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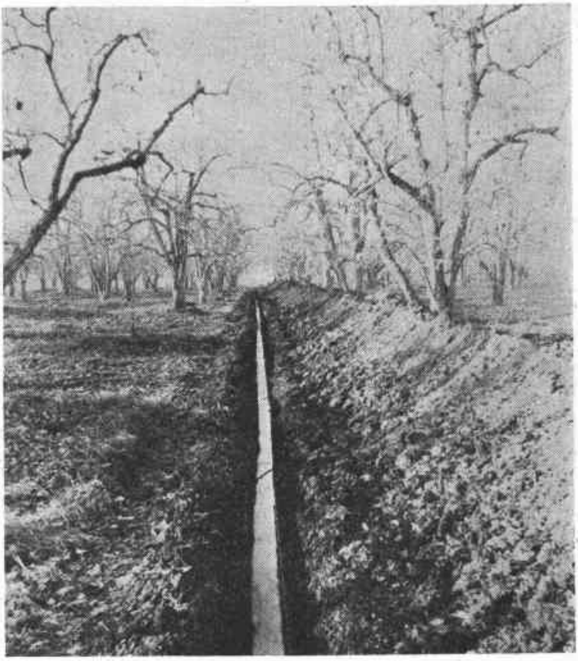

Drainage work in progress.

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Orchard Drainage in the Medford Area, Jackson County, Oregon*

By

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INTRODUCTION

Many of the orchards of the Medford area, Jackson county, Oregon, were originally planted, grew to maturity, and bore fruit for several years without irrigation. As the trees grew larger and yielded more heavily, however, it became more and more apparent that the natural precipitation, especially that of the season of growth, was not adequate to assure the best results. About 3,000 acres were under irrigation in 1911 and additional irrigation systems were constructed and in operation in 1921. After these systems had been in use for a few years troublesome conditions due to the lack of proper drainage facilities became prevalent.

Advised by representatives of the Division of Agricultural Engineering, Bureau of Public Roads, United States Department of Agriculture, and of the Soils department, Oregon Agricultural Experiment Station, after a brief reconnaissance of the area had been made, of the serious nature of the drainage problems that often follow the artificial application of water to large tracts of land, far-sighted orchardists requested that those agencies make a thorough study of the situation and recommend such steps as might appear necessary for the correction of the existing injurious conditions and the prevention of permanent damage. In compliance with this request an investigation was undertaken in July, 1929.

Two general phases of the problem have been kept in mind in carrying on the field work and in the preparation of this report—namely, (1) the extent and seriousness of the problem, and (2) the determination of practical methods of drainage with especial reference to their efficiency. This Circular is designed to make available to the orchardists and engineers of the Medford area the results of studies covering a period of sixteen months. The investigations show that the high water-table found in parts of the area is responsible for serious orchard problems requiring solution. Methods for controlling the situation at reasonable cost are described.

The studies were planned and supervised by W. W. McLaughlin, Associate Chief, Division of Agricultural Engineering, United States Bureau of Public Roads, and W. L. Powers, Soil Scientist in Charge,

*This circular is a report of investigations carried on under a cooperative agreement between the Division of Agricultural Engineering, Bureau of Public Roads, of the United States Department of Agriculture, the Oregon Agricultural Experiment Station, and Jackson county, Oregon.

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Oregon State Agricultural College and Agricultural Experiment Station, who have given freely of their time and attention to the work and the preparation of this report. The frontispiece is shown through the courtesy of R. I. Stuart and Sons.

NATURAL CONDITIONS

Topography. The topography of the area is extremely diverse. With respect to the drainage problem, three general regions may be distinguished: (1) the foot-hill lands with comparatively steep slopes and broken topography around the rim of the Valley; (2) the so-called "Desert," northeast of Medford, with extremely shallow soils and relatively slight slopes; and (3) the rest of the Valley floor, with gentle slopes and numerous drainage channels, many of which are well defined.

In the foot-hill area the differences in levels are so great and the slopes so steep that no general rise of the water-table, such as would require or could be controlled by a unified drainage system, is possible. In this area the soil is underlain at relatively shallow depths by the undecomposed country rock. In some instances ground water accumulates on the surface of this rock, with the result that depths to the water-table are relatively shallow.

The Desert area is not important from an orchard standpoint and has not been studied to any considerable extent.

The main portion of the Valley floor consists of comparatively flat terraces, sometimes several miles wide, although often much narrower. The water-table under these terraces is continuous throughout large areas, and in some instances can be controlled by unified drainage systems. Orchards are grown throughout a large part of the Valley.

Soils. The soils of the Valley are divided into three main groups: (1) residual, (2) old alluvial, and (3) recent alluvial soils. The report of the survey made in 1911* describes and maps 43 soil types.

The residual soils are those derived from disintegration of parent material in place. These soils, owing to mode of formation, are confined largely to the more mountainous and hilly districts, and occupy the smallest area of any group of the district with which we are chiefly concerned. This group is made up, for the most part, of heavy sticky soils.

The old alluvial soils comprise those of that very large area forming the first bench of the Valley. Some of the old deposits have become consolidated into cemented, densely packed, erosion-resistant types, such as are found on the Desert.

The recent alluvial soils are found chiefly along the channel of Bear Creek or along the western edge of the Valley at the base of the hills, where material from the higher slopes has formed numerous alluvial fans.

These soils are locally differentiated by the names "sticky," referring to the heavy, clayey residuals and older alluvials; "free," referring generally to transported alluvial or mixed alluvial and colluvial material; "granite,"

*U. S. Dept. of Agr., Bureau of Soils. Soil Survey of the Medford Area, Oregon, 1913, by A. T. Strahorn, L. C. Holmes, E. C. Eckmann, J. W. Nelson, and L. A. Kolbe.

referring to that coarse porous soil making up some of the alluvial fans along the west and south sides of the Valley; and "desert," referring to those having the consolidated cemented subsoil. The sticky soils are further qualified as "black" or "red."

Climate. The rainfall of the Medford region occurs mainly during the colder season, as appears in Table I. It is evident from this table that the rainfall of the past two seasons has been below normal. Water-table conditions are undoubtedly worse during years of greater precipitation.

