SOIL EROSION CONTROL...

CONTROL BY STRIP CROPPING

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HIGHLIGHTS OF EROSION CONTROL

Soil erosion occurs in almost every agricultural region. It cannot be stopped, but it can be largely controlled.

Cultivation tends to increase manifold the rate of erosion. Removing forest or sod cover from steep slopes; cultivating up or down the slope; unwise location of dead furrows, cattle runs, and field roads, and failure to maintain plenty of organic matter in the soil greatly aggravate erosion. These practices, therefore, should be avoided.

Sheet erosion, though less evident to the eye than gullying, is actually the most harmful type. It steadily carries away the rich topsoil, but so slowly as often to pass unnoticed.

Annual removal of soil by sheet erosion to a depth of one-fourth inch is a common experience on rolling land. One-fourth inch each year for forty years in many cases includes nearly all of the original topsoil.

On slopes steeper than 20 per cent, permanent cover crops are essential for control of erosion.

On cultivated slopes, adequate control of sheet erosion requires a combination of contour tillage, maintenance of a high organic matter content in the soil, and terraces on longer slopes.

Terracing is desirable on slopes 500 feet or more in length, but provision of suitable outlets is necessary. The modified Mangum broad-based terrace with variable gradient is the best type for general use. The top terrace must always be constructed first, and the others in consecutive order, down the slope.

Running crop rows across terraces increases upkeep and often causes the terraces to fail. Planting and cultivation, parallel to the terraces, protects and maintains them.

The essential steps in gully control are (1) stopping head growth, (2) preventing floor scouring and side erosion, and (3) filling of the gully.

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Soil Erosion Control

SOIL EROSION is a natural process that will continue as long as wind and water are free to move over the surface of the earth. Before man disturbed the natural vegetative cover of trees and grass, the rate of erosion was not much faster than the natural soil-building processes. Since the destruction of these natural vegetative covers, erosion has been advancing at an increasing rate each year. In 1900 there had been little abandonment of agricultural lands in the United States; in 1910, ten million acres had been abandoned; in 1935, forty million acres had been ruined and abandoned. If corrective measures are not taken immediately, another 100 million acres will have been ruined by the time the next generation is ready to take over the operation of the farms.

The problem of soil-erosion control is a vital one for the future prosperity of Minnesota agriculture. Every effort should be bent to conserving what is left of our original topsoil. In most sections, fortunately, about three fourths of it still remains. Just because erosion is a natural process is no reason that it should not or cannot be successfully controlled.

Saving the original surface soil is important because nearly all the nitrogen and organic matter are contained in it. This is usually the most fertile portion of the soil, and because of its organic-matter content it absorbs water much more quickly than the subsoil. When the organic matter content is depleted, erosion advances at an increasing rate.

Many simple practices in farm operation that the farmer may apply without outside help will be of great aid in controlling erosion on the farm, such as (1) employment of a soil-building crop rotation, thereby maintaining plenty of organic matter in the soil, (2) performing all farming operations on the contour, (3) terracing the long gentle slopes, (4) employing strip farming on short slopes, (5) keeping slopes steeper than 20 to 30 per cent under a permanent vegetative cover such as grass or trees.

Many other common practices should be avoided because they further erosion. These include (1) tillage operations up and down the slope, (2) over-pasturing, (3) burning woodlots and pastures, (4) open tillage on steep slopes, and (5) growing only soil-depleting crops.

To be effective, any practice adopted for the purpose of checking or controlling soil erosion must bring about, to the fullest possible extent, one or both of two results; that is, it must keep the soil in condition to absorb water rapidly, and it must check the velocity of the water flowing over the surface. The first of these is a problem in soil management wholly within the control of the farmer. The second often involves the use of engineering practices and frequently demands the services of a trained agricultural engineer. Nevertheless, farmers with soil-erosion control problems are advised to procure and to learn to use a farm level as it will enable them to lay out their own contours and simple terrace systems without outside aid.

CAUSES AND OUTCOME OF SOIL EROSION

The primary causes of soil erosion are the direct action of rain beating upon the bare soil and the rapid runoff of the water. Soil erosion is most severe in the heavier and more uniform soils and on steep slopes.

Spring thaws often cause serious erosion, since the surface is usually saturated in the spring, loosened by freezing and thawing, and the soil just under the surface often remains frozen and impervious to water. This causes maximum runoff.

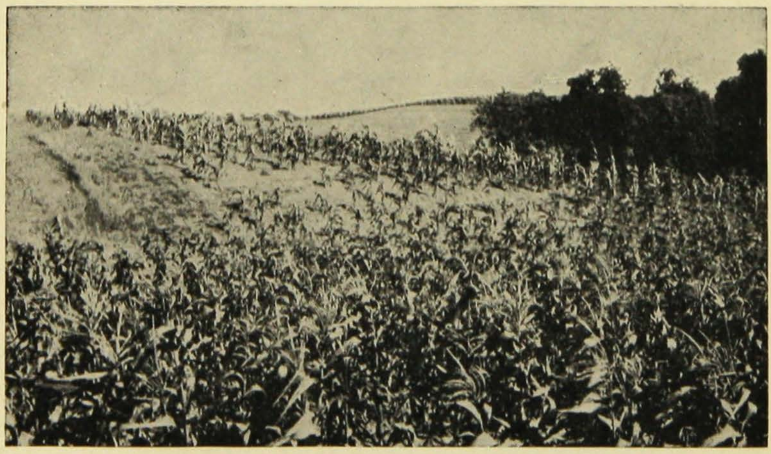

Fig. 1. Stunted Corn on Dakota County Slopes in 1930 Caused by Uncontrolled Sheet Erosion During 60 Years of Cultivation

When the flow of water is speeded up, the eroding or cutting and carrying power increases much faster than the rate of movement. This explains why steep slopes erode faster than gentle slopes. Gullies are caused primarily by water collecting in channels or shallow depressions down which it flows swiftly enough to carry away soil particles. Burrows, such as made by gophers, often cause gullies on steep unprotected slopes because they furnish smooth channels for water flowing under pressure.

Sheet erosion, or surface washing, does not itself create ditches. As the term suggests, sheet erosion is the removal of a

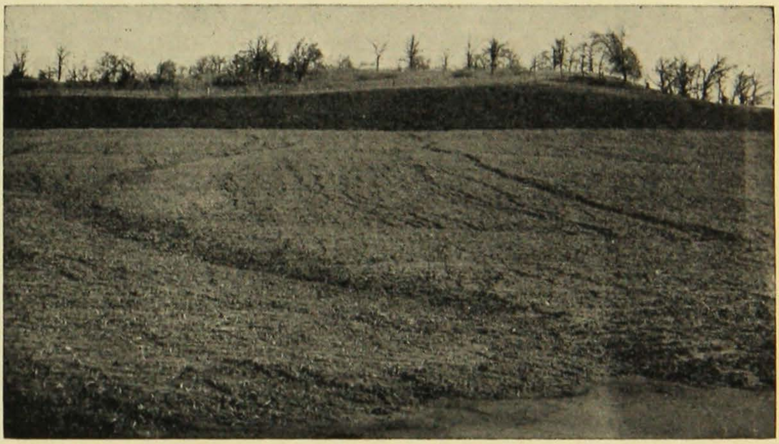

FIG. 2. A 20 PER CENT SLOPE ON A YOUNG GRAIN FIELD ADJACENT TO THE GULLY SHOWN IN FIGURE 18, FOLLOWING A 5-INCH RAIN LATE IN APRIL 1930

Note the heavy scores 3 to 8 inches deep, out of which all the soil has been washed clear to the plow sole.

thin sheet of topsoil when rainfall moves over the surface. However, the same conditions that cause sheet erosion are generally favorable for the formation of gullies, since the free runoff of water that causes sheet erosion also means the collection of large amounts of water in furrows and other depressions that are often the starting points of gullies.

Therefore, stopping or controlling sheet erosion will in many cases remove the likelihood of gullying. Such control is especially important because the effects of sheet erosion are generally more serious than those of gullying, owing to the fact that sheet erosion takes place all over the field. So gradual is its action that the damage is often unsuspected until the land owner finds almost barren spots showing up in his best fields. (See fig. 1.) To the experienced eye, however, spots of gravel and yellow clay, and stunted and sparse vegetation on the knolls are unmistakable signs of damage by sheet erosion. Even if they recognize such damage, many farmers consider it unavoidable on cultivated land.

Careful studies by federal and state agencies have shown that most of the loss of fertility commonly thought to be caused by continuous cropping is due, instead, to the action of sheet erosion which removes not only the fertility, but the very soil itself.

Soil erosion is increased by anything that tends to speed up the movement of flowing water or to lessen the ability of the soil to take up water. The practices likely to promote erosion are burning of woodlots and pastures; removing trees, grass, or other vegetation from steep slopes; shallow, inadequate plowing; failure to maintain a high organic matter content in the soil; tillage and planting operations up and down the slope; over-pasturage of hilly or rolling land, and the growing of cultivated crops on steep slopes.

In southeastern Minnesota, many slopes with a fall of 10 to 15 feet per hundred are now being farmed in row crops, and others as steep as 30 per cent are in hay or small grain. (See fig. 2.) To preserve these fields for future crop production calls for general adoption of farming practices that have been found effective in control of sheet erosion.

In many cases the depth of soil removed yearly by sheet erosion from Minnesota fields has not exceeded one eighth of an inch; in others it has been as much as one half of an inch, and in a few cases, in seasons of unusual rainfall, the rate has exceeded two inches in a year. The removal of one fourth of an inch of soil in a year, which is probably the more common experience in the southeastern and other more rolling parts of Minnesota, may seem negligible but even one fourth of an inch a year, extending through the active life of the average farmer, is sufficient to remove all or nearly all of the virgin topsoil.

