
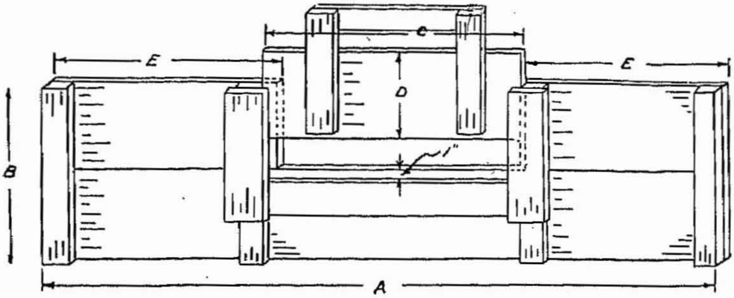
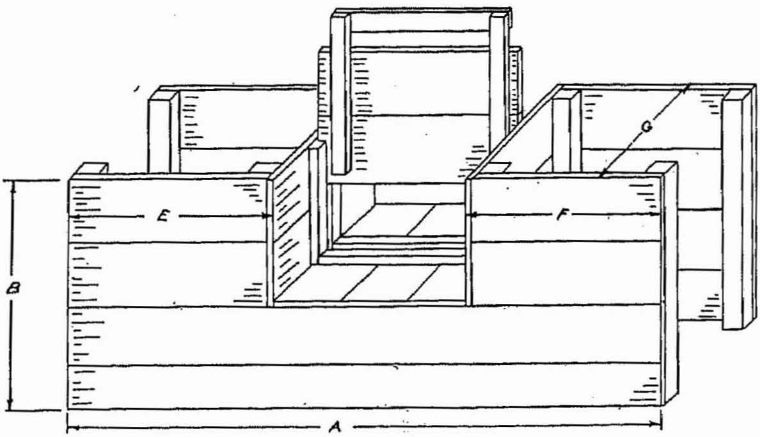


Fig. 2—Round bottom lateral made by a ditcher.
(Courtesy Killefer Mfg. Co.)

operation. This implement makes a uniform well proportioned ditch. A good ditcher is justified on the large farm by individual purchase or on the small place by rental or by purchase on a partnership or cooperative plan.




| DESIGNED FOR HEADS OF | A | B | C | D | E | Lumber thick |
|---|---|---|---|---|---|---|
| 1cfs ~2cfs | 8'-0" | 2'-0" | 3'-0" | 1'-0" | 2'-6" | 1" |
| 2cfs ~5cfs | 9'-0" | 3'-6" | 3'-0" | 2'-0" | 3'-0" | 1½" |
| 5cfs ~8cfs | 10'-0" | 3'-6" | 4'-0" | 2'-0" | 3'-0" | 1½" |




| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 3cfs ~6cfs | 9'-0" | 3'-6" | 3'-0" | 2'-0" | 3'-0" | 3'-0" | 2'-0" |
| 6cfs ~10cfs | 12'-0" | 4'-0" | 4'-0" | 2'-0" | 4'-0" | 4'-0" | 2'-6" |
| 10cfs & UP | 14'-0" | 4'-0" | 5'-0" | 2'-0" | 4'-6" | 4'-6" | 2'-6" |

Fig. 3—Plans for wooden check gates.
(From U. S. D. A. Bulletin No. 1243.)

## Control Structures

**Head Gates** are a great convenience if not an absolute necessity, to control the diversion of water out of the head ditch into laterals or onto the land. Canvas dams are satisfactory for the smaller ditches and along laterals, but are inconvenient when the stream is to be divided between 3 or 4 laterals along the head ditch. Head gates and checks make possible the complete control of the stream with a minimum of physical effort. The stream may be turned out all in one place or in smaller parts as the irrigator desires. Figure 3 shows a design of a check gate for use in a head ditch and figure 4 shows small wooden turnout convenient to regulate the amount of water needed in one place.

## Measuring Devices

Measurement of the irrigating stream is necessary if the irrigator is to be able to regulate the amount of water applied to his field. This can easily be done through the use of a weir, a simple device for measuring running water.

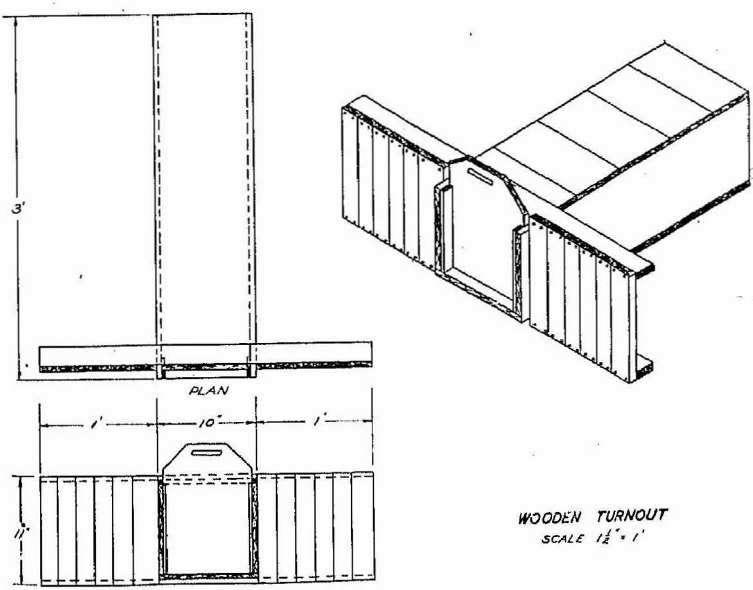



Fig. 4—Wooden turnout to regulate water from head ditch.

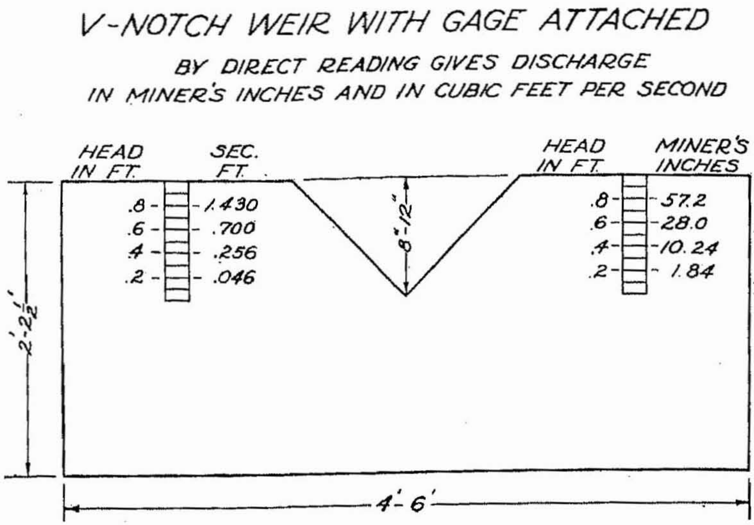



Fig. 5—90° V-notch weir for measuring small streams.

