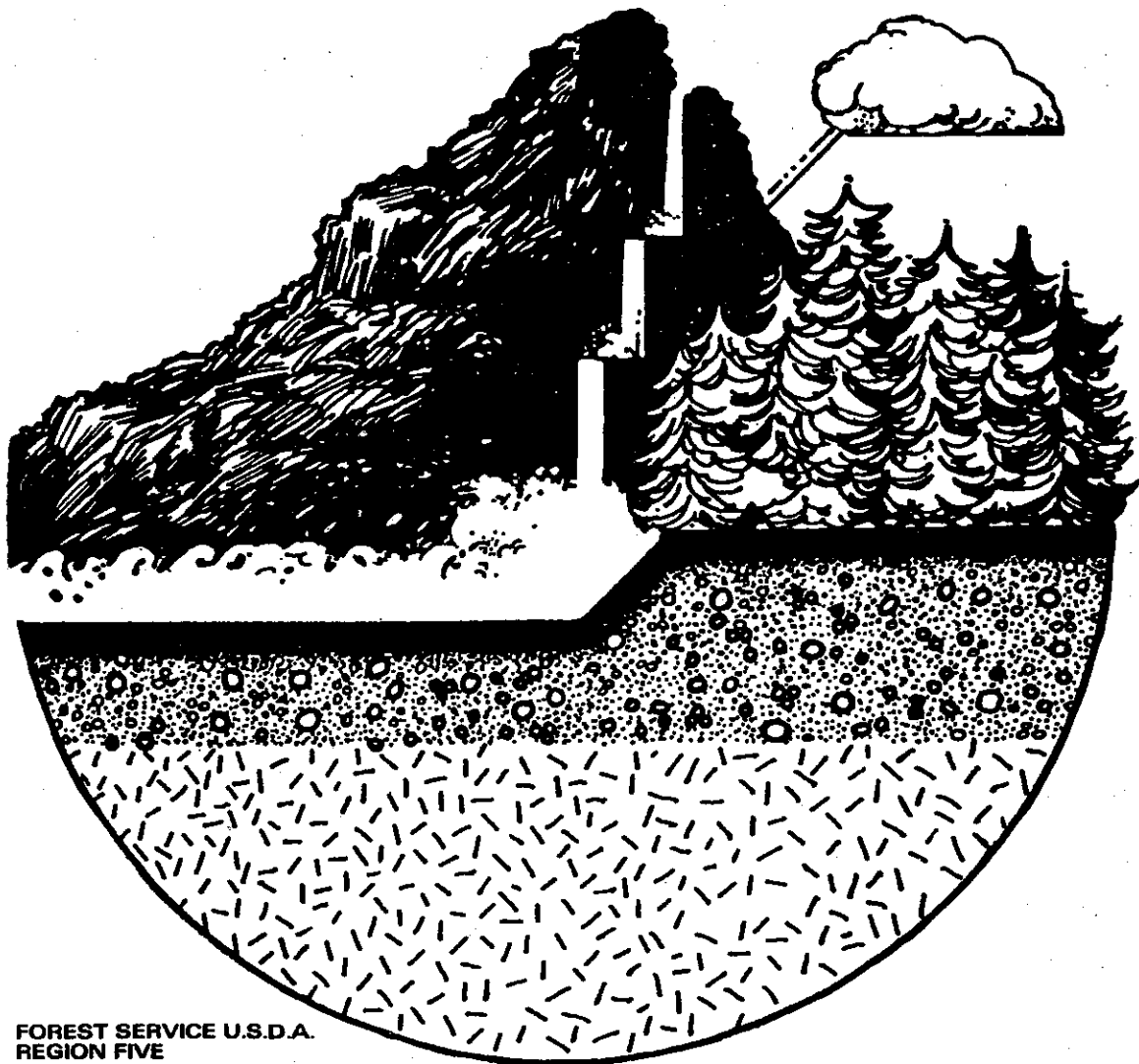


**GUIDELINE FOR  
WATERSHED IMPROVEMENT MEASURES**



**FOREST SERVICE U.S.D.A.  
REGION FIVE**

**U.S. Forest Service  
Pacific Southwest Library and Information Center  
1323 Club Drive  
Vallejo, CA 94592-1110**

NOTE

The enclosed paper Handbook of Erosion Control in Mountain Meadows is out of print. We are reissuing it exactly as it was first published in 1934. The conditions shown are much the same as we encounter today; the control measures prescribed are sound and still have application.

ANDREW A. LEVEN  
Director  
Watershed Management Staff  
6/80

### The Authors

Charles J. Kraebel (1889-1969) received his degrees in forestry from the University of Michigan: Bachelor of Arts in 1912 and Masters of Science in 1914. His career then evolved into a variety of positions as an expert advisor on erosion control: forestry researcher with the Forest Service in Oregon and Washington (1915-17 and 1919-20); consulting engineer with the Tenth Engineers during WWI in France (1917-19); Assistant Territorial Forester in Hawaii (1920-24); Superintendent of Glacier National Park in Montana (1924-27); Principal Silviculturist (1927-49) and specialist in watershed management (1949-56) with the California Forest and Range Experiment Station in Berkeley, California; Forestry Advisor for the National Taiwan University in Taiwan (1956-57); and Chief Forester for the Joint Commission on Rural Reconstruction in Taiwan (1957-61).

Arthur F. Pillsbury has had a long association with the University of California System: from 1932 to 1972, he researched and taught on the subject of irrigation and drainage systems. He was briefly loaned to the Forest Service (during the fiscal period 1933-34) where he worked with C. J. Kraebel. Since his retirement in 1972, he has been professor emeritus of Engineering and Applied Science at UCLA, and Director of University of California's System-wide Water Resource Center.



Figure 1.

A typical mountain meadow. The preservation of such areas is of prime importance in maintaining a summer forage for livestock. Sardine Valley, Tahoe National Forest, California.

Photo No. K-1055      Kraebel      6-21-33

HANDBOOK  
of  
EROSION CONTROL IN MOUNTAIN MEADOWS

by  
Charles J. Kraebel, Senior Silviculturist  
and  
Arthur F. Pillsbury, Assistant Conservationist

UNITED STATES DEPARTMENT OF AGRICULTURE  
FOREST SERVICE  
California Forest and Range Experiment Station  
E. I. Kotok, Director  
331 Giannini Hall, Berkeley, California

April 1934

## TABLE OF CONTENTS

	<u>Page</u>
Chapter I - Introduction	1
Process of erosion	2
Causes of erosion	4
Purpose of erosion control	5
Methods of erosion control	6
Chapter II - Control of Grazing	7
Chapter III - Specifications for Materials	9
Chapter IV - Control of Gully-Heads	11
Steps in the control of gully-heads	12
Criteria for design	13
Methods of controlling gully-heads	13
Suggested designs:	
Structure No. 1 - Brush and Rock Plug	15
Structure No. 2 - Post and Brush Plug	17
Structure No. 3 - Tree Plug	19
Structure No. 4 - Rock Mattress	20
Structure No. 5 - Brush and Rock Mattress	21
Structure No. 6 - Brush and Poultry Netting Mattress	22
Chapter V - Check Dams	24
General considerations	25
Criteria for dam locations	26
General specifications	27
Construction of check dams:	
Structure No. 7 - Single-Row Post-Brush Dam	29
Structure No. 8 - Double-Row Post-Brush Dam	31
Structure No. 9 - Brush-and-Rock Dam	33
Structure No. 10 - Brush-and-Poultry-Netting Dam	36
Structure No. 11 - Tree Dam	38
Structure No. 12 - Simple Tree Dam	39
Structure No. 13 - Loose Rock Dam	41
Summary	42
Chapter VI - Channel Control	43
Bank fixation	43
Protection against side cutting	43
Slash disposal in gullies	45
Preface to Chapters VII, VIII, IX, and X - Use of Vegetation	46

# TABLE OF CONTENTS (Cont'd)

	<u>Page</u>
Chapter VII - Planting Cuttings	47
Selection of species	47
Time to plant	47
How to cut stakes	48
How to plant stakes	48
Where to plant willow stakes	48
Chapter VIII - Sod Planting	52
Chapter IX - Wattle Construction	53
Locations where wattles can be used	53
Common types of wattles	53
Selection of types of wattles to be used	57
Selection of material to be used for wattles	57
Chapter X - Artificial Seeding	59
Chapter XI - Cost Records	60

## FOREWORD

This handbook has been prepared primarily as a guide to forest officers who will be engaged in erosion control activities in the mountain meadows of California. In preparing the handbook, methods developed by other agencies currently engaged in similar activities, which are believed applicable, have been included. With respect to dams and other control structures, it should be clearly understood that these are regarded as temporary but necessary aids in the process of restoring vegetation. We look to vegetation, not dams, for permanent control and to that end our efforts are directed towards hastening the process of vegetative recovery.

The authors wish to express appreciation to the following men for their aid in reviewing the manuscript and in helping with the editing:

J. W. Nelson, Assistant Regional Forester, in charge of Range Management for the California Region, U. S. Forest Service, and his assistant, R. W. Beeson.

M. W. Talbot, Senior Forest Ecologist, in charge of Range Management studies for the California Forest Experiment Station, and his assistant, A. L. Hormay.

Chapter II was written in cooperation with those above mentioned, and was also critically reviewed by Professor A. W. Sampson, Division of Forestry, University of California, and by Forest Supervisor F. P. Cronemiller, formerly of the Regional Office of Range Management.



HANDBOOK OF EROSION CONTROL IN MOUNTAIN MEADOWS

Charles J. Kraebel and Arthur F. Pillsbury

Chapter I

Control of abnormal or accelerated erosion in mountain meadows is an essential feature of any conservation work on the range lands of National Forests. Mountain meadows can be defined as those open areas vegetated with grasses and sedges kept green through most or all of the summer months by a high water table which offers a constant supply of moisture to the grass roots. Although such meadows compose only a small part of the total area of grazing land, they provide the greater part of the livestock forage through the hot, dry California summers.

Meadow erosion is characterized by sharp active gullies, from one foot to fifty feet or more in width, and from a few inches to ten feet or more in depth, which have cut through old meadows within recent years. Their recent origin, evidenced by their present active operation and by the testimony of ranchers, indicates that the disturbing factor has entered the picture since the advent of the pioneer. These gullies have caused not only a loss of fertile top soil and of meadow area, but, more serious, have drained the meadows by progressive lowering of the water table. With this increasing dryness of the sub-soil, added to the punishment of heavy grazing, the original succulent grasses and sedges gradually disappear and are replaced by less desirable plants such as sagebrush and other drought resistant species which may have little or no forage value.

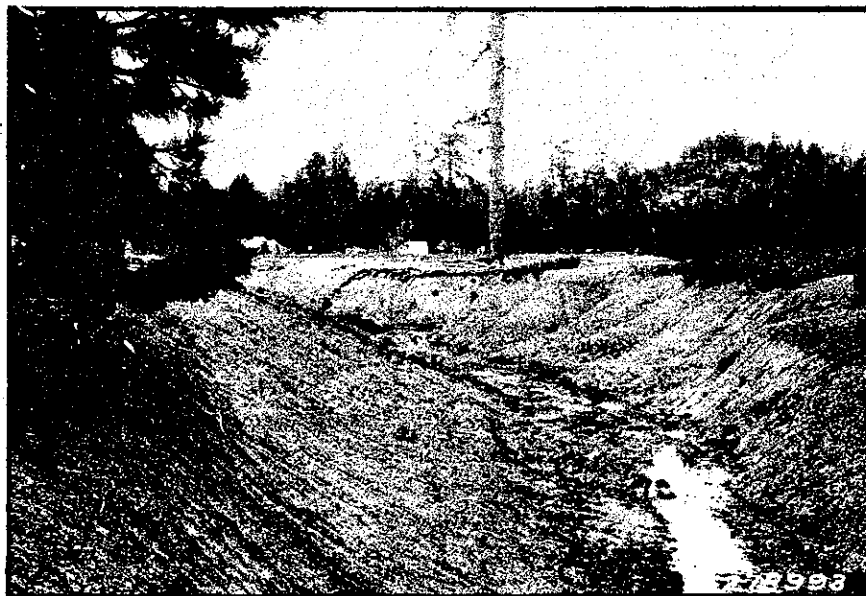


Figure 2.

