# UNIVERSITY OF KENTUCKY

## COLLEGE OF AGRICULTURE

### Extension Division

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## CIRCULAR NO. 129

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# SOIL EROSION

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By

GEO. ROBERTS, J. B. KELLEY AND E. G. WELCH

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### INTRODUCTION

Probably the greatest single cause of loss of fertility in Kentucky soils is erosion. Practically the whole area of the state is more or less rolling and much of it is decidedly so. Wherever there is enough slope to land for surface runoff of the rainfall, washing will occur unless the soil is protected by some sort of vegetation. Much erosion takes place in the form of uniform sheet washing and often is unobserved for a long time. Observation will show that on nearly all lands that are cultivated regularly without proper protection by cover crops, even very gentle slopes are ''thinner'' and redder or lighter in color than the adjacent level lands. This form of washing does far greater damage on the whole than the gullying of lands.

The statement is made in the 1916 Year Book of the U. S. Department of Agriculture that 4,000,000 acres of land have been ruined by erosion in the United States and that nearly twice as much has been seriously injured. It is stated further that 400 million tons of soil are removed annually by erosion and that the loss thus caused runs high into the millions. Hilgard, in his book, ''Soils,'' gives the estimate that the sediment deposited annually in the Gulf of Mexico by the Mississippi River would cover 268 square miles to the depth of one foot.

When these enormous losses are considered in connection with the fact that practically the entire surface of Kentucky is rolling, it must be realized that soil erosion is a problem of prime importance to the farmers of the state.

Fig. 1. A scene not uncommon in Kentucky.

## KINDS OF EROSION

There are two general types of erosion, *sheet erosion* and *gullying*.

Sheet erosion, as already indicated, is the more or less uniform washing of the soil in which no distinct gullies are formed. Because it is so uniform it is often allowed to proceed until more or less damage is done before measures are adopted to control it. Without doubt, more plant food is removed from the soil in this way than is removed in crops. In the removal of one inch of surface soil from an acre of average Kentucky soil, approximately 150 pounds of phosphorus, 300 pounds of nitrogen and 3,750 pounds of potassium are carried away. This loss represents the most available plant food of the soil, because the finer particles of soil and the part of the soil richest in humus are the first to go. Leaching of soluble plant food in underdrainage water is greatest where erosion is greatest, because erosion is greatest where there are no growing crops to protect the surface, particularly during the late fall and winter. Growing crops prevent the leaching of soluble plant food by using it.

There are two phases of gullying. One is the *headwater* phase, in which slope of the gully at its head gradually works up the hill. The other is the *over-fall* type. This type is found in grass land and in other lands where the surface layer is more resistant to washing than the subsurface layer. The water "eats" back under the more resistant layer until it breaks off in large pieces, whereupon the process is repeated.

The prevention and stopping of these various forms of erosion will be discust later.

## THE WORK OF MOVING WATER

A statement of some of the laws of moving water will serve to impress upon landowners the destructive power of water and to suggest means of controlling erosion.

1. If the rate of flow of water is doubled, the erosive power is increased four times. (Erosive power varies with the square of the velocity.)

2. If the rate of flow of water is doubled, the amount of material of a given size that can be carried is increased thirty-two times. (Amount of material that can be carried varies with the 4th power of the velocity.)

3. If the rate of flow is doubled, the size of particles that can be carried is increased sixty-four times. (Size of particle that can be carried varies with the 5th power of the velocity.)

It follows that two very important considerations in preventing erosion are to decrease the amount of water that runs off and to check the rate of flow of that which must necessarily pass away as surface run-off. The amount of surface run-off varies from nothing in regions of low rainfall and porous soils to as much as 50 per cent of the rainfall in some regions of high rainfall. It is very high in Kentucky.

## THE CONTROL OF SHEET EROSION

Perhaps more important than reducing the amount and the velocity of the run-off is treating the soil so that it will resist the washing power of moving water.

The most effective means of preventing sheet erosion is to keep the ground well covered with some kind of growth. A vegetative covering serves in many ways to prevent erosion.

1. The roots of plants hold the soil against washing.

2. Growing roots cause the soil particles to flocculate; that is, assemble themselves into granules or crumbs, which are larger and harder to move than single grains. This condition makes more pore space in the soil to take in water and reduce surface run-off.

3. Roots of plants when they decay leave passageways for the water to enter the soil, thus reducing the amount of surface run-off.

4. A vegetative covering reduces the force with which the rain strikes the soil. The beating of the rain breaks down the crumb structure referred to in No. 2, and thus reduces the amount of water that can enter the soil, while the breaking down of the granular structure makes the soil more easily washed.

5. A vegetative covering checks the rate of flow and thus gives the water more time to enter the soil.

6. If the soil is kept occupied by growing crops, more roots will be present which on decay will form humus, which in turn increases the water holding capacity of the soil and also helps to granulate the soil, a condition which, as already stated, helps to prevent erosion.

Expressed in practical terms, this means that the farmer should adopt a cropping system that will keep the ground occupied all the time, or as nearly all the time as is possible. The cropping system should provide for deep rooted crops, such as clover, and fibrous rooted crops, such as the grasses, wheat and rye.

The best crop for controlling washing is permanent grass. There is much hilly land in the state that should be kept in permanent pasture. Much rolling land that is now cultivated regularly should be kept in grass a large part of the time. Where good sods are plowed under, fairly steep lands may be cultivated for a year or two without serious washing if a winter cover crop is used. One of the reasons why it is often so difficult to grow grass on steep lands is that they have been impoverished by cultivation and erosion. Many of these poorer lands will grow fairly good redtop and Japan clover if treated with phosphate fertilizer. The poorest lands in the state can be made to produce good sweet clover if treated with limestone and phosphate. After sweet clover has been grown for two or three years, grasses can then be grown. Orchard grass makes an excellent companion for sweet clover, and in the Bluegrass region bluegrass thrives with it. Sweet clover and grass make a good combination for reclaiming impoverished land.

Even where land is to be cultivated every year a cropping system should be adopted that will keep the ground occupied. That this is not done is shown by the census figures. A little more than four million acres of land are planted to summer crops; corn and tobacco amounting to 3,887,000 acres. Assuming that the total acreage of small grains for harvest, which is 971,000, is seeded on land following the summer crops, more than three million acres of land in cultivated summer crops remain to be protected with winter cover crops or left unprotected. There are no statistics on the acreage of winter cover crops used purely as such and not harvested, but it is safe to say that two and one-half million acres of cultivated lands are left without any protection except weeds and trash.

Any rotation that has two or more cultivated crops in succession should have a winter cover crop between them. In addition to preventing erosion, as already indicated, the winter cover crop uses soluble plant food that otherwise would be leached, and returns it in available form if the crop is turned under. The cover crop is worth its cost for early pasture if it is needed, and it usually is needed.

A good cover crop cannot be grown on impoverished soil. It is a common practis to fertilize corn lightly in the hill. A cover crop following would not be benefited materially by such fertilization. It is better to use an application of about 300 or 400 pounds of acid phosphate or basic slag per acre applied broadcast and well worked into the soil. This is sufficient for the two cultivated crops between which the cover crop is used, and it

Fig. 2. Rye grown for cover crop on eroded land and pastured. Note the rye in gullies.

serves also for the cover crop. If nitrogen and potash fertilization are needed for the tobacco crop, these materials can be added in the tobacco hills in the usual way. Not only is this method better but it is usually cheaper than buying mixed fertilizers.

