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AGRICULTURAL EXPERIMENT STATION

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FARM DRAINAGE METHODS
CONSTRUCTION
1908-1922

H. B. ROE
DIVISION OF AGRICULTURAL ENGINEERING

UNIVERSITY FARM, ST. PAUL

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(CONSTRUCTION)

By H. B. Roe

INTRODUCTION

The discussions herein are largely based on the experience of the station drainage staff in farm drainage design, installation, and maintenance from 1908 to 1922. This experience covers the partial or total installation of drainage on more than twenty farms under conditions as follows:

Total watershed concerned, 7 to 550 acres, average about 217 acres.

Total watershed affected, on one farm or a group of farms in any one project, 7 to 500 acres.

Drained areas, 3½ to 170 acres.

Counties represented, 16, well scattered over the agricultural portion of this state and eastern North Dakota.

Character of surface: rolling, 14 farms; mixed, 2 farms; flat, 8 farms; peat, 2 farms.

Character of soil and sub-soil: practically every type included from deep fibrous peat to sand and clay in almost every possible condition and combination.

Installation months, late April to November, inclusive, hence there was practically no work in frost.

Methods of construction, part of the work on three farms done by a horse-drawn machine, practically all the work on two of the largest projects and a portion of it on another of the largest done with a heavy power machine, the rest all hand work.

Size of tile, 4 to 22 inches, with a general average of 6 inches.

Depth of cut, less than a foot to 10.8 feet, average about 3.65 feet.

Amount of tile, 1650 linear feet to 10.63 miles.

Open ditches have been comparatively few and mostly small and short but dug under a wide range of soil and water conditions and by various methods.

The activities just outlined have been carried on in large part for the purpose of testing methods in order to establish efficient and reliable methods of farm drainage installation. The following discussion is therefore the fruit of experience.

CONSTRUCTION OF OPEN DITCHES

SMALL STANDARD DITCHES

Ditches with bottom width of less than 2 feet, depth of only 3 or 4 feet, and side slopes not flatter than 2 feet horizontal to 1 vertical, can usually be dug most cheaply by hand. (See Fig. 1.) In ordinary soil the best hand tools for such work are tile spades and long-handled round-nosed shovels, such as are used in tile trenching. (See Fig. 11.)

If the work is staked as suggested under "Constructing tile drains" on page 11, the ditcher can carry his grades by a system of targets similar to those used in tile ditching. (See Figs. 17 to 24.)

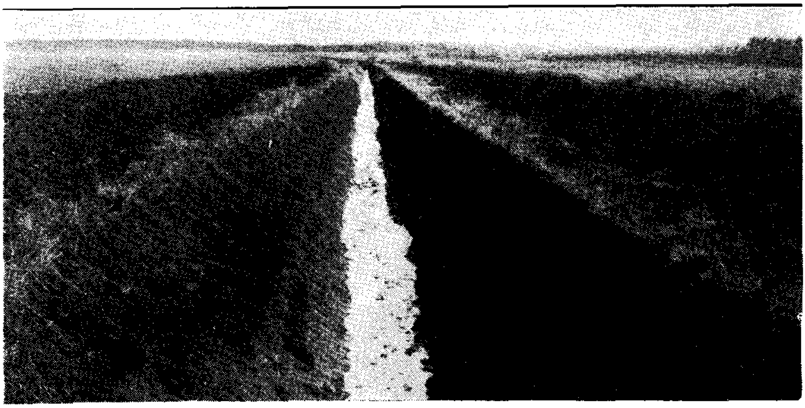


Fig. 1. A Well Built Ditch, Dug by Hand
2 feet wide on bottom, 4 feet deep

If these small ditches are very extensive it may pay to have the work done by a contractor who operates a small open ditching machine of the bucket wheel type, but the purchase of such a machine by the farmer himself is seldom justified except in case of a very large farm where the percentage of wet land is unusually high. A group of farmers might with profit own one co-operatively.

LARGE STANDARD DITCHES

Standard ditches too large to be economically dug by hand may usually be best dug by the farmer with teams, plows, and slip scrapers or wheel scrapers, the bottom and slopes being finished by hand with a spade or shovel and mattock. In such cases the ditcher can test his grade as shown in Figure 2, provided the ditch has been staked out as suggested in Figure 2.

Having reached the proper grade just opposite each stake, the ditcher can set up rough targets a fixed distance above grade, say 5 feet, in the ditch at each station and test grade between the stakes by sighting down the line of his targets over the top of a rod cut to length just equal

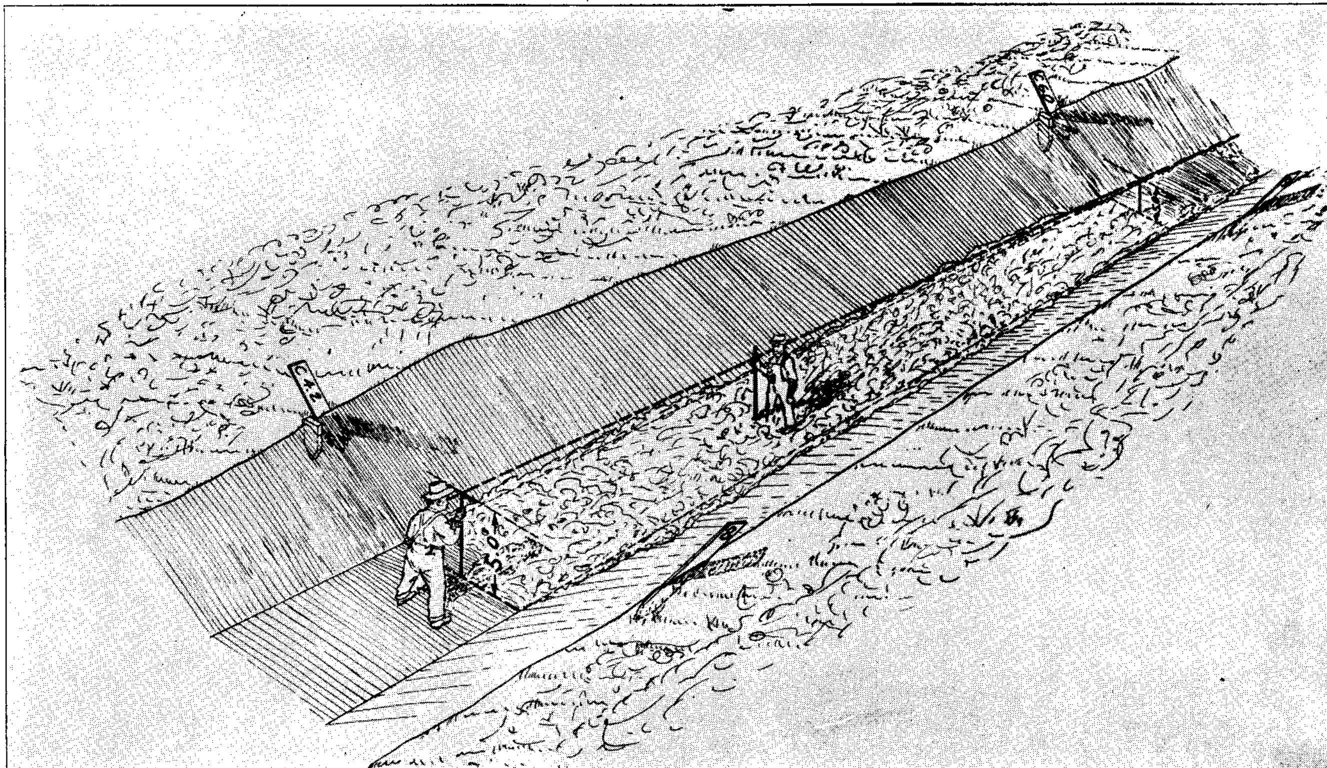


Fig. 2. Method of Testing Grade of Large Ditch Between Stakes Where Exact Levels Have Been Taken on Hubstakes Set Along One Line of Slope Stakes

to the distance he has set his targets above grade, as is done in tile trenching. In open ditching, while the bottom should be finished smooth· the grade need not be made with such nice exactness as is required in trenching for tile. As a rule variations up to ½ inch may be allowed above established grade. Even greater depressions will cause no serious trouble in an open ditch as they will usually soon fill by erosion up to the general line of the bottom of the ditch.

V-SHAPED DITCHES

V-shaped ditches are usually quite small. They may often be made with a plow run successively in the same furrow; in an intercepting ditch, always in the direction to throw the material to the down-hill side. The crumbs and loose earth may then be quickly cleaned out with a shovel.

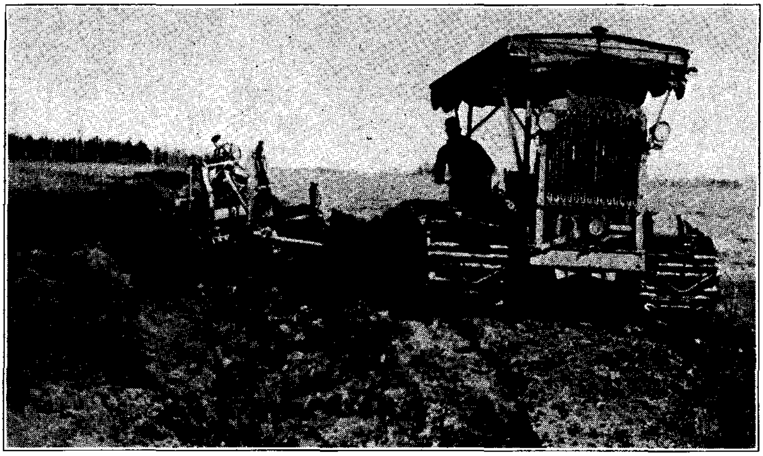


Fig. 3. Making Flood Ditches Near Meadowlands, Minn., with a 10-Foot Road Grader Drawn by Caterpillar Tractor. (Courtesy of D. & I. R. R. R.)

Fig. 4. Push Grader for Shallow Surface Ditching

Fig. 5. Digging Flood Ditches with the Push Grader Shown in Figure 4.
This machine, drawn by either horses or tractor power, does very good and rapid work at low cost in soils free from rock and roots.

When the ground across which it is to be dug is not too sloping, crosswise of the ditch line, this kind of ditch can be dug very cheaply with an ordinary road grader drawn by whatever type of power is available, but tractor power is the most satisfactory. (See Fig. 3.)

In soil comparatively free from roots and rock an ordinary push grader like that shown in Figure 4 is very economical and efficient for digging such ditches.

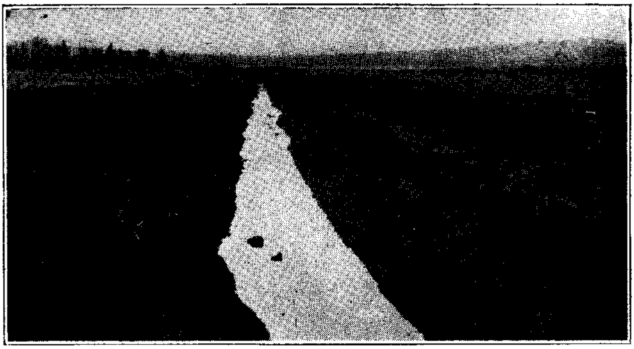


Fig 6. Small Open Ditch on a St. Louis County Farm
Three-foot base, average depth 3½ feet. Dug by team and scraper, slopes dressed by hand, waste banks spread.

CAPSTAN DITCHES

The capstan plow is a well known type of ditching machinery and has been much used. (See Fig. 7.) It is a very heavy double mold board plow mounted on wheels by which the depth of cut is supposed to be regulated.

It is usually pulled by a rope around a capstan drum, hence the name of the machine; but it may also be pulled by a heavy slow-moving tractor. The excavated material is carried to the sides by the extension wings. The use of this type of apparatus is not to be recommended because it has a tendency that can not be overcome to bury itself in low soft ground and to pull out on the hard ground, so the result is just the reverse of what is desired. The bottom of the ditch is a series of rises and falls worse than the original unditched condition, and good drainage is not secured in the majority of cases. (See Fig. 8.)