A badly gullied meadow once covered with a heavy grass sod, but now, because of a lower water table, barren except for patches of "corn lily" (*Veratrum californicum*) of no appreciable forage value. Nye Camp, Mendocino National Forest, California. Photo No. 278993 Pillsbury 7-7-33

## Process of erosion

Erosion is the transporting of soil by the actions of wind or water. It is a natural geologic process whereby disintegrated rock and soil is picked up and, in the case of transportation by water, is moved to and deposited at a lower elevation.

For the purposes of this manual, we shall be concerned with two types of erosion, namely: sheet and gully. Sheet erosion is the removal of layers of soil from continuous areas. Gully erosion is the cutting of channels. In mountain meadows the natural sod of sedges, grasses and herbs protects the soil from sheet erosion, but it does not always offer protection against gullying.

The usual gullying action in mountain meadows is characterized by gully-heads or waterfalls. As the water flows over the "head" it gains considerable momentum and steadily undercuts the bank. The gully works upstream, and once the bare gully bottom and sides are exposed, it rapidly widens and deepens.

Figure 4 illustrates the typical way in which gullies cause a lowering of the ground water table, and how that level can again be raised by proper control measures.

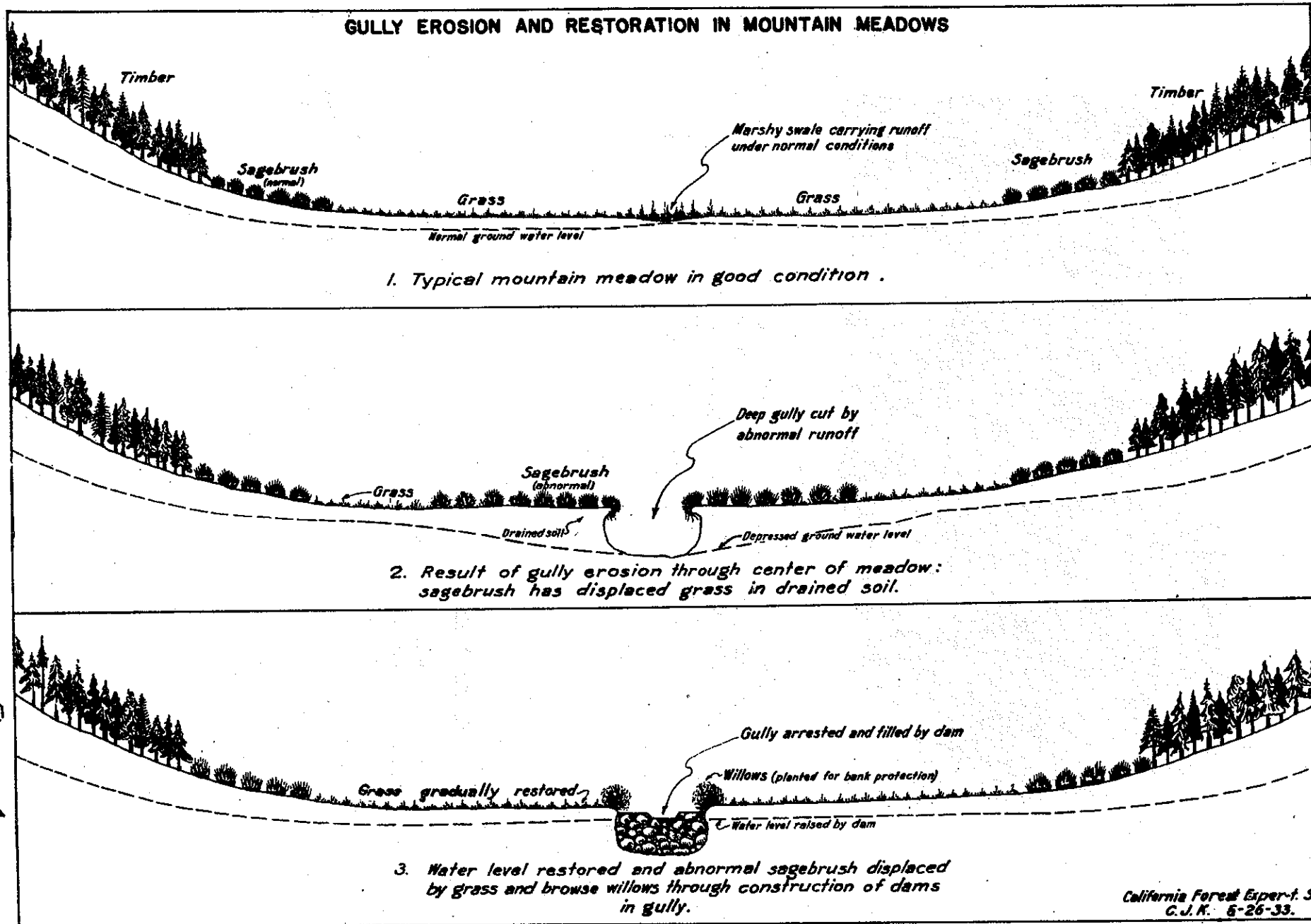
A typical gullied meadow in which sagebrush has become established along the banks of the gully is shown in figure 5.



Figure 3.

A typical gully-head working up through a mountain meadow. Gullying started immediately after the watershed had been logged over. Unless controlled, this gully will work up through the rest of the meadow lowering the water table with a result that many of the succulent grasses and sedges will be replaced by sagebrush. J. W. Nelson, in charge of Range Management, California Region, in view. Carmen Valley, Tahoe National Forest, California. Photo No. K-1060 Kraebel 6-21-33

# GULLY EROSION AND RESTORATION IN MOUNTAIN MEADOWS



-3-

Figure 4.

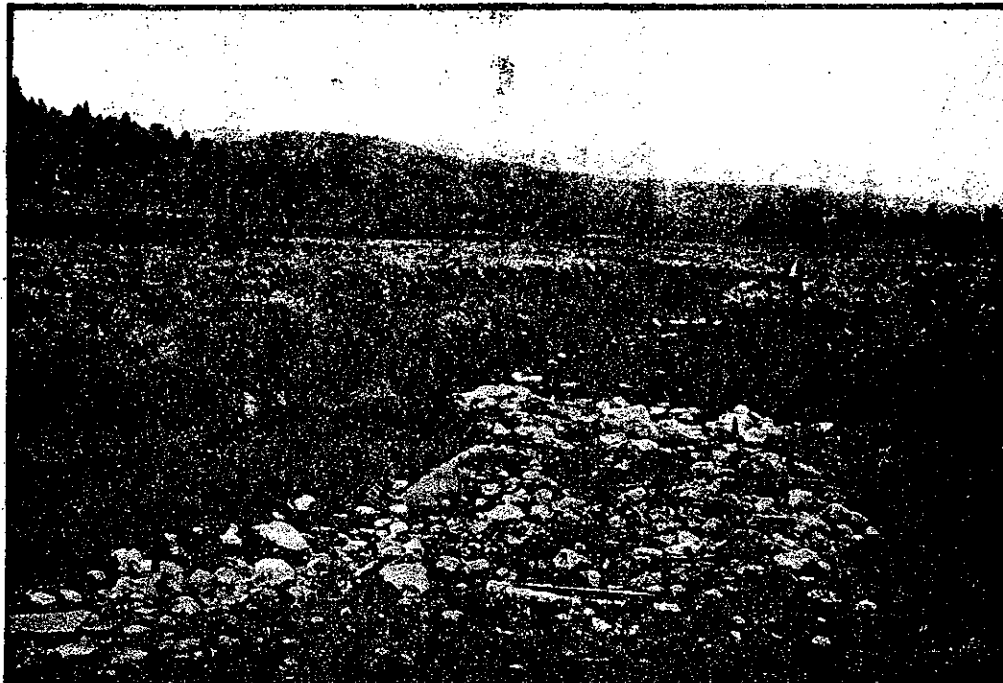


Figure 5.

Looking down a deeply gullied meadow. The wide strips of sage on each side of the gully are evidence of a low water table. Prior to the eroding of the gully (which followed logging operations in this watershed) grasses and sedges grew here, and the normal runoff was carried down the valley in shallow swales distinguished only by the darker color of sedges and other wet-soil plants. Russell Valley, Tahoe National Forest, California. Photo K-1053 C. J. Kraebel 6-21-33

#### Causes of abnormal erosion

The basic cause of accelerated erosion in the mountain meadows of California is the breaking up or depletion of the protective sod cover by a number of means of which the most important are:

1. Excessive grazing of livestock. Such grazing depletes the cover of grasses and sedges and decreases their soil-binding properties.
2. The breaking up and cutting of the protective sod, from which breaks gullies often originate, by:
  - a.) The trampling of stock over the meadow while the ground is still wet and soft.
  - b.) Trails, and casual wagon and automobile tracks.

3. Severe floods from the watershed above the meadow, which may be abnormal because of:

- a.) The denudation of the surrounding hills by lumbering or fire. In addition to the loss of protective vegetation, skid trails, eroding, supply cutting tools in the form of soil and sand with which meadow gullies are quickly cut.
- b.) The construction of modern highways and roads where great bare cut-and-fill slopes are created on the watershed above the meadow.
- c.) Any other operations, such as mining, on the watershed above the meadow where the natural vegetation is disturbed.

4. Cultivation, wherein the protective sod is deliberately destroyed to expose the soil for crops.

5. Rodent activities. Because man kills off the carnivorous mammal population that naturally stabilizes their numbers, rodents sometimes increase with such rapidity that a severe damage to plant cover results. Further, the tubular burrows dug by rodents often make a sufficient break in the protective sod to permit a gully to start, and on hillsides and streambanks they constitute "pipes" which the scouring water may rapidly convert into open gullies. In certain soil types this is known to be true of the burrows dug by ground squirrels, and may be true of those made by other rodents. On the other hand, a normally balanced rodent population may be actually beneficial, as pointed out by Joseph Grinnell (1), because of the increased weathering, diffusion, and aeration of the subsoil, and (2) because the "cultivation" of the soil by the burrowing animals promotes thrifty plant growth and permits a greater percentage of rain and snow to percolate into the ground, with possible resultant lessening of floods and erosion.

Excessive grazing and abnormal floods, it should be emphasized, are the most serious and widespread threats to mountain meadows in California, and these have caused the gullying and resultant drainage of many once valuable areas which were originally covered with heavy sod. Of the causes of abnormal floods in the vicinity of mountain meadows, lumbering seems to have been the most important, with fire second. The breaking up of the protective sod is often a contributory cause of erosion, but seldom of primary importance. Cultivation in mountain meadow regions is rare, and the seriousness of rodent infestations is open to dispute, though possibly great in some localities.

#### Purpose of erosion control

The purpose of erosion control in mountain meadows is threefold:

1. To check the progress of active gullies.
2. To bring about the refilling of the deeper gullies.
3. To restore the water tables of drained meadows to their former levels.

Thus, not only control but restoration is aimed at, for with the return of moisture to the meadows the more desirable plants will, in time, again become dominant.

#### Methods of erosion control

Complete control work can be segregated into four different phases:

1. Proper range management, which includes the elimination, or at least a marked restriction of grazing until the meadow has again become stabilized.

2. The building of proper structures to cause the filling of gullies mechanically and to control erosion temporarily until natural or artificial vegetation becomes vigorous enough to make that control permanent.

3. The planting of appropriate vegetation to make control measures more effective and permanent.

4. Control of rodents, where necessary, to prevent excessive burrowing which tends to increase erosion; and to prevent their eating the young plants artificially introduced as part of the gully control.

The first three phases of the work above enumerated are discussed in detail in the chapters following. Control of rodent infestations is a specialized field handled normally in the National Forests by the Biological Survey, and will not be discussed further in this manual.

It should be emphasized that it is essential to take a long-range view of erosion control work. Ultimate restoration of optimum conditions rather than temporary repair is the objective. A program of maintenance of work already done, and continued extension and improvement of the control or restoration methods should be undertaken. Temporary structures such as herein described may fail in time unless kept in repair, and such a failure will mean a loss of all restoration accomplished in addition to the cost of reconstruction and of the years that will have to elapse until restoration is again equally established. Thus, economy dictates that control work be maintained and improved regularly until that optimum condition is reached where the water table is restored and vigorous vegetation has created stability.