Circular 126, Montana Agricultural Experiment Station, contains tables giving the discharge for weirs of various types and sizes. Figure 5 shows a V-notch weir with a gauge attached which is graduated to give the discharge directly in cubic feet per second and in miner's inches. The use of such a gauge eliminates the need for tables. The low cost and simplicity of these measuring devices make it possible to use them not only in the head ditch but also in the laterals.

The Improved Parshall Flume is an efficient measuring device of recent development. It is particularly adapted to conditions where a weir would cause excessive ponding.[1]

It is desirable to have a measuring device where the head ditch enters the field in order that the farmer may know whether or not he is receiving the amount of water to which he is entitled and also as a guide to him in regulating the amount which he applies to each field. His problem is to convert a volume of flowing water into the equivalent depth it would cover the land if spread uniformly over the field, or an equivalent amount of rain.

[1] See Colorado Bulletin No. 423 "The Parshall Flume," by Ralph T. Parshall.

## Methods of Applying Irrigation Water

There are many ways of distributing irrigation water over a field, varying from the crude method of damming a stream with rock or brush so as to force it to overflow the banks and flood the adjacent lands at random; to an elaborate system of ditches, flumes, and pipes so arranged as to deliver water under full control to various parts of a field or to individual trees in the case of orchard irrigation.

For the irrigation of hay and pasture the flooding method serves quite well, but for intensive crops raised on high priced land where water is scarce, better control is advisable.

Several methods of distributing irrigation water listed below are in use and will be described briefly.

a. Wild Flooding
b. Border Flooding
c. Contour Flooding
d. Border Dike
e. Contour Check
f. Corrugation
g. Sub-Irrigation
h. Overhead or Spray
i. Porous Hose

## Wild Flooding Method

Wild flooding, as the name implies, refers to a rather loose system of irrigation. The ditches used are generally few in number, haphazardly located and carelessly constructed. Control of water is, therefore, limited and imperfect. A large stream may be diverted but usually a large amount is wasted in runoff. Figure 6 shows the layout of a typical wild flooding system. A single ditch conveys the water from the creek or other source to the highest point in the field from where it is allowed to spread at will. Water naturally seeks the lowest places and soon concentrates in the draws and swales while the higher parts of the field are often left dry.

This method, while still used under conditions of abundant water supply and a fairly level topography, is not recommended. It is to a limited extent suited for hay and pasture crops where an excessive amount of water would not be injurious. Points in its favor are simplicity and low cost of preparation. On fairly level land, large streams can be handled by this method, but on steep or uneven lands, a wild flooding system usually results in gullying, soil erosion, wasteful use of water, and loss of crop due to poor and uneven distribution.

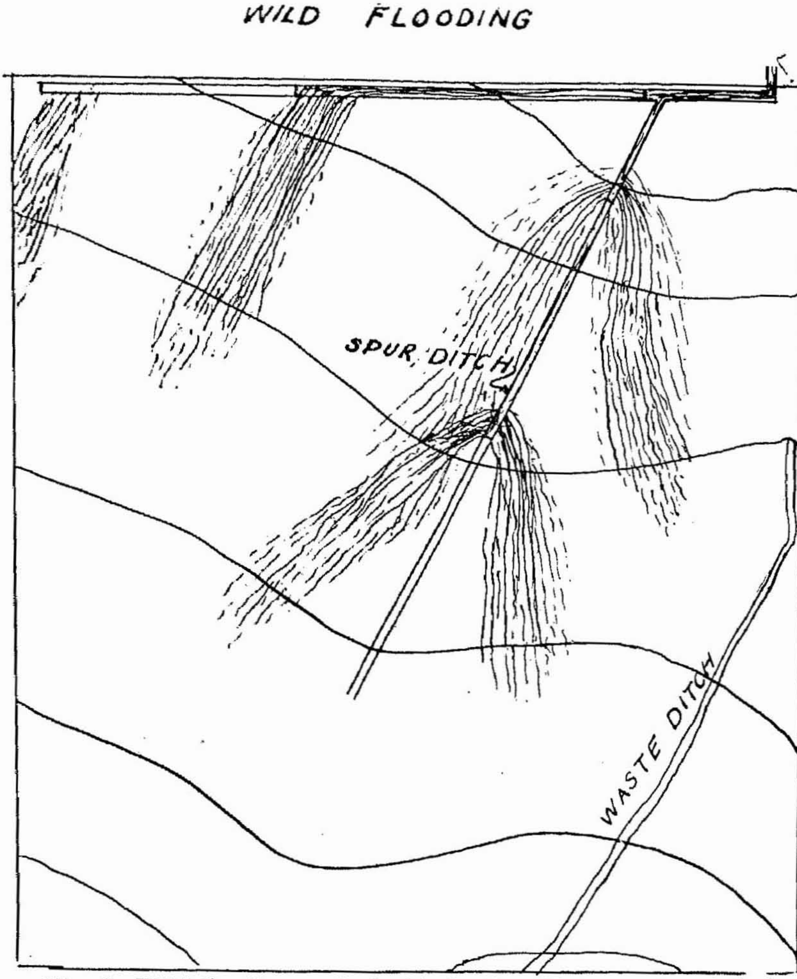



Fig. 6—Wild flooding method of irrigation; Note scarcity of ditches.

## Border Ditches

Perhaps the most common method of irrigation in this state is the border ditch method. It is simple and can be adapted to a variety of conditions. Figure 7 shows the general principle followed in laying out this system. Briefly it involves the construction of rather closely spaced ditches across the field. Usually these ditches are made parallel to each other and run down the slope of the land unless the slope is very steep. Slopes which permit the use of the border ditch method range from 1 to 1½ feet per 100. Grades in excess of 1½ feet per 100 cause

