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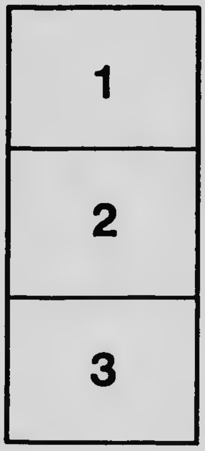
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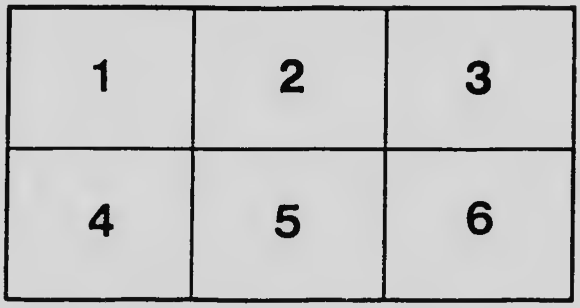
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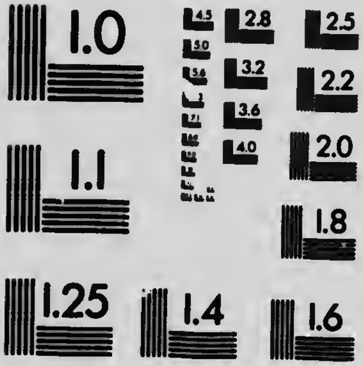


BULLETIN 175.] **[DECEMBER, 1909.**

Ontario Department of Agriculture.

ONTARIO AGRICULTURAL COLLEGE.

Farm Drainage Operations.

BY W. H. DAY.

The benefits of drainage have been considered in bulletin No. 174, entitled, "Farm Underdrainage: Does It Pay?" This bulletin will deal with the construction of the drains and the steps leading thereto. The first steps consist of a preliminary survey to determine the location of the drains, and a closer one to arrive at the grades, in case these are not determined in the preliminary survey.

SURVEYING INDIVIDUAL DRAINS.

Drainage problems may be divided into two classes, those involving individual drains running through well defined courses, and those involving a level area requiring systematic drainage, a drain every four rods more or less.

The individual drain is a comparatively easy proposition, and yet we find numerous examples of failure. During the past season our field men have tested drains which proved to have a fall the wrong way, and others which were given too steep a grade and consequently ran out of the ground, or at least too shallow to be continued, long before reaching the low flats in the back of the place, which were really the spots most needing drainage. In both cases the drains had to be taken up and regraded before being of any use. These mistakes arise either from unreliable methods or attempting to construct the ditch without method, i.e., "by the eye," which is almost equivalent to constructing it "by guess." It is not farmers alone who make these mistakes, for we have letters on file telling of "experienced ditchers" who failed to drain the low land at the back, although there was plenty of fall, as determined later by our levels. Where they occur with "experienced ditchers" who have methods of digging to grade, the trouble arises from "striking the wrong grade" at the start, because of not knowing the total fall. Now what both farmers and "experienced ditchers" need in order to avoid these costly mistakes is accurate methods of determining the grade and of digging to it. Without entering into a discussion in detail of the relative

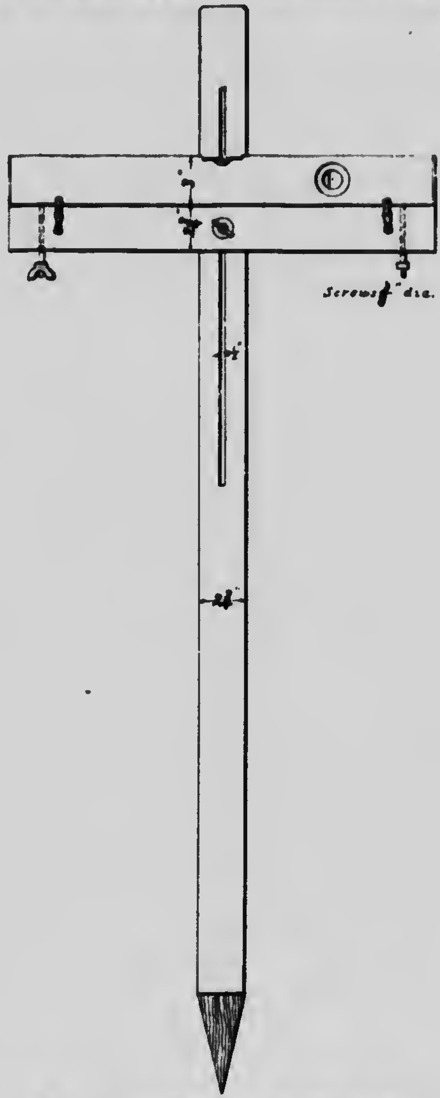


Fig. 1. Home-made drainage level.

merits of different methods, of which there are many, I will say that those to be described here are among the best known (and I think that in the large number of "experienced ditchers" whom we have met we have encountered almost every method imaginable). The individual drain with obvious course is first staked out, then its grade determined, and, lastly, it is dug to that grade.

A Home-made Drainage Level.

The first essential in determining the grade of a ditch is a levelling instrument of some sort adapted to determining the difference in level between two points. Fig. 1 shows the details of a home-made drainage level, which we devised some years ago, and which has proven very useful. It consists of

(1) An upright piece of wood 5.5 feet high, 3 inches wide, and 1.5 inches thick, sharpened at the bottom and shod with a long steel point, and with a slot 2.5 feet long beginning within six inches of the top.

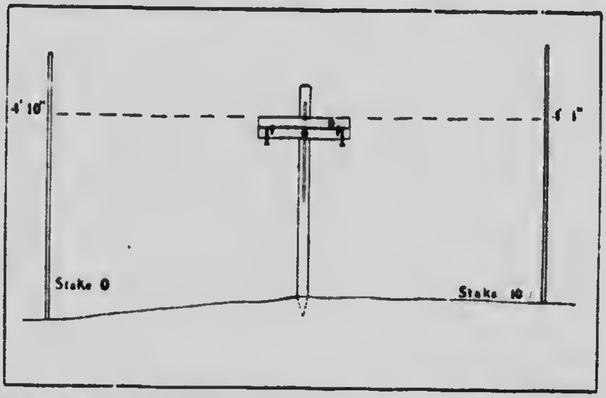


Fig. 2. Showing how to determine difference in elevation, using home-made drainage level.

(2) A cross-piece 20 inches long and 1¼ inches thick bolted to the upright by a bolt through the slot; washers at head and nut. The cross-piece may be rotated about its centre.

(3) A long carpenter's level with *straight* top sitting on the cross-piece. held loosely in position by two buttons fastened by screws to the cross-piece.

(4) Two wood screws with thumb-head, passing loosely through the cross-piece and touching the bottom of the level.

The instrument, including level, costs from $1.50 to $2.00, and so is within the reach of all.

Determining the Fall Along a Ditch.

When a man wishes to determine the fall along a proposed ditch he sets up stakes 100 feet apart from the outlet to the source, numbering them 0, 100, 200, 300, etc. He is then ready to begin taking levels. He takes the home-made level and places it between stakes 0 and 100, as shown in Fig. 2, sinking the upright *firmly* into the ground as nearly perpendicular as possible about half way between the stakes and in line with them. If it is windy, special care should be taken to set the upright deep and firm, as otherwise it will tremble too much. He next places the level on the cross-piece and makes it horizontal by tilting and then using the thumbscrews. Two men are required to do the "levelling," A to sight and B to hold the staff (or measuring pole), and place a target (pencil or something similar) across the staff where directed. Fig. 3 shows them at work. The staff is first stood on the ground at stake 0 and A sights *backward* along the top of the level and directs B to raise

Fig. 3. Showing men taking reading with the home-made drainage level.

or lower the target until it is in line with the level, and when correct B makes a note of the number of feet and inches the target is from the ground. When this is done B moves forward to stake 100 and stands the staff on the ground there and A, without moving the level, turns around and sights *forward* to the staff, directing B as before. When the target is just level with the instrument B again notes the reading.

In Fig. 2 the back reading was 4′ 10″ and the foresight 4′ 1″. In both cases the target was level with the instrument, consequently the difference in reading must be due to the rise in the ground, and, therefore, the amount of rise must be 9 inches. The *height of the instrument* is immaterial—the *difference* between the two readings will be the same, whether the instrument is on high or on low ground. When the rise or fall from stake 0 to stake 100 has been determined the level is next placed about half way between stakes 100 and 200, and the rise or fall between them determined in the same way. The level is next set between stakes 200 and 300, and the same operation repeated, and so on over the whole course of the ditch. When this is completed, all the rises or falls, as the case may be, are added together, giving the total rise or fall. If there are both rises and falls along the same ditch, as frequently occurs where a knoll or a hollow has to be crossed, the difference between the sum of the rises and the sum of the falls will give the net rise or fall. And when this is known, and also the length of the drain, it is an easy matter to find the rise or fall per rod or per 100 feet. And this enables one to decide whether he has fall enough for underdrainage. The fall in the ground surface however, is not always a test of whether a man can underdrain, for he may put his drains deeper at the outlet than at the source and thus have more fall in the ditch bottom than on the surface. This we often find it necessary to do.

As in determining the rise or fall along a proposed ditch there are numerous readings, which a man cannot "carry in his head," it is necessary to have some little book in which to note them. We find it convenient to use the form shown in table 1, which gives the field notes on drain No. 1 in a certain survey:

TABLE I.—NOTES ON DRAIN NO. I.

Stake.	Back Sight.		Fore Sight.		Fall.		Rise.		Elevation.	
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
0	4	10	......	......	......	......	......	......	10	0
100	5	2	4	1	......	......	0	9	10	9
200	5	3	3	11	......	......	1	3	12	0
300	5	0	3	9	......	......	1	6	13	6
400	4	6	4	0	......	......	1	0	14	6
500	4	7	4	3	......	......	0	3	14	9
600	4	5	4	5	......	......	0	2	14	11
700	4	7	4	8	0	3	......	......	14	8
800	......	......	5	3	0	8	......	......	14	0

Note that in six out of the eight hundred feet sections there were rises, in the other two there were falls. The six rises total 4 feet 11 inches, and the two falls total 11 inches, hence, on the whole there was a net rise of 4 feet from stake 0 to stake 800.

The last column, "Elevation," needs a word of explanation. In comparing the altitude of different places, we use the sea-level as a datum plane, *i.e.*, a given level of comparison. Toronto Bay is 250 feet, the Agricultural College at Guelph 1,150 feet "above the sea," from which we learn by subtraction that the College is 900 feet above the Bay. In a similar way we compare the elevations for different points along a ditch, but in surveying the latter we cannot use the sea as a datum, for we do not know how much stake o is above the sea, hence we must choose an arbitrary datum.

