Now, as to the depth of grass roots, we have a very extensive series of experiments going on, and the results have not yet been published. But this fact stands out, that the depth of the roots is in exact proportion to the height to which you let the grass grow. If you keep the grass short, your roots will be short—certainly so with creeping bent. We never have found those roots over 2 inches long under putting-green conditions; that is, their feeding is practically all done from the surface soil. Now if that is poor soil and you do not feed it much, the roots will go deeper. The exact details of those experiments will come out in an article one of these days; but our opinion is that 4 inches of good loam top soil is enough. It will do no harm to have more, provided you do not put so much manure and stuff in there that you can not control the growth of the grass. There are scattered all over this country putting greens that were built simply by mowing the natural grass on them, seeding with creeping bent, and then fertilizing; and although that type of putting green is becoming rare, very fine turf was grown on them.

I want to emphasize again that what we consider the main thing in regard to the depth of the soil is the nature of the subsoil. If your subsoil is good, permeable soil, such as Mr. Barrett has, you are not likely to have any difficulty; but where you have a still, heavy subsoil and only 1 inch of soil on top, your soil is altogether too thin. These are our present views.

Tile-Drainage for Golf Courses

By WENDELL P. MILLER, *Agricultural Engineering Department, Ohio State University*[1]

Tile-drains are a necessity on the average golf course for two reasons. The daily golfer readily observes that tile-drains are needed to remove surface water which accumulates during periods of excessive rainfall so as to obviate the necessity for fishing for golf balls in natural depressions and artificial traps. The second and real reason for tile-drains, and the one which I want to discuss, is the necessity for the removal of excess ground water.

Those of you who read THE BULLETIN from cover to cover know of the countless failures and difficulties in golf course management which have been charged to faulty underdrainage conditions. Practically every ill from which a course may suffer has at some time been blamed upon the thing which we call excess ground water. But have you ever heard anybody say that he had proof of damage from too much tile-underdrainage? While tile-drainage is not a cure for all the ills of the golf course, it is a factor which merits more careful consideration than it has received at the hands of architects, contractors, and greenkeepers. Those responsible for our golf courses can not be blamed for their sins of omission, because there has been and still is a great lack of fundamental drainage information and engineering data. A large part of the information which I employ when designing a drainage system, is the result of personal experience gained since my father first sent me out as a boy with a hoe to clean out the clogged tile outlets of our farm drainage system.

The following are the most important and undisputed benefits to be derived from tile-drainage:

1. By removing the excess ground water, tile-drainage firms the soil

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[1] In this article Prof. Miller presents the substance of his address on this subject delivered at the annual meeting of the Green Section, January 4, 1924.

and eliminates the direct damage to the turf from puddling caused by trampling soggy clay or silty soils. The earlier drying of the soil in the spring resulting from good drainage means that a course can be brought into condition two weeks to a month earlier without excessive labor or damage to the soil.

2. Tile-drainage not only removes the surface water and the excess ground water from the soil, but it also increases the amount of moisture available for plants.

3. It keeps the soil in a sponge-like condition, ready to receive and retain a larger percentage of the rainfall, thus reducing the amount of surface run-off and erosion of the soil.

