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SOIL EROSION AND ITS CONTROL

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Soil Erosion and Its Control*

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Part 1. Cultural Practices

The greatest single cause of loss of fertility from Kentucky soils is water erosion. Practically the whole area of the State is more or less rolling, much of it being too steep for cropping systems that require frequent plowing. Where there is enough slope for the rainfall to run off, washing occurs unless the soil is protected by some sort of vegetation. The earlier stages of erosion are chiefly more or less uniform sheet washing, which often is unheeded until gullies appear that interfere with cultivation. Usually, when this stage is reached, much if not all of the original plow layer of soil has been removed. The surface 8 to 10 inches of virgin soil contains most of the accumulated organic matter (humus) from plant growth which nature returned to the soil thru the ages before man began to till it. Soil organic matter not only contains the nitrogen of the soil, but contains the other elements necessary for plant growth in forms which become available as the organic matter is decomposed. The effect of its loss is very evident in the lower productivity of the eroded areas of slopes, as compared with non-eroded areas.

SOME STATISTICS ON EROSION

According to a report of the National Resources Board (1934) it is estimated that 35,000,000 acres of farm land in the United States have been damaged by erosion beyond reclamation for agricultural purposes; that 125,000,000 acres have had most of the original plow layer of soil removed; and that on 100,000,000 acres more a part of the plow layer has been removed. The total of these acreages amounts to nearly 30 percent of the total crop and pasture land of the United States. While no accurate estimates for Kentucky are available, it is reasonable to believe that considering the topo-

* This circular is intended for the use of both farmers and those rendering technical service to farmers. The amount of it that can be put into practice by the farmer without the assistance of an engineer will of course vary with his training and experience. It was thought advisable to use this form of circular rather than publish the material in two circulars, one "popular" and the other technical. Part 1 was prepared by George Roberts; Parts 2 and 3, by Earl G. Welch and J. B. Kelley, jointly.

graphy and the rainfall, erosion has occurred in the State equal to the average for the United States.

H. H. Bennett, chief of the Soil Conservation Service of the United States, gives the estimate* that 126 billion pounds of plant food materials are annually removed from the crop and pasture land of the United States by erosion, and that the value of the nitrogen, phosphorus and potassium removed, at the lowest prices at which they could be purchased in fertilizer materials (1928), was two billion dollars. If Kentucky had the average rate of erosion, the State's share of this loss was $34,000,000. Plant food losses from erosion are estimated, in this same publication, to be more than twenty times as great as by crop removal. Mr. Bennett quotes an eminent geologist as saying that he would be unwilling to name a mean rate of soil formation greater than 1 foot in 10,000 years. Man is allowing the soil to wash away, in many cases, at the rate of a foot in less than a lifetime. H. A. Wallace, Secretary of Agriculture, states in the United States Department of Agriculture Yearbook for 1933 (page 60) that "No nation in history has permitted its farm lands to waste away so rapidly as has the United States. Our agriculture cannot withstand such losses indefinitely."

There were in Kentucky in 1933 about 3,400,000 acres of land in corn, tobacco, and miscellaneous crops that leave the soil bare when harvested. The combined acreage of winter grains harvested in 1934 was 330,000, leaving more than 3,000,000 acres unprotected thru the winter, unless winter grain and other crops were sown for cover and not harvested. Observation leads to the conclusion that a very large part of this land was unprotected by a cover crop. In the removal of one inch of surface soil from an acre of average Kentucky soil, approximately 100 to 150 pounds of phosphorus, 300 pounds of nitrogen, and 3,500 pounds of potassium are carried away.

Kentucky is, and probably will continue to be, primarily an agricultural state. If erosion continues at its present rate, soon only part of it will support a satisfactory rural life, and that part will have a severe drain placed upon it in the form of taxes to maintain government, institutions, and roads for the State. The usefulness of land for future generations is being unduly impaired by erosion and by the filling of stream channels, causing them to overflow and injure bottom lands and other farm property. Many reservoirs are being filled with silt, greatly injuring water systems and utility plants. It would be a happy solution if farmers, upon their own initiative, would adopt farming practices which reduce erosion.

* United States Department of Agriculture Circular No. 33, Soil erosion a natural menace. 1928.

METHODS OF CONTROL

Vegetative Control. Nature, unmolested by man, usually provides a cover of adapted vegetation that protects the soil against serious erosion. Erosion on sloping land cannot be prevented without a vegetative covering. Vegetation prevents erosion (a) by checking the velocity of the run-off; (b) by making the soil more porous and thus increasing its water-holding capacity and reducing the run-off; (c) when soil well covered by plant growth is plowed up it is much more resistant to washing, both because of the amount of water it can absorb and because of the larger soil crumbs bound together by the roots of plants.

The value of a cover in preventing erosion is emphasized when the force of moving water is considered.* If the velocity of water is doubled, (a) its erosive or wearing power is four times as great; (b) the amount of soil particles of a given size that it can carry is thirty-two times as great; and (c) the size of particles it can carry is sixty-four times as great.

A good grass sod is the best protection against erosion and puts the soil in the best condition to plow up for most tilled crops, because good sods are made only by making the soil fertile, and because, as already indicated, land plowed out of sod is resistant to erosion for a time. Under Kentucky conditions, plowed land should be put back to sod crops as soon as practicable. In other words, sods should occupy as much of the rotation period as practical.

The effectiveness of grass in preventing erosion is shown by an experiment at the Missouri Experiment Station,† on land with a slope of 3.68 feet in 100 feet. As an average of 14 years, land under various cropping and tillage practices eroded at varying rates that would have required the time indicated below to remove 7 inches of soil:

Plowed 4 inches, fallowed	24 years
Continuous corn	50 years
Continuous wheat	100 years
Corn - wheat - clover	368 years
Continuous bluegrass	3,043 years

Not only does grass prevent the loss of soil by washing, but it prevents the loss of nitrogen by leaching,‡ which is a source of much loss from bare soils.

The Central Bluegrass region of Kentucky is a convincing example of the effectiveness of grass in preventing erosion. Probably no

* Illinois Agr. Expt. Sta. Bull. 207. Washing of soils and methods of prevention. 1918.
† Missouri Agr. Expt. Sta. Research Bulletin 177. The influence of systems of cropping and methods of culture on surface runoff and soil erosion. 1932.
‡ See Kentucky Extension Circular 272, Soil management for Kentucky.

THE COST OF FARMSTEAD WIRING AND ELECTRIC APPLIANCES

The cost of outlets may vary in different localities from $1.50 to $8.00, depending upon the kind of outlet and the cost of labor and materials. As a basis for estimating the cost of each installation, the Rural Electrification Administration suggests that the following prices be used for wiring:

Outlets, for ceiling, brackets, service receptacles, switches, barn outlets for lights, poultry house lights, incubator and brooder outlets, $2.50 per outlet.

Special outlets, for heavy-duty appliances such as electric range, and heating devices, $8.00 per outlet.

Motor outlets, $5.00.

Yard pole (25 feet in length), $10.00.

Interbuilding wiring, 7c per line foot.

Service line extensions beyond limit allowed in line construction contract, 10c per line foot.

There is a wide variation, also, in the types, sizes and cost of lighting fixtures and electric appliances (See Table 1).

Some idea of the cost of wiring and equipping a small house with lighting fixtures and a few appliances may be obtained by studying the data given in Table 3. The 29 outlets consist of 11 ceiling and wall lighting outlets, 8 convenience outlets, 9 wall switches, and 1 heavy-duty outlet for an electric range. The costs are based on medium-priced lighting fixtures and appliances.

CONTRACT FOR WIRING

If the work is to be done by an electrical contractor, a written contract should be signed by the contractor and owner. If the work of the contractor must pass inspection based on a code this should be so stated in the contract and provision should be made for withholding a stipulated percentage of the price of the work until the contractor presents the owner with a certificate of approval signed by an approved electrical inspector. Usually 60 percent of the price is withheld until the work is passed by an approved inspector. The contract should contain a definite agreement concerning the installation of the service entrance and fixtures in addition to outlets and switches. A suggested blank contract is shown on the second page of this circular.

Table 3. Method of calculating the cost of the wiring system, lights, fixtures and appliances for a small house.

Wiring system		
Entrance and service switches, wire and fuses		$ 25.00
28 Outlets at $2.50 (including outlets, switches and receptacles for lights and small appliances)		70.00
1 Heavy-duty appliance outlet, and wiring for water heater or electric range		9.00
Light fixtures		
Light bulbs	16 @ 15c	$ 2.40
Porches	2 fixtures, installed	1.50
Kitchen	1 ceiling fixture, installed	1.50
Living room	1 ceiling fixture, installed	5.00
Living room	1 floor lamp, installed	5.00
Bedrooms	2 ceiling fixtures, installed	3.00
Bathroom	1 wall fixture, installed	1.50
Hall and stairway	2 ceiling fixtures, installed	2.30
Cellar	2 ceiling fixtures, installed	1.50
Electric appliances		
1 Electric iron		$ 5.00
1 Washing machine		50.00
1 Vacuum cleaner		25.00
1 Refrigerator (7 cubic feet)		150.00
1 Shallow-well pump (not installed)		45.00
1 Radio		20.00
1 Electric range		150.00

Formerly No. 14 wire was used almost exclusively for residence branch circuits but owing to the increasing variety of electrical appliances used in the home, No. 12 wire is recommended. Electric ranges, water heaters, and some motors require larger wires, the sizes of which must be determined.

For further information consult your county or home agent, or write to the Kentucky Agricultural Experiment Station, Lexington, Kentucky.

on exactly the contour and each end of it were stopped, water would stand in it to the same depth the full length of the furrow. Contour cultivation is especially helpful with row crops like corn and tobac-

Fig. 1. Sweet clover starting on badly gullied land.

Fig. 2. The same as Fig. 1, but later in the season.

co. It is not uncommon to see corn cultivated the last time with the slope, and cover crops seeded the same way. Experiments in Alabama* showed that where cotton rows were run with the slope

* Alabama Experiment Station Bulletin 245. Sheet erosion studies on Cecil clay. 1936.

the loss of soil by erosion was about twice as great as where the rows were on the contour.

In strip cropping, the hillside is laid off in strips approximately on the contour, and strips of crops like hay or grain are alternated with intertilled crops like corn and tobacco, so that run-off from them is checked. A regular rotation may be used on the strips, just as a rotation is used in fields on more level ground, provided intertilled crops and crops forming continuous cover are alternated. It is often helpful to leave sod strips between the strips in strip cropping. It may also be helpful to leave sod strips at intervals on the contour on steep land where a long slope is to be broken for row crops.

Part 2. Terracing

TERRACES AS A FACTOR IN CONTROLLING EROSION

As stated in Part 1 of this circular, terracing is needed under many conditions to supplement cropping practices in the control of erosion. A terrace is a ridge of earth thrown up across the slope of land to retard the flow of water and conduct it to an outlet which should be permanently protected from erosion. Terracing should always be combined with good cropping practices and the soil treatment necessary to produce good crop growth, otherwise terraces cannot be fully effective. Practices that should be adopted for all terraced land are as follows:

1. Lime and fertilizers where needed.
2. Legumes and grasses in crop rotations.
3. Winter cover crops to aid in controlling sheet erosion between terraces and prevent leaching.
4. Contour cultivation to facilitate terrace maintenance.
5. The conservation and use of animal manures and crop residues.

WHERE TO CONSTRUCT TERRACES

Terracing may be used to aid in controlling erosion on productive soil, and as the initial step in restoring eroded infertile soil to a productive condition. Terraces are advisable on slopes having an average grade of 12 percent (12 feet of vertical drop to 100 feet of horizontal distance) or less, that are subject at any time during the crop rotation to serious sheet erosion or gullying and are not too badly depleted of fertility to be economically restored and maintained. Frequently, terraces may be used to advantage on slopes at tops of hills where grades are not in excess of 12 percent, as a means of keeping ridge water from eroding steeper portions of the same slope at lower elevations. Where terraces are built on a slope adjacent to bottom land, they not only aid in controlling erosion on the slope but protect the bottom land from excess of water from the slope, since the water collected by terraces into one outlet can be conducted across the bottom to a natural drainage channel.

TYPES OF TERRACES

Two distinct types of terraces are used in controlling erosion; the bench terrace and the ridge terrace.

Bench Terraces. Bench terraces change the slope of the land into a series of benches. They are now seldom used except in places where necessity requires the cultivation of very steep land, because they involve too much waste land between the benches and because of the difficulty of moving teams and farming equipment from one bench to another.

Ridge Terraces. Ridge terraces are simply ridges of earth thrown up across the slope at intervals, the distance between them depending upon the steepness of slope and the character of soil. Since ridge terraces are not used on steep slopes, they can be constructed and maintained by moving earth up hill or down hill as required. The ridge is wide enough to permit one or more rows to be planted on it thus avoiding waste land. Ridge terraces may be classified as narrow base or broad base, depending on the width from upper to lower side. Those having a width less than 18 feet are narrow-base terraces, while those 18 feet or more are broad-base terraces.

Wide terraces are to be preferred, since heavy farm machinery may be operated over them more easily and they are less apt to be broken. Terraces may be increased in width by throwing earth towards the middle of the ridge when plowing. Terraces more than 20 feet in width cannot be economically constructed or easily maintained on slopes having a grade greater than 12 percent.

DIMENSIONS FOR BROAD-BASE TERRACES

Insufficient height and width are probably the chief causes of breaks in terraces. Terrace systems must be so designed and constructed that they will not be overloaded with water in periods of maximum rainfall. Experience has shown that it is not advisable to build terraces in Kentucky that have dimensions, when thoroly settled, less than those shown in Figure 3. Terraces to be used as a reclamation measure in connection with pasture or meadow and other soil improving practices should be of the dimensions indicated, because heavy rains may occur before vegetation has been established; also because in most instances the land will later be plowed for a cultivated crop.

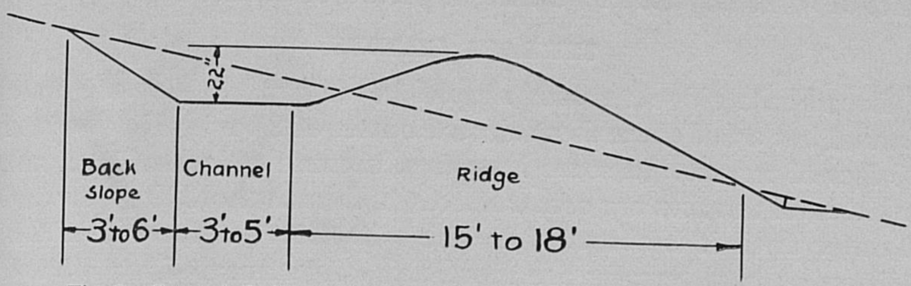


Fig. 3. Suggested dimensions for newly-constructed broad-base terrace.

A wide water channel with a bottom level crosswise is desirable, since, other things being equal, this increases the capacity of the channel and permits the water to flow in a wide, shallow stream at a low velocity rather than in a deeper stream at a higher velocity. The bottom width of the channel should not be less than 3 feet and should be 5 feet where the terrace length exceeds 900 feet.

A back slope should be made at the upper side of the water channel above the terrace to remove the vertical wall left by plow or terrace grader, to increase the capacity of the channel and to decrease the tendency of the soil immediately above the terrace to move down into the channel. The back slope should be as narrow as practical when terracing in pasture or meadow land, to avoid destruction of vegetation, but in no case should it be less than 2 feet.

Height of Terrace. The height of a terrace is the vertical distance from the bottom of the water channel to the top of the terrace ridge. The minimum height recommended for a settled terrace is 18 inches. Newly constructed terraces will settle 2 to 6 inches, depending on the amount of packing the soil receives during construction. The height of a terrace ridge should be determined by measurement, since it is usually less than it appears to be. There is always a tendency to build terraces with insufficient height which is largely responsible for the overflow of ridges during heavy rains. Measurements for height should be made only after loose earth at the top of the ridge has been well tamped.

Width of Terrace. The total width of a broad-base terrace consists of the base width of the ridge, the bottom width of the water channel above the ridge and the width of the back slope, which is the horizontal distance from the upper side of the water channel to the original ground level above the channel. The width of the base of the terrace ridge is very important, since it determines to a large degree the amount of work required to maintain the terrace. A terrace with a base less than 15 feet in width, even tho the height may be adequate, can hardly withstand the leveling effect of farm implements during a period of cultivation.