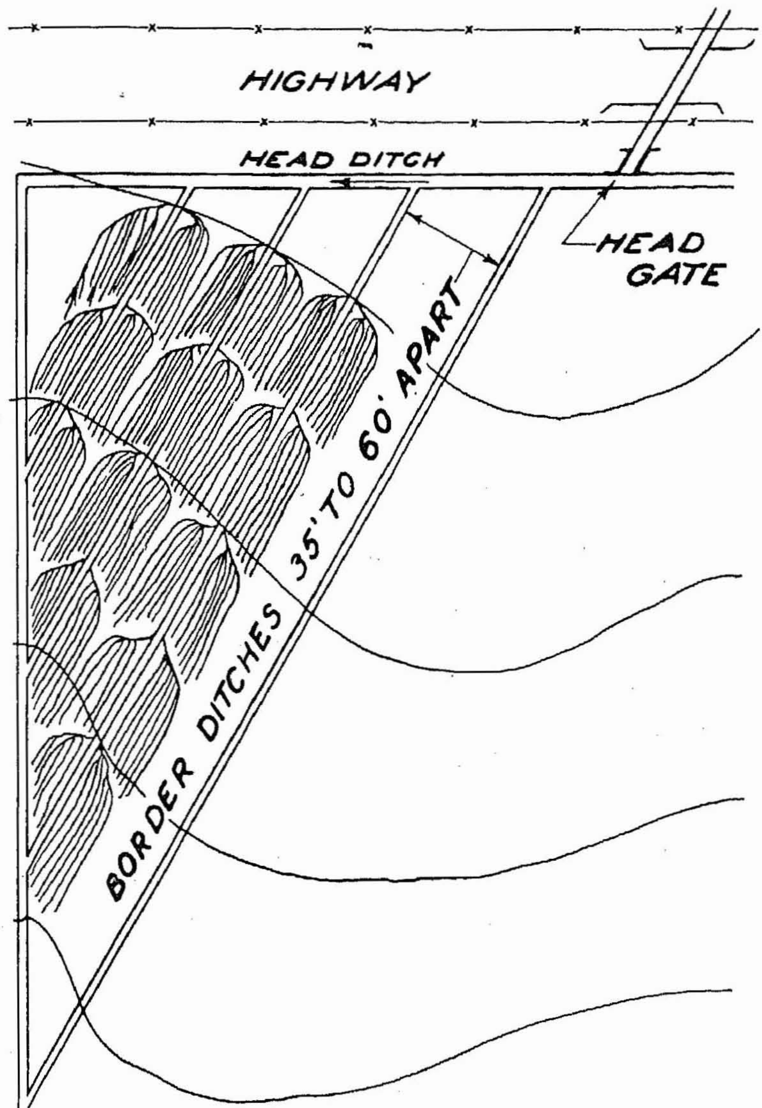



Fig. 7—Border ditch method with ditches parallel to slope. Note close spacing.

considerable difficulty in the control of water by the border ditch method. For such steep grades the contour ditch system is preferable.

Border ditches are generally spaced from 35 to 60 feet apart, the closer spacing applying to the steeper slopes and the wider spacing to the flatter slopes. In general a slope of less than 1 foot per 100 will permit a spacing of 60 feet while a slope of 1½ feet per 100 requires ditches not over 35 feet apart. Naturally the water will spread farther across a gentle slope than a steep one. The distance that water will spread laterally from the ditch governs the spacing of the ditches. The aim is to space them at such a distance that the water from a lateral will spread half way to the next one without a great deal of shovel work. The border ditch system is adapted to the irrigation of hay, grain, or pasture crops.

## Leveling and Floating

Special preparation for the border ditch method consists (1) of harrowing and floating the surface thoroughly so that the water will spread readily and evenly; and (2) of locating and making the ditches or laterals.

For leveling or floating the homemade box leveler shown in figure 8 works very well. It should be drawn crosswise of the field at right angles to the direction of the ditches. It is made from 2-inch material using 2x10 planks for runners and

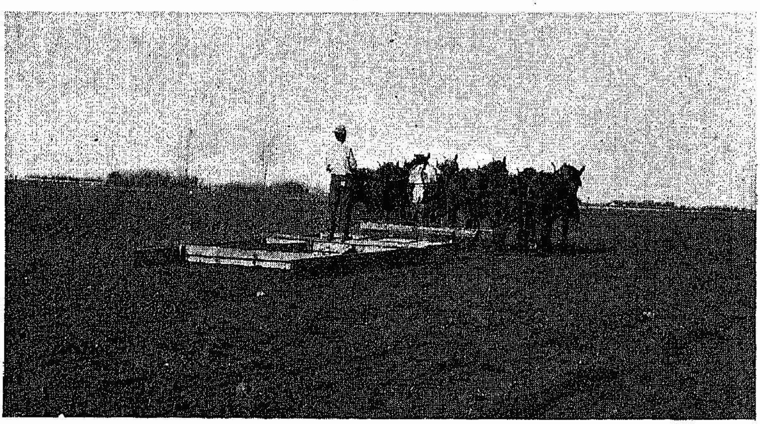


Fig. 8—Homemade box leveler.

cross pieces and 2x6's for braces. The cross pieces are improved by protecting them with angle iron. This implement does best work when made rather long in proportion to the width. Eighteen feet in length should be considered a minimum with 24 to 36 feet desirable. The width should range from 7 to 9 feet. The pull is almost directly proportional to the width. Additional length adds very little to the pull. Trials made on the Montana Agricultural Experiment Station farm gave an average pull of from 90 to 107 pounds per foot of cut. A leveler with a 7 foot cut makes a good load for four large horses or six average horses.

Figure 9 shows an automatic leveler which does excellent work leveling up dead furrows, old ditches and other irregularities in the field. It can best be handled by a tractor although 6 large horses can take care of it quite well.

Border ditches may be made with a lister plow or with a ditcher. They are therefore rather shallow, not over 6 inches below the level of the land. Generally they are spaced by approximation without a survey, since great precision is unnecessary.

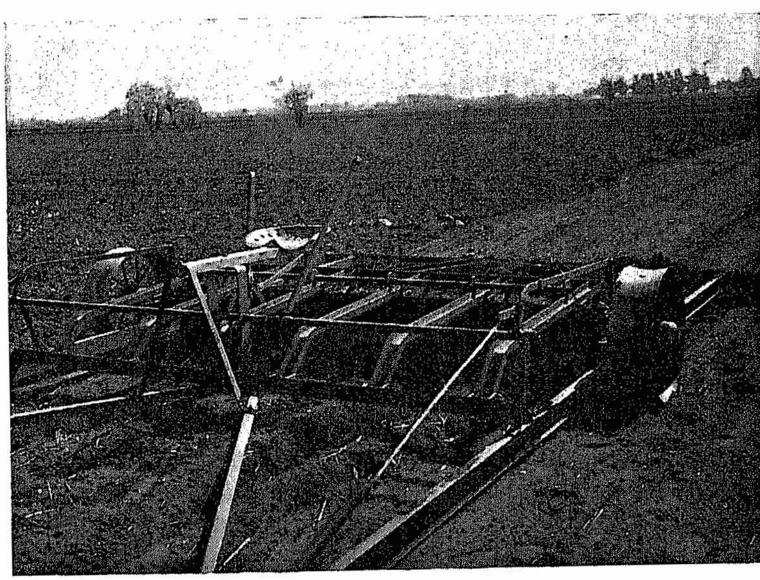


Fig. 9—Automatic leveler.

The ditches are usually made after the grain is up, because then there is less likelihood of their becoming "grown-in" with grain and weeds by the time irrigation begins. If the grade is steep, that is over 1½ feet per 100 feet, it may be an advantage to have ditches made immediately after seeding as then the grain which grows up in them acts as a check to prevent erosion. Control of the water in the border ditches is accomplished by checking the flow with either dirt dams or canvas dams.

The dirt dams are made with a homemade implement called a dammer, which is drawn through the ditch with one horse. It drags up the loose dirt which is dumped at intervals of from 30 to 50 feet by raising the handles of the dammer.

Canvas dams are sometimes used but they work better in larger ditches. The amount of water which can be handled by an irrigator using the border ditch system ranges from one cubic foot per second up to 3 or 4 cubic feet per second, depending upon the skill of the irrigator and the condition of the field which he is irrigating. The general practice is for one irrigator to handle about 3 ditches, each carrying from ½ to 1 cubic foot per second. A good irrigator will irrigate 4 to 6 acres per day with this system. On clayey soils where percolation losses are small, border ditches can be made to serve the same purpose as border dikes, the small banks formed when making the ditches will confine the water to the strip between ditches and the water may be turned down the strip in the same way as when border dikes are used.