Rye is probably the most reliable cover crop for general use, altho wheat and barley may be used. Crimson clover is fairly satisfactory in some parts of southwestern Kentucky.

Often it is desired to seed grass and clover following a cultivated crop. An excellent procedure is to sow a cover crop of rye in which grass and clover are seeded in the usual way. The cover crop is pastured off and does not come in competition with the grass and clover, as would a grain crop for harvest. Any grain that is not consumed may be left to fall down and form a covering that affords some protection to the young grass and clover.

Cornstalks, weeds and trash, if cut down, will prevent washing to some extent by checking the rate of flow and catching the soil. It is worth while to cut stalks in the fall, not only for this reason but because they will decay more readily when turned under in the spring.

Increasing the organic matter of the soil by the use of manure or turning under crops and crop residues helps to control erosion because of the granulating and binding effect of the humus formed by the decay of the organic matter.

The use of lime helps to control erosion because it promotes granulation of the soil. It also helps by increasing crop growth, as do fertilizers when properly used. Usually the larger the crop growth on soils, the less the erosion, because of the larger root growth and residue of stubble.

Sloping lands that wash should be plowed, planted and cultivated on the contour; that is, across the direction of the slope. These operations, when performed with the slope, make furrows which increase the run-off of water, but, when performed on the contour, the furrows hold the water and give it more time to enter the soil.

The time and character of plowing influence erosion. Soils should not be plowed in the fall for spring planting, if they are liable to wash during the winter, but should be protected by sod or cover crop. Sometimes, however, a good sod broken in the fall will not wash during the winter, altho on a decided slope.

The character of plowing may contribute to washing. Shallow plowing on a slope is conducive to washing. Plowing should be from 6 to 8 inches deep. It is not unusual to see a thinly plowed layer of soil entirely removed from a slope by a heavy rain. Plowing to the same depth year after year may form a "plow sole," or hard layer of soil which prevents ready percolation of water and causes a greater run-off.

Sometimes, where it is necessary to cultivate steep lands rather frequently, erosion may be checked to some extent by leaving sod strips ten or fifteen feet wide at intervals on the contour.

Tile-draining of wet sloping land will greatly reduce erosion by reducing the surface run-off.

## TERRACING

Under some conditions deep plowing, contour cultivation and cover crops fail to check erosion. In this event terraces may be used.

Terracing consists chiefly in so altering the slope of the land by throwing up obstructions in the form of ridges of earth across the slope as to retard the flow of water or to hold it until it is absorbed by the soil. These ridges may be culitvated or may be sown to grass and left in permanent sod.

Fig. 3. The bench terrace.

## TYPES OF TERRACES

There are two distinct types of terraces; the bench terrace (Fig. 3) and the ridge terrace (Fig. 4). The bench terrace changes the slope of the land into a series of benches. After several years of cultivation, benches become level on account of the practis when plowing of throwing the soil down the slope. The ridge terraces are simply ridges of earth thrown up across the

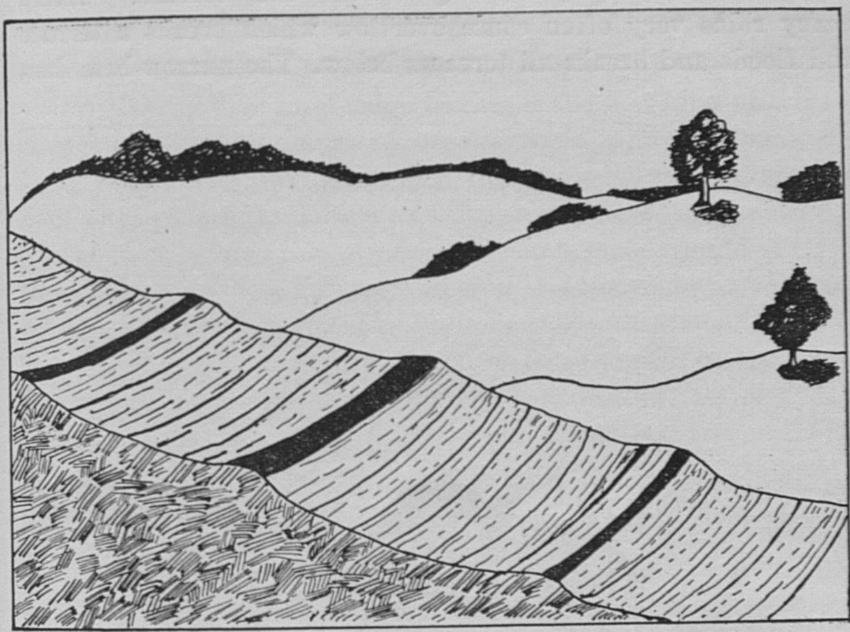

Fig. 4. The broad-base ridge terrace.

slope at intervals, the distance between them depending upon steepness of slope and character of the soil. Bench terraces are adapted to steep slopes, while ridge terraces are used to better advantage on more gentle slopes. Conditions are rare in Kentucky where the bench terrace is at present advisable.

## RIDGE TERRACES

There are two types of ridge terrace, the narrow-base and the broad-base. Narrow-base terraces have a width at the base of from three to six feet and are about twelve inches high. Either type of terrace may be level, thruout its course, holding the water until it is absorbed by the soil, or it may be given a slope not to exceed 6 inches in 100 feet, so that it will carry the water around the hill slowly to an outlet.

The narrow-base ridge terrace, as well as the bench terrace, is kept in sod; therefore there is some loss of cultivated land on this account. In addition, weeds usually grow on the terrace and spread seeds to other parts of the field. Moles are apt to start a break by tunneling across the terrace. Extra heavy rains very often cause overflow which breaks a terrace and floods and breaks all terraces below. The narrow-base does

Fig. 5. Narrow-base ridge terrace in Mason County, Ky.

not possess any advantge not possessed by the broad-base terrace and under ordinary circumstances is less desirable than the broad-base type. However, when laid out level, it is sometimes successfully used on very sandy soils that are capable of absorbing large quantities of water.

The broad-base terrace is built from ten to fifteen feet wide at the base and is at least fifteen inches higher at the center than the upper edge of the base. As already stated, the broad-base terrace may be laid out level or with a fall not to exceed six inches to one hundred feet, to carry the water at a low velocity to an outlet at the end of the ridge. The former is called the level-ridge terrace and the latter a graded-ridge terrace. Either level or graded broad-base terraces may be cultivated and are crossed readily by large farm machinery without injury to the terrace. There is no waste land and no growth of weeds to distribute seed to cultivated ground.

### THE BROAD-BASE LEVEL-RIDGE TERRACE

The broad-base level-ridge terrace is the best kind of terrace on soils to which it is adapted, because there is no washing of the terrace channels. All the water that falls between terraces is held back, the terrace acting as a dam until the water is absorbed or is evaporated.

The terrace must be very carefully constructed and maintained, for a sag of a few inches may cause an accumulation of water which may break the terrace. The channel on the upper side of the terrace must be kept open as a reservoir. This requires considerable work and frequent inspection.

### THE USE OF TILE

In many cases the broad-base level-ridge terrace can be made much more effective if drain tile is used to carry off some of the water. The tile should be placed in gullies or draws and is installed as indicated in Fig. 6.