TERRACE GRADES

Broad-base ridge terraces should be so graded that the water channel has a fall towards a selected outlet of 2 to 6 inches for each 100 feet of terrace. In some instances, because of lack of a suitable outlet, level terraces are constructed which must hold the impounded water until it is absorbed by the soil. Level terraces should be built only where terraces are short, the soil permeable and slope of the land gentle. Usually all these conditions are found only near the top of a hill. Level terraces should, as a rule, not exceed 300 feet in length. One or both ends of the water channel should be filled to a level of approximately 8 inches below the top of the terrace ridge to permit drainage during exceedingly heavy rains rather than overflow of the ridge.

Where terraces are built with insufficient grade, waterlogging of the soil is apt to result in injury or the destruction of crops, especially such crops as tobacco that require well-drained soil. Excessive grade in a terrace results in the removal of much top soil in drainage water and may cause erosion in the water channel. The recommended grade of 2 to 6 inches per 100 feet of terrace has been proved well adapted to Kentucky conditions. Since the ends of terraces where they enter a terrace outlet are apt to have an abrupt drop or grade in excess of 6 inches in 100 feet, the last 10 feet of all terrace channels should be kept permanently in vegetation. It is often advisable to sod at least 6 feet of the end of each terrace channel immediately following construction to prevent scouring at that point which may result in an increase of grade thruout a considerable length of the terrace. If sod is not available, the end of the terrace channel should be seeded heavily to a quick-growing crop for protection until a sod is established by seeding.

Uniform and Variable Grades. A terrace with a uniform grade is one that has the same grade per 100 feet thruout its length. A terrace with a variable grade is one in which the slope is increased at regular intervals from the upper to the lower end. Experimental data show the variable grade terrace to be the most effective in preventing erosion in the terrace channel. It also causes a lower velocity at the upper end of the terrace and a higher velocity at the lower end so that the tendency of water to concentrate at the lower end is decreased. Terraces with a variable grade are less apt to break than those with a uniform grade. Changes in grade are usually made every 300 feet. Table 1 shows the amount of fall that should be given variable grade terraces of different lengths for average soil conditions and where sod crops are to occupy the land a major portion of the time.

Table 1. Fall in inches per 100 feet for variable-grade terraces.

Length of terrace Feet	Fall per 100 feet Inches
0* – 300	2
300 – 600	4
600 – 900	5
900 – 1200	6

* 0 at high point in terrace line.

SPACING FOR TERRACES

The major factors to be considered in determining the spacing of terraces are: the downward movement of soil between terraces, the volume of water that the terrace channel must carry and the character of the soil. Where the terraces are too far apart, heavy rains transport an excessive amount of soil into the water channel. Altho the soil may not be lost from the field, it depletes the area from which it is moved and may decrease the capacity of the channel to such an extent that water breaks over the terrace ridge. The carrying capacity of terraces is fixed, within certain limits, by the height and width of the terrace ridge over which farm implements can be operated. A spacing greater than that recommended may result in more water entering the channel than it was designed to carry.

A porous soil absorbs water faster than heavy soil. On fields where most of the top soil has been removed by erosion, the spacing

Table 2. Spacing of terraces for Kentucky conditions.

Slope Feet per 100 feet	Vertical drop between terraces* Feet	Inches	Horizontal spacing	Linear feet per acre
3	3	0	100	435
4	3	6	87	495
5	4	0	80	545
6	4	4	72	600
7	4	8	66	650
8	5	0	62	700
9	5	3	60	750
10	5	6	55	790
11	5	9	52	835
12	6	0	50	875

* For eroded fields, the vertical drop should be reduced by 6 inches.

between terraces should be reduced. Table 2 suggests a spacing for terraces in Kentucky that has proved satisfactory where recommendations for size and grade of terrace channel given in this circular were also adopted.

TERRACE OUTLETS

It is essential that a definite plan be made and carefully executed for the control of erosion in terrace outlet channels. An unprotected outlet may result in the formation of a gully that will be hard to check. Erosion in an unprotected terrace outlet may cause an abrupt drop at the end of a terrace which in turn causes cutting of the terrace channel. Terrace water should be confined in a definite channel until it has reached an area where it will cause no damage by eroding or flooding crop land. Outlets may be protected from erosion by vegetation, by permanent dams, or by a combination of the two methods. Vegetative outlets may be planned and constructed by farmers. The services of an engineer experienced in erosion work are usually required where a series of permanent check dams are to be constructed in a terrace outlet. Permanent check dams usually are required to prevent erosion at the end of terraces if a gully is used as a terrace outlet. The bottom of the outlet must be lower than the end of the terrace channel, otherwise water flowing in the channel will have a tendency to check the flow of water from the terrace. This may result, during a very heavy rain, in overflow of the terrace ridge. The vertical distance between the bottom of the outlet channel and the bottom of the terrace channel at the junction of the two should not be less than the maximum depth of flow anticipated in the channel as suggested in Table 3. Erosion at the end of a terrace due to the increased grade resulting from the difference in elevation between a terrace and outlet channel may be prevented by a low permanent dam or by sloping the last ten feet of the terrace channel and protecting the slope with a dense-rooted sod.

Outlets with Vegetative Cover. Outlets may consist of a wooded area or a permanent sod or meadow strip. It is essential that velocity of water in an outlet channel protected by vegetation only, be kept below a certain limit to prevent erosion, preferably five feet per second, and that the area drained into such a channel be limited. This is accomplished by providing a wide, shallow channel rather than a narrow, deep one. The bottom of such an outlet channel should be as nearly level crosswise as possible, else water will be concentrated at the low places in the channel and increase the liability of erosion at those points.

All outlets protected by sod or meadow strips should be kept in a high state of fertility in order to maintain a dense covering. If the top soil is not fertile or if it is necessary to grade and re-seed or sod an outlet channel, or portions of it, the same soil treatment should be used as is generally recommended for the improvement

Fig. 4. A well-graded outlet channel.

of soil on the farm being terraced. Where a terracing program is adopted for a farm, it is advisable to terrace fields while they are in sod or just previous to the time when the sod is broken so that the vegetative growth in desirable outlets may be retained. Where dense-rooted vegetation has been effective in controlling erosion in a wide natural drainage channel before terracing, it will usually be sufficient after terraces are constructed unless the area drained to any point in the outlet is considerably increased as a result of diverting water from its natural course. Terracing is apt to increase the normal volume of water at the upper end of a natural drainage channel by a greater percent than at the lower end. In order that the greatest possible use be made of vegetative outlets, terraces should be kept as short as possible.

Dimensions of Graded Vegetation-covered Outlet Channels. Table 3 suggests minimum dimensions for outlet channels protected by vegetation only, on grades up to 13 percent. When the construction work is completed the effective depth of flow of an outlet channel below the level of a terrace channel at its outlet should be the depth indicated in inches in the table. If sod strips are used as an aid in establishing vegetation or if a portion of an outlet is to be completely covered with sod moved from another place, the depth of the outlet where sod is to be placed should be increased by the thickness of the sod used. The width of an outlet channel should not be less than that which permits the use of a mower, even tho a narrower channel might keep the velocity below the required limit of five feet per second. In order to establish vegetation on the sides as well as the bottom of a graded outlet channel the sides should have a slope of not more than three feet horizontal distance, to one foot of vertical distance.

Table 3. Depth and width of shallow, sodded outlet channels.*

Area in acres	Run-off cu. ft. per sec.†	Percent grade in channel (Feet fall per 100 ft.)							
		2	3	4	5	7	9	11	13
2	9	6″x 8′	6″x 8′	6″x 8′	6″x 8′	6″x 8′	6″x 8′	6″x 8′	6″x 8′
4	16	12″x 8′	6″x 8′	6″x 8′	6″x 8′	6″x 8′	6″x 8′	6″x 8′	6″x 8′
6	22	12″x 8′	8″x 8′	8″x 8′	8″x 8′	8″x 8′	8″x 8′	6″x14′	6″x12′
8	27	12″x 8′	8″x10′	8″x10′	8″x10′	6″x12′	6″x12′	6″x16′	6″x14′
10	32	12″x10′	8″x12′	8″x10′	8″x10′	6″x12′	6″x12′		
12	37	12″x10′	8″x14′	8″x12′	8″x12′	6″x15′	6″x15′		
14	42	12″x12′	8″x16′	8″x14′	8″x12′	8″x12′	6″x16′		
16	46	12″x13′	8″x16′	8″x16′	8″x16′	8″x16′	6″x18′		
18	50	12″x14′	12″x12′	8″x16′	8″x16′	8″x16′			
20	55	12″x14′	12″x13′	8″x16′	8″x16′	8″x16′			
22	59	12″x16′	12″x14′	12″x12′	8″x18′	8″x18′			
24	62	12″x18′	12″x14′	12″x14′	12″x12′	8″x18′			
26	66	12″x18′	12″x16′	12″x14′	12″x14′				
28	70	12″x18′	12″x16′	12″x14′	12″x14′				
30	74	12″x20′	12″x16′	12″x16′	12″x16′				

* Depth of flow in inches. Width in feet at bottom of channel. Side slope 3 to 1.
† Estimated for rolling, cultivated land.

The capacity of the outlet should increase from the upper to the lower end as the drainage area increases. The change in dimensions should usually occur at the junction of terrace and outlet. The area drained to each point on the outlet can be computed from the length of the terraces and the horizontal distances between them. The slope of the channel can be determined as described on Page 24. Having determined the area drained by the outlet and the slope of the channel, its proper depth and width may be determined from Table 3. Where the outlet is to be constructed and vegetation established before terraces are constructed, the entire terrace system should be planned and the approximate length of terraces and their junctions with outlets determined before the dimensions of the outlet are fixed.

Natural Drains as Outlet Channels. Where natural drains exist that are not badly eroded, terrace outlet channels may be established with a minimum of effort and expense. The natural drain when covered with vegetation becomes a permanent waterway. Vegetation should be established before terraces are constructed.

Fig. 5. Vegetation established in a natural drainage channel previous to terracing.

The necessary soil treatment should be given to assure a vigorous growth of vegetation on the entire strip. If the natural drain is covered with vegetation but contains some breaks, they should be repaired by sodding. Frequently, it will be necessary to regrade portions of the channel in order that it conform to the requirements of an ideal waterway. The outlet should be as straight as possible, altho gentle curves are not considered objectionable. The meadow strip may be wide enough to justify mowing for hay, or harvesting seed from such a crop as lespedeza. Vegetation established in a natural drain should have a fibrous root system such as grasses have. Where dense-rooted vegetation has been effective in controlling erosion in a wide natural drainage channel before terracing, it will be sufficient after terraces are constructed unless the area drained to any point in the outlet considerably increases the water to be carried by the channel. The cross section and grade of the drainage channel should be compared with those given in Table 3 to determine the area that can be safely drained over given sections of a natural outlet. Terracing is apt to increase the normal volume of water at the upper end of a natural drainage channel by a greater percent than at the lower end. Figure 5 shows a sod well established in a natural drain of a field previous to the time of terracing.

Constructed Outlet Channel. Where natural drains cannot be used to advantage, it will be necessary to construct waterways, properly graded and protected from erosion. The dimensions of outlet channels required for various areas and slopes are shown in Table 3. The grading of a constructed outlet channel can best be done

Fig. 6. An outlet channel cut to proper depth and width with terracer grader.

with a grader such as is used for constructing terraces. If for any reason the construction of terraces precedes the construction of the outlet, it will be difficult to establish vegetation in the outlet because of the increased flow of water from the terraces. Special precautions are necessary to control erosion while a sod is being established from seed. Strips of sod 12″ to 24″ in width, placed crosswise at intervals of 5 feet center to center on slopes up to 5 percent grade, as illustrated in Figure 7, are of considerable help in controlling erosion until other vegetation becomes established. The sod strips should be placed in trenches with the top of the sod flush with the bottom of the graded channel. Seedings of a quick-growing crop that produces a fibrous root system in a comparatively short time, and grass and legumes, should be made immediately. The selection of the crop to be seeded will depend on the season of the year when work is being done. A very satisfactory aid in establishing a sod in a graded channel where terracing has preceded the protection of the outlet is the use of a straw mulch held in place with woven wire staked down. A shallow seed bed should be prepared in the bottom of the graded channel, limed, fertilized, seeded broadcast by hand, and covered lightly. The straw mulch should be applied evenly at the rate of from $1\frac{1}{4}$ to $1\frac{1}{2}$ tons per acre. The woven wire should be staked down on top of the mulch with staples 6 or 8 inches in length, made from No. 9 wire. Old discarded woven wire may be

Fig. 7. Sod strips used to check erosion in an outlet channel while sod is being established from seed.

used. Mulch and woven wire should cover the full width of the outlet. They act to prevent scouring of the outlet channel and to stimulate the growth of grass by conserving moisture. The woven wire must be removed before hay or grass is cut with a mower.

In some situations water from terraces can be confined to a sod strip already established outside a natural channel, by moving earth with a plow or grader so as to form the sides of a channel. Care must be taken that the machine used to move the earth does not make a rut in the new channel; otherwise a gully may be started in the outlet. If a plow is used to form a side wall above the original ground level, the furrow down the slope may be protected from erosion by strips of sod placed at intervals of six or eight feet. An outlet of this kind should not be made where the depth of channel required exceeds eight inches.

Where an outlet channel is constructed without excavation, the ends of terraces should be turned down hill at the outlets, to facilitate ready drainage of the terraces. The vertical drop resulting from turning the end down hill should not be less than the depth of the outlet channel required, as indicated in Table 3. Since turning the terrace down hill at the outlet results in a grade at that point, greater than that originally established, the end of the terrace channel should be sodded to prevent it from scouring.

Fig. 8. An outlet protected from erosion by a straw mulch and woven wire until vegetation is established. (Courtesy of Soil Conservation Service.)

The Use of Dams in Outlet Channels. Dams are used in outlet channels as a permanent means of controlling erosion. They are so designed and located that they reduce the grade of the channel between them to 1 percent or less and thereby reduce erosion. A channel in which a complete series of dams has been built is not dependent on vegetation for protection. A dam is placed just below each terrace outlet. Where terraces are built on both sides of the outlet channel, one dam may protect two outlets. The notch in the dam should be at such an elevation that it maintains the proper differences in level between outlet channel and terrace channel. The proper size of notch is very important, since insufficient capacity may result in the flow of water around the ends of the dam and failure of the structure. The construction of an apron on which water falls after passing over the dam is also of importance, since it keeps the water from undermining the dam from the lower side. Wing walls must be set well into the sides of the channel to allow for settling of earth. The amount of water passing over a dam depends on the size of the drainage area, the surface condition of the land and the intensity of rainfall. The amount of water to be passed over a dam is indicated in cubic feet per second. The number of cubic feet per second or the "runoff" for dams in terrace outlets should be based on a maximum rainfall intensity to be expected once in 10 years, from rolling cultivated land that has been ter-

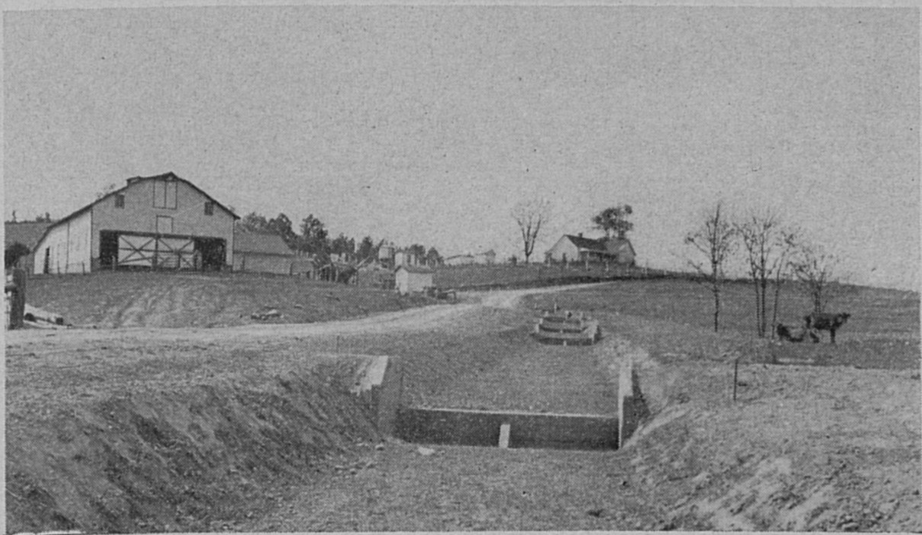


Fig. 9. A terrace outlet protected from erosion by a series of concrete dams.

raced. The runoff in cubic feet per second for terraced areas up to 30 acres is shown in Table 3. Further information concerning the design and construction of dams is contained in Part 3 of this circular.