## Chapter II

### CONTROL OF GRAZING

Grazing has been a leading factor contributing to erosion in mountain meadows. The erosion may result from the impoverishment of the meadow grass itself, and such impoverishment may be the result of grazing abuses on the meadow or on the immediate drainage or watershed above. Such abuses may occur in any of the following three ways.

1. Too many animals being grazed, whereby the carrying capacity of the range is exceeded. Frequently, too, the numbers of grazing animals have been adjusted to the feed available during a cycle of wet years. The continued grazing of the same number of stock during a cycle of dry years has resulted in a break-down of sod cover in critical spots in consequence of which gullies have been started.

2. Grazing too early. Damage may be excessive when stock are brought onto the area before the grass has attained sufficient growth. This results in stunted development and loss of reseeding ability of the grass. More important, the soil is usually wet and soft early in the year and the sod is readily broken up by trampling.

3. Poor distribution. Stock naturally tend to concentrate on meadows, in canyon bottoms, and in small areas near water, especially in poorly watered semi-arid regions. Consequently, especially during the warm season, the forage on such areas is usually overgrazed, because cattle do not of their own accord move onto the hill feed until cooler weather occurs and the forage has matured and become dry. The maximum grazing value of the range as a whole is thus not secured, and the meadows may be left in a depleted condition subject to erosion. The usual methods to secure proper distribution of stock (i.e. improved salting practice, water development, and occasional riding) are not always successful on many California ranges. Sometimes it may be necessary to stock the range on the basis of meadow carrying capacity alone, rather than on the basis of the meadow plus the hill or timber feed.

In undertaking control of erosion in mountain meadows, further regulation of grazing should be considered under two conditions: (A) where serious erosion and recent investment in erosion control require drastic action, and (B) where incipient or mild erosion probably can be corrected merely by changes in grazing practices.

- (A) Where a high investment has been made in control structures or in reseeding or planting, it is essential that grazing be excluded from the immediate area of the control works until conditions are again stabilized. This prevents animals from injuring the structures by trampling up and down the gully banks, and by grazing and browsing the erosion-control vegetation. This may be done by: a) fencing the controlled gully area, or b) eliminating grazing from the vicinity. Economy should dictate the choice between the two methods, but normally the former will be the cheaper because

only a short fence is usually required to enclose the eroding gullies. It should be emphasized that elimination of grazing is advocated only to protect the control works for a few years until the vegetation is sufficiently reestablished to endure normal grazing.

(B) In the absence of complete experimental data on the handling of stock in high mountain meadows with reference to its effect on erosion, long experience and careful observation indicate the advisability of the following methods:

1. Regulating the numbers of stock and the grazing season so that stock are neither brought in too early nor permitted to graze the meadow beyond its carrying capacity.

2. Preventing congestion of stock in small areas by:

- a) Where erosion is starting or is anticipated along stock trails that follow stream courses, control may be effected by putting narrow fenced exclosures partially across the valleys at intervals. Care should be taken not to build fences across narrow points in canyons, nor to build the fences all the way across valleys in such a way as to interfere too seriously with the natural movements of stock. The fenced exclosures usually consist of narrow strips possibly anywhere from 25 to 100 feet wide and extending, in length, fifty feet or more to each side of the eroded channel. These dimensions are only suggestions; actual sizes will have to be determined for each condition encountered. The purpose of the strips is to develop barriers of dense vegetation to aid in controlling erosion down the center of the valley. It will ordinarily be impracticable to graze these small areas.
- b) Where canyons widen out into meadows at intervals along their courses, it may be feasible to fence such meadow areas, and not open them for grazing until the hill feed is utilized. This may sometimes necessitate the development of water outside such enclosures. The economy of this method has not been investigated, but appears feasible in semi-arid regions.
- c) Distribution of salt and watering places away from the congested areas.



## Chapter III

### SPECIFICATIONS FOR MATERIALS

The criterion for the selection of materials for use in structures for gully control is to utilize any satisfactory materials which are most readily and most cheaply available. In some cases hauling material for several miles may be necessary, but usually material can be found close to the site which can be adapted for use. Some variation of the methods given in this manual are to be expected as the materials available will vary considerably, but in general the materials to be used in the various structures can be classified as follows:

1. Dam brush: For this material either chaparral or tree branches will be satisfactory, although the latter are usually easier to handle. It should be somewhat flexible, and usually should be green and heavily leaved. Brush that is dry and brittle is difficult to handle, and does not make a satisfactory dam. The brush should be cut into small enough pieces so that it is easy to pile into a dense mass; usually three or four feet is the maximum convenient length. All of the following have been used with success, but the list is far from complete: pine, fir, cedar, live oak, willow and orchard prunings.

2. Apron brush: The requirements for apron brush are the same as for dam brush, except that it must be long and flexible. For this reason the chaparral types are not so desirable, because long, straight, and flexible branches five to ten feet long are seldom found. Willow, and branches of the various evergreen trees are excellent.

3. Litter: This may be any fine-textured vegetative material to be used under aprons and against the upstream faces of dams. In mountain meadows the best and most readily available material is the forest litter or leaf mulch that is raked up from under the trees. In a pine forest this material consists mostly of pine needles, which are excellent. Weeds are usually good. Straw and manure are excellent materials when available. If none of the above can be obtained, any fine, dense brush such as sage may be used.

4. Trees: Where trees are specified, they should be freshly cut, and should have a dense foliage. Evergreen trees only should be used.

5. Logs: Logs should be straight and sound and of the sizes specified.

6. Posts: Any good fence post material is satisfactory. Where willow stakes are recommended they should be used if possible because they will take root and grow. Care should be exercised not to strip off the bark and to plant them right side up.

7. Stakes: Any sound coniferous wood that will not rot too quickly is good. Several coniferous woods in order of their lasting qualities are: cedar, juniper, cypress, and pine. Fir is the poorest

conifer. Or, if possible, use willow stakes where their use is recommended. Directions for cutting and planting willow stakes are given in CHAPTER VII, PLANTING CUTTINGS.

8. Poles: These should be straight and of sound wood.

9. Rock: Flat rock is far superior to round cobbles, because of less tendency to roll during floods. It may pay to haul such flat rock a considerable distance in preference to using cobbles. Rocks should never be taken from gully bottoms and other places where they act as a natural erosion preventive pavement over the soil.

10. Poultry netting: This material is commonly called "chicken wire". Any convenient width is suitable.

11. Wire: No. 9 to No. 12 galvanized iron wire is satisfactory.

## Chapter IV

### CONTROL OF GULLY-HEADS

A gully characteristically works up a stream from the lower end. A common example is where a main stream bed is quickly cut down by abnormal erosion, leaving undisturbed tributary channels "perched" at the former level. Such tributary channels cut back rapidly and, in mountain meadows, often create deep gullies where but shallow swales existed before. When there is a break in the channel gradient, a "waterfall" is formed as shown in figures 3 and 6. The falling water churns against the bare earth behind the "falls" and erodes the soil rapidly at this point. Meantime, at the crest of the waterfall the soil, held together by the roots of the meadow sod, is able to resist erosion, and as the undercutting proceeds the sod-crest begins to overhang the subsoil. From time to time chunks of this overhanging sod break off and fall into the gully. Thus the rate a gully-head works upstream depends on the soil structure and texture, on the amount of root binding material, on the maximum flow of the gully and on the gradient of the channel. But its progress will be steady until measures are taken to stop the undercutting. Figure 7 shows, in a general way, the method commonly used to check headward erosion. Figure 8 shows a gully-head controlled in this manner.

*Note how falling water undercuts gully*



Figure 6.

Side section of a gully-head showing the process of undercutting.

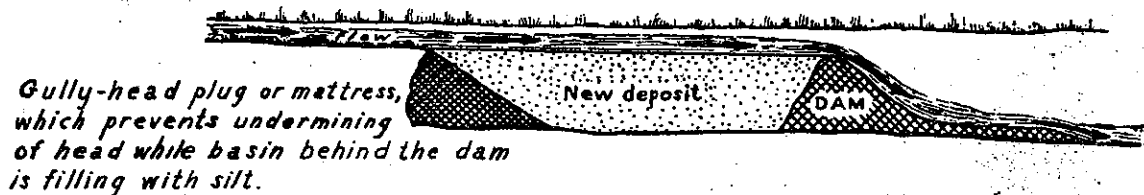


Figure 7.

Side section of a controlled gully-head.

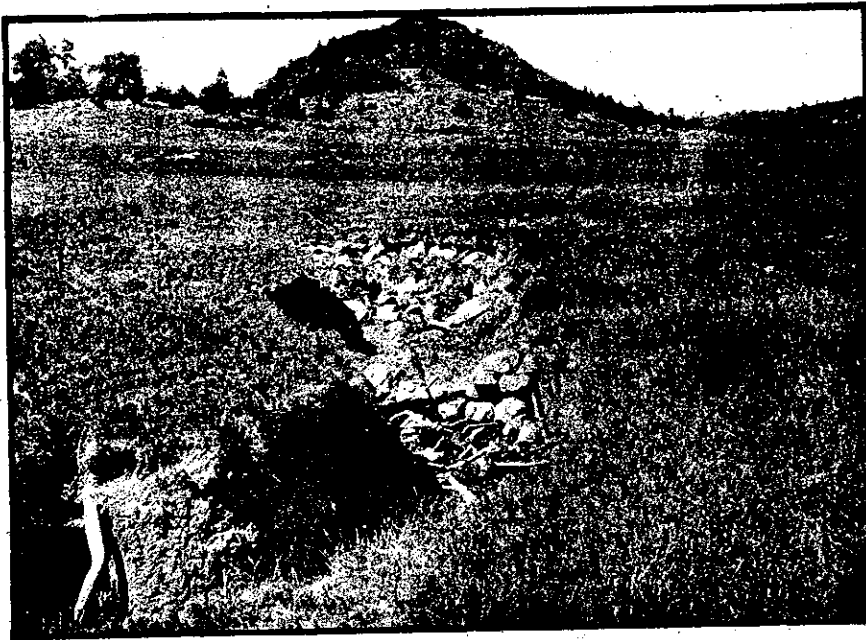


Figure 8.

An active gully-head that has been controlled with a brush and rock gully-head plug and a check dam by the method illustrated in Figure 7. Crouch's Meadow, Cleveland National Forest, California.  
 Photo No. 283990 Pillsbury 8-17-33

#### Steps in the control of gully-heads

There are generally four steps in the control of gully-heads, the first two being illustrated in Figure 7. The steps, in the order in which they are undertaken, are listed below:

1. Construction of either a plug or mattress against the gully-head. These plugs and mattresses, constructed of any suitable material, have the immediate but temporary effect of stopping the action of the waterfall in undermining the head. This effect might be only temporary, because of the possibility of a small opening starting behind the structures, which would in time allow new gullies to form and work upstream.

2. Construction of a check dam a few yards downstream from the gully-head plugs and mattresses. The catch-basin formed behind such check dams will fill with sediment within a few years, and as it will eliminate or greatly diminish the height of any drop in the streambed level between the dams and the gully-heads, the danger of a new gully starting is minimized. Such check dams should be constructed in accordance with methods described in Chapter V, CHECK DAMS.

3. The planting of appropriate vegetation. Usual methods suitable for meadow erosion control involve temporary structures. To

make control permanent, the planting of appropriate vegetation must go hand in hand with the construction of dams and gully-head plugs and mattresses. One of the most vigorous growing and otherwise satisfactory plants for this purpose found in California is the willow. Its use is fully described in Chapter VII, PLANTING CUTTINGS. Also, where there are bare slopes along the gully banks SOD PLANTING or ARTIFICIAL SEEDING should be undertaken, methods being described in Chapters VIII and X respectively.

4. The protection of structures and vegetation against browsing and trampling of livestock. As described in Chapter II, this may be done by: (a) restricting or eliminating grazing until the control has been made permanently effective, or (b) constructing a temporary fence around the gully or gully-head. It should be emphasized that some such protection is usually necessary, and that its omission may result in complete destruction of the work done.