In the example given we have chosen it ten feet below the ground surface at stake o. Then the elevation of the surface above this datum plane at stake o is 10 feet. Since there is a rise of 9 inches to stake 100, its elevation will be 10 feet 9 inches, and so on with all other stakes. To find the rise from any one stake to any other, we have only to subtract the elevations as given in the last column. For instance, the rise from stake o to stake 800 is 14 feet, minus 10 feet, equalling 4 feet, the same as we obtained by subtracting the total falls from the total rises. Thus the last column, while not absolutely essential, is the most convenient means of comparing any one station with any other. If starting our survey at the source instead of at the outlet, we would choose for the elevation of the starting point some height greater than the total fall to the outlet.

Difficulties in Using Home-made Drainage Level.

The home-made drainage level is simple and the method of using it is simple, yet we find that many have trouble with it because: (1) They are not trained in sighting, and it is difficult for some to sight accurately along a straight-edge; (2) On a warm day there is a sort of blur when one sights over a spirit level. The sun beating down on the level heats it, and it in turn then heats the air, which is thus made less dense, "thinner" we would say, using a colloquial term, than the air beyond the ends of the level, and for a short distance above the level the layers (?) of air vary in density with the height, so that the rays of light coming from the target to the eye are bent—refracted, to use the technical term—in passing from the dense air at the end to the "thin" air of varying density over the level, and consequently we think the target higher up than it really is, and thus get a false reading. We are all familiar with refraction; even the youngest school-boy has put a stick in a pail of water, or maybe a pond, and wondered why the stick was "bent." The rays of light coming from the submerged part of the stick are refracted or bent in passing from the dense water to the less dense air, making the stick appear too high in the water. Mirages, so common in the West, are due to refraction—the light passing through air of varying density makes distant objects appear suspended in the sky. Similarly the light from the target in passing from the dense air to that less dense and less uniform in density is refracted, giving a false reading. The trouble may be overcome in a measure by sighting along the corner of the level instead of over the top, but even then it is very difficult to eliminate the error entirely, and very hard on the eyes, both of which those who have tried to sight over a spirit level on a hot day know full well.

Drainage Peep Sights for Use on Spirit Level.

Since the home-made drainage level was first described we have been striving to devise a simple set of peep sights that would overcome these difficulties, and we have now succeeded.

Fig. 4 shows a pair of them. The chief point to note is that each has a peep-hole and a cross-wire. When in use they are clamped on a spirit level so that the peep-hole of one is opposite the cross-wire of the other. With them the line of sight is raised sufficiently above the level to avoid the error of refraction, and the most inexperienced can sight accurately, as looking through the peep-hole it is very easy to tell when the target is in line with the wire. Fig. 5 shows the sight clamped in proper position on the end of a spirit level. The body of the sight is made out of one piece of sheet brass bent into the shape shown in the figure. It is punched and drilled as required, the wire soldered in, and a nut soldered on one end for the set screw. At first we hoped they were so

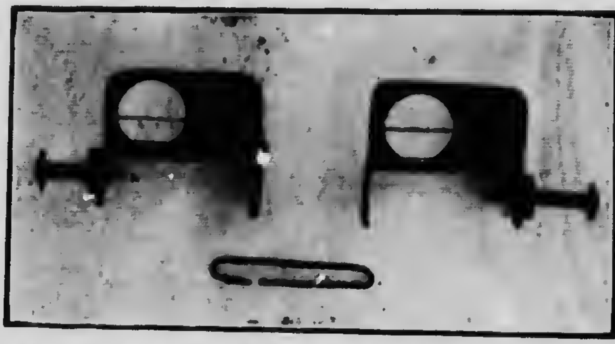


Fig. 4. A pair of drainage peep-sights, and keeper for fastening the sights together.

simple that farmers might have their tinsmiths make them up. Every set we made was correct on first trial, but, after testing with our surveyor's level several sets made by tinsmiths, we found that it was a pretty difficult thing for them, not understanding the value of absolute accuracy, to get the two peep-holes and the two cross-wires all exactly the same height, and that a small variation made a considerable error in the readings and that therefore it was necessary to have every set tested, and corrected if in error, before they could be relied on. Convinced, however, that the sights would be of great practical value to those wishing to do drainage work, I submitted the idea to a firm which has facilities for making the sights accurately and testing them, and they consented to make a small trial lot, and, if the demand is sufficient, to make more and keep them in stock for sale.

As these sights must often be carried about in the pocket when not in use, and as the cross-wires are very fine and therefore somewhat frail, i

Fig. 5. Peep-sight properly clamped on level

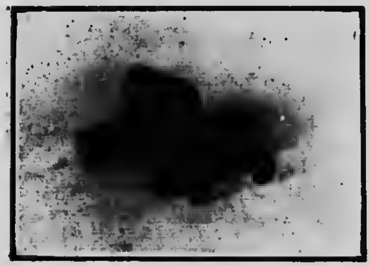


Fig. 6. A pair of peep-sights clamped face to face.

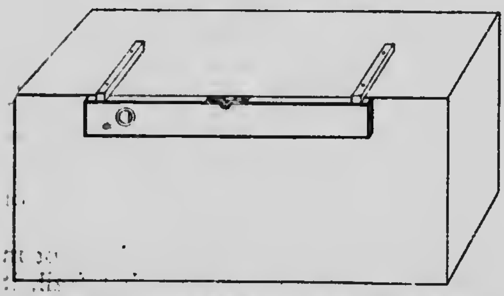


Fig. 7. Truing a spirit level by its top.

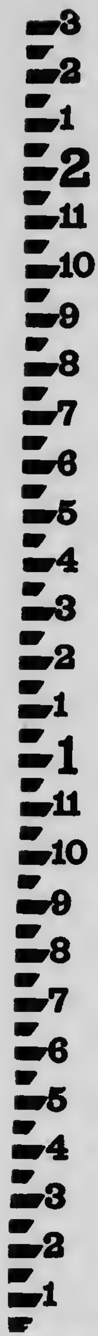


Fig. 8. Lower portion of staff or measuring stick, showing feet and inches. (Reduced.)

was necessary to devise some simple means by which the latter might be protected. Fig. 6 shows the two sights clamped face to face by a small brass keeper. In this position the wires are absolutely protected and the sights may be conveniently carried in the pocket.

By actual test with a surveyor's level we know that this simple outfit, consisting of the cross, the spirit level and the sights, used as directed, is accurate enough for all practical purposes, and that with it a man can readily decide whether he has fall enough for underdrainage by determining the grade per 100 feet; and he can also use the same instrument in digging his drain true to grade, as we shall see later.

At this point it might be well to remark that a dark lead pencil or anything dark makes a poor target for use either with or without the sights. Something pure white is much better, and for a simple reason; both the level and the wire are dark in color and the white target gives more contrast, and is, therefore, more easily seen, more accurate—and easier on the eyes as well. A little strip of wood ⅛ to ¼ inch thick painted white, or white cardboard, either of which may be carried in the vest pocket, makes a splendid target. We make ours about six inches long and one-half inch wide for half its length, and an inch wide for the remainder. The narrow end is used when sighting short distances, up to 50 feet, and the wide end for a longer distances. We also cut a slot up the centre of the target for use with the sights and note the reading through this slot. When the sights are used this is more correct than reading the top or bottom of the target.

Limitations of the Spirit Level.

With the sights distances of 150 feet on either side of the level can be read accurately, and if a wider target were used greater distances still might be read. But here comes in another difficulty; one cannot be certain when the spirit level is absolutely level, for it has no graduations on the glass by which one can tell when the bubble is exactly centred. By frequently testing spirit levels with a surveyor's instrument over various distances we know they cannot be relied on for more than 50 feet each way, and we advise against using the homemade level over greater distances than 50 feet. I have just measured a spirit level with calipers fine enough to read 1-256 of an inch, and find that one end of the wood is deeper than the other by 1-64 of an inch. I supposed both ends of the wood did not season quite the same, but I found the brasses on the two ends differed by the same amount, so that the error is probably one of manufacture. The level is 2 feet long, so that 100 feet equals 50 lengths of the level; therefore, the error due to the level itself in 100 feet is 50-64, or pretty nearly 5-6 of an inch. In 200 feet there would be 1 2-3 inches of error, which is becoming rather too large. Hence the level should not be used over more than 100 feet—that is, 50 feet on each side. In using the spirit level for drainage work the ends should be reversed every 100 feet; then if there is any constant error in it, half of the errors will be in one direction and half in the other, and these will balance, making the net result correct. If the level I have just referred to were only one foot long, instead of two, then the error in 100 feet would be twice as much, or 1 2-3 inches; hence in buying a level for drainage work one should get it as long as possible, for the longer it is the less likelihood of large error.

How to Test and True a Spirit Level.

To test a spirit level to see if it is correct one should place it on a table and if not level put a very thin wedge or paper under the lower end and build it up till the bubble is centred. Then mark with a lead pencil the exact spot the level is sitting on, and then reverse the level, placing it back in exactly the same spot. If the bubble does not centre now the level is wrong. Many levels are made so that one end of the glass may be raised or lowered by a screw which is located under the brass cap at one end of the glass. If the level is wrong this cap should be removed and the error *half* corrected, as nearly as may be, by turning the screw. When this is done the level is built up or lowered on one end until the bubble centres again. Then it is reversed once more for another test, and if there is still error, another adjustment made, then another test, and so on till it is correct. Before tampering with a level, however, one should be very sure it is wrong, and in the adjusting and testing great care should be exercised.

By the method just described the level is trued from the bottom, but in drainage work it is the *top* of the level we are using and hence it should be tested and trued by the top. To do this we tack two strips of board to a box, table, or bench, letting them project past the edge about the thickness of the level, the strips being almost the length of the level apart. When this is done the level is held with its top against the bottom of the strips. Fig. 7 shows the position. Should one end be too low a thin wedge is inserted between the strip and the table and pressed in, raising the strip till the bubble centres. Then the level is reversed, and if the bubble centres again the top of the level is correct, but if it does not centre it is not correct and the brass cap should be removed and the end of the glass raised or lowered enough to correct *half* the error. The wedge should be withdrawn or driven in as the case may be to correct the other half. If the *half* has been struck exactly the bubble will now centre when the level is reversed. If the *half* has not been struck exactly there will still be a small error and this should be corrected in the same way, and another test made. When the bubble centres, no matter which way the level is placed, then the top is correct with the glass, and very accurate work can be done with it. We would strongly recommend the testing and adjusting of levels in this way when intended to be used for drainage work. Great care and accuracy should be exercised in the adjusting.

The level previously mentioned which was 1-64 inch out in depth of the two ends was tested and trued in this way so that the top was correct, and when used with the peep sights and checked with the surveyor's level was found to be accurate within ⅛ to ¼ of an inch over 100 feet, that is 50 feet on either side.

We have already mentioned that many of the spirit levels have no graduations on the glass and consequently it is difficult to tell when the bubble is exactly centred. With such we have found it a good plan to take a new file with sharp corners (not a three-cornered one) and after removing the brass plate make two scratches across the glass the proper distance apart and then true the level by these scratches in the manner above described. Without these marks it is impossible to true a level with any degree of accuracy.

Of course if the level is not an adjustable one it cannot be trued, and must be used as it is whether correct or not, or else discarded and another procured.