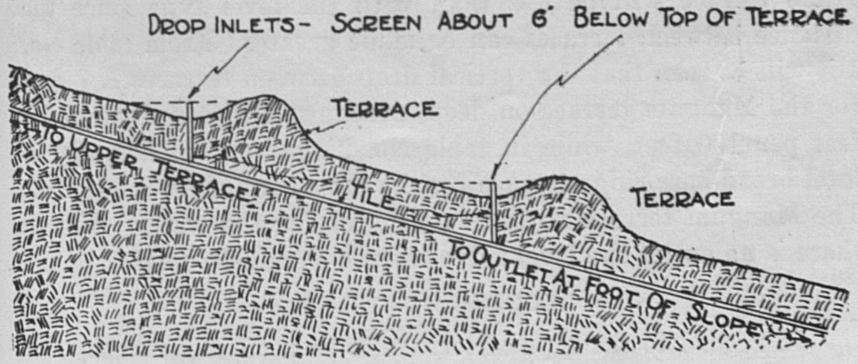


Fig. 6. Tile under terraces.

### THE MANGUM TERRACE

The broad-base graded-ridge terrace, or the Mangum terrace, is similar to the broad-base level-ridge terrace, with the exception that the terrace is given a very slight fall so that the water is carried around the hill at the upper side of the ridge in a wide stream at a very low velocity. It has been found that average soils are not seriously washed in broad terrace channels where the fall does not exceed 6 inches in 100 feet, and it is recommended that this fall never be exceeded. The terraces may be laid out with a uniform or a variable grade. The best results are obtained where the variable grade is used since it tends to prevent the accumulation of the water at the lower end of the terrace. Variable grade means that the slope of the terrace is not uniform from one end to the other, but that the rate of fall is increased from the upper to the lower end at intervals. This variable grade enables the channel to carry water at the lower end faster than at the upper end, thus preventing an accumulation at the lower end where there is the most water to be carried.

The Mangum terrace possesses all the advantages of the broad-base level-ridge terrace with the exception that some of the fertile soil may be removed from the field. Where the fall of the terrace does not exceed that recommended in this circular, the amount of soil removed from the field will be negligible. On account of the movement of water there is very little chance that it will break over the terrace, which is a very important consideration. The cost of terracing a field with the variable-grade terrace will be less than with the level type since the distance between terraces can be made greater. From table No. 1 it will be seen that the vertical drop between terraces is 7 feet for the Mangum terrace on deep, porous soil with a slope of 15 feet per 100 feet, while in table No. 2 the vertical drop for a level broad-base ridge terrace for the same conditions is 3¾ feet. The Mangum terrace requires an outlet for the water. Where there is no outlet the level-ridge terrace should be used.

## RECOMMENDATIONS

In regard to the type of terrace to be used in Kentucky the following recommendations are made:

1. The bench terrace and the narrow-base terrace should be used only on steep slopes and very porous soil. Since steep slopes are best left in permanent pasture or woods, and since

there is very little sandy soil in the state, these two types of terrace are rarely to be recommended.

2. The broad-base level-ridge terrace should be used only where no suitable outlet can be secured for the Mangum terrace.

3. Where the broad-base level-ridge terrace is used, tile should be installed to remove the water from the upper side of the embankment at draws and deep gullies.

4. The Mangum terrace with variable grade, altho not quite so efficient in preventing erosion as a properly constructed level-ridge terrace, is much less apt to give trouble, and for general conditions is the most practical.

## CONSTRUCTION OF BROAD-BASE RIDGE TERRACES

### Best Time for Constructing Terraces

Terraces may be constructed at any time of the year when the soil is in proper condition. The best time is during the months of August and September, because of the opportunity of planting a cover crop to protect the freshly moved earth during the winter. During these months the rainfall is usually lighter than at any other season of the year, and as heavy rains before the terrace has settled may cause serious damage, this is the safest time for the work.

### Equipment Required

1. Farm level.
2. Rod and target.
3. Measuring line.
4. Stakes.
5. Plow.
6. Terrace drag or grader.
7. Slip scraper.

The most accurate instrument for determining the line of the terrace and the one with which the work can be done most rapidily is the surveyor's level. There are several inexpensive farm levels on the market and the instruments are very useful for other purposes, such as land drainage and building construction. An adjustable rod for reading elevations can be purchased with the level. Some farmers have made and used various triangular devices with levels attached for determining the line of the terrace, but where a variable grade is desired these tools are impracticable.

A measuring line for getting the correct distance from one point on the terrace to the next should be provided. Since these points should be either 25 or 50 feet apart, depending on the regularity of the slope, a smooth wire 25 or 50 feet long with loops in the ends may be used instead of a tape or chain.

Wooden stakes for marking the points which have been located are required. A large number of stakes is not necessary, provided the men locating the terrace are followed closely with a plow to mark the line of the embankment. Tobacco sticks make excellent stakes.

A turning plow or disk plow is used for loosening the soil so that it can be more easily moved by the grader or terrace drag.

The home made drag or terrace drag is most often used for building up the terrace. Other implements sometimes used are the four-wheeled road grader or the commercial ditcher and grader. A cut is shown (Fig. 7) of a reversible terrace drag which is very efficient as a road drag as well as a terrace drag.

The slip scraper sometimes is used when it is necessary to build the embankment higher at points where the terrace crosses a draw or gully.

### Preliminary Survey

Some time should be spent in a preliminary survey of the field to be terraced before actual work of laying out is started, particular attention being paid to the following points:

1. Outlets.
2. Slope of the land.
3. Character of soil.
4. Length of terraces.

### Outlets

If water can be carried into a woodland for final disposal, it will cause little or no washing. The water may be carried to a roadside ditch or gully, but this water course should be protected from additional erosion by means of dams made of rock