#### Criteria for design

The following criteria should be adhered to in any control of gully-heads:

1. A compact layer of "litter" must be packed against the head itself to stop undercutting, against the side near the head to prevent side-cutting, and along the bottom to serve as a cushioning apron.

2. This litter must be firmly held in place so that it will not be washed out during floods. Usually, this calls for the use of good-sized tree branches or brush to be placed over the fine material, and that, in turn, secured in place with posts, stakes, rocks, etc.

#### Methods of controlling gully-heads

Because of different conditions encountered, it has been found necessary in California to devise five distinct methods for gully-head control. These methods are briefly described as follows:

First method: Where the channel carrying the run-off immediately above the gully-head is heavily sodded, and where there is consequently a definite overhang of the crest of at least six inches, as in figure 3, it is practical to plug the head without modifying the slope. Figures 9 to 11 illustrate how the crest overhangs, and show three types of "plugs" that can be utilized.

Second method: Where the gully-head has no definite overhang and where it slopes slightly upstream, it is advisable to cut the slope back so that the run-off will have a gradual rather than a vertical drop. To protect the bare slope so created until the catch-basin behind the downstream dam has become silted, it is necessary to cover that head-slope with a "mattress", and to extend that mattress along the bottom of the gully for four feet or more to serve as an apron. Figures 12 to 14 illustrate several types of mattresses.

Third method: Numerous situations will be encountered in the progress of erosion control work where gully-head plugs or mattresses do not appear feasible. Typical situations are:

- a. Where side gullies are branching out from main stream channels and owe their existence to the poor condition of the vegetation and to the height of the drop into the main channel rather than to any appreciable flow of water.
- b. Where the banks and heads of gullies are eroded principally by run-off from melting snow on the meadow itself.
- c. Where the gully-heads are too wide or too deep to be readily controlled by methods one or two, and are not subjected to extremely heavy flood flows.
- d. Where the headward erosion is caused more by the loose condition of the soil and lack of a binding vegetation than by any appreciable flow of water.
- e. Where the gully gradient is too steep for the construction of a dam below the gully-head and where flood flows are not great.

Such gully-heads should be sloped back to the natural angle of repose of the soil and the slope so created permanently stabilized with appropriate vegetation. Methods of stabilizing these slopes with vegetation and of constructing "wattles" for temporary mechanical control are found in Chapter IX, WATTLE CONSTRUCTION.

Fourth method: Large gully-heads can often be controlled by diverting the water away from the gully above the head by a system of ditches. The meadow is thus irrigated and increased forage results. Locations where this method can be used, however, are not common in California.

Fifth method: Flumes have sometimes been used to carry water over a gully-head. This method is not ordinarily recommended because of the expense, and because great care must be taken in construction. It is essential that the capacity of the flume be sufficient to carry extreme flood flows, and that elaborate cut-off walls be constructed at the intake to prevent any undercutting or sidecutting. The flume may be built of galvanized metal, wood, concrete, rock or brick masonry. Such installations must be regularly inspected and maintained to keep them working.

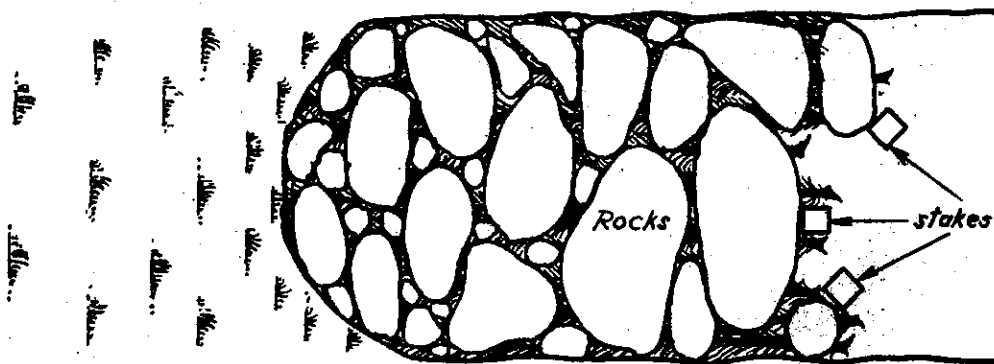
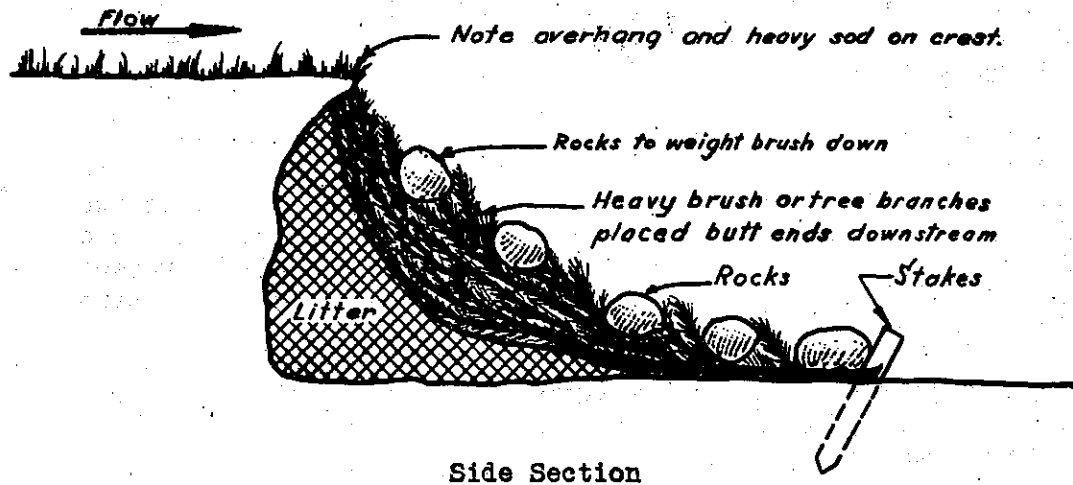
#### Suggested designs

The design of and the construction procedure for the common types of gully-head plugs and mattresses for use in mountain meadows are presented with sketches covering structures Nos. 1 to 6, inclusive.

Detailed specifications for the "litter", "brush", etc. are found in Chapter III, "SPECIFICATIONS FOR MATERIALS".

Structure No. 1 - Brush and Rock Plug

(For use where crest is well sodded and overhangs 6 inches or more.)



Plan

Figure 9

Brush and rock gully-head plug

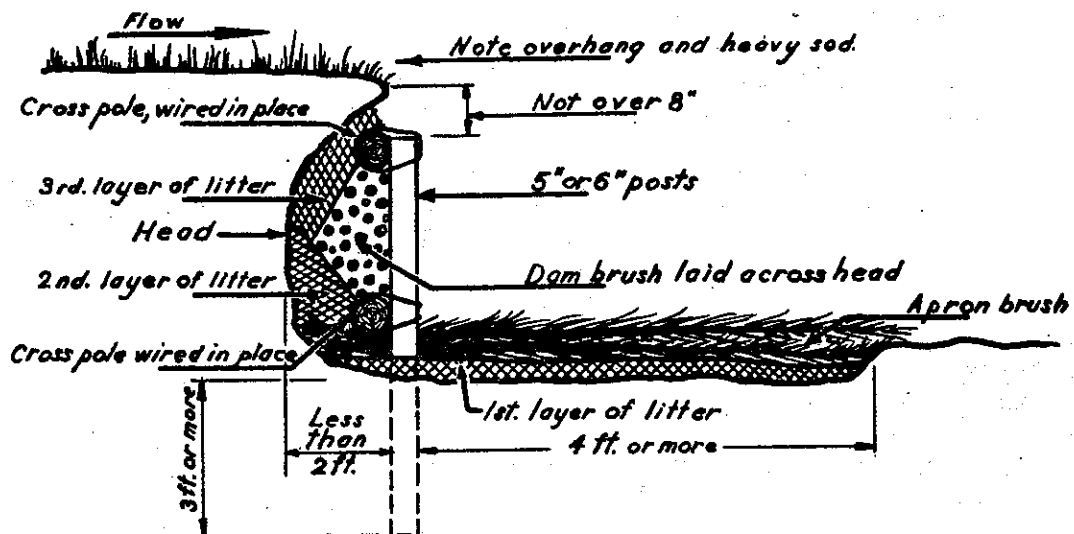
### Construction procedure

1. Place a thick, solidly packed mat of "litter" against the undercut portions of the gully-head and extending downstream about two and one-half times the height of the head, as shown in figure 9.
2. Place a layer of "apron brush" on top of the litter, as shown in the sketch. The butt-ends should point downstream. Tamp down by walking back and forth on top.
3. If the gully may be subjected to heavy flood flows, set a row of stout stakes or posts across the gully to prevent the rocks from rolling downstream. The spacing of the stakes can vary from one to two feet. Willows or cottonwoods can be used for the stakes or posts, care being taken to set them with butt-ends down so that they will grow (see Chapter VII, PLANTING CUTTINGS). Part of the work of vegetative control is thus taken care of.
4. Cover the dam brush with a layer of rocks, sufficiently heavy to stabilize the whole plug against the force of expected flood waters. Use flat rocks where possible.
5. Where it is found that the litter has fallen out of place, leaving an opening between the top of the head and the plug, this crack or opening should be packed solidly with litter and a heavy stick used to pound the material down into the opening.

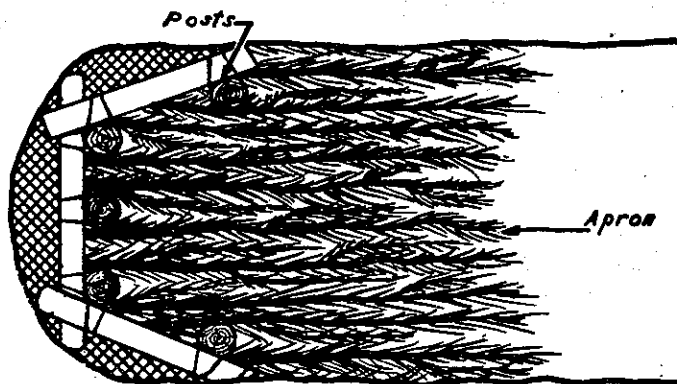


## Structure No. 2 - Post and Brush Plug

(For use where crest is well sodded, and overhangs 6 inches or more.)



Side Section



Plan

Figure 10

Brush and post gully-head plug.

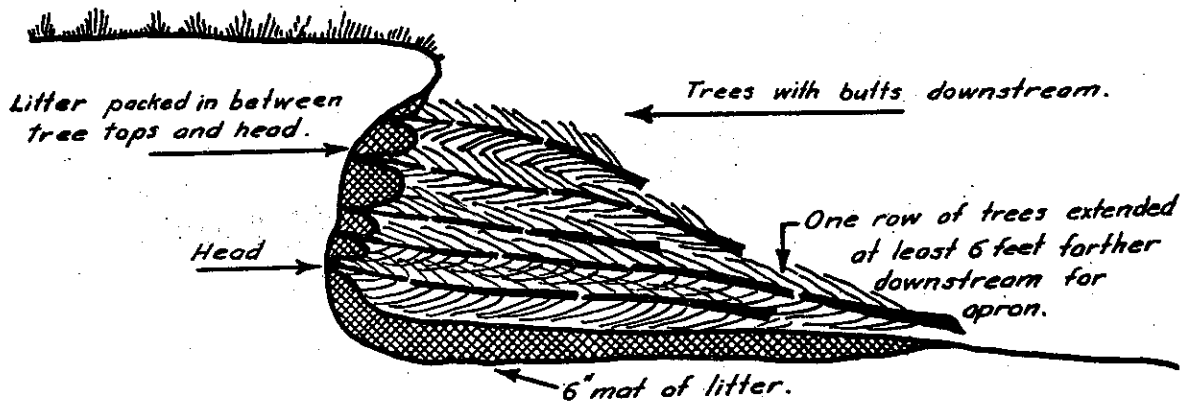
### Construction procedure

1. Cut posts 5 to 6 inches in diameter and long enough to come within 8 inches of the crest of the head and to be buried at least 3 feet. Dig post holes 2 to 3 feet apart as close to the head as possible (within 2 feet) and set posts in place.
2. Place a mat of "litter" 4 to 6 inches deep over the bottom of the gully, shown in the sketch as "1st layer of litter".
3. Place a 4-inch layer of "apron brush" on top of the litter, as shown in the sketch. Extend the butt-ends as far as possible upstream from the posts, with the top ends downstream. This brush, with the underlying litter, constitutes the apron.
4. Place lower cross poles on top of the butt-ends of the brush on the upstream side of the posts, and wire to posts and apron brush. No. 9 wire is satisfactory.
5. Place the second layer of "litter" as shown in the sketch, packing well against the gully-head.
6. Place "dam brush" across the gully on the upstream side of the posts and weight in place with upper cross poles, as shown in the sketch. If necessary, wire cross poles to posts. The cross poles must be below the crest of the head. Be sure to leave a space so that the third layer of litter can be filled in against the head.
7. Pack the third layer of litter into the space between the cross brush and the head, as shown in the sketch. A post or stout stake will be handy to pound this material into a compact mass.

