TILE-DRAINAGE

by

Arthur C. Brancher.

1884.
In the younger days of our country, all that was necessary for the making of a farm, which would yield fair returns for the time and labor expended upon it, was to stake out a section of our rich and rolling prairie land, break up the knolls and high places, plant in corn, wheat, oats or potatoes, and await the harvest—the ponds, sloughs, and flats being left as so much waste land. The land has steadily increased in value, however, until economy and profit—now equally demand a closer utilization of the soil—a demand which all the civilized countries of Europe have long since granted as essential to their existence and well-being.

A matter of economy and profit—now, in time it will become a dire necessity. What now is low, wet land, must in future bear its share of the produce of the farm, and cease, as well, to poison the air.
we breathe with its noxious malaria.

Tillage drainage offers the means of accomplishing all that is desirable in the improvement of the producing qualities of our waste lands, and by its agency thousands upon thousands of acres of good, rich soil, which now lie idle and but grow up to rank and useless weeds and slough-grass, may be made to bloom as a garden and yield its fruits unto the labors of man.

The intention of this paper is to discuss the economic location and construction of such drains as will effectually remove the surplus of surface-water and leave the land in a suitable condition for cultivation. The questions to be settled in any given case may be enumerated as follows:

(a) Why to Drain. (b) Kind of Tile. (c) Cost of Tile.
(d) Size of Tile. (e) Utilization of Fall. (f) Location of Drain. (g) Surveying and Leveling. (h) Method of Laying. (i) Depth of Drain. (j) Outlet.
Many of these questions, once determined, remain the same in all cases, and may be called general questions; others require a special determination for each case, and may be called specific questions. They will be discussed in the order given:

Why to Drain.—The reasons for drainage are very numerous and of vital importance in the economy of the farm:

Drainage renders the soil more porous by the removal of stagnant water and the percolation of the living waters of occasional showers.

The depth of the soil is increased by the percolation of water which formerly either remained upon the surface as a pond, or flowed over it in a sluggish manner as a slough.

Drained land permits the roots of all kinds of vegetation to strike deeper into the ground than is possible in an undrained and water-logged soil, thus...
enabling it to attain a more thrifty growth and the better to withstand the damaging effects of droughts, wind-storms, dashing rains, etc.

Much nutrient—such as plants, including ammonia and other substances from the atmosphere, is carried away by the water flowing over the surface of undrained land. By proper drainage, this may be saved, and, along with the particles of applied fertilizer, carried into the ground by the percolating waters, where it may be utilized by the plant in its growth.

The soil attains the temperature required for germination much earlier in the spring, by the saving of the immense amounts of heat required to evaporate the water from undrained soils.

The temperature beneath the surface is much less affected by exterior changes, because the porous nature of the soil admits of the presence of still air, which is known to be a good non-conductor of heat.
Thus the chilling effect of a sudden north wind, so common and so detrimental to seed which is planted early, may be almost wholly unfelt.

Drained land invariably breaks up more mellow and in better condition generally than undrained soil. It does not "bake" in the sun, and is not thrown from the plow in large, shining lumps, which but a sledge will break.

It may be cultivated much more satisfactorily and with less labor than is required to bring this lumpy, undrained land to proper condition.

The land which before was waste and useless is now of the best on the farm and will repay with interest all expense of putting in the tile.

Many other reasons might be suggested, but that it pays to drain should be so obvious to all, that further remarks would be but useless; hence the foregoing must suffice.
Kind of Tile — Doubt no longer existing as to the utility of drainage, the next thing to be determined is the manner of accomplishing the desired end, whether by open ditch, blind or mole ditch, or by application of some of the various forms of tile.

If large quantities of water are to be carried long distances with moderate fall, the open ditch or canal, properly graded and constructed, is undoubtedly the best means at hand; but for less volume of water, some form of covered ditch is of vastly superior utility.

The best way to decide between the various forms which have been used is to recount them and see which is of most common occurrence and gives the best satisfaction.

Everyone is acquainted with the irregularities of the open ditch — its annual filling up and cleaning out, and the very imperfect way in which it works, even at its best. Hence, for general drainage, it is unconditionally discarded from among the means at hand.
The "blind" or mole ditch consists of an underground waterway, constructed by means of the "mole flow." It has many defects. It necessarily partakes of the irregularities of the surface, and the top and sides of the waterway, being unsupported and unprotected, are liable to wash and cave, until, at length, great subterranean cavities are formed which prove especially dangerous and trying to horses and cattle. Or, on the other extreme, the willow-roota and crawfishes find their way into it and soon fill it up, thus rendering it useless. Being but a poor means at its best, and subject, as it is, to such serious defects, the "blind" or mole ditch may be rejected as entirely unfit to meet the requirements of an efficient drain.