CONTROL OF SHEET EROSION

Soil erosion cannot be stopped completely, but the soil and water losses can be greatly reduced by changing some of our common farming practices. Sheet erosion particularly can be greatly checked by increasing the rate at which the soil will absorb water. This may be accomplished by deep tillage, by tile

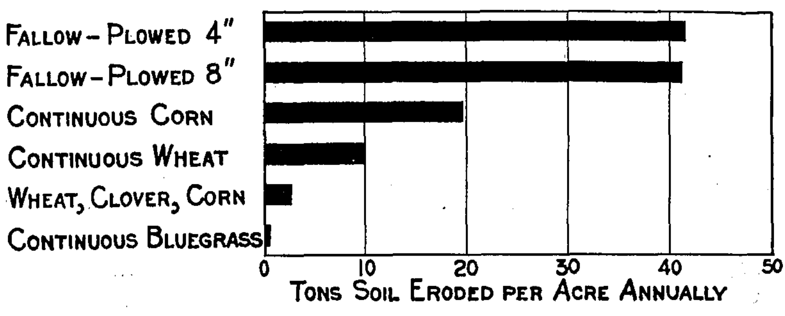

Fig. 3. Soil Losses on a 3.7 Per Cent Slope, Resulting from Different Uses of Farm Land; No Erosion Control Methods Used (Data from Missouri Research Bulletin 177)

drainage, and by increasing the organic matter content through abundant use of barnyard manure. Other good farming practices that aid in controlling erosion are discussed on the following pages. The wide differences in soil losses resulting from different uses of farm land are brought out sharply in figure 3.

Cultivation of steep slopes.—Bennett of the Soil Conservation Service states that "for some reason man has not resorted very much to the oldest and most effective measure for controlling erosion, that is, thick-growing vegetation, such as trees and grasses. The primary effort has been to get trees off the land and to destroy the matted prairie grasses so that cultivated crops might be grown." Slopes steeper than 12 per cent should not be cultivated unless special precautions are taken. They frequently lose 50 to 80 per cent of their original nitrogen content, largely through erosion, during the first 10 to 20 years of cultivation.

Slopes steeper than 25 per cent should *never* be cultivated, but should be left in permanent hay crop, pasture, or timber. All slopes steeper than 40 per cent should be taken out of pasture and reforested.

Over-pasturing and burning.—A bluegrass sod that has been over-pastured—a condition of frequent occurrence in Minnesota for several years past—loses most of its effectiveness as a means of controlling rapid runoff and consequent erosion. Not only is the rate of runoff and of erosion greatly increased, but the actual value of the pasture, in pasture days per season, is reduced.

On over-pastured sod, the precipitation runs off as on a roof. A few days after the rain, the pasture is as dry and brown as it was before. If the livestock were taken off while there was still a considerable mat of grass left, this would retard the flow of the water long enough for the soil to absorb it, and two or three days after the rain there would be a luxurious new growth. Burning pastures has the same effect as over-pasturing.

The Soil Conservation Service reports, during a continuous rainy period in Oklahoma in May 1930, the runoff from a forest area with an accumulation of leaf mold was 250 gallons of *clear* water per acre; from a similar area that had been burned over, the runoff was 27,600 gallons of *muddy* water.

Crop rotations.—Erosion may be controlled largely by planning a proper crop rotation that will offer protection for the land and build up, rather than destroy, its fertility. On gently rolling lands—slopes up to 3 per cent—a good crop rotation, including corn, small grain, and a legume and grass hay crop, will greatly reduce the rate of runoff and the rate of erosion over that which would occur by practicing continuous planting to tilled crops or even to small grains. The great increase in soil loss due to improper farming is forcefully shown by some experiments carried on at the Missouri Experiment Station on a 3.7 per cent slope, which is relatively flat compared to many farms in southeastern Minnesota. (See fig. 3.)

Contour farming.—On slopes steeper than 3 per cent, a crop rotation alone will not sufficiently control soil erosion. It is necessary, in addition, to farm on the contour or to terrace. The first is a very effective and cheap method of control. It consists in plowing the land and planting all the rows on the contour, across the slope rather than with it, as is the all too common practice.

When farming across the slope, each plow or cultivator furrow makes a miniature terrace that will help to hold the water until it is absorbed by the soil. In farming up and down the slope, these furrows become channels in which the water accumulates and rushes down in a torrent, cutting out gullies from a few inches to over a foot deep between rows.

Nichols, at the Alabama Agricultural Experiment Station, found that for a one-inch rain in 9 minutes when the rows were *on the contour* there was a very small loss of soil from cultivated fields on slopes up to 10 per cent, while, when the rows were *with the slope,* the soil loss increased from a negligible amount on flat land to nearly a ton per acre from a 10 per cent slope. On steeper slopes running up to 20 per cent, the rate of soil loss resulting from the same rain was much greater.

In every case the contoured rows produced greater yields than did rows running with the slope. Nichols' experiments indicate clearly that sloping land should not be cultivated up and down the slope, if the soil fertility is to be maintained.

Strip farming.—Strip farming has been practiced in Pennsylvania for many generations and has proved very effective in retaining the soil. It is a practice of planting a series of strips of different crops across the slope (see fig. 4). The strips are much more effective when they are put approximately on a contour than when they are run in uniform widths across the general slope of the field. The series of strips is usually limited to two or three crops, but more could be included if desirable. If the slope is long enough, the series is repeated. A row-crop strip should always have a strip of grain or hay below it, not another intertilled crop.

The strips may range in width from 50 to 100 feet, depending upon the steepness of the land. A system of crop rotation can be worked out among the strips just as well as among fields.

Usually the strips of grain and hay can be made to absorb the irregular width caused by the unevenness of the slope of the land, and the strips of corn (or other row crop) can be made of uniform width. The runoff from the cultivated land will be retarded when it goes through the sod strips and will drop its silt load in the grass instead of carrying it on to the streams.

Strip farming is very effective for controlling erosion where the slopes are short, 500 feet or less. On the other hand, where the slopes are long, terracing should be employed. A combina-

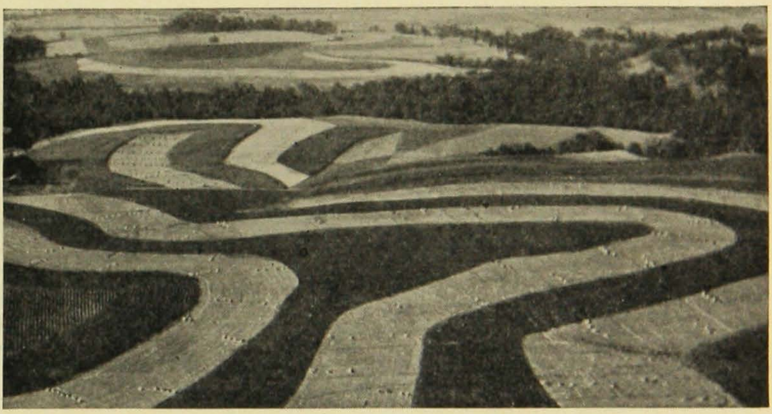

FIG. 4. STRIP FARMING ON A SLOPE IN SOUTHEASTERN MINNESOTA (COURTESY U.S.D.A. SOIL CONSERVATION SERVICE)

tion of terracing and strip farming reduces the soil losses to a negligible amount. If a shortage of plow land makes it necessary to cultivate slopes too steep to terrace economically, it is especially essential that strip farming be employed in conjunction with diversion terraces which are spaced at two and three times the interval for regular terraces. Because of the wide spacing, it is necessary to sod a strip extending from the ridge of the diversion terrace to a point 20 to 50 feet above the terrace.

TERRACING

Terracing, in conjunction with contour or strip farming and a well-balanced crop rotation, is the most effective means of controlling erosion on cultivated fields. To be effective, terraces must be properly constructed and maintained. Many people have the wrong idea of the purpose of terracing. They want to terrace their steep and badly eroded slopes which have already lost practically all their original topsoil instead of terracing the gentle slopes which still have three fourths or more of their original topsoil. The steep and badly eroded slopes are frequently not worth terracing. Terracing should be done on the gentle slopes before all the topsoil is washed away, not after.

Soil losses.—At the ten government soil-erosion experiment stations, fairly well distributed over the United States, results obtained on the relative losses of soil from terraced and unterraced lands demonstrate conclusively the great value of terraces as conservers of soil. At Guthrie, Oklahoma,—the station with the longest record—the average annual soil loss from *unterraced* 5 per cent slopes was 64.12 tons per acre, which corresponds approximately to a depth of three-eighths inch.

From similar *terraced* slopes the loss was only 2.21 tons per acre, or only 3.4 per cent of that from unterraced land. At LaCrosse, Wisconsin, where the local conditions of soil type, slope, and rainfall are most nearly comparable with those of Minnesota, the loss from fields of a 13 per cent slope was 31.7 tons for unterraced land as compared with only 2.2 tons for terraced land. This great contrast between the loss of soil on unterraced and terraced land is the general experience over the country.

Best types of terraces.—There are many types of terraces, but the modified Mangum terrace, named after the man who originated it, is best suited to Minnesota conditions. It consists of a

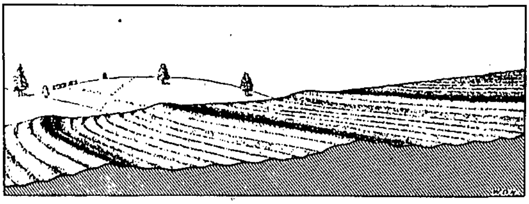

Fig. 5. Mangum Terraces on a Fairly Steep Slope Showing How One Blends Into the Other Next Below It, Making the Field a Succession of Terraces (From U.S.D.A. Farmers Bulletin 1669)

broad ridge of earth 15 to 24 inches high, thrown up across the slope approximately along the contour (see fig. 5) but having, in the direction of its length, a varying rate of fall sufficient to carry the water *slowly* to an outlet channel at the end.

TERRACING PRACTICE

The laying out of terraces, however, is a job requiring considerable training and technical skill. A field level and the knowledge of how to use it are absolutely necessary. A commercially made farm level and rod giving good satisfaction and widely used in terracing work may be obtained for about $25.

The construction of terraces is a job that, for best and most economical results, requires some experience in handling grading machinery. It is, therefore, recommended that the farmer, before starting terracing, first seek technical counsel and aid.