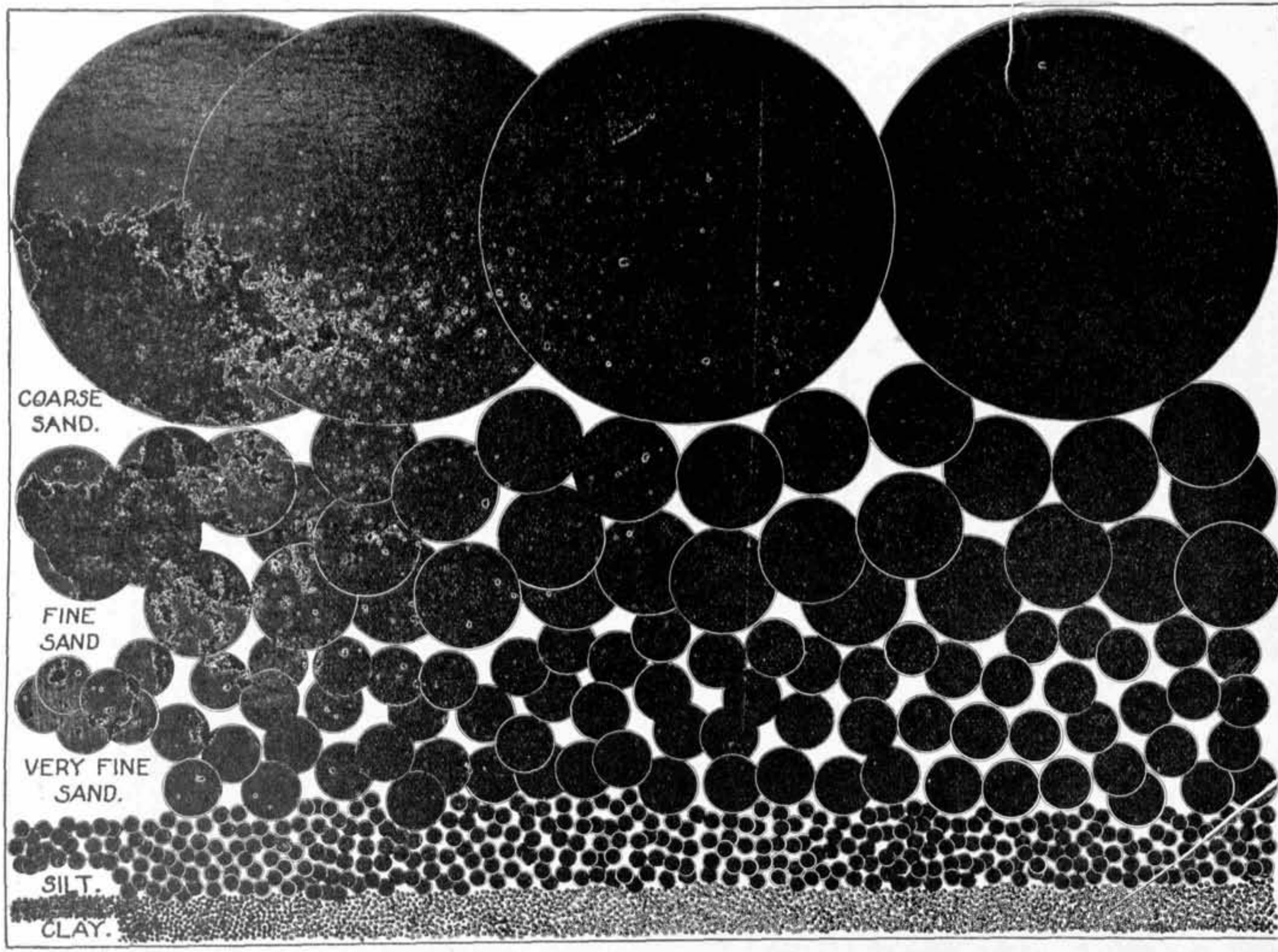
4. By increasing the aeration of the soil, it promotes greater bacterial action, which in turn increases the available supply of plant food.

5. It eliminates winterkilling and frost-heaving of the grass roots.

Several other minor benefits have been listed from time to time but most of them are secondary to the ones mentioned.

All soils are composed of decayed rock and organic matter. A soil of one region is likely to differ from the soil of another region in source of origin, mode of origin (glacial, residual, etc.), time of origin, and so many other factors that the drainage characteristics of two soils may be entirely different. From the drainage and soil-moisture standpoints the most important point of variation in soils is that of size and arrangement of soil particles in the soil mass.

For the purpose of describing soil texture, the Bureau of Soils of the United States Department of Agriculture divides all soil material, on the basis of the size of the soil particles, into 7 "soil separates." These separates, listed in order of size of soil particles, are as follows: clay, silt, very fine sand, fine sand, medium sand, coarse sand, and fine gravel. All soils are then classified by determining the percentage of each of the above separates contained. There are three groups of "soil classes." Those which contain less than 20 per cent of silt and clay particles are called sand soils. Those that contain between 20 per cent and 50 per cent of silt and clay are in the group called sandy loams. The sand and sandy loam groups usually have natural underdrainage and seldom require uniform tile-drainage for the control of excess ground water. Soils of the third group, those which cause trouble by lacking natural underdrainage, contain more than 50 per cent of silt and clay. The most common soil classes of this group are silt loam, clay loam, silty clay loam, silty clay, and clay soils. On page 68 a comparison of the diameters of the various soil separates is illustrated. The white areas are the soil voids or spaces which can be occupied by excess soil water or by air. The black line around each soil particle represents the film of soil moisture which surrounds each soil particle. This film of moisture is the only water that plants can use. Now imagine that the soil particles shown in the diagram are thoroughly mixed, so that the fine sand fills the voids between the coarse sand, and the silt and clay fill the smaller voids resulting from the mixture of sands. This process of filling the voids with still smaller and smaller particles of clay has gone so far in some soils that the voids have become too small to permit the percolation of water through the soil. On the other hand, with a soil in which the soil particles are quite uniform in size, the smaller the particles the greater the percentage of voids in a