The utter inefficacy of the open ditch has led to the development, through a long series of improvements, of the covered, or tile ditch, as it is called to-day. We will notice these briefly, which will bring us to the accepted
fact that round draining tile is the best, both for ease and accuracy of laying and convenience in handling and manufacture.

A very common way to make a drain, formerly, was to dig a ditch, as for tile, partially fill with brush, broken stones, straw, or any porous material, and cover with dirt. In other cases, bricks placed edgewise in parallel rows with a space of a few inches between them, and a covering of bricks, have been employed. Another method consisted in laying two logs lengthwise and placing another upon them, leaving a space for the water beneath. Sometimes logs were hollowed out and placed with the opening down.

These methods have all been superseded by the draining tile, of which the earliest form was the "horseshoe," or three sided tile. This was rendered of little avail, because of the lack of protection from crawfish and roots of willows, which tended to fill up the tile and stop the drain.
The next step was to make a closed tile with a flat-bottom, but unequal shrinkage and warping in the process of manufacture made these very undesirable to use, as they were difficult to lay on account of poor fitting. Then came the hexagonal and pentagonal forms, and afterwards the oval and circular, the latter of which is now almost exclusively used, by reason of its convenience of manufacture, handling and laying. A good joint may always be secured, as the tile may be turned until it will fit, which is not the case with the oval, horse-shoe or flat-bottomed tile.

The tile should be made from a well-tempered mixture of brick and fire-clay, great care being taken in the drying and burning, that they do not shrink unevenly, causing them to warp and crack. When burned, they should be of uniform size, hardness and strength and of perfect shape. A good test of the quality is to strike two of them together, lightly at first and continuing
until broken. A clear, ringing sound and a fine-grained fracture are good indications of a superior tile. Porosity is of little or no consequence, as the water finds its way into the tile through the joints. Do not be deceived by manufacturers who claim porosity a necessity, for it is more than likely that their object is to create a demand for a weak, loose and "shaky" product. The utmost of care is necessary in selecting the tile to be used, in order that no imperfect ones may find their way into the drain, for the utility of the drain, like the strength of a chain, is measured by its weakest tile.

Cost of tile. — The cost of tile has decreased very materially in the last five or six years, owing to the increased facilities for manufacture, and also the greater number of persons engaged in that industry. Moreover, there exists a large demand for a good and cheap tile, while a higher-priced tile would enjoy a very limited one. The price of tile at present, April, 1854, is as follows:
The following table gives the price per thousand of the tiles manufactured by various companies: (Car-lots)

<table>
<thead>
<tr>
<th>Factory</th>
<th>2&quot;</th>
<th>3&quot;</th>
<th>3½</th>
<th>4&quot;</th>
<th>5&quot;</th>
<th>6&quot;</th>
<th>7&quot;</th>
<th>8&quot;</th>
<th>9&quot;</th>
<th>10&quot;</th>
<th>12&quot;</th>
<th>15&quot;</th>
<th>18&quot;</th>
<th>24&quot;</th>
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<td>Joliet</td>
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<td>$13</td>
<td>$16</td>
<td>$23</td>
<td>$30</td>
<td>$40</td>
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<td>$85</td>
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<td>72</td>
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<td>120</td>
<td>170</td>
<td>270</td>
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<td>50</td>
<td>85</td>
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</tr>
<tr>
<td>Monmouth</td>
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<td>18</td>
<td>27</td>
<td>34</td>
<td>45</td>
<td>60</td>
<td>72</td>
<td>90</td>
<td>122</td>
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<tr>
<td>Ottawa</td>
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<td>12</td>
<td>15</td>
<td>15</td>
<td>24</td>
<td>32</td>
<td>45</td>
<td>60</td>
<td>80</td>
<td>100</td>
<td>130</td>
<td>---</td>
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<tr>
<td>Whitehall</td>
<td>10</td>
<td>13.50</td>
<td>15</td>
<td>18</td>
<td>27</td>
<td>36</td>
<td>54</td>
<td>72</td>
<td>150</td>
<td>180</td>
<td>225</td>
<td>300</td>
<td>525</td>
<td>750</td>
</tr>
</tbody>
</table>

+ Lower Price.
Size of Tile. — In deciding upon the size of the tile to be used in the main drains, many questions must be considered, such as the area of the land to be drained, the number of branch or lateral drains, the rate of fall, length of drain, amount of rainfall, etc. The general tendency is to use a larger tile than would be necessary if it were properly put in, so as to utilize its full capacity; for if it is an inch too high at this place and an inch too low at that, a large percentage of the capacity of the tile is lost, and a smaller tile well laid would surpass in efficiency this poorly laid though larger one.

