

9bp  
June, 1944

Iowa State College Library

APR 25 1944

Bulletin P65

# TILE *Drainage* for INCREASED PRODUCTION

AGRICULTURAL EXPERIMENT STATION—AGRICULTURAL EXTENSION SERVICE  
SOIL CONSERVATION SERVICE,  
UNITED STATES DEPARTMENT OF AGRICULTURE, Cooperating  
IOWA STATE COLLEGE AMES, IOWA

AGRICULTURAL EXPERIMENT STATION—AGRICULTURAL EXTENSION SERVICE, Cooperating  
IOWA STATE COLLEGE AMES, IOWA

## CONTENTS

	PAGE
Importance of drainage in soil management.....	147
Management practices which improve drainage conditions.....	148
Drainage ditches.....	149
Essential requirements for tile drains.....	149
The tile outlet.....	150
Location of tile drains.....	151
Depth and spacing.....	154
Securing greatest possible fall.....	158
Selection of tile.....	160
Laying the tile.....	162
Maintenance of the system.....	167
Table showing areas drained by tile.....	174
What's wrong with our drainage systems .....	175

# Tile Drainage for Increased Production

By C. H. VAN VLACK and R. A. NORTON

Organized drainage districts in Iowa include approximately 6 million acres of land, representing an original investment of over \$75,000,000. There are 18,519 miles of public drainage improvements (ditches, tile lines and levees). There is no record of the immense amount of private drainage work which has been done in Iowa, but it probably is far greater in extent and is more evenly spread over the state than the public drainage improvement. In spite of this, many thousands of acres of crops were lost or badly damaged in 1942 and 1943 because of inadequate drainage.

Production of food can be increased by bringing into production much low, level and fertile Iowa land which is not being farmed because it is too wet. Efficiency in production also can be increased. Countless seepy hillsides in the rolling sections of the state are unproductive and interfere greatly with field operation of equipment.

Furthermore, a poorly drained field which is fairly productive in some seasons and not in others may be more of a handicap to satisfactory crop production than swamp land, for when a field is plowed, planted and cultivated and no crop is harvested, the land is wasted, and the labor, power and machinery costs and seed are totally lost.

## Importance of Drainage in Soil Management\*

Removal of surplus water from wet land will increase its productivity and thus make possible an increase in value of crops raised. Proper drainage also makes cultivation easier and lowers the cost of production.

Drainage aids in maintaining a granular structure which is particularly desirable in fine-grained soils such as often occur in the bottomlands or on the flats and in swales of upland soil areas. Fine-grained soils, when rid of excess water, have the desirable properties of coarse-grained soil such as loams

---

\*The sections of this bulletin on importance of drainage in soil management and management practices which improve drainage conditions were written by Prof. B. J. Firkins, Agricultural Experiment Station.

and silt loams in permitting more rapid passage of moisture and air. As a result of improved tilth of the soil through granulation and better airing, the roots of crops will penetrate deeper, thereby increasing their foraging capacity for soil nutrients and available water. Removal of excess water improves soil conditions for the reproduction and functioning of many microorganisms. These microorganisms increase the supply or availability of plant nutrients for crops. Manure and all other organic matter present in or added to soils must have air for its decomposition and conversion into available nutrients.

Well-drained soils warm up earlier in the spring and can be worked earlier. This results in a longer growing season, less danger from early frosts and improved quality of the crop.

Adequately drained soil has a greater water absorbing capacity which means less water to run off and contribute to destructive erosion.

#### **Management Practices Which Improve Drainage Conditions**

In addition to open ditches and tile drainage systems which provide outlets and remove surplus water, certain management practices help remove drainage water more rapidly. One of the most important practices is to include a deep-rooted legume crop, such as alfalfa or sweet clover, in the rotation. Such crops will be most effective when properly inoculated, and grown on land which is limed if the soil is acid. Such legume crops are particularly valuable on soils with heavy impervious subsoils, such as the claypan soils of southern Iowa, some of the Floyd and Carrington areas of northeastern Iowa and many of the poorly drained Clyde and Webster areas of northern Iowa classed as meadow soils. Opening up the tight substrata of these soils facilitates more rapid movement of drainage water to the tiles. In many of the pockets where there is no natural outlet and the water table is high, however, a legume crop is not effective. So, the solution to the drainage problem in such areas is the removal of trapped water through tile drains.

Physical properties of heavy soils also are improved by plowing under, or otherwise incorporating farm manure and crop residues. Every effort should be made to conserve and return to the soil the maximum amount of such materials.

The ground should not be worked when too wet or a puddled structure may develop which will impair the effectiveness of the drainage system.

### Drainage Ditches

Drainage ditches, or open channels, are often required to serve as outlets for tile drains and to remove surface water.

Since drainage ditches must carry surface water as well as ground water, their capacities should be greater than those of tile drains for the same number of acres drained. The capacity of individual field drainage ditches usually need not be computed since the minimum size practicable to build is adequate.

The cost of open drainage ditches is estimated by the cubic yard. To calculate the number of cubic yards per foot of length of ditch, multiply the average width by the average depth and divide by 27.

If an open drainage ditch is to be dug for the benefit of a single farm, it should be possible for the farmer who has had some drainage experience to do the work. However, if the undertaking involves several farms, or an extensive area of several hundred or possibly thousands of acres, a competent drainage engineer should be employed.

### Essential Requirements for Tile Drains

Not all drainage systems have been satisfactory. Many, while providing some improvement, are not as effective as they should be. If any one of a number of essentials for an adequate tile drainage system is lacking, or faulty, the whole system is certain to be unsatisfactory and will soon cease to function as planned. Each of the following important considerations might well be termed elements of good design:

1. A suitable outlet.
2. Tile drains properly located.
3. Adequate depth and spacing of the tile drains.

4. Greatest obtainable fall for tile up to 2 feet per 100 feet.
5. Quality and size of tile properly chosen.
6. Correct laying of the tile.
7. Watchful and careful maintenance of the drainage system.