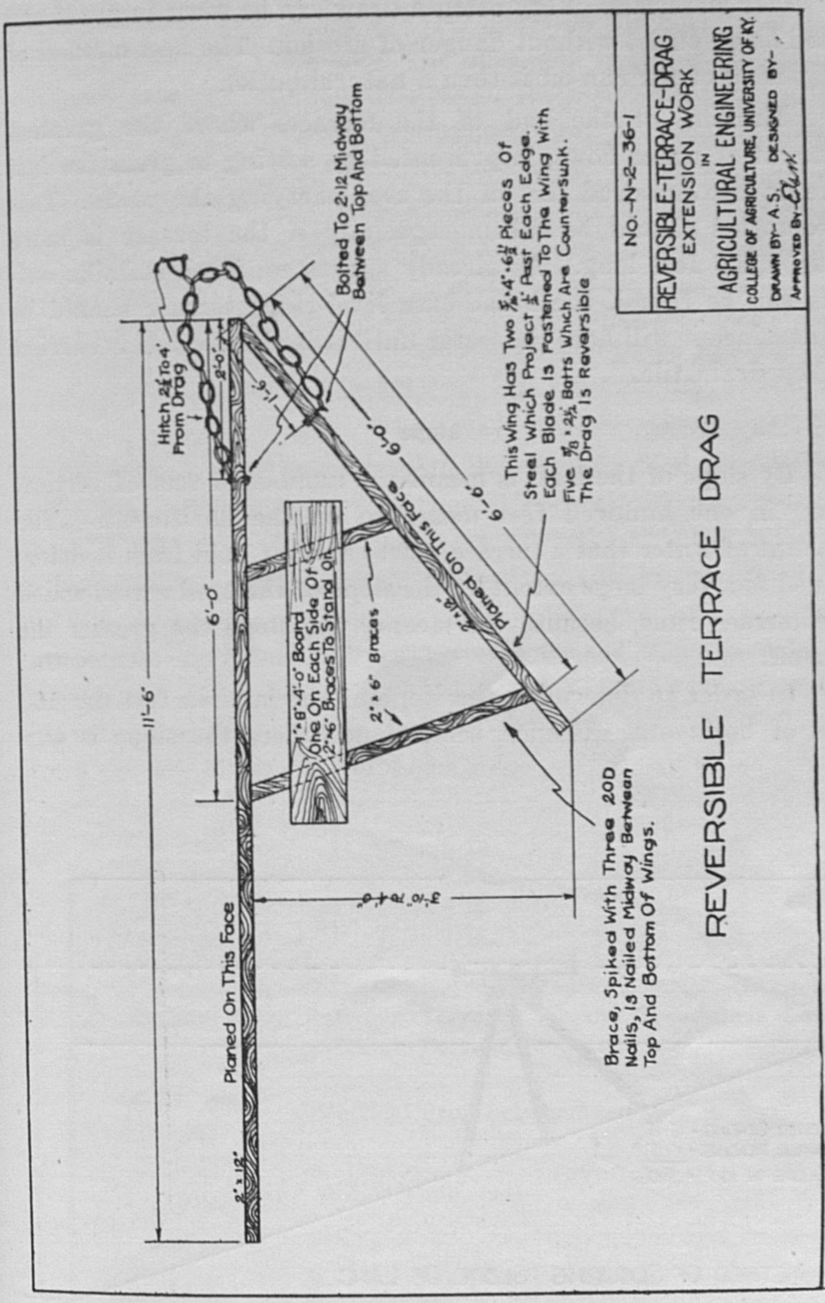


Fig. 7. Reversible terrace drag.

or other materials. Very often a draw can be sown to grass and used as an outlet without danger of erosion. The best method of disposing of the run-off is thru a natural outlet.

Erosion, at the end of the terrace, where the greatest amount of water flows, is prevented by sowing to grass the last one or two hundred feet of the area carrying the water. This precaution should be taken, especially if the terrace is more than 1,200 feet long. As already suggested, if no suitable outlets can be found, the broad-base level-ridge terrace should be built, since it will hold the water until it is absorbed or is carried off by drain tile.

### Slope

By slope of the land is meant the number of feet of vertical drop in one hundred feet measured on the horizontal. The amount of water that a terrace must carry or hold back is determined to a very large extent by the slope of the land across which the terrace runs, because the steeper the slope the greater the run-off.

In order to determine the slope of the land in feet per 100 feet of horizontal distance, select land where the slope is uni-

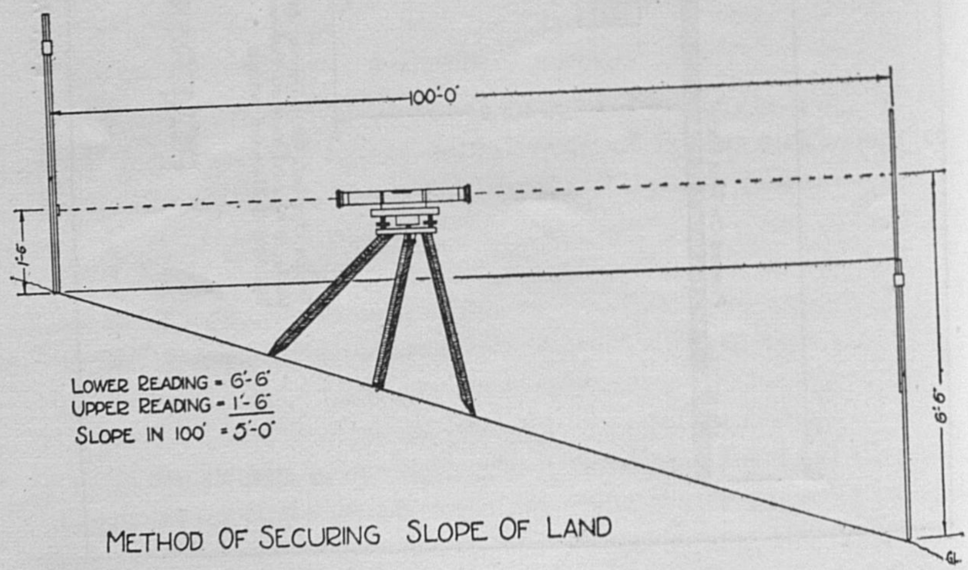


Fig. 8. Method of determining slope of land.

form. Establish two points 100 feet apart on the horizontal and in the direction of the slope. The next step is to set up the instrument and level it. The location of the instrument should be about half way between the two points selected so that readings may be made on the rod when held on each of the selected points without moving the instrument. The difference between the rod readings at the two stations will give the drop in feet per 100 feet of distance on the slope. (Fig. 8.)

The slope of the land must be known before the proper distance or the vertical drop between terraces can be determined.

As already stated, the vertical fall between terraces must be less for the broad-base level-ridge terrace than for the Mangum terrace, since all of the water must be held rather than permitted to run off gradually.

The slope and corresponding vertical drop between terraces for both types of broad-base terrace are shown in the following tables:

**Table 1.—Vertical Drop Between Terraces for the Mangum Terrace.**

| Slope per 100 feet | Vertical drop between terraces in feet. | |
|---|---|---|
| | Loam soils | Tight, heavy soils. |
| 5 feet | 4 ft. | 3 ft. |
| 8 feet | 5 ft. | 4 ft. |
| 10-12 feet | 6 ft. | 5 ft. |
| 15 feet | 7 ft. | 6 ft. |

**Table 2.—Vertical Drop Between Terraces for the Broad-Base Level-Ridge Terrace.**

| Slope per 100 feet. | Vertical drop between terraces in feet. | | | |
|---|---|---|---|---|
| | Sandy soil | Loam soil | Clay loam soil | Clay soil |
| 3 feet | 4½ ft. | 3½ ft. | 2½ ft. | 2 ft. |
| 15 feet | 4½ ft. | 3¾ ft. | 3 ft. | 2½ ft. |

### Character of Soil

It will be noticed that in table No. 2 the vertical drop for a slope of 3 feet per 100 feet in clay soil is two feet, while with sandy soil the vertical distance can be increased to 4½ feet. The sand will absorb water faster than the clay, leaving less to be carried off. The ability of the soil to absorb water generally will be known from past experience in the cultivation of the field.

### Length of Terrace

The broad-base ridge terrace with a variable grade should not be over 1200 or 1300 feet long if the slope of the land is over eight feet. If the slope is between 5 and 8 feet, the terrace may be 1600 feet long. The grade of the terrace never should exceed 6 inches per 100 feet, and if the grade can be kept below this figure, there will be less chance of loss of soil. The approximate length of the terrace should be determined in order to be sure that the fall will not exceed the 6 inches per 100 feet. The length of terrace may be increased somewhat by running the first two or three hundred feet level, provided the slope of the land is not greater than 5 feet in 100 feet.