The use of dams for controlling erosion in outlet channels adds considerably to the cost of the outlet and may interfere with mowing the channel to control weed growth or harvest hay crops. However, where a gully must be used as a terrace outlet or where acreage and slope are in excess of those indicated in Table 3, the use of dams is advisable.

Outlets Protected by Both Dams and Vegetation. In many outlets protected from erosion by vegetation, a dam is needed at the lower end to lower the water to a stabilized grade in a creek or gully. Such a dam is shown in Figure 10. Low dams 12 or 18 inches high also may be used to reduce the slope of the outlet between terraces and so reduce the hazard of erosion while a sod is being established. Such a dam is shown in Figure 11. One or more dams may be required in an outlet channel in a place where a combination of acreage and slope makes control of erosion by vegetation alone questionable.

HOW TO PLAN A SYSTEM OF TERRACES

Preliminary Survey. A survey of the field to be terraced should be made before the establishing of terrace lines is started, particular attention being paid to the outlets, slope of the land, character of

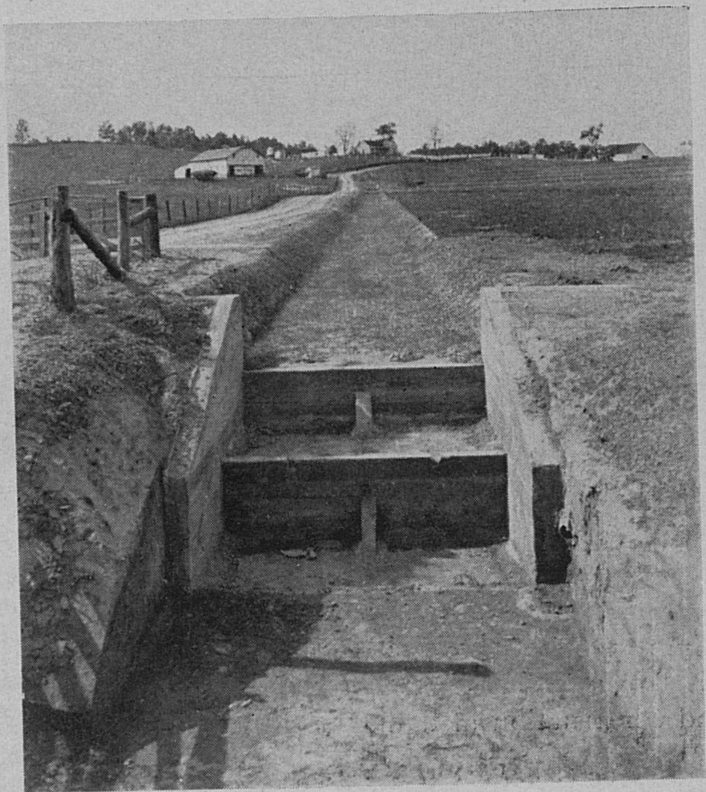


Fig. 10. A dam used to lower water to a stabilized grade at the end of an outlet protected by vegetation.

soil, location of gullies and length of terraces. The following suggestions will aid in simplifying the construction of terraces and the maintenance of terrace outlets.

1. Inspect all available outlets and select those which can be protected from erosion with the least labor and which avoid excessive terrace length, and provide for terracing adjoining land.
2. Never use a public road ditch as an outlet for terraces.
3. Consider the possibility of so locating the outlet that those parts of a field, such as gullied, rocky, or steep areas, where it is the most difficult to construct and maintain terraces, will be at the upper ends of terraces, where the least amount of water must be carried by the terrace channel.
4. Water should be drained away from rather than into a deep gully, if possible.

5. Where unterraced land lies above the field to be terraced, special provision must be made to prevent an excess of water in the top terrace of the system. Ditches constructed to prevent water from flowing from one field to another are apt to wash or fill with sedi-

Fig. 11. A low concrete dam used to reduce the grade in an outlet channel.

ment and are frequently expensive to maintain; therefore they should be considered only as temporary expedients. The higher land on a farm should be terraced first.

6. As a general rule, the terrace at the top of the slope should be just above the first signs of erosion.

Slope of the Land. By slope of land is meant the number of feet drop in one hundred feet measured on the horizontal. The amount of water that a terrace must carry 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.

To determine the slope in feet per one hundred feet of horizontal distance, establish two points 100 feet apart on the horizontal and on a line in the direction of the slope, as shown in Figure 12. Set up the instrument about half way between the two points and level it. The difference between the rod readings at the two stations gives the drop in feet per 100 feet of distance. The slope of the land is often expressed as the "percent of slope." For example, a 5 percent slope is one with 5 feet vertical drop in 100 feet of horizontal distance.

Since the slope of the land is a major factor in fixing the spacing of terraces, and on many fields the slope is not uniform, it is essential that the average slope be determined. Where the slope varies as in Figure 13, the average of the various slopes must be taken to get the proper terrace interval. If the slope at A or B were used to represent the slope of the field, terraces would be too far apart at

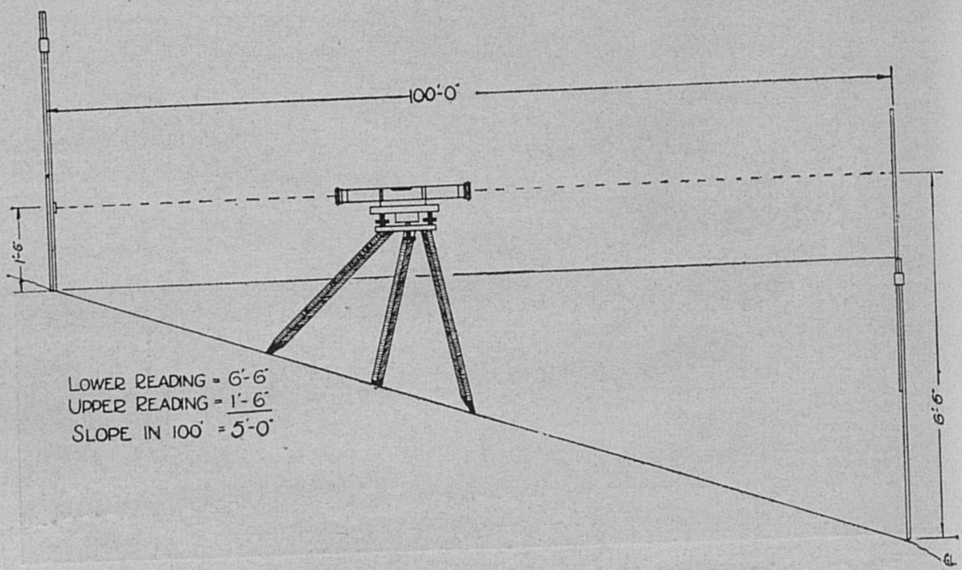


Fig. 12. Method of measuring slope of land.

C and D, and if the slopes at C and D were used, terraces would be too close at A and B. Where the slope changes as indicated in Figure 14, it is necessary to determine the slope at stations different distances from the top of the slope, otherwise terraces will be improperly spaced.

TO STAKE OUT THE SYSTEM OF TERRACES

Surveying Equipment. An inexpensive farm level with telescope or a surveyor's level and a surveyor's rod graduated to feet and inches are most convenient for establishing terrace lines. A farm level and rod can be bought for $18 to $25. Where there is not enough work to justify the purchase of an engineer's level, a homemade terrace level without telescope, for which plans may be obtained from the College of Agriculture, will prove satisfactory. The use of a 50 or 100 foot tape in measuring distances adds to the accuracy of the work. Tobacco sticks are very convenient for marking stations on the terrace lines until they have been marked with a plow.

How to Begin. The first terrace located should be at the upper part of the area and at the vertical distance below the highest point equal to the vertical drop selected from Table 2 as proper for the average slope of the land at this part of the field. Set up and level the instrument so that the telescope is about one foot higher than the highest point on the slope. With the rod at the highest point the target should be moved on the rod until it coincides with the horizontal cross hair of the instrument and the rod reading, the

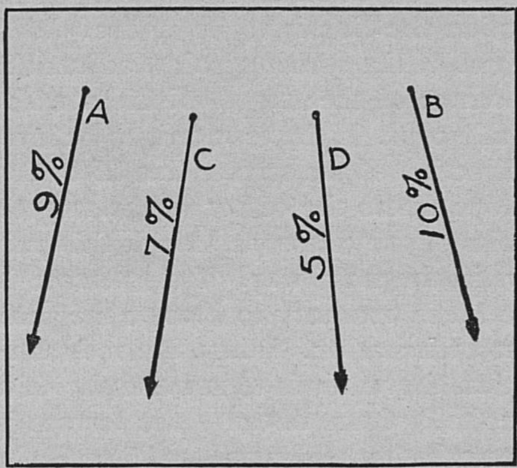


Fig. 13. The average of all slopes should be used in determining the proper terrace interval.

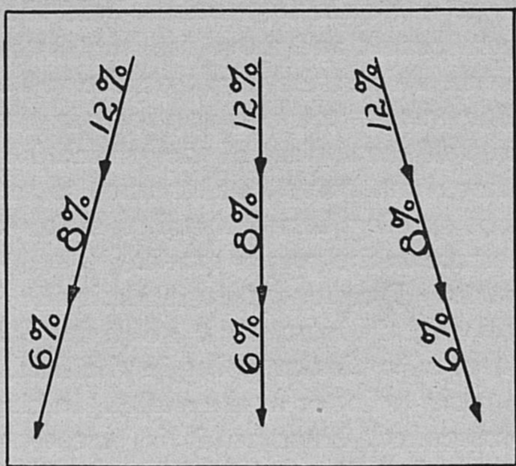


Fig. 14. Terrace intervals should change with changes of slope.

height of the target above the ground, recorded. Add to the recorded rod reading the vertical drop for the terrace and set the target at that reading on the rod. Carry the rod down the slope to a point where the target coincides with the horizontal cross hair. The last point located will be a point on the terrace line. The selection of the proper vertical interval for the top terrace will result in the first terrace crossing the slope at the line where the first signs of erosion appear. This fact is frequently used as a check on the selection of the proper vertical interval for the first terrace below the high point of the slope.

How to Locate the Terrace Line. After a starting point on a terrace line has been fixed, the terracing level should be set at approximately the same elevation as the starting point and some 300 feet in the direction the line is to be staked. With the telescope leveled and the rod at the starting point, adjust the target on the rod so that the center of the target coincides with the horizontal cross hair of the telescope. If the terrace is to be level, move the rod forward in the direction of the terrace line 25 or 50 feet and locate a point on the slope where the center of the target again coincides with the cross hairs of the telescope. Mark this point with a stake and locate others in the same way. If the terrace is to have a fall towards an outlet, it is necessary to change the position of the target on the rod at each station. When the rod-man is carrying the rod in the direction the water is to run, he should raise the target one-fourth or one-half of the distance the terrace is to fall in 100 feet, depending on whether stakes are set 25 or 50 feet apart. If the rod is being carried in the direction opposite to that in which the water is to run, it should be lowered the proper distance. 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 on the proposed line. Adjust the target on the rod the same as was done when the line was started and continue in the same manner as at the beginning. If the surface of the ground is smooth and the terrace line has few short curves, stakes may be set 50 feet apart, otherwise a 25-foot spacing between stakes makes easier the construction of the terrace to the proper grade.

Spacing Terraces. Frequently, it is desirable to change the spacing of terraces slightly from those given in Table 2, to get a desirable location at a particular point in the field, such as at the head of a gully, a rocky point or at the outlet. In changing spacings from those recommended, however, it is best to decrease rather than increase the vertical distance between terraces. The vertical distance from a terrace to the one below may be conveniently established at the outlet. However, a variation in the total amount of fall in the lines resulting from a difference in the length of lines may cause an extreme variation from the desired spacing near the ends of terraces. Where this condition exists, the situation may be improved by establishing the vertical distance from a terrace to the one below at a point midway of the last line staked.

Grade in the Terrace Line. Table 4 serves as a guide in staking out a variable-grade terrace. The figures in the top horizontal line indicate the total lengths of terraces in feet; the figures below those showing the length of terraces are for lengths of sections of the terrace. In the vertical column on the left is the fall of each section, in inches per 100 feet. For example, the table shows that a terrace 800 feet long would have 2 inches fall per 100 feet in the upper 300 feet, 4 inches per 100 feet in the next 300 feet, and 5 inches per 100 feet in the remaining 200 feet nearest the outlet.

Table 4. Length of sections in variable-grade terraces and fall per 100 feet in sections.

Section grade. Inches per 100 feet	Total length of terrace in one direction									
	300	400	500	600	700	800	900	1000	1100	1200
2	300	300	300	300	300	300	300	300	300	300
4	—	100	200	300	300	300	300	300	300	300
5	—	—	—	—	100	200	300	300	300	300
6	—	—	—	—	—	—	—	100	200	300

Resetting Stakes on the Terrace Line. After the terrace lines have been staked, it may be noticed that some stakes are set above or below the average line of the terrace, whether it be straight or curved. This is usually the result of irregularities in the surface of the ground at the points where the rod was held. The stakes which are off the general course of the terrace should be moved so that the terrace line does not have sharp or frequent curves. Before grading is begun, it is well to mark the line of stakes with one plow furrow so that it can be more easily followed. Where deep gullies occur, they should be partially filled at the terrace line to facilitate crossing them with team or tractor.

To remove undesirable sharp curves at gullies, the terrace

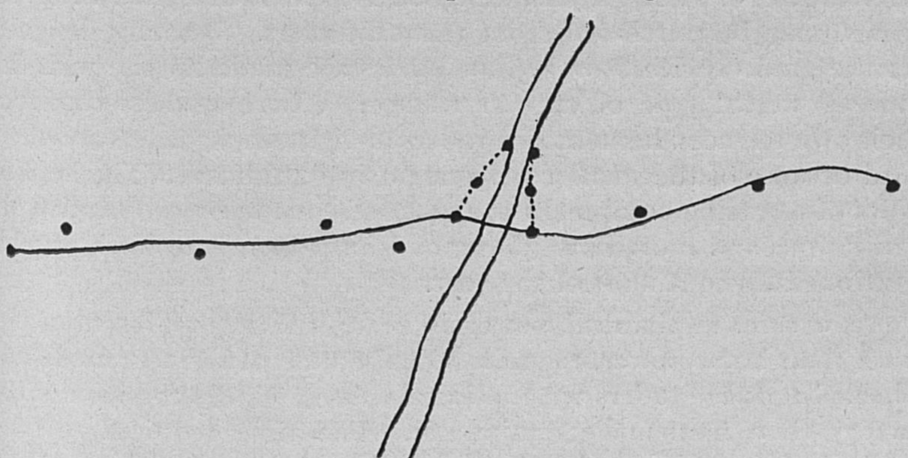


Fig. 15. Line of terrace across a gully.

should follow the course indicated by the solid line in Figure 15 rather than the dotted line. This straightening of the terrace at gullies requires a larger amount of earth to build the terrace ridge to the proper height, but this item is more than offset by the saving in time in building the terrace on a straight line rather than a sharp curve and by the decreased number of short rows required in contour cultivation. Tillage operation will move earth into gullies above fills and eventually result in the elimination of the gully.