### The Tile Outlet

The first problem in planning and installing a tile line is to locate a suitable outlet. Probably more tile drainage failures have been caused by an inadequate outlet than by all other causes of unsatisfactory operation put together. (Fig. 1.) Since a natural waterway, an open ditch, or another tile line may be used as an outlet, oftentimes the cooperation of a number of landholders is necessary for the construction of open ditches or outlet channels before tile drain construction becomes feasible.

The tile outlet needs protection against washing of the banks of the ditch into which it discharges. A substantial



Fig. 1. This washed-out bulkhead caused loss of tile back 65 feet into the field. The loss is continuing and will until relaid and a substantial bulkhead such as is shown in fig. 4 is constructed. The old material will be quite useless in the reconstruction. Adequate foundation, the provision of an "apron" for the water to spill out upon and properly placed wing walls will be needed.



**Fig. 2.** This is what often happens when the tile outlet is not protected or the bulkhead fails. Water flowing out of the end of the tile washes back under it until the first tile drops, then the next one, and so on the process continues, cutting back far into the field. The remedy here is to relay this line, using bell-end sewer tile, cemented, and then construct a concrete bulkhead.

bulkhead of stone or concrete with an "apron" below the tile for the water to spill on is essential.

It is good practice to construct the bulkhead as soon as the lower end of the ditch has been dug, because then the first tile can be cemented firmly in position. At the same time protection is afforded the mouth of the ditch while construction is underway. Because of probable damage from alternate freezing and thawing it is desirable to substitute corrugated galvanized iron culvert pipe whenever possible for the first 14 to 16 feet of tile next to the bulkhead. Sewer tile with cement joints for 15 feet may be used if laid on solid ground (figs. 2 and 3).

#### Location of Tile Drains

The location of the tile lines is governed by the location of the outlet, topography of the area, and character of soil and subsoil. Through rough land and where the area does not



**Fig. 3.** This 8-inch tile outlet is improperly protected. An 8-foot to 10-foot length of corrugated culvert pipe or salvaged well casing or a similar length of vitrified sewer pipe with cemented joints may be used to replace the last few feet of such a line. The earth should be mounded over the pipe smoothly and the area should be sodded. For tile over 10 inches in diameter, or if there is any chance that surface water will flow out of the tiled field and overfall at the outlet, a substantial concrete bulkhead such as that shown in fig. 4 is essential.

involve more than a single farm, the use of the "natural system" may be employed. (Fig. 6.) As the name implies, this means laying tile along the depressions where the soil is too wet for cultivation, with as much fall as possible toward the outlet. Some of these lines will empty into others. Thus the system may branch and have mains, sub-mains and laterals.

In rather flat areas which are uniformly too wet for cultivation, however, it is advisable to design a complete system of some rather regular layout, such as the "gridiron system" or the "herringbone system" (see illustrations). The former, which is one of the most efficient systems possible for tiling wet areas, consists of a main tile running across the lower end

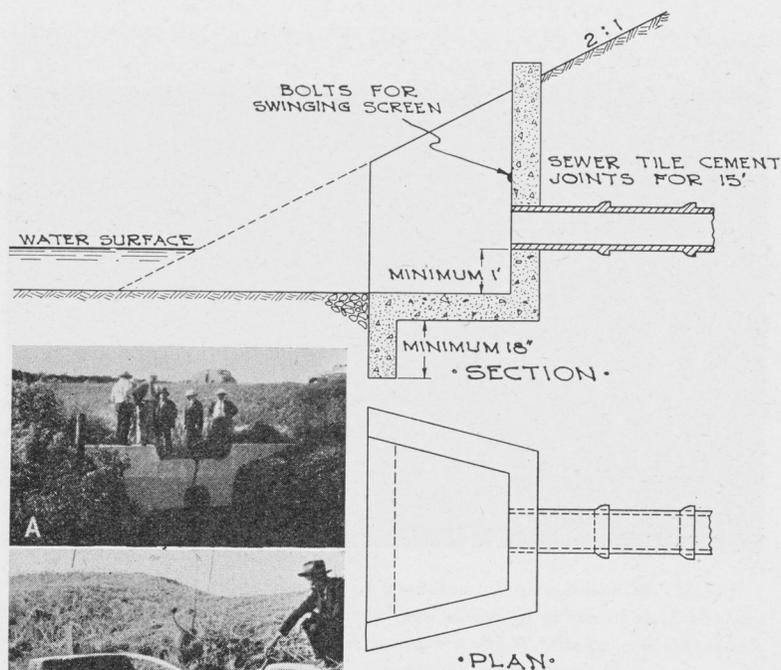
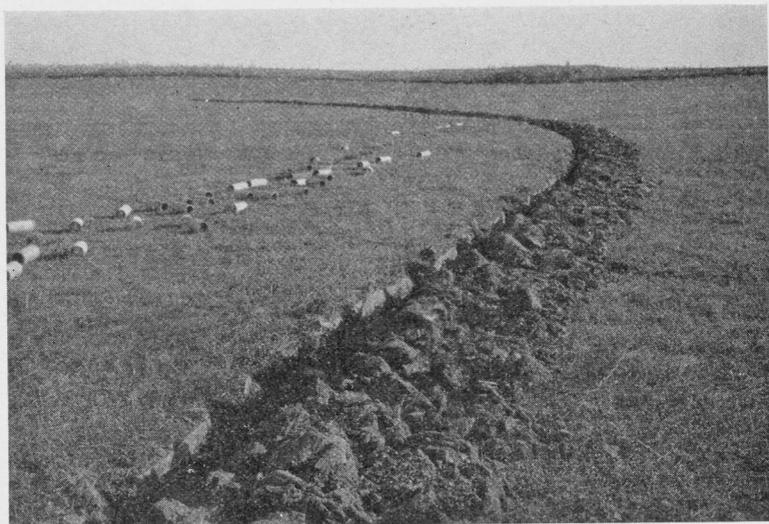


