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RECLAMATION BY DRAINAGE
An Example of Reclamation From Seepage and Alkali by Means of Leaching and Drainage.

J. C. FITTERER. Irrigation Engineer

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Reclamation by Drainage.

INTRODUCTION.

From the very beginning of irrigation in the western states, there arose new complications resulting from the changed conditions brought about by the very act of irrigation itself. Apparently a tangible example comes before us of the trite saying that every blessing has an accompanying evil. The first and unstudied idea pertaining to the raising of crops upon land in the semi-arid west is simply to apply as much water as can possibly be obtained; even with some, that this application will furthermore take the place of fertilization and cultivation as well as supplying the necessary moisture. The error of such a conception readily becomes apparent upon recounting the different necessities for plant growth, of which moisture is but one. Farming is not made simpler by reason of irrigation; to the contrary, it often becomes more complicated. The methods of good farming prevalent in the eastern and middle western states are not to be cast aside and neglected, but rather supplemented by an additional agency—water—usually supplied gratuitously there by nature (although somewhat irregularly), while in the semi-arid states man of himself must provide it in assured and regular quantities to the growing plants. The tiller of the soil thus gains complete control of all the necessary elements but at the same time the responsibility of their proper use falls upon himself, as he can no longer look to a beneficent sky for part of his needs. To compensate him for his added labor, irrigation becomes an absolute guarantee or assurance of his annual returns in full measure and in proper season.
Two things are complementary and must go hand in hand wherever the irrigator runs his ditches and laterals, viz:

1. Irrigation, and
2. Drainage.

As well might a city provide an ample water supply and neglect the installation of a sewer system as for a project to avoid the inquiry into and ultimate construction of drainage outlets wherever found necessary.

Two ways present themselves in which proper drainage may be established: First, nature may have given a deep, porous subsoil as an ample outlet for surplus water, thus avoiding the supersaturation of the surface layer. Second, wherever this condition does not obtain, then it devolves upon the irrigator to supply the deficiency, as much so as for him to provide water where it is not found.

It may happen that at first an open sublayer gives ample means of escape for waste water; but finally after a longer or shorter period of time, through the infiltration of finer particles, soil, humus, etc.,—and the products of continual cropping and cultivation,—the underground outlets become clogged and then artificial drainage must intervene. A general realization of the need of drainage, where not naturally provided, has been rather slow in impressing itself upon the ranchman, particularly in a newly settled section, but in the course of years, portions of the land soon give evidence of water logging, grasses and grains refuse to grow, water sedges, salt grass, and other water loving vegetation appear, and to make matters worse and accentuate the all too apparent distress, alkali shows in leprous spots as the climax of an unpropitious fate; and all resulting from a lack of proper drainage, coupled in many cases with an over supply of water and its careless use.

**WATER TABLE.**

*Definition:* The water table, or plane of saturation, as understood in drainage, is the surface of free water wherever
found. In other words, it is the surface water seen in wells. This water table is not necessarily stationary for any length of time, but fluctuates in its position with reference to the surface of the ground. Neither need it nor does it always remain below the ground surface. Taken in an extended sense, lakes and the ocean may be considered as examples of a water table above the land surface.

When settling upon raw land, the plane of saturation lies at considerable depth, often beyond the reach of ordinary well rigs and tools, yet after irrigation has begun the rise of this plane becomes apparent to the most casual observer and frequently continues until perhaps it reaches the root zones of plants or even covers the ground in depressions.

To illustrate the evolution of the process of ruining land by injudicious irrigation, with none or but little drainage, or even with proper use of water and no care of waste, (which is always likely to occur) Fig. 1 is presented as giving an ideal series of sketches showing what generally happens in such cases.

A. With a proper relation of conditions we find the plants furnished with abundant moisture and yet opportunity provided for complete aeration and warmth. The plane of saturation lies deep enough to permit root penetration yet near enough to the surface to supply moisture through capillarity.