TABLE I. MONTHLY AND ANNUAL PRECIPITATION IN INCHES AT MEDFORD, OREGON

(From U. S. Weather Bureau Records)

Month	Fifty-year normal	1929	1930
	Inches	*Inches*	*Inches*
January	2.78	1.47	2.45
February	2.36	0.24	1.59
March	1.70	0.93	0.49
April	1.25	1.54	1.09
May	1.21	0.41	0.82
June	0.73	2.54	0.12
July	0.36	......	T
August	0.24	......	T
September	0.52	T	1.58
October	1.34	1.14	0.30
November	2.48	0.02	2.17
December	3.11	6.45	1.06
Annual	18.08	14.74	11.67

Water used for irrigation. Little information is available as to the actual use of water on the orchards of the Valley. It is certain that the average is not excessive as the gross duty for the three irrigation districts covering the area studied was 2.09 acre-feet per acre during 1929. Since water is not measured to the users, and since soils, individual irrigators, and crops vary greatly, the use on different farms covers an extremely wide range. Measurements made during 1929 and 1930 show extremes of 3.3 and 14.2 acre-inches per acre for single irrigations, and of 4.7 and 42.8 acre-inches per acre for the season. On those fields where the larger amounts of water were used there was certainly a great loss of water by deep percolation. Very considerable losses from seepage occur in the canal systems. Together, these losses cause the summer rise in the water-table noted hereafter.

FIELD STUDIES

Water-table survey. The first step in the study was to determine the position of the water-table in the agricultural lands of the Valley. This survey was made by measuring the distance from the ground surface to the water surface in a large number of domestic and other wells and finding the elevation of the ground surface at these wells by running lines of levels from the established bench marks of the United States Coast and

Geodetic Survey. Approximately 90 semi-permanent bench marks were established throughout the Valley as part of this work.

In order to determine the seasonal fluctuations in the water-table the depths in approximately 160 of the wells have been measured at frequent intervals throughout the course of the study. Conceptions of ground-water conditions have been obtained by studying the data in each of six topographic divisions of the area. These divisions are as follows:

1. That area east of Ashland, bounded on the north and east by Bear Creek, on the south by the more abrupt hill slopes, and on the west by the city of Ashland.

2. That area south and west of Phoenix, bounded on the east by Bear Creek, on the north by Coleman Creek, on the west by Talent Lateral, and on the south by Wagner Creek.

3. That area south and west of Medford, bounded on the east by Bear Creek, on the north by the Medford-Jacksonville highway, on the west by the first line of hills, and on the south by Coleman Creek.

4. That area northwest of Medford, bounded on the east by Bear Creek, on the west by Jackson Creek, on the north by the confluence of the two creeks, and on the south by the Medford-Jacksonville highway.

5. That area west of Jackson Creek, extending from Jacksonville to Rogue River, bounded on the south and east by Jackson Creek and Bear Creek, on the north by the Pacific highway and on the west by the "Old Stage" road.

6. That area called "The Desert" bounded on the southeast by the Medford-Crater Lake highway to the Snowy Butte store, on the south by the road running east from this store, on the east by the first range of hills, on the northeast by Antelope Creek and Little Butte Creek, on the north by Rogue River, and on the west by Bear Creek.

Water-table fluctuations. Figure 1 shows the average depth to water as indicated by the well measurements in each of these divisions for each month during the period August 1, 1929, to October 1, 1930. The curves in this figure are plotted from the average depths in from 7 to 31 wells in the respective groups. The curves show, in general, the fluctuations of the water-table throughout the season but do not show the depth to water in the greater part of the areas represented. In each of the divisions except division 6 the records of a few wells in which the water stands far below the surface are included in arriving at the average. The data from these wells balance the data from a larger number of shallower wells.

In general, the water-table has fluctuated in a similar manner in each division of the area. It fell to the lowest level of the period studied in December, 1929, then rose to a peak in February or March, and fell off at the end of the winter rains. In each division the irrigation during the summer of 1930 caused a rise or at least a halt in the fall of the water-table. In division 2, south and west of Phoenix, the summer peak is much higher than the winter peak, unquestionably because of the seepage from irrigation ditches and deep percolation losses from irrigated fields. In this section the most serious troubles with the ground water come during the summer and are directly traceable to percolating irrigation water.

In none of the other divisions was the summer peak as high as the winter peak. At first this would seem to indicate that irrigation had not increased the need for drainage to any marked extent over the area as a whole, but two important facts tend to make this conclusion doubtful. First, the supply of irrigation water during the summer of 1930 was much below normal. That this shortage had a marked effect on the water-table is evident from the fact that in all divisions the water-table was lower in September and October, 1930, than in the same months of 1929, and in all but division 5 the same is true for the month of August. With a normal

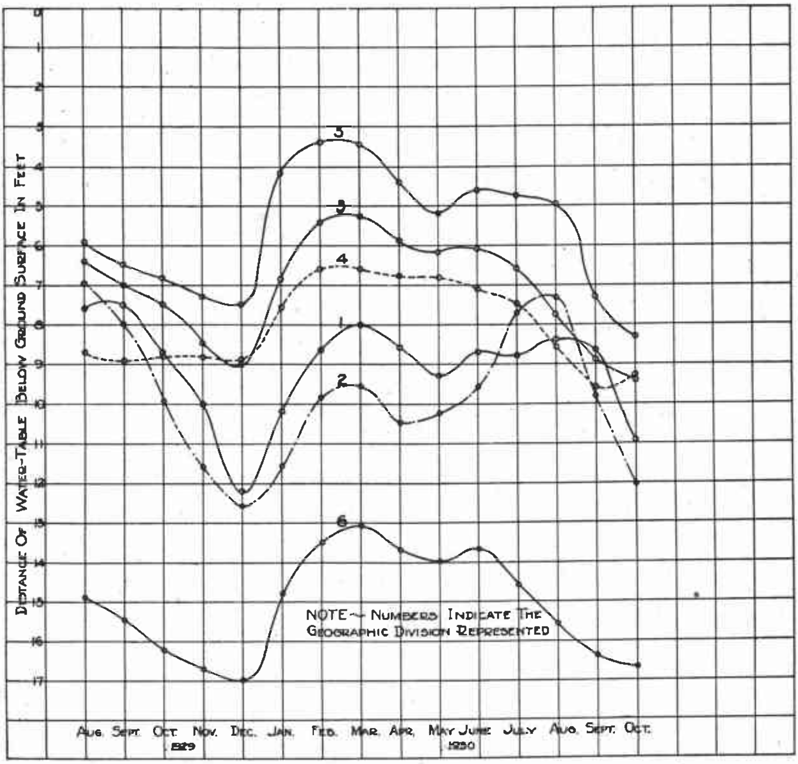


Figure 1. Water-table fluctuations in six divisions of the Medford area.

supply of irrigation water, the summer peak of 1930 would doubtless have reached a higher stage than that shown by the curves and in most instances probably would have exceeded the winter peak. Second, the curves show that, except in division 4, the water-table fell sharply after the close of the 1929 irrigation season until the beginning of the winter rains, and again after the cessation of the winter rains until the beginning of the irrigation season. It appears probable that if there were no irrigation the water-table would fall continuously, although perhaps more slowly, from the end of one rainy season until the beginning of the next. It seems probable that, as a result, the water reaching the ground water from the winter rains would not be sufficient to bring the water-table as near the surface as do the summer irrigation and winter rainfall combined.