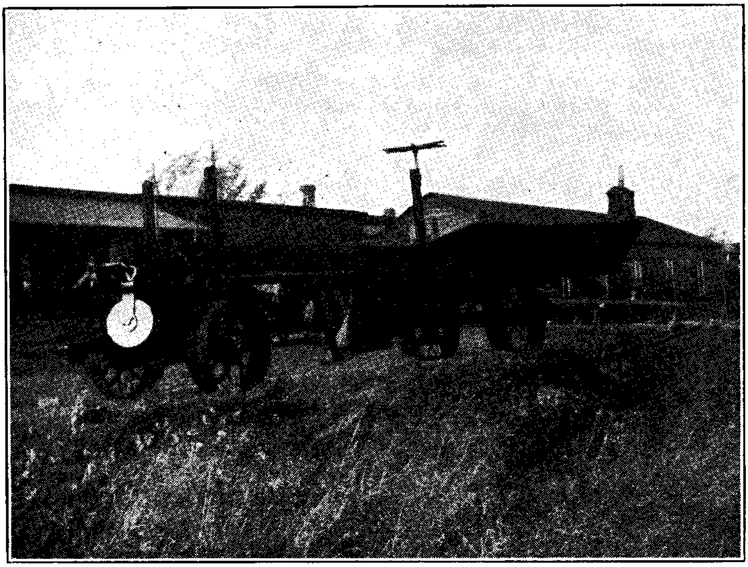


Fig. 7. Capstan Ditching Plow

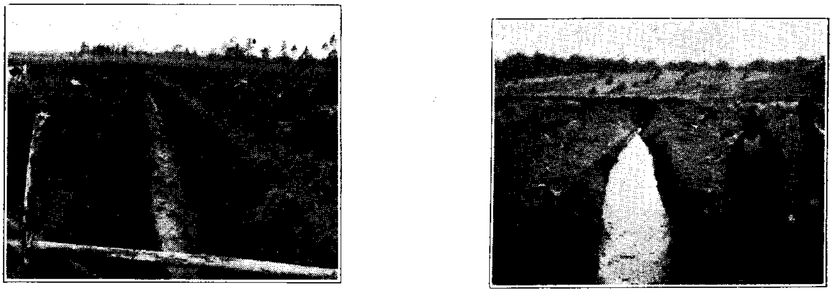


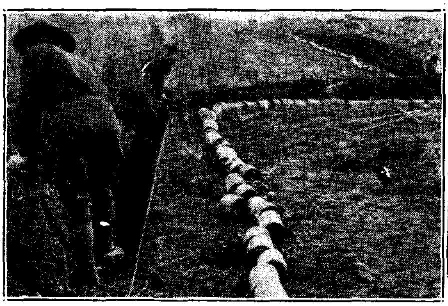
Fig. 8. Capstan Ditches
Left, What the farmer pays for; Right, What he gets: hollows dug deeper, knolls high

WASTE BANKS SHOULD BE SPREAD

The earth excavated from a ditch should not, except in the cases especially noted, be piled up in waste banks along the sides of the ditch as it is unsightly, acts as a weed catcher, and seriously obstructs the flow of the surface flood into the ditches. This material should be spread over the field surface on each side of the ditch. When this is done, if it is plowed and fertilized no injury is done to the field, which can be cultivated right up to the banks of the ditch. (See Fig. 6.)

CONSTRUCTING TILE DRAINS

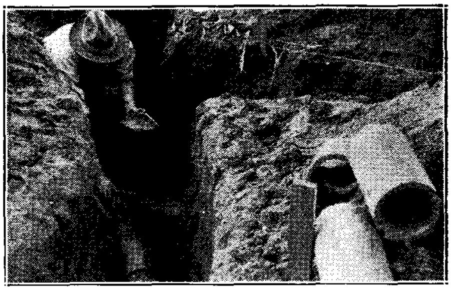
In this discussion it is assumed that the tile drains have been staked out according to the following method. Starting at the outlet of the main, the line is measured out carefully and a marker stake (a stake about 2 feet long and 1½ inches or more wide) placed each 100 feet on straight lines and every 10 to 50 feet on curves, according to their sharpness. On the front of each of these stakes its station number, that



Top Spading to Guide Line

Laying Tile with Tile Hook and Testing Grade with String Targets

Making Junctions by Hand and Laying Tile

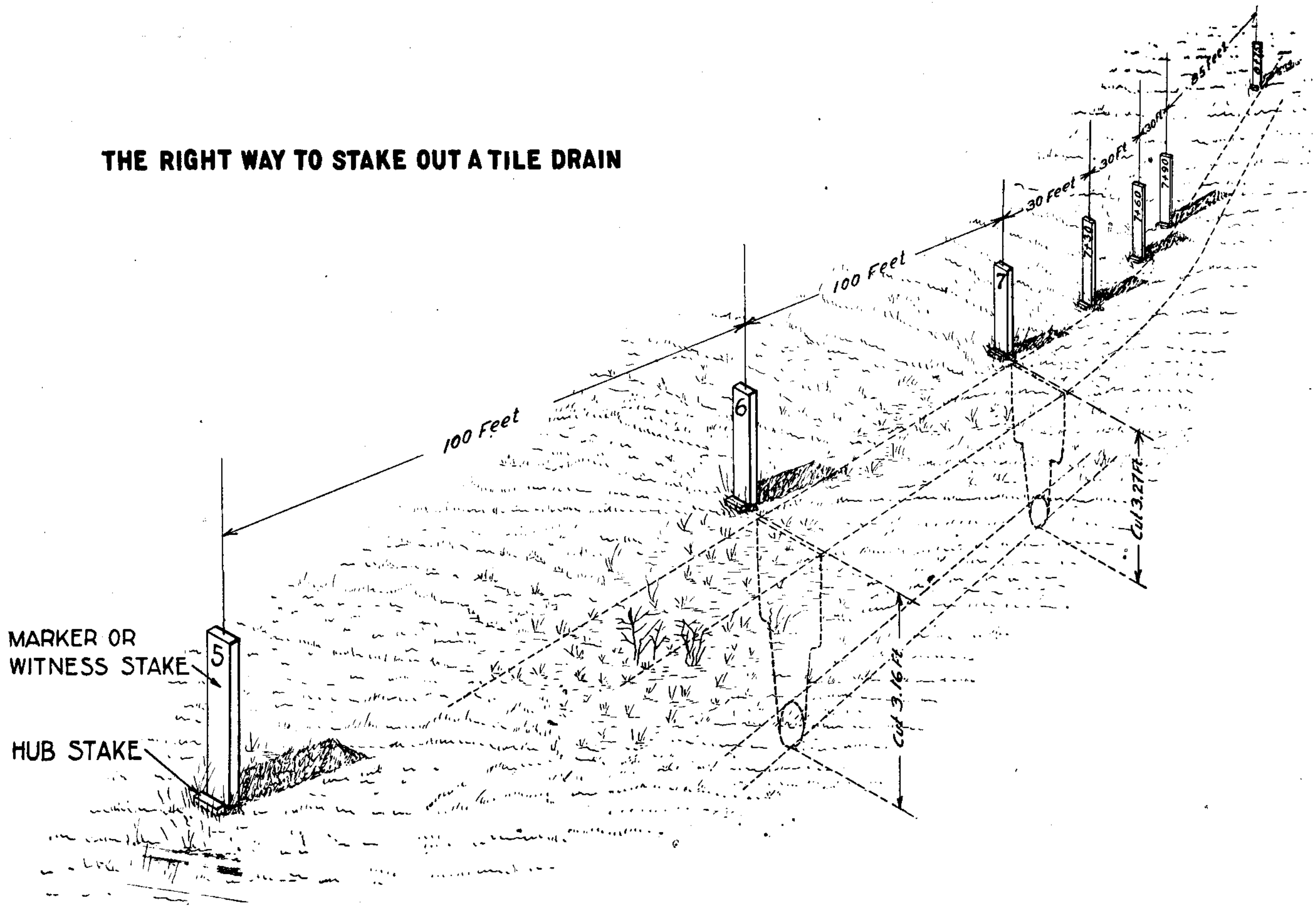


Laying a Hand Made Junction

Fig. 9. Field Practice in Farm Tiling, School of Agriculture, University Farm, St. Paul

is, the distance of the stake in hundreds of feet from the lower end of the tile line, is plainly marked. A hub stake, a short stout stake with a square sawed top, is driven solid and nearly flush with the ground just in front of each marker stake. Figure 10, page 12, shows this method

THE RIGHT WAY TO STAKE OUT A TILE DRAIN



of staking tile lines. Exact levels are taken by the engineer on the tops of the hub stakes. From these the grades of the tile lines are determined and the cuts from tops of hubs to finished grade at bottom of trenches are worked out. The latter figures are tabulated by line and station, points of change of grade and rates of grade also being given and a copy given to the tiler to guide him in setting the targets by the aid of which he digs his trenches to correct grade. The locations of all surface inlets or catch basins, of grade reducers, and the like is shown by special stakes plainly marked to show what they stand for.

The end stake of any line should be so marked, for example, 7+60 End of Lateral 2. Some engineers mark the cuts at each stake on the marker stake but the writer believes it better not to do so but to furnish the tiler a table of cuts for each line as shown in Table II.

There are other methods than those discussed, covering various minor details, but those presented have been found by the staff of this station to be generally the most efficient. Very few tilers can dig and lay tile by water grade and this method is not to be recommended.

TOOLS

Figure 11 shows the tools ordinarily used in tiling by hand.

Figure 12 shows a special perforated shovel called a muck shovel, which is very serviceable for cleaning out the crumbs in sticky wet soils.

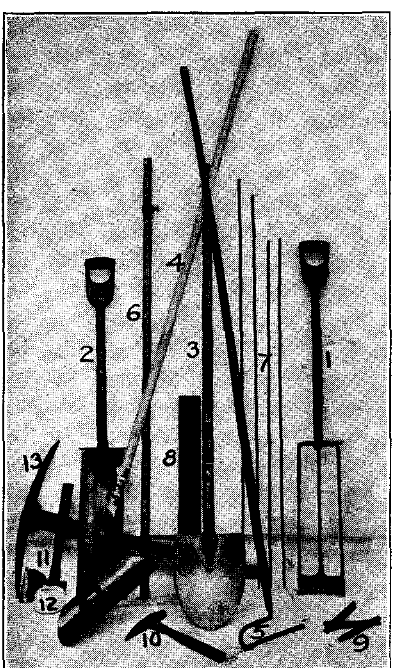


Fig. 11. Tools Used in Tiling by Hand

1. Skeleton blade spade
2. Solid blade spade
3. Longhandled round-nosed shovel
4. Drain cleaner
5. Tile hook
6. Five-foot gauge rod
7. Target rods
8. Carpenter's level
9. Six-foot rule
10. Prospector's pick
11. Hand ax
12. Ball white cotton twine
13. Pickax
14. Chalk line (100 ft.) not shown

The bulk of the spading is done with a tile spade. In very loose crumbly soils the solid blade is best, but in soils whose texture or moisture is sufficient to hold the soil particles together, the skeleton blade tile spade is the handiest, as it is lighter and sticky soil drops from it more readily.

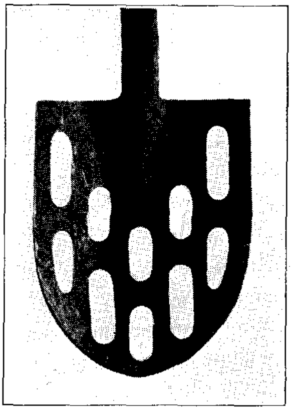


Fig. 12. Muck Shovel for Use in Wet Sticky Soils

SPECIAL TRENCHING TOOL FOR SOILS FILLED WITH ROCK FRAGMENTS

The trenching tool shown in Figure 13 is effective for tile trenching in very hard clay soil, especially if the clay is filled with rock fragments as in a large area in the northeastern part of the state. It is really a modified ice chisel, readily made from a Ford axle, the extension for the handle being made of ¾ inch round steel and the step from a piece of bar steel ¼ inch by 1 inch.