B. As the water table rises, through irrigation under unfavorable circumstances, some plants in low places begin to suffer and show signs of impoverishment.

C. This tendency, in its final state, leads to crop destruction upon the entire tract affected, and thereafter continued sterility, unless remedied.
NORMAL POSITION OF WATER TABLE

WATER TABLE RISING AND ENCROACHING UPON ROOT ZONE

WATER TABLE PARTLY ABOVE GROUND AND ROOT ZONE FLOODED

FIG. I.
Reclamation by Drainage.

ROOT ZONE.

It is to fix the underground location of the water table with which the drainage engineer is concerned, and this position is clearly dependent upon the surface stratum necessarily demanded by various crops in which to perfect a complete and sturdy root system. Root penetration in most cases (expressly excluding aquatic plants) is due mainly to the following:

1. The particular kind of plant considered. Vegetation possesses innate tendencies with respect to the spread of the root system, as much so as to peculiarities of stalk and crown. Some trees, growing tap roots, delve quite deeply; while others not so endowed confine their underground growth to a lesser depth, although perhaps a greater superficial area. Grasses and grains are similarly constituted. Alfalfa, for example, being prone, under favorable conditions, to grope very deeply for moisture, while some of the grains and root crops are less inclined to extensive exploration beneath the surface. This general statement, however, seems true in the light of experience and observation, viz: that, within prescribed limits, the roots of plants attempt to secure requisite moisture, as much so as do animals, with an infinitely wider range of movement, seek the springs and water courses at which to slake their thirst.

2. The position of the water table. The location of the plane of saturation absolutely precludes the possibility and necessity of root extension beneath its surface. Where it lies deeply, plants may and will burrow and delve, but if it approaches the seed bed too closely it becomes a menace instead of a benefit.

3. Methods of irrigation used. With sprinkling, for example, (as upon lawns) the moisture is mostly superficial and consequently the roots lie within a shallow stratum. Wild flooding may induce a deeper growth, since it usually leads to deeper saturation. Furrow irrigation emphasizes this tend-
ency still more, while proper sub-irrigation, where its operation approaches theoretical perfection, may increase the root zone and at the same time partly control the fluctuations of the water table.

ALKALI.

The deposition of alkali is usually attributed to three main causes—

1st. Light rainfall, insufficient to wash out and transport the harmful salts by surface run-off; which condition is strikingly prevalent in the Rocky Mountain West.

2nd. Poor drainage, principally a lack of underground channels (of whatever sort) whereby water containing the alkalis in solution is allowed to stagnate and perforce eventually approach the surface.

3rd. Excessive surface evaporation, inducing a concentration and lodging of salts at the root crowns of plants.

The source of alkali may be found primarily in the particular soils themselves, or carried from soils so affected by the irrigation water used.

STATION FARM EXPERIMENT.

A vexing example of water logging occurred on the Station Stock Farm, due to heavy irrigation in past years while yet under the occupancy and direction of the state penitentiary, and since then to the constant subsurface flow of water from hay ranches located farther up the Laramie river valley and on bench lands to the southwest. The topographic map of the portion in question is given in Plate 1, and an inspection of its configuration reveals the favorable surface conditions for bogging. Along a N. and S. line passing through the group of Station buildings is seen a low ridge, while to the west of this and north of the road is a meadow lower than its bordering ridge above mentioned. This meadow is said to have formerly yielded large returns in native hay and oats, but ceased to do so upon the appearance of bogs and alkali. Its condition
MAP
OF PART OF
STOCK FARM
UNIVERSITY # WYOMING
LARAMIE, WYO.
SHOWING PORTION CONCERNED
IN ALKALI RECLAMATION

CONTOUR INTERVAL 1 FOOT
SCALE

LEGEND

---_.--_._-_.-._---_._-.---~. __.
-. -._._._-=-~ ..........-.~---.- .-.- '-.
PL TE I.
N
was such as to promise no return whatever even in stunted grass for light pasturage.