The Staff or Measuring Stick.

No elaborate staff is needed with this outfit. A strip of clear pine board six or eight feet long with the feet and inches marked on it does nicely. Some of the manufacturers of surveying outfits have very heavy white tapes 1¼ inches wide with the feet and inches marked on them in heavy black figures and lines, especially made for this work. Fig 8 shows a piece of one of them.

When in use they are tacked to a strip of board 1¼ inches wide, and when not in use they may be rolled up and put away. They cost from 60 cents to $1.50, depending on length, quality, etc.

Determining the Grade of the Ditch.

From the elevations determined in finding the fall along the ditch a profile may be made and the grade worked out. The different steps in making a profile may be performed as follows:

(1.) Procure a piece of cross-section paper similar to Fig. 9, on following page. It is ruled in large squares one inch to the side, and these again into small squares one-tenth or one-twelfth of an inch to the side. This can be obtained from any bookseller at five to ten cents a sheet 15x20 inches in size. If cross-section paper is not at hand, a large sheet of foolscap may be ruled with light upright lines and made to answer well. For clearness of reproduction some of the vertical lines have been omitted from the profile shown in Fig. 10.

(2.) Let elevations be measured *up and down* on the paper, and distances between stakes be measured *right and left*. The datum plane or level of comparison will then be at the bottom of the paper, and stake 0 at the left hand side. If, however, the elevations were large, it would require a very big piece of paper to show the ground surface and also the datum plane; hence it is customary in such cases to show some other horizontal plane a few feet lower than the lowest point along the ditch, e.g., if the lowest elevation were 40 feet, the 30-foot level would be shown where the datum plane is in Fig. 10.

(3.) Let one large square up and down equal two feet of elevation.

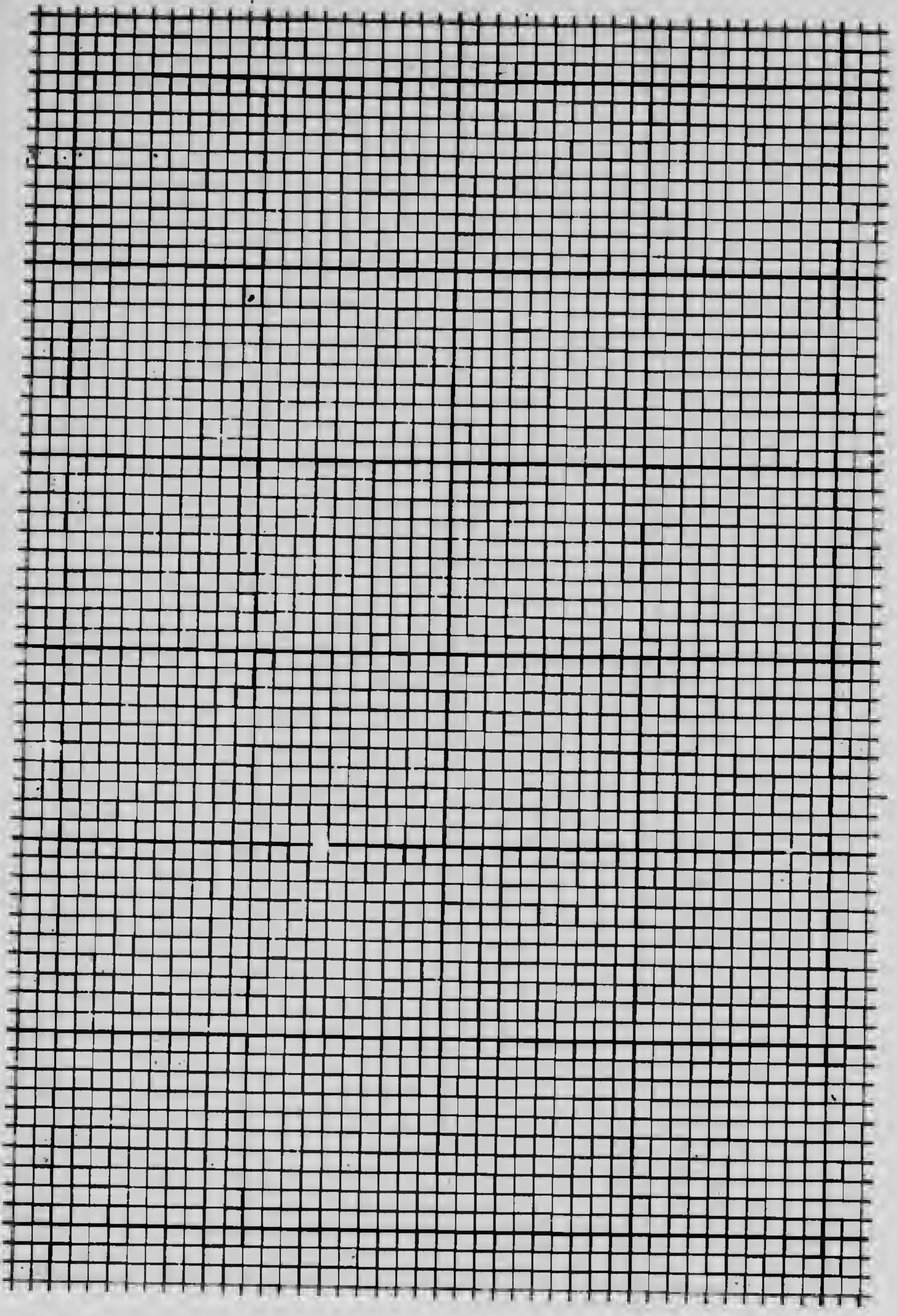


Fig. 9. Cross-section paper: It may be obtained with lines light green, light blue or orange, the green or blue being probably the better.

(4.) Let one large square right and left equal 100 feet from stake to stake.

(5.) Number the stakes along the datum plane as shown in Fig. 10.

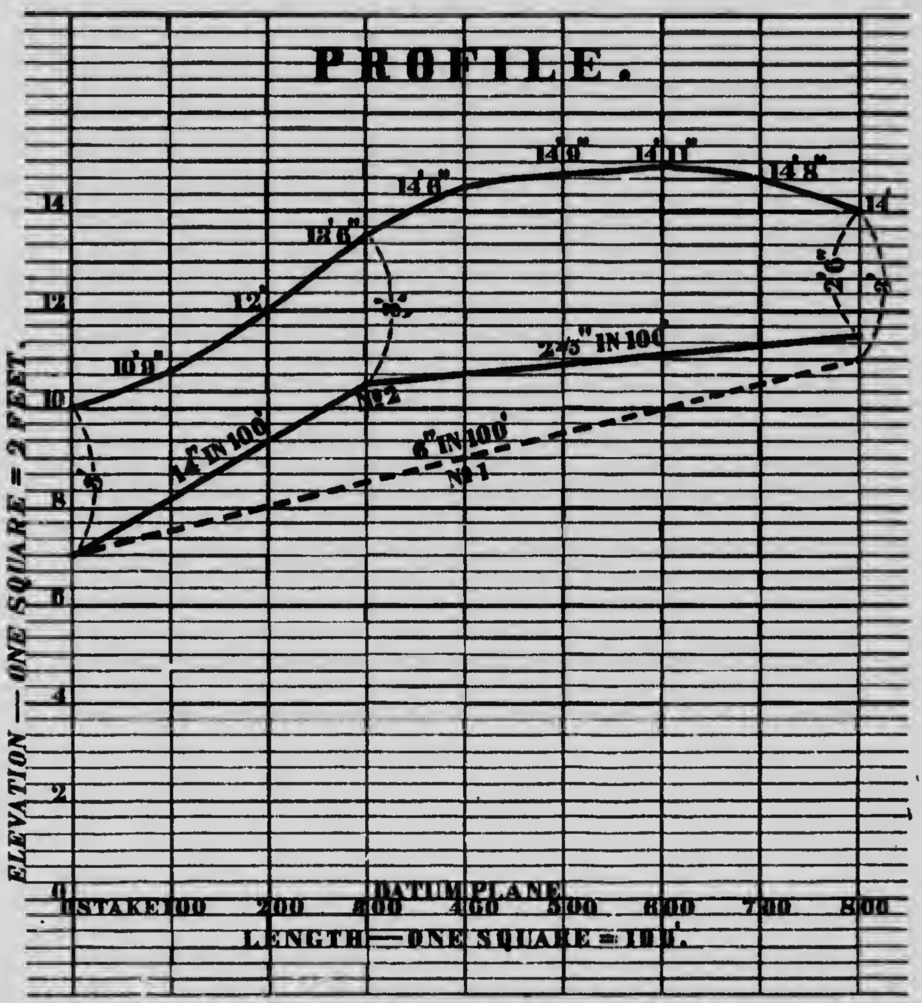


Fig. 10. Profile of drain, illustrating method of determining the grade or grades of the ditch bottom.

(6.) At each stake make a dot the proper distance above the datum plane, showing the elevation at that stake, *e.g.*, at stake 0 in the figure a dot is made 10 feet, *i.e.*, 5 squares, above the datum; at stake 100 a dot is made 10 feet 9 inches, *i.e.*, 5¼ squares above the datum; at stake 200 a dot is made 12 feet above the datum; and so on, the proper elevation at each stake being marked by a dot. These figures are taken from the field notes already given, page 5.

(7.) Join all these dots by a line. This gives the shape of the ground surface from source to outlet, or the "lay of the land," as one farmer expressed it, from stake 0 to stake 800, showing at a glance just where the fall is slow or rapid.

(8.) At stake 0 make a dot as far below the ground surface as the ditch is to be deep at the outlet. This is determined by the nature of the outlet, and is always known; let us suppose it is three feet in this case, (that would equal a square and a half on the paper); hence we make a dot at 7 feet, for the ground surface is at 10 feet.

(9.) Then at the other end of the ditch, stake 800 in this case, make a dot below the ground surface, showing the depth there. The depth at the source is usually a matter of choice. In this case let us choose 3 feet as a trial depth. Then the dot would be made at 11 feet, for the ground surface is at 14 feet.

(10.) Lay a ruler on the paper and draw a very light line joining the two dots at the end—see dotted line No. 1 in Fig. 10. This line will show where the ditch bottom would run if the ditch were dug at uniform grade and made 3 feet deep at both ends. By counting the number of spaces between this dotted line and the ground surface at any point, the depth of the ditch can be learned. Applying this test, we see that the ditch shown in the figure would be four feet deep or more throughout most of its length, if ditch bottom No. 1 were used, and that it would be five feet or more for over half its length, in some places being 5½ feet. Hence we conclude that it is not advisable to dig this ditch three feet deep at both ends and of uniform grade, if it can be avoided—there is too much digging.