Fig. 4. Concrete bulkhead for tile drain. The minimum thickness of concrete wall, apron and wings is 6 inches. Eight-inch thickness is important for structures serving above

a 5-inch tile outlet. Tile of 24-inch diameter or larger should be provided with bulkhead wall thickness of at least 10 inches. The overall length of the concrete apron should be not less than three times the diameter of the tile and under no condition less than  $2\frac{1}{2}$  feet. When available, reinforcing tie rods should connect the wing walls with the main wall. Where surface overflow will enter the main ditch at the same point as the tile, a weir notch of liberal proportions should be provided over the tile as shown in (A). Care should be taken that ample bearing surface is provided the structure. Bulkhead (A) is failing due to insufficient footing and no wing walls as is indicated by the large crack from the weir notch down to the tile. Structure (B) is stable, but the hollowed-out head wall is insufficient to prevent surface drainage cutting over and around the wing walls. The structure should be recessed into the stream bank, otherwise the banks might erode away leaving the tile outlet protruding into the channel.



**Fig. 5.** Sometimes it is necessary to extend a tile line across a well-drained area in order to reach wet lands at the juncture of two or more slopes farther uphill. A plow furrow has been thrown up to serve the tiler as a guide in starting his ditch.

of the area and one set of parallel laterals entering the main ditch (fig. 8). Less total length of tile is required for the gridiron than for the herringbone (figs. 8 and 9). In either system, the junction of the laterals with the main should form an angle of 30 to 60 degrees. The mains should follow the general direction of the natural water courses, and the laterals should be laid in the direction of greatest slope.

**Hillside wet spots** (seepy areas) should be drained by laying a tile drain across the slope above the spot where the ground is wettest. The drain will intercept the water which is brought to the surface by an impervious layer of soil that prevents its downward flow (fig. 11).

#### Depth and Spacing

It is important in tiling to remove rapidly the surplus water from that part of the soil which is penetrated by a large portion of the crop roots. From the standpoint of soil character-

Fig. 6. The natural system of tile drainage can be used for small irregular areas. The lines of tile are located in the swales, depressions and low spots to conform with the topography.

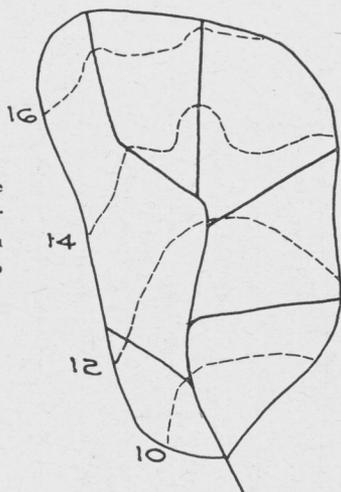


Fig. 7. General view of field where tile are being laid in a modified gridiron system. The plan shown is quite satisfactory for the field, but the sub-main leading from the right enters the main (left foreground) a little too nearly at right angles just before the main passes into a neighbor's field. The landowners could have cooperated on this project so the lateral at the extreme right of the picture and those beyond could have joined directly into the main.

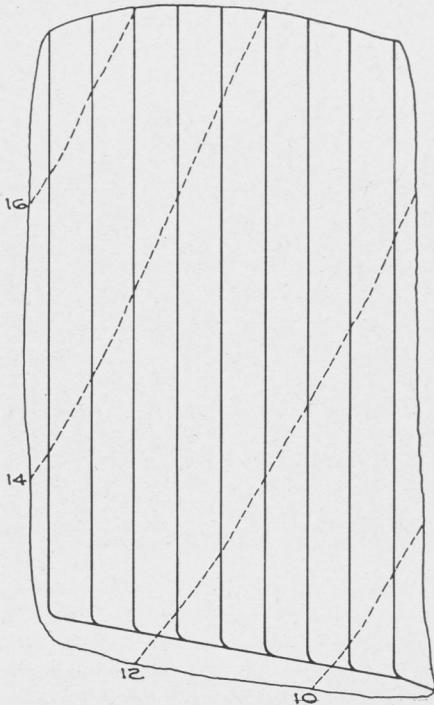


Fig. 8. The gridiron system is the most efficient system for flat areas or land with an even continuous slope. The main should extend along the short side of the field or land with the parallel lines of drains on the uphill slope.

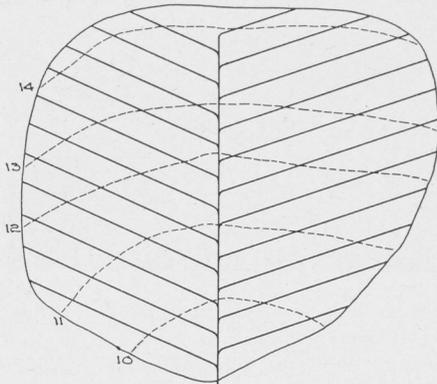


Fig. 9. The herringbone system is well suited to areas which lie on both sides of a narrow swale. It should be noted that laterals on one side of the main enter it at points midway between those on the opposite side. If streams enter the main opposite each other the water flow is retarded.