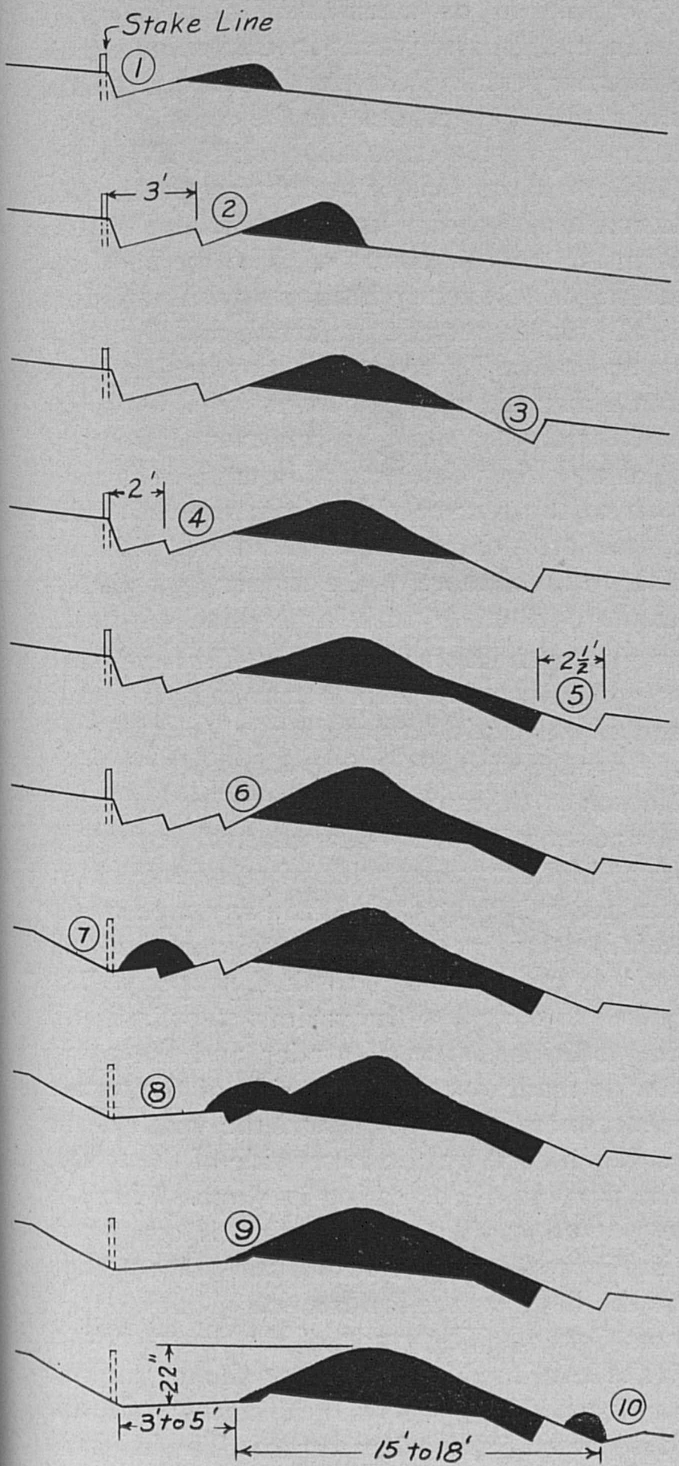
CONSTRUCTION OF TERRACES

Effect of Change of Slope on Grade of Terrace Channel. Where the terrace runs from land with a given slope to a steeper or gentler slope, provision must be made during construction to maintain the grade as staked in the terrace line.

The method which has been commonly used in Kentucky and is recommended in this circular is to establish the grade in the terrace line which is desired in the terrace channel and build the center of the terrace ridge below the line of stakes so that the water channel, when completed, will conincide with the line as staked. After grading is completed, the ridge should be checked for height above the terrace channel and all low sections filled to the required height. Low sections in the terrace ridge occur usually only where the terraces cross depressions resulting from gullying. Regardless of the method used in locating the terrace in reference to a staked line, fills are required in these low sections.

Terracing Machinery. Terraces may be built with graders drawn by horses, farm tractors or crawler type tractors commonly used for pulling heavy road machinery. Terrace graders may be made on the farm according to plans obtained from the College of Agriculture, or steel graders, designed for use with light tractors or teams, may be purchased from manufacturers. Specially designed terrace graders with 9 or 10 foot blades are made for use with the more powerful type of crawler tractor. Where farmers construct their own terraces, homemade graders or light steel graders are often used because of the smaller investment in equipment. The heavier types of terracing equipment are adapted for use by cooperative organizations and individuals doing custom work where work may be continued thruout most of the year.

As a rule, mechanical power is more satisfactory for terracing work than horse power, regardless of the type of terracer used, and wheeled terrace graders with adjustable steel blades are more satisfactory than homemade equipment. The time required to construct terraces of ample height and width with graders that are not



First Trip. Cut about 8 in. deep with blade on sharp angle to line of stakes cutting about 3 ft. wide, disregarding drifting except to keep blade clearing.

Second Trip. Cut about 3 ft. down hill from first cut. Set blade to drift just clear of rear wheel and cut as deep as blade will carry accumulated load without clogging.

Third Trip. Cut on lower side a fair load with the blade set to deliver well on ridge but not over it.

Fourth Trip. Cut about 2 ft. from first cut to about same depth, delivering to top of the ridge.

Fifth Trip. Cut as shallow as possible on lower side filling previously cut furrow and delivering a little dirt almost to ridge dressing up the lower side of terrace.

Sixth Trip. Cut about 3 ft. down hill from fourth cut with blade set to deliver well on top of the ridge. This trip should build the ridge to proper height.

Seventh Trip. Backslope upper side of channel, cutting as much dirt as possible or necessary to give about a four to one slope. Use heel of blade.

Eighth Trip. Clean out terrace channel with blade carried almost level on sharp horizontal angle, delivering the load to base of ridge. Care should be taken to leave channel bottom on an even grade. High spots should be cut down backing up for them if necessary.

Ninth Trip. Deliver load from eighth trip near top of ridge, dressing up and completing upper side with terracer.

Tenth Trip. Backslope cutting as much dirt as necessary to remove furrow wall on lower side. Terrace should be smoothed by use of harrow following terracer.

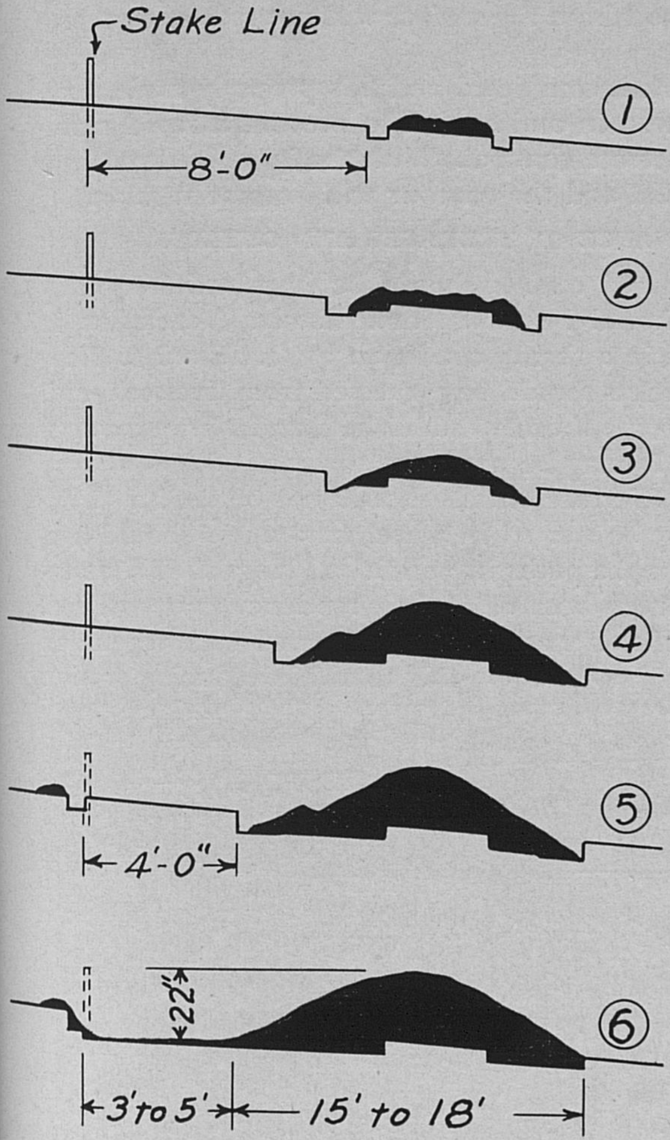
Fig. 16. Steps in building flat-bottom channel terrace with 40 h. p. tractor and blade grader.

adjustable to working conditions or when insufficient power is available for the grader in use, usually results in discontinuance of the work before the terrace has been built to the desired dimensions.

Procedure in Construction. Suggestions for the order in which cuts may be made for throwing up a terrace ridge with heavy power terracing machinery (40 horsepower tractor and terracer with 10-ft. grader blade) and light machinery drawn by horses or farm tractors are given on Pages 29 and 31 of this circular. The methods suggested have been varied slightly in many instances with variations in soil conditions, type of finished terrace preferred, and the steepness of slope. On slopes up to 6 or 7 percent, soil may be thrown on to the terrace ridge from either the upper or lower side. On slopes over 10 percent, most of the terrace must be constructed from the upper side. Where light terracing equipment is used, it is more difficult to throw soil on to the terrace ridge from the lower side because of the shorter blade on such machines; therefore, with such equipment, it is advisable to build more of the terrace from the upper side than when heavier equipment with larger blades is used.

To Construct Terraces with Horse- or Farm-Tractor-Drawn Graders. Figure 17 suggests a procedure for constructing a terrace with a flat channel when a homemade terrace drag, a V-shaped steel terracer, or a light wheel grader with blade 6 to 8 feet long is used. A plow may be used to loosen earth immediately preceding the homemade terrace drag or in advance of the V-shaped steel terracer, if the ground is hard or dry. Light terracers with wheels should move soil without plowing unless it is very dry. With any type of terracer with a steel blade, it is necessary to keep the point of the blade cutting into the firm soil to cause the soil to shed properly. The number of rounds required to complete the various steps indicated below depends on soil conditions, type of grader and the power used. The number of trips made on the lower side of the terrace depends largely on the steepness of the slope and the width of the cross-section of terrace. Work done on the lower side of the terrace ridge is primarily for the purpose of decreasing its slope. When the terraced field is to be plowed soon after terracing is completed, plowing as illustrated in Figure 18 may be substituted for a portion of the grading to reduce the slope on the lower side.

Checking the Terrace Grade. The grade of the water channel should be checked with the level used in staking out the terrace line, to locate possible high points. High points should be removed with the grader before work is started on another terrace. The height of the ridge above the channel should also be checked and brought to the proper height at all low points without delay. The failure to make cuts and fills promptly may result in breaks in the terrace ridge, since the water falling during a heavy rain could not flow to the terrace outlet as planned.



1. Plow first furrow 8 ft. below the line of stakes, throwing the soil down hill returning with a backfurrow about 4 ft. below the first, thus throwing soil up hill.

2. Plow a second round.

3. Follow the plowing with the terracer to get as much height as possible before widening the terrace.

4. The plowing and dragging should be continued until a width of 10 ft. is obtained.

5. The next furrow should be plowed at the stake line throwing the soil up hill. In plowing out this land deep narrow cuts should be made on the upper side.

6. Continue the plowing and dragging with equipment until the entire land is plowed and dragged out. The furrow on the lower side should be worked down when the terrace is completed.

Fig. 17. Constructing the broad-base terrace with horse-drawn or farm-tractor-drawn equipment.

Making Fills in Terrace Ridges. Many breaks which occur in terrace ridges are caused by the lack of proper fills where terraces cross depressions or gullies. Fills should be made sufficiently wide at the base and of such height that when the earth moved into the fill has thoroly settled the terrace at the fill will be uniform in cross section with other sections of the terrace. A fill should be 6 to 12 inches higher than the terrace ridge at either side, depending upon the depth of the fill. Earth for fills should be moved from just above the fill rather than from below, and from areas adjacent to gullies where the removal of soil from the surface will not reduce crop production.

After terracing work is completed and fills properly made, deep gullies should be plowed in and seeded to prevent a rapid movement of soil into the terrace channel. With the lapse of time, these depressions will be filled and the contour will become regular.

THE MAINTENANCE OF TERRACES AND OUTLETS

Outlets. Terraces and outlets should be inspected frequently and needed repairs should be made immediately. Vegetation in outlets should be kept in a thrifty condition by fertilization. Newly seeded or sodded outlets should be protected from livestock until the vegetation has become thoroly established, and always protected from overgrazing. It may be necessary to fence outlets to keep out livestock entirely. Terrace outlets should not be used as driveways, since gullies may be started in wheel tracks, nor should livestock be permitted to make paths in an outlet. Hogs should be excluded from terrace outlets because of their tendency to uproot sod. Terraces and terraced fields should be kept covered with vegetation as much of the time as possible, not only to aid in reducing erosion

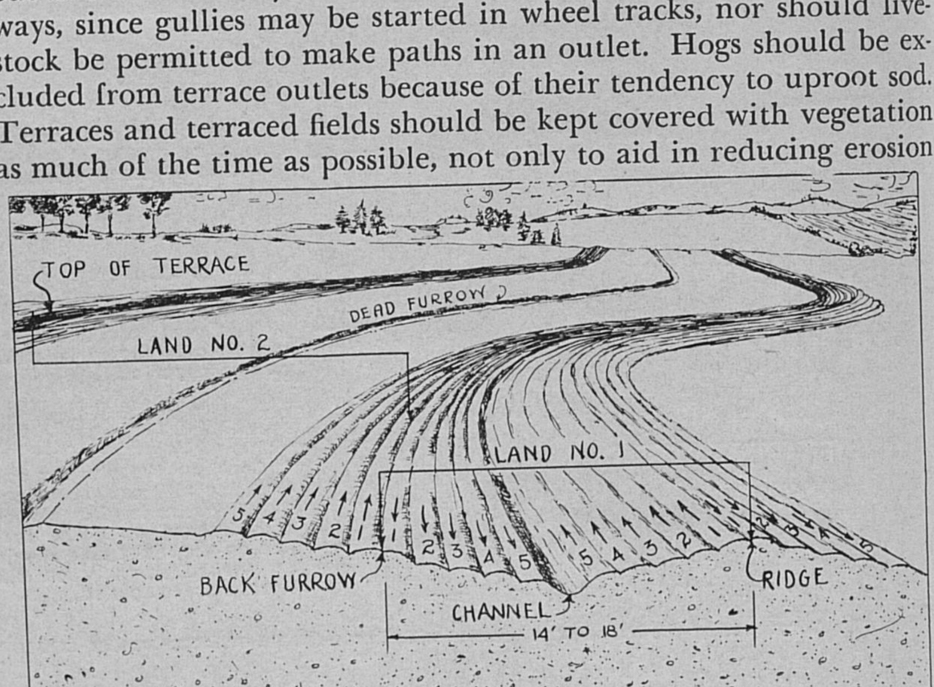


Fig. 18. Method of plowing a terraced field.

and leaching but also to reduce to a minimum the amount of sediment deposited by drainage waters on the vegetation in outlet channels.

Plowing Terraced Fields. The most satisfactory method of plowing a terraced field is illustrated in Figure 18. This method should maintain the terrace at its original height and increase its width. Any other system of plowing necessitates the use of a terrace grader to build up the ridge after a period of cultivation. The cost of plowing a terraced field as suggested is not materially greater than the cost by other methods.

The first furrow is thrown to the top of the terrace ridge in land No. 1. The return trip is made at a distance from the ridge equal to twice the distance from the top of the ridge to the center of the terrace channel. When land No. 1 is finished, the dead furrow should fall in the channel. Land No. 2 extends from the top of the ridge of one terrace to land No. 1 below. In making the back furrow between land No. 1 and land No. 2, the height of the ridge should not be so great but that it will be worked down when the soil is prepared for planting.

Planting a Terraced Field. The amount of time required to maintain terraces is dependent on the method of laying out the rows of an intertilled crop as well as the size of the terraces and the method used in plowing the field. All terraced fields should be planted with the rows running in the general direction of the terraces. The practice of contour cultivation or running the rows of a cultivated crop on a level across the slope is of itself an important factor in controlling erosion. Where rows are run with the slope on terraced land, soil is washed into the terrace channel and altho it may not be lost from the field, it decreases the water-carrying capacity of the channel and injures the area from which it is washed. Rows run with the terraces also decrease the rate of runoff during rains, increase the amount of water absorbed by the soil and therefore make more moisture available for plant growth.

Terraced fields may be planted in one of two ways: parallel with a key terrace or with each terrace as a guide, depending on the slope of the land. No other system of planting other than laying out rows with each terrace should be followed if the land exceeds a 5 percent slope, contains depressions caused by gullying, is low in fertility, or does not absorb water readily. Seeding or drilling grain with the terrace usually results in a more uniform stand on the terraces and aids in preventing erosion between terraces.

Planting with a Key Terrace. A system of planting called the Key Terrace System is often used on slopes not exceeding 5 feet fall in 100 feet, to avoid short rows. In this system, a terrace that is uniform in curvature and located about midway of the slope is selected as a guide for laying out all rows in the field that will be on land not exceeding a 5 percent slope. The first row is laid out just above the water channel of the key terrace and all other rows are planted parallel to the first row. Some of the rows may cross terraces but as a whole they run approximately parallel to the terraces.