Whether it can be avoided or not depends upon the amount of fall from stake 800 to stake 0. The fall is 4 feet, which is equivalent to a grade of 6 inches in 100 feet. Now this is much steeper than is absolutely essential for effective drainage. The minimum grade for safety with small tile is about 2 inches in 100 feet. A drain to be *safe* must have grade enough to give the water a *velocity sufficient to move any sand* that may enter at the joints of the tile. Two inches in 100 feet in 3 or 4 inch tile will give that velocity and a little to spare. Many tile drains laid on slower grades than this have done and are doing good service, but where there is any possibility of coarse sand entering the tile, they are within the danger zone. On the same grade water runs faster in large tile than in small ones, for instance, in 12 inch tile it runs a shade more than twice as fast as in a 3 inch, and consequently large tile may safely be laid on a slower grade than small ones.

Then, coming back to our problem, we see that we have plenty of fall, hence we can dig the upper section of the drain to a slow grade, and the lower section to a steep grade. As we are striving to escape digging let us choose a depth of 2 feet 6 inches (instead of 3 feet) at stake 800, and

3 feet at stake 300, the depth at the outlet remaining 3 feet as before. Joining the dots made at these three places we obtain a new ditch bottom No. 2, with a change of grade at stake 300, the grade of the upper section being 2 2-5 inches in 100 feet, and of the lower section 14 inches in 100 feet. This is a much more desirable bottom than that shown by the dotted line, the deepest digging being a shade less than 4 feet, and the shallowest 2 feet 6 inches. The average saving in digging by using bottom No. 2 rather than No. 1 would be almost one foot throughout the entire length of the drain. In case the second trial did not give us a satisfactory bottom we would make still further trials till a satisfactory one was found. A similar profile may be made for any drain, once the elevations at the different stakes are known. There is one critical point in each drain, viz: the outlet; knolls and basins, where they occur, are also critical points—we must choose grades that will not require us to go too deep in the knolls nor too shallow in the basins. When striking the grades we consider first the critical points—the others will look after themselves.

(11.) To determine the grade on a section of drain when the depth is different at the two ends of the section, we proceed as follows: Subtract the elevation of the ground surface at the two ends (this gives the fall. on the surface), and then add or subtract the difference in depth, according to which end is the deeper. For example, the upper section of the drain in Fig. 10: 14 minus 13 feet 6 inches equals 6 inches, hence in the ground surface there is a fall of 6 inches; but the drain is six inches deeper at stake 300 than at the upper end, hence the fall in the ditch bottom is 6 plus 6, which equals 12 inches in 500 feet; hence the fall per 100 feet equals 12 inches divided by 5, which equals 2 2-5 inches.

With methods for finding the fall along the ditch and of determining its grade, we are ready to deal with the construction of the individual drain, but before passing to that we shall consider the more extensive and involved problem where a general survey is needed before construction is begun.

SURVEYING FOR COMPLETE DRAINAGE SYSTEMS.

To be sure many of our Ontario farmers have long had methods of laying out individual drains, and during the last few years many have adopted those just described, but when it comes to the planning of a general system for 50 or 100 acres, a system composed of several miles of drains, every part of which must fit in with every other part, the grades of which must be sufficient for effectively draining all low spots, and yet not require too deep digging in knolls, the depths of which must, nevertheless, be great enough in flats to protect the tile from frost, the outlets for which must be ample and free—when it comes to the planning of such a system, many of which are imperative in almost every county if proper drainage is to be secured, few, if any, have been or are now in a position to undertake such work intelligently, and for obvious reasons: Firstly, because some knowledge of surveying and mapping is needed, and secondly, because a surveyor's level is essential, neither of which the farmer has. Nor until recently has he been able to obtain assistance in the matter. In the autumn of 1905, however, the department of Physics, which had for some years been teaching the subject of drainage, was authorized to go out through the Province, when farmers applied for assistance, and make a general survey of the land, locate the outlets and the drains, determine the grades and size of tile, and finally send the farmer when ready a map of his farm showing the complete system of drains, the grades, the sizes of tile, etc. It is the writer's intention to give here a brief description of the method of surveying the land and laying out the system, and a detailed description and interpretation of a map, not in the hope of enabling farmers to undertake these general surveys, for we know the work is too involved and the instruments needed too delicate

Fig. 11. Dumpy level (on tripod) used in drainage surveying.

and expensive for that, but in order that when we have made a survey for a man and sent him his map, a copy of this bulletin will enable him the better to understand the map and construct his drains according to it.

The first operation consists in taking the levels and working out the elevations every 100 feet square all over the area in question. The instrument used for this work is an ordinary dumpy level, shown in Fig. 11. The telescope is mounted on an axis and rotates horizontally so that it may be set in the centre of a block of land and readings taken in every direction all around it, instead of in only two as with the home-made level.

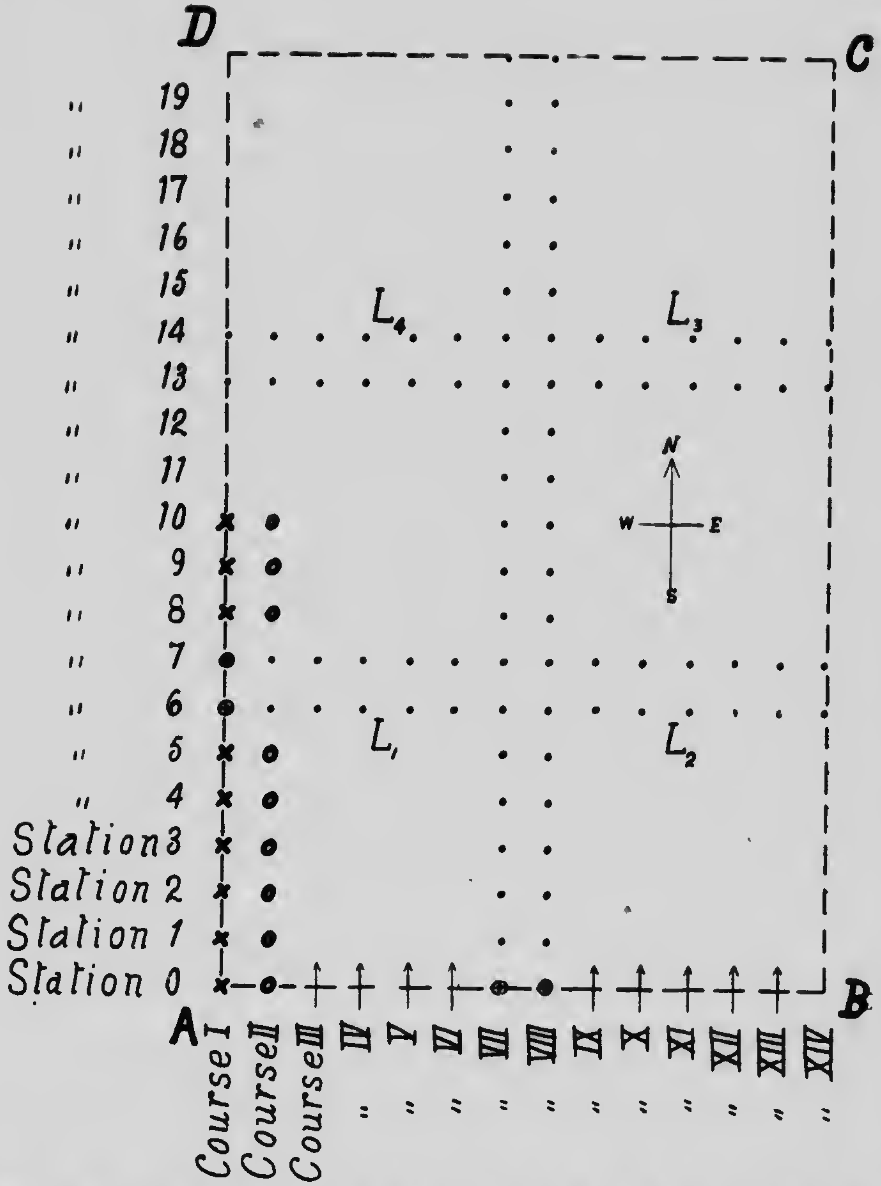


Fig. 12. A field laid out for drainage surveying—two rows of stakes 100 feet apart running through the centre of the field, and two pairs of cross rows, one near either end.

Laying Out the Farm for Leveling.

Now, if we are to take levels every 100 feet square we must have some method of finding those points without measuring them all, for it would mean an immense amount of labour to measure out and stake a whole farm. The method we follow may be understood by the aid of Fig 12. A B C D represents the area to be surveyed. After having walked over it in company with the owner and learned all we can about it, located the probable outlet, and formed an estimate of the probable difficulties to be encountered, we select a base line, say A D, and run two rows of stakes right down through the centre, parallel with the base line, and a full number of hundreds of feet from it, both the rows and the stakes in them being 100 feet apart. When this is done, we run a pair of cross-rows at right angles to the first two, rows and stakes being 100 feet apart as before. If the piece is so large that the cross-rows cannot be seen half way, two pairs may be needed, as shown in the figure, or even more. Lath are used for stakes where available. We make no attempt to stake out the area permanently, for in very few cases is the draining to be done immediately, and permanent stakes through the fields would be in the way in the meantime. But enough permanent stakes are set to enable the farmer to put up the rows again if necessary to locate the drains. These permanent stakes are always indicated on the map, as will be seen later.

Taking the Levels.

When the staking is done as indicated, the level is set up near one corner, say at L_1. As with the home-made level, two men are needed, a levelman and a staffman. When the instrument is "levelled up," the staffman sets the staff on the ground in the corner of the field, *e.g.*, at A, sighting two ways, east and north in this case, and putting himself in line with stakes in two directions. When the level-reading has been taken, he moves north 100 feet from the corner, as shown by the X opposite the words "station 1," sighting himself in line both north and east as before. Another reading is taken by the levelman. The staffman then moves 100 feet farther north, as shown by the X opposite "station 2," sights himself in line in two directions, and another level is taken. He continues to travel along the course as shown by the X's, setting the staff on the ground at every station, and allowing the levelman to take a reading. When he has got as far along course 0 as the levelman can read, which usually happens at about station 10, he crosses over to station 10 of course 1, and sets the staff every 100 feet, as shown by the o's, the levelman taking a reading in each case. When he has arrived at station 0 of this course, he crosses over to station 0 of course 2, and readings are taken along it up to station 10, and so on. Back and forth over the field the staff is set at distances of 100 feet until all around the level the stations have been read as far as the levelman can see. In case there are any marked knolls, depressions or watercourses between the 100-feet stations, readings are taken there also. The instrument is next moved to a new block and set up, *e.g.*, at L_2. The first reading in the new block is always taken on some station already read in the old block, so that the elevations in the two may be reduced to the same datum or sea-level. When all the readings in block 2 have been taken, the instrument is moved to L_3, and so on until the whole area has been "levelled." The levelman keeps the notes in a form similar to that given on page 5 for the home-made level, save that there is only one column for "readings" instead of two. The "elevations" are worked out for all the stations as with the individual ditch.

The levels are next taken along the outlet. Knowing what the elevations are over the area to be drained, we are in a position to tell when we have gone far enough down the outlet to get clearance for all the drains.

Making the Map.