Water-table map. The well data clearly indicate that in certain portions of the Valley the water-table approaches the surface so closely that serious damage to orchards has been caused, or may be expected, wherever local conditions favor such a result. Conditions are so variable that no survey of this nature can show in detail what individual orchards or tracts of land are injured by the high water-table; but the survey does show, in general, in what areas there is a likelihood that unfavorable growth conditions in an orchard are due to this cause. Furthermore, the fact that the water-table as located by this survey is at a safe depth below the ground surface in any section is not proof that every small area and individual orchard in that section is free from ground-water troubles.

Plate I shows those areas where the mean depths to the ground water, as indicated by the well measurements made February 1, 1930, were (1) less than 5 feet; (2) between 5 and 10 feet; and (3) more than 10 feet from the surface. In the unshaded portions of the map either data are not available to show the average depth or the depths vary so widely from point to point that the average depth is without significance.

The great extent of the area in which the average depth to the ground water was less than 5 feet indicates the far-reaching character of the drainage problem. The data are not sufficiently complete and the scale of the map is not large enough to show the conditions on individual tracts of land. Where the general level of the water-table is less than 5 feet from the surface, however, there are a great many individual tracts where the depth of unsaturated soil in which tree roots can grow is extremely limited. Such tracts need drainage. One object of this report is to emphasize the need for every grower to determine for himself whether his orchard is in this condition. Even outside of those areas where the general level of the water-table is close to the surface, many tracts are in need of drainage.

While the map shows the position of the water-table during the winter, a map showing the conditions during the peak of the irrigation season would be very similar. The areas having the high ground water are not quite so large but occur at about the same places and are of about the same shape.

Orchard survey. In order that a definite estimate of the areas in orchards which may be in need of drainage might be obtained a crop survey was made. The results of the survey of orchards on the area included in the water-table study are given in Table II.

In the winter of 1930 one-third of the area in orchards within the districts studied had depths to the water-table of less than 5 feet, and another one-fourth had depths to the water-table of from 5 to 10 feet. This shows the great importance to the orchardists of making ground-water investigations in all orchards where unsatisfactory results are being obtained in the growth of trees or production of fruit and in all tracts where new plantings are contemplated.

TABLE II. DEPTH TO THE WATER-TABLE IN ORCHARDS OF A PORTION OF THE MEDFORD AREA

Depth to water-table*	Acreage in orchards†	
	Area	Percentage of total acreage
	acres	%
Area having less than 5 feet	3,000	34
Area having between 5 and 10 feet	2,290	26
Area having more than 10 feet	3,440	39
Area having undetermined depth	90	1
Total acreage	8,820	100

*On February 1, 1930.
†Crop survey of 1930.

RELATION OF WATER-TABLE TO ORCHARDS

Effect of high water-table. A high water-table is injurious to growing fruit trees regardless of whether it occurs during the summer or winter. In either case it reduces the development and growth of roots in the subsoil, with the result that the trees are obliged to draw their moisture and plant foods mainly from the shallow layer of surface soil above the saturated zone. If the roots have penetrated into the subsoil during dry periods and the water-table afterwards rises, submerging that zone, and remains high for a considerable period of time, many of the roots in the saturated soil may die or be seriously injured. The smaller feeding roots are particularly subject to injury. As a result the growth of the tree is retarded and the development of fruit is adversely affected.

Usually the first visible injury occurring in a bearing orchard is a cessation of growth. Trees in a wet spot will fail to show any new growth for a year or two. The next indications are generally the "die-back" of a few branches and the appearance of sparse, yellowish foliage. Gradually more branches die until finally the whole tree is gone. Often trees will remain alive for many years but will make little or no growth. The trees shown in Figure 2 illustrate this gradation. The one on the right shows healthy foliage but not much new growth, the center one shows some dead branches and very scanty foliage on others, while the third tree is completely dead. This group shows the typical spreading of trouble outward from a low spot as the water-table rises.

Certain physiological troubles in the fruit such as "drouth spot" and "black end" also may be associated with a high water-table. If the ground water is close to the surface, the volume of soil from which the trees can draw moisture is limited and during especially hot and dry periods they may not be able to obtain water fast enough to keep the fruit growing properly.

Figure 3 shows the effect of a high water-table on a growing orchard. Both photographs were taken in the same orchard and at the same distance from the trees. The trees are of the same age, are on similar rootstocks, and have had uniform treatment. The soil is similar throughout the orchard. The only apparent difference is in ground-water conditions. During the winter months the water-table has stood within 2 feet of the surface in the section of the orchard shown at A and 5 or 6 feet below the surface in the area shown at B. Contrasts between fruit crops raised on areas having poor drainage and those obtained on well-drained areas are equally striking.