It is essential that all brush be placed to "interlace" as much as possible. To accomplish this, place a few branches at a time, by hand, rather than to drop in thick bundles with all butts together so that they cannot interlock with tops or butts of other adjacent bundles. Also, never pitch the brush into place carelessly with a pitchfork.

### Structure No. 3 - Tree Plug

Where trees are available from thinning or from clearing rights-of-way for truck trails, etc., they can be used successfully for plugs provided they have heavy trunks and dense, green foliage. To be used on heads with a well-sodded overhang of 6 inches or more.



Side Section

Figure 11

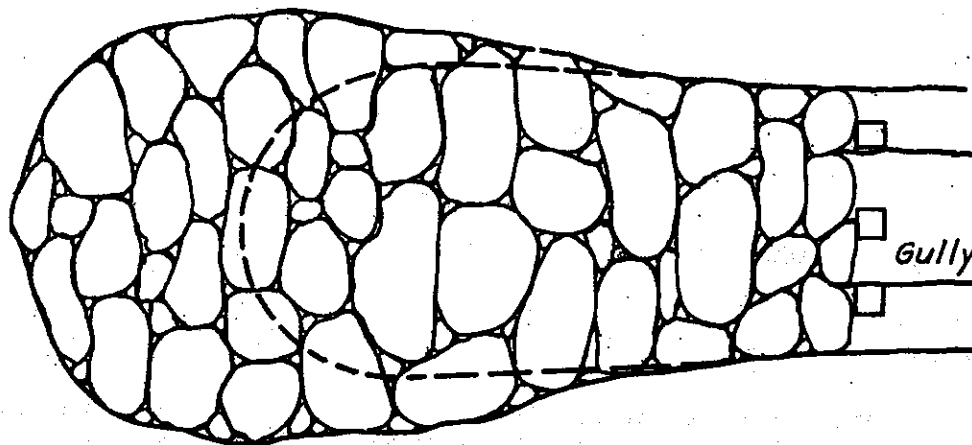
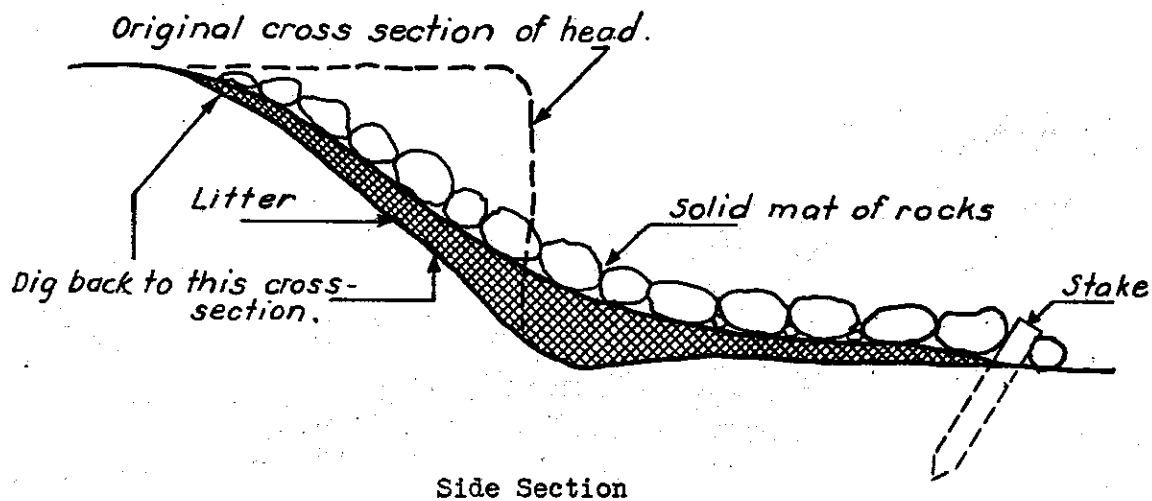
Tree gully-head plug.

#### Construction procedure

1. Lay a six-inch mat of "litter" over the gully bottom extending from the head to a point about fifteen feet downstream.
2. Lay a row of trees on the gully bottom with the butts downstream and the tops up against the head. The bottom limbs of all trees placed should be partially lopped down to make them as compact as possible.
3. Place a second row of trees about 6 feet farther downstream than the first row, with the butts downstream to serve as an apron. Branches on the under side should be partially lopped to enable trees to settle firmly into stream bed.
4. Pile trees into the gully-head with the tops as close to the head as possible, and the butts downstream. They should be piled up to the top of the gully at the banks, but should be one or two feet lower in the middle.
5. Fill in any cracks between the tree branches and the head itself with litter. Pack firmly.

#### Structure No. 4 - Rock Mattress

(For use on heads with slight or no overhang, in places where rock and litter are the only readily available materials.)



Plan  
Figure 12

#### Rock gully-head mattress

#### Construction procedure

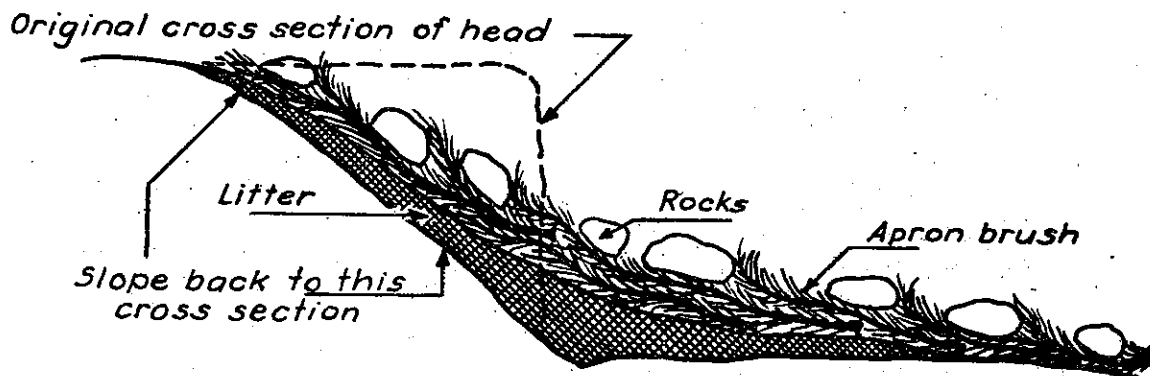
1. Slope back the gully-head and the banks near the head as shown in figure 12. This can be done by hand or with scraper or plow.
2. Place a thick layer of "litter" over the slope created and for a distance of at least five feet along the gully bottom.
3. Lay a solid mat of rock over the fine litter, starting at

the bottom, and working upstream. Flat rocks are preferred.

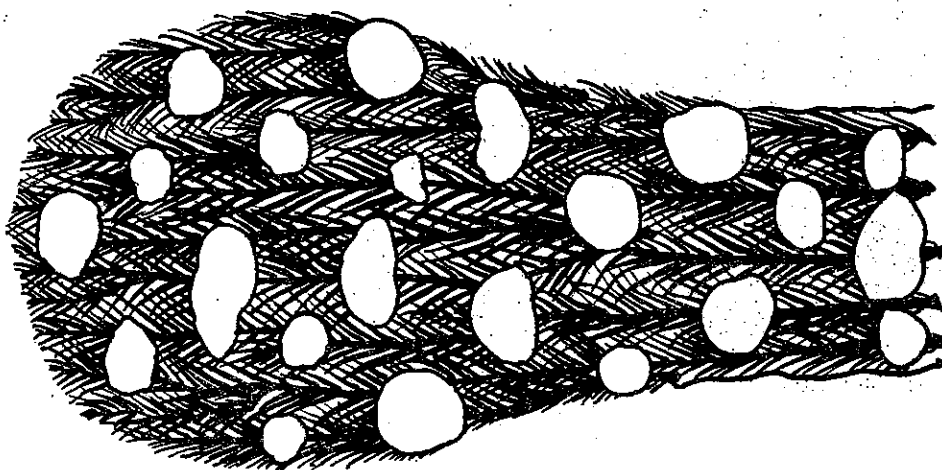
4. If there is danger of the rocks being moved in floods, drive strong stakes spaced about one foot apart across the gully bottom as shown.

Structure No. 5 - Brush and Rock Mattress

(For use on heads with slight or no overhang, where brush and rock are both available.)



Side Section



Plan

Figure 13

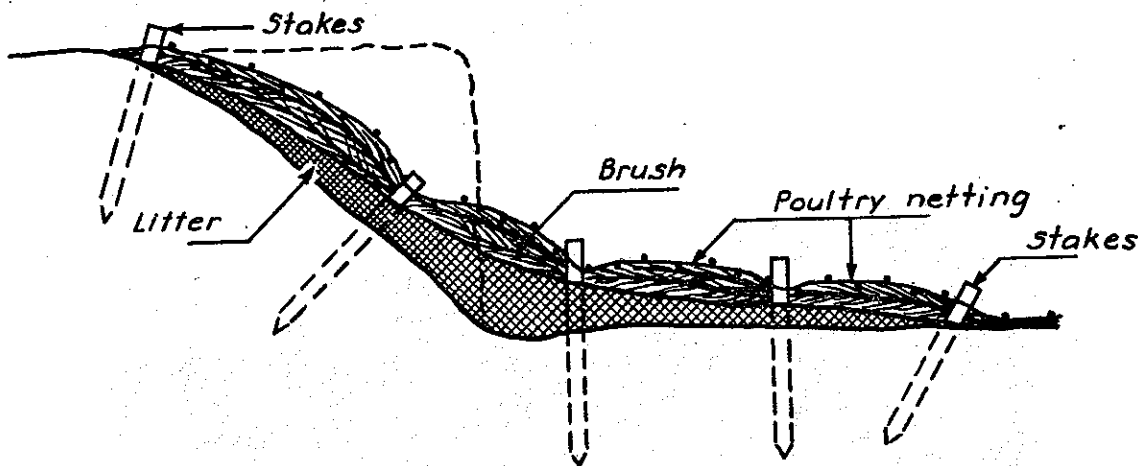
Brush and rock gully-head mattress.

### Construction procedure

1. Slope back the gully-head and the banks near the head as shown in figure 13. This can be done by hand or with scraper or plow.
2. Place a thick layer of "litter" over the slope created and at least five feet along the gully bottom.
3. Cover this material with a layer of "apron brush". Start at the downstream end, and work upstream. The butts should point downstream in all cases.
4. Weight the brush down with a sufficient number of rocks to keep the mass from being shifted by maximum floods which may flow over it. Flat rocks should be used if procurable.

### Structure No. 6 - Brush and Poultry Netting Mattress

(For use on heads with slight or no overhang, where rocks are not readily available.)



Side Section

Figure 14

Brush and poultry netting gully-head mattress.

### Construction procedure

- 1, 2 and 3. Same as for Structure No. 5.
4. Place one thickness of poultry netting over the entire mattress. Where two sections are joined, overlap about one foot.

5. Stake down as shown, forcing the netting down tight against the brush. Set downstream row of stakes first, pull netting tight, and stand on netting while setting each successive row of stakes. The stakes should be spaced about one foot apart across the mattress. They should be about two feet long. A small notch in the upstream side of the stake will aid in holding the netting down but staples, firmly driven, are more satisfactory for this purpose.