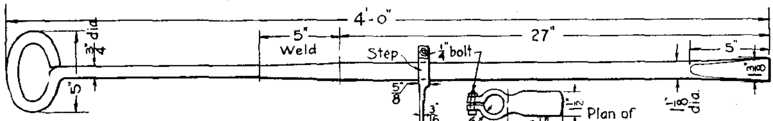


Fig. 13. Special Trenching Tool, Adapted tc Trenching in Very Hard Clays Filled with Rock Fragments

DIGGING TO GUIDE LINE

Digging should begin at the outlet and proceed up stream. A guide line should be stretched along the stakes as shown in Figure 14. Top spading should be done to this line. It is very necessary to dig the trench to straight lines and on smooth curves. The only way to get this result is to use a guide line. If the top spading is done to imperfect line it is practically impossible to smooth up the line on later spadings. On curves this line should be stretched reasonably tight past the regular stakes, and between stakes it should be drawn outward to a smooth curve and fastened by pegs as shown in Figure 15.

Fig. 14. Top Spading to Guide Line
Only the unskilled workman will try to dig the ditch straight without a line. Note that the workman faces the outlet and casts his material into a heap all on *one* side of the trench.

Fig. 15. Guide Line on Curve
Note the short pegs holding the line to a smooth curve.

A light-weight hard-twisted cotton clothes line or a heavy chalk line makes the best guide line. It is possible to use binder twine, but it does not hold its position very well, especially in the wet.

METHOD OF CUTTING WITH TILE SPADE

As a rule, in digging with a tile spade one should not set it square across the trench or attempt to take either a full-width or a very thick bite, as the side friction will be too great to break it loose readily. After the blade is settled to its full length the handle should be thrust slightly forward to break the side bond of the earth slice before the spade is pried backward to lift out the slice. Figure 16 shows the order and shape of cutting that should be taken on top and on second spadings for a 3-foot trench.

CLEANING OUT THE CRUMBS

The crumbs that the tile spade loosens but does not lift out of the trench are best removed by means of the No. 2 long-handled round-nosed shovel. The man stands in the trench facing up grade and casts out the crumbs all to one side.

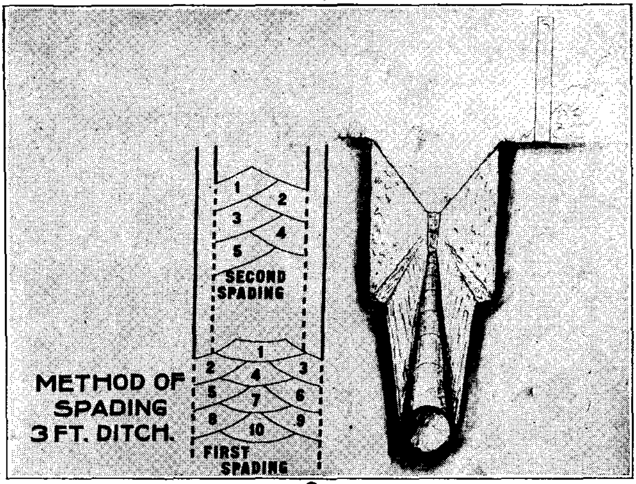
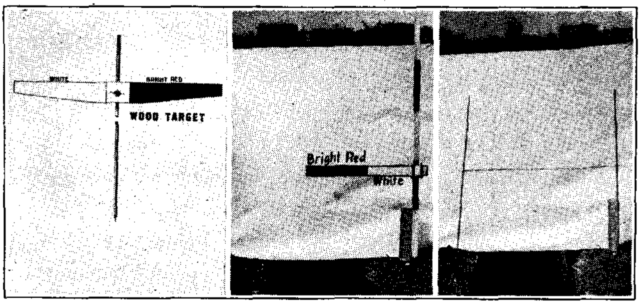


Fig. 16. Plan of First and Second Spading and Sectional Perspective for a 3-Foot Ditch for Small Tile

TARGETS

A line of targets must be set as a guide by which to finish the trench to exact grade. The object of the targets is to establish a line in the air a fixed distance above and parallel to what is to be the line of the bottom of the finished trench. The height of this line above the bottom of the trench should be convenient to the height of the tiler, say 5 feet.

There are various types of targets any one of which is tolerably satisfactory. (See Fig. 17.) If wood or metal targets are used, the white and red faces should be set alternately against each other along the line, as red will not show against red or white against white but either will show plainly against the other.



a b c

Fig. 17. Types of Targets Used in Tiling

a. Swivel, wood or metal, b. One way, wood or metal, c. White string targets

The white string is the most satisfactory type for use in tiling by hand. A dark object should be set up behind so that the string can be readily seen.

SETTING THE TARGETS WHEN THE CUT FROM THE HUB STAKE IS LESS THAN FIVE FEET

For convenience let 5 feet be assumed as the height the target is to be set above grade. The method is as follows:

1. Subtract the established cut at the given station from 5 feet. (See placard in Fig. 18.)

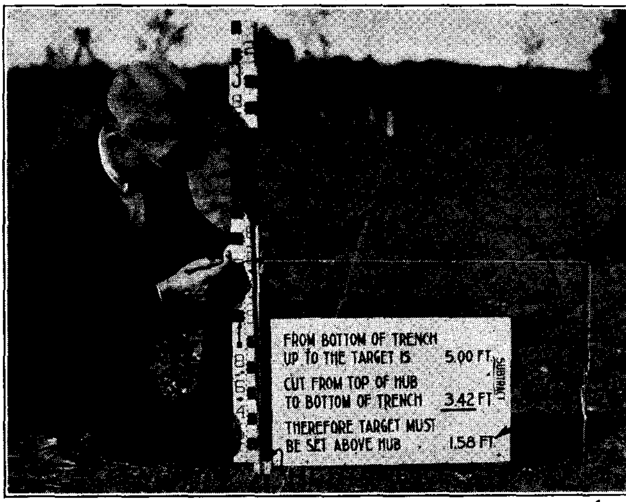


Fig. 18. Setting a White String Target 5 Feet Above Proposed Bottom of Trench

2. Drive a small iron rod (5/16 inch or 3/8 inch) or a stiff tall stake just back of or beside the hub on the outside and a similar rod square across the proposed trench from the first rod. (See Fig. 18.)
3. On the first iron rod measure up from the top of the hub the amount, 1.58 feet, obtained in step 1 and tie a piece of hard twisted white cotton twine to the rod at this point; stretch this twine across to the second rod and tie it, making it as near level as the eye can judge. (See Fig. 18.) The zigzag rule is the handiest measure to use. These rules are graduated in feet and inches on one side and in feet, tenths, and hundredths on the other. (See Fig. 19 for reduction of decimals of a foot to inches.)
4. Level the string with a carpenter's level (see Fig. 20). Check the measured height (1.58 feet) on the first side and after adjusting this, if needed, check the leveling.

NUMBER OF TARGETS NEEDED AT ONE TIME

Targets should be set at not less than 3 stakes along any given strip of continuous grade at any one time, and 5 or 6 is better. Each target must be set from the cut required at its own particular hub stake, as

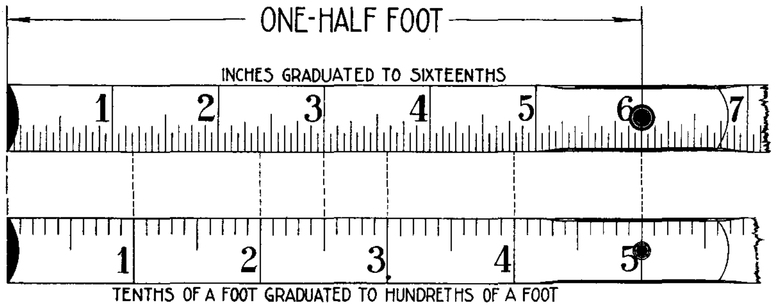


Fig. 19. Section of Zig Zag Rule (½ Actual Size) for Converting Decimals of a Foot to Inches

shown in Figure 21. If the engineer's work and the target setting are both perfect, all the targets along any given grade will line up and be projected against the background as one line, and *the line of sight* along such a series of targets, as line AB in Figure 21, *will at all points be just 5 feet above the proposed bottom of the finished trench.*

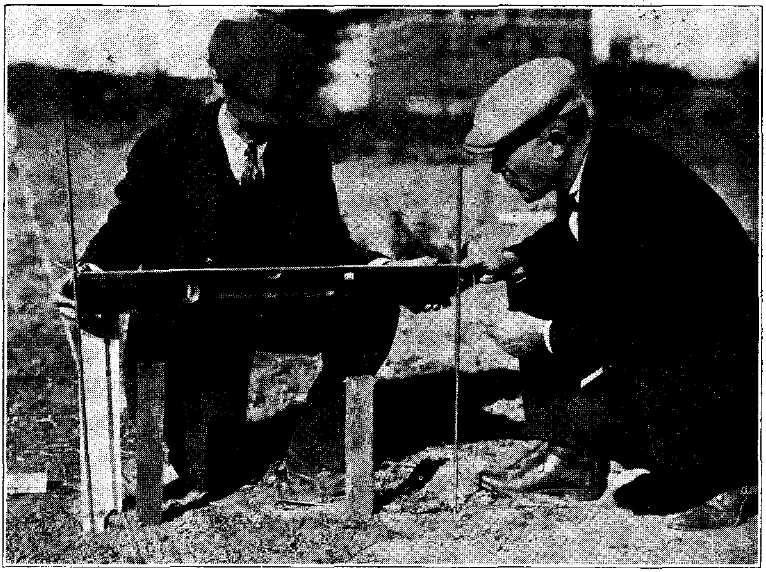


Fig. 20. Leveling the Target
String is first attached at desired height as shown on left, then brought to level position and tied to stake at right.

CORRECTION OF APPARENT ERRORS IN LINE OF TARGETS

For several reasons a series of targets along a given stretch of grade may not line up perfectly. In such a case, assuming that the greater number of targets which do line are on the correct grade, move the others up or down as the case may be until they come into line, being sure to keep all targets level. Before any such adjustment examine all hub stakes to be sure that none have been disturbed. If any great differences occur at any stake it is probable that either the recorded cut is wrong or that there is a mistake in the measured height of the target.

WHEN THE CUT FROM THE HUB STAKE EXCEEDS FIVE FEET

If the cut from the hub stake exceeds 5 feet, or whatever distance is to be used as the target height, the targets can not be set until the trench has been excavated below a cut of that amount. In that case the rods holding the target must be driven slanting into the sides of the trench, 5 feet must be subtracted from the cut, and the remainder measured *down* from the hub or from a level line set across the top of the hub.

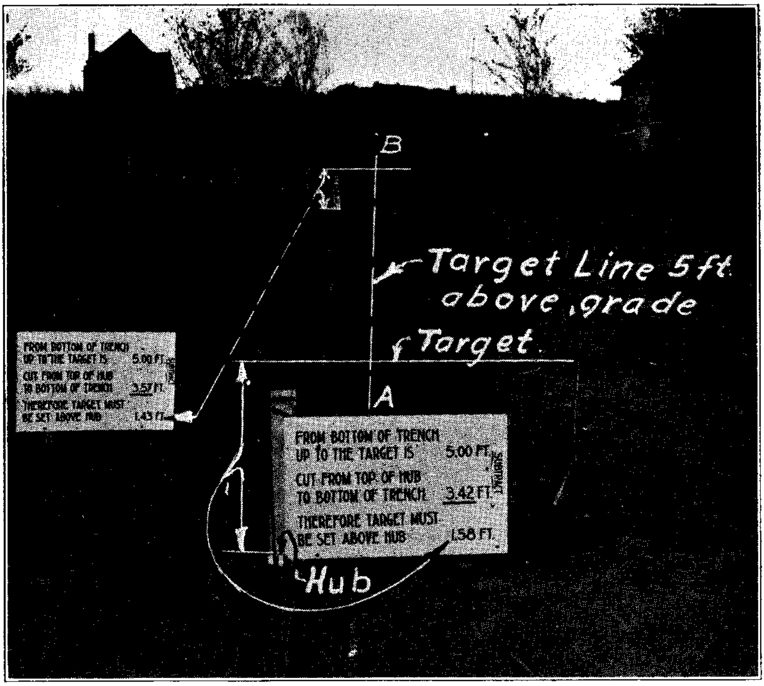


Fig. 21. Targets at Two Consecutive Stakes Establish the Line of Sight 5 Feet Above Grade

SETTING TARGETS ON CURVES

On sharp curves on steep grades any two targets being used on any stretch of trench should straddle the trench parallel to each other as the flare of radial lines from one side of a trench to the other often makes enough difference in distance between stakes seriously to affect the rate of grade and the correct bottoming of the trench. If the hubs are on the inside of the curve, the flare will be a divergence and the trench will be graded too deep. If the hubs are on the outside, the flare will be a convergence and the trench will be graded too shallow. Figure 22 shows in plan the working out of this problem.