Required depth of water-table. No absolute limit can be put on the depth at which the water-table must be maintained for the satisfactory growth of trees. Many factors, such as the length of time the water-table

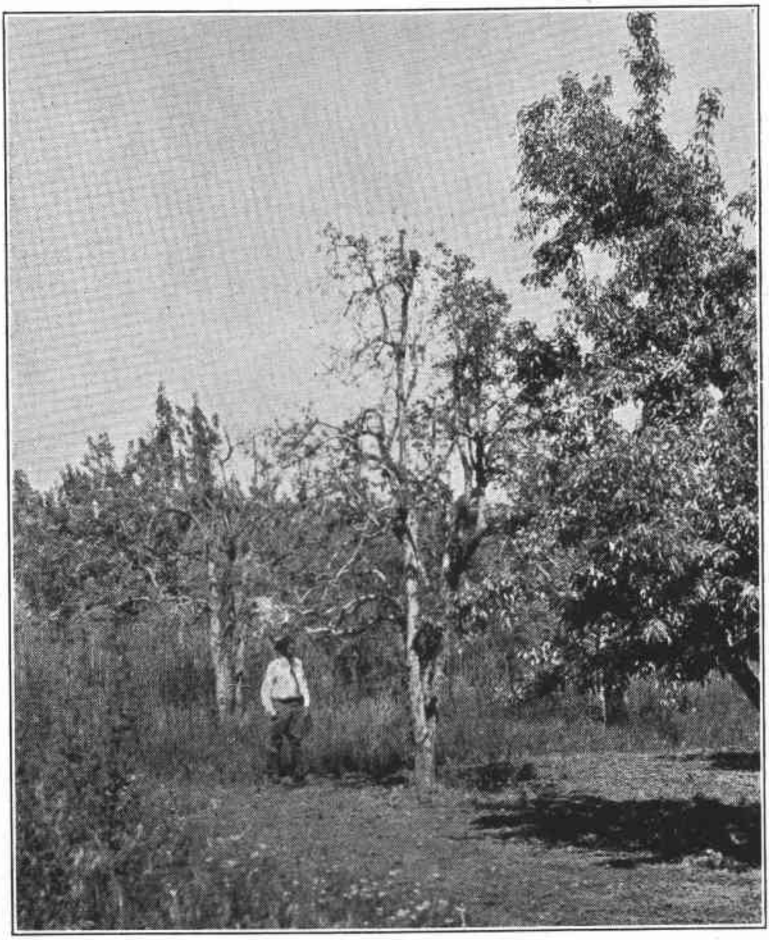
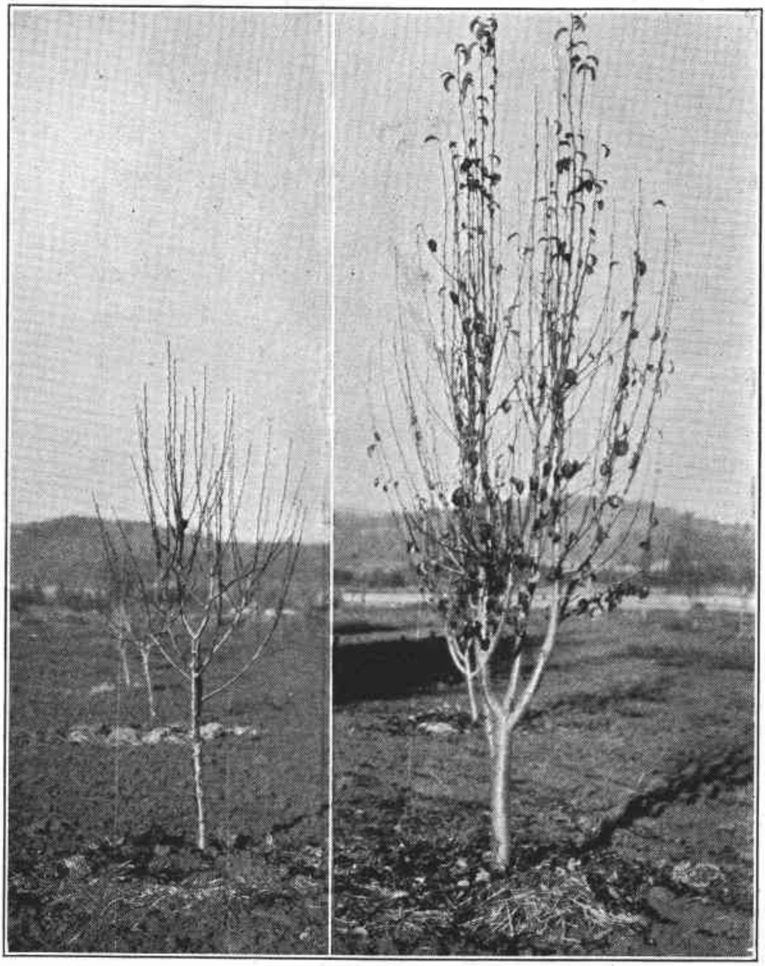


Figure 2. Effect of high water-table on bearing pear trees.