## Chapter V

### CHECK DAMS

The chief purpose of check dams in gullies, from the standpoint of erosion control, is to decrease the velocity of the water moving down the gully. By decreasing the velocity, silt is deposited in the gully instead of additional material being eroded away. With enough properly designed check dams, erosion in a gully cannot only be stopped, but the gully will be filled with the deposited silt.

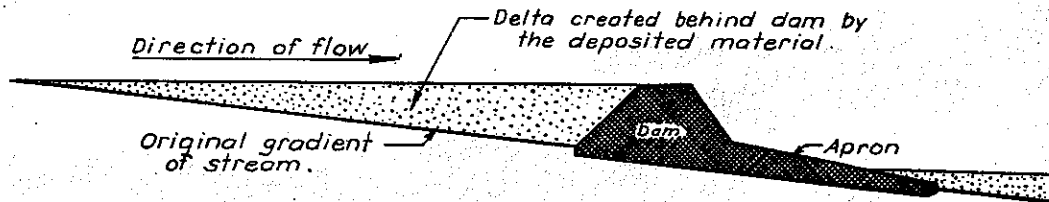


Figure 15

Side section of a gully check dam showing upstream delta formed by deposited silt.

The velocity of the flowing water is decreased by lessening the effective gradient, that is, the slope of the channel down which the water flows. Check dams do this as shown in figure 15. When the dam is first built, it effectively impedes the flow of the water by acting as a barrier and causing silt to be deposited in the catch-basin created behind. When the catch-basin is filled with silt, it is known as a "delta". See figure 16. This delta is almost completely formed; the water flows along the comparatively level surface, cascades over the dam, and is "cushioned" at the bottom against the apron. By constructing a series of such check dams along the gully, instead of having a stream channel of comparatively steep slope or gradient, there results a series of gentle slopes or deltas with "cushioned" cascades in between.

Advantages of reclaiming a gully with check dams are as follows:

1. Headward erosion is stopped (especially when built in combination with head controls).
2. The deepening and widening of the gully is stopped.
3. The formation of side gullies is stopped or minimized.
4. The area of the gully itself is reclaimed.
5. The ground water table is raised.



Of all the advantages, the last is the most important. In California, where the weather is characterized by long, dry summers, the roots of the grass in mountain meadows must obtain their moisture from a high ground water level. As illustrated in figure 4, a gully provides a channel through which ground water is drained from the meadow, and the water table becomes too low to be available to the root systems of grass and sedges. As these die out, the meadow is gradually taken over by vegetation of low forage value, such as sage and weeds, which require much less moisture and are able to survive on the limited amount held in the soil (from the winter rains) against the gravity drainage.

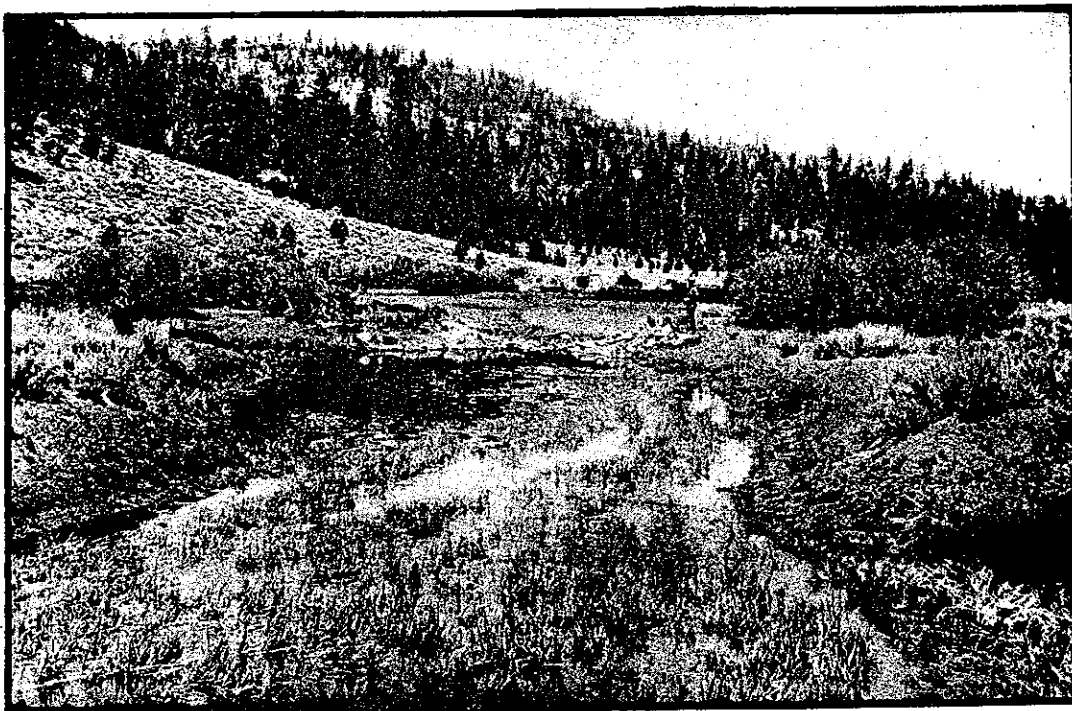


Figure 16

A catch-basin behind a mountain meadow check dam almost completely filled with silt to form a delta. The gully was originally over eight feet deep. Note that the sagebrush, once covering the meadow, is dying and is gradually being replaced by grass. Dixie Valley, Plumas National Forest, California.

Photo No. K-1069

Kraebel 6-22-33

#### General considerations

Because of the poor foundation conditions generally encountered in meadow gullies, and for the essential reason of economy, the following considerations should be adhered to in constructing check dams in mountain meadows:

1. Numerous low dams along a gully are preferred to a few high dams. A "low" check dam is considered to be not over three or four feet

in height. There is less danger of such structures washing out in time of flood, and if they should wash out less damage will result. Further, low dams are more economical than high dams.

2. It is more economical to reclaim a gully by stages, than to try to do it at one time or with one set of dams. The best method is to construct a series of low dams along the gully. When the catch-basins behind these dams have filled, another series of dams can be built on top of or just upstream from the original dams as illustrated in figure 17. One to three years will ordinarily elapse before it is necessary to construct a new set of dams, although occasionally one big storm may be sufficient to fill the catch-basins.

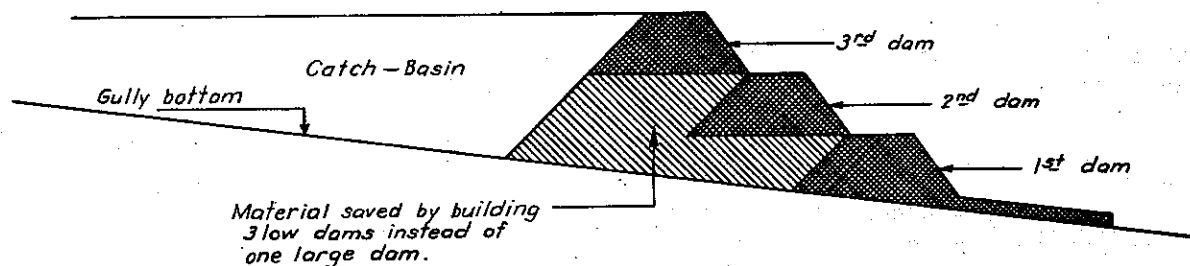


Figure 17.

Side section of a gully showing saving in constructing several low dams periodically, rather than one high dam.

3. Temporary rather than permanent check dams are usually preferred. Once a gully has been reclaimed, and the erosion properly controlled by vegetation, the check dams serve no further purpose. It has also been found that temporary semi-pervious dams, consisting in part of brush, forest litter and other such material, are more effective in reclaiming gullies than more impervious dams. While the dams should be of a semi-pervious and temporary nature, leaving permanent control of the reclaimed meadow to be obtained by proper vegetative methods, it should not be assumed that dams need not be carefully designed and built.

#### Criteria for dam locations

1. Spacing: The spacing between dams, i.e. the "interval", depends upon the gradient of the gully. The minimum interval used should bring the crest of one dam level with the apron of the one next above. Dams may have a somewhat greater interval than this minimum spacing, but the catch-basins behind a series of dams should cover at least one-half of the total length of the gully.

2. Key locations: Dams can be more economically built, and can be made more effective and stable if placed in key locations such as:

- (a) Immediately below the conjunction of two or more gullies. In that way, one dam is made to create two or more catch-basins, and its effectiveness is thereby increased.
- (b) At narrow points of the gully, where a dam of certain height can be built with less material than can one in a wider place.
- (c) At points where the gully is not eroding as rapidly as at other points, either because of a gentler gradient, better foundation material such as rock in the gully bottoms, or because of the protection afforded by vegetation.

#### General Specifications

1. Cost: Check dams should be as cheaply built as possible to realize the greatest return on the investment. This involves the use of those suitable materials which are most readily available, and the wisest use of man-power and equipment.

2. Vegetation for permanence: Either by artificial revegetation, or by the protection of the natural vegetation in the gully and in the watershed above, the control value of vegetation must be utilized to the fullest possible extent.

3. Adequate spillway: Provision must be made to pass flood flows safely over the dam. This necessitates a low center as shown in figure 18, which draws the overflow towards the middle of the channel, so that there is no tendency to cut around the dam. The dam at the sides must be built sufficiently higher than the center so that a space is provided of sufficient cross-section to pass off the maximum floods. Usually, in high mountain meadows without large watersheds behind them, it will be found sufficient to build the sides one to three feet higher than the center.

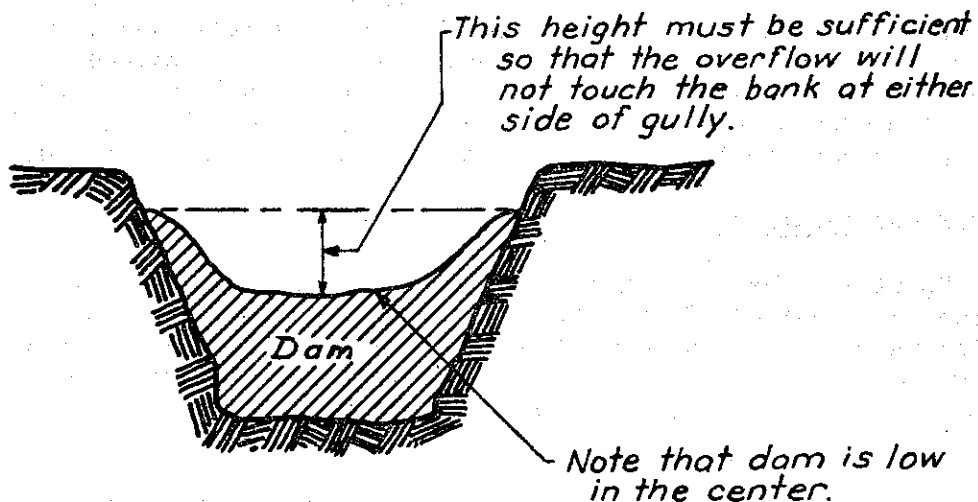


Figure 18  
Elevation of gully showing low-center spillway.

4. Apron: An apron below the downstream face of the dam is essential to prevent the falling water from undercutting the dam. Such an apron is shown figuratively in figure 19. The aprons are usually built by placing a layer of forest litter, pine needles, straw, or fine green brush across the gully bottom and sides, and covering with heavy anchored brush, rocks, wire netting or other material to keep the water from lifting or floating bits of the apron downstream. Where sage can be used for the lower layer of the apron it can be pulled from the meadow at the gully edges and thus hasten the recovery of the better forage plants.