To remedy this state of affairs, and at the same time serve as a demonstrative experiment, the Wyoming Experiment Station, co-operating with the U. S. Bureau of Drainage Investigation, laid out and installed a drainage system as shown on the map.

**SOIL.**

The soil forms but a very thin layer, not at all comparable to the deeper soils of the Central Mississippi valley. Scarcely 12 inches could be even thus characterized. Below this is found for an indefinite depth a rather coarse, sandy gravel composed of the prime products of granite decomposition; granite appearing as the central mass in the Medicine Bow and Laramie mountains. These mountain ridges enclose the Laramie valley, the former to the westward and the latter to the eastward, at a distance from crest to crest of about forty-five miles, and both having a general north and south trend.

At a point marked "X" on the map, near the west side of the Station horse barn, clay was struck at a depth of between seven and eight feet. Furthermore, in Tile Well No. 120, directly north of this location, it was again encountered at 4.5 feet. Near Sta. 6, Lateral No. 2, clay was reached at a depth of 2 feet, for a length of 20 feet; also a 15 foot strip in the bottom of the trench between Stas. 19 and 20, on the same lateral. Quicksand appeared in the bottom for 40 feet near Sta. 4 on the main lateral, and for a short distance on Lateral No. 2, between Stas. 9 and 10, in which locations extensive caving occurred, to prevent which shoring and bracing had to be resorted to.

All the other tile wells, as also the balance of the drains, lie in gravel. Presumably a clay sub-stratum exists at varying depths below the gravel, and plays an important part in the disposition of the ground water.
It was in such a fairly porous surface formation that water logging occurred, together with an abundant deposition of white alkali.

DRAINS.

The installation consisted (1) of a 10" "Main" tile drain 549 ft. long, cutting through the low marginal ridge between the river bottom and the meadow, serving as a carrier of the collected seepage. (2) A cut-off or intercepting lateral marked "No. 1," laid with 10" tile for 707 ft., with 8" tile for 781 ft., and with 6" tile for 727 ft., thus having a total length of 2,215 ft. The purpose of this lateral was primarily to cut-off and collect the underground flow from the mesa above and prevent this flowage from entering the meadow subsoil. (3) A collecting drain marked "No. 2," consisting of 1,474 ft. of 10" tile, 805 ft. of 8" tile, or a total length of 2,279 ft. From this drain a stub marked "No. 3" extended for 200 ft., consisting of 6" tile.

The average distance between the lines of Nos. 1 and 2 was about 500 ft. Plate 2 is a profile of the drains, from which the average depth is seen to be about 5 ft.

SILT BASINS.

At the angle points and elsewhere, spaced from 600 to 700 ft., sand boxes or silt basins were located to relieve the drains of their burden of sediment and silt. Fig. 2 gives the typical plan of construction. The locations of the boxes are noted on the drainage map.

TILE WELLS.

With the object of observing the changing position of the water table, tile wells were located in lines at right angles to the drains and spaced from 50 to 100 feet apart and 3 to 5 feet deep. They are numbered from 10 to 123, and their location is indicated on the general map.

The details of the same are depicted in Fig. 3.
Old Box Car Doors for Covers

Earth

Tile drain

Section A-A

Silt

Plan

SILT BASIN

FIG. II.

Cover removed

Scale

1 2 3

Inches

Feet
Section of Tile Well

FIG. III.

Wooden Cover

6" Clay Tile

Bottom View
Detail of Cover
INFLOW.—WATER APPLIED.

Irrigation water was secured from the Pioneer Canal, passing one mile west of the Stock Farm, and just before entering the latter it flowed over a 2-foot trapezoidal weir, on which the varying heads were measured both by rule and by an autographic register.

Table 1 compiles the data pertaining to the amounts applied for various months during the year 1908.