### Staking Out the Terrace

The first terrace built should be at the upper side of the field and at a vertical distance from the highest point in the area to be terraced equal to the vertical distance selected as the proper vertical distance between terraces. The line of the terrace should be marked out by stakes set at 25 foot intervals, the first stake or starting point being at the end of the terrace opposite the outlet. The level should be set at approximately the same elevation as the starting point and about 300 feet towards the outlet and adjusted so that the telescope will be level when turned in all directions.

With the rod at the starting point, adjust the target so that the center of the target on the rod will coincide with the horizontal cross hairs of the telescope. Move forward toward the outlet a distance of 25 feet, or 50 feet if the line is to be nearly straight, and without moving the position of the target on the rod or changing the length of the rod, locate a point on the slope level with the starting point. Continue to locate other points on the slope at 25- or 50-foot intervals within a range of 300 feet of each side of the level. Holding the rod at different stations without changing it will locate the terrace on a level. If the terrace is to be graded instead of being level, follow the instructions for setting the target as given in table No. 3 taken from an unnumbered circular by J. V. Philips, College of Agriculture, University of Georgia.

**Table 3.—Target Settings in 25-Foot Intervals for Laying Off Terraces With Variable Grade Where Slope of Land is 5 to 8 Ft. per 100 Ft.**

| Rod at | Change of Target | Ins. | Rod at | Change of Target | Ins. |
|---|---|---|---|---|---|
| 0 ft. | Set Target | | 825 ft. | Raise | ½ |
| 25 ft. | No Change | | 850 ft. | Raise | ½ |
| 50 ft. | No Change | | 875 ft. | Raise | ¾ |
| 75 ft. | No Change | | 900 ft. | Raise | ¾ |
| 100 ft. | No Change | | 925 ft. | Raise | ½ |
| 125 ft. | No Change | | 950 ft. | Raise | ¾ |
| 150 ft. | Raise | ¼ | 975 ft. | Raise | ¾ |
| 175 ft. | No Change | | 1000 ft. | Raise | 1 |
| 200 ft. | Raise | ¼ | 1025 ft. | Raise | ¾ |
| 225 ft. | Raise | ¼ | 1050 ft. | Raise | 1 |
| 250 ft. | Raise | ¼ | 1075 ft. | Raise | ¾ |
| 275 ft. | No Change | | 1100 ft. | Raise | 1 |
| *300 ft. | Raise | ¼ | 1125 ft. | Raise | 1 |
| 325 ft. | Raise | ¼ | 1150 ft. | Raise | ¾ |
| 350 ft. | Raise | ¼ | 1175 ft. | Raise | 1 |
| 375 ft. | Raise | ¼ | 1200 ft. | Raise | 1 |
| 400 ft. | Raise | ¼ | 1225 ft. | Raise | 1 |
| 425 ft. | Raise | ¼ | 1250 ft. | Raise | 1¼ |
| 450 ft. | Raise | ¼ | 1275 ft. | Raise | 1 |
| 475 ft. | Raise | ¼ | 1300 ft. | Raise | 1¼ |
| 500 ft. | Raise | ¼ | 1325 ft. | Raise | 1¼ |
| 525 ft. | Raise | ¼ | 1350 ft. | Raise | 1¼ |
| 550 ft. | Raise | ¼ | 1375 ft. | Raise | 1¼ |
| 575 ft. | Raise | ½ | 1400 ft. | Raise | 1¼ |
| 600 ft. | Raise | ¼ | 1425 ft. | Raise | 1½ |
| 625 ft. | Raise | ¼ | 1450 ft. | Raise | 1¼ |
| 650 ft. | Raise | ½ | 1475 ft. | Raise | 1¼ |
| 675 ft. | Raise | ½ | 1500 ft. | Raise | 1½ |
| 700 ft. | Raise | ¼ | 1525 ft. | Raise | 1¼ |
| 725 ft. | Raise | ½ | 1550 ft. | Raise | 1¼ |
| 750 ft. | Raise | ½ | 1575 ft. | Raise | 1½ |
| 775 ft. | Raise | ½ | 1600 ft. | Raise | 1½ |
| 800 ft. | Raise | ¾ | 1625 ft. | Raise | 1½ |

*Where slope of land is over 8 feet per 100 feet and less than 15 feet per 100 feet start readings at 300 feet in the table, reducing length of terrace to 1325 feet.

The above is safe for ordinary loam soils. For a tight soil make vertical drop 1 foot less than figures given.

When it becomes necessary to move the instrument, hold the rod at the last point that has been located and move the level into a new position around the slope and nearly on the proposed line. Adjust the rod and target the same as was done when the line was first started and continue in the same manner as at first. Follow the table in regard to rod adjustments from the point where the change was made if the table is being used.

### Constructing the Terrace

Starting with the line of stakes, throw six or seven furrows to the center; then use the grading machine to draw the soil toward the center of the plowed strip. Follow this work by plow-

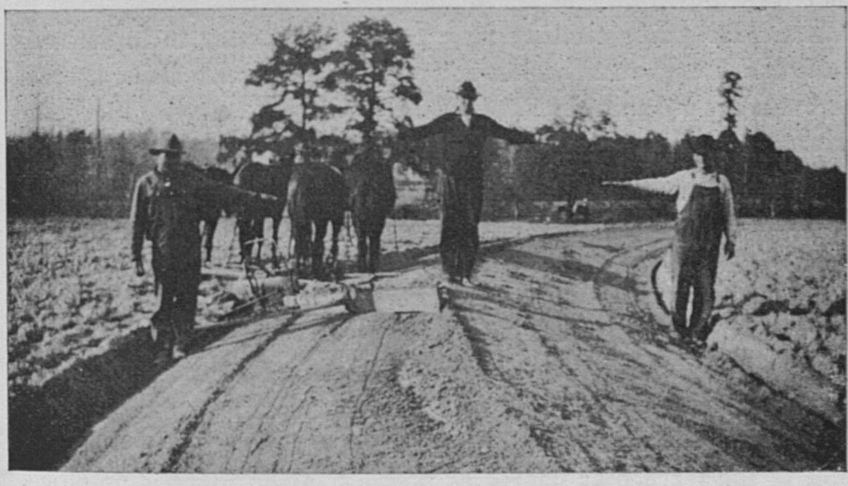

Fig. 9. Finishing a broad-base terrace.

ing four additional furrows and draw the earth toward the center as before, until the middle of the terrace has a height of at least 15 inches above the upper channel and the base is not less than 12 feet wide. Since the terrace, especially while new, is most likely to break over at sharp turns, special care should be taken at points where the embankment crosses gullies or draws. At a draw the line of stakes will move up the slope a short distance on one side and then come down on the other side. Instead of following the stakes at this point, it is safer to plow straight across the depression and build up the terrace at the low places to correspond with the level at either side. With the lapse of time these low places will gradually become filled and the contour will become regular. Very often loose rock is present which can be used to advantage for building up these low places. A slip scraper can be used in moving earth, but care must be taken not to remove enough earth from one spot to decrease its productivity.

### Maintaining the Terrace

*Inspection.* After the first heavy rains the embankments should be inspected for breaks and if any are found they should be repaired immediately. While the freshly moved earth is loose, there is a possibility of its settling more in some places than in others. Irregular settling may permit the water to break thru during a heavy rain. This is not likely to occur after the soil becomes settled, unless the rainfall is very heavy. The most critical period for the terrace is during the first year.