Planting with All Terraces. Where the slope exceeds 5 feet fall in 100 feet, rows should be laid out with each terrace as a guide. Short rows will occur in this method of planting, but lessening the liability of broken terraces and the decreased work of maintenance fully offset the slight increase in time required to plant and culti-

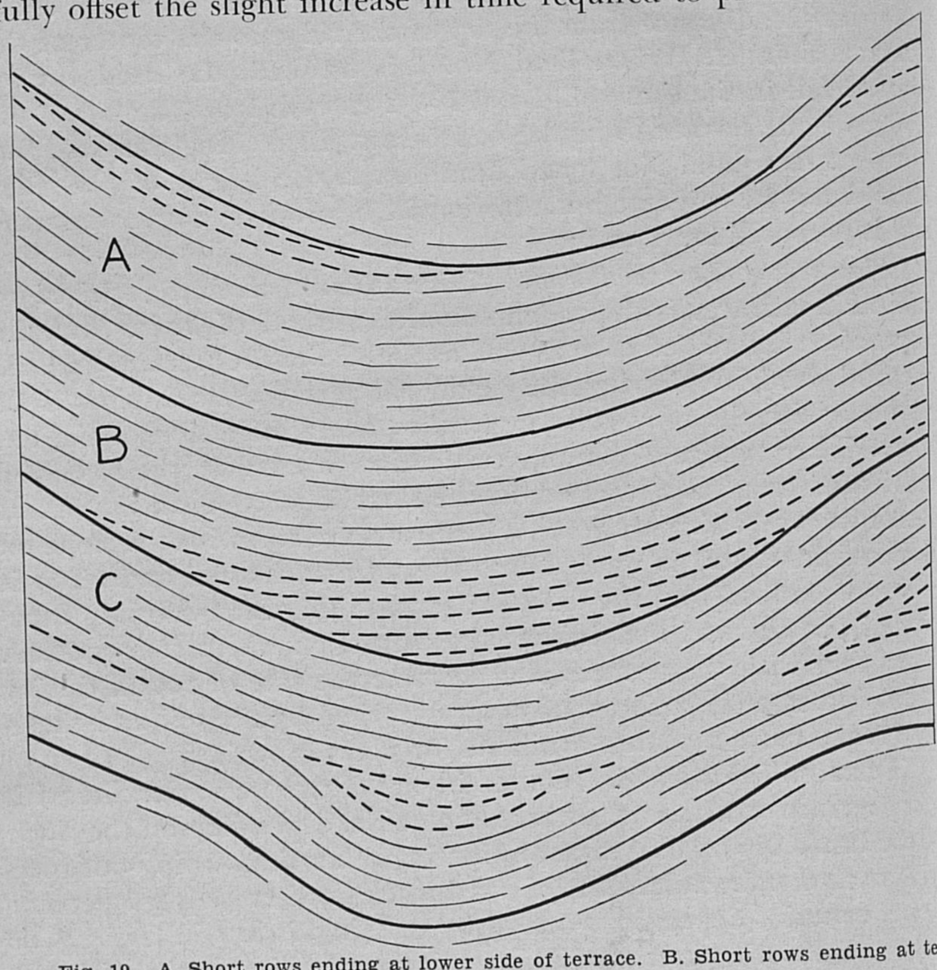


Fig. 19. A. Short rows ending at lower side of terrace. B. Short rows ending at terrace channel. C. Short rows ending between terraces.

vate the short rows. The first two rows at each terrace should be laid out so that the space between them falls in the lowest portion of the terrace channel. Laying out other rows parallel to the first and above them results in short rows ending at the top of the hill or at the terrace above that planted first. Where rows are laid out parallel to the first rows and below them, short rows end at the terrace channel below that first planted. If rows are run parallel to the first two planted both above and below the guide rows, the short rows end between terraces. See Figure 19. Short rows ending below a terrace may result in slight erosion at their ends, while rows ending at the terrace channel may deposit some sediment in the terrace channel. Short rows ending between terraces are more difficult to cultivate without damaging the growing crop. There is little difference in the three methods of planting where each terrace is used as a guide. Personal preference is usually the factor which determines the method used. Where a terraced field is cultivated in row crops as long as two consecutive years, it is probably best to use a different method of planting each year.

Part 3. Gullies and Their Treatment

Causes of Gullying. Gullying is an advanced stage of erosion, starting, as a rule, after a considerable amount of top soil has been removed by sheet erosion. Gullying may be started by alternate thawing and freezing followed by heavy rains, by water collecting in natural depressions lacking a good vegetative covering, in wheel tracks, in plow furrows, in mole runs, in livestock paths, in crop rows planted and cultivated with the slope, by a break in a terrace and by overflows from drainage channels.

Damage. The formation of gullies causes damage in one or more of the following ways:

1. Fertile soil is carried away, making the eroded area less productive.
2. Reservoirs and natural drainage courses are filled with silt which will require great expense to remove.
3. Soil washed from infertile hillsides is deposited on bottom land, making it less productive.
4. Gullies obstruct the passage of teams and farm implements.
5. Gullies endanger livestock that may graze near the edges of the undermined banks.
6. Gullies may undermine roads and make travel unsafe.
7. Gullies reduce the area of tillable land, income, and land value.
8. Gullies increase production costs.

METHODS FOR CONTROLLING GULLYING

Two objectives are sought in controlling both sheet erosion and gullying; to increase the capacity of the soil to absorb water and resist erosion, and to check the velocity of the water flowing over the surface. Both involve problems of soil management in connection with the use of fertilizers, cropping systems, and land utilization, as explained in the first part of this circular, and also involve the use of engineering practices in laying out and constructing terraces, terrace outlets, diversion ditches and gully-control structures. The methods to use in controlling gullies in any given area depend upon the number, location, size and slope of the gullies; the area, topography, vegetative cover and drainage conditions of the land; type of soil, and upon whether the gullies are to be filled and restored to crop use, partially filled and used as drainage channels, or merely protected against further enlargement.

Fig. 20. A well-constructed fill in a terrace line across a gully.

On some areas, no engineering control practices are required. On fields not too badly gullied, where the slopes and soil conditions are suitable for restoring the land to the profitable production of cultivated crops, the gullies may be partially filled with straw, corn stalks, or other temporary obstructions anchored in place and then plowed in and the gullying controlled by means of cover crops, contour plowing, contour cultivation, strip cropping and terracing, as explained in Parts 1 and 2 of this circular. On rolling or hilly land which is not to be terraced, but is to be reclaimed for timber and permanent pasture, the gullies should be partially filled and protected from further enlargement by using check dams and planting the channels and banks to trees and grasses. Some areas have lost so much of the fertile top soil and are so badly gullied that it would not pay to attempt to control the gullies or reclaim the land for agricultural purposes; however, the planting of trees will be justified, since they check the loss of soil from such an area and thus decrease the amount of infertile soil deposited on bottom land or in stream channels.

The control of erosion in gullies requires the stopping of head erosion, the prevention of erosion on the sides and floor and the filling of the gully. On the following pages are recommendations, specifications and illustrations of many structures which have been used in Kentucky and have proved to be practical in controlling gully erosion on some areas. From these may be selected the type of control structure suitable for the various gully conditions.

Structures for Checking Head Erosion. To stop gullying, head erosion, or the growth of the gully up the slope, must be prevented. This may be accomplished by several different methods.

1. *Terraces* control head erosion because the runoff water is permanently diverted from the gullies to other outlets.

2. *A diversion ditch* placed above a series of gullies may be used to concentrate the flow of surface water from above into a single channel which can be protected against erosion or into a natural water course. This method may be used on short, steep slopes or where the lower portion of the slope is to be terraced and the land

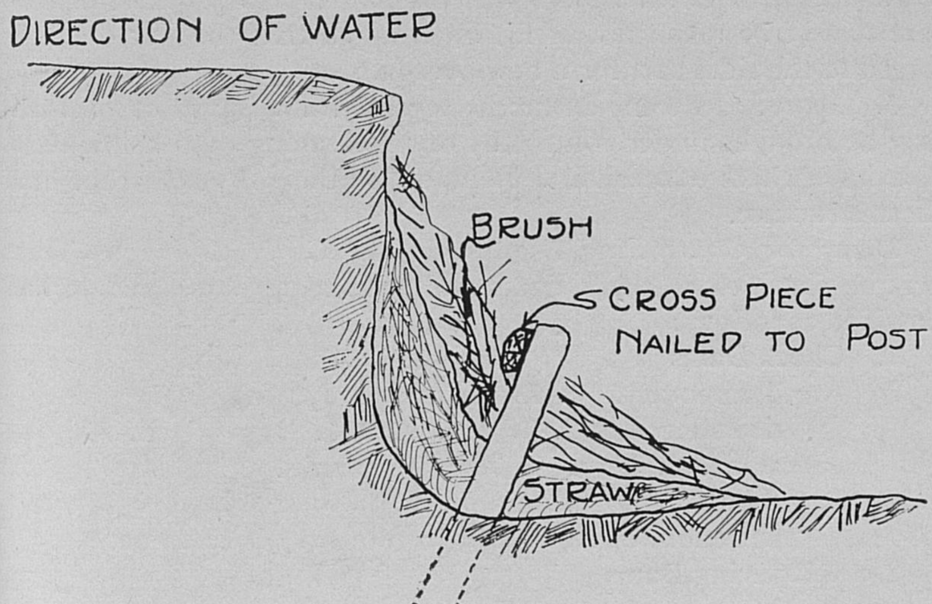


Fig. 21. Method of checking over-falls.

above the diversion ditch is in pasture or timber with a slope length greater than the terrace interval required for that field. Diversion ditches should not be placed below plowed, unterraced areas. In such locations a channel with too flat a grade will fill rapidly and one with too steep a grade will cause a gully.

3. *Sod strips* may be left in natural depressions where runoff water would start a gully if the vegetation were removed. In plowing or cultivating a field containing sod strips, time may be saved by passing over the strip with the plow or tillage tools raised rather than making frequent turns at the edges.

4. *Mattresses of brush* and stones held in place by woven wire and stakes, box troughs made of creosoted lumber or galvanized sheet iron, and aprons of stone and sod or concrete may be used to conduct the surface water over the over-falls to prevent head erosion. A temporary but effective structure which is often used to stop head erosion while a vegetative covering of grass and trees is being established is illustrated in Figure 21. Posts are set firmly in the bottom of the gully just below the over-fall. They should be about 3 feet apart and form a sharp curve down stream. Straw is packed between the posts and against the banks of the over-fall almost to its top. The straw should also extend between and below the posts. The straw is held in place by green brush well packed on top of the straw and held down by cross pieces nailed to the posts. 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.

5. *Dams.* In some instances several head banks or over-falls may be brought under control by one soil-saving dam below them. A series of check dams should be placed in the gully below the head check structure.

Dams for Controlling Erosion in the Gully Channel. These may be classified as check dams and soil-saving dams, and further classified as follows:

1. Check Dams
   - A. Temporary. 1. Brush and straw; (a) single posts, (b) double posts. 2. Woven wire. 3. Bags of sod. 4. Loose stone. 5. Logs. 6. Wooden planks.
   - B. Permanent. 1. Masonry; (a) loose stone, heavy construction, or stone laid in mortar. (b) concrete.
2. Soil-Saving Dams
   - A. Masonry; 1. stone, 2. concrete.
   - B. Earthen.

Check dams are placed in gullies to reduce the velocity of the run-off water sufficiently to prevent further deepening and widening of the gullies. They also serve to catch soil, thus covering the bottom of the gully with a soil suitable for establishing vegetation.

Brush dams should be used only in medium and small gullies

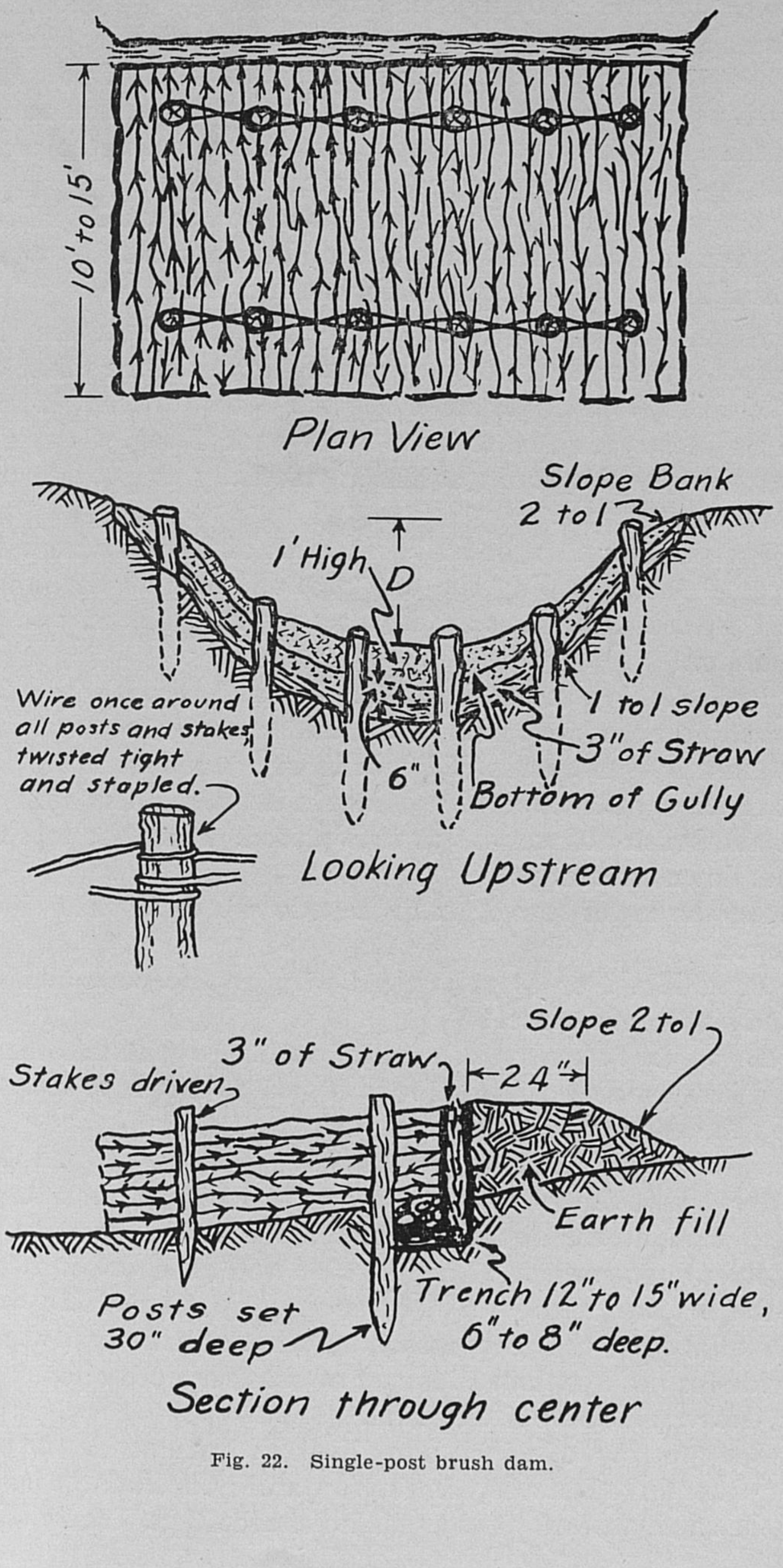


Fig. 22. Single-post brush dam.

where ultimate protection may be established by vegetation. Altho these dams are the least permanent, having an effective life of approximately 2 to 6 years depending upon durability of posts, stakes and brush used, are tedious to build and require constant attention to maintain, they are recommended on farms where the brush is available because they do not require a cash outlay.

The single-post brush check dam is adapted to small gullies. Its chief advantage is the small cash outlay for materials. Its weakness is the constant attention required for maintenance.

Specifications for Single-post Brush Dam. 1. At the site of dam, excavate a trench 6″ to 8″ deep and 15″ wide, the width of the gully and up the side slopes at a slope of 1½ to 1 or less, placing the dirt on the up-stream side, to be used for back filling. Carry the excavation up into the banks as far as necessary to provide the required weir notch area.

2. Posts should then be set at intervals of 2 feet and to a depth of at least 2 feet, tamping the dirt around them as the holes are filled. If the soil conditions are satisfactory, the posts may be pointed and driven.