When the elevations have all been determined, we are in a position to construct our map. Fig. 13 shows one of these maps complete. The different steps in the making of a map are as follows:

(1) We procure a piece of cross-section paper (see Fig. 9) large enough to hold a map of the survey, allowing 1 inch=100 feet, and at the corners of the squares all over the map we mark the elevations. In the map shown the small figures appearing at regular intervals over the field indicate the elevations at those points.

We are now in a position to compare the levels of different parts of the farm. For instance, the N.W. corner has an elevation of 32.7, and the N.E. corner an elevation of 17.9 feet, hence along that north side there is a fall of 32.7 minus 17.9=14.6 feet in a distance of 2,200 feet. The fall along the south side is much less, however, being only 23.3 minus 19.8 =3.5 feet. If, however, we undertake to compare many of these elevations two at a time in this way, we see at once that we have an endless and confusing task.

(2) To render the comparison of elevations easy, and to show at a glance the general slope of the land, we next put in *contour lines*. They are the dotted lines curving in and out across the field. Notice the first of these on the east end of the field. It begins with an elevation of 18.0 feet on the north side, and ends with an elevation of 18.0 on the east end, and moreover every point along it has the same elevation, as may be seen by observing that when it crosses between two elevations one is a little less than 18.0, and the other a little greater, and the contour always divides the intervening distance proportionally. Now look at all the elevations to the east of the 18-foot contour—they are all less than 18 feet, and all those on the west of it are greater; hence, the low land is to the east, the high land to the west.

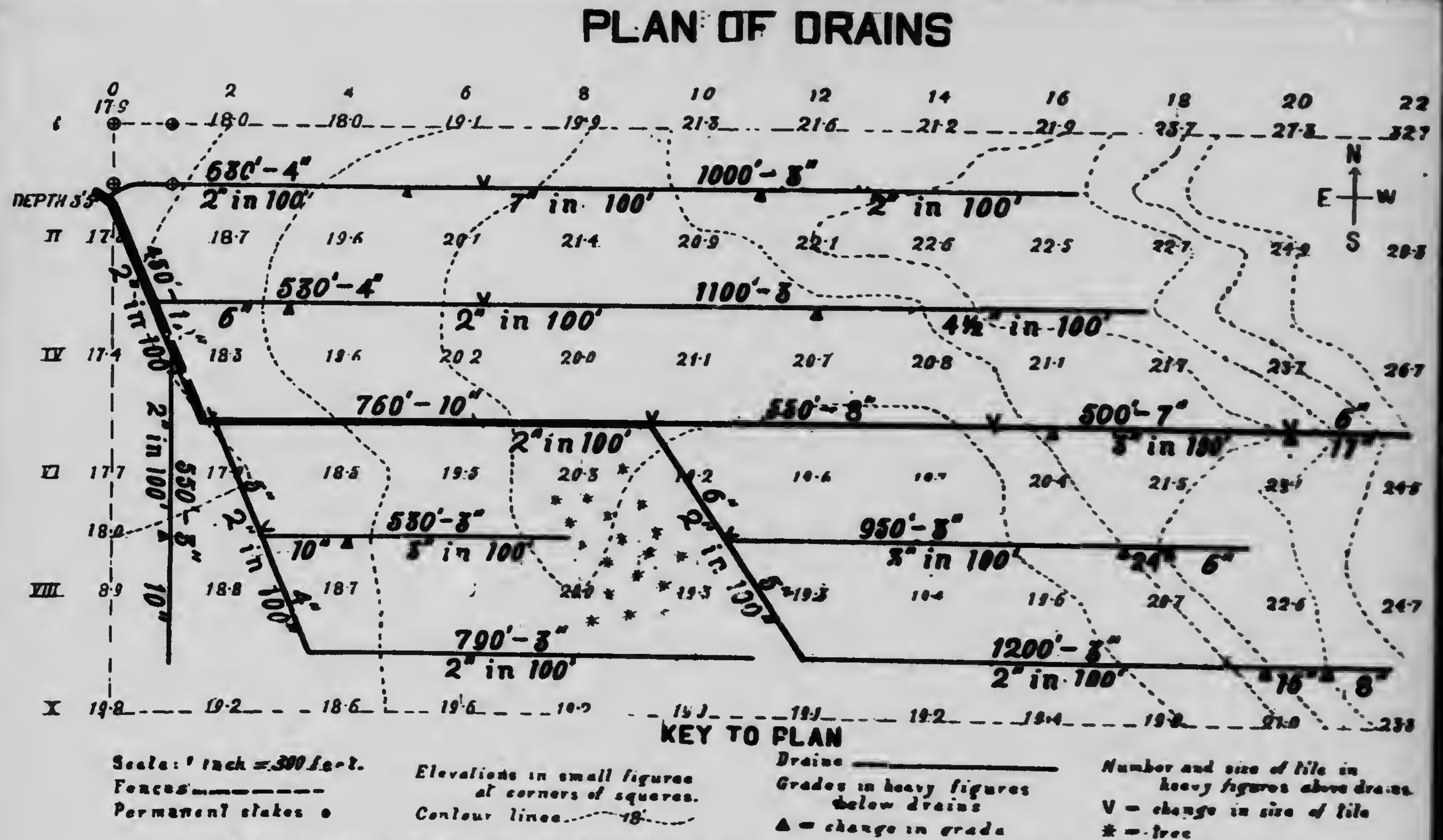


Fig. 13. Plan of drains, showing location of drains, depth at outlet, size of tile, grades, etc.

Now look at the 19-foot contour, the next dotted line to the west. Every point on it has an elevation of 19 feet, and hence there is one foot of fall from this to the 18-foot contour.

The 20-foot contour is a very irregular one, beginning at station 8 on the north side and ending at station 18 on the south side. The 21-foot contour is more regular, but also runs almost diagonally, while the others run in the same general direction.

These contours aid very materially in indicating the general slope of the land, but they show us several things specifically:

(*a*) The greatest fall is along the shortest distance from one contour to the next, approximately at right angles to them.

(*b*) When the contours are far apart and irregular, they indicate flat, level land, but when close together and regular they indicate a steeper slope.

(*c*) A loop of the contour toward the outlet indicates a knoll at that point.

(*d*) A loop away from the outlet indicates a "flat" extending backward toward the higher land, and usually indicates the position for the main drain.

(3) With the contours as a guide, we locate the main drains and the laterals, keeping the mains in the lowest land as far as possible, and the laterals at right angles to the contours as nearly as may be. At the same time we endeavour to adopt a system that gives long drains rather than short ones, as there will be fewer junctions, unless such a system is distinctly inferior in some other way. The heavy black lines in the map indicate drains. The distance apart at which drains should be placed is fully discussed on page 25.

(4) We next take the hardest spot in the whole area to drain, *i.e.*, the lowest and farthest from the outlet, and make a profile (as described on pages 11-15) from there to the outlet, using the minimum depth in the low spot, getting as much grade as possible, and yet striving to avoid too deep digging. This gives us the depth of our main throughout.

(5) The grades of the laterals are then worked out, using a profile if necessary. This can be done now, since we know the depth where they join the main and the approximate elevation of the land every 100 feet.

Wherever a change in grade occurs, the point is indicated by a solid black triangle pointing to the ditch. All grades are stated below the drain, *e.g.*, "8¼" in 100'" means 8¼ inches fall in 100 feet.

(6) We next decide on the size of tile, using as a guide the table to be given later on page 24. The number and size of tile are entered above the drain, *e.g.*, 950'-4" means 950 feet of 4-inch tile. A change in size of tile is indicated by a V at that point.

(7) Each map is accompanied by a "key" explaining all the symbols used in the map. (See Key, Fig. 13.)

(8) The depth of the main at some point is always given. When

this is known, and also the grade, the main is begun at this point and constructed either up stream or down, as the case may be, and when the main is dug, the depth of each lateral at the junction is known, and the laterals may be dug, beginning at the main. Let me say again, *the place to begin operations, according to one of our maps, is the point on the main where the depth is given.*

(9) If the owner wishes to know the length of any particular drain, he can find it by measuring the line on the map, for 1 inch on his paper equals 100 feet in the field.

These maps have proven of great practical value. In numerous instances the owners have gone ahead and completed the whole system in one job, while in many others a field or two is drained each year. More-

Fig. 14. A typical drainage demonstration.

over, they are retained as a record, giving all the facts about the system, so that any drain may be located if desired. When the farm is sold or handed down to the son, the map is especially valuable, as it shows the new occupant what drains there are and just where each may be found.

For these same reasons those who put in systems of drains of their own planning might do well to make a map for future reference.

Drainage Demonstrations.

At the conclusion of the survey, after the map has been worked out in the rough, a public meeting is held in the field where the survey has been made, and the methods of finding the fall, determining the grade, digging the ditch true to grade, etc., are demonstrated. The map is examined, difficulties discussed, and details of construction dealt with, and, in fact, drainage in all its aspects is fully considered. Fig. 14 shows a typical scene at a demonstration, with an average attendance.

These demonstrations are beneficial in many ways. Besides giving much information about drainage, they are practically a public pledge of the owner to "do something," to put in some of the drains, and usually he does so at an early date; secondly, they lead the public to watch results, and the effect is sometimes remarkable. An instance was given in Bulletin 174, where within one year's time nine neighbours began under-draining as the result of one drainage demonstration. Where the movement has now reached its third and fourth years, practically whole communities are draining, *e.g.*, in the vicinity of the Horticultural Experiment Station at Jordan Harbour, Lincoln County. The station farm was drained in 1907 with eleven miles of tile, and this year there have been enough drains put in there, within a radius of five miles, to keep a traction ditcher busy all summer.

What Size of Tile to Use.

In every drainage problem we are confronted with the question, "What size of tile shall we use?" a question that cannot be answered offhand. As a matter of fact, it is the last thing decided in our drainage surveys. We cannot decide it from the acreage alone, we must know the grade of the ditch, for the steeper the grade the more water will run through a tile of given diameter. For example, if we double the grade of a tile the velocity of the water is increased approximately 40 per cent., and consequently the same tile will carry 40 per cent. more water on the new grade, and consequently it is capable of draining 40 per cent. more land. Thus we see that to decide the size of tile to use in a given case we must know the acreage to be drained through the tile and also the grade. As a result of extensive scientific experiments a rule has been formed by which the size of tile can be determined when the acreage, the grade and the maximum amount of rainfall in twenty-four hours are known, but the rule and its application are too complicated and mathematical to be dealt with here. Suffice it to know that there is such a rule and that some one has been kind enough to apply it to all practicable grades and sizes of tile and tell us what acreage can be drained through each size on each grade. This information is contained in McConnell's table, which is given herewith.

TABLE II.—SIZE OF TILE PIPE OF MAIN DRAIN.

(McConnell.)