Relative Sizes of Soil Particles.

given soil mass. In other words a bucketful of dry clay will hold more water than a bucketful of dry coarse sand. In nature one rarely finds a soil in which the soil particles are of uniform size, and hence almost every soil class, and even the soil types of a given class, have widely varying water-holding capacities and drainage characteristics. Many other factors, such as organic matter content, cultural methods, and kind of crops grown, also change the drainage characteristics and complicate the problem.

This discussion of soil structure has been given in the hope that it will explain why it is impossible at the present time to give any set rules for the proper spacing and depth of tile lines which will apply to all soils. This also explains why the drainage systems of two adjoining golf courses which may be alike in structural details, give unlike results in the removal of excess ground water. It also means that the answer to the question, How much drainage is needed? must be secured from each particular soil by careful physical examination. The answer is not to be found in text-books on methods of constructing drainage systems.

Excess ground water acts as a lubricant on the soil particles. When the ground is full of excess ground water the soil particles can easily roll around on one another, and we say that the ground is soft and waterlogged. Working or trampling a soggy soil will cause the smaller particles to slip in between the larger particles, thus making a more compact soil mass. When a soil thus treated dries out, it becomes very hard, and is spoken of as a puddled soil. Grass will not thrive on puddled soils, and under such conditions tile-drainage removes the water very slowly.

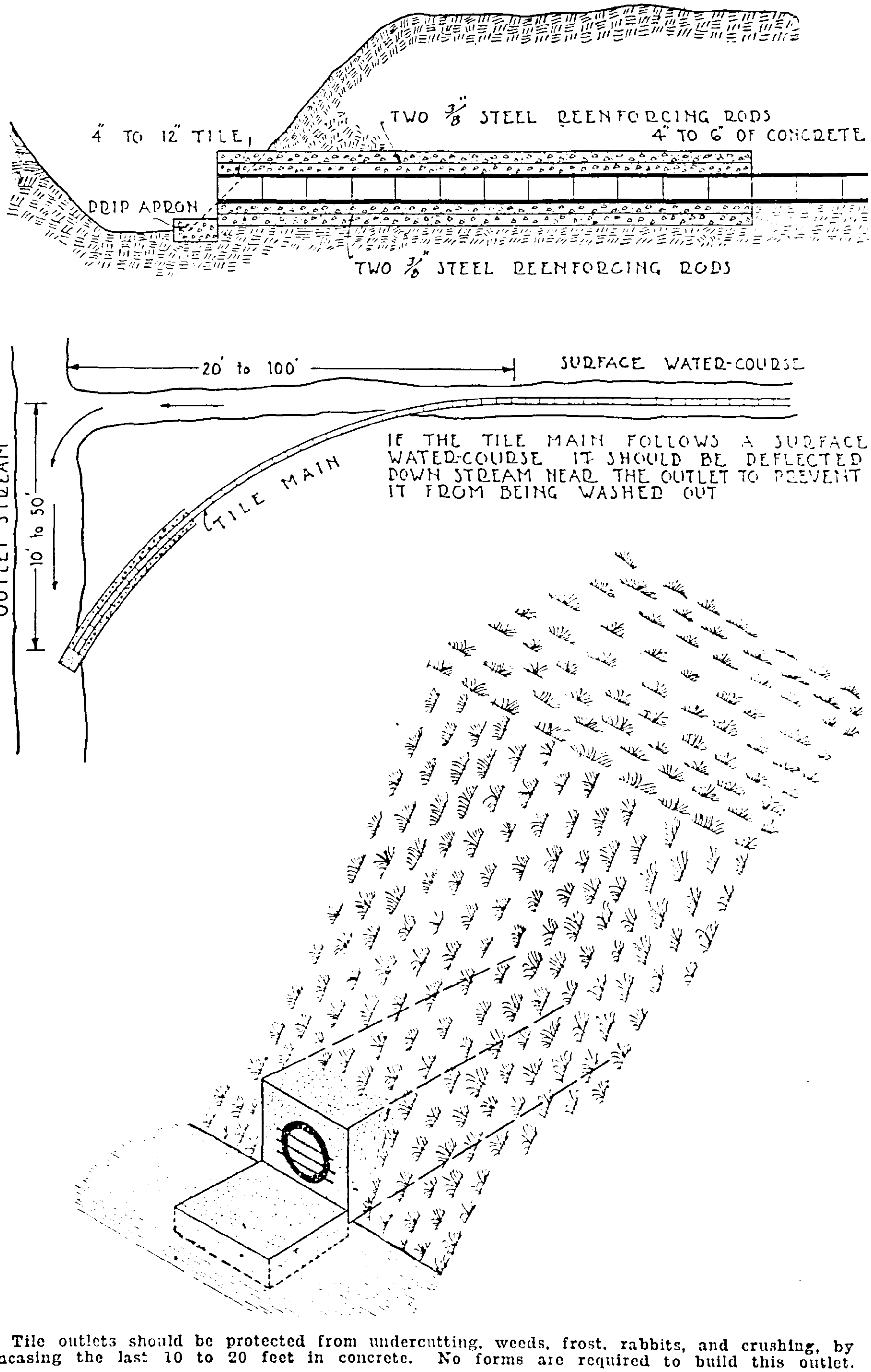
Air and water can not occupy the same space at the same time. Nature abhors a vacuum; hence when the excess ground water is removed from a soil by tile-drainage, air immediately filters into the voids between the soil particles. Tile-drainage prevents the air starvation of plant roots and of the soil bacteria which assist in making available the plant food of the soil.