After the field has been irrigated and before harvest time, the ditches must be plowed in so as not to interfere with the harvesting machinery. The plowing is done with one horse and a walking plow. This naturally destroys some crop. Each ditch when plowed in leaves a bare strip of from 3 to 5 feet in width. Considering a spacing of 40 feet therefore the land occupied by ditches with this system amounts to about 12 to 15 per cent of the field.

The advantages of the border ditch system are (1) simplicity, (2) adaptability, (3) it needs very little preliminary preparation although careful leveling or floating generally saves time and labor during the irrigation season.

The disadvantages of this method are: (1) that the field is cut up by a large number of ditches, (2) that considerable difficulty is experienced in distributing the water uniformly over the field, (3) erosion is likely to occur in the ditches when this system is used on land of a comparatively steep slope, (4) that 12 to 15 per cent of the land is occupied by ditches and therefore does not produce crop.

## Contour Flooding

The contour ditch method of irrigation requires the field laterals to be located almost on a contour rather than to simply plow them down the steepest slope as was done with the border ditches. The contour ditch system is therefore adaptable to steeper slopes than the border ditch system since the velocity of flow is controlled by regulating the grade in the ditch. For slopes in excess of 1½ feet per 100, the contour ditch system is recommended over the border ditch system. Figure 10 shows a general plan of irrigating a field by the contour ditch system. The ditches or field laterals are made from 200 to 300 feet apart with a grade of .2 to .4 feet per 100 feet. The flat grade is desirable for ditches designed to carry more than 1 cubic foot per second. Small ditches require steeper grades.

If the topography of the field is very irregular, being cut up by ridges and swales, it will then be necessary to supplement the contour ditches by making short spurs along the ridges, otherwise it will be found difficult to get the water to follow down the ridge the entire distance between laterals.

Locating a ditch with a uniform grade is done best with an engineer's level or transit. If an instrument is not available a homemade device called a "cricket" such as shown in figure 11 may be used. It consists of a straight-edge 16½ feet long equipped with well braced legs 3½ feet long. A carpenter's level rests in a small frame in the middle of the straight edge and is adjusted so that the level bubble is in the center when the device stands on level ground. When used to locate a ditch a small block is nailed on the bottom of one of the legs to allow for fall in the ditch. A ¾-inch block will give about .4 foot fall per 100 and a ⅜-inch block, which is the thickness of a lath, will give ⅜-inch per rod or about .2 foot per 100 feet.

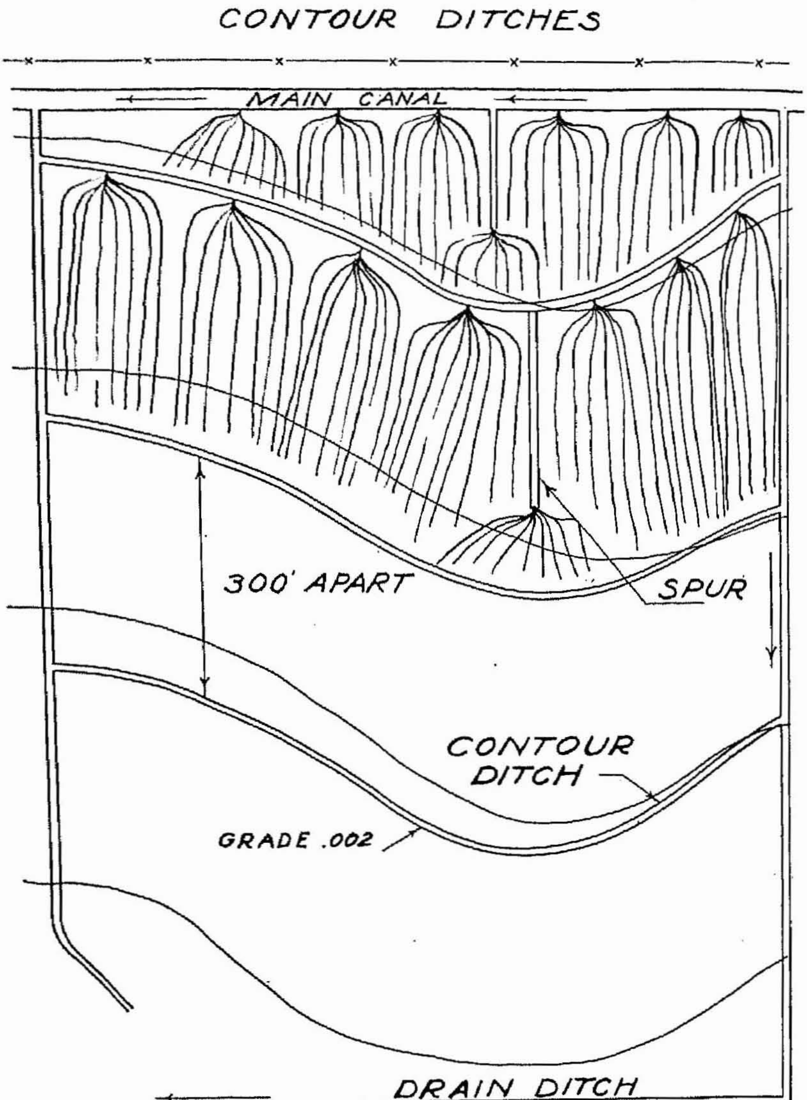



Fig. 10—Typical contour ditch system for irrigating steep irregular fields.

When locating a contour ditch the operator places the device with the short leg a little below the water surface in the head ditch and swings the other end around until the bubble in the

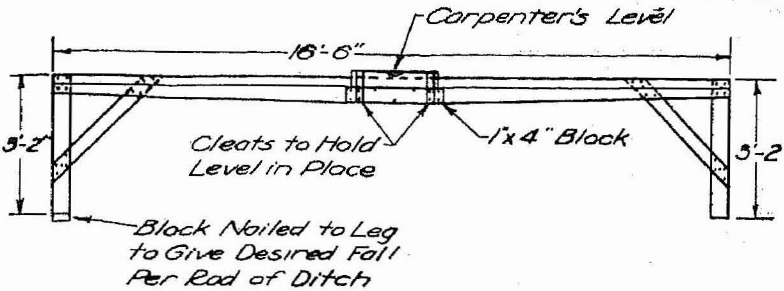



Fig. 11—"Cricket," or homemade level.

level comes to the center. A helper marks the point by driving a small stake beside the longer leg. The "cricket" is then carried forward placing the short leg beside the stake, swinging the other end around until the bubble returns to the center, and so on, repeating the process across the field.

A ditch so located conforms to the warped surface of a field in a series of easy bends, and water will flow in it with a uniform velocity. The water may be checked out onto the land wherever desired by the aid of canvas dams, manure dams, or permanent wooden check structures.