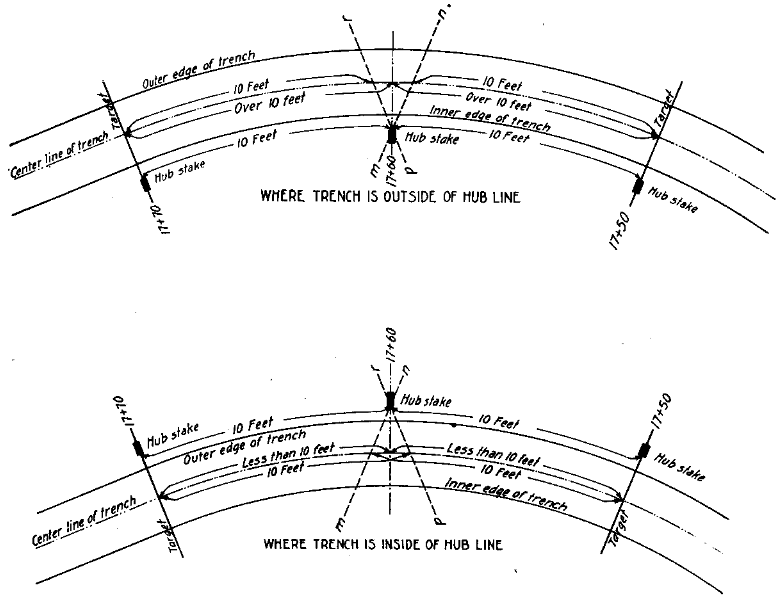


Fig. 22. Setting Targets on a Curve
Dotted lines show positions in which targets at 17+60 should be set to be used with targets at stations on either side, that is, mn is the position in each case for use with station 17+50 and pr is the position in each case for use with station 17+70.

SETTING TARGETS AT POINTS OF CHANGE OF GRADE

The tiler works up grade from the outlet and facing the outlet, hence the target line by which he is working is always down grade from him and over a finished part of the trench. Therefore at the outlet and at points of changes of grade after the targets have been set, behind the tiler along the grade on which he is about to work an additional target must be set by eye below the outlet or below the point of change of grade, in line with those extending up grade from this point, so that the workman may always have below him a target line from which he may check until he passes the second regular stake on a given grade. (See Fig. 23.)

HOW TO USE THE TARGETS

Gauge rod.—Figure 24 illustrates the use of the targets after they are set. Line AB is a sighting line passing through all the targets on a given grade. If the targets are set 5 feet above the grade of the bottom of the trench, when the top of a 5-foot stick or gauge rod held vertically with its base resting on the bottom of the trench lies in the

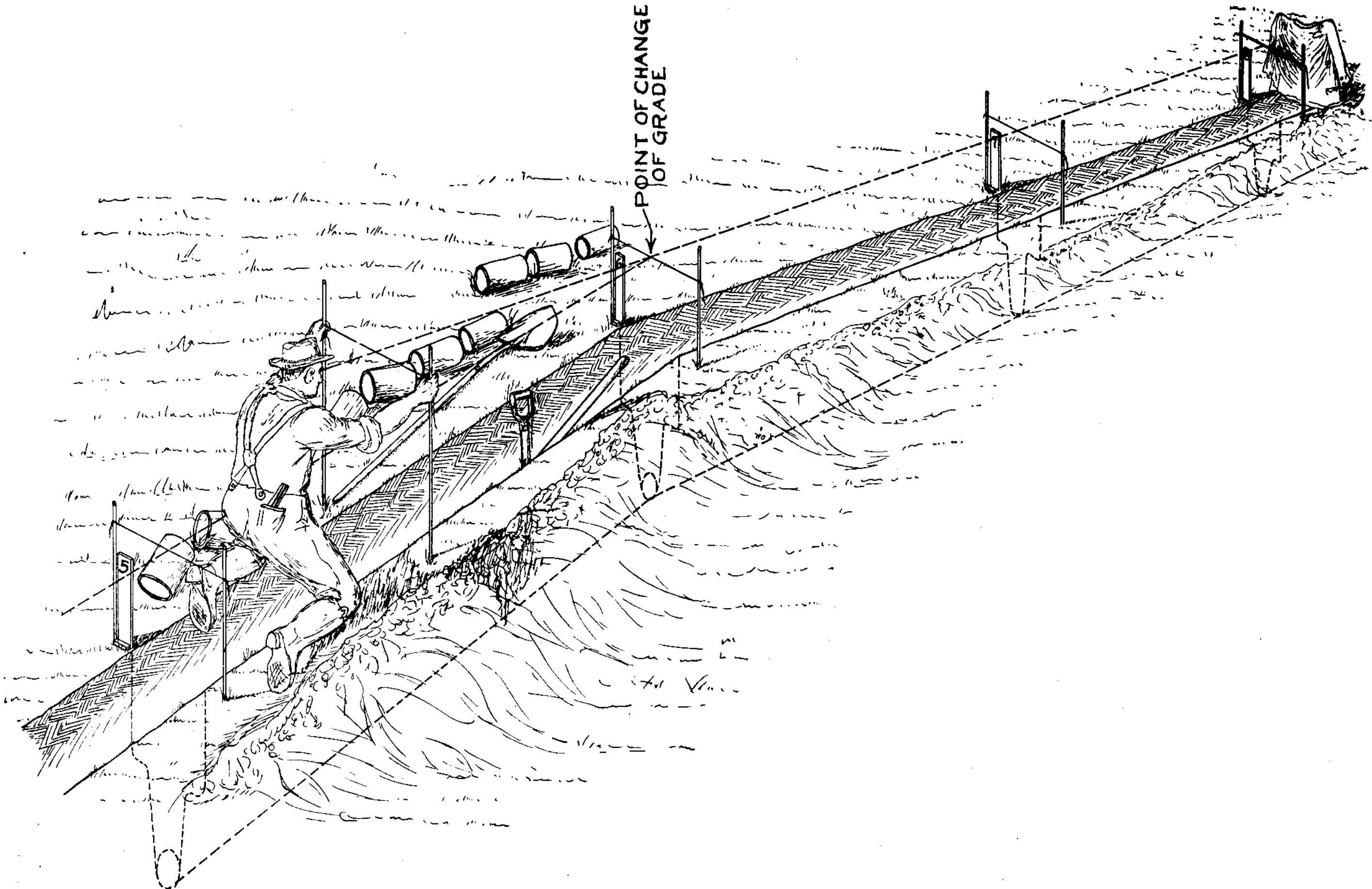


Fig. 23. Lining in Additional Target Below Outlet or Point of Change of Grade

line of the targets, the bottom of the trench at that point is at proper grade. In this way the tiler may test the grade of every inch of the trench. Many workmen prefer to put a notch in the handle of the drain cleaner at the proper height from its point instead of using a separate staff, but in loose or soft ground the weight of the drain cleaner alone will often cause its cutting edge to settle enough to cause serious error in testing the grade. Therefore a slender wood staff with square-sawed ends is to be preferred.

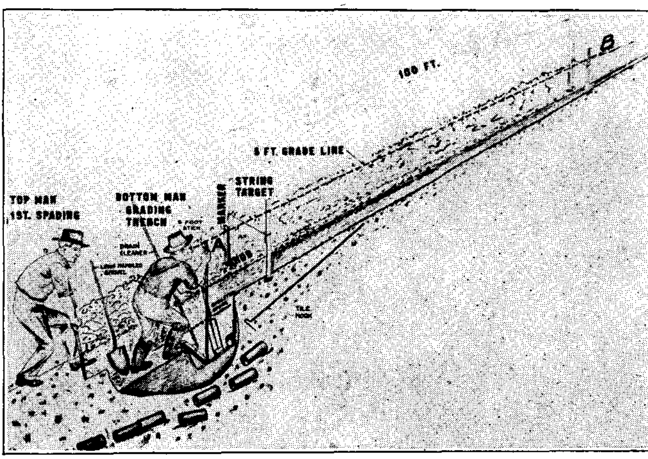


Fig. 24. Method of Tile Trenching by Hand

The man digging the top is here shown too close to the bottom man, but this is due to limitations in drawing the picture. Ordinarily these men should be 50 feet or more apart.

FINISHING THE TRENCH TO GRADE

Bottoming the trench.—The tool used in finishing the bottom of the trench is the crumber or drain cleaner which is made in different sizes to finish the bottom to a shape that just fits the outside of any size tile. The handle can be set at just the right angle to enable the tiler to control its motions exactly. Figure 25 shows the method of grading the bottom of the trench with the crumber.

If the bottom of the trench checks too high in any spot, the crumber should be placed snug against the bottom of the trench where the grade is correct, just back of the high spot, and drawn forward with this finished part of the trench as a guide, until the blade of the crumber cuts off the high spot much as a jointing plane trues up the edge of a board. Great care should be taken to plane just to grade and never to cut too low. If, however, one does cut too low in any spot this hollow should be filled back with well pulverized material like the bottom of the trench. This material should be well tamped with the crumber and the bottom of the trench again planed to grade.

Fig. 25. Method of Finishing Tile Trench to Grade

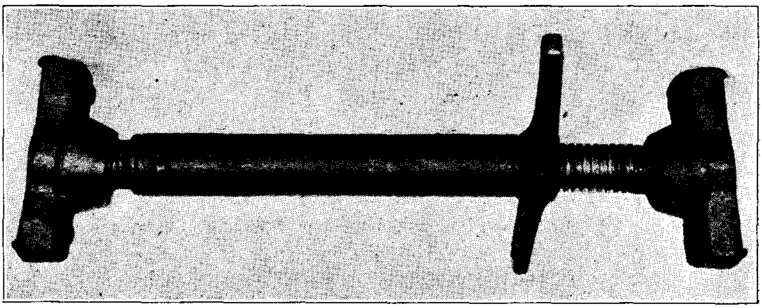
DIGGING DEEP TRENCHES

The blade of a tile spade is 20 inches long. Hence a 3-foot trench is what is spoken of as two spadings deep and is taken out as shown in Figure 16. If the trench is any considerable amount over 3 feet in depth, a third spading or even more must be taken out, according to the depth. (See Fig. 26.)

Fig. 26. Tile Trenching Over Two Spadings Deep
One side of trench is cut away to show the method.

STAYS, TRENCH BRACES, AND CURBING

Where the depth of trench exceeds 8 feet it will be necessary to use staging and two or more lifts, the bottom man casting to the first staging from which a second man passes the soil to another staging or to the top, according to depth. In loose material or in clay or other material liable to slide along lines of cleavage or cracks or to cave, it is necessary in trenches more than 6 feet deep to use plank stays and trench braces as shown in Figure 27, to prevent caving. In deep trenches where there is a tendency to slide or cave over a considerable length of the trench, the only safety either for the work or for the workmen lies in using continuous curbing held in place by lagging and bracing that will not give way. This type of protection is shown in Figure 28. In general all such curbing must be removed after the tile is laid and blinded; but if it is necessary to leave any of the curbing in the soil there should be at least 4 inches clear space for back filling between the curbing and the tile on each side.