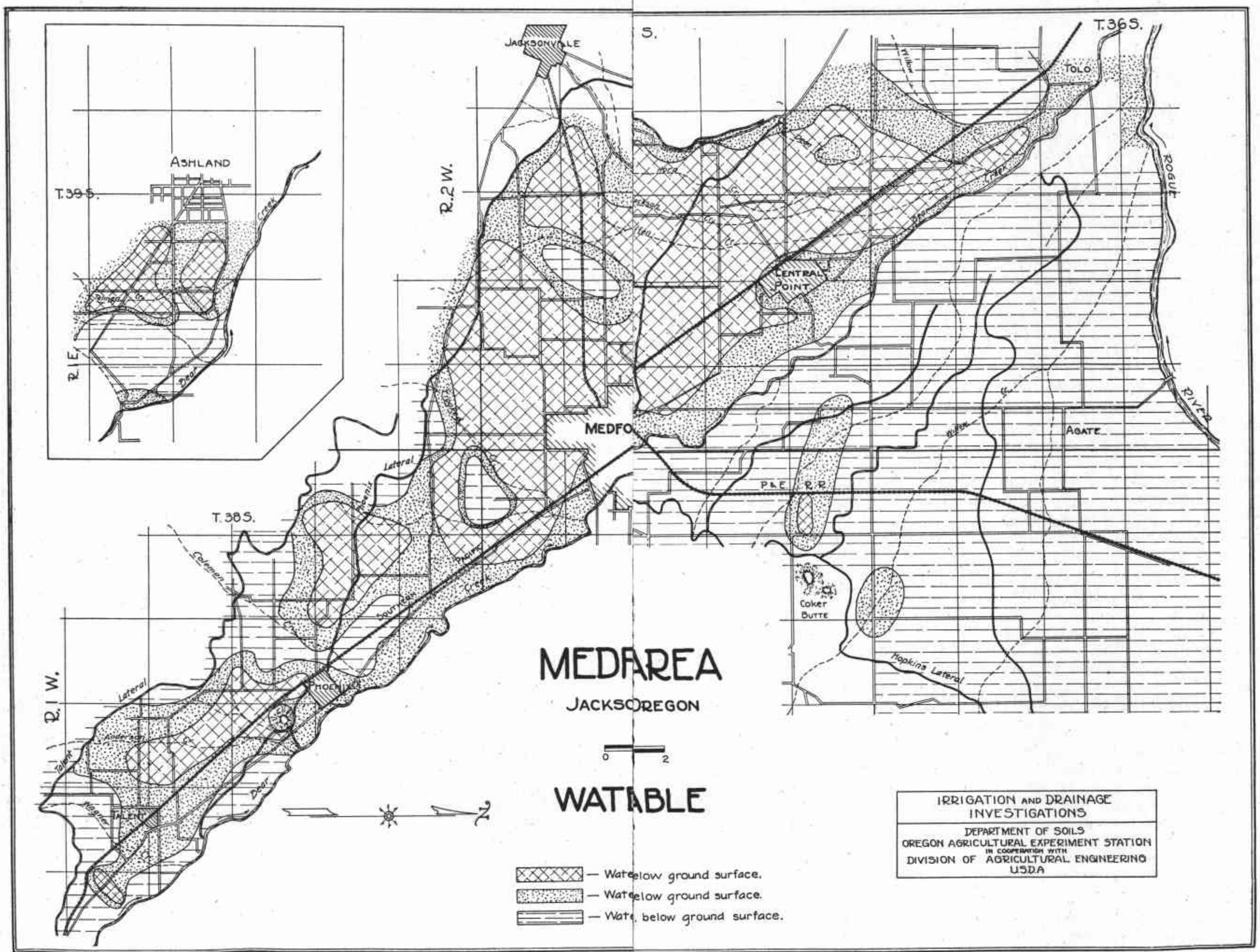
remains near the surface, the character of soil and subsoil, the rootstock on which the trees are grown, the lack or the sufficiency of irrigation water, whether the water-table is high when the trees are planted or not, serve to make difficult any determination as to the minimum depth at which the water-table may be held without danger of harmful results.

The water-table should be 6 or 8 feet below the surface throughout the year for ideal conditions where the soil is somewhat uniform and permeable for roots to that depth. If the water-table rises near the surface during heavy irrigations or rains, and falls again to a safe depth within 3 or 4 days, no harm is done. It is known that submergence for a few weeks, however, even during the dormant season, will kill the small fibrous roots and may



A. Region of high water-table. B. Region of low water-table.
Figure 3. Effect of water-table on growing pear trees.

kill larger roots. The root hairs, which function in the absorption of water, will be the first to die, and the destruction of any large proportion of them will hinder plant growth.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JACKSOREGON
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WATABLE
IRRIGATION AND DRAINAGE INVESTIGATIONS
DEPARTMENT OF SOILS
OREGON AGRICULTURAL EXPERIMENT STATION
IN COOPERATION WITH
DIVISION OF AGRICULTURAL ENGINEERING
USDA
— Watelow ground surface.
— Watelow ground surface.
— Wat, below ground surface.
JACKSONVILLE
MEDFO
CENTRAL POINT
TOLO
AGATE
Coker Butte
PHOENIX
TALENT
ASHLAND
T.36S.
T.38S.
T.39S.
R.2 W.
R.1 W.
R.1 E.
ROGUE RIVER
P&E R.R.
Hopkins Lateral
Lateral
Bear Creek

If the subsoil is a coarse sand or gravel, or is so hard or impervious that roots can not penetrate it, the presence or absence of a water-table in the subsoil can, of itself, do no harm. A permanently high water-table under such conditions may hinder drainage, however, and thus create a temporary condition of saturation in the surface soil which would be harmful.

Certain rootstocks, notably the Japanese seedlings used for pears, are especially susceptible to injury by reason of a high water-table. Rather paradoxically, a high water-table may be more injurious where irrigation water is not available than where orchards are irrigated frequently. The reason is that in orchards where the ground water is near the surface the feeding zone of the roots is limited to a shallow depth. Without irrigation the soil in this shallow zone dries out quickly. The trees are unable to obtain all they need from the saturated subsoil because they have no roots in that zone, and capillary action is too slow to bring the moisture in sufficient quantities up to the main feeding zone. This condition especially prevails where the water-table remains close to the surface for several weeks during the winter and early spring, and drops to a considerable depth during the summer. Under such conditions drainage which will keep the subsoil from becoming saturated during the winter or spring is essential for successful fruit production.

For these reasons it is impossible to set a definite depth at which the water-table should be held. Experience leads to the suggestion that the possibility of a need for drainage be considered wherever the water-table is less than 5 feet from the ground surface. Healthy orchards are found where the water-table is permanently within that distance and also where, for considerable periods, the soil is saturated almost to the surface; but in such instances special conditions make this possible. On the other hand, trouble is very likely to be encountered with some or all of the trees in an orchard where the water-table remains for long periods above this depth.

TYPICAL DRAINAGE PROBLEMS

In addition to the general survey of water-table conditions in the Medford area, detailed studies have been made of the drainage problems of a number of individual orchards. These studies indicate that several characteristic problems recur in various sections in the area, either alone or in combination. The drainage systems which will best solve the problems vary materially.

Flat wet areas. Perhaps the most common dangerous condition found is where the water-table is close to the surface over a comparatively large, flat area. In such tracts rather large blocks of trees and perhaps whole orchards may show distress caused by ground-water conditions. The trees may have made very poor growth as compared with similar trees on better-drained soil. If such trees are dug out, the roots are found only in the shallow surface soils, or if there are any deeper roots they are found to have been killed, or at least to be in an unhealthy condition.

Here, the trouble may be corrected by means of what are known as collecting drains. In laying out a drainage system for such a large flat area, a comparatively large number of test holes should be bored to determine at what depths the most porous strata lie. If a porous layer can be found at a depth of less than 8 feet from the surface, the collecting drain should, if possible, be laid in that stratum.

Relief wells. If the porous material lies at still greater depths, it will be necessary to bore relief wells into the water-carrying strata in order that the ground water may easily pass upward into the tile line. Such wells should be bored in the bottom of the tile trench and then either filled with coarse gravel or a vertical stack of tile. They can best be bored by using a posthole auger with an extension handle.

Figure 4. Boring relief well in bottom of tile trench.