When a check dam is put in a contour ditch the water pours over the bank in a thin sheet over a wide stretch. If a large stream is carried in the ditch, two or more check dams may be used to distribute the stream farther and prevent erosion. In such cases part of the water is allowed to pour over the first dam and be picked up by the second.

Figure 12 shows a contour ditch newly made with a farm ditcher. It is about 10 inches deep, 15 inches wide on the bottom and 36 inches wide on top. With a grade of .4 feet per 100 it will carry 2.5 second feet or 100 miner's inches. Such a stream is sufficient to spread across a 100 to 125 foot strip. This will require two canvas or check dams.

Although contour ditches afford good control of water while distributing it over a field, a certain amount of floating or leveling should be done to smooth up the field as much as possible, otherwise the water will soon collect into the swales and low places. Whenever this occurs several evil results follow: (1) uneven

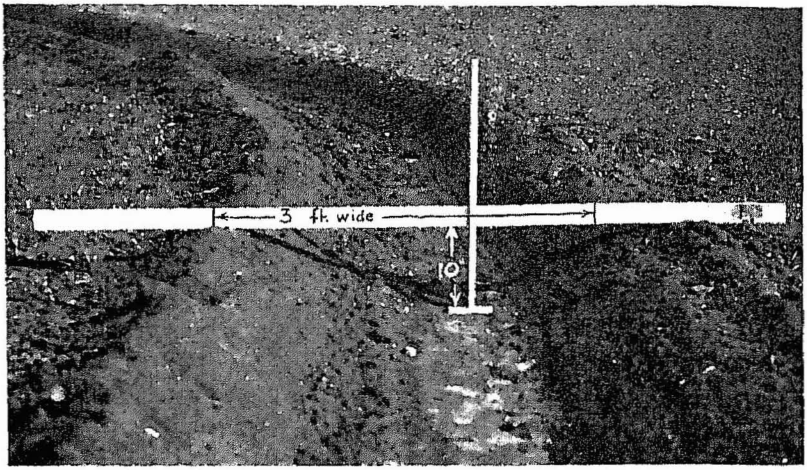



Fig. 12—Contour ditch made with a flat bottom ditcher.

distribution of water, some spots left dry, and others swamped, (2) soil erosion—a large volume or stream of water flows faster and has more erosive power than a small stream, (3) loss of water—waste water is often a total loss, (4) damage from waste water to highways and to neighbor's crops.

The leveling or floating can best be done parallel to the ditches. It can be done with either the homemade leveler or float shown in figure 8, or with an automatic leveler shown in figure 9. In extreme cases it may be necessary to fill deep gullies or holes with fresnos or heavy grading machinery.

The advantages of the contour ditch method are: (1) that it permits control of water on land which is too steep to irrigate by ordinary flooding methods, (2) prevents erosion, (3) saves land by requiring only ½ as many ditches as would be needed for the border ditch method.

There are two objections to this method: (1) the difficulty in locating and constructing the ditches to the proper grade, (2) the crooked ditches which cut the field up into unequal parts of irregular shape.

## Border Dike Method

The border dike method is adapted to the irrigation of hay, grain, or pasture on land with uniform slopes preferably not exceeding 1 foot per 100, although this method has in some cases been used on steeper slopes. Briefly it consists of a system of parallel dikes spaced from 20 to 50 feet apart with the intervening strip smoothed so that the water will flow slowly down between the dikes in a thin sheet. The dikes divide the land into long strips running parallel to the slope of the field.

The border dike method permits complete control of the irrigation water. When a stream is turned into a border strip it cannot spread beyond the dikes bordering the strip consequently it is confined to a definite course across the field. Figure 13 illustrates how a field is laid out for the border dike system

If the system is to operate successfully, careful preparation of the field is necessary. First the entire field should be floated or leveled so as to eliminate small irregularities, such as dead furrows, back furrows, small gullies, and old ditches. Large swales and knolls can be handled with grading machinery such as shown in figure 14, but the final floating or finishing can be done with a homemade box leveler shown in figure 8 or with an automatic leveler shown in figure 9. The point is that the smoother the field the better the job of irrigating that can be done.

After the field has been smoothed or floated, the dikes are located by marking with stakes so that they may be made straight and at the proper distance apart. As previously stated, the direction of the dikes is parallel to the slope so that the border between the dikes will be level. The spacing of the border dikes depends upon the slope of the field, the nature of the crop and the type of soil. For the steeper slopes, such as 1 to 1½ feet per 100 the dikes should not be more than 30 feet apart. For more level lands having a slope of less than 1 foot per 100 the spacing may be 40 or even 50 feet apart. This suggests a rule that the steeper the slope is the closer the spacing for border dikes.

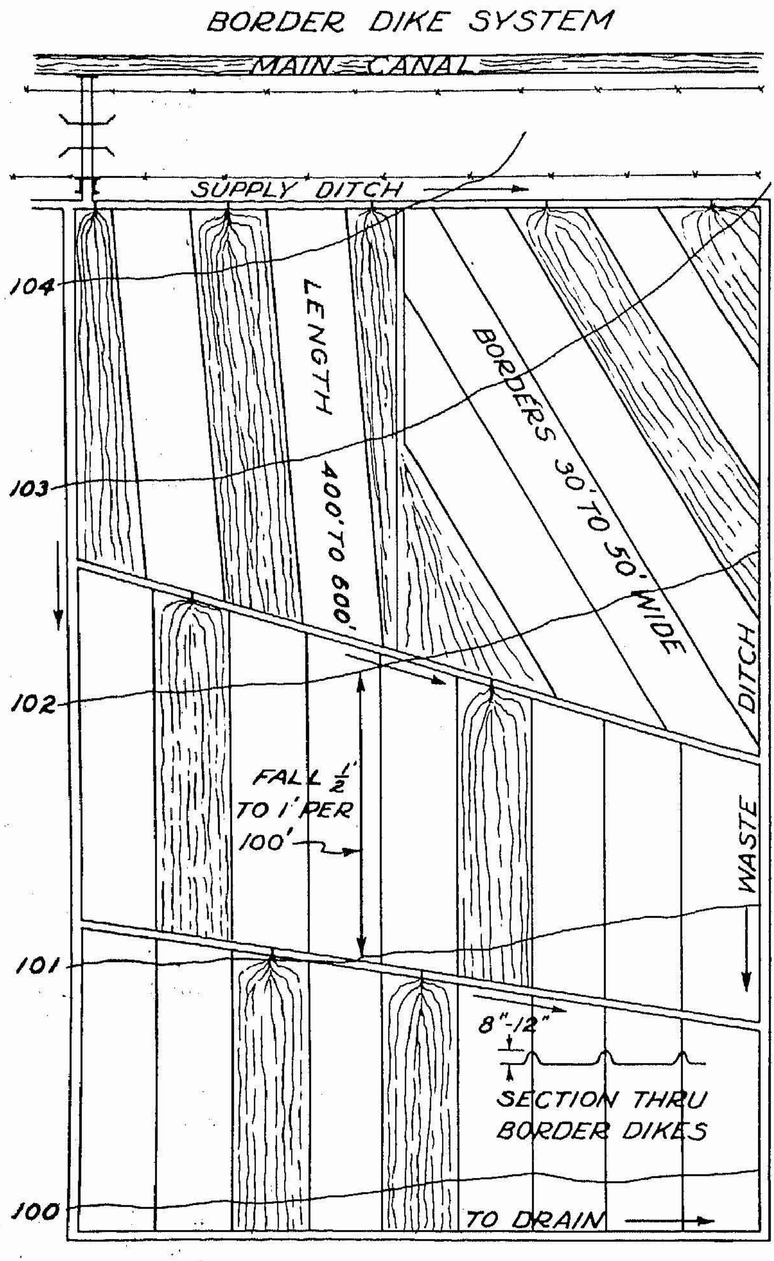



Fig. 13—Typical border dike layout.