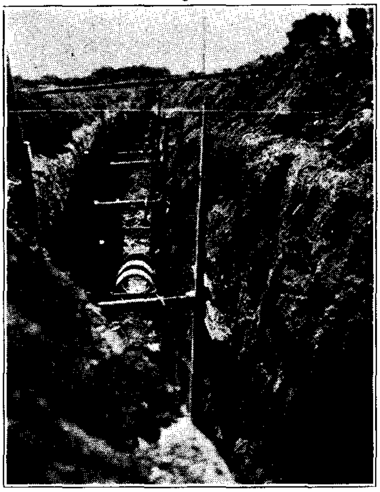


Fig. 27. Trench Braces and Plank Stays
Above. Trench brace alone.
Below. Trench braces and plank stays in position in tile trench

TILING BY MACHINE

Several machines are available for tile trenching, almost any of which do fairly satisfactory work within the limits of what they are built to do. These machines fall in two main classes. One class includes heavy traction machines moved and operated by their own power, either steam or gasoline, usually the latter. They are built in different sizes to cut trenches up to a depth of 6 to 8 feet and for

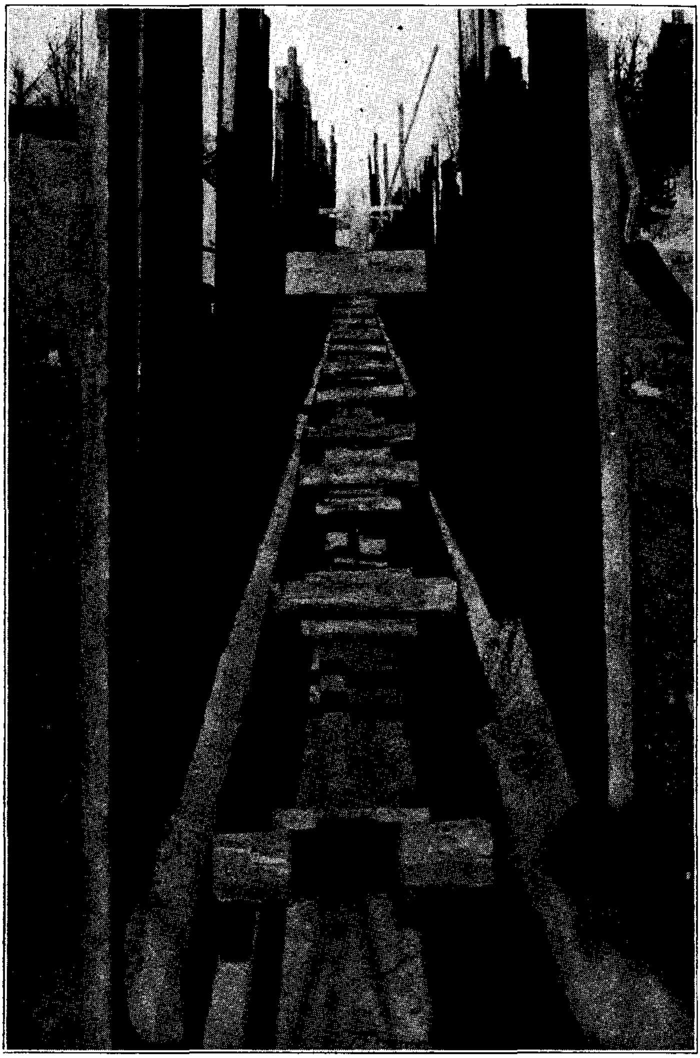
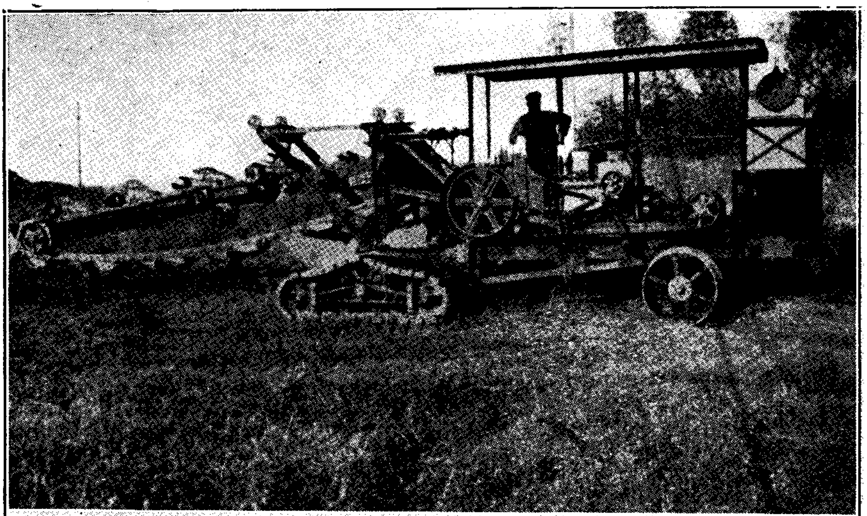


Fig. 28. Curbing in Deep Trench Liable to Cave and Slide

tile running from the small sizes up to or beyond those ordinarily required for individual farm mains. The investment involved is several thousand dollars. They are therefore intended for ownership and operation by drainage contractors rather than by the farmers themselves. It is often profitable on large farm drainage projects to employ the services of a contracting concern owning and operating such a machine. Figures 29 and 30 illustrate two types of heavy traction trenchers. Machines of this class are equipped with a depth gauge under the control of the operator who is guided by a line of



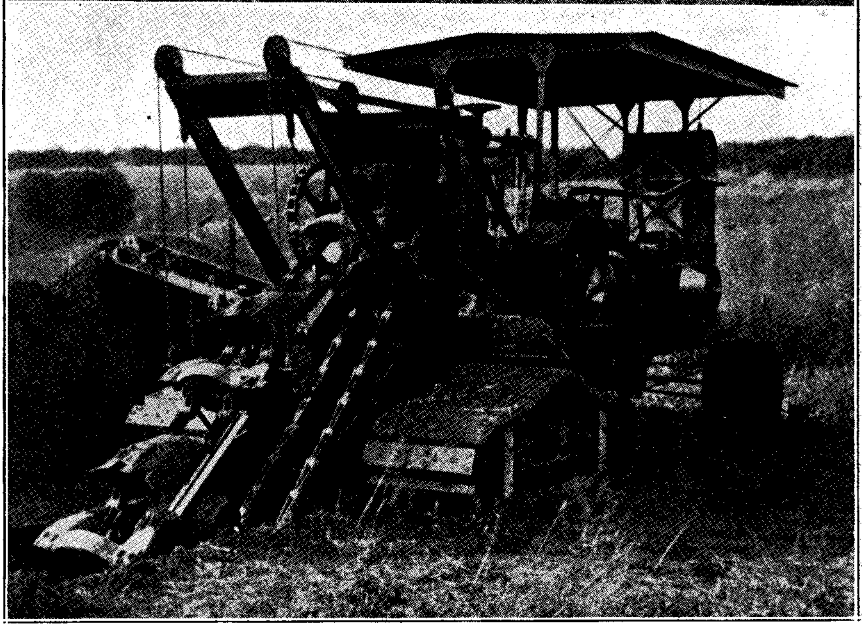


Fig. 29. Tile Ditcher, Bucket Ladder Type

Above, set for traveling; below, at work, a very fast digger

In uneven ground it is not easily possible with this machine to cut true to grade. The trench must usually be finished by hand.

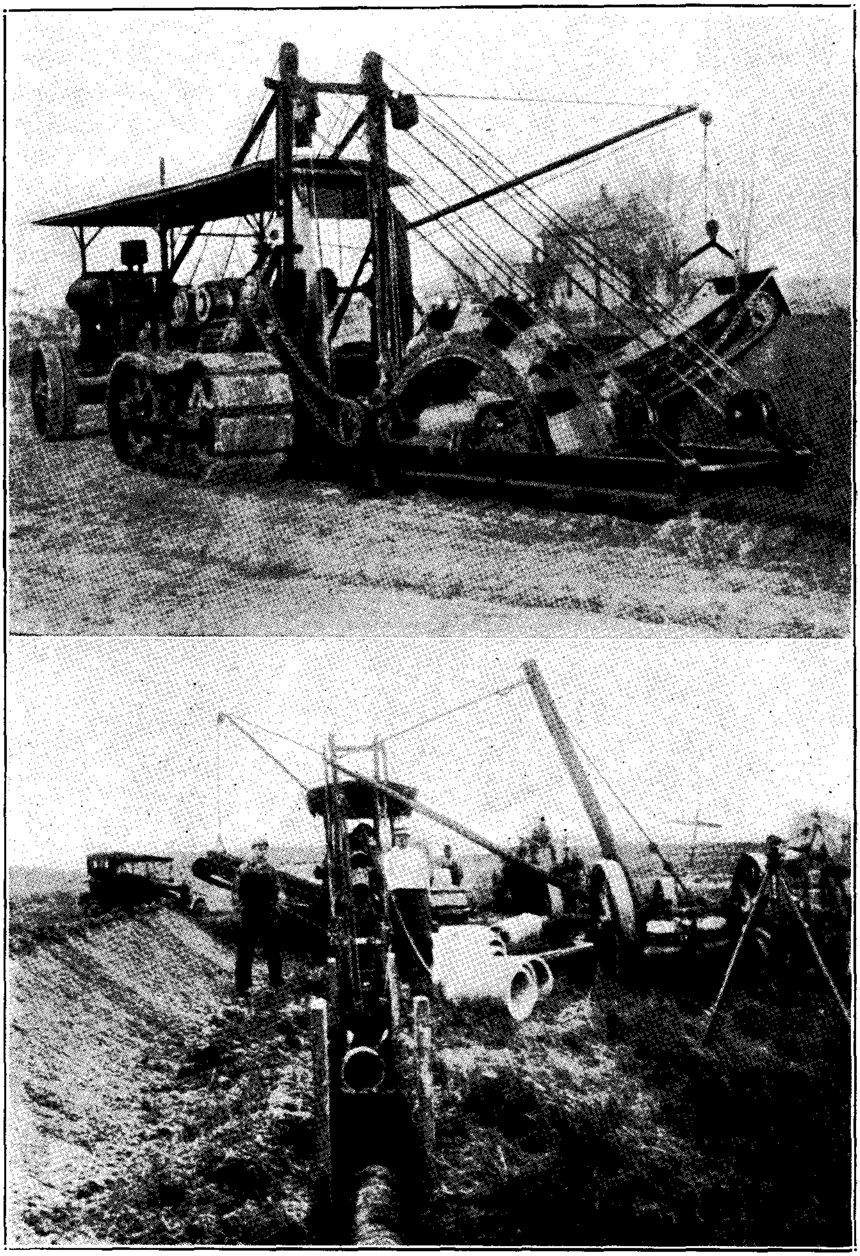


Fig. 30. Tile Ditcher, Bucket Wheel Type

In soils free from rock, much greater speed can be made than by hand. With care this machine can be made to dig a finished trench, true to grade.

high stemmed metal targets set as described for hand work, but very much higher. In the more rigid types of soil a skilled and careful operator can dig to grade. When this is not possible the machine work must be kept well above grade and the trench must be finished by hand. Junctions of branches and sharp curves can not be dug successfully with these machines, hence must be done by hand. The bucket ladder type (see Fig. 29) will in general cut a sharper curve in a deep trench than will the bucket wheel type. (See Fig. 30.) The latter machine, used quite extensively during the last seven years on flat land in the western part of the state under the supervision or observation of the author, will not readily cut a curve of less than 100 feet radius in the size of machine suitable for farm tiling. Any of theses power machines cut a much wider trench than is needed for small tile but the more rigid bucket wheel type leaves a shallow groove in the bottom of the finished trench in which the small tile may be readily laid without danger of its rolling or being forced out of line.

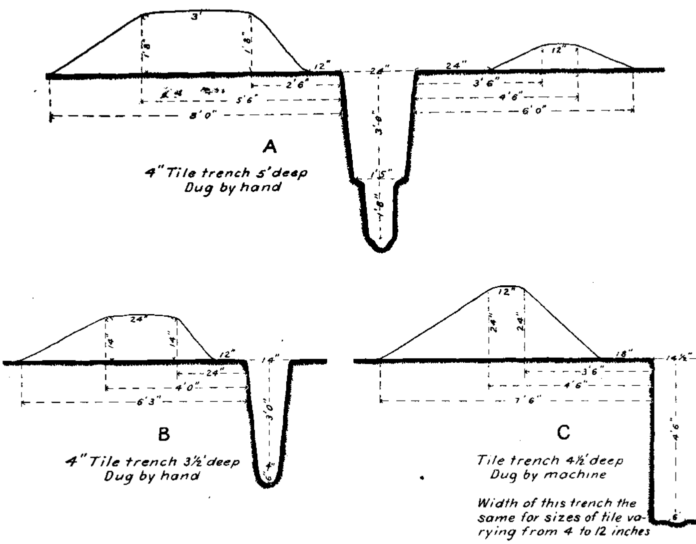


Fig. 31. Cross-Section of Small Tile Trenches Dug by Hand and by Machine

Figure 31 shows in cross-section a trench of minimum width that a power machine will dig in comparison with a hand-dug trench.