Locating terraces.—The proper location of terraces is governed by the character of the soil and by the natural slope of the land. Table 1 gives the proper vertical spacing of terraces for different degrees of slope. The proper vertical distance from the top of the hill for the first terrace is the same as the proper vertical interval between successive terraces for the same rate of natural slope. Once the rate of natural slope is determined, therefore, the proper distance from the top of the hill to the first terrace can also be taken from table 1.

Table 1. Proper Vertical Interval Between Mangum Terraces and Feet of Terrace per Acre

Slope of land in feet per 100 feet	Vertical distance or drop between terraces in feet*	Linear feet of terrace per acre
1	2.00	220
2	2.75	320
4	3.40	515
6	4.00	655
8	4.75	745
10	5.50	795
12	6.30	830
14	7.10	860

* Where the soil is extremely susceptible to erosion, so that washing is likely to occur between the terraces, the vertical distances given should be decreased by one-half foot. On the other hand, if the soil contains considerable humus and is capable of absorbing a large part of the rainfall so that it is not easily eroded, the vertical distance may safely be increased one-half foot.

Unless the natural slope is very uniform for a considerable distance down the hill, the rate of slope from the last preceding terrace should be determined in each case before locating the next one. If the rate of natural slope varies considerably along the terrace, the steeper part should govern the vertical interval. However, in no case should the distance between terraces exceed 200 feet.

Since the terraces must be placed closer together as the slope becomes steeper, the number of feet of terrace per acre increases with the slope as given in table 1.

The proper spacing of terraces is a very important problem in terrace design. If they are spaced too close together, the job is unduly expensive and interferes to a greater extent with farming operations. On the other hand, if they are spaced too far apart, there is excessive erosion between terraces.

The federal soil erosion experiment stations are conducting experiments on the effect of the length of slope on soil loss. At Bethany, Missouri, three parallel plots were laid out, one 90 feet long, one 180 feet, and the third 270 feet long. The 90-foot plot lost approximately 10 tons of soil per acre. The 180-foot plot lost 10 tons per acre from the upper 90 feet and 23 tons per acre from the lower 90 feet. The 270-foot plot lost 10 tons from the first 90 feet, 23 tons from the second 90 feet, and 46 tons per acre from the third 90 feet. Similar results were also obtained at the station at LaCrosse, Wisconsin.

Gradients for terraces.—For terraces much longer than 300 feet the rate of fall should increase from the top toward the outlet about as shown in table 2. Where the length does not exceed 300 feet, a uniform rate of grade of 0.15 to 0.20 per cent gives best results.

Table 2. Rate of Fall for Terraces, Beginning at the Upper End

Length of terrace, feet	Drop in terrace in feet per 100 feet of length
0 to 300	0.10
300 to 600	0.15
600 to 900	0.20
900 to 1,200	0.30
1,200 to 1,500	0.40

Length of terraces.—For best results terraces should not be more than 1,200 feet long. Shorter ones are much better. In extreme cases an occasional terrace up to 2,000 feet is permissible. In terraces appreciably longer than 1,500 feet it will be best to make the variable gradient intervals each approximately one fifth of the total length of the terrace rather than to make the outlet interval with the heaviest rate of grade absorb all the extra length. (For example, in a 2,000-foot terrace, the grade intervals would be 400 feet long and the rates of grade for successive intervals from the top toward the outlet, as in table 2.) *In no case should a rate of grade greater than 0.40 feet in 100 feet be used on terraces.*

If outlets can be made available at both sides of a long field, it is better to divide the terrace gradient at the center of the field, at the top, and run the two halves down to outlets at opposite sides of the field.

Width of terraces.—For best results the finished slope, either of the ditch or of the terrace bank, should never be steeper than one foot vertical rise to five feet horizontal run, as this is about the steepest slope over which the field machinery can be operated successfully. The flatter these slopes can be made at reasonable cost, the greater the ease of field operation and the less the liability of serious erosion. Terraces constructed with no slopes steeper than one to five feet will have a horizontal width of base of 30 to 40 feet, from the top of the cut slope on the upper side to the toe of the fill on the lower side. The width may be increased each year by throwing the soil to the center of the terrace ridge in plowing until, on moderate slopes, the lower edge of one terrace meets the upper edge of the next below, and the whole field, as often happens, becomes a series of terraces. (See fig. 5.)

Height of terraces.—In southeastern Minnesota the lowest satisfactory theoretical height of terraces, from the bottom of the ditch to the crown of the fill, when completed, is 15 inches or 1.25 feet.

The terrace banks, when first graded, should be built up to a height of about 18 inches above the ditch bottom as shown in figure 6. This allows about three inches for rounding-off the top and three additional inches for settlement, still leaving the firm, settled terrace 12 inches high.

If carefully built and maintained, and inspected after heavy storms, such a terrace will last a long time and is in little danger of being overtopped by anything short of a cloudburst. It is not good economy to build terraces that are less than 12 inches high when thoroughly packed and settled. Nor should they be built higher than is necessary for adequate carrying capacity as the extra height increases both the cost and the difficulty of farming operations.

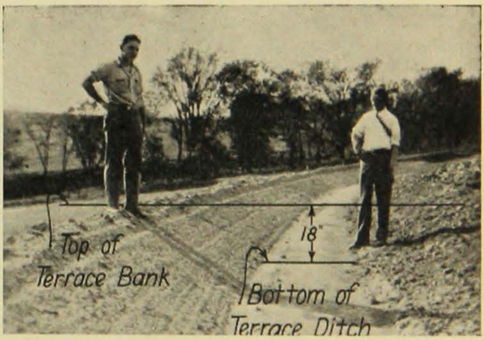

FIG. 6. A FINISHED MANGUM TERRACE EIGHTEEN INCHES HIGH

Staking and checking terraces.—Great accuracy of linear measurement along the terraces is not essential. The rodman can pace off along the contour the intervals wanted between stakes. In general a stake should be set, at the proper grade, every 50 feet of length, and on sharp turns of the contour much closer.

It will be found best, where at all possible, to set up the level in a position where the whole of any given terrace can be set from it without having to move the level. However, where the level must be moved, the same care and accuracy should be exercised in reading on turning points as in other classes of leveling work.

Twice the difference between two level readings 50 feet apart directly up and down the slope will give the slope of the land per 100 feet.

The vertical drop from the top of the hill to the first terrace, or from one terrace to the next, is then measured with the level, to determine a starting point in each case. From this point the line of the terrace may be run out each way, the rodman stepping off a succession of 50-foot distances approximately along the contour. At each 50-foot point on the given terrace line the levelman will take a reading and move the rodman straight up or down the slope at right angles to the line of the terrace until the reading shows just half the desired rise or fall per 100 feet, according to whether the terrace line is being run up or down grade.

For example, if the rate of fall for the section being laid out is 0.30 of a foot per 100 feet, and, at a given point, the proper grade rod reading is 4.50, at the next point, 50 feet away, the grade rod reading will be 4.65, if the line is being run down grade (toward the outlet), or 4.35, if up grade (away from the outlet), the change in grade for 50 feet in length along a 0.30 per cent grade being 0.15 foot. At the next point the proper reading will be 4.8 or 4.2 according to whether the terrace is being run down or up grade.

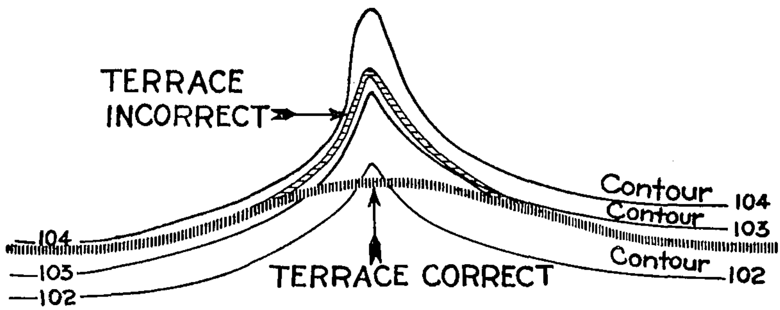

FIG. 7. CORRECT LOCATION OF A TERRACE ACROSS A SMALL GULLY OR RAVINE (COURTESY OF THE AUSTIN-WESTERN CO.)

Readings of the rod held on the ground should be read only to the 0.1 of a foot nearest to the proper grade rod reading. At each point thus found, a stake should be set with the number or letter of the terrace marked upon it for the guidance of the man plowing out the terrace. For example, if the top terrace is marked "A" all stakes on it should be so marked, all on the second one "B", all on the third "C", etc. On rough or rounding hillsides it may be necessary in places to set stakes every 25 feet.

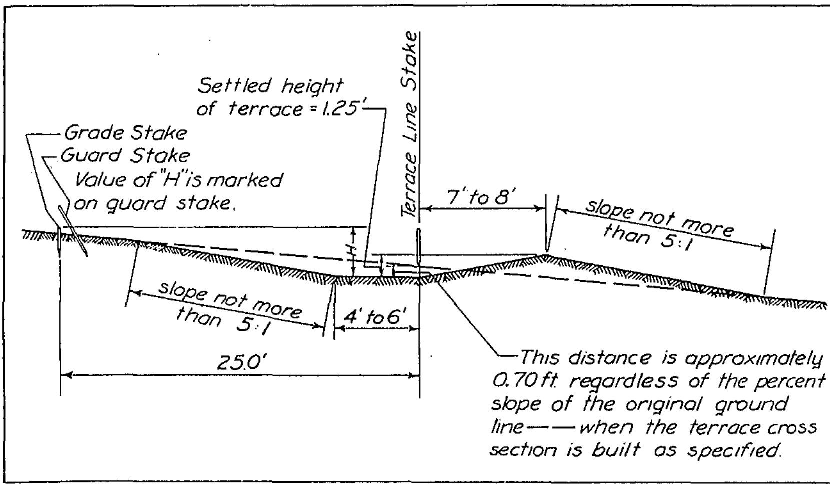

FIG. 8. A TERRACE CROSS SECTION IN RELATION TO THE STAKED TERRACE LINE AND THE GRADE STAKES

This section was originally designed by the Agricultural Engineering Division, University of Minnesota, and then modified to meet working conditions by the Soil Conservation Service.