*Plowing.* After the first year, practically the only attention that need be paid the terrace is in plowing. The soil should be thrown toward the center of the terrace each year. This will widen the base of the terrace and keep it at the proper height. As pointed out previously, if the terrace is of considerable length, the last two or three hundred feet should be kept in grass so that the water at that section will not cause undue erosion; otherwise the terrace can be cultivated. Rows should run parallel to the terrace as nearly as possible, altho there is no objection to crossing the terrace occasionally in order to eliminate short rows. Rows should never run directly up and down the slope.

The terrace channel should be kept open. Often cornstalks or other trash will dam the channel and cause an overflow. A little precaution will keep a terrace in first class working order.

It should be understood that terracing alone, altho an important aid, will not prevent erosion. Along with terracing should go good soil management, involving all that has been said in the first part of this circular about good cropping systems, cover crops, grass and tillage. In some parts of the South may be seen a great deal of terraced land left without cover crops during the winter. In spite of the terraces the land erodes badly.

## GULLYING

### The Prevention of Gullies

The control of sheet erosion will in a large measure prevent the formation of gullies. Where conditions are favorable for sheet erosion, large volumes of water collect which must be carried away as streams which will produce gullies.

A means of preventing the formation of gullies in draws is to lay tile in them with an inlet at the head of the draw where there is a tendency for gullying to begin.

Gullying in draws very often can be prevented by keeping the draw in sod. Redtop makes a good grass for this purpose. In plowing up a field in which there are sodded draws a strip of sod should be left wide enuf to take care of the maxium flow of water.

### Conditions Favoring the Formation of Gullies

Many conditions contribute to the formation of gullies, among which may be named the following:

Seeding and cultivation with the slope of the land. Large gullies may be formed by this cause in a single season.

Dead furrows, paths, mole runs and wheel tracks are frequently the beginnings of gullies.

Some animals, especially sheep, have a habit of congregating on the highest points, thus killing the grass and compacting the soil, which results in gullying.

### Methods of Stopping Gullies

*Plowing in Gullies.* Gullies which are only a few inches to a foot or so in depth may be stopped by filling them with a plow. If the gully is more than a foot in depth, obstructions should be placed in it before plowing-in, in order to help hold the soil against washing before it becomes settled or is occupied by a crop. The obstructions should be placed from one to two rods apart, depending on the steepness of the slope. They may be made of stones or by driving stakes into the bottom of the gully. (See Fig. 10.) Behind the obstructions should be placed straw, stalks or brush. The dams or stakes should be low enough not to interfere with plowing after the gullies are filled.

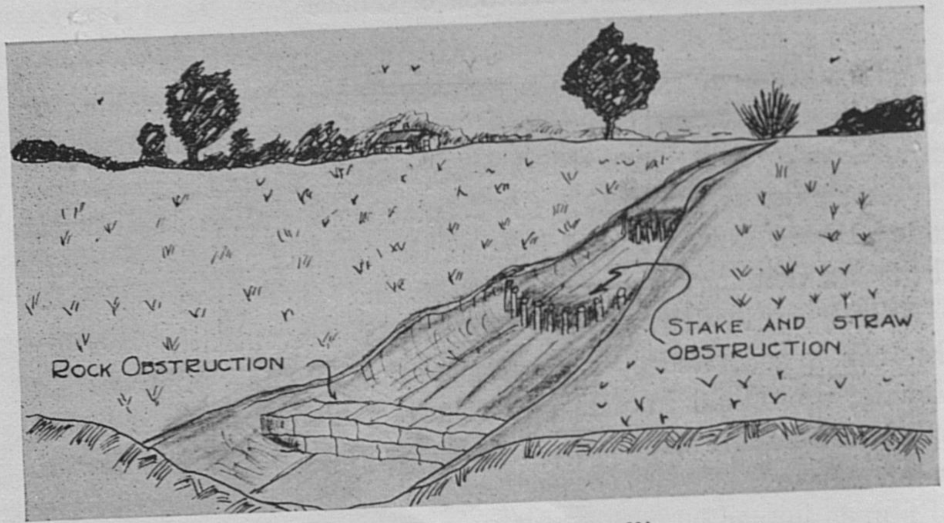


Fig. 10. Obstructions in gullies.

After filling the gullies, the ground should be prepared and seeded to some quick growing crop, such as rye, wheat or oats, to prevent washing. With the temporary crop should be seeded grass and also clover, if it will grow. If the soil contains lime and sufficient phosphate, clover can be grown, especially sweet clover, which will grow in the poorest of soil if treated as indicated and inoculated. Redtop is a good grass for sowing on filled gullies, but if the ground is not limed Japan clover is recommended instead of red or sweet clover. If manure is available, a dressing will greatly facilitate the growth of the sod crop.

The plowing-in method is the quickest method of stopping gullies and is recommended in all cases in which the expense is not too great.

*Staking-in Gullies.* Many gullies are so large that the expense of plowing-in becomes too great. In such cases the staking-in method may be used. Stakes of sufficient size are driven into the bottom and sides of the gully (see Fig. 11) so as to form a curve down the stream. Straw or other litter is placed behind

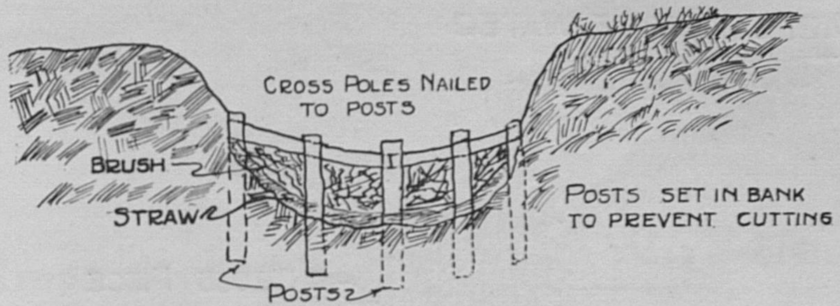


Fig. II. Method of staking-in large gullies.

the stakes for several feet. Upon the straw, brush is placed, well tramped in and held down by nailing strips from one stake to another. The finer brush should be at the bottom. Some straw and brush should extend below the stakes in order to prevent the water from wearing the gully deeper by pouring over the obstruction. The straw and brush filling should extend up the sides of the gully to prevent cutting into the sides and around the obstructions. The distance between obstructions is determined by the slope of the gully. Where stones are available, dams may be built in place of using the stakes, but provision always should be made to protect the gully just below the dam against water pouring over and wearing the gully deeper.

When the gully has filled to the top of the obstructions, new ones should be placed between the old ones.

*Checking Over-falls.* The over-fall type of gully has been described on page 5.

In stopping this type of gully it is very necessary to stop the progress of the over-fall. This may be accomplished in the following manner. Posts or stakes are set firmly in the bottom of the gully just below where the water falls over. (See Fig. 12.) They should be set about 3 feet apart and form a sharp curve down stream. Straw is packed between the posts and the bank of the over-fall and almost to the top of it. The straw should also extend between and below the posts. The straw is held down by green brush well packed on the straw and held down by cross-pieces nailed on the posts.