The other general class of machine comprises several types of lighter horse drawn machines whose use is pretty definitely limited to rather small tile and shallow trenches. These machines will not work in stony soil and the finishing of the trench must always be by hand. Under suitable soil conditions where the job is quite extensive these machines may often be used, with profit, to do the bulk of the digging. The investment involved runs from about $300 to $600. Their ownership on large farms where drainage is a considerable problem may often be justified, and joint ownership by a group of farmers may often be a feasible and satisfactory arrangement. Figures 32 and 33 show two types of machines of this class. Where these lighter machines are used the hub stakes must be set after the machine

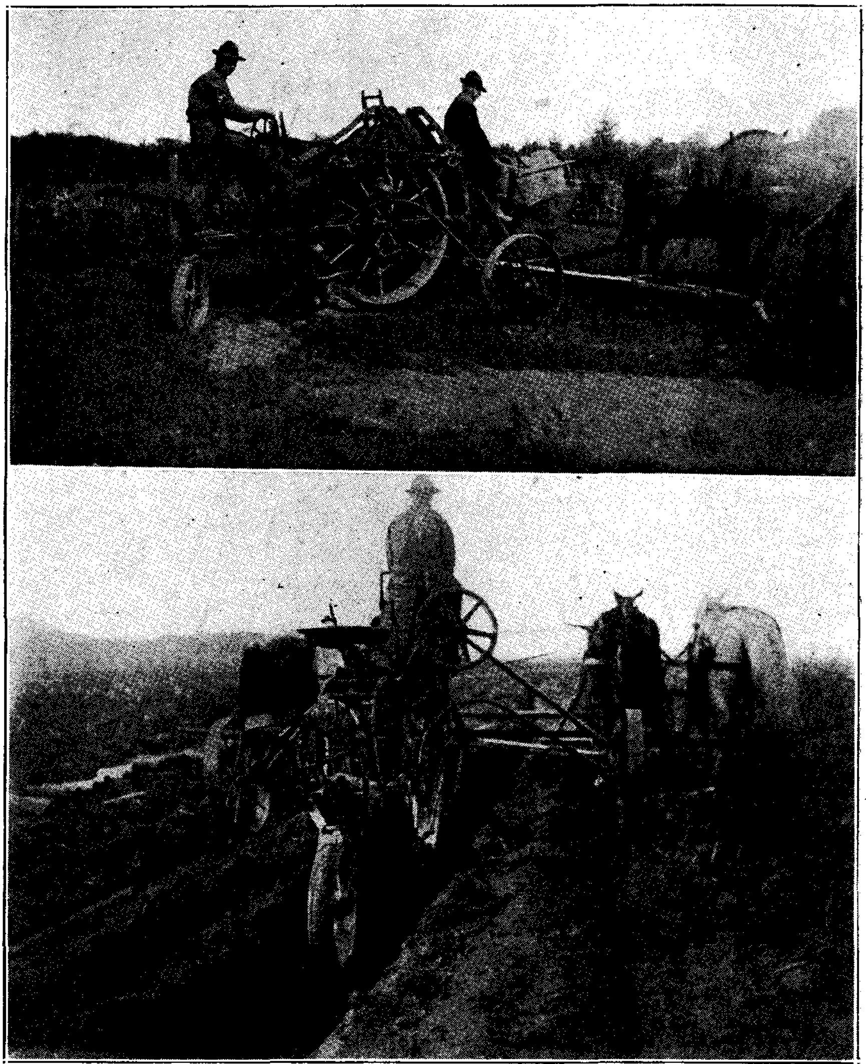


Fig. 32. Tile Ditcher, Light Traction Type

With this type the trench must be finished by hand. It is a good servant in soils free from rock, when skilled labor is scarce.

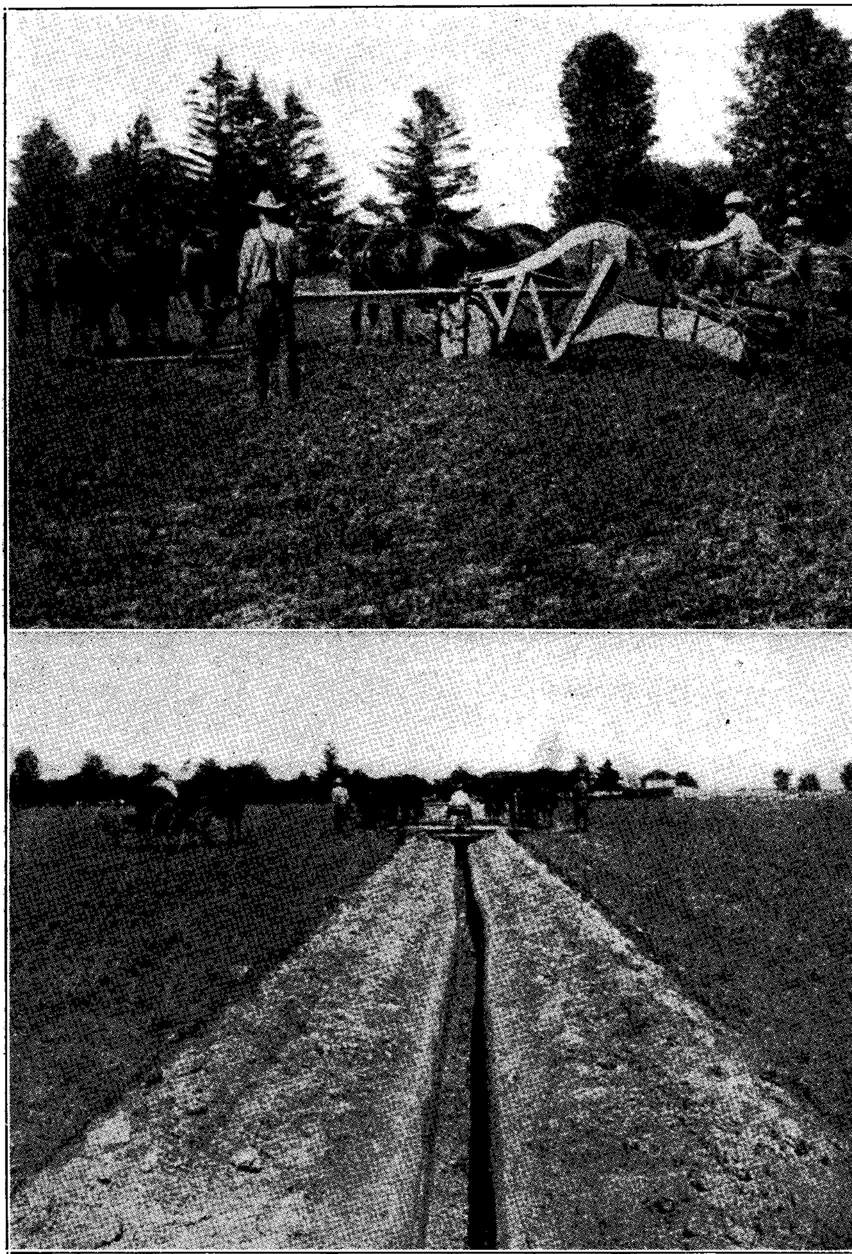


Fig. 33. Tile Ditcher, Simple Plow Type
Fairly rapid top work, but the trench must be finished by hand.

work is completed, as this lighter plow type of machine usually wipes out all stake lines while operating. There are more recent machines of this class than those shown that have not yet been fully proved, but which no doubt will eventually have a wider range than the older types, altho the general limitations named will be true to a large extent of many machines of this class. This station purchased and operated for a part of two or three seasons one of these lighter machines of the type shown in Figure 32. Our experience leads us to conclude that under the hand of a skillful operator almost any of these machines will do about all they are intended to do. The limit of the average horse-drawn machine is about a 4-foot trench. In Minnesota the machine tile trencher has not yet been a large factor and direct experience with it has been distinctly limited. However, the tile trenching machine will probably be more and more generally used with increasing difficulty of securing skilled hand labor at reasonable prices. At present there seems to be little difference in the cost of drainage as between hand and machine work. Those wishing to pursue further the matter of tile trenching machines are referred to Farmers' Bulletin 1131 of the United States Department of Agriculture, available without charge on request to the office of Publications, Washington, D. C.

LAYING THE TILE

The tile should be laid to an even line with tight joints presenting the appearance, before covering, of a continuous pipe. (See Fig. 34a.) They should be kept laid up to within a few feet of the finished trench. If a length of tile does not fit tight against that previously laid it should be turned on its longitudinal axis until the position is found in which the tightest possible joint is secured. Each piece of tile as laid should be given a smart tap by tile hook or heel to make it fit tightly against the last laid piece. (This should not be done with small concrete tile whose ends are made very perfect, tending to make the joints too tight. Such tile should therefore be laid with rather loose joints.) Where joints lie open more than 1/8 inch in ordinary loam or clay soils, on curves, or because of imperfections in the ends of the tile, these open joints must be covered with broken pieces of tile (tilebats) grass clods, hay, or tar paper. Tile up to 8-inch may be laid very readily either by means of the tile hook (see Fig. 34a) or by hand (see Fig. 35). Larger tile must be laid by hand, and sizes too large to be readily lifted must be handled by means of a rope, a derrick, or some kind of mechanical hoist. (See Figs. 36 and 37.) The tiler should reject all tile that are too soft, cracked, or so ill-shaped that a smooth line can not be obtained.

Fig. 34a. Laying Tile with Tile Hook—Sectional Side View

Fig. 34b. Line of Tile in Trench, Ready to Blind

Fig. 35. Laying Tile by Hand—Sectional Side View

Fig. 36. Handling Large Tile with Derrick

Fig. 37. Lowering Large Tile into Trench with Rope

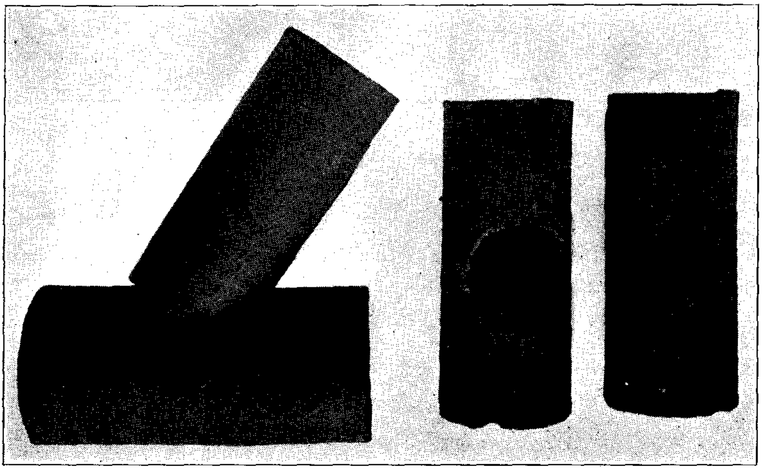
MAKING JUNCTIONS AND TRIMMING TILE FOR CURVES

For sizes of tile up to and including 12-inch, factory made junctions are quite readily obtainable, but the tiler should know how to make his own junctions on the ground by hand. (See Fig. 39.) Any

a. b.

Fig. 38. Cutting a Hole for a Junction in a Large Main
a. Starting the hole b. Enlarging the hole

light hammer or hand ax with sharp square corners on a flat face on one side and a pointed end or slender corner on the other may be used, but the best tool for this purpose is the light prospector's pick (No. 10, Fig. 11) in a 1/4 pound or 1/2 pound weight. Figure 38 shows the method of cutting the hole in a tile line already laid. To cut the hole for a junction in a small tile, a good way to start is thoroly to fill a length of tile with dry sand to prevent vibration, holding the tile between the knees with two small boards to keep the sand in. Then a prolonged series of very rapid light taps in the same spot with the face of the hammer will soon result in a small hole without cracking the tile if care is used and the job not hurried. The enlarging is done as shown in Figure 38b.