In staking the terrace line across draws or small gullies, it is necessary to avoid too sharp turns in the terrace by dropping below the established grade line and setting a stake in the bottom of the gully as at the point of the vertical arrow, figure 7, with the necessary fill marked on its face.

After determining the position of the terrace line, a grade stake should be set 25 feet directly uphill from each stake on the terrace line. (See fig. 8.) The top of the grade stake should be set approximately flush with the surface of the ground and marked by marker stakes extending a foot or more above the surface. A level reading should be taken on the top of each grade stake. The difference between the reading at the terrace line stake and on the grade stake plus 0.7 foot will be the approximate vertical distance from the top of the grade stake to the bottom of the finished terrace channel.

Order of construction.—The top terrace should always be constructed first, and the others in consecutive order, down the slope. If it should rain before the job is completed, the top terrace could take care of the water falling on the slope above it, and any succeeding terrace all the water falling on the slope between it and the next terrace higher up.

But if a lower terrace were constructed first, or if one or more terraces were temporarily omitted in the order of construction, the water would be apt to pile up behind the lower terrace far in excess of its capacity. In this case it would be washed out with all below it, thus causing greater damage than would unchecked erosion on an unterraced field.

Marking out the terraces.—The first step in construction must be to run a simple plow furrow along the stake line on each terrace. This marks the line continuously and more clearly than it is marked by the stakes. It is difficult to follow an irregular line of stakes while operating a grader, but a continuous furrow can readily be followed.

Grading the terraces.—The first cut is taken with the point of the blade directly in the furrow marking the terrace line. The material from this first cut is then moved approximately 16 feet down hill from the original stake line. When a ten-foot terracer blade is used, it usually takes three trips to move the first cutting to its desired position. The material from succeeding cuts should be moved over against that from the first one.

For an average loam soil, a ten-foot terracer blade will move the soil horizontally five to six feet per trip depending upon the moisture content of the soil and the volume of earth being moved. It requires 15 to 20 rounds to construct a 30- to 40-foot terrace with the top of the ridge 18 inches higher than the channel.

From experience, the engineers in the Soil Conservation Service have found that the best results are obtained when the original

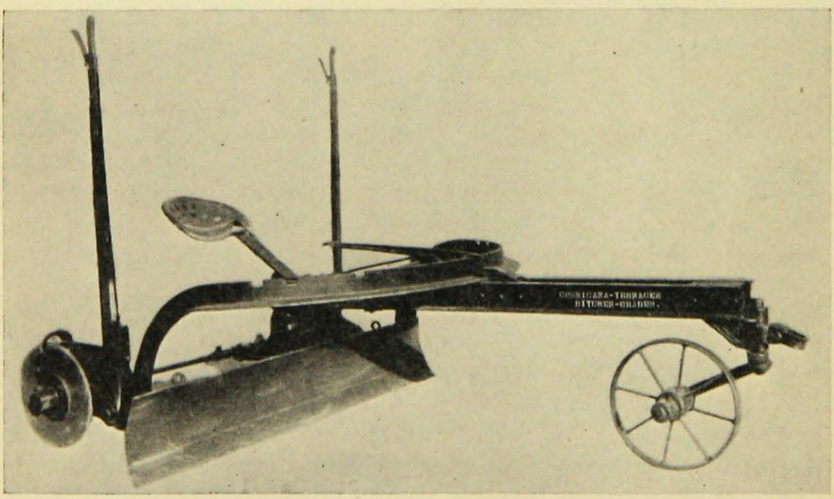

FIG. 9. A SMALL TERRACING MACHINE MUCH USED WITH SATISFACTORY RESULTS

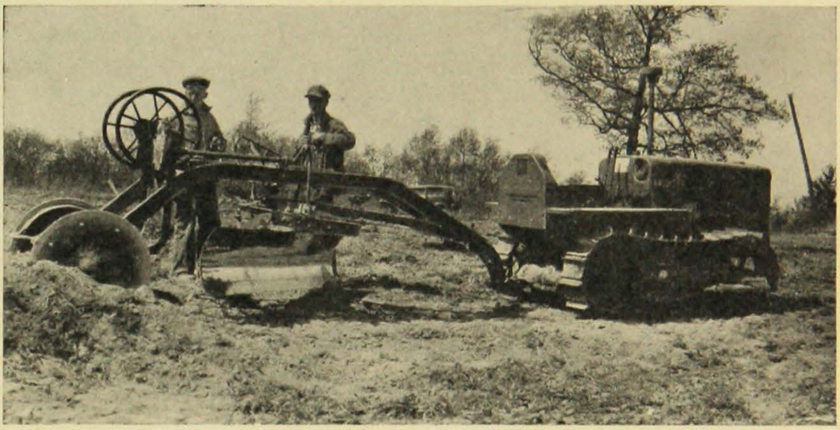

FIG. 10. TERRACER-GRADER WITH 10-FOOT BLADE AND DRAWN BY TRACK-LAYING TRACTOR

stake line is set at a point on the ground which is approximately over the point of intersection between the bottom of the terrace channel and the inner slope of the ridge of the completed terrace.

In constructing the terraces across draws or shallow ravines it will be necessary to *build the embankment of the terrace higher to offset the drop in the surface, and heavier to prevent cutting from the impact of the water flowing down the draw.*

Checking the terraces.—The terrace channel may be checked by measuring down from the under edge of a 20-foot straight edge held horizontally over the terrace channel with one end on a grade stake. The distance from the bottom of the straight edge down to the finished terrace channel should be equal to the difference in elevation between the original ground surface of the stake line and the top of the grade stake plus 0.7 foot. Also there should be 18 inches between the top of the ridge and the terrace channel.

Any high spots in the ditch grade, or any low spots in the embankment revealed by checking must be remedied by reworking with the grader, with a team and scraper, or by hand. Then the work should be rechecked with the straight edge and any defective places still remaining should be rectified. Only in this way can proper functioning be assured and overtopping during freshets be guarded against.

Terracing equipment.—If economy of time is no object, good terraces can be built with a small road- or terracer-grader (see fig. 9) or even with a steel or plank drag fitted with a steel cutting edge. But the best type of grader from the standpoint both of good work and economy of time, is a large size terracer-grader. The distinguishing feature of the terracer-grader is an extra high blade curved to about one sixth to one fourth of a full circumference and widely and easily adjustable both in tip and lateral angle (see fig. 10). Such a grader blade rolls rather than pushes the earth ahead of it. Furthermore, it not only requires relatively less power to draw it, but it also puts the earth more nearly where it is wanted with each round of the grader. Several commercial concerns make this type.

TERRACE OUTLETS

The provision of suitable outlets for terraces is the most important part of a terracing program, but frequently the most neglected. Although natural channels, drainage ditches, and road

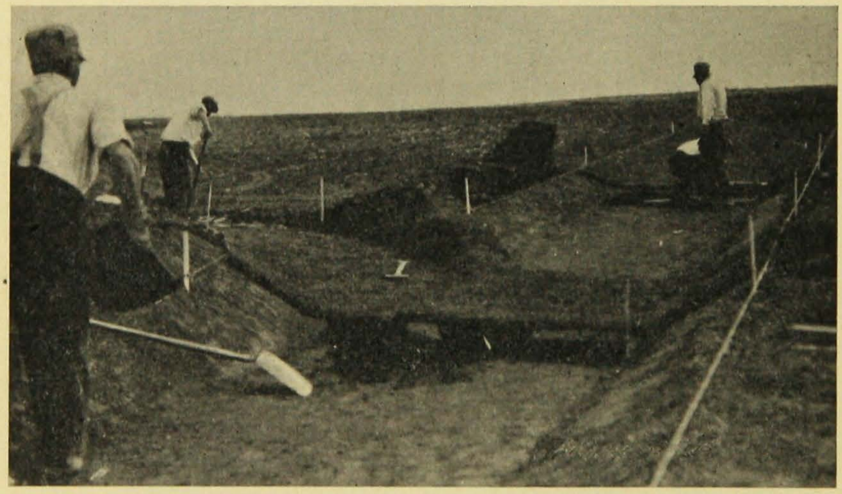

FIG. 11. SODDING A TERRACE OUTLET

The mouth of the terrace on the left is also sodded for a distance of 25 feet. (Courtesy of U.S.D.A. Soil Conservation Service.)

ditches may be so used if located convenient to the terraced field, artificial outlets as shown in figure 11 are usually more satisfactory as they can be so constructed as to prevent channel erosion.

When constructed with a terracer-grader, it is advisable to make the bottom of the outlet channel slightly V-shaped instead of flat. That is, the center of the bottom of the channel should be 5 to 18 inches deeper than the edges, depending upon the total width and the grade of the channel. (See fig. 12 and table 3.)

Table 3. Recommended Widths and Depths of Sodded Terrace Outlet Channels
(Rainfall intensity of 4 inches per hour)*

Area drained	Width of channel (w) for the following slopes				Depth (d) of channel for the following slopes			
	3%	5%	10%	15%	3%	5%	10%	15%
acres	feet	feet	feet	feet	feet	feet	feet	feet
5	......	10	10	10		0.5	0.4	0.4
10	10	10	12	18	1.0	0.6	0.6	0.4
20	15	15	25	35	1.0	0.9	0.6	0.4
40	20	30	50	70	1.4	0.9	0.6	0.4
80	40	60	100	......	1.4	0.9	0.6	......
120	60	90	......	......	1.5	1.0	......	......
160	80	......	......	......	1.5	......	......	......

* For rainfall intensity of three inches per hour, make width (w) three fourths of the values given in the table.

This type of channel does not silt up so rapidly as a channel with a flat bottom and vertical sides, since small discharges are concentrated at the center of the channel. In addition, this type of channel is easier to construct. The excavated material should be moved to the edge of the channel and spread out so that the slope of the banks is not greater than one foot rise to four feet horizontal distance. That is, in figure 22, the ratio, h/b, should be ⅛ or less or never steeper than one foot vertical rise to four feet horizontal run. It is important to have the side slopes so gentle that a mowing machine could be used to cut weeds that may infest the channel. Also, if the machinery and especially the tractor is equipped with rubber tires, the terrace outlets at the edge of the field can be used as a turning row.