Laterals will usually require from two to four-inch tile, and mains from four to eight-inch, according to circumstances. It must be remembered that the drain is at work continually, and tends to keep the water removed from the soil, so that, although the capacity of the tile might not be sufficient to carry off at once the rainfall of a freshet, the ground is kept in a condition to receive the surplus, which may thus be carried away at its leisure. This must
also decrease, necessarily, the required size of tile. In capacity, a four-inch is equivalent to two threes, a six-inch to three fours, almost, an eight-inch to two sixes, etc. The following table gives gallons per minute for various falls: (for 100 feet):

<table>
<thead>
<tr>
<th>Size</th>
<th>1&quot; fall</th>
<th>2&quot; fall</th>
<th>3&quot; fall</th>
<th>6&quot; fall</th>
<th>9&quot; fall</th>
<th>12&quot; fall</th>
<th>24&quot; fall</th>
<th>36&quot; fall</th>
<th>48&quot; fall</th>
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<td>19</td>
<td>23</td>
<td>32</td>
<td>40</td>
<td>46</td>
<td>64</td>
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<td>91</td>
</tr>
<tr>
<td>4&quot;</td>
<td>27</td>
<td>33</td>
<td>47</td>
<td>66</td>
<td>81</td>
<td>93</td>
<td>131</td>
<td>163</td>
<td>190</td>
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<tr>
<td>6&quot;</td>
<td>75</td>
<td>105</td>
<td>129</td>
<td>183</td>
<td>224</td>
<td>258</td>
<td>364</td>
<td>450</td>
<td>516</td>
</tr>
<tr>
<td>8&quot;</td>
<td>153</td>
<td>216</td>
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<td>375</td>
<td>450</td>
<td>529</td>
<td>750</td>
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<td>503</td>
<td>617</td>
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<td>1469</td>
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<td>2554</td>
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</tr>
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<td>1651</td>
<td>2022</td>
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<td>5704</td>
<td>7047</td>
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<td>24&quot;</td>
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<td>7202</td>
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<td>30&quot;</td>
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<td>12550</td>
<td>14504</td>
<td>20516</td>
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<td>28787</td>
</tr>
</tbody>
</table>
Utilization of Fall.—This is a matter which demands much
and well-directed attention, for nothing will impair, in such
great-degree, the utility of the drain, as poorly distributed fall.
It is not economy to use all the fall at the head of the drain,
to "give the water a start," so to speak, and expect it to find
its way through forty rods of flat ditch at the outlet;
nor yet is it wise to use it all at the outlet, to avoid deep
digging in a ridge, and expect an extensive "flat" beyond
to drain itself ups-hill to the "divide." An irregular grade
is of course detrimental. It will be best, in general, to
run on rather a moderate fall at the head of the drain,
using heavier fall at the outlet, proper regard being had
of course to the depth. Increasing the fall near the mouth
will have the same effect as an increase in the size of tile,
which becomes necessary on account of the numerous
lateral's. It may be, and generally is, necessary to resort
to both of these expedients to accommodate the increased
volume of water. The determination of any given case
will depend upon the configuration of the ground. Examples of true and false utilization of fall are given on page 28. The method of "runnin' back be the water," without the use of grade stakes will usually result in such false utilization of fall.

Location of Drain. — In order to locate to the best advantage a system of drains, the utmost of judgment and consideration is required. A careful inspection at a time when the crops are off the fields will usually suffice to point out to the unaided eye of a practiced engineer the most available routes, while at times the assistance of a few lines of preliminary levels will prove of vital importance in cases where the fall is undecided and the country very flat. For instance, a farmer wished to drain a large pond into one of two tiles, which "headed" at a distance of about eighty rods. A line of levels showed a fall of but a few inches in the first case, while in the second case the tile was really higher by about a foot.
than the bottom of the pond. The true outlet was found in directly the opposite direction by cutting through a ridge.

The contour of the country will determine the alignment of the drains, care being taken to keep as nearly straight as possible without departing too much from the natural channels of drainage, while a proper regard for fall and depth will fix the grade. The general location having been decided upon, we are now ready to proceed with the surveying and leveling of the lines, a part of the work of proper drainage which is too often performed in a very imperfect manner, if not neglected altogether.