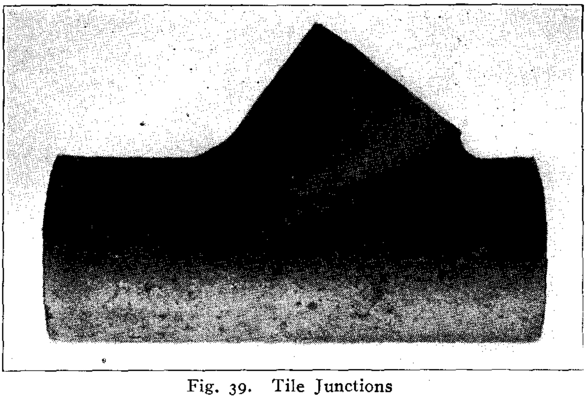


Fig. 39. Tile Junctions
Above, hand made; below, factory made

Where curves are too sharp or tile too large to lay in curves with joints open and covered with tile bats on the outside, the open joints may be avoided by cutting the ends of the tile to a slant to fit the curve. This cutting may be done with a hand ax or tile pick much as a mason trims brick or stone, or better by catching the end of the tile in the jaws of a monkey-wrench and breaking off fragments as needed by pressing down sharply on the handle. (See Fig. 40.)

a. b.
Fig. 40. Trimming Ends of Tile for Curves
a. With a hand ax b. With a monkey wrench

KEEPING TILE CLEAN

The tile must be kept clean while laying. Earth in a tile line will attract roots and cause a stoppage. Earth is easily dumped out of small tile while laying. With large tile the usual method is to tie a large burlap swab to a short length of small rope and draw it forward through each newly laid tile.

TRENCH DAM

In a wet trench a sheet iron dam (see Fig. 41) should be used whenever the work of laying is temporarily stopped, to prevent fouling of the tile.

SAND SHIELD

In sand or quicksand in a wet trench, a sand shield of galvanized iron (see Fig. 42) is used to prevent the sand from running in and spoiling the bed of the trench. The bed of the trench is finished inside this shield and the length of tile laid, the sand shield is then pulled forward its own length and the process repeated. This process insures laying the tile to grade.

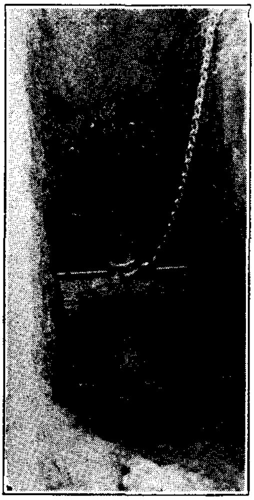


Fig. 41. Trench Dam in Position

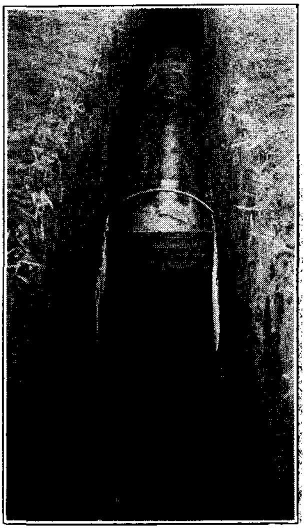


Fig. 42. Sand Shield in Position

BLINDING

Any freshly laid line of tile should be covered to a depth of from 4 to 6 inches close up to the end of any day's work to hold it in place against the action of the elements or any other disturbance until the trench filling is completed. This is called blinding the tile. It is done by the tiler walking astride the trench and cutting down earth from both sides of the trench below the surface with a tile spade. In blinding care must be taken not to disturb alignment of the tile or the batted joints.

REFILLING TRENCHES

Almost any method that will move the material may be used in refilling the trenches. It may be done by hand with shovels, by plow, by team and scraper, by road grader drawn by tractor power, or by numerous other special methods and devices. Short sections near buildings, fences, and other places inaccessible by teams and machinery, must be filled by hand, as must also a short length of trench at the outlet to provide turning ground for teams and machinery.

Under ordinary conditions the quickest and cheapest way to refill small or shallow trenches is with a common walking plow drawn by two teams, one on each side of the ditch, the apparatus being arranged as shown in Figure 43. The long evener should have a series of holes six inches apart bored near its center for the king pin, to permit of quick re-adjustment to fit the ground, position of trench, etc., as the plowing is done up and down either side of the trench regardless of the position of the spoil bank.

Fig. 43. Filling Trenches with Plow

Fig. 44. Type of Scraper Well Adapted to Filling Trenches and Digging Shallow Ditches

If a scraper is used the team must be attached to it by means of a long light chain, as the work is done cross-wise of the trench, the team being on one side and the scraper on the other. The ordinary slip scraper is clumsy and rather slow. Figure 44 shows a small buck scraper especially built for trench filling. This scraper is also useful in excavating wide, shallow ditches in wet soil.

On large jobs the most satisfactory equipment for trench filling is the regular road grader with a 10- or 12-foot blade and drawn by tractor power (see Fig. 45), the same equipment as is shown in Figure 3 for making flood ditches. In soils reasonably free from big roots and stones the drag grader shown in Figures 4 and 5 is also a good trench filler. Both these types of equipment are also well suited for levelling the surface after trenches are filled.

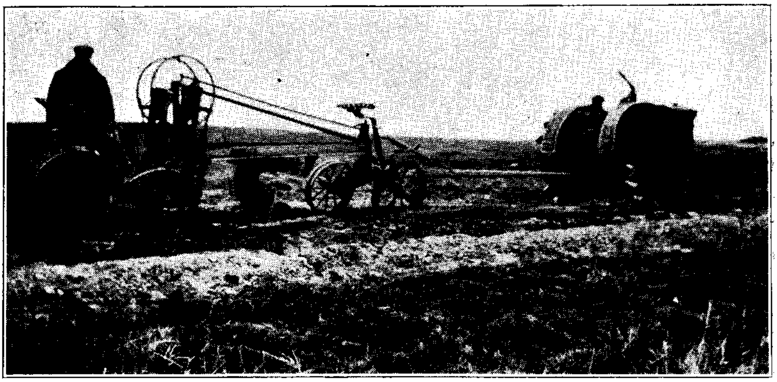
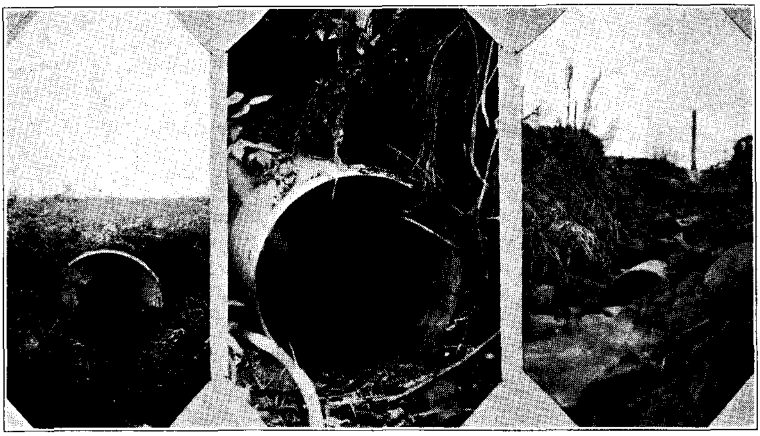


Fig. 45. Filling Tile Trenches with Road Grader Drawn by Tractor, on a Farm in Stearns County

PROTECTING TILE OUTLETS AGAINST WASHING AND CRUSHING

Outlet protections for this purpose are usually provided for in the plans and specifications furnished for their construction. The essential thing, not only in planning them but even more especially in their construction, is to make them permanent. If the tile line ends at or very near the bottom of the outlet ditch or stream gorge, so that there is no appreciable drop from the tile to the stream or but little side current in the stream to cause scouring and undermining, an inexpensive and satisfactory method of outlet protection is to finish the tile line with 15 or 20 feet of continuous corrugated iron culvert of good grade. In this case all that is needed is tightly to cement the joint between the last tile and the culvert and see that the culvert itself lies on a firm natural bed of clay or other soil. A ring of 3/4-inch round iron rolled into the outer end of the culvert gives additional stiffening against crushing. (See Fig. 46 for effective outlet culverts of this type.)



a. b. c.

Fig. 46. Corrugated Iron Tile Outlet Culverts

a. A bell-ended corrugated culvert for a 16-inch tile in Stearns County; set in 1921 in bottom of road ditch.

b. An outlet culvert for a 15-inch tile extending through a highway embankment to the down-stream side; even with bed of water course. Set in Scott County in 1919.

c. An outlet culvert for a 12-inch tile in the bed of and direction of the outlet stream. Set in St. Louis County in 1915.

If no culvert is used and the tile is carried to the outlet, the joints should be tightly cemented for the last 15 or 20 feet so that seepage from them will not cause scouring and undermining. It is also best to use bell-ended sewer pipe with the bell ends turned upstream. When no continuous culvert is used a masonry or concrete bulkhead is indispensable, preferably about the type shown in Figure 47.

It is often necessary to use a bulkhead even with a culvert where the traffic is heavy or where there is a decided drop from the end of the tile line to the outlet stream or where the current in that stream causes a scouring action at the tile outlet. In such cases, without a bulkhead undermining and eventual destruction of the outlet is almost certain to occur. Figure 48 shows such a case where the abrupt drop of the water from the tile was about five feet and the only protection against washing out was a mass of loose rock piled under and around the lower end of the culvert. This culvert was set in 1916. Lack of proper protection resulted in a gradual weakening of the entire foundation and a heavy flood in May, 1922, washed away the entire outlet, leaving the condition shown in Figure 48, b.

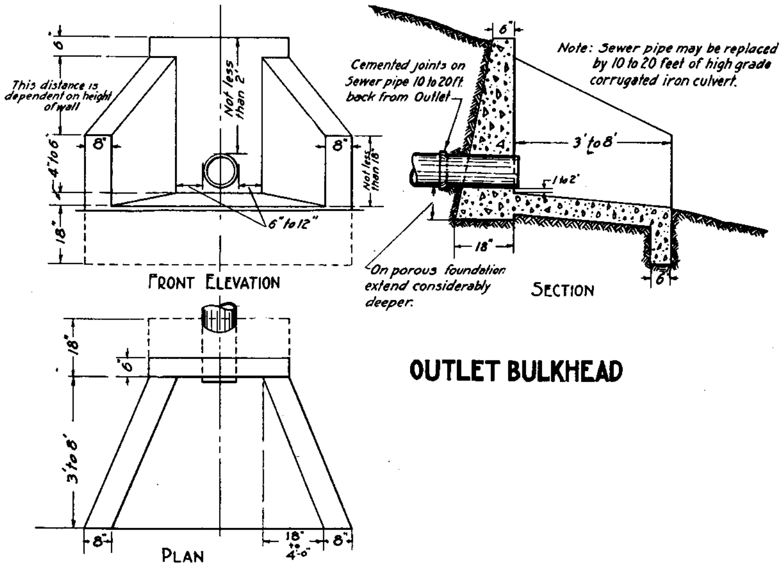
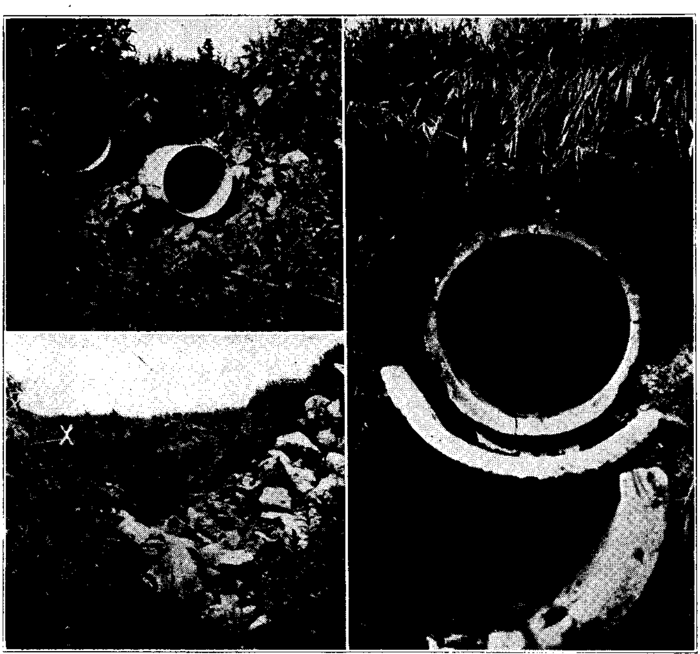