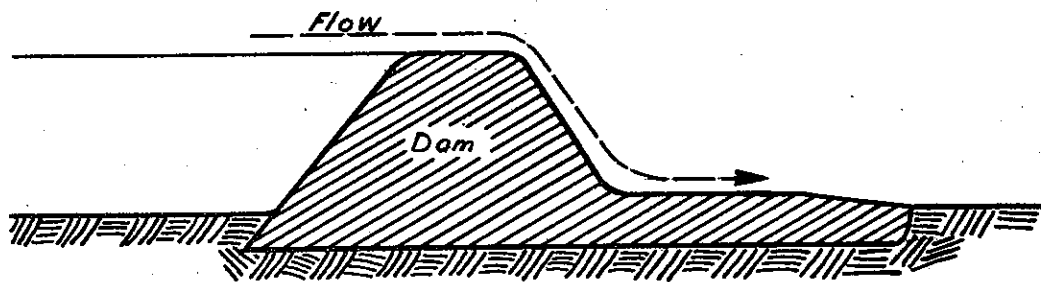


Figure 19

Side section at check dam showing downstream apron.

5. Sealing the dam: While check dams are not intended to be impervious, material should be placed against the upstream face fine enough and stable enough to prevent large cracks or "pipes" opening through the dam where sufficient water can pass to undercut the structure. Forest litter, pine needles, straw, sage or other fine, green brush have been found most satisfactory for this purpose. This fine material should be packed against the upstream face of the dam and into all the cracks and openings.

Sometimes additional layers of clay or other fine earth have been placed on the upstream faces of the dams. This may make a dam more nearly impervious, but because dams may settle after being built, cracks may form in the clay fill and may cause a washout.

The catch-basin above a check dam should not be filled with loose brush, as this tends to remove the litter and silt from the water which would otherwise aid further in sealing the dam.

6. Height of dams: As previously stated, there should be numerous small dams rather than a few high dams. A maximum height of three or four feet has generally been found best in mountain meadows.

#### Construction of Check Dams

Specific instructions for constructing various types of check dams

follow under directions for structures Nos. 7 to 13, inclusive. Designs will therein be found that can be fitted to the conditions and to the materials available in most mountain meadows in California.

#### Structure No. 7 - Single-Row Post-Brush Dam (2)

This type of dam has not been used extensively in California, but it appears to be well suited to many conditions encountered.

This dam is suitable for gullies up to five feet deep and up to fifteen feet wide, as shown in figure 20. Figures 21 to 24 illustrate the method of construction.

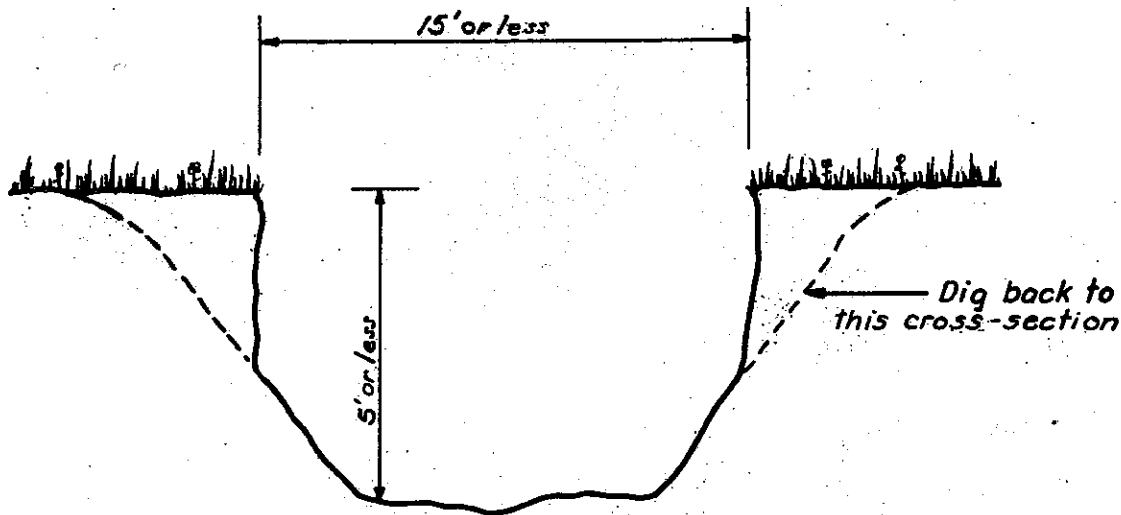


Figure 20

Cross-section of gully showing maximum gully size for best use of the single-row post-brush dam.

#### Materials required:

- 2 to 4 - posts with 4 inch tops and about 6 feet long
- 2 to 4 - stakes, 3 inches diameter, 3 feet long

(Note: Posts and stakes cut from willow trees and planted right side up are excellent because they will sprout and grow. If willows are not available, cedar makes good posts.)

- 2 - poles, 3 to 4 inches in diameter, 6 feet long
- 20 - staples
- 15 - feet of No. 9 galvanized wire
- dam brush, apron brush and litter.

---

(2) Data from Extension Circular 741, University of Nebraska Agricultural College.

## Construction procedure

1. Slope back the banks, if too steep, as shown in figure 20. Throw the fresh dirt upstream from the dam.

2. Set posts of sound wood with 4-inch tops. The center posts should be long enough so that they can be buried 3 to 3½ feet, and extend up to within one or two feet of the top of the gully bank. The outer posts need not be set quite so deep but should extend higher as shown in figure 21. Space the posts 2 feet apart. Willow posts are recommended.

3. Set 2 to 4 stakes 3 inches in diameter and 3 feet long, as shown in figure 21. Use willow, if possible, and plant right side up so they will sprout.

4. Place a 6-inch layer of "litter" between the posts, and on the gully bottom and sides downstream from the posts for about 6 feet.

5. Place brush or green tree branches as shown in figures 22 to 24, inclusive. The long, straight limbs, "apron brush", should be placed in a layer across the bottom. For the rest of the dam, the shorter "dam brush" should be used. The butt ends should be placed upstream. Usually, the gully can be almost filled with brush and when the cross poles are placed, the brush will be forced down into a compact mass.

6. Place the cross poles on the upstream side of the posts. One or two men should stand on these poles to



Figure 21

Elevation of gully after banks have been dug back. The posts have been set, and the layer of litter has been placed.

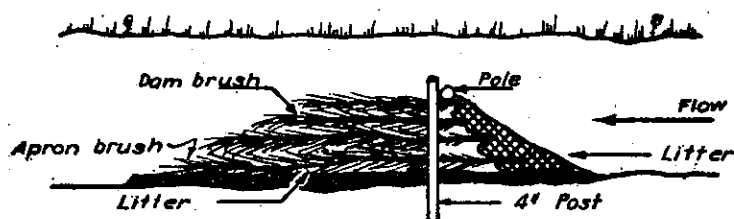


Figure 22

Side section of completed dam. Note that the longer brush is on the bottom to form an apron.

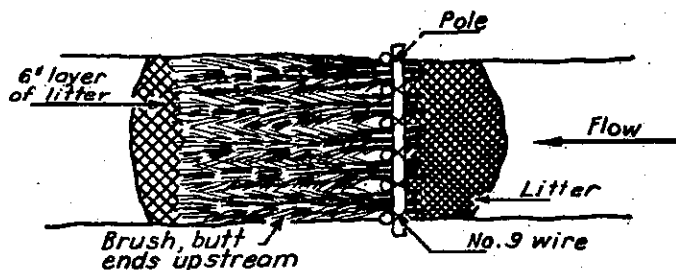


Figure 23

Plan of completed dam. Note that the brush is carefully piled and tramped, with the butt ends laid upstream between the posts.

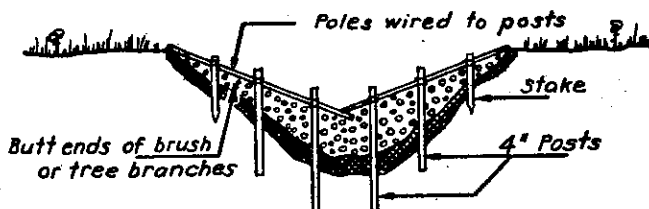


Figure 24

Elevation of dam, looking downstream, complete except for litter against upstream face.

compress the brush properly while the poles are being wired to the posts and stakes with No. 9 galvanized wire.

7. Place a layer of "litter" against the upstream face of the dam, and carefully pack into the openings between the butt-ends of the brush.

#### Structure No. 8 - Double-Row Post-Brush Dam (2)

This type of dam has been used most on gullies fifteen to twenty feet wide and five to seven feet deep. However, it may safely be used on much larger mountain meadow gullies, provided the center height of the dam does not exceed about four feet.

#### Materials required:

1. Posts: The center posts should be 8 to 8½ feet long and 6 to 8 inches in diameter, but shorter posts may be used at the side of the ditch and may be only 4 to 6 inches in diameter. Willow posts are excellent.

2. Wire: About 3½ feet of No. 9, soft, galvanized wire is required for each foot of width of the gully from bank to bank.

3. "Apron brush", "dam brush" and "litter".

4. Stakes: 2 to 3 feet long. Use willow if possible.

#### Construction procedure

1. Slope banks back, if too steep, as shown in figure 25. Throw the loose dirt upstream from the dam.

2. Set posts as shown in figure 26.

3. Place 6-inch layer of "litter" on gully bottom and banks extending about ten feet downstream from the posts, as shown in figures 26 and 27.

4. Place about one-foot layer of "apron brush", butts upstream and hooked to the lower row of posts as shown in figure 27. This brush should extend downstream about ten feet or more.

5. Drive a row of stakes across the gully through the middle of the apron and wire the limbs down to form a dense mat. Willow stakes are preferable.

6. Entirely fill the space between the two lines of posts with "dam brush" laid cross-ways of the gully. Thoroughly pack and pile above the tops of the posts for a foot or more.

7. Staple wire to a post at one end, stretch tight, and thread

---

(2) Data from Extension Circular 741, University of Nebraska Agricultural College.

back and forth as shown in figure 29. It is usually necessary to have one or more men stand on the brush while wiring to help force the brush into a compact mass.

8. Place litter against the upstream face of the dam, as shown in figures 28 and 29.

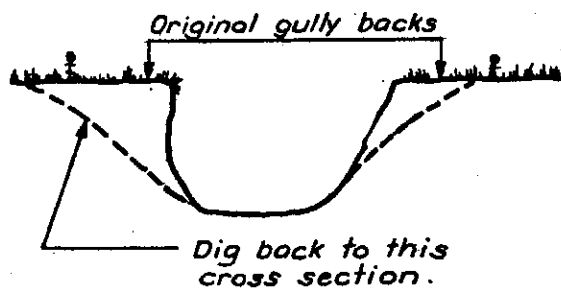


Figure 25

Sectional elevation of gully showing how banks should be sloped back.

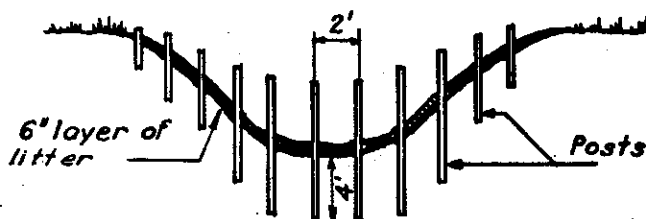


Figure 26

Sectional elevation of gully showing posts and litter in place for dam. Note that the posts are lower in the center.

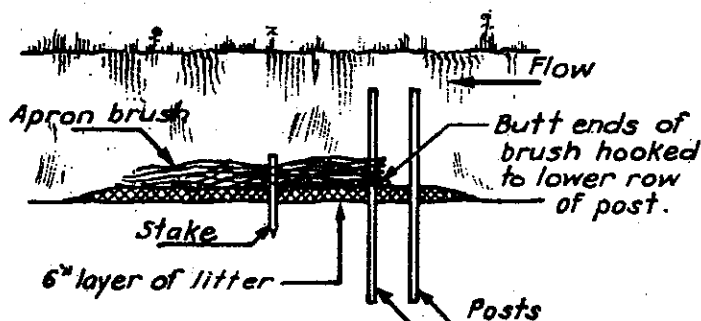


Figure 27

Side section of dam after apron brush has been placed.