Fall.	Acres Drained.					
	3-inch tile.	4-inch tile.	6-inch tile.	8-inch tile.	10-inch tile.	12-inch tile.
1 foot in 20	18.6	26.8	74.4	150.0	270.0	426.0
1 " 30	15.1	21.8	60.4	128.0	220.8	346.0
1 " 40	12.9	18.6	51.6	108.8	189.6	298.4
1 " 50	11.9	17.0	47.7	98.0	170.4	269.0
1 " 60	10.9	15.6	43.4	90.0	156.0	246.0
1 " 70	10.0	14.5	39.9	83.0	144.4	228.1
1 " 80	9.3	13.4	37.2	77.0	135.0	213.0
1 " 90	8.1	12.6	35.0	72.5	127.0	200.5
1 " 100	7.3	11.9	33.1	69.2	120.6	190.5
1 " 150	6.7	9 5	26.6	56.0	97.3	154.4
1 " 200	5.7	8.2	22.8	48.0	83.9	132.5
1 " 250	5.1	7.5	20.4	42.4	74.4	117.0
1 " 300	4.6	6.9	18.4	38.2	65.5	107.0
1 " 400	4.1	5.9	16.5	32.6	60,3	90.7
1 " 500	3.7	5.2	14.8	30.1	54.0	81.6
1 " 600	3.3	4.7	13.3	28.0	48.6	74.0
1 " 800	2.9	4.1	11.4	24.0	41.9	65.0
1 " 1,000	2.6	3.7	10.2	21.2	37.2	56.0
1 " 1,500	2.1	3.0	8.5	16.8	30.8	47.0
1 " 2,000	1.9	2.8	7.4	15.0	25.0	40.8

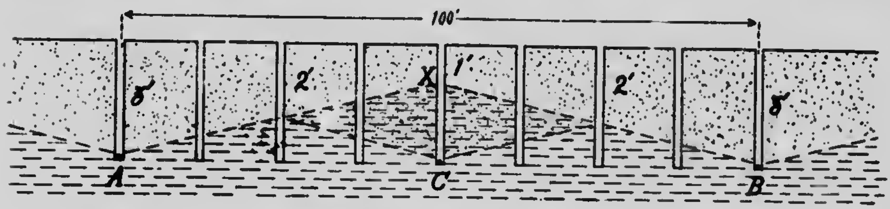
Using the maximum rainfall at Guelph as a basis I have applied the rule and worked out several grades and sizes of tile, and found that the table corresponds very closely with our requirements here, and so we have adopted it in all our work.

The use of the table may be illustrated as follows: Suppose a man has 12 acres to drain and the slope of his main is 1 foot in 600, then we look down the list of falls till we find 1 foot in 600 and follow this line to the right. A 3-inch tile would not do; it drains only 3.3 acres. A 4-inch tile drains only 4.7 acres. A 5-inch tile, not given, but probably drains about 7 to 9 acres. A 6-inch tile fills the bill, as it is capable of draining 13.3 acres. The size to use for any other slope is determined in the same way. For instance, if 70 acres are to be drained on a grade of 1 foot in 100, an 8-inch tile will be necessary. The table applies to the submains and laterals as well as to the mains.

Owing to the great amount of friction in small tile compared with the volume of water they can carry, they are much more likely to clog with sediment than the larger ones, so much so indeed that a 2-inch tile should never be used except on a steep grade. In time they are almost sure to clog on a slow grade. For the same reason, the use of 2½-inch tile is not encouraged.

Depth of Drains and Distance Apart.

The depth of the drains and the distance apart are other points that must be decided before the map can be completed. These are related questions, and one cannot be intelligently discussed without the consideration of the other. We have already seen (Bulletin 174) that the roots of ordinary crops penetrate three or four feet into the ground, and that if not given an opportunity to do so before droughts come they are unable to make the depth afterward, as they soon begin to feel the scarcity of water. We may, then, lay down as a fundamental law that the drains should be deep enough to permit the fullest root development of which the plants are capable, and which they demand for best results. Now the water table in a drained field is in a zigzag form like a rail fence, low at the drains and high between. If in a field that is underdrained three feet deep one were to dig a series of holes as deep as the



= drained soil

= undrained soil

= soil undrained when drains are 100' feet apart, but drained when they are 50 feet apart.

Fig. 15. Showing the relation of depth of drains to distance apart.

drains every few feet between them, and if after a heavy rain he were to observe the water in the holes for a day or two he would find that in a very short time no water would remain in the hole at either drain, but that the one situated half way between would hold considerable water for a long time, and the others would have less and less in them as he approached either drain, thus showing that the water table stands highest half way between the drains and slopes toward them on either side. In a clay in fairly good condition it will be found this slope is about 1 foot in 25, in loam 1 foot in about 33. Applying these gradients, let us see what they mean. Fig. 15 represents a clay soil with drains A and B 100 feet apart. Wells are dug 12.5 feet apart. At the end of 48 hours after a heavy rain the water will stand about as indicated by zig-zag lines, in a gradient of about 1 in 25, and hence will be two feet deeper in the centre well than at either drain. Hence if the drains are three feet deep there will be three feet of drained soil over A and B, but only one foot at X. Capillarity and soil resistance to water flow play an important part in holding the water highest half way between the drains, and the gradient 1 in 25 represents their combined strength in clay, hence after this gradient is reached drainage becomes very, very slow, and the water table stands in this irregular shape until lowered by evaporation from the soil and plants. But during the months of April, May, and sometimes June, when the rains supply at the surface all the water needed for evaporation, none is drawn from below for this purpose, hence during the early months of growth the water stands as indicated by the dotted line AXB. Consequently root development is hampered at X, as 1 foot of soil is not enough. There are two ways to remedy the defect, either to dig A and B deeper or else put a drain at C half way between. If A and B were lowered 1 foot there would then be 2 feet of drained soil at X, and 4 at A and B, or an average of 3 feet throughout the field. If a tile were put in at C the same depth as at A and B there would be 3 feet of drained soil there as well as at A and B, and 2 half way between, giving an average of 2½ over the field. From which it would appear that the drains should be at least 3 feet deep and close enough together to give at least 2 feet of drained soil half way between. Applying the gradients 1 foot in 25 for clay and 1 in 33 for loams we see that for depths of 3 to 3½ feet the drains should not be more than 50 to 66 feet apart in clay and 66 to 100 in loam. But this is only a general conclusion and judgment must be used in each individual case. Practical experience shows however that in heavy clays it is profitable to put the drains even as close as 25 to 30 feet.

THE CONSTRUCTION OF THE DRAIN.

When the survey either for an individual drain or for a general system has been completed, and the profile or map giving the grades is in the farmer's hands, he is in a position to begin the construction of his drains. He needn't worry much about methods of operation if an "experienced ditcher" is employed, for in the vast majority of cases these men have methods of following grades sufficiently accurate to enable them to construct any system of drains when given the initial depth and the grades. An occasional test however will be a satisfaction to him and at the same time prevent any possible tendency on the ditcher's part to shirk the grades in order to get shallower digging.

But in many cases the farmer must put in his own drains, for there are not enough ditchers to do half the ditching that is being done. For the benefit of beginners and others wishing to improve the methods they have the different operations will be discussed in detail.

Use of Plough in Digging the Trench.

In the spring and early summer, when the ground is wet and soft, the ditching spade may be used to good advantage for removing the earth almost to the grade line, and the bottoming scoop may be used to secure a smooth, even bottom. But as soon as the ground becomes too firm for spading, either operations must be stopped or some method of loosening the earth employed. "Experienced ditchers" usually choose the former, so that for a large part of the year they busy themselves with other work, for if they have to use the pick they "cannot make wages" in the hard ground. With a team of horses and a plough at one's disposal, however, ditches can be dug as cheaply in the summer and fall as they can with the spade and scoop in the spring.

Perhaps the most effective way of using the plough is somewhat as follows:

(1) Using an ordinary plough, the drain is opened up as wide as possible, one furrow being thrown each way. In stubble, fallow or

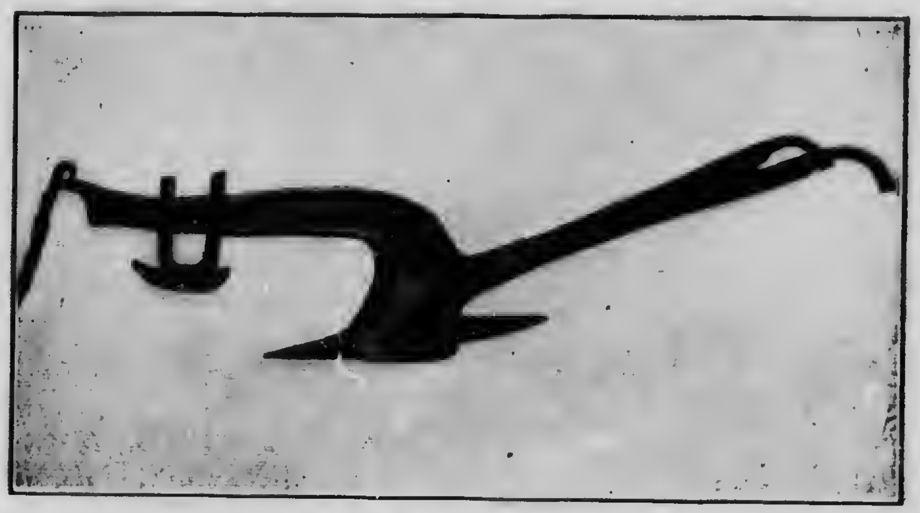


Fig. 16. The pick plough.

ploughed ground these furrows will not need shovelling, as they will be thrown well out; in sod they may need rolling farther back.

(2) Using an ordinary plough, two more furrows are turned, one each way, in the bottom of the ditch already formed, each furrow being thrown toward the centre of the ditch. The second will turn the first back partly, but this serves only to loosen the soil more thoroughly. The sides of the ditch, which were very sloping after the first ploughing, have been trimmed off perpendicular and straight by the land-slide in the second ploughing, which is now ready to shovel out; and it will be found in prime condition.

The ditch at the present stage should be about 18 inches wide. It may be objected that this causes needless shovelling, to which the answer is that the plough is to be used till the ditch is 2½ to 3 feet deep, and it is necessary to have the top wide enough to accommodate the handles. The bottom will not be as wide.

This operation should be repeated till the ditch is about 15 or 18 inches deep. In order that the horses may walk comfortably, one on each side of the ditch, the lines are opened up as wide as possible and a long doubletree used. To permit the plough to go deep enough in the ground, a chain about six or eight feet long is put in between the beam and the doubletree. This plough will not be found satisfactory after a depth of 15 or 18 inches is reached, as the drain gradually becomes narrower.

(3) Now using a *drainage plough* of some sort, a furrow is ploughed right down the centre of the drain and another in the same groove coming back. This forms a narrow ditch in the bottom, both sides of which are trimmed straight and perpendicular. With a narrow shovel this furrow may now be removed. This operation is repeated again and again until the drain is almost as deep as required.

Fig. 17. Ditching plough.