Fig. 10. Modified herringbone system of tile drains; rather wastefully planned by the landowner but nicely executed by the tiler. A 6-inch line in the foreground carries water from an established tile system on the neighboring farm in the background. An 8-inch main, to the right, and a 6-inch main, to the left, both receive water from systems of comparatively short laterals. Two 8-inch mains would have served the purpose or possibly one 10-inch or 12-inch main would have been ample. Laterals should be made to enter such mains at about  $45^{\circ}$  to  $60^{\circ}$  angles or as it is sometimes stated, "They should about quarter the slope."

istics, common practice is to place tile 4 feet deep in light, open soils and  $2\frac{1}{2}$  to 3 feet deep in tight soils.

Within limits, the greater the depth of the tile, the greater can be the spacing of the tile lines. However, the texture of the soil to the tiling depth should have much to do with the spacing of drains. In very tight clay soil 30 to 40 feet should be the maximum spacing. In heavy soils having a friable structure adequate drainage may be obtained with a spacing of 70 to 80 feet. The lighter textured loamy and sandy soils overlying heavier subsoils will need drains spaced at least 100 feet. Sandy and gravelly soils seldom need drainage unless they are underlain by an impervious layer at a depth of 3 to 4

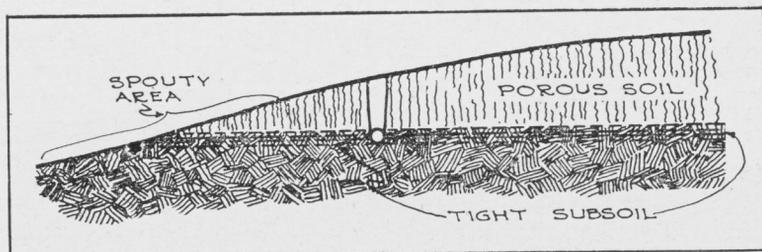


Fig. 11. Seepy ground on hillsides should be drained by intercepting the water some distance above the "spouty" area, since wet spots along hillsides usually are caused by an impervious layer of soil which stops the downward flow of water. If the seepage water must be carried down a slope greater than 2 percent, cement-jointed sewer tile should be used on that steep grade to prevent washouts due to high water velocity.

feet, under which condition tile may be spaced 150 to 200 feet apart.

Excessive drainage is possible under some conditions where drains are placed too deep. While the usual function of tile is to remove surplus water from the soil, there are conditions under which it seems desirable to retain available moisture in the soil. An example might be that of light soils during dry seasons when shallow-rooted crops are being grown.

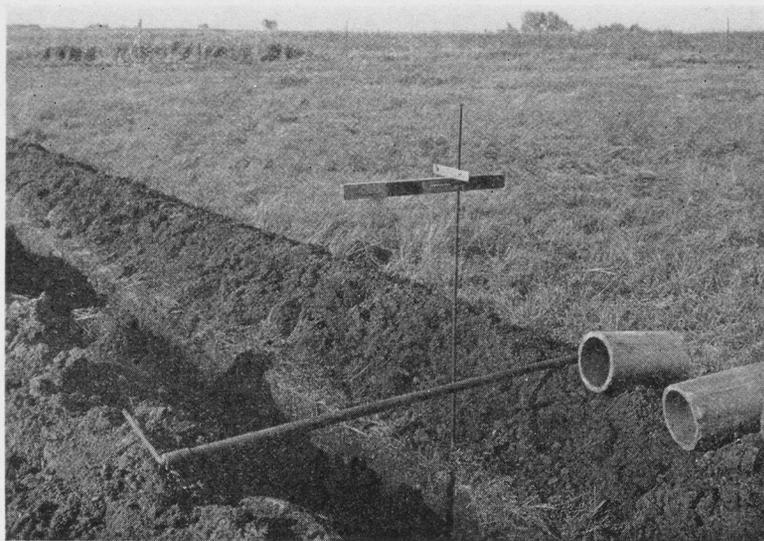
#### Securing Greatest Possible Fall (up to 2 feet per 100 feet)

The greatest possible grade or fall should be provided a tile drain up to 2 feet in 100 feet. In areas with less than 2 percent slope there is little danger of providing too much fall in underground drainage. Too little grade is to be feared, especially when tile are laid in soil which tends to seep in and silt the drain. Provide at least 1 inch fall per 100 feet in a 4-inch drain. A fall of 2 inches or greater should be obtained, if possible, to prevent trouble from filling up. Larger tile can be laid with less fall than smaller sizes. With any size of tile, the greater the fall the greater the carrying capacity of the tile.

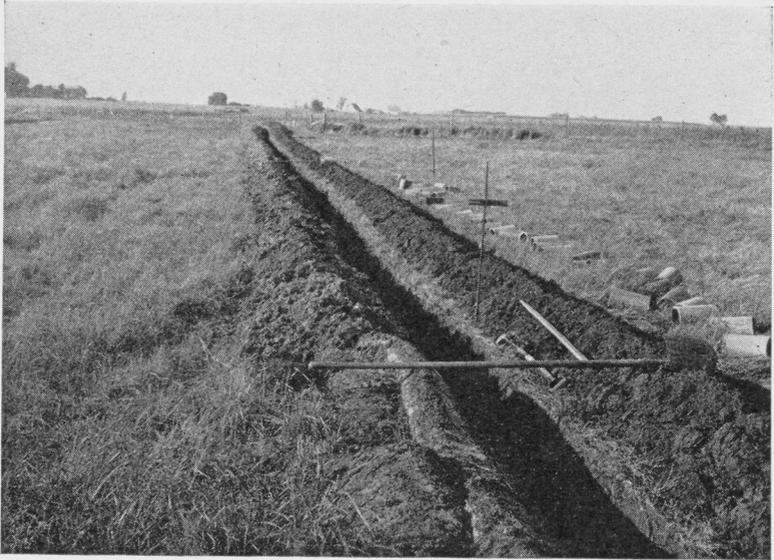
It is important to keep the grade of the tile line uniform. At least, avoid changing from a steep grade with high water velocity to a flatter grade with lower water velocity. Such a

change may cause the tile to fill with sediment. A satisfactory method of bringing a tile ditch to grade is illustrated in figs. 12, 13 and 14.