Tile-drains are to the soil what the spillway is to the dam. If it were not for proper spillways to limit the head of water in our big dams, the water would wash out the dams. Exactly so tile-drains, by limiting the height of the water-level in the soil, prevent the water from heavy rains running away over the surface of the ground, as it would if the ground were already full of water.

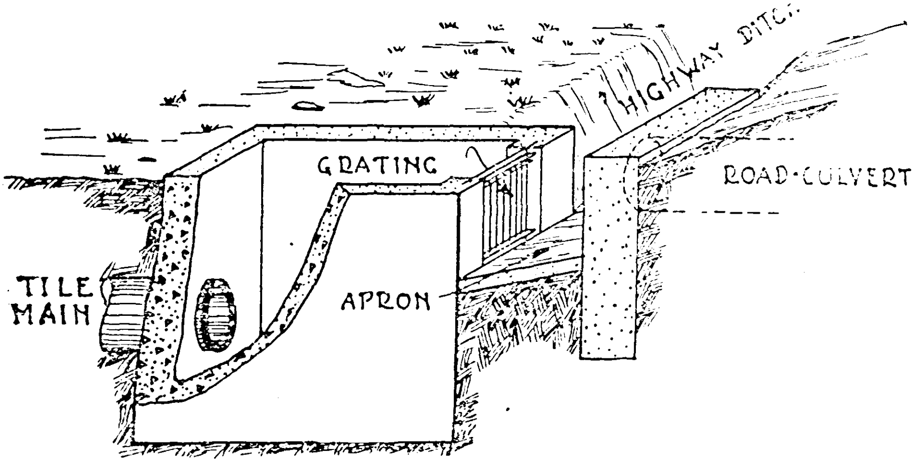
Soil particles change very little in size with change in temperature, but water expands greatly when freezing. Hence the plants on a waterlogged soil suffer more in winter than those on dry soil, because the expansion of the freezing water breaks the roots.

With this discussion on *why* tiles drain, a few remarks on *how* tiles drain may not be out of place.