For this third operation a special plough is necessary—we want something to dig a narrower trench than heretofore. A home-made ditching plough may be made as follows: Take an ordinary plough and remove the mould-board. This of course removes the attachment for the lower end of the right handle, but bolt a narrow block between the handles and run a brace from it to the back bolt in the beam, and the handle is as steady and as firm as ever. Put on a new narrow point. If one has much draining to do, it is advised to make further and permanent alterations. The rod between the handles should be taken out, shortened, and replaced, thus bringing the handles closer together. The top section of the ditch need not now be so wide as before. It is also wise to shorten somewhat the braces that run from the head to the handles, thus raising the latter; the wide section of the ditch need not be so deep as before. An ordinary subsoil plough serves very nicely where the ground is not too hard. The "pick plough" manufactured by various plough companies is far better. (Fig. 16.) So also is the special ditching plough manufactured by one of our Ontario firms. (Fig. 17.)

In hard ground the home-made drainage plough is very difficult to control when the ditch becomes deep—sometimes it goes too deep, at other times, because of its lightness, it skims along the surface, doing no good. The subsoil plough, too, has these defects, and besides it is not strong enough in very heavy soil. I have seen a subsoil plough twisted so out of shape as to be useless for any purpose, and that simply because of the stiffness of the soil and uncontrollability of the plough. The pick plough and the ditching plough have none of these defects—they are heavy and therefore strong enough for all purposes, ride steadily at a uniform depth and are easily held. Because of their weight they are somewhat cumbersome in turning at the end, but they perform their work so effectively that this slight drawback may be overlooked. The pick plough is not made primarily for drainage work, but for tearing up pavement, old roads, etc., hence the handles, as in an ordinary plough, are too low and too wide. But they can be raised and narrowed as described above—which was actually done on some of them which I have seen used for drainage purposes.

Actual test has shown that the "pick plough" reduces the cost of digging by 42 per cent. compared with pick and shovel. The "ditching plough" probably does about the same. It is found that they can be used to depths of four feet or over, and some who have followed this method claim that even if the ground can be spaded it is cheaper to use the plough and shovel method.

Grading the Ditch.

Having dug the ditch within a few inches of its final depth, the next operation is to remove the remaining earth, leaving the ditch bottom with an even fall throughout. The accompanying drawing (Fig. 18) will aid in understanding the method to be described:

Two cross-heads are set up 100 feet apart, one at stake 0 and the other at stake 100, as shown in Fig. 18. Both are put 6 feet 6 inches above the ditch bottom, the one at stake 100 thus being higher than that at stake 0 by the amount of fall in 100 feet, *e.g.*, if the fall is 14 inches in 100 feet, then cross-head 100 is set just 14 inches higher than cross-head 0. The stakes must be stout and driven firm in the ground. A light cord—binder twine does very well—is then stretched *tight* and tied over the cross-pieces, so that the sag is negligible. Since one end is 14 inches higher than the other, this cord has the same fall as the ditch bottom is to have, and hence if the latter is made parallel to the cord it will have the required fall. It is necessary to provide a light testing or "travelling" stick 6 feet 6 inches long, since the cord is that height above the ditch bottom. With a narrow shovel the earth is gradually removed until the stick standing on the ditch bottom just passes under the line, as shown in the drawing. When such is the case the ditch is deep enough at that point. When every point between stakes o and 100 just test 6 feet 6 inches from the overhead line, the grade of this section is uniformly 14 inches in 100 feet. Any other grade is arrived at in a similar way.

But how shall we place the cross-heads 6 feet 6 inches above the ditch bottom?

First.—If not already known, we must determine the depth of the ditch at the outlet. A drain usually empties into another tile drain or into an open ditch, the depth of either of which may be determined by using the drainage level and the measuring staff as follows: Set up the

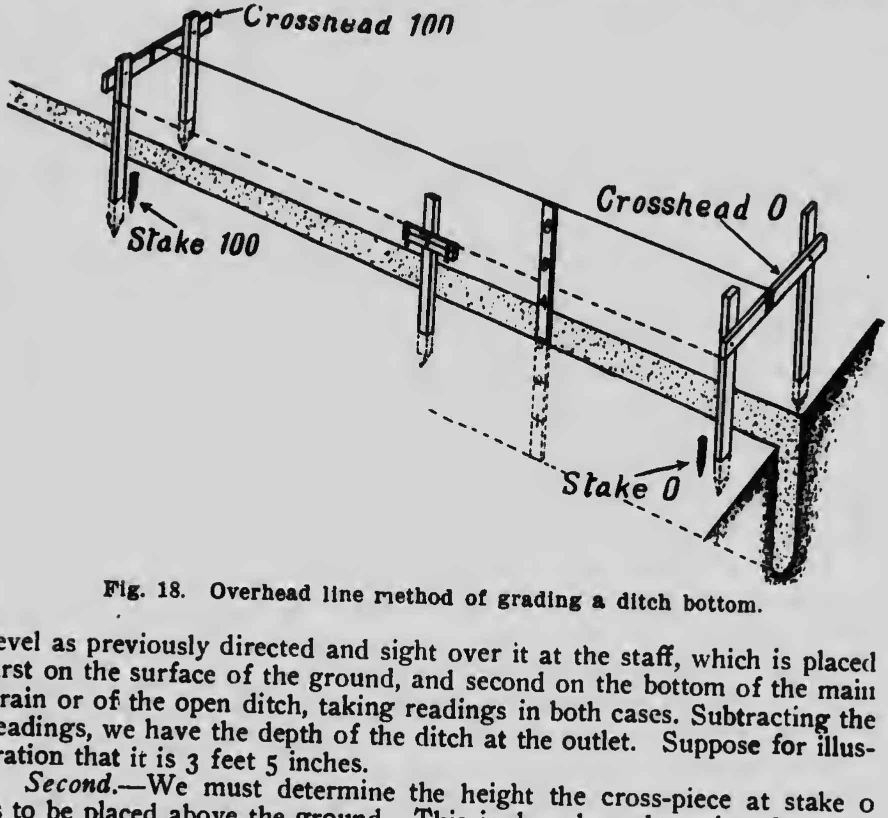


Fig. 18. Overhead line method of grading a ditch bottom.

level as previously directed and sight over it at the staff, which is placed first on the surface of the ground, and second on the bottom of the main drain or of the open ditch, taking readings in both cases. Subtracting the readings, we have the depth of the ditch at the outlet. Suppose for illustration that it is 3 feet 5 inches.

Second.—We must determine the height the cross-piece at stake o is to be placed above the ground. This is done by *subtracting the depth of the ditch from the length of the testing stick,* i.e., if the ditch is 3 feet 5 inches deep, as supposed above, then cross-head o would be 6 feet 6 inches minus 3 feet 5 inches=3 feet 1 inch above ground. One end of the cross-piece is clamped or nailed to one of the stout stakes at this height (3 feet 1 inch), the cross-piece is then levelled by means of the spirit level, and the other end fastened to the other stake.

Third.—We must find a point on stake 100 that is higher than cross-piece o by the amount of fall in 100 feet, and fasten the cross-piece at that point. For instance, if the fall is 14 inches in 100 feet cross-piece 100 must be nailed 14 inches higher up than cross-piece o.

To do this we set up the home-made drainage level about half way between stakes o and 100, sight to both stakes, as shown by the dotted line in Fig. 18, and put marks on the two stakes. *These marks are level with each other.* We now measure the distance between cross-piece o and the mark. Let us suppose cross-piece o is 6 inches above the mark. Then cross-piece 100, to be 14 inches higher, must be 6 plus 14, or 20 inches, above the mark on it. If cross-piece o is below the mark, we subtract the distance from the grade or the grade from the distance to find how far cross-piece 100 must be above or below the mark, *e.g.*, if the grade is 14 inches in 100 feet and cross-piece o is 6 inches *below* the mark then cross-piece 100 must be 14 inches minus 6=8 inches *above* the mark, but if cross-piece o is 18 inches below the mark then cross-piece 100 must be 18 minus 14=4 inches *below* the mark. For any other grade the cross-pieces are set in a similar manner. When they are thus placed, the cord which is tied stretched over them is 6 feet 6 inches above the ditch bottom and parallel to it.

But why have the overhead line 6 feet 6 inches above the bottom? Usually 6 feet is not enough to clear the man and his shovel; 7 feet would be more than is necessary, unless it is a very deep ditch.

To grade the second section of the ditch a cross-head must be set at stake 200. This may be roughly done by sighting it in line with cross-heads o and 100, but it is always wise to set up the level and by means of it get cross-head 200 placed exactly the right amount above cross-head 100. The same applies to subsequent sections.

In practice it is found convenient not to tie the line to the cross-pieces, but to simply pass it over them and tie a fairly heavy stone to it. This keeps it always at the same tension and takes up any stretch that may occur. As a heavy line sags some on a 100 feet section, it is usually found best to interpose one or two light cross-heads between the end ones, by which they can be sighted in position. Instead of intermediate crossheads some use two light sticks, bolted together at the top like the letter A, with notches in one of them for the line, which may be raised or lowered either by the use of the notches or by closing or spreading the bottom of the sticks.

There are numerous devices for aiding in digging a ditch to the required grade, but the overhead line here described is, in our judgment, the best we have seen. We know men who have abandoned others in its favour, but none who have abandoned it for others.

Laying the Tile.

When the first section has been graded, and while the line is still strung, it is wise to lay the tile, so that they may be tested to grade by the same line, a notch being cut in the testing stick at a distance from the end equal to the outside diameter of the tile. This gives the best alignment of the tile, and the fewer irregularities there are the less the danger of partly or wholly blocking with sediment. Another reason for not allowing the digging to get too far ahead of the laying is that rain is liable to occur at any time, causing the sides to cave in and otherwise interfering with the finished bottom.

Good joints need no protection against sediment, except in quicksand, but joints that are at all open should be covered to prevent sediment entering the tile while the earth is becoming set. Sods placed with the grass next the tile are excellent for this purpose. Tar paper also is good, but it should not go all round the tile, it should lack two inches or so of meeting on the under side. This precaution allows the water to enter the joint from below. There is practically no water enters through the pores of the tile. Some years ago I sealed one end of a 3-inch, a 4-inch, a 5-inch and a 6-inch tile and set them in water one foot deep sealed end downward, putting weights on them to hold them down. They were left in that position for 44 hours. At the end of that time the amount of water in them varied from ¼ to ¾ of a tumblerful, showing that water passes very slowly through the pores. Then it must enter through the joints, hence the precaution of putting the tar paper over the top and sides only. When quicksand is encountered, the tile may be laid on strips of board about six inches wide. In case tile have to be laid near water-loving trees, such as elms, willows or soft maples, they are almost certain to be blocked with roots in a year or two. The safest plan is to sacrifice the trees. If this is not done, sewer tile should be laid in that section of the ditch and the joints cemented, but tile so laid do not drain the land through which they pass. The roots of fruit trees sometimes block tile when laid too shallow and too near the trees, hence tile in orchards should be laid rather deep and midway between rows of trees where possible.

None but sound tile should be laid. This point cannot be too strongly emphasized. Early last spring I chanced to call at a farm which I had surveyed some years previously, and which had been drained in the meantime. "There's no use putting in tile on that piece yonder," said the owner, pointing as he spoke to one of the finest parts of his farm.