Breaking the grade often saves much deep digging but entails serious hazards. Since water's capacity to carry silt depends on its velocity, reduction of that velocity, though ever so little, will cause some deposition of the silt. Water at a velocity of 2 miles per hour will carry particles of soil weighing 64 times as much as particles which can be carried by water moving at 1 mile per hour. (The capacities vary as the sixth power of the respective velocities.) If, instead of digging a little deeper through a rise in ground level to maintain grade, you reduce the grade to save extra excavation, you



**Fig. 12.** A simple target used by some tilers to assist in maintaining proper grade for tile lines. The horizontal bar, painted red and white, is clamped at a suitable distance above grade, usually about 5 feet, by means of a wing nut. Note the small pocket level resting on the cross bar in sighting position. A hook for adjusting the position of tile in the ditch lies across the ditch in the foreground. Tile should be turned until the joints fit tightly at the top. Any irregularities causing cracks between joints should be at the bottom of the line.



**Fig. 13.** A pair of targets in position about 5 feet above the grade of the tile line. Tools in the foreground are a "crumber" or drain cleaner for smoothing and rounding the bottom of the ditch, a tiling spade with cutaway sections and a stick of known length over which the tiler sights to determine whether the bottom of his ditch is "on grade."

may easily reduce the velocity of the water one-half, or its silt-carrying capacity to only one sixty-fourth of what it was before. Accordingly, many of the larger particles will be deposited in this section of the tile, with the result that before long the tile will be seriously choked.

#### Selection of Tile

Since water enters the tile at the undersides of the joints, as it would enter leaks in a boat, and not through the walls of the tile, porous tile are no more efficient than impervious tile. In general, tile which absorb large quantities of water are weaker than those which absorb small amounts. Good drain tile should be round with clean-cut ends so that it may be laid to grade in a well shaped ditch bottom. For the larger sizes (12 inches and larger) good qualities are assured by specify-

ing that all tile used shall meet the standard specifications of the American Society of Testing Materials. These specifications cover clay and concrete tile and are available from the Secretary of the Society at Philadelphia, Penn. Well-burned and properly made clay tile and well-made and properly cured concrete tile are durable and equally satisfactory.

**Tile size** depends upon the area to be drained, porosity of the soil, topography and the grade or fall which can be obtained. A size no smaller than 5 inches should be used except when the grade is short and steep. The carrying capacity of a 5-inch tile is virtually twice that of a 4-inch tile. While this rate of increase in capacity does not continue for each increase in tile size, the capacity of a larger tile is much greater than is indicated directly by comparison of diameters.

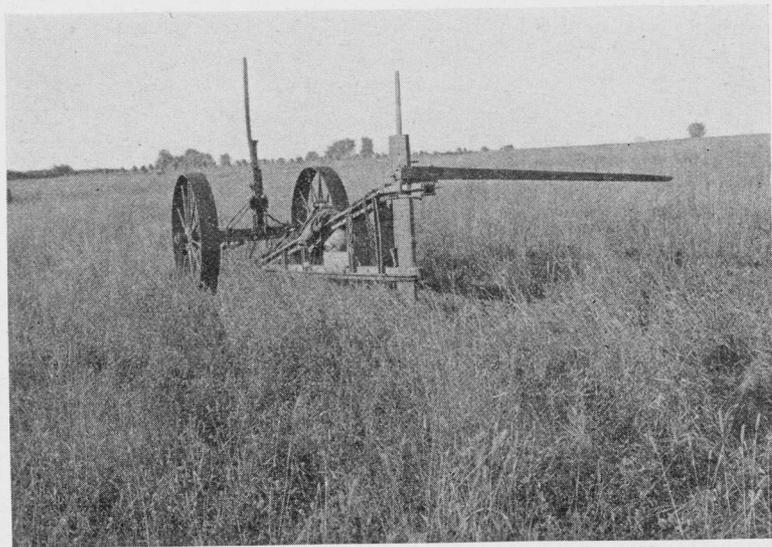


**Fig. 14.** Tiler using targets to establish the grade line of his ditch. By sighting over a stick of known length at the two distant targets he can trim the bottom of his ditch to just the proper depth. The target behind the tiler has been swung out of his way temporarily. A "crumber" or drain cleaner lies across the ditch behind the tiler and a pair of four-pointed tongs for removing medium weight stones from the ditch may be seen beyond his left shoulder.

To secure the proper and most economical balance in tile sizes for an extensive drainage system of mains and laterals, a competent drainage engineer should be employed. He will take into account the run-off to be taken care of, the most suitable depth and spacing of laterals, the available grade, and the arrangement of the drains into systems that will best suit the land and most economically provide thorough drainage.

#### Laying the Tile

Digging for tile should begin at the outlet and proceed upstream. Great care should be taken not to excavate below



**Fig. 15.** Mole-tile ditching machine specially suitable for laying 4-inch to 6-inch tile in soil which is reasonably free from stones and where a reasonable grade is available. Does not work very well where the land is flat. Note jackknife extending to right just above the long horizontal lever. The operator watches the knife through an engineer's level or transit with telescope tilted slightly uphill in the direction of progress. Should a large stone be encountered, the knife will suddenly rise above the line of sight. Under good conditions 200 feet of tile can be laid in 30 to 35 minutes after all preliminary work has been completed.