3. Pack the area at the site of the dam and trench with a 3″ layer of straw, fill the trench with brush, and tramp it in place.

4. Place long branches of brush in layers and then the shorter ones parallel to gully, liberally filling in between them with straw. Tramp the brush at intervals as it is placed. Place the tops of the branches down stream.

5. Set the lower row of stakes but do not drive them down to final depth.

6. Place No. 9 or 10 galvanized wire on the posts and stakes, twist and staple it in place.

7. Drive the stakes to anchor the brush. To maintain the structure in a firm condition, it will be necessary to drive the stakes from time to time as the brush and straw dries and settles.

Specifications for Double-row Post Brush Dam. 1. At the site of the dam, slope the gully banks to a 1½ to 1 slope, for a length of 10 feet, placing all the dirt on the upper side of the dam.

2. Excavate a trench 24 inches wide and at least 8 inches deep across the bottom of the gully, extending it into the side banks a distance of at least 12 inches measured perpendicularly to the slope to provide for not less than 12 inches of brush at ends of dam. Place all dirt excavated above site of dam.

3. Set two rows of 4-inch posts in pairs just outside the trench, placing them three feet apart in the row and in holes 24 inches deep. Tamp the earth around posts as the holes are filled. Where soil con-

ditions are suitable, the posts, if sharpened, can be driven to the proper depth with a post maul.

4. Put a three-inch layer of strawy material in the bottom of the trench and place the brush, varying in size up to 2 inches in

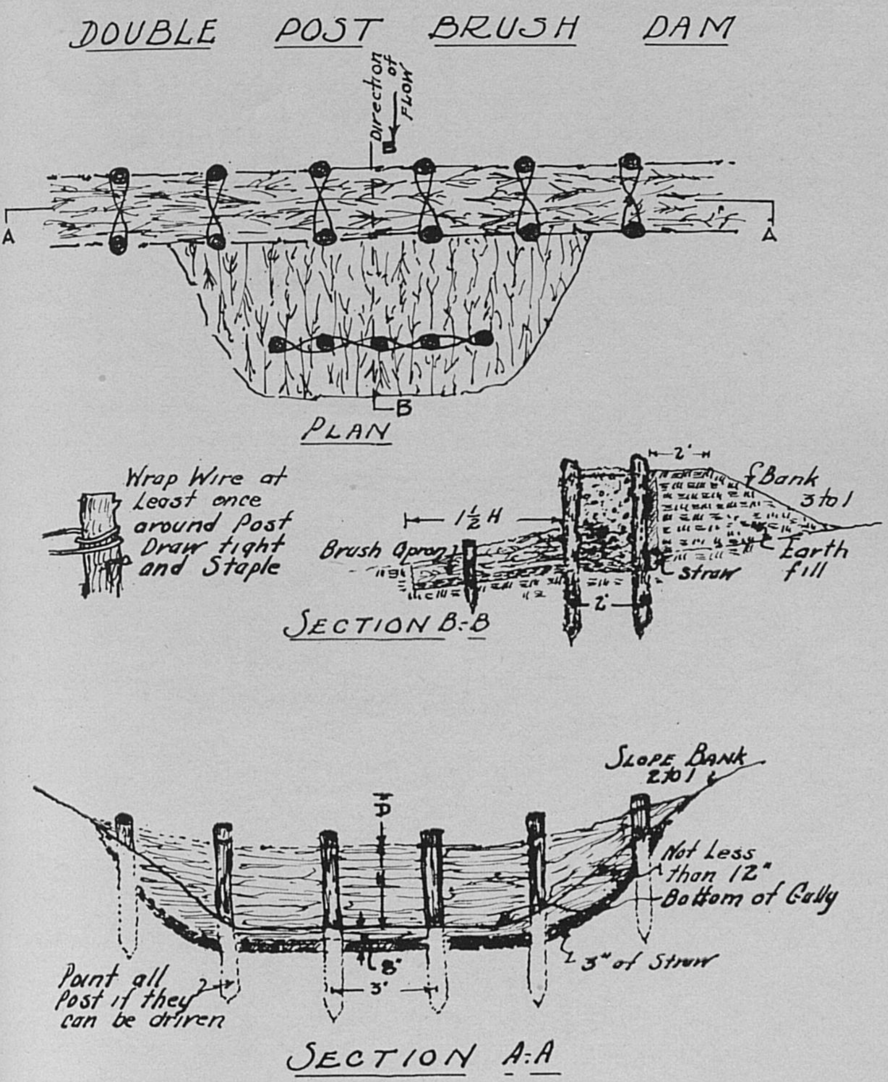


Fig. 23. Double-post brush dam.

diameter, using the smaller branches at the bottom. Keep the brush at a uniform height the entire width and length of the dam, as the dam is built, placing the apron material as explained in item 5. Tramp the brush down occasionally as filling progresses.

5. A separate apron below the dam for the water to fall upon

is formed by laying brush perpendicularly to the dam as illustrated, with the tops placed down stream, and the butt ends placed in alternate layers across the brush in bottom of dam. Aprons are not always necessary on dams less than 18 inches high, where the drainage area is small.

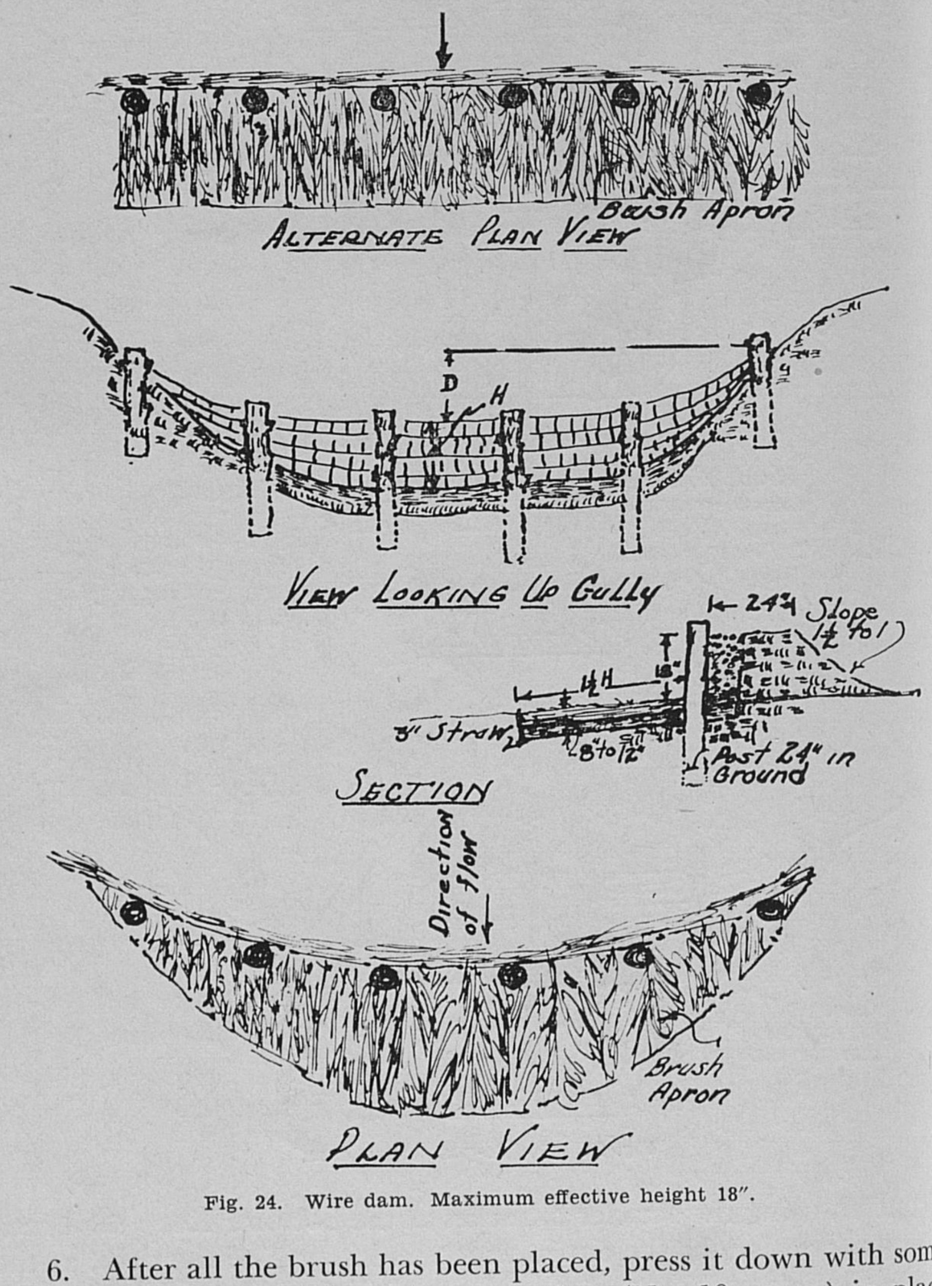


Fig. 24. Wire dam. Maximum effective height 18".

6. After all the brush has been placed, press it down with some system of levers and place the cross wires (No. 10 gauge) in place and staple to posts. Also stake and wire down apron in same manner. If the posts can be driven, the packing of the brush may be ac-

complished after the wires have been placed by driving the posts to the desired depths. If this latter method is used, the posts should not be driven to full depth until after brush is placed. Keep in mind that the center of the dam should be lower than the ends to form the weir notch.

7. Complete the dam by packing a 4-inch layer of straw against the up-stream face, while tramping in an earth back-fill as illustrated in Figure 23.

Specifications for Wire Dam. 1. Slope both banks of the gully at the place dam is to be built to 1½ to 1 slope and for a length of 10 feet.

2. Dig a trench 8″ to 12″ deep across the gully, continuing the trench up each bank far enough to provide the necessary depth of notch.

3. Set 4-inch posts, 3 to 4 feet apart at the lower side of the trench to a depth of 24 inches below the bottom of the excavation.

4. Staple a length of 26-inch galvanized wire hog fencing (having No. 11 top and bottom strands and No. 14 stays) to the end posts, wrapping the wire around each end post, leaving the wire just slack enough so that it will be taut when pulled down and stapled to the remaining posts, forming a flat-bottom notch as illustrated. Place the wire on the posts with the small meshes at the top.

5. Back-filling. A layer of fine brush, slabs or split poles, and a 3-inch layer of straw should be packed tightly against the upstream side of wire from top to bottom, holding them in place with a tamped earth fill.

Sod Bag Dam. (May be used in narrow, shallow gullies, 3 feet

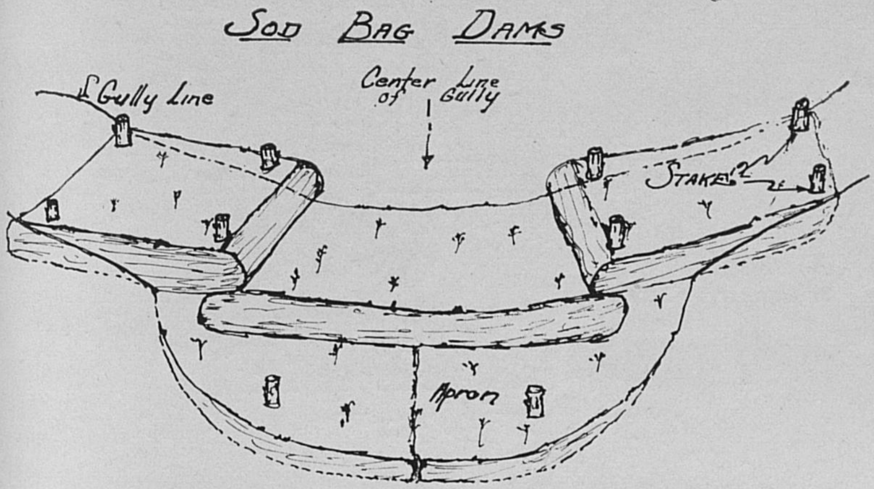


Fig. 25. Sod bag dam.

or less in depth, having a drainage area of not more than one acre.)

Specifications for Sod Bag Dam. 1. Slope banks of gully 1½ to 1 with a plow.

2. Excavate a trench across the gully, at the site, approximately 18″ wide and deep enough that top of bags, when placed, will be flush with bottom and sides of the gully.

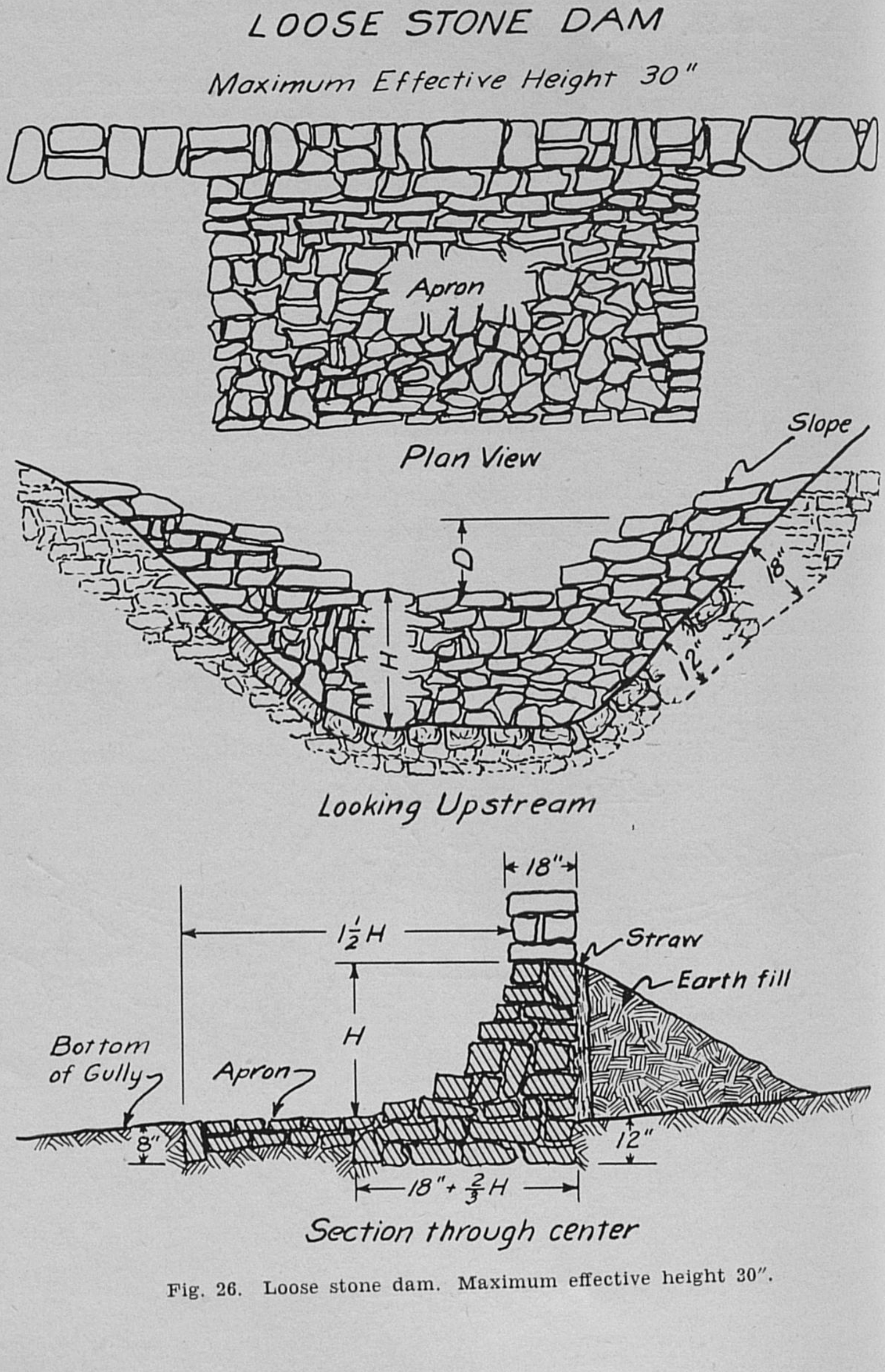


Fig. 26. Loose stone dam. Maximum effective height 30″.

3. Fill burlap bags about $^2/_3$ full with a good sod or with a top soil and sow with a grass mixture or small grain.

4. Space dams 15 to 40 feet apart depending on slope of gully.

5. Use three or more bags to each structure, providing an adequate spillway. Anchor them in place with driven stakes. On the steeper slopes provide an apron using one or more half-filled bags, extending them 6 inches or more on each side of the notch.