Fig. 47. Good Type of Outlet Bulkhead for Tile Drain



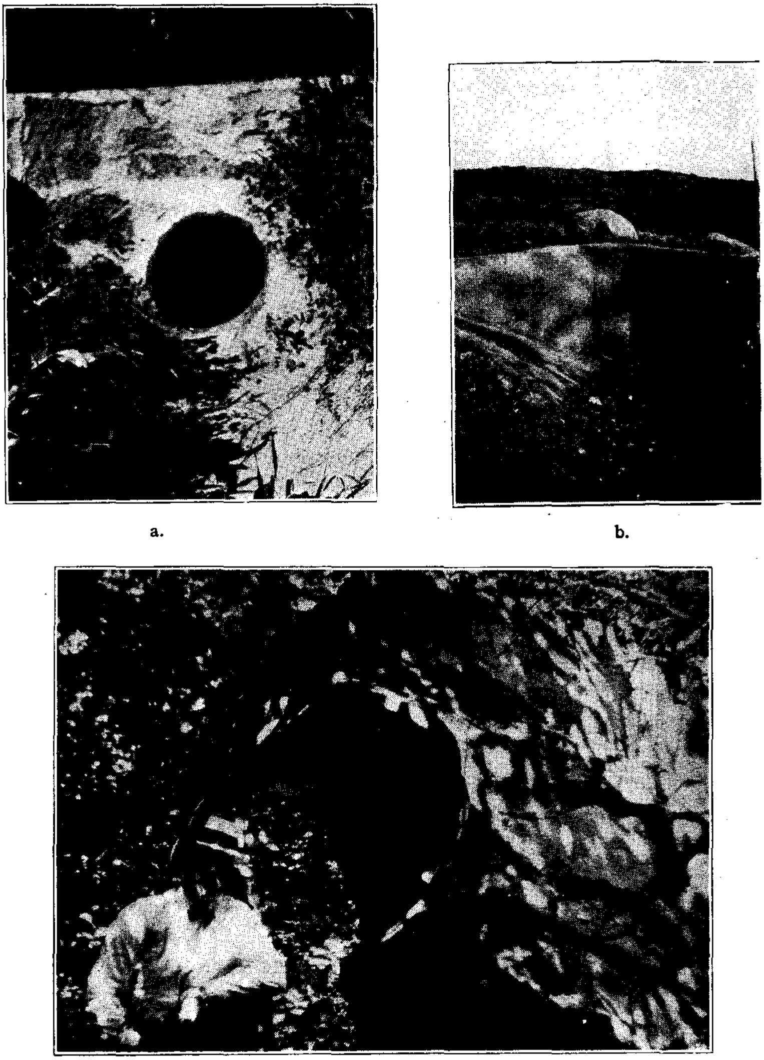
a. b. c.

Fig. 48. An Unprotected Corrugated Iron Outlet Culvert (Lower Right) to a 22-Inch Tile Drain in Clay County. Set in 1916

a. Original culvert, extending through a road and surrounded and supported by loose rocks—photograph 1920.

b. Where the culvert had been—after the flood in May, 1922.

c. A close up of the present end of 22-inch tile 30 feet back of the original outlet; Point X in b.



a. b.

c.

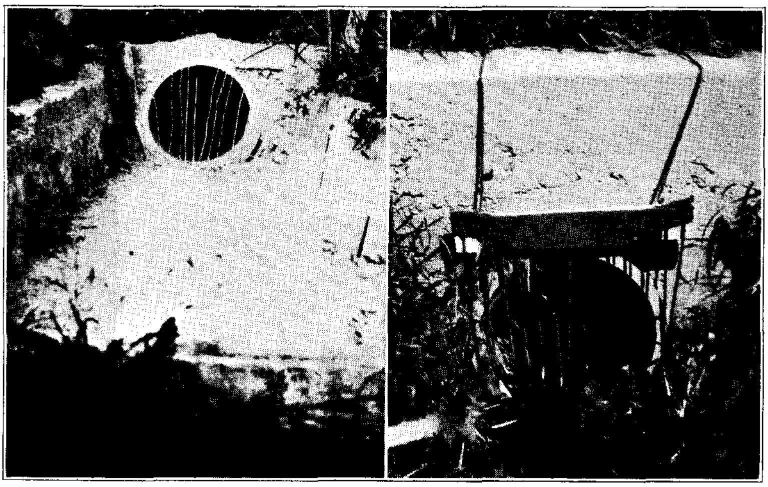
Fig. 49. Masonry Bulkheads on Good and on Poor Foundations

a. A well-built masonry bulkhead around an 18-inch tile; constructed on a firm foundation in 1909. Photograph, June, 1922.

b. A good concrete bulkhead around a 6-inch tile at the top of a sandy lake bluff and protected by a concrete flume extending to the base of the bluff.

c. All that remains of a similar bulkhead built around a 20-inch tile but on a yielding foundation of silt in 1919. Photograph, June, 1922.

Too much emphasis can not be laid on carrying the footing of an outlet bulkhead deep enough to obtain a firm natural foundation of gravel, rock, or hard clay, preferably the last, and on protecting it from undermining by seepage. Figure 49, a, shows a properly constructed masonry bulkhead around an 18-inch tile built on a lake bank in Traill County, North Dakota, in 1909, that is still in as good condition as when first built because carried down to a firm dry foundation and protected from undermining by a flood trough and seepage apron in front. Figure 49, b, shows all that remains of a bulkhead built of similar materials in 1910 around a 20-inch tile in Itasca County, Minn., but on a shifting silty river bank and without a flood trough or other sufficient protection against undermining. A gully about 15 feet deep and more than 100 feet long has been washed out behind this old ruin and the eventual repair of the damage will cost many times the original cost of the bulkhead.



a b

Fig. 50. Screened Outlets

a. Screen built of heavy galvanized wire embedded in the concrete—not removable.

b. Removable screen of small iron rods in wooden frame and held in place by thrusting bottom of rods into ground and hooking top over bulkhead.

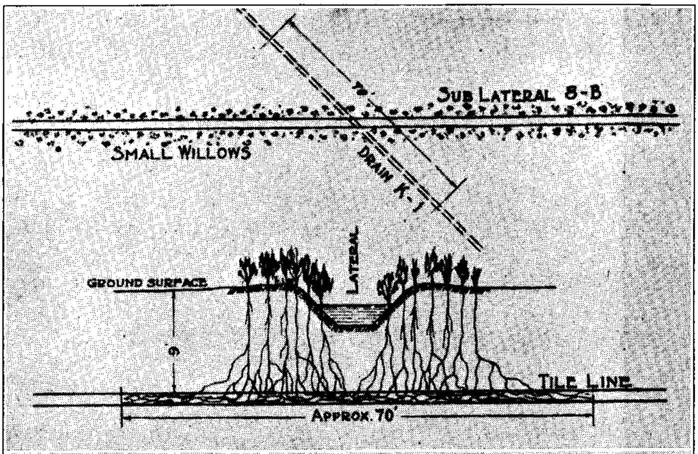
These outlets also illustrate two types of serviceable concrete bulkheads both of which have been in use several years.

SCREENING OUTLET AGAINST ENTRANCE OF BIRDS AND ANIMALS

A screen is necessary to eliminate one dangerous cause of clogging the drain. It may be built of fine-mesh poultry netting or in the form of a grating of slender iron bars. It may be imbedded firmly in the concrete of the outlet bulkhead or into a removable metal or wood frame. The removable type is preferable, as it readily permits the cleaning away of refuse behind it that tends to clog the outlet. For the fixed type see Figure 50, a, and for an inexpensive but effective screen of the removable type see Figure 50, b. The space between bars should ordinarily not exceed one inch.

WILLOWS NEAR TILE LINES

It is important to know that willows and some other soft, water-loving trees growing over or near tile lines will send their roots into the tile in search of food and water and quickly clog the tile. (See



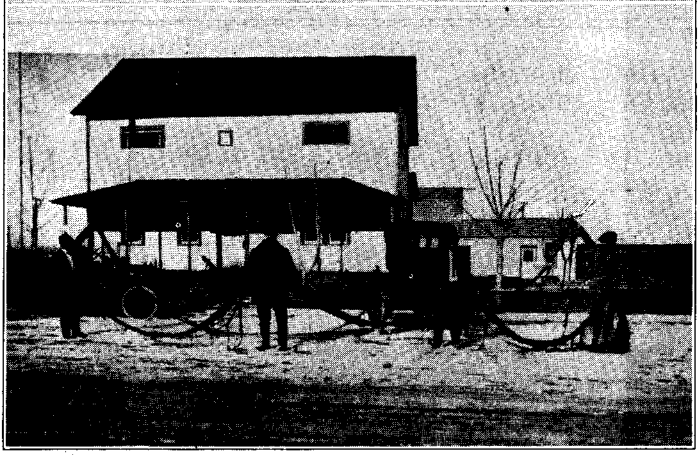


Fig. 51. Willow Roots Clog Drain Tile
Above. Location of willows and the tile lines Below. Roots from the tile

Fig. 51.) Such trees should be thoroly grubbed out, or all tile lines within 50 or 60 feet of such trees should be laid with bell-ended sewer pipe and the joints cemented with strong cement mortar.

DRAINAGE BY WELLS

Wells as outlets for drainage are always a lottery and are not to be recommended. Their efficiency is in direct proportion to the dry reservoir capacity of the sand or gravel bed into which they are sunk. If such beds lie wholly within a pocket of impervious soil and their size is comparatively limited, there being no natural outlet, the efficient life of the well as a drainage outlet will be until the sand pocket is filled with water and no longer. It is not feasible to determine, within reasonable cost, the water capacity of any such sand or gravel bed. Wells dug into clays are totally useless as drainage outlets; and drainage into deep wells as well as into surface wells, is a menace to health and is forbidden by law.

LITERATURE ON DRAINAGE CONSTRUCTION

BOOKS

Land drainage, by Powers and Teeter. John Wiley and Sons, New York. 1922.

Land drainage, by Parsons. McGraw Hill Co., New York. 1915.

Engineering for land drainage, by C. G. Elliott. John Wiley and Sons, New York. 1903, 1912, 1913.

Drainage Engineering, by Murphy. McGraw Hill Co. 1920.

BULLETINS

Land drainage, by H. B. Walker. Kansas Agr. Education Bul. No. 1 of Vol. V. 1912.

Tile drainage on the farm, by A. G. Smith. U. S. D. A. Farmers' Bul. 524. 1913.

Drainage of farm lands, by C. G. Elliott. U. S. D. A. Farmers' Bul. 187. 1904.

Farm drainage (A manual of instruction), by C. F. Brown. Utah Exp. Sta. Bul. 123. 1913.

Tile drainage on the farm, by E. R. Jones and O. R. Zeasman. Wisconsin Agr. Exp. Sta. Bul. 284. 1917.

Tile drainage, by J. A. Jeffery. Michigan Exp. Sta. Special Bul. 56. 1911.

Tile drainage, by E. W. Lehmann and F. C. Fenton. Missouri Agr. Ext. Circ. 34. 1917.

Tile drainage, by A. H. Leidigh and E. G. Gee. Texas Exp. Sta. Bul. 188. 1916.

Installation of an experimental drainage system, by John T. Stewart. Minnesota Agr. Exp. Sta. Bul. 110. 1908. (Out of print.)

Farm drainage, by John T. Stewart. Minnesota Agr. Ext. Bul. 13. 1914. (Out of print.)

Farm Drainage for larger and better crops, by H. B. Roe and G. R. B. Elliott. Minnesota Farmers' Institute Annual No. 33, pp. 60 to 90. 1920.