**TABLE 1.—IRRIGATION IN 1908.**

<table>
<thead>
<tr>
<th>Month</th>
<th>No. of Days Irrigated</th>
<th>Quantity Applied Acre-feet</th>
<th>Average Depth, Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>July</td>
<td>14 days</td>
<td>8</td>
<td>0.13</td>
</tr>
<tr>
<td>August</td>
<td>30 days</td>
<td>83</td>
<td>1.38</td>
</tr>
<tr>
<td>September</td>
<td>30 days</td>
<td>66</td>
<td>1.10</td>
</tr>
<tr>
<td>October</td>
<td>11 days</td>
<td>24</td>
<td>.40</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td></td>
<td><strong>181</strong></td>
<td><strong>3.01</strong></td>
</tr>
</tbody>
</table>

During 1909 the supply in the Pioneer Canal was rather erratic. The total delivered to the Stock Farm tract is estimated at 80 acre feet.

The area affected by alkali, and which it was sought to reclaim, totaled 80 acres, thus giving an average depth for 1908 of \(2\frac{1}{4}\) feet, and for 1909 of 1 foot.

Flooding on this tract was only possible during the irrigation season, for at other times the supply canal remained dry. If a continuous flow throughout the year had been available, the results from the leaching out of alkali should have been more rapidly effected.

Besides this, the rainfall added somewhat to the available quantity as shown in Table 2 and graphed in Fig. 4.
Reclamation by Drainage.

FIG. IV.

PRECIPITATION CURVE

Inches of Precipitation

1908 1909
Adding the annual precipitation to the irrigation, we find that for 1908 the average total depth was 3.4 feet, and for 1909 1.8 feet.

It is fair to state that over the entire area (taken as extending one-half mile north of the county road, and a quarter-mile east of the west fence) the larger part of the flood water naturally collected in that portion between the north and south irrigation dikes and directly north of the former; particularly in the various depressions indicated by the topography. Hence the south 40 acres of the 80 were undoubtedly subjected to greater leaching and washing, but on the other hand, surface indications pointed to a greater accumulation of alkali there.

Plate 3 shows the varying quantities of water used in irrigation, plotted in cubic feet per second.

**OUTFLOW—DRAINAGE WATER.**

At "A", the outlet of the main drain, a concrete basin with a 1-foot trapezoidal weir was placed, and an autographic water register installed to record the quantity of discharge from the drainage system. In the half-tone cut, Frontispiece, is given a view of the outlet basin, the end of the 10" tile drain and the register house.
IRRIGATION AND DRAINAGE CURVES

PLATE III. 1908
LEGEND

- TILE DRAINS
- TILE WELLS
- WELL NUMBERS
- WATER TABLE
- SCALE
- PROFILES
- LINES OF TILE WELLS
- FLUCTUATIONS OF WATER TABLE

PLATE IV.
Reclamation by Drainage.

Plate 3 graphically represents the outflow in connection with the flood water. A notable fact is the almost constant discharge from the main drain throughout the unirrigated portion of the year, varying not more than from one to three-tenths of a cubic foot per second. The appearance of frost seemed to have but little effect. The only attributable cause is the apparent sub-surface flow prevailing in the Laramie valley, due to irrigation of hay land extending for miles above the Experiment Station. This underground movement is quite slow in rate and therefore persists long after the irrigation season is over.

Another feature is the lagging of the outflow “crest” and outflow “trough” behind the corresponding irrigation curve crest and trough, during irrigation, as plainly shown in the plate.

FLUCTUATION OF THE WATER TABLE.

With the beginning and continuance of flooding the underground water plane became naturally greatly disturbed as to position, and to show the same more tangibly (in section) Plate 4 was prepared pertaining to the year 1908, and covering the dates of July 7, July 15, July 31 and August 13.

The same data, only in plan, are presented on Plate 5, in which the surface of the water table appears in the form of dotted contours, analogous to the topographical representation of ground surfaces.