Figure 4 shows a pressure relief well being bored in the bottom of a collecting tile line into a deeply buried porous stratum. Such wells are effective in lowering the water-table when most of the water is carried in gravel or sand strata at depths of from 10 to 15 feet. If it is impossible to obtain an outlet at sufficient depth to permit laying the collecting tile in a fairly deep porous stratum, the tile must be laid at the greatest depth possible and relief wells used.

Depth and spacing of collecting drains. The depth and spacing of collecting drains will depend on the character of the soil and subsoil. In the coarser soils such collecting tile may be placed at considerable distances apart, perhaps as much as an eighth of a mile, or even a quarter of a mile in extreme cases. Such porous material is rather rare in the Medford area, however, and the depth of drains will usually not warrant spacing greater than 500 feet. In the case of the finer soils which do not have sufficiently porous subsoils it will be necessary to lay tile very much closer together, and at somewhat shallower depths.

Drainage of "sticky" soils. Where the tile must be laid in comparatively impervious material, the tile should be "blinded"—that is, covered in the trench—with clean gravel to a depth of from 4 to 6 inches above the top of the tile. In the case of extremely tight subsoils it may be necessary to back-fill the whole trench with porous material. Loose rock is sometimes available for this purpose. In other cases it is desirable to fill the trench nearly to the surface with prunings or other coarse organic material which will not decay rapidly.

In the case of the very sticky soils which lie directly on the bed rock, there is still some question as to the efficiency of subsoil drainage and in those instances every care should be taken to prevent the entrance of excess water. In any case, an effort should be made to find any porous layers existing within reasonable depths and to tap them with tile lines or relief wells.

In certain sections extremely tight subsoils prevent the water which collects in the surface soil from draining downward into more porous

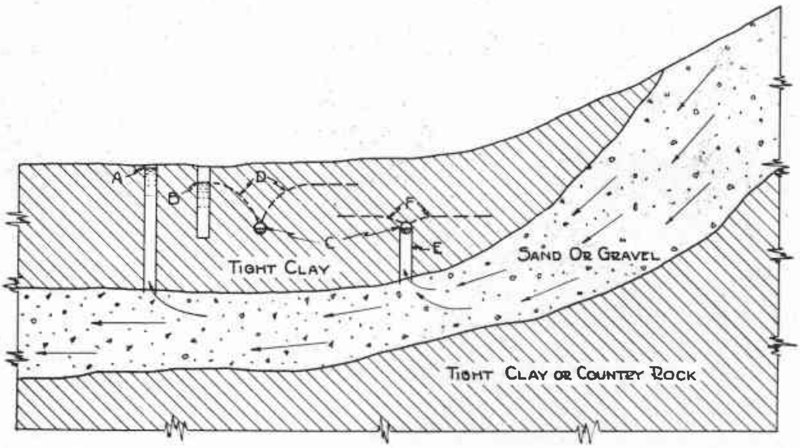

Figure 5. Effect of relief well in lowering the water-table.

strata which would permit deep drainage. This condition causes the soil to become saturated, even when the deeper strata are not full of water. Such a condition gives rise to a false, or perched, water-table near the surface, while the true water-table may be much lower. Studies are under way with a view to a determination of the best methods of relieving this condition. With proper irrigation methods there should be no difficulty with such a perched water-table during the summer months. With respect to a comparatively heavy winter rainfall, which sometimes occurs in the Medford area, there will be difficulty in correcting this condition. The possibility of using "mole" drains should not be overlooked.

Drainage of draws. Another type of drainage problem occurs where seepage from canals or from higher land is concentrated in shallow draws. In such cases trouble is first experienced with the trees at the center of the draw. If remedial measures are not taken the trouble spreads and a rather wide strip may eventually be injured. Figure 2 illustrates a typical case of this kind.

The proper method of relief for this condition depends on the topography and subsoil conditions. If the seepage from the canal or from the higher land is flowing along the surface of an impervious layer at a comparatively shallow depth, an intercepting drain just below the canal or along the upper edge of the orchard affected will be the best method of meeting the situation. Such an intercepting drain must be placed just on the surface of the impervious subsoil. If the overlying material is comparatively loose, no special effort will be necessary to obtain percolation. If, however, the overlying material is itself comparatively impervious, the tile should be blinded, as previously described, by the use of gravel or other porous material.

In some instances the underlying impervious stratum will be too deep to be reached by an intercepting drain. In such cases the drainage will necessarily be more nearly of the collecting type. If the draw is narrow and the cross slopes comparatively steep, a single line of tile down the center of the draw may be effective. Here again the necessary depth and spacing will depend upon the character of the subsoil. If the draw is wide and flat, a tile line down each side, or possibly even more lines, will be required. Here again every effort should be made to place the tile in the porous layer if there is one at a reasonable depth. If the porous layer occurs at a depth too great to permit of laying the tile upon it because of the excessive cost of excavation or the location of the outlet, relief wells may be useful.

Percolating irrigation water. The water-table survey has shown quite clearly that in certain areas canal seepage and the irrigation of higher land has caused a cumulative rise in the water-table. Owing to the fact that the well records in this study cover little more than a single year, one of unusually low precipitation during which the irrigation water supply was extremely short, sufficient data to show the net rise which may be expected from year to year are not available. A ground water-level curve for certain sections in the Medford area similar to those shown in Figure 1, but covering a period of years, would show two peaks and two valleys. Each year's winter rainfall causes a peak which is not common in the more arid regions. The curve would probably show that each season the water-table rose a little higher than it did the previous season, and that it would eventually reach the surface unless drainage conditions were improved.

Where the saturated condition is due to an accumulation of ground water covering a period of years, it will often be possible to obtain relief by collecting the excess water at the most convenient places. Ordinarily this will mean that comparatively deep drains will be used in those tracts where the porous strata come near enough to the surface to make such drains effective.

In such areas the drainage problem is distinctly a community problem, since the excess irrigation water is the cause of most of the trouble. Relief from such a rising water-table can best be obtained by the construction of a sufficiently comprehensive system of drains, covering the whole of the tract affected. The best organization for obtaining such relief is a drainage district organized under the state law. The cost of such a drainage system may be properly apportioned among the various landholders, including those who are contributing to the problem and yet whose land is not injured. This type of organization is especially desirable where comparatively long and expensive outlet drains are required.