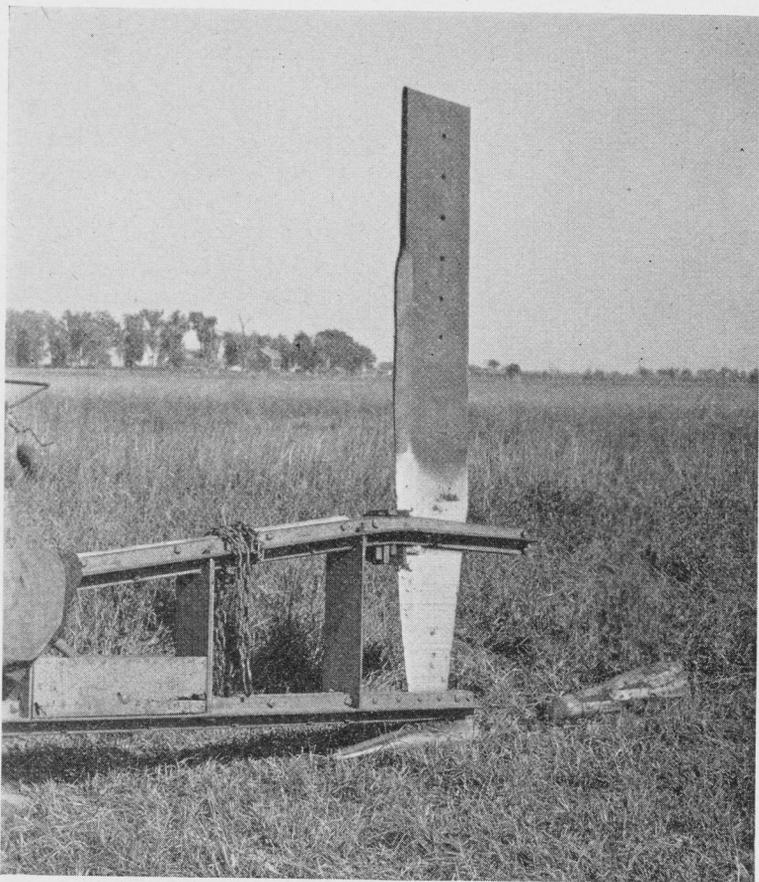


Fig. 16. Mole-tile ditching machine with cutting blade and mole in position for moving to a new location. The pointed "mole" is about 4 or 5 inches in diameter at its largest point. The following "plug" is of oak, sheathed with metal wearing strips and is of about 4 inches greater diameter than the nominal size of tile being laid. A flexible, trough-shaped, steel ribbon (not shown) 200 feet long is attached to plug and the tile are laid on it as the ribbon progresses and pulls them into the soil.

grade. On the other hand, a high spot in the ditch reduces the grade above that point. The tile gradually fills with silt above the high spot since the reduced velocity causes the

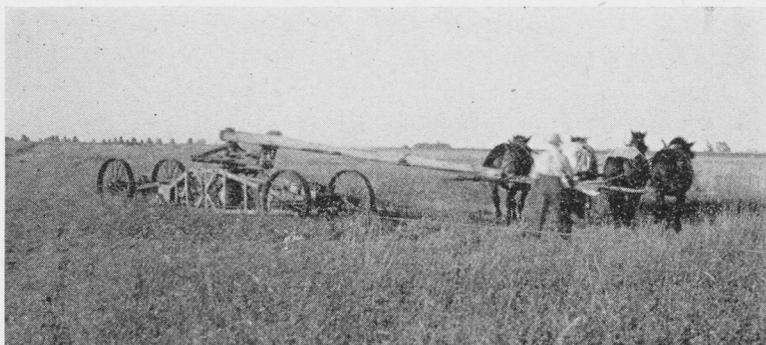


Fig. 17. Capstan used for pulling the mole-tile ditcher blade through the soil. The weight of 5-inch tile on the 200-foot steel ribbon may approach 1 ton. Horses require considerable training to avoid injuring their legs on the taut cable.

heavier particles of water-carried soil to be deposited, as was pointed out under the cautions in reducing grade. For extensive systems, and especially when labor is scarce, it is advisable to engage the operation of a tile-trenching machine.

A mole-tile ditching machine with which it is possible to lay

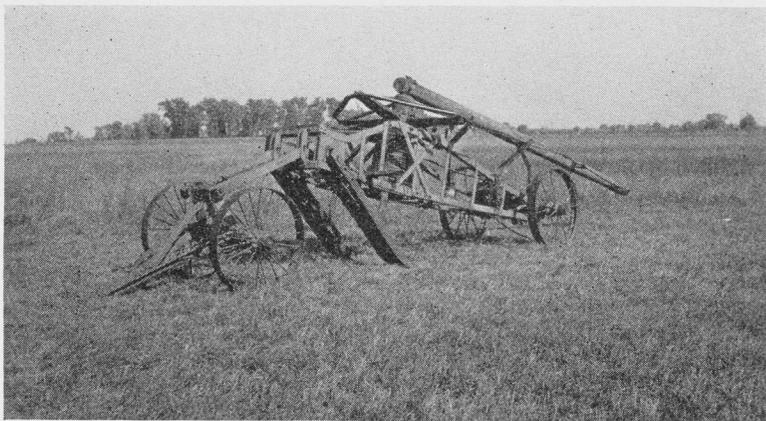


Fig. 18. Capstan truck in new position before load is applied. The two huge spuds dig into the ground and prevent the truck from being dragged backward toward the tile laying machine.