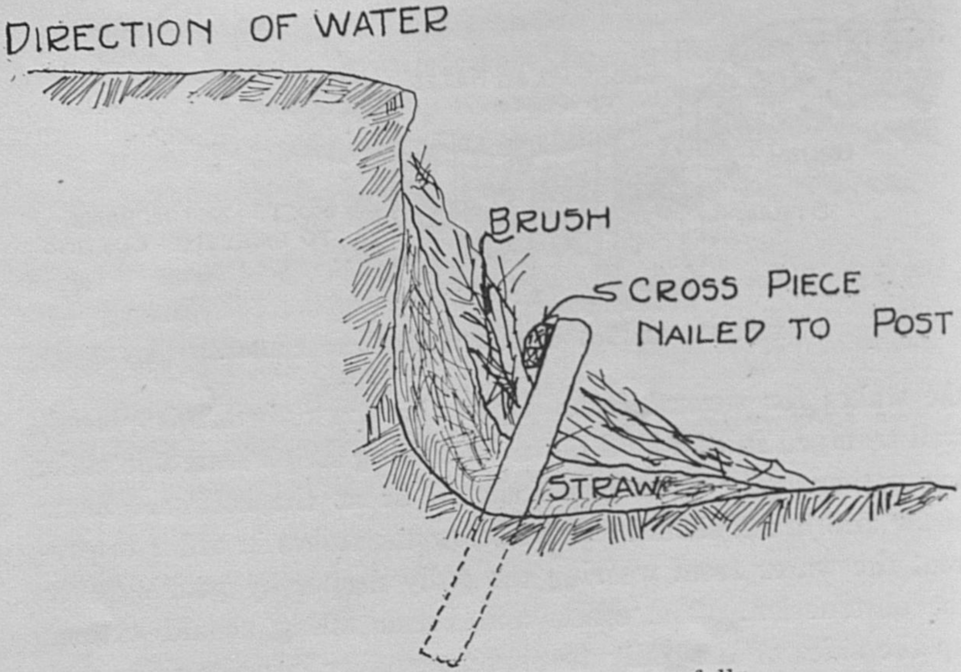


Fig. 12. Method of checking over-falls.

Special care should be taken not to fill in so much that the water will be forced to the sides and form new over-falls.

Below the over-fall the gully should be staked-in, in the manner already described.

*Woven Wire Obstructions.* Where gullies are large, woven wire obstructions may be used to good advantage. Posts are set about three feet apart, the outer posts being set in the bank. They should extend from one and a half to two feet above the bottom of the gully, and should lean down stream. Several thicknesses of old wire fence are fastened to the posts and straw is placed above it. When the gully fills to the top of the obstructions, new obstructions should be built between the old ones.

*Combined Tiling and Staking-in.* Where seepage water flows in the gully for a considerable period after rains, it is advisable to lay a line of tile in the bottom of the gully (see Fig. 13) to remove the water so that it may be possible to seed some sod-forming crop. In determining the size of tile to be used, it should be borne in mind that drains from adjoining land

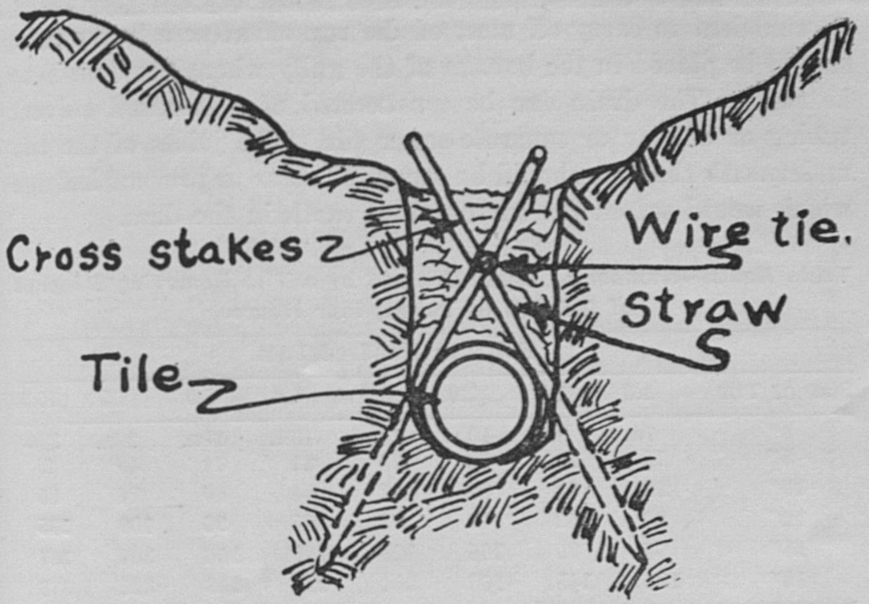


Fig. 13. Combined tiling and staking-in.

may some day be connected with it, hence the tile should be large enough to carry all the water that may be delivered to it. From the standpoint of checking erosion, tile that is too small is worse than no tile at all, for where water under pressure from the higher laterals is forced out at every joint instead of seeping in, the soil above and around the tile has little chance of holding together.

*The Earth or Adams Dam.* An earth dam having an underdrain with a raised inlet (see Fig. 14) has been used successfully in Missouri and Iowa for stopping large gullies. This dam is commonly called the Adams dam, because J. A. Adams, a farmer of Johnson County, Missouri, designed and used it with success.

The earth dam may be located in one of the following places:

1. At a narrow place between two well sodded banks.
2. Just below the junction of several gullies or ditches.
3. Sometimes it is placed so as to make a convenient crossing.

In constructing the dam, an under drain of a size (see Table 3) sufficient to carry off most of the run-off after a heavy rain should be placed in the bottom of the gully where the dam is to be made. The drain can be constructed of galvanized culvert tubing or of clay or concrete sewer tile. The joints of the tile underneath the dam should be cemented so as to prevent leakage which would soften the surrounding earth in the dam.

**Table No. 3.—Number of Acres Drained by a Tile Removing 2 Inches of Rainfall in Twenty-four Hours.**

| | Fall Per Hundred Feet. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Size of Tile | 1.0 | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 7.5 | 15.0 |
| 6″ | 7a. | 9a. | 10a. | 13a. | 15a. | 18a. | 29a. | 28a. |
| 8″ | 15 | 19 | 22 | 29 | 31 | 34 | 40 | 43 |
| 10″ | 29 | 32 | 38 | 47 | 54 | 60 | 74 | 85 |
| 12″ | 42 | 52 | 60 | 73 | 85 | 96 | 100 | 135 |
| 15″ | 75 | 90 | 105 | 129 | 149 | 166 | 204 | 237 |
| 18″ | 131 | 145 | 166 | 204 | 236 | 263 | 321 | 373 |

At the inlet end of the drain is placed an elbow tile to which the vertical inlet tiles may be added from time to time as the gully fills in with soil. The top end of the inlet tile should always be kept from one to two feet above the surface of the surrounding soil in the gully. The dam will stop the flow of the water and the soil particles will be deposited while the water is rising to the top of the inlet, the raised inlet preventing the sediment from being washed thru the outlet. The top of the inlet should be covered with a screen to prevent the tile from becoming clogged, and a guard made of four posts with boards nailed across and woven wire fencing nailed around them should be constructed around the inlet to protect and hold the vertical inlet in place. The inlet with guard should be placed from 15 to 25 feet from the inside bottom edge of the dam so that it will not clog up so readily as if placed right at the edge of the dam, where the brush and the other objects carried down by the water tend to collect.