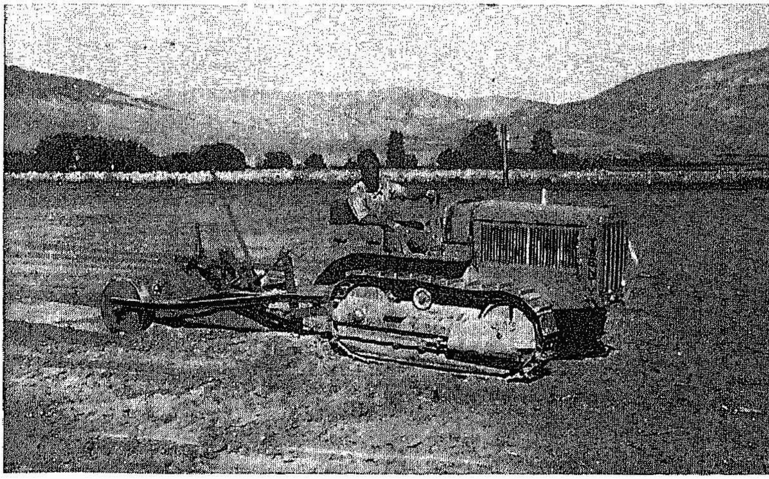


Fig. 14—A rotary scraper or "tumble-bug" for land leveling.

The crop also affects the width of border. A heavy growth of grass or alfalfa permits a wider spacing than a thin stand of grain or hay because the heavy stand of vegetation has a tendency to spread the water while a light stand such as one would expect with young grain, would permit gullies to form and cause the water to collect rather than spread.

A wider spacing is permitted for heavy soils than for light porous soils. The light soils erode more easily so that if the irrigator attempts to use a large stream, which would be necessary with a wide border, there would be more danger of the water collecting sufficiently to cause erosion than if a smaller stream were used. For example: on a field with a uniform slope of ½ foot per 100 with clay soil on which it is planned to raise alfalfa, the dikes may be spaced 50 feet apart, while on the other hand with a slope of 1½ feet per 100 and light loam soil on which grain is to be planted, the dikes should be not more than 20 feet apart.

## Construction of Border Dikes

Border dikes may be constructed in a number of ways. The simplest way, requiring a minimum of equipment, is to plow a back furrow with a mold board plow, throwing about three furrows each way, then draw a homemade implement called a ridger along this dike to smooth it up, and fill the furrows left by the plow. This homemade implement is shown in figure 15. The dimensions given are of rather large proportions, especially the width at the front. The reason for the extreme width in front is to more effectively fill the furrows or barrow pits left

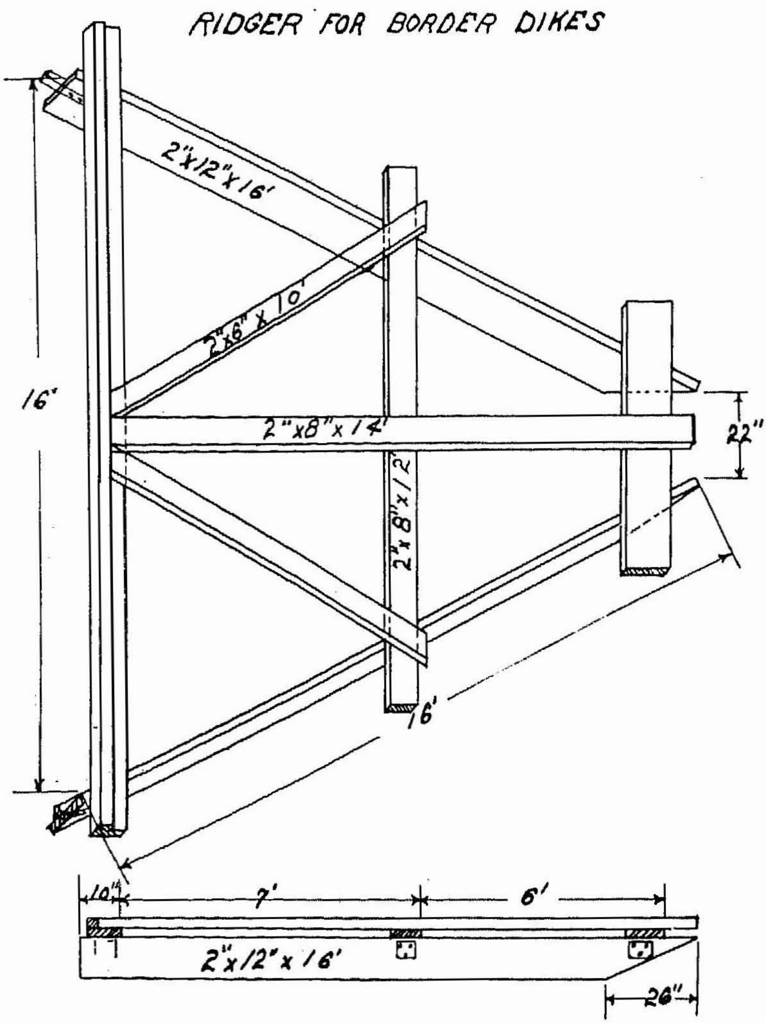



Fig. 15—Homemade ridger for finishing border dikes.

by the plow. If these are not completely filled so that the border is level laterally between the dikes, the water will have a tendency to collect near the dikes and cause erosion. The depressions or barrow pits may be eliminated by plowing the strip between dikes as a land, leaving a dead furrow in the middle which can be leveled in the usual way. From the standpoint of simplicity this method has much in its favor. A 2-bottom gang can be used just as well as the walking plow.

A ditcher or small grader can also be used to ridge up the dikes after a foundation core has been formed with a plow.

Another way, and perhaps the cheapest way from the standpoint of labor is to make the foundation of the dike with a disk ridger, or short 4-foot disk, like the one shown in figure 16. A round trip is made along the line of each dike. This piles up moist earth sufficient for the V-ridger to make a dike of good proportions. The grain or other crop may then be planted right over the dike and no land will be unoccupied or left to weeds.

An attempt to make the dikes in one operation has resulted

Figure 16—Four foot disk ridger for building border dikes.