**Fig. 19. Laying tile on the flexible steel ribbon which is dragged behind the mole-tile ditcher. The foreman of the crew is watching the operation of the machine through an engineer's level as explained in fig. 11. Note homemade stoneboat for hauling tile to strategic points where tile laying is in progress.**

tile very rapidly under favorable conditions is shown in figs. 15 to 18, inclusive. Figures 20 and 21 show an inexpensive homemade device for distributing tile in fields. This is handy for use with the tile-laying machine or when the tile are to be laid by hand.

Tile laying should follow the trench digging as closely as possible. The ends of the tile should be made to fit together tightly by turning as needed. Any irregular fitting should be adjusted so that the top side fits closely and the more open portion of the joint is on the underside. On-the-job connections may be made as indicated in fig. 23 if commercial fittings are not available. Pieces of broken tile may be used to cover small openings on the tops or sides to prevent soil from getting into the tile.

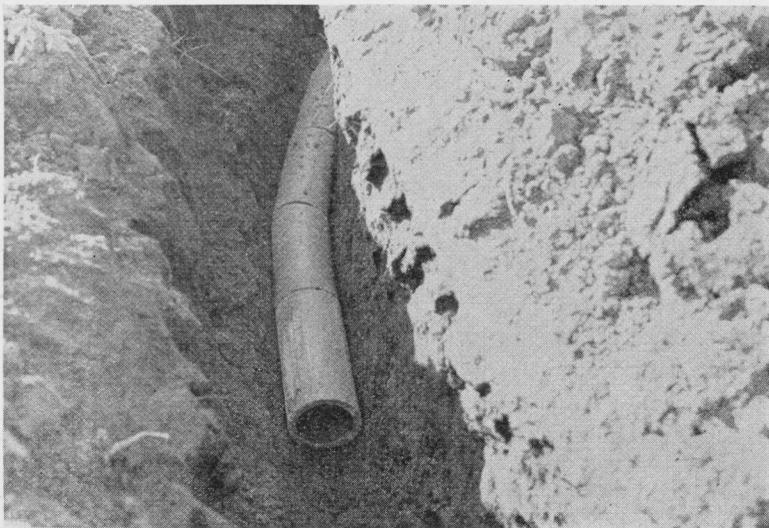
The importance of laying the tile and covering with a few inches of earth (blinding) as soon as the trench is completed



Fig. 20. Homemade stoneboat for hauling tile for distribution along proposed tile lines or to strategic points where tile are needed incident to operation of mole-tile ditching machines.



Fig. 21. Homemade stoneboat used for hauling tile about fields. Ease of loading and unloading this device is its important feature.



**Fig. 22.** A careful tiler will chip off the ends of adjacent tile on bends made "on the job." This assures a reasonably smooth path for the water in tile and prevents cave-ins which might occur if surface water should find a path to an imperfect joint in the top of the line.

to grade cannot be overstressed (fig. 24). Caving of the banks is always likely, which might roll the tile out of line.

#### Maintenance of the System

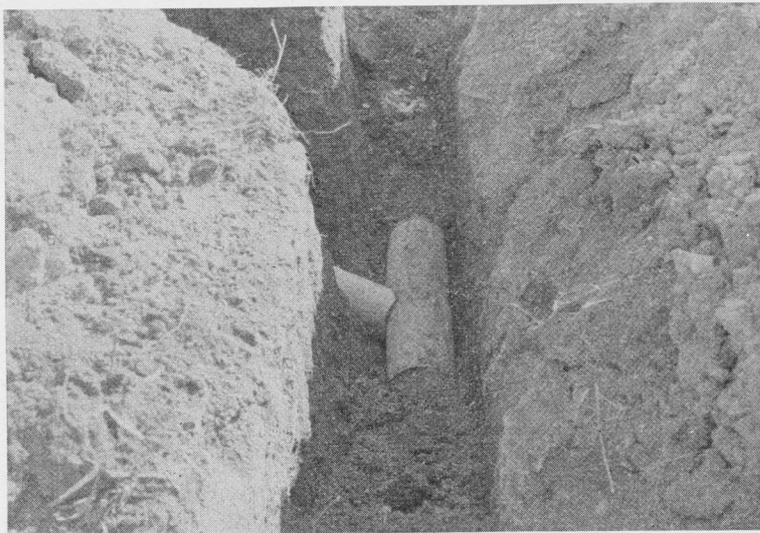
Open ditches should be kept free from tree and weed growth (fig. 25) which tends to slow down the velocity of the stream and cause excessive silting. Logs, brush, old fencing and other debris should be kept cleared from the channel. Controlled pasturing of the berm and spoil banks with livestock other than hogs (fig. 26) will assist in preventing tree and weed growth and will cause no serious difficulty.

If obstructions are not kept out of the channel, silting will diminish the capacity of the ditch and will submerge tile outlets emptying into the ditch.

Tile drains to be effective must be kept open. It seems to be the common impression of landowners and others that once

tile are installed they should continue to function indefinitely without any attention. The chief difficulty is that of keeping the outlets in good condition (figs. 1 and 2). Root growth may cause tile stoppage. Any hole or "cave-in" over the tile line indicates that a tile is out of position or has broken (fig. 28). This damage should be corrected at once lest the line above become filled with silt. Erosion control practices should be employed over the drainage area to reduce silting in the tile and ditches.