Generally, the most practical and economical way to get an effective outlet is to construct and seed the channel about two years in advance of putting in the terraces, but in case it is not possible

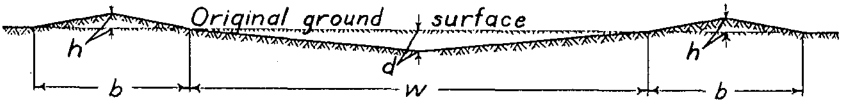

FIG. 12. CROSS SECTION OF A TERRACE OUTLET CHANNEL

See table 3 for values of d and w to fit the required conditions. h/b should be ⅛ or less.

to construct the outlet ahead of the terraces, two alternatives are usually followed. First, the water from the terrace is diverted into a temporary channel until a firm sod has been established in the permanent outlet. Second, the permanent outlet can be sodded with strips of sod and securely fastened down by stapling poultry netting over it. If the slope is less than 10 per cent and the sod is tough, the netting may be removed as soon as the sod

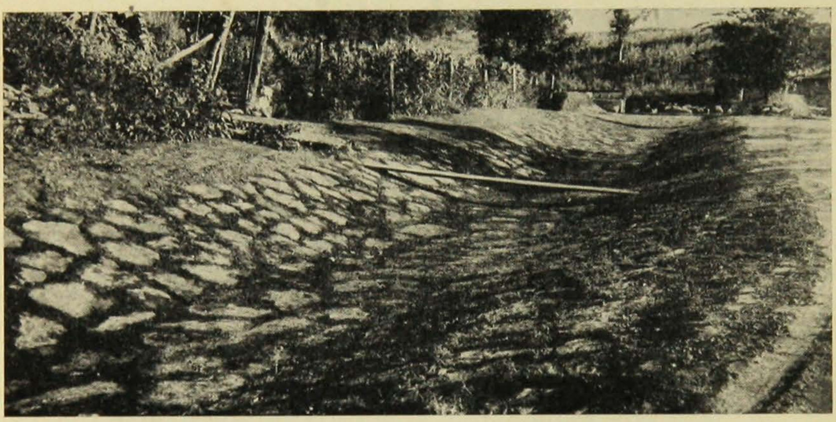

FIG. 13. TERRACE OUTLET PAVED WITH FLAGSTONES AND WITH THE SPACES BETWEEN THE STONES CALKED WITH SOD

is well established. When the slope is 10 per cent or more, it is better to leave the netting over the sod as a safety factor.

A heavy application of barnyard manure to the outlet channel should be made either when seeding or sodding since the subsoil is low in fertility.

Where soil, slope, and climatic conditions are unfavorable for establishing a firm mat of sod in the outlet channel, a flagstone pavement over the bottom of the outlet, with the spaces between the stones calked with sod (see fig. 13) is much better than a cement surface. In the course of a year or two the sod forms a mat over the stone pavement. Several such outlets have been installed by the Soil Conservation Service and are proving ef-

FIG. 14. TERRACE OUTLET PAVED WITH TARVIA

fective. Where a field road crosses a terrace or terrace outlet, a stone pavement across the channel extending the width of the road protects both the channel and the bank. For best results, the stone should be at least six inches thick.

In woods, on stony areas, or on steep grades where it is impossible to get grass to grow or hold, a tarvia-surfaced channel may be used. (See fig. 14.) Since such a channel will withstand the water flowing at a higher velocity, it can be constructed narrower and deeper than a sodded channel.

Method of protecting outlet.—Whenever possible, the outlet channel should be constructed without any appreciable drop between it and the terrace. If the drop from the mouth of the

FIG. 15. AN EFFECTIVE TYPE OF TERRACE OUTLET BUILT OF RUBBLE MASONRY

terrace to the bottom of the outlet is only one or two feet, a sodded flume is usually sufficient. However, if the drop is several feet from the terrace to the outlet, a rock, concrete, or galvanized iron flume is needed to conduct the water from the terrace down to the outlet channel. (See fig. 15.) In all cases it is a good plan to keep the terrace ends in tough permanent sod for a distance of 25 feet or more from the outlets.

TILLAGE OF TERRACED FIELDS

Soil erosion can be reduced by proper crop rotations, by contour farming, or by terracing, but the greatest reduction in the rate of erosion comes when all three of these methods are applied at the same time.

When the rows cross the terraces, the water running down the cultivator furrows between the rows carries considerable silt.

When the velocity of this water is reduced at the terrace, the silt load is dropped, thus filling the terrace. If the rain is intense enough or continues long enough, the terrace will be filled with silt and will overflow. When the tillage implements go over the

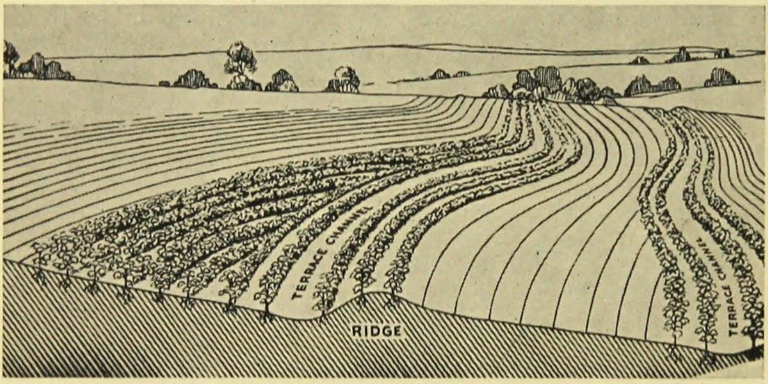

FIG. 16. PLANTING PARALLEL TO TERRACES

See arrangement of the short or point rows. (Courtesy of the Caterpillar Tractor Company.)

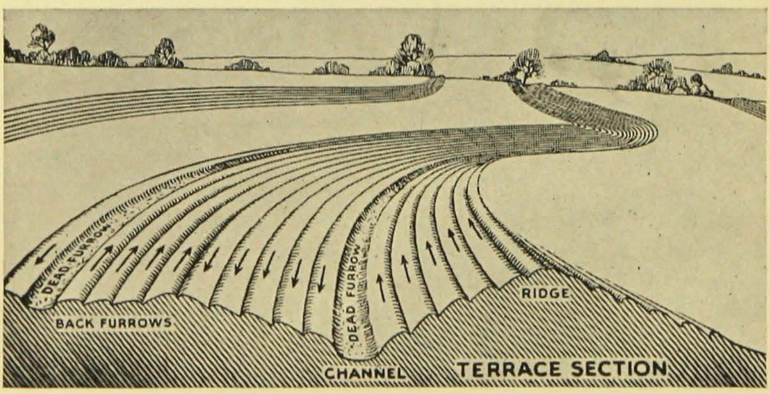

FIG. 17. METHOD OF MAINTAINING TERRACES WHILE PLOWING

Arrows indicate direction in which furrows are made. (Courtesy Caterpillar Tractor Company.)

terrace, they "dig in" deeper than on the natural slope, consequently reducing the effective height of the ridge. The maintenance cost is greatly reduced by having the rows run with terraces instead of across them.

MAINTENANCE OF TERRACES

One of the most effective methods of maintaining the terrace ridge is to plow a backfurrow around each ridge. If additional capacity of terrace is necessary, a dead furrow may be made in the terrace gutter. (See fig. 17.) In case this additional capacity is not needed and it is desirable to shift the position of the dead furrow from year to year, this may be done by making the backfurrow around any given terrace wider or narrower than it was the previous year.

Since the terrace lines are not parallel, that is, the lines are close together on steep slopes and become farther apart as the slope becomes more gentle, the lands will not be the same width across the field, thus forming point lands that will have to be plowed out by intermediate turns. To avoid turning on the plowed land, the plow should be turned across the approaching point end when the land is reduced to a width of 10 to 12 feet. When the unplowed land has been reduced to a width of 10 to 12 feet for the full length of the field, it can, of course, then be plowed without making any intermediate turns.

Farming across the terraces is not recommended, but when the rows do run across the terraces, the channel must be cleaned out at least once a year and usually more often. This can be done with a light terracer or road grader.

Terraces should be inspected after each rain to see that all "breaks" are repaired and that all "fills" are cleaned out.

The recommended practice is to run the rows along each terrace, permitting the point rows to come between the terraces. All point rows should be run parallel to the terrace above them. (See fig. 16.) By farming on the contour, not only is the cost of maintenance of the terraces reduced, but also the yield of crops is increased in the long run.

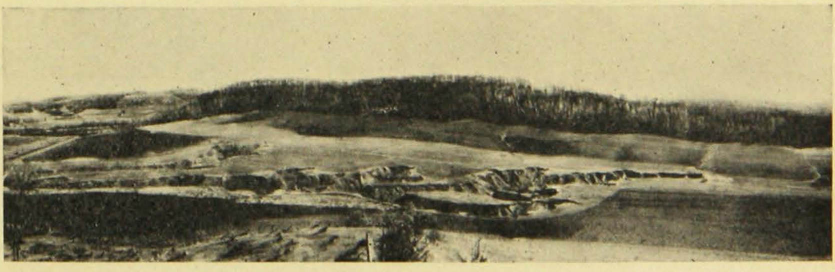

FIG. 18. A GULLY 20 FEET DEEP AND 150 FEET WIDE, WITH SEVERAL BRANCHES, THAT THROUGH 40 YEARS HAS EATEN ITS WAY ACROSS AN 80-ACRE UNIT OF A RICH VALLEY FARM IN GOODHUE COUNTY

COST OF TERRACING

The cost of building terraces is influenced by several variable factors. Terraces cost much more to construct in wet soils than in dry soils, and more in heavy soils than in light soils. Roots, rocks, sprouts, and stumps, as well as gullies in a field, add materially to the cost of terracing. Terrace-building by an inexperienced operator is likely to cost much more than terrace-building by an experienced one. The cost per acre will be greater on steep slopes and on short terraces than on flat slopes and on long terraces. Terracing by the regular farm forces during periods when farm work is slack is a recommended economy in terracing-labor cost.