An inspection of these two plates shows the marked influence of the drains in preventing the over-saturation of the soil. The water table directly over the tiles did not rise much above them, since they were not flowing under pressure. To each side it rises rapidly and then slopes off more gradually until it assumes an otherwise normal position or until the next line of drains is reached. The profile between tile wells No. 70 and No. 78 on Plate 4, illustrates this quite clearly, although it is seen in all of the other sections.
Turning to Plate 5, it is apparent that the water table contours, as they near the drains, are drawn towards them quite rapidly, follow along the line for a distance then double back, and leave again at some point on the opposite side. To express it differently, the drains form a "trough" in the ground water plane; the sides of this trough being steeply inclined at first and thereafter approaching the horizontal.

Upon this action depends the proper spacing of drain lines in order to prevent the free water surface from getting too near the root zone at midway points.

For the aid of the agriculturist confronted with a similar problem, we might enumerate two factors which play a conspicuous part in this respect.

1st. The porosity of the soil, and, 2nd, the depth of the tiling. For example, in porous ground the water can flow between the soil particles more readily, thus permitting of a wider spacing and deeper drain location for a desired result; while in a compact, tenacious formation a closer arrangement of lines and shallower depth would be found best. The distances commonly used as a result of experience vary from 40 to 200 feet, while the depths extend from 2 to 5 feet, all according to the character of the tract to be reclaimed. Cases have arisen in a stiff clay where tiles at 4 feet were practically ineffective, but when laid at 2 feet served admirably.

The final layout of any system, after all, rests wholly upon the peculiarities of the special tract itself. General practice may and does summarize the thought and experience applied and gained in drainage operations, yet it can only set certain modes of procedure which must always be modified to meet local needs.

RECLAMATION COMPLETE.

As the flooding on the tract proceeded the alkali gradually disappeared, except on knolls not covered; the harbingers of waterlogging (salt grasses, etc.) vanished, and native grasses
tours, rapid, and long it differs plane and the lines too may the problem spiculite tiling between wider while of line of distance to 20 according have ineffec
t the may and ge models local
gally of wa
began to resume their former sway. A small band of sheep grazed the area during the summer seasons and were found to crop particularly close in the parts extensively flooded and leached, where the vegetation gave appearance of being quite attractive and succulent.

In the season of 1911 a large acreage was planted to a mixed stand of oats and field peas, which grew very well and gave a fair yield. The plant growth indicated an almost complete removal of alkali, except upon a few knolls where flooding was impossible.

COST.

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor; trenching, laying tile and back-filling</td>
<td>$360.00</td>
</tr>
<tr>
<td>Labor; flooding area, estimated</td>
<td>120.00</td>
</tr>
<tr>
<td>Cost of tiling</td>
<td>375.00</td>
</tr>
<tr>
<td>Lumber for shoring and silt basins, estimated</td>
<td>50.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$905.00</td>
</tr>
<tr>
<td>Average cost per acre of land reclaimed</td>
<td>$11.30</td>
</tr>
</tbody>
</table>

CONCLUSIONS AND RECOMMENDATIONS.

A few leading statements may well be inserted by way of summary.

1st. Delay in beginning to drain, where its aid is fully indicated, is suicidal. Procrastination is not only the thief of time, but a robber filching many a dollar from the ranchman whose meadows are saturated with alkali water.

2nd. Use tile amply large—rather too large than too small—for the first cost is not the sole item of importance, since the subsequent expense of excavation, cleaning and relaying of clogged tile too small in the first place, amounts to almost a new installation.

3rd. Space the rows close enough for the tile to perform their work in keeping down the crest of the water table between them. To err in this direction is at least on the side of efficiency.
In the foregoing experiment it was noted that the lines averaged five hundred feet apart, which can scarcely be recommended for general practice. The extreme porosity of the seeped soil probably alone rendered this arrangement practicable.

4th. Lay the tiling to a definite grade throughout. Sags fill with sediment, and "humps" many times form insurmountable barriers for drainage efflux.

5th. Above all, avoid over-irrigation.