Maps of drainage systems are important aids to an intelligent maintenance program. They should show the location of all ditches and tile lines; their size and depth; their grade; their distance apart. As repairs or extensions are made the maps should be revised. If the system was designed by a



**Fig. 23.** Commercial Y's and bends may be used in tile lines but often they are unavailable, particularly where a line of one size may connect with a line of a larger size. Then the joints may be fitted on the job. By exercising care, very accurate joints may be made. Usually chips are "barred off" by means of a monkey wrench and the edges are further smoothed with a light hammer. Where a lateral enters a larger sub-main or main the grades of the tops, rather than the lower sides, of the tile should be made to intersect. This prevents accumulation of sediment in the lateral.

registered engineer and constructed under his supervision, both the map and cost data can be recorded in the office of the county recorder and become a part of the legal description of the property.

Even though no engineer was employed the owner should make simple pencil sketches which provide the above suggested information for his own files.



Fig. 24. A poor job of aligning tile. Note tile are out of line by about the thickness of tile wall between eighth and ninth joints from bottom of picture; also three joints out of line at the beginning of the curve, just below the hat on the right bank of the ditch. Tile lines should always be "blinded" by filling with a light layer of fine soil to prevent them from rolling out of line. Backfilling may be completed by teams and scrapers or by a bulldozer if available.



Fig. 25. Trees growing in the bottom of the ditch hold trash, which checks the flow of this stream. As a result silt is deposited and the ditch gradually fills up submerging tile outlets along the open ditch.



Fig. 26. Controlled grazing of open ditch banks by cattle and sheep—never hogs—is one way to prevent the growth of young trees. This ditch is in good condition because it has had the proper kind of care and treatment. It will not fill up as will those with heavy growth of trees and weeds along them. Since most of the mud and silt in the tile and ditches comes from the erosive action of water over the soil, effective erosion control measures should be employed on not only the land which is drained, but also on all areas from which water flows to the drains and ditches.



Fig. 27. Looking upstream at an open ditch which shows a recently leveled spoil bank. Note how high the point of the leveled bank is near the ditch so that rain falling on the banks drains away from the ditch and enters the ditch through surface inlets. This is to prevent the washing of surface soil into the ditch itself. Bromegrass is good for seeding down and holding ditch banks.



Fig. 28. A broken or misplaced tile has caused this sunken area or "hole" over a 12-inch tile line. Unless the broken tile is replaced at once, the entire drain line above the damaged section may become filled with soil. Then the only remedy would be to relay that portion of the system, which is costly. Often timber or concrete supports are needed for the relaid tile.



Fig. 29. Where surface drainage requirements are not extensive, surface inlets are oftentimes provided to admit water to tile drains. When these inlets are used it is important to use larger tile and install silt wells to catch and retain silt carried by the surface water.

The inlets should be screened with cast-iron grating and kept free from trash. Care should be taken that breaks are not neglected as shown in this cut of a roadside inlet. This type of inlet is not practical in a cultivated field. If the volume of water is not great a satisfactory inlet can be obtained by filling a short section (a few feet) of the trench with gravel or broken rock to within about a foot of the surface. The top foot of the trench can be filled with porous soil to permit uninterrupted cultivation of the area. (Oftentimes this rock or gravel fill is helpful in tight soils to hasten the removal of water over flooded tiled fields.)

If flooded areas are extensive, it is generally preferable to remove the water by a system of shallow surface drains.

TABLE SHOWING AREAS DRAINED BY TILE

Diameter of tile inches	Grade per 100 feet in decimals of foot with approximate equivalent in inches									
	0.08 1 in.	0.10 1-3/16 in.	0.12 1½ in.	0.16 2 in.	0.20 2 ¾ in.	0.25 3 in.	0.30 3 ¾ in.	0.40 4 ¼ in.	0.50 6 in.	0.75 9 in.
	Acres of land drained									
5	12	13	14	16	18	20	22	25	28	34
6	19	21	23	25	28	32	35	40	46	57
8	39	44	48	55	62	69	76	88	100	125
10	70	77	84	98	110	120	130	145	165	210

To determine size of tile required, look in the column showing the amount of grade available for the tile line and find the number of acres to be drained. Follow this line to the left to column 1 where the size of tile may be found.

- Examples:
1. Find the size of tile required to drain 69 acres if 3 inches of fall per 100 feet is available. Enter the table in the column headed 0.25 foot or 3 inches; follow down the column to 69 acres then to the left to column 1. An 8-inch tile will carry the water from this area.
  2. Find the size of tile to drain 75 acres at a grade of 1½ inches per 100 feet. Look in the column headed 0.12 or 1½ inches. 48 acres may be drained by an 8-inch tile while 84 may be drained by a 10-inch tile. The larger size of tile should be selected.
  3. Given: To drain 32 acres if a fall of 4 inches per 100 feet is available. 4 inches per 100 feet is a steeper grade than 0.30 and flatter than 0.40, so we must look at both columns and select values between those shown. A 5-inch tile would drain about 23 acres at the stated grade. A 6-inch tile would drain about 37 acres, therefore it would be ample for the acreage stated in this problem.

## What's Wrong With Our Drainage Systems?

1. Silting has occurred in open ditches thus reducing their carrying capacity.
2. Trees and brush have grown up in ditches and channels and on spoil banks.
3. Tile outlets are seriously submerged or completely closed.
4. Inlets are not adequate or have filled up.
5. Tiles have broken allowing tile line to silt in.
6. Bulkheads have washed out permitting tile lines to wash out.
7. Some of the original work was not well designed because of lack of adequate information.
8. Levees have failed due to breakage and lack of maintenance.

---

Cooperative Extension Work in Agriculture and Home Economics, Iowa State College of Agriculture and Mechanic Arts and the United States Department of Agriculture cooperating. Extension Service, R. K. Bliss, director, Ames, Iowa. Distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914. Agricultural Experiment Station, Iowa State College of Agriculture and Mechanic Arts, R. E. Buchanan, director, Ames, Iowa.