Where the most suitable heavy equipment has been available, a good job of terracing has been done for from $1.75 to $3.50 per acre. Under such conditions it may be said in general that a normal cost is about the same as that of a good job of plowing. However, ownership of the heavier equipment usually is feasible only on a co-operative or community basis. With only the lighter equipment usually available to the individual farmer, the cost will generally be several times the costs just quoted.

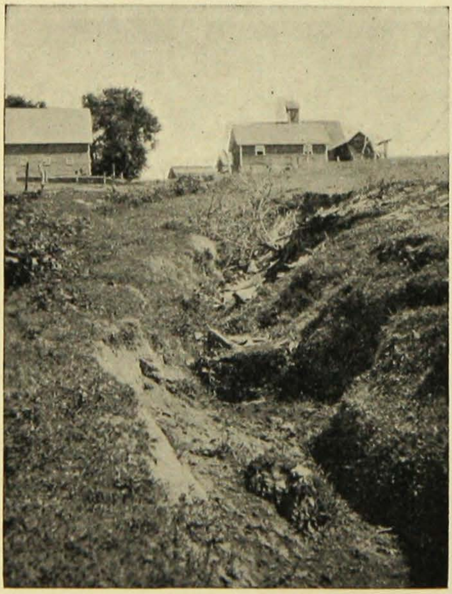

FIG. 19. A GULLY ON A CENTRAL WINONA COUNTY FARM MAKING ITS WAY STEADILY TOWARD THE BUILDINGS ON THE FARMSTEAD

GULLIES

Although not so serious as sheet erosion, gullying is the more widely recognized type because its damage to fields is so easily seen. (See figs. 18 to 21.) Some other harmful effects of gullies are not so apparent; for example, the danger they present to livestock. In the early stages, gullies are comparatively easy to stop, but many farmers pay little attention until they have become so large as to interfere seriously with farming operations and are almost impossible to control. (For example, see fig. 18.) Gullies are only a normal result accompanying or following heavy, uncontrolled sheet erosion.

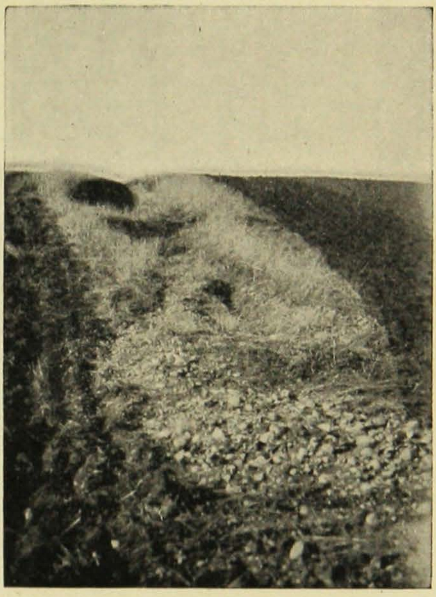

Fig. 20. A Gully 100 Feet Long, 10 Feet Wide, and 6 Feet Deep, Developed During a Single Heavy Rainstorm from a Dead Furrow Plowed in the Direction of the Slope, Now Partly Healed by Vegetation

A dead furrow extending down the slope often develops rapidly into a deep gully. (See fig. 20.) The same thing often results from wagon tracks or cattle paths running with the slope.

GULLY PREVENTION

Diversion ditches.—Gullies are frequently started by allowing water from higher land to collect at the top of a field and to flow across it without control. A diversion ditch with a low rate of fall, which will collect the water at the upper side of the field and carry it away slowly to a suitable outlet, will prevent the formation of a gully in such a case.

A proper diversion ditch, two to three feet deep, can be constructed cheaply with a plow and slip scraper, although a road- or terracer-grader is better. Such a ditch should have a fall of not more than six inches in 100 feet in any part of its length, and if it is long (1,000 feet and upward) the rate of fall should be variable, increasing from the upper end toward the outlet as is done with terrace grades. The ditch must be laid out with a level to insure the proper rate of fall.

Sod strips.—In a natural field depression where considerable water flows during rains, it is a good plan to leave a strip of bluegrass or timothy sod in the bottom of the depression, extending the whole length of the depression. The surface of this sod should be slightly lower than the surface of the land on either side. This strip should be slightly V-shaped across the direction of flow in order that small quantities of runoff will not silt up the channel. The center of the channel should be 5 to 18 inches lower than the edges, depending on the width. The required width of the strip will depend on the rate of fall of the depression and on the area of the watershed for which it serves as an outlet. In general, the narrowest width of such a sod strip should be 20 feet and an additional foot of width should be added for each acre above 20 in the watershed.

It is much easier to lift the plow or other tillage implement while crossing this sod strip than it is to have to make frequent turns at the edge of the gully which is very likely to form at

FIG. 21. RICH BLACK LOAM IN THE ROOT RIVER VALLEY, HOUSTON COUNTY, BURIED 4 FEET DEEP BY SAND, WASHED IN A SINGLE SEASON FROM A LARGE GULLY THROUGH THE HIGHER LAND

such a location if no preventive measure is taken. However, in time, these sod strips tend to build up until they cause the water to flow on either side of them instead of over them. When this occurs, the sod strips should be widened on each side sufficiently to include the strips where new channels tend to form. On steep slopes where the water tends to cut in spite of the sod, it may be necessary to hold the sod down by means of poultry netting.

GULLY CONTROL AND ELIMINATION

In gully control there are, as a rule, three essential steps. In order of operation and importance, these are: Stopping head erosion, preventing floor scouring and side erosion, and filling or reclaiming of the gully. However, attention to these, as three separate steps, is usually applicable only to gullies of considerable depth and size.

Sod and straw barriers.—In small depressions, where there is a tendency to wash, cross barriers of sod have been found effective. Strips of bluegrass sod may be put in old feed or fertilizer bags and tamped in tight, end to end, at intervals (4 to 10 feet apart) across the bed of the wash. By the time the bags have rotted away, the sod will be well set.

These cross barriers should be laid with the center slightly lower than the edges of the channel and with their surface a little below the land surface on either side of the depression.

Another effective method is to fill the depression with straw and then lay woven wire over it, fastening it securely with stakes driven almost flush with the surface of the ground. With this type of protection one should be sure that the center is left lower than the edges. Barriers of the kind herein described prevent serious erosion and have the added advantage that they can be crossed with any implement, whereas it is necessary to drive around a dam.

Straw in gully control.—Very small gullies in open fields with moderate natural slopes may be checked and eliminated by filling them with straw and then plowing in dirt from the sides on the straw and heavily seeding the gully strip with some quick-growing dense grass.

Sod in gully control.—Coarse, fast-growing grass, such as brome grass, red top, or even quack grass, and a little sweet clover to supply nitrogen for the grasses, sown in gullies, is effective in checking erosion. It also prevents caving of slopes and deeper scouring of the gully floor.

Trees and gully control.—Where there is an abundance of natural soil moisture, willows and other fast-growing trees, planted across the floor and along the slopes of gullies, are an effective agency in the control and elimination of gullies. When set in dense rows across the gully floor at regular intervals, they act much as a series of check dams in retaining eroded material, and when they grow sturdily they also make good anchors for brush dams. When used on the slopes to prevent side erosion and caving, it is best to plant them deep and close together in rows following the contour.

Stopping head erosion.—Gullies should be stopped while they are small, since stopping large ones is costly and often impossible. After a gully is once started, its growth is apt to be very rapid, owing to the undermining action of the falling water at its head and the freezing and thawing action along its walls in the spring. In reclaiming a gully of appreciable size, the first need is to stop this head erosion; that is, to prevent the gully from advancing. To do this the scouring and undermining action of the water, and, if possible, its overfall must be stopped.