Fig. 17—Homemade buck scraper or fresno for building border dikes.

in the design of a homemade diker-ridger. This device is described in detail in Montana Circular 281.[1]

This diker-ridger builds a dike of good proportions, when two trips, one complete round, is made for each dike. This dike must be packed well, because the diker leaves the earth in loose condition. With this implement it is not necessary to use the homemade ridger shown in figure 20.

The objections to the homemade diker-ridger are: (1) the power required and (2) the fact that only dry loose dirt goes into the dike, making it difficult to get a stand of grain or alfalfa over it.

The best method from the standpoint of ease of construction and quality of the finished dike is to build the foundation of it with a scraper, then shape it up with the ridger and pack it down well with a packer. A simply constructed homemade fresno is shown in figure 17. It is a modification of the California buck scraper. It is made of planks shod with iron. With its use the

[1] Montana Experiment Station Circular 281—A Diker Ridger, by H. E. Murdock.

earth to build the dike is taken from the high places within the border strip rather than from a narrow strip next to the dike. Thus there are no barrow pits left to fill up along the dike, and the ridger (see figure 15) can be cut down to ½ size since its only function becomes the smoothing or finishing of the dike. These swales or barrow pits are serious objections to each of the methods previously described, as they interfere with the uniform spreading of water over the border. Figure 18 shows the finished dike with the border strip floated smooth, ready for planting.

The advantages of the border dike method of irrigation are: (1) ease of controlling large streams of water for irrigating; thus saving time and work while irrigating (2) uniform distribution of water; because the water being under full control at all times can be led to all parts of the field as desired, (3) low upkeep; when the field has once been prepared for this method very little maintenance is needed, (4) saving of land; as the field is not cut up by numerous ditches to clean out. The disadvantage is the extra time and work it takes to prepare a field for this method of irrigation. With a short growing season the farmer is more concerned with the time saved in preparation than he is

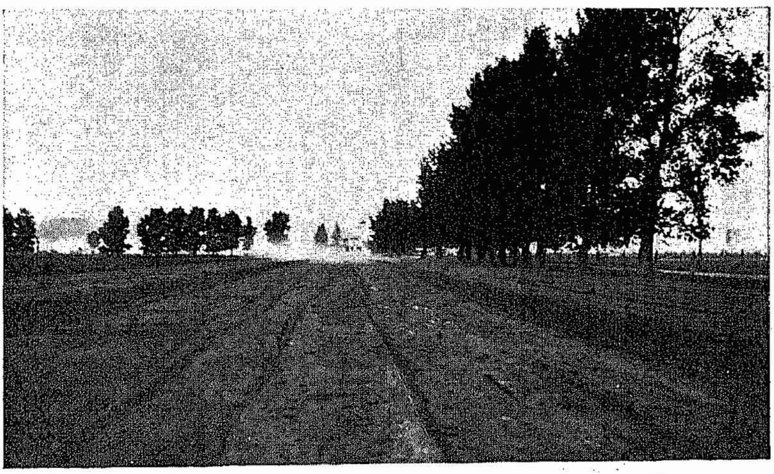


Fig. 18—Finished border dikes with border strip leveled ready for seeding.

with the time saved in applying water later in the season. However, since the border dike system is best suited for hay and pasture crops where the preparation doesn't have to be done each year, while the benefits are enjoyed for many years, a few days extra work in preparation are well justified.

### Contour Check Method

The contour check method is a modification of the border dike method. The essential difference is that with this method the dikes are made on contour instead of parallel with the slope. The land between the dikes is then divided into sections or squares called checks. The operating principle of the system is that each check or square fills up and overflows into the adjoining one until the field is covered with a large number of shallow rectangular ponds or basins filled with water, and the water is held in this way until it can be absorbed by the soil.

This method is particularly adapted to flat or level lands and for grass or hay crops which will not be damaged by being covered with water several hours at a time. It is also well suited for flood irrigation[1] where the water supply is taken from a coulee fed by flood water so that a large stream is available for a short time rather than a steady stream for a longer time which is desirable for the border dike system.

### The Corrugation Method

The corrugation method is best suited for row crops, grain and field peas. It works best on gently sloping lands with a fall not over 2½ feet per 100 but can also be adapted to rather steep slopes with a fall of 5 feet or more per 100. Briefly described the system consists of small parallel furrows about 4 inches deep and spaced about two feet apart, which carry the water across the field.

Figure 19 shows a field being corrugated with a homemade marker or corrugator. A small stream of water is turned into each corrugation and allowed to trickle slowly down the row so that the water has a chance to soak laterally from one furrow half way to the next one. In this way all the land does not get flooded and consequently no baking or cracking occurs in the soil.

[1] See Montana Experiment Station Bulletin 301, Conservation of Water by Means of Storage Reservoirs, Diversion Dams and Dikes by O. W. Monson.

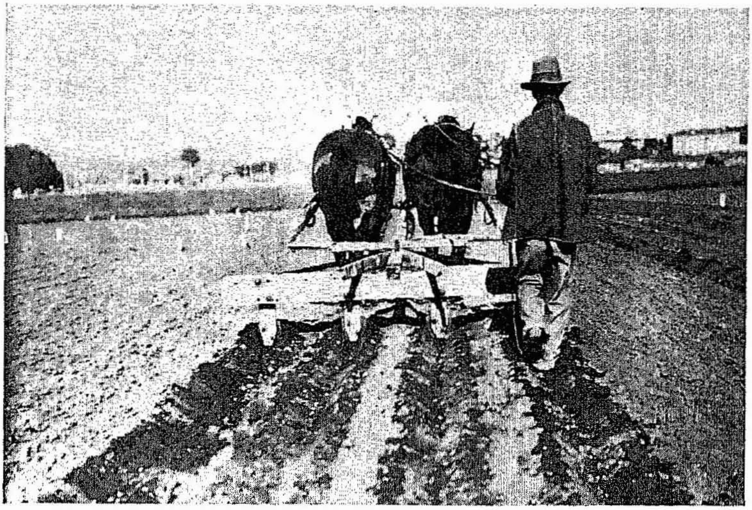


Fig. 19—Shovel type corrugator.

This is one of the chief advantages of this method, and is particularly helpful for new seedings of hay or grain.

Figure 20 illustrates the essential features of the corrugation system such as the location of ditches, the spacing of the corrugations and the length of run, etc. The length of run should not exceed 600 feet, and 300 to 400 foot runs are more satisfactory than longer ones as there is less likelihood of erosion at the upper end of the furrows.

This method is efficient in the amount of water used and is, therefore, advisable when water is scarce. With the flooding method a small stream cannot be used effectively. It seems impossible to get it over the ground. Instead of flowing down the field it forms a puddle or seep in one place, and causes a high percolation loss or waste of water.

The corrugation method makes it possible to use a small stream by dividing it into furrows so that it can be kept together and be made to cover more ground than if allowed to find its own way down the field.