Artesian conditions. A common condition in the Medford area, as well as in many other sections, is found where the water is traveling in a relatively deep, porous stratum, under sufficient hydrostatic head to force it almost, if not quite, to the surface. Figure 5 illustrates this condition. Very often the drainage problems most difficult of solution are of this character. Instances have been found in the Medford area where the water-table stands practically at the surface of the ground within a very few feet of drains which are reasonably deep and otherwise satisfactory. The reason is that the water is rising through the soil owing to the pressure from below. It can be shown that under such conditions tile drains will be effective for only a very short distance on each side, regardless of the character of the drain itself or of the back-filling in the trench. Where this condition is encountered, some means must be found for relieving the underground pressure. In most instances thus far investigated in the Medford area this can readily be done by means of the type of relief well discussed heretofore. Such relief wells must be bored to the pervious stratum which is carrying the underground water, and must be located at intervals sufficiently close to relieve that pressure.

Springs. In certain areas the ground water comes to the surface in distinct springs, or small seeped spots. In most cases these spots are due to the movement of the ground water through crevices in the country rock. The source of the water may be the winter rainfall on the higher ground, or it may be seepage from the canals or deep percolation from irrigated fields. In any case, it often travels at such great distances beneath the surface that it is impossible to intercept the flow by tile lines laid at economically practicable depths. In such cases the only means of relief is by tapping the springs at the point where they appear on the surface. If the country rock is very close to the surface it may be possible to tap the spring by digging a trench directly to the crevice or source and carrying the water off in a tile drain or into a neighboring surface drainage way.

In other instances the water may spread over a considerable area—perhaps an acre or more. In such cases relief is best obtained by placing an intercepting tile around the upper edge of the wet area. In every case borings must be made to determine as nearly as possible the source of the water. In some instances such wet spots or springs are due to the outcropping of a porous stratum, such as is illustrated in Figure 6B. When this is the case the best location for an intercepting tile line is along the upper edge of the wet area, far enough up the slope so that the tile may be placed at the bottom of the porous stratum, and at a depth of from 4 to 7 feet from the ground surface. In such cases, the problem of obtaining a satisfactory outlet is usually very simple as the springs occur on the steeper slopes and the tile may be carried out to a natural drainage way within a comparatively short distance.

SUMMARY OF DRAINAGE METHODS

In the main, the problem in the Medford area is one of underground drainage. There are instances, however, where surface drainage would be highly beneficial. In parts of the Valley it has been customary to dump prunings and other rubbish into the natural drainage channels, with the result that the channels are almost completely filled. This practice is especially detrimental in those areas where the water-table is close to the surface and the soils are porous enough so that the natural drainage channels would, if left in their natural deep state, furnish satisfactory drainage. It would be highly desirable to clean these channels out to at least their original depth.

On the very tight, sticky soils it is advantageous to supply sufficient surface drainage so that the winter rainfall is carried off before it has an opportunity to soak into the soil. This practice is now carried on by some orchardists and might profitably be extended to other areas.

Deep drainage may be effected by means of either tile or open ditches. In the Medford area open ditches should be used only as outlets for comparatively large areas. The objections to open ditches are that they take up valuable land and are hard to maintain. Moreover, in addition to the expense and difficulty of maintaining open ditches is the still more important fact that such maintenance is almost always neglected. It is very exceptional to see a deep, open drain that is properly maintained over a period of years. The drainage problem in the Medford area is thus seen to be chiefly one of the use of tile drains. Such drains may be classified in general as collecting, intercepting, and pressure-relief drains.

Intercepting drains. Wherever it is possible to intercept the flow of underground water before it comes near enough to the surface to cause serious injury, this is by far the best plan. Intercepting drains are useful either where the ground water is traveling through a definite porous stratum or where it is traveling down the slope on the top of an impervious layer—in each case within a reasonable distance from the surface. In the former instance intercepting drains should be located where the greatest depth of porous material and the greatest depth below the water-table can be obtained with the selected outlet and at reasonable cost. Where the water is traveling on the top of an impervious stratum, intercepting drains should be laid at the surface of that stratum near the upper edge of the area to be protected, as illustrated in Figure 6A.

To attempt to intercept the flow of water from higher land or from canal seepage is useless unless the drains can be located either at a considerable depth in a porous stratum carrying water or on the surface of an impervious stratum on which the water flows. In some instances it has been suggested that canal seepage might be intercepted by a deep drain at the foot of the canal bank. Unless such a drain penetrates deeply into the water-table or reaches an impervious stratum on which the water is traveling, it will be of little if any value.

Collecting drains. Collecting drains are constructed in wet areas and are intended to skim off the water lying too near the surface to permit successful crop production. In some instances they are laid in fairly porous material and will draw off water lying above the plane in which they lie.

The spacing and depth of collecting drains depend partly on the topography of the ground, but more especially on the character of the soil and subsoil in which they are placed. In the porous soils of the Medford area collecting drains should be placed at depths of approximately 6 or 7 feet and with spacings of from 400 to 600 feet. Where the surface soil is underlain by a comparatively tight subsoil and this by porous strata of sand or gravel at varying depths—the usual condition found in the Medford

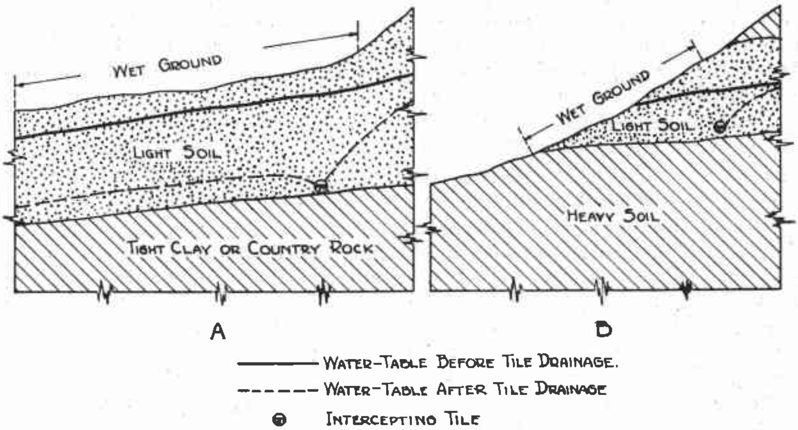

Figure 6. Illustrations of the use of intercepting drains.

area—it is necessary to locate collecting drains in such manner that they will cut the porous strata as often as possible. If the porous stratum is within about 8 feet of the surface, the drain should be placed in it. If the porous material lies at a greater depth, down to about 15 feet, the drain should be located at a moderate depth, usually about 6 feet, with relief wells bored into the porous substrata. Such relief wells can be bored by means of posthole augers with extension handles, and should be filled with coarse gravel or with vertical lines of tile.