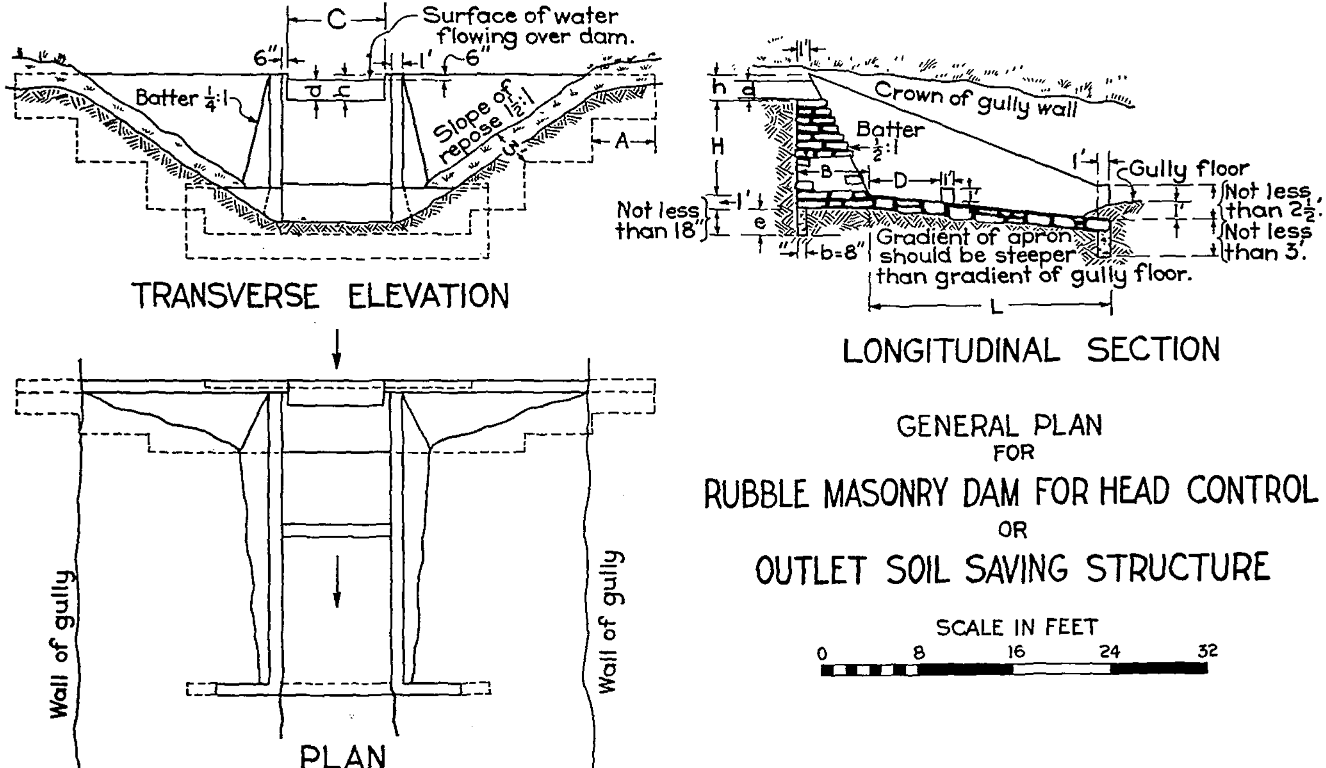

FIG. 22. PLAN OF RUBBLE MASONRY DAM FOR HEAD CONTROL OF GULLIES OR FOR USE AS A SOIL-SAVING DAM

Wherever possible, the best way is to divert the water into some nearby watercourse before it enters the head of the gully. If this is not possible, in the case of small gullies up to about four feet in depth, the headwash may be stopped by a low dam or obstruction built of posts, wire, and brush tight against the head. This brush mat should be laid close, with butts upstream, underlaid by straw and securely fastened underneath in order to withstand and break the force of the falling water and prevent undermining. The gap behind the dam will quickly fill with soil and the caving away of the headwall will be stopped.

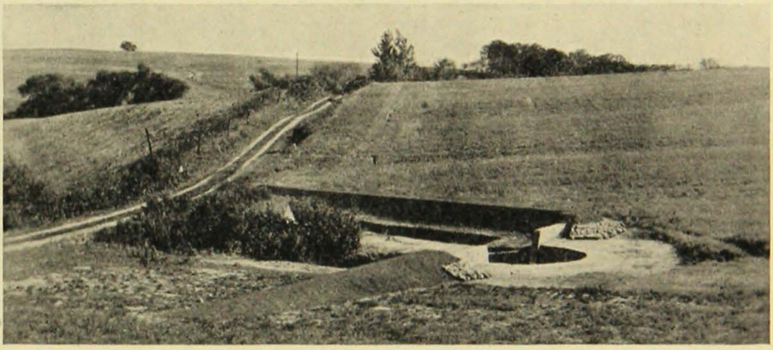

FIG. 23. A CIRCULAR ARC SPILLWAY ON RUBBLE MASONRY FOR HEAD CONTROL OF GULLIES (COURTESY OF THE U.S.D.A. SOIL CONSERVATION SERVICE.)

In large and deep gullies it is difficult to drop the water to the lower level without serious undermining. In such a case it is usually necessary to construct a plank or galvanized iron flume, a corrugated iron culvert or a concrete or masonry dam provided with a vertical drop and some sort of apron with side or wing walls. Such head control works may cost from $100 to $1,000 or more depending upon the size of the gully and the quantity of water to be carried.

Masonry or concrete dams.—Where a gully is advancing toward the farm buildings or across a field of productive land, a permanent, well-designed structure (see fig. 22) should be built to stop further advances of the gully. To insure sufficient capacity and strength to meet the demands of a given location, such headworks should be designed by and built under the supervision of a competent engineer.

Where the gully is very narrow at its head for the water that it must carry from heavy rainfall, figure 23 shows a type of dam with a circular arc spillway especially suited to such a case. This type has also been used effectively by the engineering staff of the Soil Conservation Service in southeastern Minnesota.

General recommendations.—The following is a list of the different types of gully control work:

a. Grading in, mulching, and seeding.
b. Sodding waterways and constructing temporary structures.
c. Constructing reservoirs with tile outlets or side spillways.
d. Diverting water from gullies by diversion ditches and dikes.
e. Making a rock-sod flume waterway.
f. Constructing lumber and corrugated metal pipe flumes.
g. Constructing permanent structures of masonry or reinforced concrete, as flumes, check dams, drop inlets, etc.

Table 4. Types of Gully Control Construction Recommended for Different Slopes and Different Areas

Slope of waterways	Drainage area in acres								
	1-2	3-5	6-10	11-15	16-25	26-40	41-80	81-150	Above 150
per cent	Recommended method to use								
1- 2	a	a	a	b	b	b	b	e	g
3- 4	a	a	b	b	b	b	c	e	g
5- 6	a	a	b	b	b	c	d	e	g
7- 8	a	b	b	b	c	d	d	g	g
9-10	a	b	b	c	d	e	e	g	g
11-14	a	b	c	d	d	e	f	g	g
15-18	b	b	d	d	e	f	f	g	g
19-25	b	d	d	e	f	f	g	g	g
26-35	b	d	d	e	f	f	g	g	g

The Soil Conservation Service gives the approximate upper limit in table 4 at which the various types of gully control works, as listed above, should be used for the different slopes and different drainage areas. For example, for slopes up to six per cent and for small drainage areas, 5 acres or less, the first method (a) is recommended for gully control. If the drainage area is large, above 150 acres, a permanent structure (g) should be used. It may be advisable to use the more permanent structures on the flatter slopes or on the smaller drainage areas, but it is never satisfactory to use the temporary or light construction on steeper slopes or larger drainage areas than recommended in table 4.

For guidance in effective use of simple masonry dams, similar in general to that shown in figure 22, the following recommendations, based on both experience and laboratory tests, are offered.

1. Gully floors with gradients of three per cent or greater are usually unstable. They require check dams at intervals that will stabilize the gradient at two per cent or less, and heavy, hand-placed riprap for a width of six to eight feet is needed below each check and below the apron of the main dam with its surface lying

within the new stabilized gradient. The crest of the first check dam below the main dam should be at practically the same elevation as that of the toe of the apron on the main dam.

2. The apron of the main dam should be from 10 to 30 feet long, according to the height of the dam and the maximum flow of water over it. The apron floor should be on a gradient steeper than that of the gully floor below it in all cases where the natural gradient of the gully floor exceeds two per cent; the submerging of the toe of the apron a foot below the gully floor is desirable. The cut-off wall at the toe of the apron should extend at least three feet, vertically, below the toe.

3. There should always be a cross wall a foot high extending across the floor of the apron at right angles to the direction of water flow and at a distance from the foot of the dam of from three to seven feet, according to the height of the dam and the maximum flow of water over it.

Creosoted plank flumes.—In many areas where the land is rough and the drainage area small, the expense of a masonry or concrete head-control structure would often not be justified; but

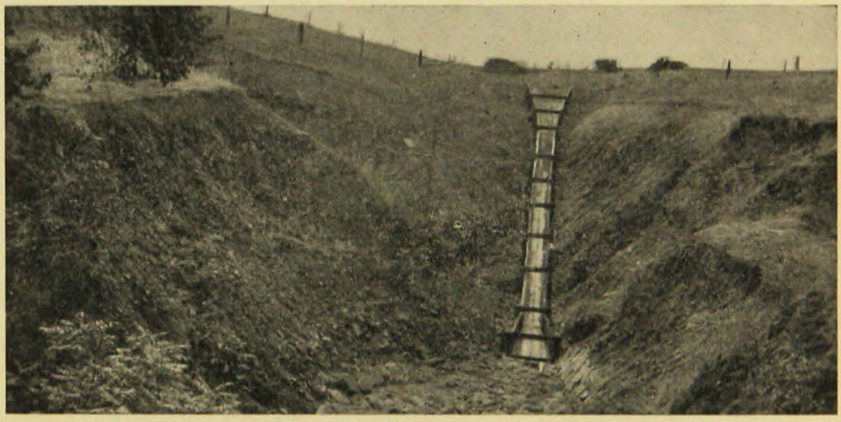

FIG. 24. CREOSOTED WOODEN PLANK FLUME

frequently, in such cases, a creosoted plank flume (see fig. 24) can be built at moderate cost. It will last for a number of years, its maintenance cost will be small, and, before it must be wholly renewed, vegetative control can often be established.

Sodded flumes.—When the overfall at the head of the gully is less than 10 feet and the area of the watershed is small (less than 10 acres), bluegrass sod flumes have been effectively used on slopes up to 15 per cent to conduct the water from the head to