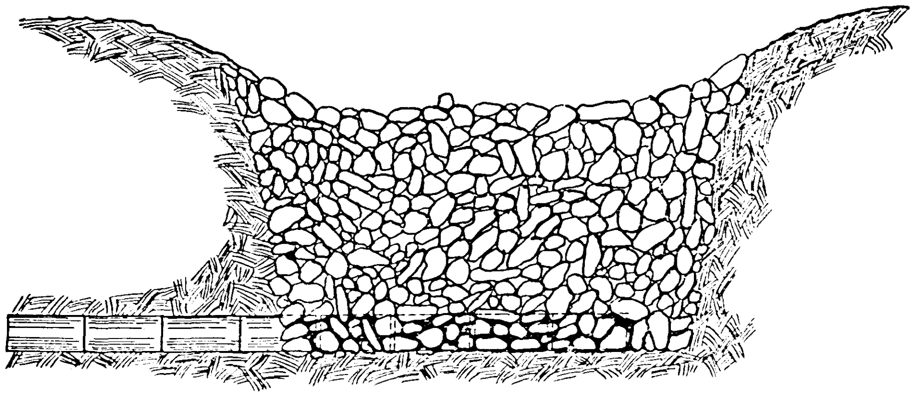
The Outlet.—A good outlet is the first essential of good drainage. No amount of care in the design and construction of a tile-drainage system will overcome the handicap of a poorly chosen or poorly protected outlet. The ideal outlet provides for free flow from the mains at all times, is low enough to permit a good grade in the main, yet requires a depth of cut which is just sufficient to take care of the flow from submains and laterals. A majority of the drainage systems have their outlets in an open ditch or tile built and maintained by the county. When these county drains are being constructed or rebuilt, the abutting property owners may well give more attention to seeing that they provide a complete and sufficient outlet.



Tile outlets should be protected from undercutting, weeds, frost, rabbits, and crushing, by incasing the last 10 to 20 feet in concrete. No forms are required to build this outlet.



Flood water from road culverts and ditches can be safely admitted to the mains if intakes and screens are provided to prevent debris entering the tile. The box should be covered with a concrete slab, removable for cleaning out the basin.

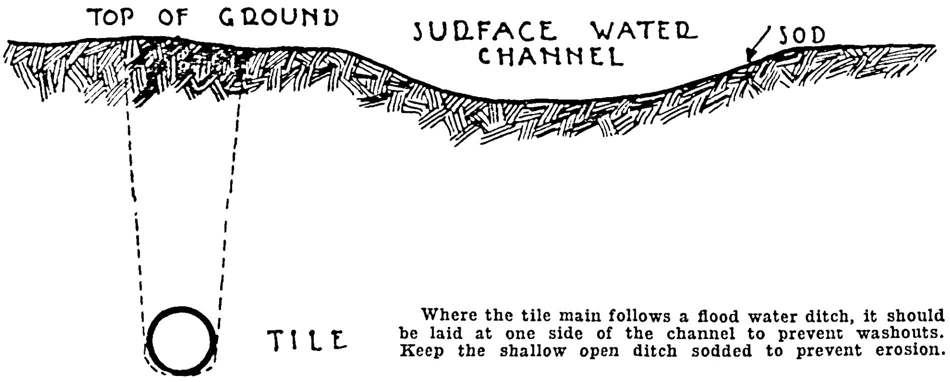


A coarse stone intake may be used where a catch-basin is not desired.

CONCRETE FOR PERMANENCE.—Proper protection of the outlet is the best insurance of permanent efficiency in a tile system. An unprotected outlet is often undermined by the outflowing water, and the tiles will drop, one by one, until a large ditch or gully is washed back for some distance into the field or until the tiles are completely obstructed by weeds and mud. A concrete or masonry head-wall with a splash-apron to prevent the water from undermining the wall should be built at the outlet of the main. If located in the natural channel of the surface runoff, the head-wall should have a spillway large enough to take care of surface water. The foundation and wing-walls should be deep and heavy enough to prevent the spillway from ever being washed out or toppled over. The last 10 feet of the main should be constructed of bell-and-spigot sewer pipe with cemented joints. If the main comes so close to the surface of the ground that there is danger of the tile being broken, old iron well-casing or iron road-culvert pipe should be used instead of sewer pipe. The end of the tile should be protected with a grating of iron rods or a trapdoor to prevent the entrance of animals.