Specifications for Loose Stone Dam. 1. At the site of the dam, slope the gully banks to 1½ to 1 for the entire length of the dam and apron.

2. Dig a trench 1 foot deep at base across bottom of gully and extending at least 18 inches into banks, measured perpendicularly to the slope. The width of excavation at base of dam should be 18 inches plus $^2/_3$ the height of dam to bottom of spillway notch.

3. Excavate for the apron at least 8 inches deep, across bottom of gully, and up 2 feet on slope of both sides.

4. Lay large, flat stones in the main body of the dam keeping the up-stream face vertical and batten the downstream side so that the thickness of the wall at the bottom of the dam is 18″ plus $^2/_3$ the height of dam at bottom of spillway and the top is approximately 18″ thick. The effective height of dam is to be not greater than 30″.

5. Place a 3- or 4-inch layer of straw against back of dam and back-fill with tamped earth as illustrated.

6. Lay the apron, using large, flat stones with the top of the floor level with bottom of gully.

Log Dam. (Maximum effective height 18″.) (Figure 27.)

Specifications for Log Dam. 1. Slope both banks of the gully to 1½ to 1 for a length of 6 feet at the site of the dam.

2. Excavate a trench across the gully the same width and depth as the diameter of the bottom log so that it may lie beneath the floor of the gully. The trench should extend at least 24″ into the banks, measured perpendicularly to the slope.

3. Set two or more posts not less than 6 inches in diameter at foot of excavation to a depth of two feet below the bottom of the trench the distance between the posts forming sides of notch being equal to the calculated length of the spillway notch. If this distance exceeds 6 feet, set a shorter center post.

4. Place a 3″ layer of strawy material in bottom of trench.

5. Select straight, sound logs for the dam. Hew the top side of the bottom log and two sides of the others to provide flat-bearing surfaces for the logs so that when they are placed, the cracks between them will not exceed ¼ inch. Chink the cracks with straw or grass.

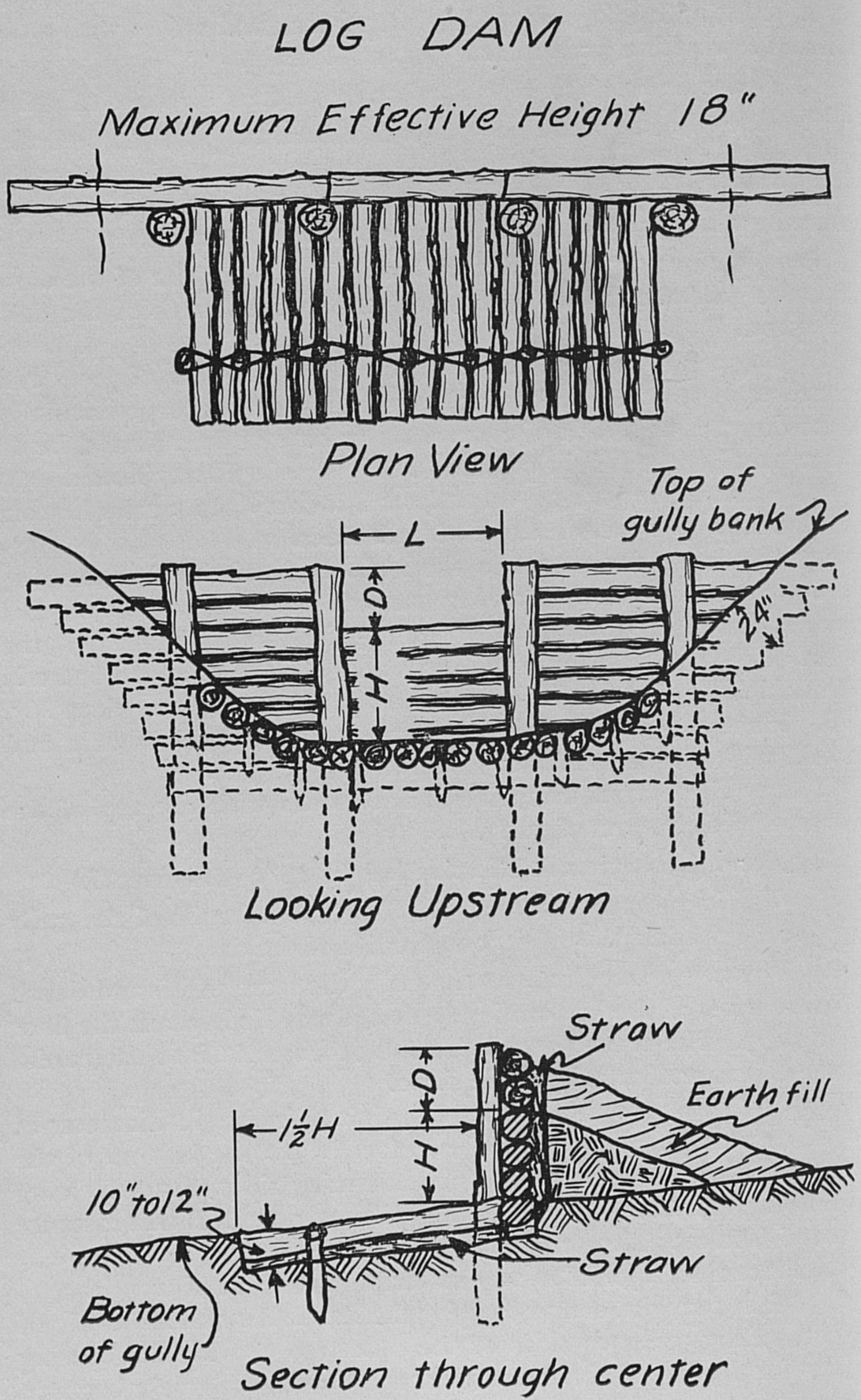


Fig. 27. Log dam. Maximum effective height 18".

6. Wire all the logs securely to the posts with No. 10 galvanized wire.

7. Place a 3-inch layer of straw against back of dam and back-fill with well-tamped earth to a slope of 1½ to 1. Back-fill the cor-

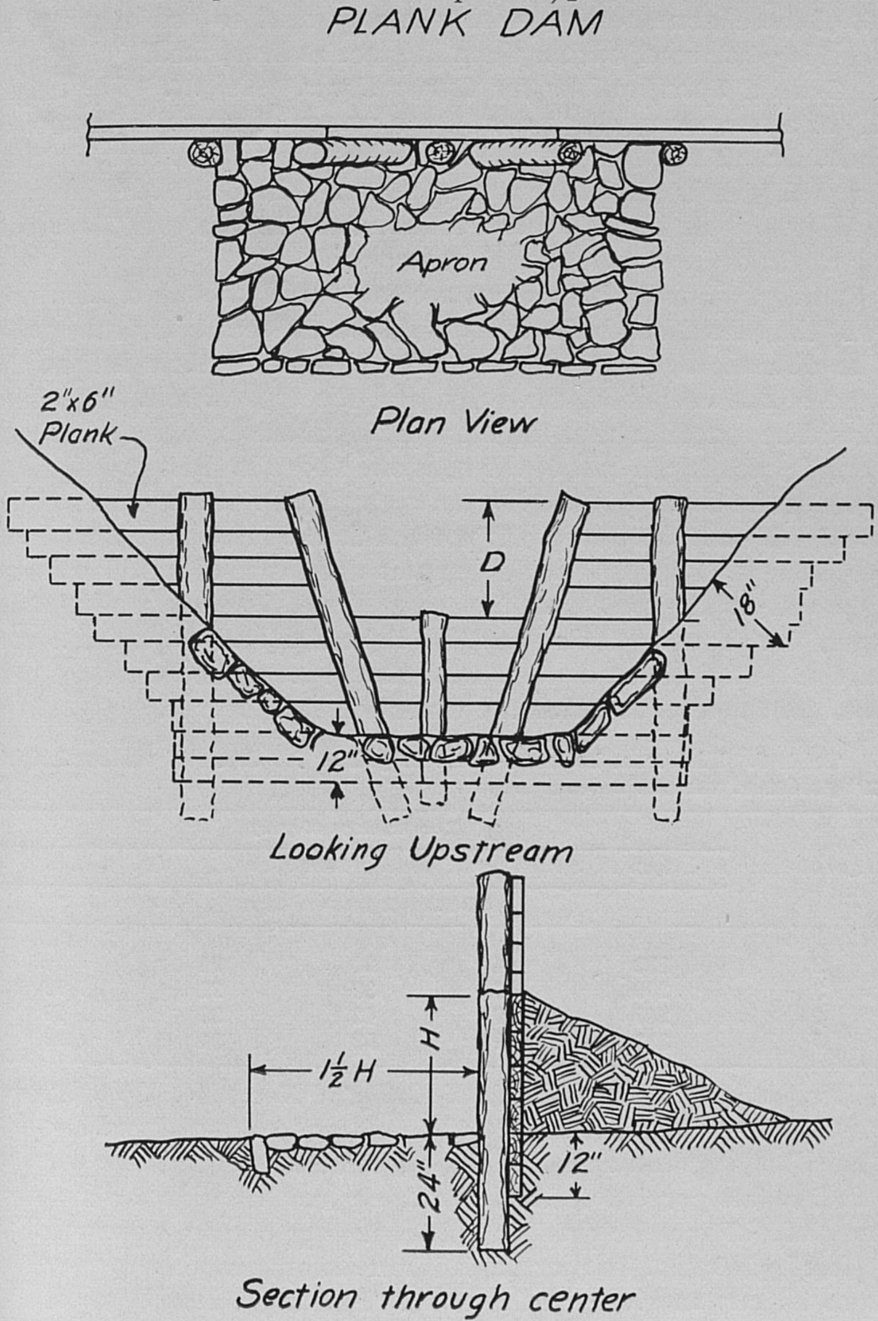


Fig. 28. Plank check dam.

ners between the wings and banks to direct the flow of water thru the spillway.

8. Where the height (H) from bottom of gully is 18″ or higher and an apron is required, it may be made of flat stones as in Figure 26, of loose stones, or by placing logs parallel to bed of gully. If small logs are used, anchor them in place as illustrated.

General Specifications for Check Dams. Height. The height (H) of a temporary check dam, from center of notch to bottom of gully, should not exceed 2½ feet and in most instances should be less. For greater height the water pressure behind the dam increases tending to cause leaks thru and underneath the structure, and scouring by the overflow is harder to control.

Spacing. Where check dams are to be used to stop erosion in a gully they should be built at intervals the entire length of the gully. The distance between the dams depends upon their height, the slope of the bottom of the gully, and the type of soil. The dams should be spaced so that the fill that accumulates to the top of one extends back to the foot of the next one above it. Best practice is to so space the dams that the rise between the top of one dam and the bottom of next one above it is not less than 6″ nor more than 2 feet per 100 feet. The slope of fill depends upon type of soil. For coarse sand and small gravel use a 2 percent slope. For fine sand and silt loam, use about 1 percent and for light silts and clays, use .5 percent. The top of the dam, as used here, means the bottom of weir notch or the level at which the water will flow over it.

Table 5. Distances between dams in gullies for dams of various heights and gullies of various bottom slopes.

Height of dam	Bottom slope of gully				
	2 ft. in 100 ft.	5 ft. in 100 ft.	10 ft. in 100 ft.	15 ft. in 100 ft.	20 ft. in 100 ft.
	Distances between dams				
Feet	Feet	Feet	Feet	Feet	Feet
2	133	44	21	14	10
3	200	67	32	21	15
4	267	89	42	28	20
5	333	111	53	34	26

Table 5 taken from Farmers' Bulletin No. 1234, United States Department of Agriculture, "Gullies—How to Control and Reclaim Them," is based on a surface slope for the fill between the dams of 6 inches fall per 100 feet. The table gives the distances between dams of different heights for gullies having bottom slopes of 2 to 20 feet in 100 feet. In practice it is not always practical to space the dams exactly as given in the table. The table may be used as a guide, but the vertical intervals should be adjusted to suit conditions. In some instances, by changing the spacing slightly, dams may be located in narrower sections of the gully and on better sites where less labor and materials will be required to build them. If

Table 6. Rates of run-off in cubic feet per second from timber, pasture and cultivated land for group 3 states (Based on rainfall frequency once in 10 years).

	Unterraced Areas						Terraced
	Timber		Pasture		Cultivated		Cultivated
Area drained, acres	Rolling 5 to 10% slope	Hilly 10 to 30% slope	Rolling 5 to 10% slope	Hilly 10 to 30% slope	Rolling 5 to 10% slope	Hilly 10 to 30% slope	Rolling 5 to 10% slope
2	2.9	4.5	6.7	8.8	11.9	15.3	9.2
4	5.5	7.5	12.2	15.3	21.0	28.0	15.7
6	8.3	10.7	17.5	21.8	31.0	40.5	21.6
8	11.1	13.6	22.3	27.3	39.4	50.4	26.8
10	13.8	16.3	27.2	33.0	47.2	58.8	32.1
12	16.0	18.8	31.9	38.1	54.2	66.3	37.1
14	18.3	21.3	36.1	43.2	60.2	73.5	41.7
16	20.4	23.7	40.0	48.1	66.0	80.2	46.0
18	22.2	25.8	43.5	51.7	70.1	80.2	50.1
20	23.8	27.4	46.6	55.0	76.3	92.7	54.3
25	26.9	31.5	53.2	62.6	88.3	106.7	64.4
30	29.2	34.7	58.9	69.6	98.7	119.4	73.7
35	31.0	37.9	63.7	75.1	107.0	134.0	83.0
40	32.0	41.0	67.8	80.0	114.5	150.0	93.0
45	35.0	46.0	71.0	85.0	125.0	170.0	105.0
50	50.0	56.0	80.0	98.0	138.0	189.0	122.0

Tabulated from curves prepared by C. E. Ramser, U. S. Department of Agriculture.

Table 7. Approximate discharge capacity of broad-crested spillways.* Cubic feet per second.†

Length of spillway in feet	Head on creast of spillway. Feet.							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
	Corresponding flow of water. Cu. ft. per second.							
2	2.3	6.4	11.8	18.1	25.3	33.3	41.9	51.2
4	4.5	12.8	23.5	36.2	50.6	66.5	83.8	102.4
6	6.8	19.2	35.2	54.3	75.9	99.8	125.7	153.6
8	9.1	25.6	47.0	72.4	101.2	133.0	167.6	204.8
10	11.3	32.0	58.8	90.5	126.5	166.3	209.5	256.0
12	13.6	38.4	70.5	108.6	151.8	199.5	251.4	307.2
14	15.8	44.8	82.3	126.7	177.1	232.8	293.4	358.4
16	18.1	51.2	94.1	144.8	202.4	266.0	335.3	409.6
18	20.4	57.6	105.8	162.9	227.7	299.3	377.2	460.8
20	22.6	64.0	117.6	181.0	253.0	332.5	419.1	512.0
22	24.9	70.4	129.3	199.1	278.3	365.8	461.0	563.2
24	27.2	76.8	141.1	217.2	303.6	399.1	502.9	614.4

* C. E. Ramser. "Brief Instructions on Methods of Gully Control."

† Computed by the formula, $Q = 3.2\,LH^{1.5}$
in which Q = discharge in cu. ft. per sec.; L = length of spillway, in feet;
H = head of water on crest of spillway, in feet.

this method of spacing is used, the height of the dams may be determined from the table after the actual distances between them are determined.

The following formula may be used to determine the distance between dams in gullies having a bottom of any slope for any height of dam:

$$D = \frac{H}{Sb - Sf} \times 100$$

When D = distance between dams, in feet
H = height in feet of dam to bottom of weir notch
Sb = slope in feet per 100 feet of bottom of gully
Sf = allowable slope in feet per 100 feet of surface of fill between dams. (May vary from 6″ to 2 feet per 100 feet.)

To Determine the Size of the Spillway Notch. Each check dam should have a notch in the center to permit the run-off water to pass thru without damage to the structure. The styles of notches used are shown by Figure 29. On the left side of each is given the equation for determining the effective area of the notch. It is first necessary to determine the area of land draining into the gully above the dam and the rate of flow of the water in cubic feet per second. The rate of flow depends upon the size and shape of the area, the slope of the land, the vegetative covering, the absorbing capacity of the soil, and the intensity and duration of rainfall. The frequency with which given rates of rainfall may probably occur plays an important part in determining the size of the notch in a dam. Unless the notch is large enough to permit all the water from intense rains to pass thru it without flooding, the banks of the dam may be washed out at the ends. For Kentucky conditions the rate of run-off in cubic feet per second may be determined by using Table 6, Page 49, which is based on the maximum rainfall expected to occur once in 10 years. The size of the weir notch can then be obtained by using data given in Table 7.