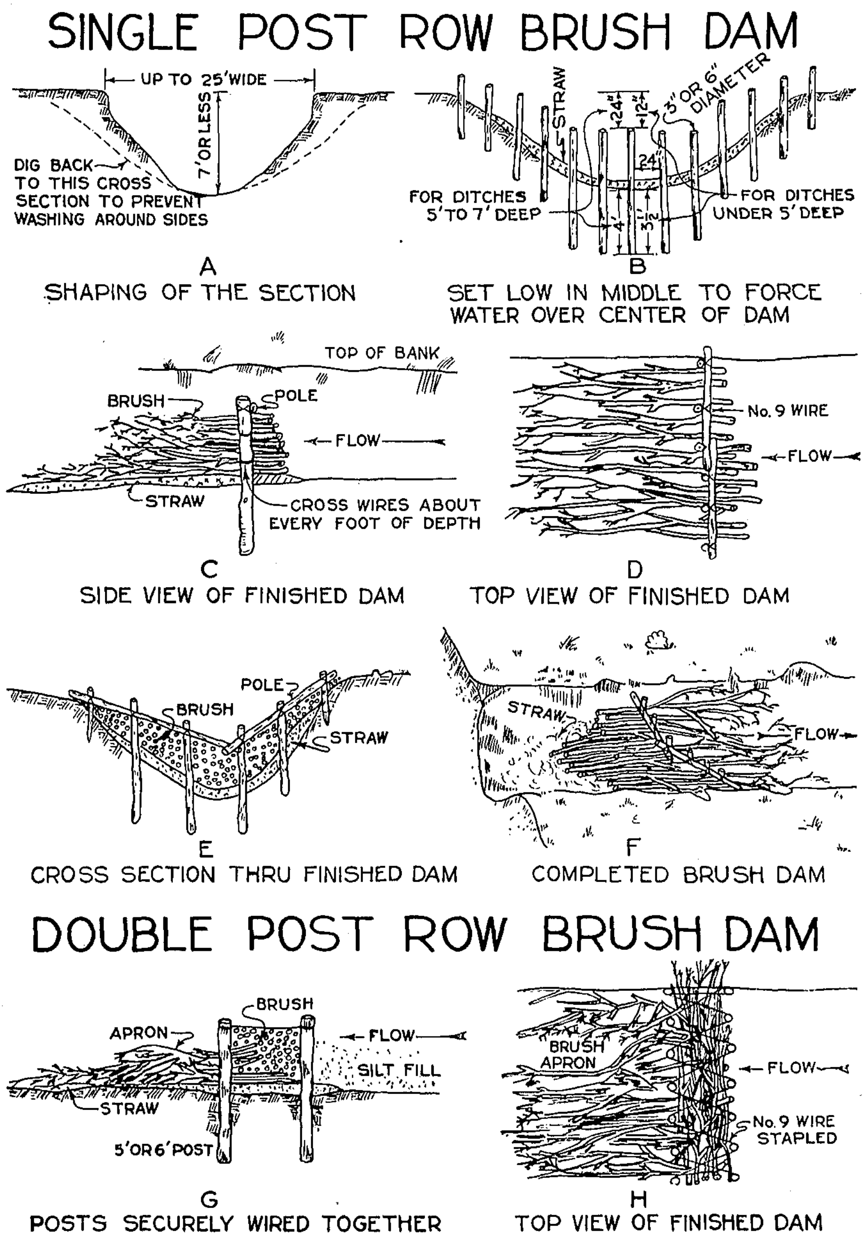

FIG. 25. HOW TO BUILD BRUSH DAMS

The brush must be laid methodically with butts upstream and be packed by tramping as laid. (Adapted from University of Nebraska extension material bv I. D. Wood.)

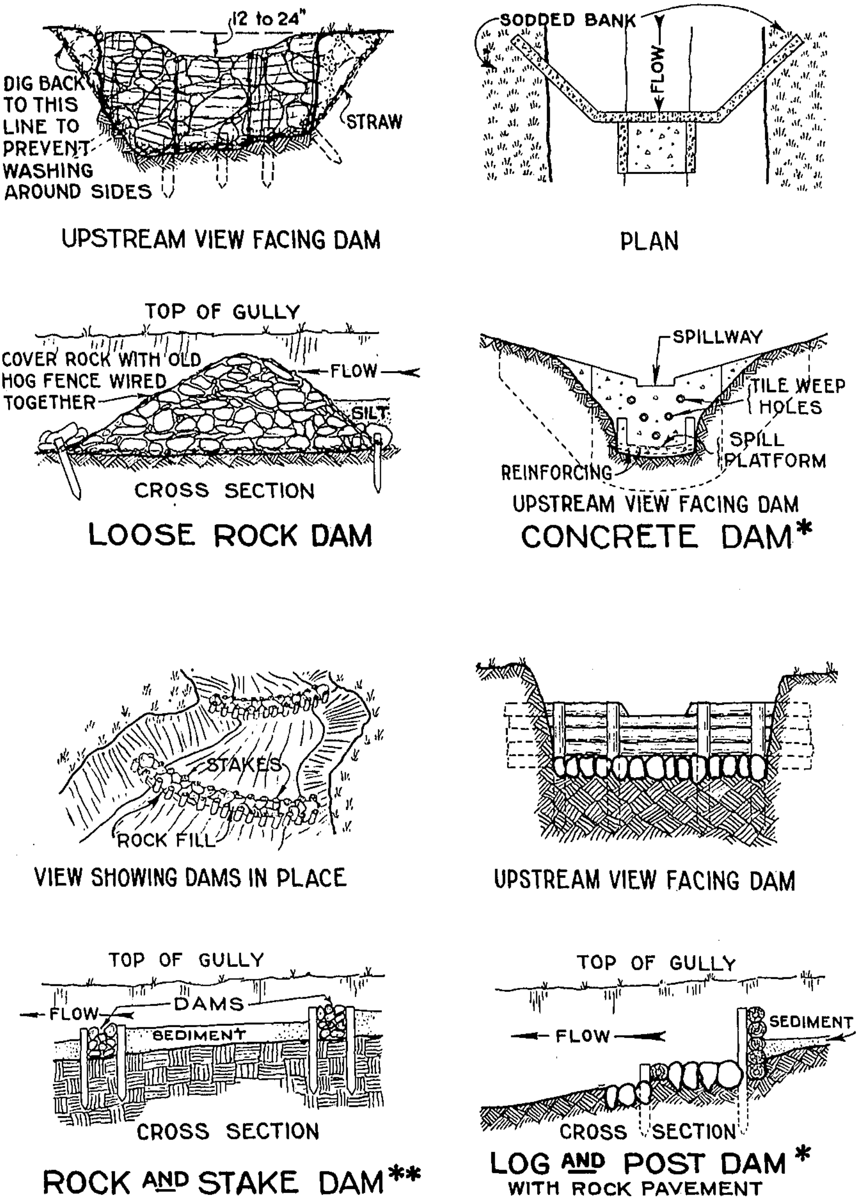

FIG. 26. VARIOUS EFFECTIVE TYPES OF CHECK DAMS IN COMMON USE

* Adapted from U.S.D.A. Farmers Bull. 1234.

** Adapted from Univ. of Neb. Ext. Circular No. 123.

the floor of the gully. To construct a sod flume, the head of the gully must be sloped back until the fall is not greater than 15 feet in 100 feet of horizontal distance. The flume should be constructed in the same manner as a sodded terrace outlet (see fig. 11 and table 3). The exposed subsoil should be fertilized and then sodded with strips of tough sod. Strips of poultry netting should be laid flat and securely fastened down to hold the sod firmly in place.

Check dams.—Once the head erosion is cared for, check dams should be built across the floor of the gully at frequent intervals throughout its length.

The purpose of the check dams is to reduce the rate of fall of the gully floor, thus checking the velocity of the water and tending to avoid the deeper scouring of the gully floor and the undermining of its walls.

Except at the outlet of the gully, it is usually sufficient to construct the check dams of loose rock, woven wire, or posts and brush. They are cheap and easily built. (See figs. 25 and 26.)

Fig. 27. A Series of Properly Spaced Brush Dams That Have Caused a Gully Originally About Six Feet Deep to Fill Up

Note the silt deposited behind each dam extending from the top of one to the base of the next one upstream. (Courtesy of C. E. Ramser, U.S.D.A. Bur. of Ag. Engr.)

As soon as the first dams are filled to the top with eroded material, new ones should be built. Any ordinary gully can be filled quickly in this manner. (See fig. 27.)

Check dams should always be made lower at the center than at the edges so the water will not cut around them. Frequent low dams are more economical and less apt to wash out than a few high ones. The dams should be so spaced that the new stabilized gradient between them, when once established, does not exceed two per cent. Brush dams give the best satisfaction when built of green brush with the leaves still on and the butts extending upstream. The butts should be well choked with old straw or hay. A loose brush pile in a gully is useless as the silt-

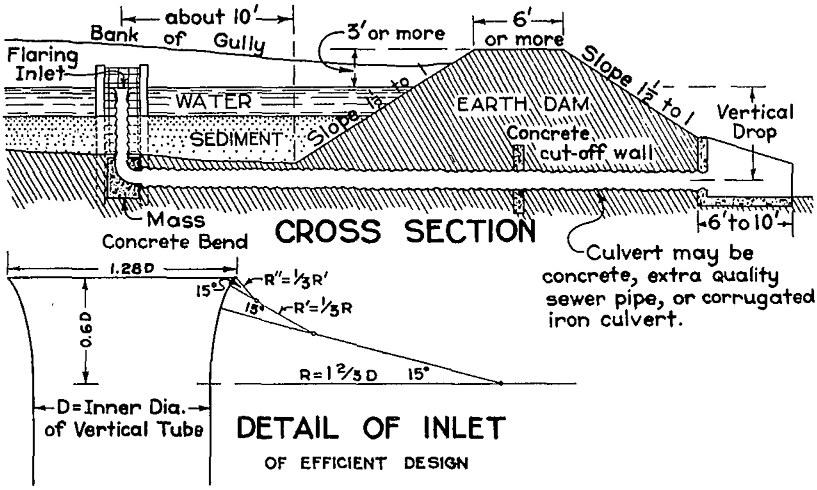

FIG. 28. EARTH SOIL-SAVING DAM AND CULVERT WITH VERTICAL DROP INLET (ADAPTED FROM U.S.D.A., FARMERS BULLETIN 1234)

laden water will pass through it without depositing any appreciable amount of soil. It is not advisable to put a straw stack in a gully, as the water is likely to cut around the stack and enlarge the gully.

Where the quantity of water to be taken care of is considerable, or its flow continuous, or when local availability of materials seems to justify it, these check dams may be built to best advantage of concrete or rubble masonry. In this case the general design of figure 22 should be used although, the drop over check dams usually being small, the masonry apron just below the dam can usually be replaced by one of heavy, hand-placed riprap.

Soil-saving dams.—In a gully of appreciable size through which considerable eroded material from adjacent fields continues to pass, one or more soil-saving dams may be desirable, so constructed of masonry, concrete, or earth as to retain the silt burden but let the water by. At least one such dam, at or near the mouth of the gully, is necessary to its elimination.

Earth soil-saving dams should always be provided with a concrete or willow mat spillway and apron to prevent washing and undermining. In case of a high dam, a culvert with a vertical drop inlet is required to conduct the water under the dam, which should be at least three feet higher than the inlet to the culvert. (See fig. 28.) Ordinarily the culvert should be designed with sufficient capacity to carry with safety the largest amount of water that was ever known to discharge through the gully. In addition to the culvert, a spillway should be provided as an emergency measure to take care of exceptional rainstorms.

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