A Systematic System.—With the outlet located, a complete survey should be made of all the area which the outlet will ever be called upon to serve. With this information at hand, a complete drainage scheme can then be outlined. If the layout is planned only a little at a time, and is so constructed, the result will probably be a collection of overlapping small systems, which will make up one large and inefficient system. With the plan for the whole area completed in the beginning, it is, however, possible to install at first those lines which serve the wettest portions and yet contribute toward the finally complete and efficient system. In most cases the employment of a competent drainage engineer is cheap insurance against future difficulties.

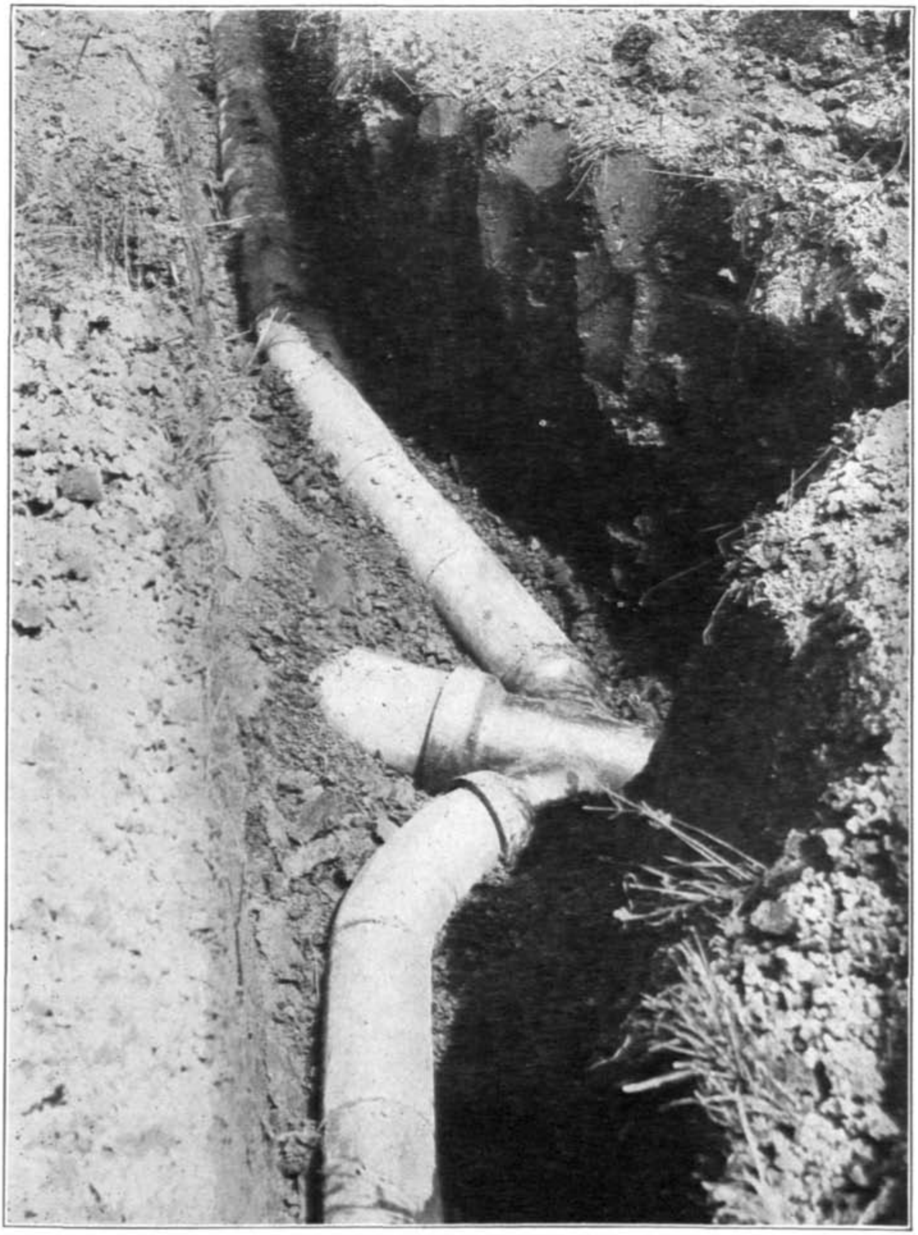
Drainage Geography.—So far as possible, the mains should follow the lines of lowest elevation through the area to be drained, so that the laterals can have good fall and yet not be too deep. The laterals should be straight, and as far as possible should run in the general direction of the greatest slope. They should preferably be laid out in parallel lines. The schemes of lateral layout in general use are (1) the natural, (2) the