Example. Determine the rate of run-off in cubic feet per second and the size of a rectangular notch to use in a check dam for an unterraced area of 25 acres consisting of 5 acres of rolling timberland, 10 acres of rolling pasture, and 10 acres of rolling cultivated land.

In the first column of Table 6 find 25 acres and opposite it to the right in column headed "rolling timber land" is found 26.9 cu. ft. per second. One-fifth of 26.9 is 5.38 cu. ft. per second run-off for 5 acres of timberland. Then go back to the 25 acres in column 1, and again trace opposite it to the right into the column headed "rolling pasture" and read 53.2 cu. ft. per second. Two-fifths of 53.2 is 21.28 cu. ft. per second run-off from the 10 acres of rolling pasture. In the same manner, from the table we determine the run-off from 10 acres of rolling cultivated land to be $^2/_5$ of 88.3 or 35.3 cu. ft. per

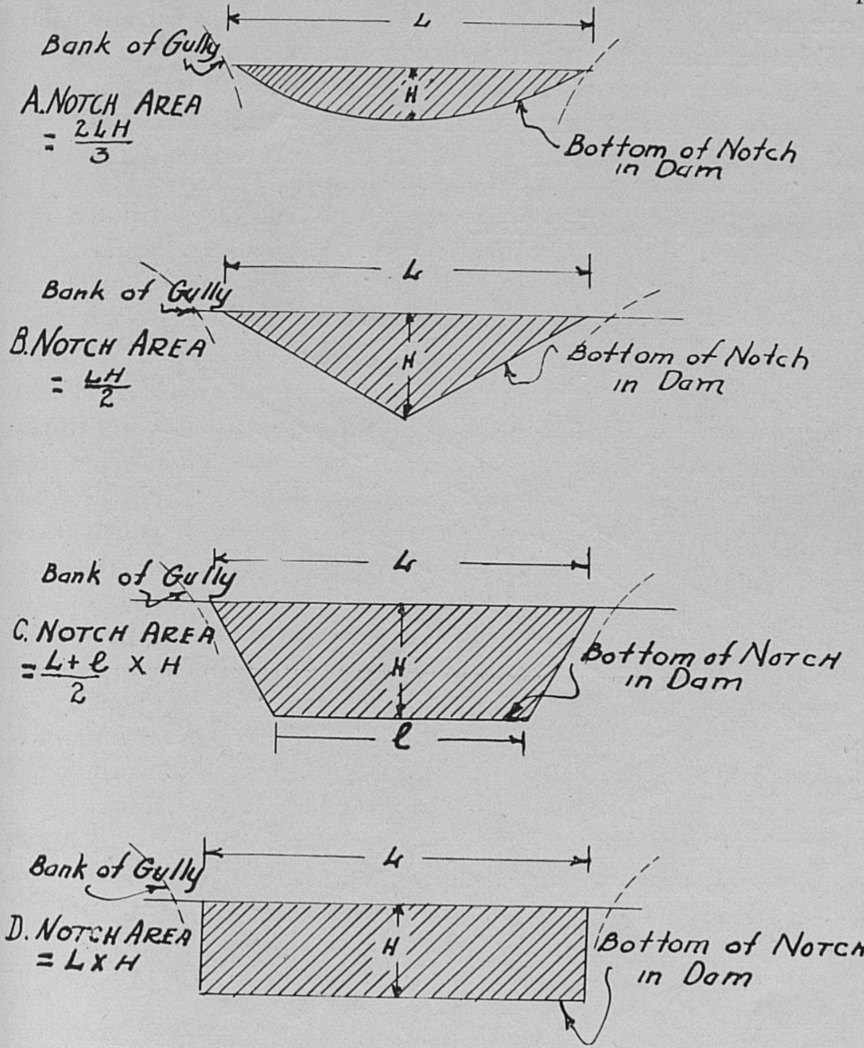


Fig. 29. Styles of notches which may be used in check dams.

second. The total run-off for the 25 acres is the sum of 5.38 + 21.28 + 35.3 or 61.96 cubic feet per second. However, for Kentucky conditions, we recommend that the run-off as taken from Table 6, Page 49, be increased 10 percent, thus making the run-off in this case 61.96 + 6.19, or 68.15 cu. ft. per second.

Using this discharge and referring to Table 7 for a depth of notch of 1.5 feet, the length of spillway required is almost 12 feet or 11.91 feet. If the width of gully is less than this length of spillway, a deeper and shorter spillway will have to be used. Since Table 7 is for a rectangular notch, if one of the other styles (Figure 29) is used the notch area should be the same (1.5 × 10.98 = 16.47 square feet).

If the dam is to be used in a terrace outlet, get the rate of run-off from the last column of Table 6. The run-off for terraced land is less than for similar unterraced land. Since any terraced area may be cultivated and terraces are not often used on slopes exceeding 12 percent, the run-off from terraced areas should be estimated as for terraced cultivated rolling land.

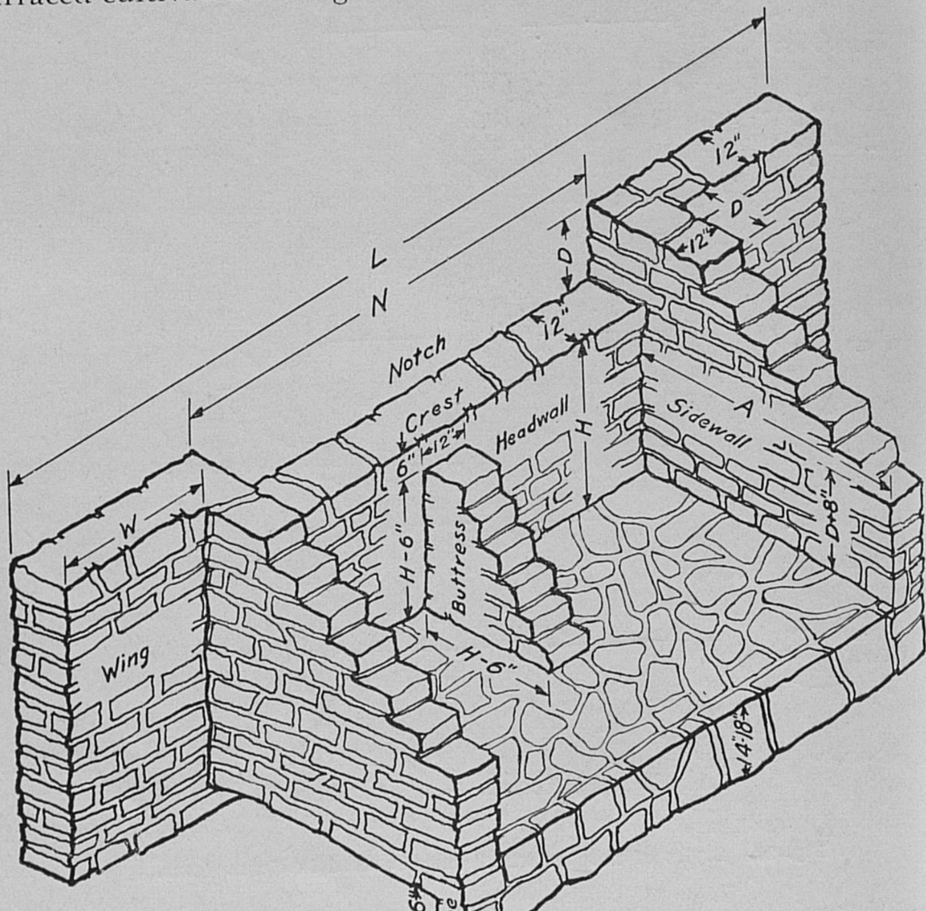


Fig. 30. Typical rubble masonry dam for terrace outlet or gully control.

Sloping Gully Banks. After the check dams have been built, the sides of gullies up to 20 feet in depth should be sloped 1 to 1 and the top of the bank to a 2 to 1 slope, to provide a suitable site for planting. The excess material should be left in the gully. In some instances, dynamiting may be used in sloping the banks and preparing them for vegetative coverings. If plows are used, care must be taken to avoid leaving dead furrows in which water entering the gully may concentrate in sufficient volume to start branch gullies.

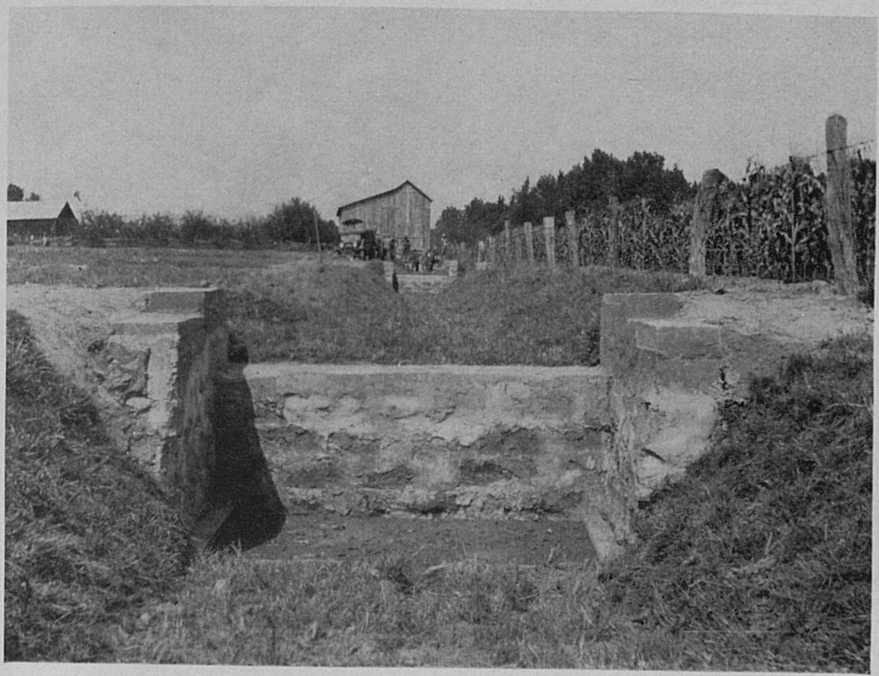


Fig. 31. Rubble masonry dam for a terrace outlet.

Permanent Check Dams. For terrace outlets or gully control these should be made of stone or concrete blocks set in mortar, reinforced concrete, or a combination of these materials. Figures 30 and 32 show dimensions for structures to a maximum height (H) of 5 feet from top of apron to bottom of notch. Structures of a greater height must be especially designed by a competent engineer.

Specifications for Rubble Masonry Dam. (Refer to Figure 30.)

1. The length of notch N and its depth D should be determined from the amount of run-off from area above the dam and the width of gully at the site.

2. W, the length of wing walls should never be less than 4 feet where H is less than 4 feet and should equal H where H is greater than 4 feet. (For sandy soil, W should equal 1½ H.) The wing walls should extend into the banks of the channel a distance (W) and to a depth of 20 to 22″ below grade of floor of channel.

3. L, the over-all length of dam, equals N + 2W.

4. H represents the height of head wall above top of apron.

5. LA, the length of apron, should equal H + D.

6. The apron may be made of concrete 6″ thick or stone 8″ thick set in concrete.

7. The head wall should never be less than 12″ thick. Where H is greater than 3.3 feet, make top of head wall 12″ thick and 0.3H in thickness at bottom.

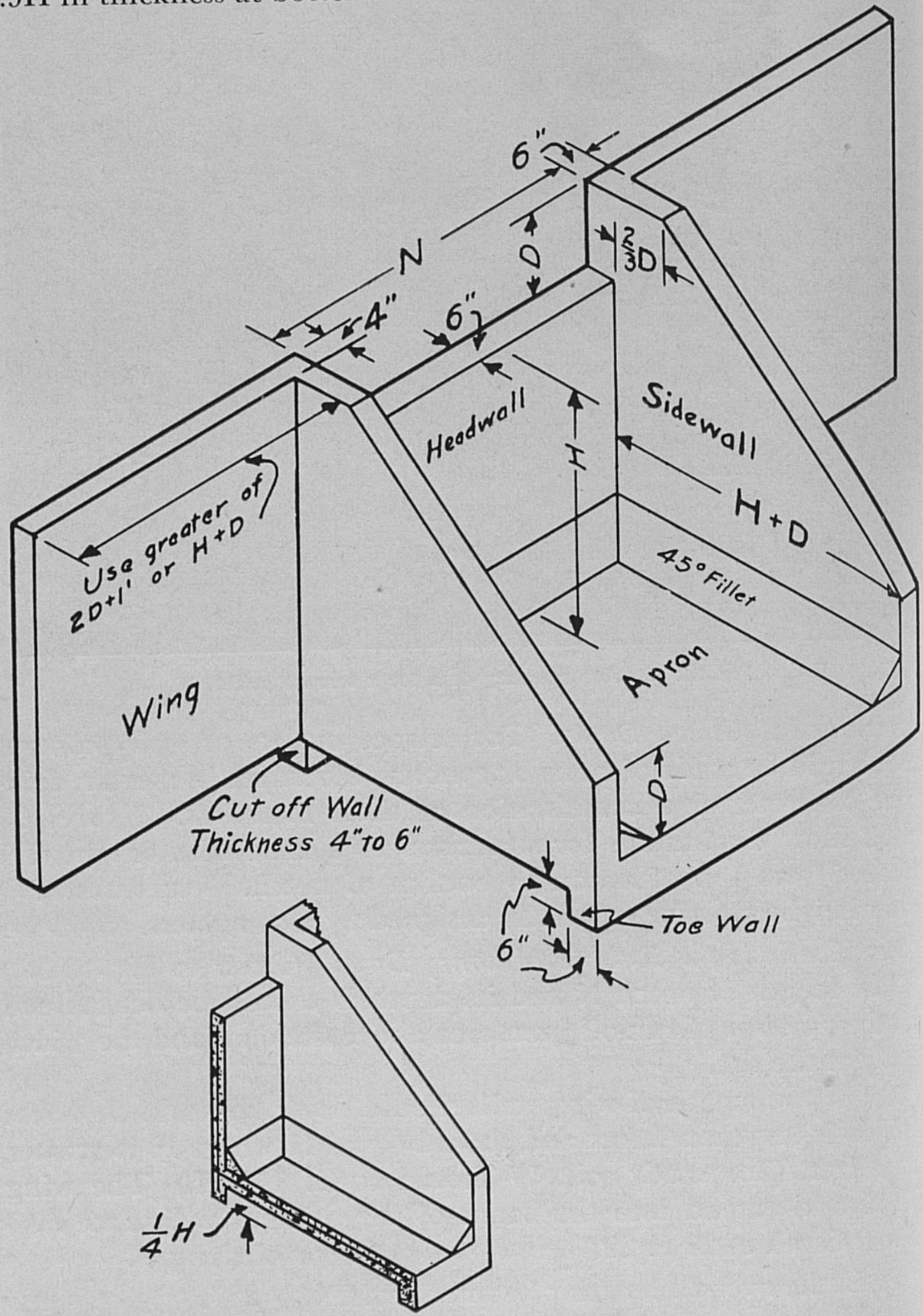


Fig. 32. Typical small concrete dam for terrace outlet or gully control. (Plan L. 262 SCS.)

8. Extend the toe of the apron 14″ to 18″ into the ground below the floor of the terrace outlet or gully.

9. Use a buttress only when the notch span, N, exceeds 8 feet, making its height and base equal H minus 6″.

Fig. 33. Typical small concrete dam in gully.

Specifications for Concrete Dam. 1. Dimensions given in Figure 32 are minimum dimensions.

2. The size of the notch (N) and D should be determined from the amount of run-off from the drainage area above the dam as illustrated on pages 50 and 51.

3. When N is greater than 6 feet, buttress walls spaced 6 feet apart should be constructed to brace head wall.

4. The wing walls should be made longer and cut-off walls deeper in types of soil which are easily eroded.

5. The top of apron should be on grade level with channel floor.

6. The apron thickness should be 4″ where H is 3 feet or less, 5″ where H is 4 feet, and 6″ where H is 5 feet.

7. A 45° fillet should be constructed on all inside corners of the apron.

8. All concrete to be reinforced with ½″ steel rods placed 18″ apart both ways.

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