The custom is to turn from 1 to 4 miner's inches in each furrow depending on the slope of the field. For flat slopes, of less than 1 foot per 100 the larger amount is desirable, but for steep slopes, that is, slopes exceeding 2 feet per 100 a smaller stream is advisable, otherwise erosion will occur. For a slope of 5 feet per 100 for instance only a small trickle is needed to flow down the furrow.

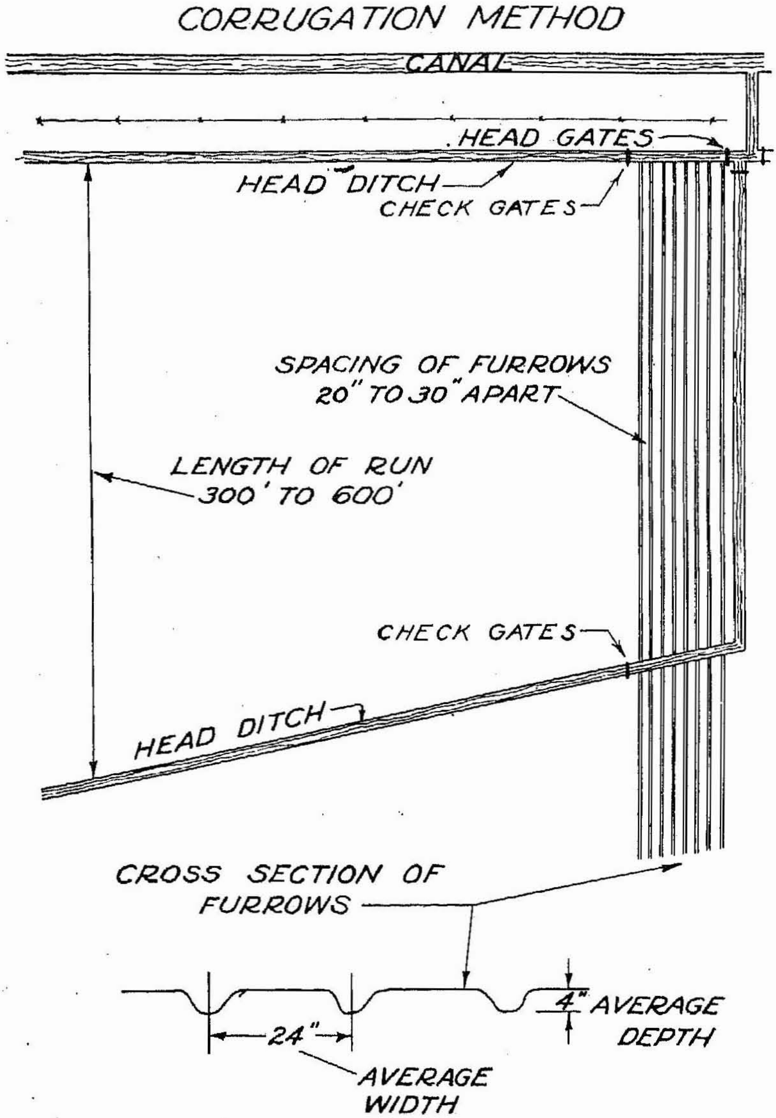



Fig. 20—Layout for the corrugation method of irrigation.

The advantages[1] of the corrugation system are (1) that it saves water, (2) is most efficient method when only a small stream is available, (3) prevents baking and cracking of soil, (4) is adaptable to steep slopes and uneven ground.

The disadvantages are (1) makes the field rough for harvesting, especially at right angles to the furrows, (2) an irrigator cannot handle as large a stream as by other systems. The corrugation method may be used in connection with the border ditch and also the border dike method as an aid to overcoming difficulties incident to rough lands and warped surfaces.

### Sub-Irrigation

Sub-irrigation is a method of distributing irrigation water by means of sub-surface conduits, or of raising the water table through seepage from ditches or from surface spreading.

Conditions favorable for sub-irrigation are loose open soil which can be quickly drained, underlaid by a hardpan sufficient to prevent a rapid percolation downward. Such natural conditions exist in comparatively few places.

Artificial sub-irrigation involves a good deal of expense, and is, therefore, not recommended for extensive use. The cost of trenching and laying tile over a large field is prohibitive for ordinary field crops.

Sub-irrigation has been advocated for the irrigation of gardens when water is scarce because much surface evaporation is eliminated. It is true that evaporation from the surface is slightly reduced but to offset this the seepage loss is often increased and especially so if the soil happens to be of a loose porous type. Actually this method is as likely to be wasteful of water as it is to be economical. If the structure of the soil is such that a hardpan is found at a depth of 1½ to 2 feet then the percolation loss will be comparatively small and the capillary spreading of the water laterally is accelerated.

The sub-irigation method will not be discussed in detail here because very little investigational work has been done along this line at the Montana station. The reader is therefore referred to the following publications: (1) Montana Extension Circular No. 63—Sub-Irrigation for Gardens by E. E. Isaac, (2) C 97—Texas Extension Service, Sub-Irrigation for Gardens by M. R. Bentley and J. L. Rosborough, (3) Bulletin No. 240—Colorado Experiment Station, Irrigation by Means of Underground Porous Pipe by E. B. House.

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[1] A more detailed discussion of the corrugation method is found in U. S. D. A. Bulletin No. 1348 "The Corrugation Method of Irrigation."

## Overhead or Spray Irrigation

Spray irrigation is used mainly for irrigation of lawns and gardens in Montana, but it is more widely used in other sections of the country where occasional light irrigations are necessary to keep market garden crops and even field crops growing during periods of drouth. For example, such crops as canning peas, and sugar beets have been successfully irrigated by the spray system in Washington and California during the past 5 years. It has been observed that such leafy crops as peas, sugar beets, lettuce, and cabbage respond better to spray irrigation than to surface flooding. Observations at the Montana Agricultural Experiment station during the past two years indicate that the quality of certain garden vegetables is improved when irrigated by the spray system.

The interested reader is referred to the following publications on the subject: (1) U. S. D. A. Farmers Bulletin No. 1525—Spray Irrigation in the Eastern States; (2) U. S. D. A. Circular No. 195 —Tests of Spray Irrigation Equipment by F. E. Steabner; (3) Bulletin 268—Washington Experiment Station, Irrigation of Orchards by Sprinkling.

## Porous Hose Irrigation

A new method of applying irrigation water is the use of a specially treated fiber hose through which water is conducted along the row of crop and allowed to ooze slowly out and moisten the earth next to the plants. This method originated at the Michigan Experiment station and is fully described in Extension Bulletin No. 133, Michigan State College, Porous Hose Irrigation by O. W. Robey. A short trial at Montana Experiment station with this type of hose has given entire satisfaction.

There are several points in favor of the porus hose method. First it is very economical of water. There is very little evaporation loss because the water is concentrated over a small area next to the plants. There is no runoff loss because the water is applied so slowly that the soil can absorb it as fast a applied. Seepage loss may be entirely prevented by shutting off the water when the soil has been moistened to the proper depth.

Objections to the method are that it is slow and somewhat expensive, although in these respects it compares favorably with the spray system.