At the bottom of the dam, on the upstream side, should be constructed a guard wall made of concrete or rock placed to pre-

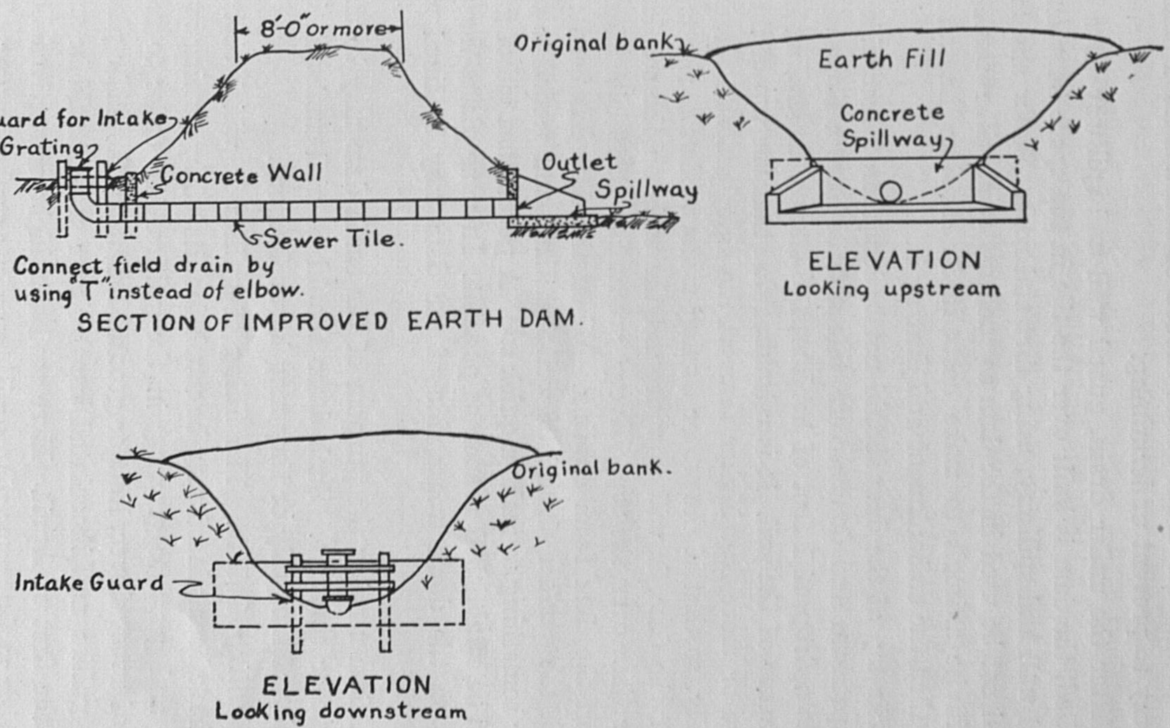


Fig. 14. Details for the construction of the earth or Adams dam.

vent the water from cutting out the dam, and on the downstream side at the under drain outlet should be constructed a concrete spillway to prevent undermining.

After the under drain, guard wall and spillway have been installed, the dam is built over the tile in the space between the guard wall and spillway, using dirt and rock. Straw and brush should not be used in the dam as such material will rot and will also invite animals to make nests in it, causing the water to work thru the embankment and destroy it.

The top of the dam should not be less than 8 feet wide and the upstream and downstream side should have a slope of 1½ feet to a drop of 1 foot of horizontal distance, depending upon the nature of the soil. It is recommended that the top of the fill be two or more feet higher than at the side banks of the ditch or gully, so that if the water during a storm should rise to the top of the dam, it will flow around the ends on the sod banks rather than over the top. Every precaution should be taken to prevent the dam from eroding. When the dam has been completed, the surface should be well fertilized and seeded to oats, rye or something to make a quick sod. A permanent sod of grass should be established as soon as possible. In some places the side banks on the downstream side of the dam may be lined with rocks.

A dam serving the purpose of the earth dam may be made of stone or concrete. Such dams should be well anchored into the sides of the gully or they may be washed out.

*Planting Gullies.* The filling of gullies in which obstructions have been placed may be much facilitated by getting sweet clover and grass to growing in the gullies. In order to get a stand of sweet clover, lime or ground limestone should be placed in the gullies and inoculated sweet clover seed should be sown about the first of April. More seed should be sown the following spring so that some plants will come into seed each year. The sweet clover should be allowed to seed and fall into the gullies. After sweet clover is well established, grass should be seeded with it.

The illustrations in Figs. 15 and 16 show how sweet clover will fill gullies where conditions are favorable for its growth. In many limestone regions it is not necessary to lime the gullies in order to get sweet clover. This is the case where fragments of limestone are found in the bottom of the gully.

Fig. 15. Sweet clover starting on badly gullied land in Pendleton County, Ky.

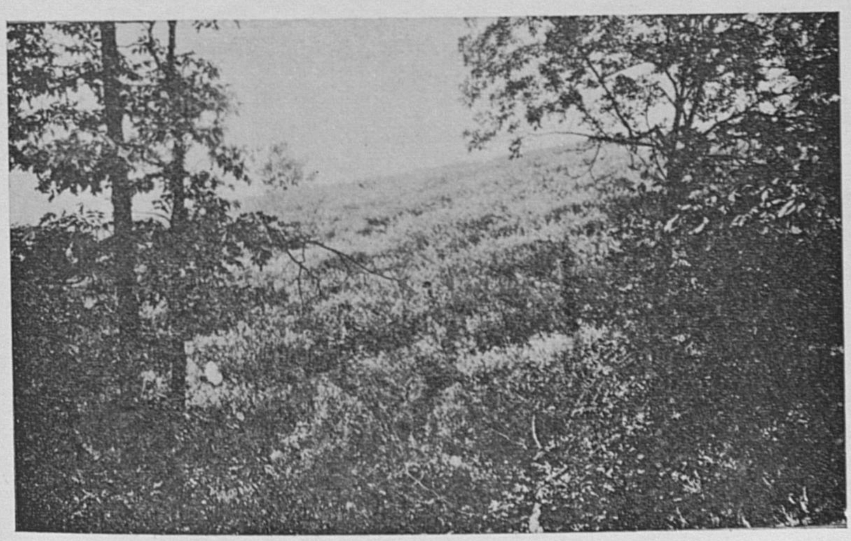

Fig. 16. The same as Fig. 15, but later in the season.

In the limestone hills of northern Kentucky, gullies can be stopped by using the loose limestone found in or near the gullies for making dams and by seeding sweet clover in the gullies.

In many places land has become so badly gullied that none of the means suggested seems satisfactory. In such cases the ground may be set to locusts rather thickly. As they become too much crowded they may be thinned out. When the locusts have made some headway in improving the soil, grass of the kind adapted to the region should be seeded among the trees.

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The following publications have been consulted in the preparation of this circular:

Bulletin No. 207, Illinois Experiment Station.

Extension Bulletins Nos. 73, 74, 77 and 78 of the Iowa State College of Agriculture.

Farmers' Bulletin No. 997, U. S. Department of Agriculture.