Where the tile main follows a flood water ditch, it should be laid at one side of the channel to prevent washouts. Keep the shallow open ditch sodded to prevent erosion.

gridiron, and (3) the herringbone systems. (1) The natural system is used to drain the hollows and depressions in land which is too rolling to permit of a more regular layout or where the entire area does not require uniform underdrainage. The lines are more or less irregular, since they follow the depressions. In uniform drainage these lines become the mains and submains, and the laterals will be laid out according to one of the following schemes. (2) In the gridiron system the laterals are on only one side of the main. This is usually the most economical system which can be used in draining level land and flat slopes, since only the land immediately adjoining one side of the main will be double-drained. With this scheme it is usually possible to get the shortest length of main and the fewest number of junctions in proportion to the total length of laterals. (3) The herringbone system, so called because of its resemblance to the skeleton of the herring, has the laterals entering the main from both sides; and while the land on both sides is double-drained, yet it will be so drained only where it is wettest, a feature which is often of benefit in those places where this system is adapted.

Draining for Posterity.—If correctly planned and constructed, tile



Ready-made junction-tiles should be used to connect laterals to the mains. Loose-fitting connections should be avoided.

drainage is much more nearly everlasting than most other improvements on the golf course. However, one clogged outlet or tile may render a whole system useless. Attention to the correct construction of the fine details is absolutely essential to secure proper performance. Where possible, laterals should enter the main from above. If mains can not be placed deep enough to permit this type of junction, the last two rods of tile should be given a gentle curve in the direction of flow in the main and as much increased fall as is possible. Ready-made junction-tile or sewer-pipe fittings should always be used. Loose-fitting connections should be cemented.

To allow for expansion, soft clay tiles should be spaced at least ¼-inch between joints, and hard burned tiles at least ⅛-inch apart. To prevent accumulation of silt in the lateral lines, it is good practice, where possible, to give them a gradually increasing rate of fall as the outlet is neared. Abrupt decreases in the rate of fall should never be made, unless provision is made for collecting silt that may be carried by the water. As far as possible the rate of fall should be kept uniform even though there are small surface irregularities. To prevent the roots of water-loving plants and trees from clogging the tile lines, all trees and brush should be cut along tile lines. Elm, willow, cottonwood, and elderberry are particularly troublesome. Where the tiles must pass under trees of these species the tiles should be incased in concrete.

The Measurement of Golf Holes

By Alan D. Wilson

So many questions are asked as to the proper manner of measuring golf holes that it has been suggested this article be written, not however to lay down any hard-and-fast rules but simply to give a practical method and one which we believe to be in the nearest accord with the best-recognized practice. In order to give the article authority, it has been submitted to Howard F. Whitney, Chairman of the Rules of Golf Committee, and it is published with his approval.

As discs and cups are constantly moved, no absolutely accurate measure of a hole can be had from day to day, but it would seem as if the fairest measure of the average distance would be from the center of the back or so-called championship tee to the center of the green. If also regular tees and short tees are used, the holes may likewise be measured from them if it is desired to give this information on the card. If these shorter tees are not measured, a player can approximate the length of the hole pretty closely from the measure given from the back tee.

The question is constantly asked whether holes should be measured in an air-line or along the contour of the ground. For practical reasons the contour of the ground is usually the better method. In the first place it is much easier, and in most cases it gives a result almost identical with that of the air-line method. If the play is over rising ground followed by falling ground and then another rise, it is true that the contour method slightly increases the length, but as a large part of the play is uphill, this seems entirely fair, because the hole plays long even as measured. Of course, in certain exceptional cases the air-line method should be used. Let us take, for instance, a one-shot hole of, say, 160 yards in a direct line, played from a high tee over a deep ravine to a high green beyond. The air-line measurement would be 160 yards. If a contour measurement were used, following down into the ravine and up the other side, it might show a distance of 200 yards, which would be entirely misleading, as the contour of the ravine in no way enters into the shot. In general, then, for the sake of practical convenience, holes should be measured on the contour of the ground; but in the unusual case where the contour does not enter into or affect the play of the shot, the air-line method should be used.

Dog-leg holes should be measured from the back or championship tee on the line of play which would be used by the standard good player—a