Surveying and Levelling.—That this should be thoroughly and judiciously done is of two-fold importance: First, it is necessary, in laying the tile, to have suitable grade-stakes for reference; second, a complete record of all lines of tile, as to depth, bearing and distance, will prove of much value when all traces upon the surface have
disappeared. Much time and labor will frequently be saved by this means in searching for lost lines of tile when it is necessary to find them for the purpose of removing obstructions, making connections, or finding an outlet for some remote and undrained pond.

The grade or elevation of all drains should be referred to one or more well-preserved bench-marks in the vicinity, while the bearing of an initial line should be determined by one or more witness points, which may consist of trees, chimneys, lightning-rods, church spires, etc.

The field-book should be ruled with columns for stations, readings, elevations, depths, and remarks, as shown on next page, and the notes kept as therein. In working up the notes, long strips of paper bound into tablets are of much convenience. The profile is made from the elevations, while the plat is made from the compass notes, if any have been taken. The following is an example of the details of the work, which shows all important features as to the method:
<table>
<thead>
<tr>
<th>Station</th>
<th>Reading</th>
<th>Elevation</th>
<th>Depth</th>
<th>Remarks</th>
<th>Station</th>
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<td>12.55</td>
<td>2.55</td>
<td>T.I.</td>
<td>5/6</td>
<td>3.54</td>
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<tr>
<td>1</td>
<td>5.34</td>
<td>14.69</td>
<td>4.09</td>
<td>Fäll =</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>4.31</td>
<td>15.72</td>
<td>4.52</td>
<td>1.2 for 100</td>
<td>17</td>
<td>4.47</td>
<td>18.55</td>
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<td>3.00</td>
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<td>3.72</td>
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<td>1</td>
<td>5.76</td>
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<td>17.67</td>
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<td>3/ for 100</td>
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<td>11.60</td>
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<td>3.97</td>
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<td></td>
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<td>3.49</td>
<td>Fäll = 9 feet</td>
</tr>
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<td>3.35</td>
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<td>4.25</td>
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<td></td>
<td>7</td>
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<td>100 feet</td>
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<tr>
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<td></td>
<td></td>
<td>8</td>
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<td>9</td>
<td>3.20</td>
<td>13.53</td>
<td>3.33</td>
<td></td>
</tr>
</tbody>
</table>
Drain No. 1.

Pull = 1.2 ft. per 100.

Vertical Scale = .25 in. = 1 ft.

Drain No. 2.

Pull = 8 ft. per 100.

V. S. = .25 in. = 1 ft.
Computation of Field Notes.

Given:

\[ O = 12.85 - \frac{1000}{2.55} \]

Let \( r, s, g, \) and \( d \) stand for reading, elevation, grade, and depth, respectively, for convenience of explanation. The method of working up the notes is as follows: Assume \( e_0 \) to be 12.85, or as much above 10 as the depth at that stake. Take \( r_1 \) from \( r_0 \) and add or subtract from \( e_0 \) according as the sign of the difference is plus or minus. This gives \( e_1 \). Take \( r_2 \) from \( r_1 \) and add algebraically to \( e_1 \). This gives \( e_2 \).

Continue thus to \( e_5 \), which is a turning point. As usual, take foresight on \( s_1 \) from \( r_4 \), and add to \( e_4 \). Then take \( r_6 \) from backsight on \( d_5 \) and add to \( e_5 \). Continue.

Check: \( r_0 = r_5 + e_0 = e_5 \), or \( 7.15 - 3.26 + 12.85 = 16.77 \).

Checking between \( d_4 \) and \( d_6 \), we have \( 5.20 - 3.90 + 16.77 = 18.43 \), but our elevation as found is 18.23; hence some error has been made. Going back to \( r_3 \), say, to check,

we have \( 5.20 - 3.90 + 16.77 = 18.07 \), which is correct. Hence the error is beyond \( r_3 \). Going over the work again from \( r_3 \) on, we find we have subtracted 10 instead of adding it, as we should. Making this correction, the work
checks, as it should. This check is very important and almost infallible.

For the depths, assume initial grade to be 10. Then for each subsequent station the grade is increased .6 to station 6, after which the fall is decreased to .15 per station. To check the grades: Multiply the fall per station by the number of stations and add the product to the grade of first station. Thus, to check "g 6" we have \((6 \times .6) + 10 = 13.60\). To check "g 16" we have \((10 \times .15) + 13.60 = 15.70\), hence no error in grade has been committed. The depth at any station is found by subtracting the grade from elevation. Thus, \(e + g 4 = d 4\), or \(16.74 + 12.40 = 4.44\). To check depths, we have \(d 4 + g 4 = e 4\).