CONSTRUCTION

All tile should be laid carefully to grade in order that the carrying capacity may not be reduced by the accumulation of silt at low places. This is especially necessary where the grade of the tile is flat. The grade line should be laid out with a surveyor's level. Figure 7 shows the so-called grade boards, all of which are set at certain distances above the bottom of the trench. A mason's line stretched from board to board over the center of the tile line serves as a guide in digging the trench and laying the tile to grade.

Wherever such tile is laid in very impervious soil it should be covered with gravel or other porous material. Gravel is much to be preferred, and should be applied to a depth of from 4 to 6 inches over the top of the tile. In fine sandy or silty soils such a gravel covering is useful in preventing the entrance of silt into the drain. All of the water collected by a line of tile enters at the joints, practically none seeping through the walls of the pipe itself as tile of the best quality is not porous. Even with joints made as close-fitting as possible—a precaution necessary to prevent the entrance of sand and silt—water will enter freely. Excavation of the trench should

Figure 7. Excavating trench for drainage line.

start at the outlet and should proceed upstream. Each day the tile should be laid in the section of the trench that has been completed that day. In fact, if the walls of the trench tend to cave badly it may be necessary to follow the excavation with tile laying even more closely. There is always the danger in the irrigated regions of irrigation waste water breaking into the trench. Certain Oregon soils, moreover, harden as they dry, and it becomes very difficult to grade the bottom if the trench is left unfinished for any considerable time.

The use of tile smaller than 6 inches is not recommended in any case. Objections to smaller tile are: insufficient carrying capacity, ease of displacement in the soil, and liability to obstruction. In the Medford area 6- to 12-inch tile are most commonly used.

The size of the tile to be used should be carefully estimated with reference to the character of the water-bearing stratum, the source of water, the area served, and the grade on which the lines are laid. Table III indicates the maximum length of a single tile line of any one size, or the total length of several tile lines, below which it will be necessary to increase the size of the tile. As indicated in this table, the capacity of the tile varies with the slope. The total length of a tile line, including branches, above any point in a drainage system should not exceed the maximum length given in Table III for the size of tile and the grade at that point.

TABLE III. MAXIMUM LENGTHS IN FEET OF TILE LINES ON VARIOUS GRADES

Size	Grade in feet per thousand feet			
	1	2	4	8
6-inch	1000	1500	2000	3000
8-inch	2000	3000	4500	6500

No tile should be laid on a grade flatter than one foot in a thousand. If smaller than 6-inch tile is used, which is *not* recommended, the minimum grade must be 2 feet per thousand. Owing to the natural slopes in the region it will seldom be necessary to lay tile on the minimum grades.

Drain tile. Whether concrete or clay tile is used it should be of good quality. Drains in the Medford area are nearly always laid at greater depths than is common in humid areas, and therefore will be more expensive to replace if for any reason they fail. In the past some trouble has been encountered because of the disintegration of concrete tile in this area. For these reasons it is believed that the poorer grades of tile should not be used. It is recommended that any drain tile used should meet the specifications of the American Society for Testing Materials for "Standard Drain Tile." These specifications require that tile 6 to 12 inches in diameter shall have a minimum supporting strength of 1,200 pounds per linear foot. Water absorbed in undergoing the standard test, which requires boiling in pure water for five hours, must not exceed 13 percent for clay tile or 10 percent for concrete tile.

Tile should be carefully inspected and should meet the following specifications:

> "Drain tile shall be substantially uniform in structure throughout, and the inspector shall investigate this property by examining fractured surfaces.
>
> "Drain tile shall give a clear ring when stood on end and while dry tapped with a light hammer.

"Drain tile shall be free from cracks and checks extending into the body of the tile in such a manner as to decrease the strength appreciably. Tile shall not be chipped or broken in such a manner as to decrease their strength materially or to admit earth into the drain."*

Tile outlets should terminate in small concrete structures, in order that they may not be washed out. The importance of keeping the tile outlet and the ditch below free from obstructions can not be too strongly stressed. Submergence of the outlet for short periods may be unavoidable in some cases, but submergence or obstruction for any long period of time may render the drain useless.

Sand traps or manholes should be used whenever there is a change from a steeper slope above to a flatter slope below. Manholes or inspection holes at frequent intervals throughout the system are useful in order that a continuous check may be kept on the working of the tile lines.

Drainage problems in the Medford area are not easily solved and a competent engineer should be employed whenever more than a few hundred feet of tile are to be laid. Such an engineer will be able to save an amount more than his fee in designing and laying out a system which will secure satisfactory results.

Drainage costs. The cost of installation of drainage systems under local conditions varies greatly. Costs on a number of projects undertaken in 1930 ranged from 22¢ to 50¢ per running foot for the complete job, exclusive of engineering advice. In general, it is more costly to construct drains by hand than by machine.

The average costs for drainage systems within a radius of 8 miles of Medford are about as follows:

6-inch tile, 27¢ per running foot
8-inch tile, 32¢ per running foot
10-inch tile, 38¢ per running foot
12-inch tile, 48¢ per running foot

These amounts include excavating to a maximum depth of 5½ feet, tile cost (concrete tile), hauling, laying, and blinding tile with 4-inch cover of clean crushed gravel, back-filling, sand traps, and outlet protection. The cost of engineering is to be added to the estimates given.

On a typical 6-inch tile job, costs can be segregated about as follows:

Operation	*Cost per running foot*	*Percentage of total cost*
		%
Excavation	$0.12	44.4
Tile	.07	26.0
Hauling tile	.01	3.7
Laying tile	.02	7.4
Blinding with gravel	.02	7.4
Back-filling	.02	7.4
Sand traps	.01	3.7
Total	$0.27	100.0

*Standard Specification for Drain Tile (C 4-24); Am. Soc. for Testing Materials; Philadelphia, Pennsylvania; 1924.

REFERENCES

Detailed instructions on the construction of drains and a more general discussion of the subject may be found in the following books and bulletins:

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