"Why?" "Because the soil is so fine it washes right into the tile," was his answer. "That man working there is digging up a drain now where there was a wash in."

I remembered the soil, and believed it should drain all right. We went over and examined the spot, and I was convinced the fault was not in the soil, and said, "There is a flaw in your tile."

"Well, the digger hasn't found any; here they lie, all perfect."

"Then there was a flaw in the laying."

The point was soon decided, however, for the next tile taken up was imperfect. About half way round one end there was a half-inch piece broken out.

"Well, now, I told those fellows not to put in any broken tile" was his response. "They hadn't any experience in tile-laying, but I thought they could do this little piece all right, seeing it has such good fall."

Sound tile, and reliable, experienced men to put them in, is a good motto.

Sometimes two lines of tile are laid in the same trench. This practice is not to be commended, as the water flowing in the triangular space between them is liable to wash away the soil in soft spots, causing the tile to side roll and partially or wholly block the drain.

Fig. 19. The steam ditcher, working on the farm of J. A. Lind, Beamsville, Ont.

The Steam Ditcher.

The discussion of methods of construction would not be complete without some reference to the traction ditching machine, which is now being introduced into Ontario. It digs the ditch full depth, true to grade, and leaves the bottom ready for the tile in passing once over the ground. They are manufactured by the Buckeye Traction Ditcher Co., Findlay, Ohio. Fig. 19 shows one of these machines in operation on the the farm of Mr. J. A. Lind, Beamsville, Lincoln County. It is owned by Mr. Walter Day, the writer's brother. The machine began operations in May, and what the people think of the style of ditch it digs may be judged from the fact that it has not once been short of work in the meantime, and that it has more jobs ahead of it now than when it began in the spring. In clean land it easily averages from 90 to 100 rods of 3-foo 'itch per day, including stops, sometimes digging 130 to 140 rods a day n very stony land it has dropped as low as 50 rods average on one ..hile on others, with less stone, it has averaged 75 rods. From my intimate knowledge of the performance of this machine during the past five months, I say without reserve that the steam ditcher has come to stay. It will revolutionize ditching operations in Ontario in a few years—indeed, it will solve the "labour problem" so far as ditching is concerned.

FILLING THE TRENCH.

The filling of the trench needs little comment. A small amount of earth should be shovelled in, just enough to protect the tile, and then

Fig. 20. Side view of corrugated metal outlet.

the plough may be used to good advantage. A few rounds will fill the trench completely, and a good crown should be formed to protect the drain from large quantities of water washing into it through the porous soil at the first rain. The crown sheds the run-off water into the furrows at the side. Some use the road grader for filling, others the "road planer," something similar to the grader, but with a smaller mould board, not reversible, mounted on three small wheels. Others use the ordinary drag scraper, and even the split-log drag does fairly well. Perhaps for the majority of people the plough is the most convenient.

Protecting the Outlet.

The outlet is often a source of trouble. Clay tile, if exposed to repeated freezing and thawing, as they are at the outlet of a drain, will chip and crumble, allowing the earth to drop down and obstruct the flow of water, and often the stock tramp on and break them. Sometimes the water undermines them and they side roll. To overcome these difficulties wooden boxes, from 6 to 12 feet long, are frequently used. Sometimes the last two or three feet of the ditch is built up with concrete surrounding the tile. Sewer crock are frequently used for the last four or six feet. All of these devices are good, and are preferable to leaving the end tile

Fig. 21. End view of corrugated metal outlet.

exposed, but the wood soon decays at the end, the cement may be broken in time if undermined, and the sewer crocks are subject to displacement by undermining. Since corrugated metal culverts have been coming into use, it has occurred to me that a six or eight-foot length of corrugated galvanized iron pipe would make an ideal outlet for tile drains; and, besides, if one end was fitted with cross-rods, as it might easily be, it would give a sure protection against muskrats, which sometimes infest and block the drains. During the summer of 1909 a gentleman living near Beamsville, Lincoln County, put in a system of drains. After the first heavy rain in the autumn he went down to the outlet to see if they were working. He was just in time to see a muskrat nest float out of the main drain. If, as often happens, it had been too securely lodged to be driven out by the water, the whole system would have been partially or wholly blocked. I have discussed the point with some of the metal culvert people, and, as a result, am able to present herewith side and end views of such an outlet. (Figs. 20 and 21.) A six or eight inch tile of this kind can be had for about 35 cents a foot, with 50 cents extra for the cross-rods. The ten and twelve inch sizes would be worth 40 cents a foot, with the rods extra. The rods, as well as the pipe, would be galvanized. I see no reason why this should not be superior to either lumber, cement, or sewer crock for outlet protection.

The outlet should be protected in still another way—the open ditch or creek below the tile should be kept well cleaned out. If it is allowed to fill up and interfere with the free escape of the water from the tile the efficiency of the drain is impaired in a like degree. Perhaps there is no more fruitful source of trouble with drains than the failure to keep the outlets free. Once each year they should be inspected and put in proper condition.

Sand Traps.

Sometimes it is impossible to get steep enough grade in drains to insure a velocity of water sufficient to flush all sand from the tile. This condition may be aggravated by turns in the drain, the entrance of laterals, or a change from a steep to a slow grade, all of which check the velocity of the water. In such cases sand traps should be used at the troublesome points. These consist of boxes of wood, brick or concrete, from eighteen inches to four feet square, depending on requirements, and about two feet deeper than the drain. Fig 22 shows a section of one of them. The water flows much more slowly in the box than in the tile, consequently the sand settles, leaving the water clear as it emerges. This object is better attained by having the outlet and inlet tiles diagonally across rather than directly opposite each other. If they are opposite, the water tends to flow straight through, with only a slight check in speed, and little chance for the sand to settle, but if diagonally across, it has to make two turns, and its velocity must be greatly reduced. It is also well to have the inlet at least half the diameter of the tile higher than the outlet, as this gives the former better clearance when nearly empty. These traps should be examined from time to time, and cleared of sediment as occasion demands.

The first drainage survey the writer made was one demanding a sand trap. Mr. Noah Bechtel, who lives a few miles out of Berlin, had three troublesome springy spots on a side hill. The soil was a sandy loam. The three drains from the springs had to be united in the flat, where the velocity of the water would be much slower than coming down the steeper grades. A sand trap twenty inches square was placed where the three met, and a main led from it. The next summer, when in Guelph one day, Mr. Bechtel took the trouble to come out to the College to report. He said the cement for the box cost him 50 cents, and he and the boys built it in about a quarter of a day. In the one spring it had filled with sand almost up to the tile, but in half an hour they had cleaned it out,

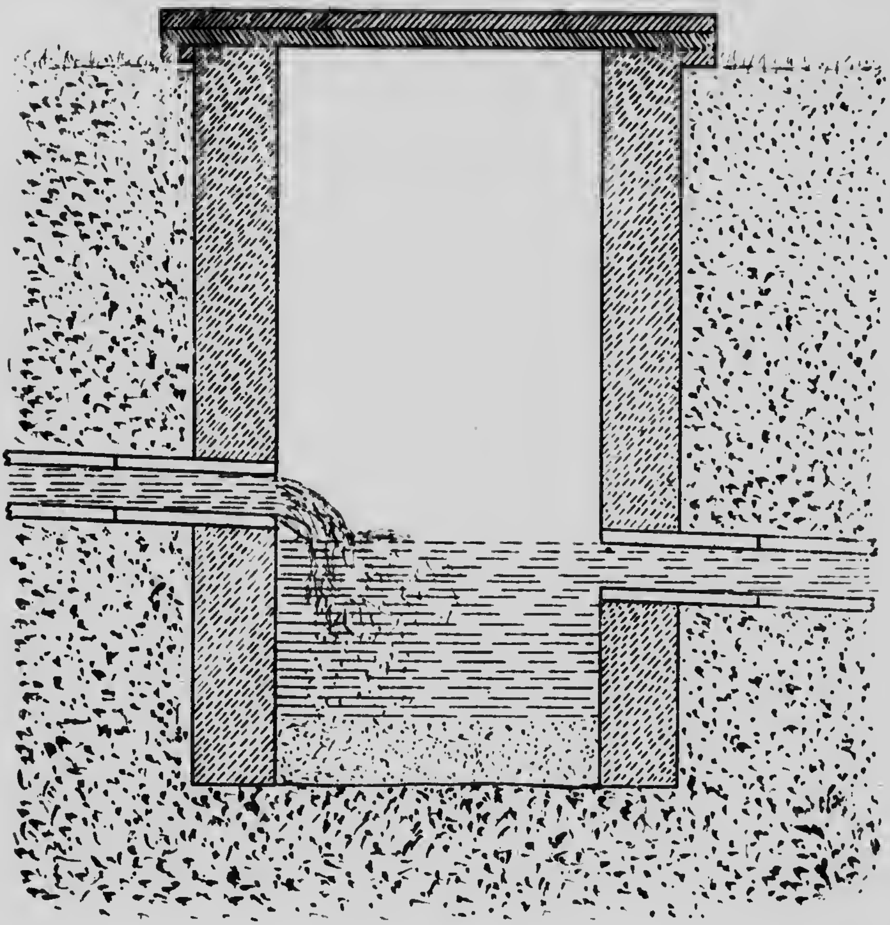


Fig. 22. Sand trap.

and it was then ready for the next spring. Indeed, it has been found necessary to clean it once each year.

Where the grade is so slow that sand is likely to bother, the traps should be placed at turns and junctions, also where the slow grade begins, and at intervals of 400 to 600 feet in long stretches not affected by turns, junctions, or changes in grade.

There is another use for these traps that is worthy of mention. In some cases it is found wise to lead an open drain into a tile. A sand trap with a screened side toward the open ditch is the best form of junction. The screen keeps out practically everything but sand, and the trap catches that. The tile will not carry all the water that comes down the open ditch at times of freshet, so it is wise to leave over the tile a depression with very flaring banks for the surplus. As soon as the freshet is over, the tile takes the remaining water. The depression is no obstruction to tillage, and will grow crops as well as the rest of the land.

Many sand traps have been observed in various districts, and often they are large, unsightly things that obstruct farming operations considerably. It seems to me that all that stands above ground is waste material. Less expense would build a strong cover just level with the ground, and then these traps would be neither eye-sores nor serious obstructions.

CONDITIONS ON WHICH SURVEYS ARE MADE.

It may not be out of place to state, in conclusion, the conditions on which drainage surveys are made. There is no charge for the services of our drainage advisors, their salary being paid from a special drainage appropriation, but their travelling expenses, consisting of railway fare at a cent a mile each way for this work, meals on the way, if any, and cartage of instruments, if any, must be paid by the parties for whom surveys are made. They must be met at the station and returned to it, accommodated while on the job, and furnished with the necessary assistance for the work. As several surveys are usually made on one trip, the actual cash outlay for any one farmer is not likely to exceed $2. It may be even less; or, in exceptional cases, where farmers live in remote sections, it might amount to $5.

Those wishing to make application for surveys should address the department of Physics, O. A. C., Guelph, whereupon regular application forms will be sent.

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