In checking the depths, it is wise to keep the elevations concealed with a strip of paper, uncovering each in turn as the sum is read off. Thus the checking may go on very rapidly without fear of mental bias from knowing the result, only stopping to investigate those cases in which disagreement occurs. A careful application of the foregoing checks on
all the steps of the work, will insure results whose liability
to error is a minimum, and upon the accuracy of which it
is perfectly safe to depend.

The notes now completely worked up and recorded in the
field book of the engineer, must be copied into the hand book
of the ditcher, depth and number of stake, with rate of fall,
being sufficient. It is best to reduce depths to feet and inches,
as most ditchers understand it better than if given in feet
and tenths. Care must of course be taken to avoid "copying"
mistakes, which may be detected by comparison.

Too much care cannot be given to the detection of all
possible errors by repeated checks and counter-checks, for incorrect
notes are worse than none at all; with them, the drain is certain
to be put in wrong, while without them there would be a chance
to strike the right grade—a mere chance, to be sure, but much
to be preferred to certainty of wrong. Even though not more
than one error is discovered in a month, if it is the only
one that has been made it is more economical to use the
checks and detect it, than not to use them and feel morally sure you do not make more than one mistake in a year. But such certainty is impossible.

Method of Laying.—In laying tile, two men constitute a "team" and will lay about eighteen rods of three to four foot ditch per day. The first man takes off the top dirt with a shovel and then takes one spading with a twenty-two inch tile spade, the best form of which is shown on page 30. He cleans up the loose dirt with a common round shovel. The second man in turn takes a spading and "bottoms up," using "boring rods" and "shusher," as shown on page 30; he thus keeps the bottom finished as he goes, and by means of the rod puts it to grade within a quarter of an inch—an eighth either way. In good soil during fair weather a week's digging may be done and laid up all at once, but for safety and fear of rain it had best be laid up each evening as fast as dug. This also prevents the bottom from becoming covered with dry cloths which in the course of a week will fall into the ditch.
Thus avoiding the necessity of cleaning out. In ditches of
four feet deep and under, it is best to lay the tile by hand,
as much better joints may be made in less time than with the
tile hook.

In deep digging, and especially if bothered with water and
quicksand, it is customary to keep the tile laid up as fast-
as the bottom is made, which is kept to grade by means of
the 'boring rod.' In this way the last spading may be
thrown back upon the tile, thus saving the high pitching.
See page 29.

After the tile is laid, it is secured by chipping in the
clay from the sides of the ditch, as clay makes a much bette-
"bed" for the tile than black loam. The ditch is then filled up
with the flow or scraper.

**Depth of Drain.**—Much difference of opinion exists
as to the proper depth of drain, some favoring shallow and
others deep ditches. In the prairie soils of Illinois, underlaid
with a porous sub-stratum of clay, depth is very desirable.
for drainage, but of course it adds to the expense, and is sometimes made impracticable by poor outlet. In general it may be stated that from three to five feet is a good average depth, with now and then a six, eight, ten or twelve foot cut. It is very undesirable to put it in less than thirty inches in depth, both on account of frost and by reason of its decreased efficiency of draining. There is a much greater tendency to run too shallow than too deep, and especially if running by the water.

Outlet:—Much trouble has been experienced in getting a good outlet for tile drain. If left open, rabbits, rats, mice, etc., enter the tile and die, thus stopping the drain. If protected with a screen, a large percent of the capacity in time of flood is lost. An excellent outlet, where the fall is sufficient to admit of it, consists of a Y or T joint of sewer pipe, two inches larger than the tile, set up on end as shown on page 27, the water being admitted at the side. This joint will always remain full of water, whether the tile runs half a
quarter full, thus effectively excluding animals of whatever kind. Moreover, the submerged outlet increases the capacity of the tile by causing it to run full, when otherwise it would run but partially filled.

General Remarks. - The rate of fall should never be less than 2 per 100 ft. when avoidable, though in extreme cases it has been used as low as .075 or even .05 per 100 ft. This is not advisable, however.

Some men claim that drainage does no good and yet the same men keep a sharp eye out and put in tile where there is the least excuse for it. Others claim that engineering for tile is useless, as a better drain may be made without, and yet they invariably call for an engineer in case they lay a piece of tile. It is customary to charge such men two prices for the engineering, for they avowedly throw away of their own accord one price and should be made to lay the other for the work.
Drain Outlet.
False Distribution of Fall.

Red line represents true grade.
Deep Digging.
Location of Drains.