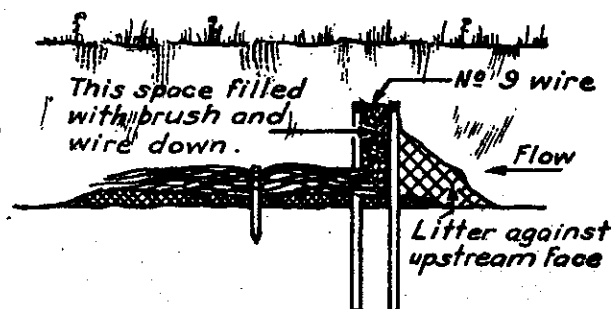


Figure 28

Side section of completed dam.

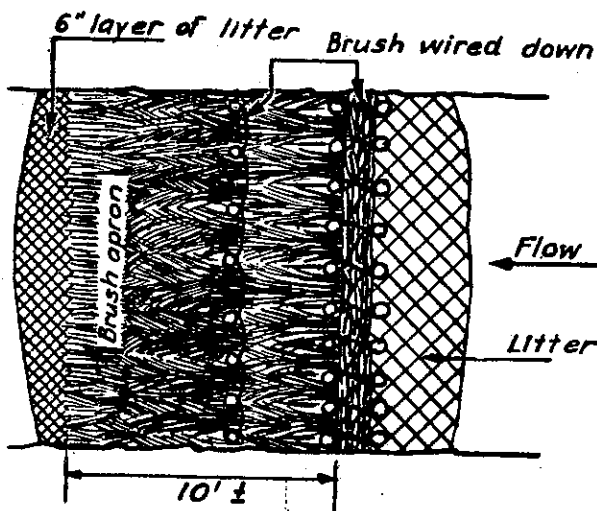


Figure 29

Plan of completed dam.



### Structure No. 9 - Brush-and-Rock Dam

An excellent dam where rock and brush are plentiful but considerably more brush is required than for structures Nos. 7 and 8. Figures 32 and 33 show two views of such a dam just after completion.

Materials: Apron brush, dam brush, litter and rock.

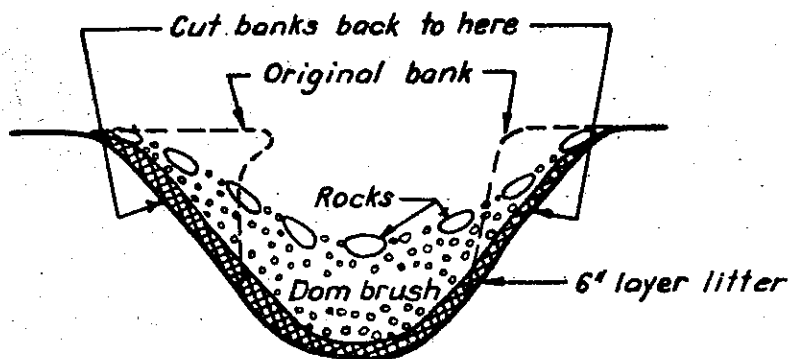


Figure 30  
Sectional elevation of gully showing brush-and-rock dam.

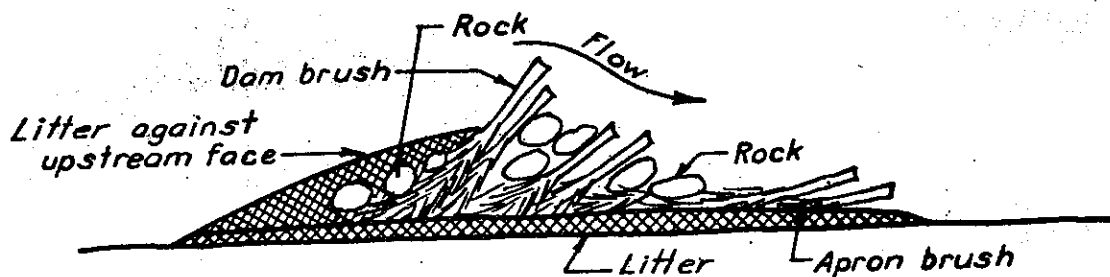


Figure 31  
Side section of brush-and-rock dam.

### Construction procedure

1. If banks where the dam is to be located are nearly vertical, they should be sloped back for a distance of 12 to 15 feet as shown in figure 30. The loose earth should be thrown upstream from the dam.
2. Place a 6-inch layer of "litter" along the gully bottom and sides for a distance of 12 to 15 feet, as shown in figures 30 and 31.
3. Across the gully, on top of the downstream end of the layer of litter, place an 8-inch layer of "apron brush", as shown in figure 31. The butt-ends of the brush should point downstream.
4. Near the upstream end of the apron brush lay a row of rocks about one foot high across the gully on top of the brush. Flat rocks are superior to round rocks.
5. Place about a 4-foot layer of loose "dam brush" across the gully with the butt-ends pointing downstream and extending just over the top of the row of rocks.
6. Lay a row of rocks across the middle of this layer of dam brush; at the same time walking on the brush to tamp it down. Flat rocks should be used if available, and the row should be about 1½ feet high. The weight of the rocks should compress the brush until the dam is only about 2 feet high.
7. In a similar manner, place a layer of "dam brush" on the upstream side of this row of rock.
8. Weight this last layer of brush down with sufficient rock to hold the brush in place.
9. Place a four-inch layer of "litter" against the upstream face of the dam.



**Figure 32**

Looking across brush and rock dam during construction. Note the three rows of rocks holding the brush down. The center height is three feet. Lower Doane Valley, Cleveland National Forest, California.  
Photo No. 284004

Pillsbury 9-5-33



**Figure 33**

Looking downstream at brush and rock dam shown in figure 32 after completion. The litter on the upstream face is pine needle. In the lower left-hand corner of the picture there is a gully-head controlled with a brush and rock plug.  
Photo No. 284002

Pillsbury 9-5-33

### Structure No. 10 - Brush-and-Poultry-Netting Dam

(A satisfactory dam in small gullies up to 10 or 12 feet wide where "dam brush" is plentiful, but rock is scarce.)

Materials required: Dam brush, poultry netting, staples and stakes or a few rocks.

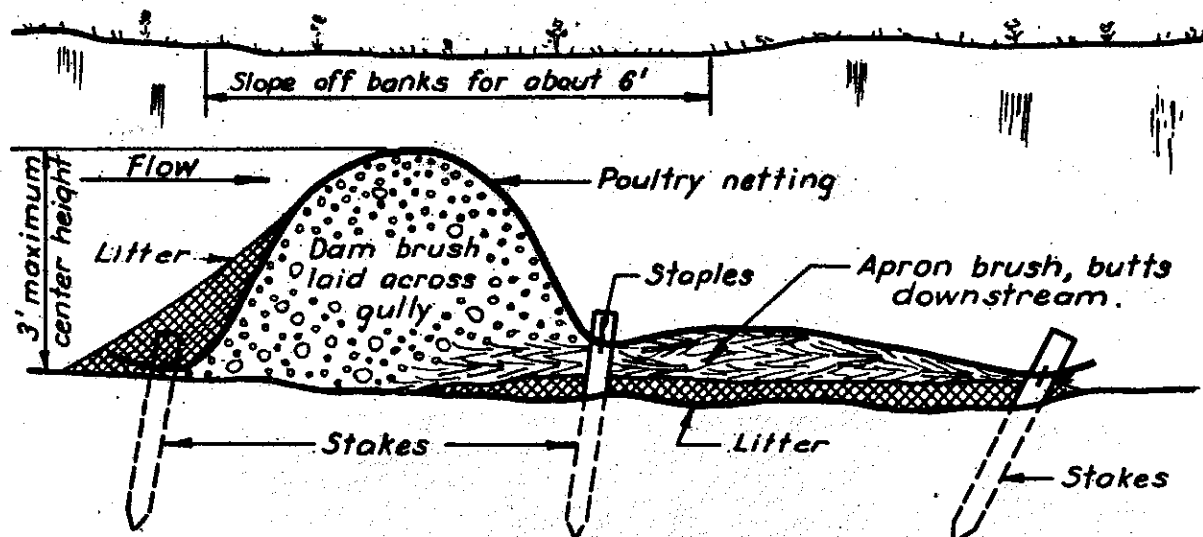


Figure 34  
Side section of brush-and-poultry-netting dam.

#### Construction procedure

1. If banks are vertical, slope them back to the natural angle of repose for a distance of about 6 feet where the dam is to be located.
2. Place a 4 to 6-inch layer of "litter" for a distance of 8 or 10 feet along the bottom and sides of the gully.
3. Cover the litter with a layer of "apron brush" about 8 or 10 inches thick when loose and with the butt-ends pointing downstream. If necessary, "dam brush" can be used in place of apron brush.
4. Cut poultry netting into about 18 foot lengths. Lay over the apron, as shown in figure 34, and stake at the downstream end of the apron. The stakes should be at least 3 feet long. They should be of willow, if possible. Before the stakes are completely driven, staple the netting to them so that it will be firmly anchored down as the stakes are driven the rest of the way.
5. Similarly, stake the netting down at a point 6 feet upstream, walking on the apron so that it is more readily forced down into a compact layer. If necessary, put in additional stakes wherever the apron

tends to bulk up. Fold the remaining lengths of poultry netting back over the apron while the "dam brush" is being placed.

6. Place the "dam brush" in a compact interwoven mass across the gully and up the banks, building up so that it will have a center height of about 3 feet when finally forced down by the netting. This will require that the brush be piled loosely to a height of 6 feet or more. The branches should be laid crosswise of the gully.

7. Pull the loose ends of the poultry netting over the "dam brush" and stake down as shown in figure 34. The stakes should be similar to those previously used. It will probably be necessary to have one or two men stand on top of the dam while staking the netting down, otherwise the brush may not be forced into a compact mass.

8. Place a layer of litter across the upstream face of the dam when the structure is complete.

Note: Sometimes rock is used to weight down the edges of the poultry netting when difficulty is encountered in driving stakes into the gully bottom. Such a dam is shown in figure 35.

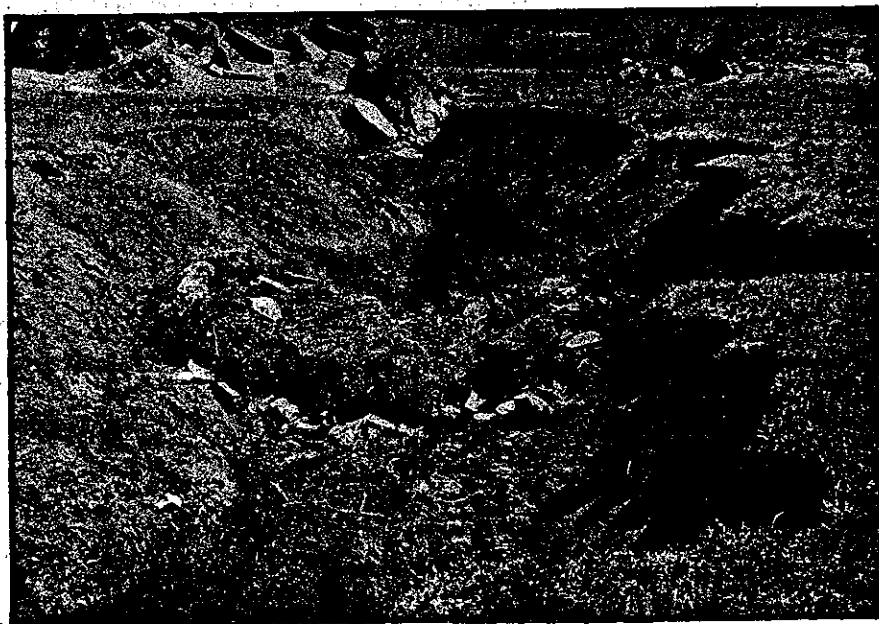


Figure 35

A small brush and poultry netting dam in a mountain meadow gully. The poultry netting is held down with rocks. The dam has a center height of two feet. A somewhat greater height could have been obtained if the brush on the upstream end had been piled crosswise of the gully. The gully is to be controlled progressively, that is, the height of the dam is to be increased as soon as the catch-basin behind has filled with silt. Photo No. 283987 Pillsbury 8-17-33

### Structure No. 11 - Tree Dam

(A good type of dam in localities where small trees are plentiful, need thinning or where they are being cut to clear rights-of-way, etc.)

Materials required: Small green, densely foliated trees and "litter".

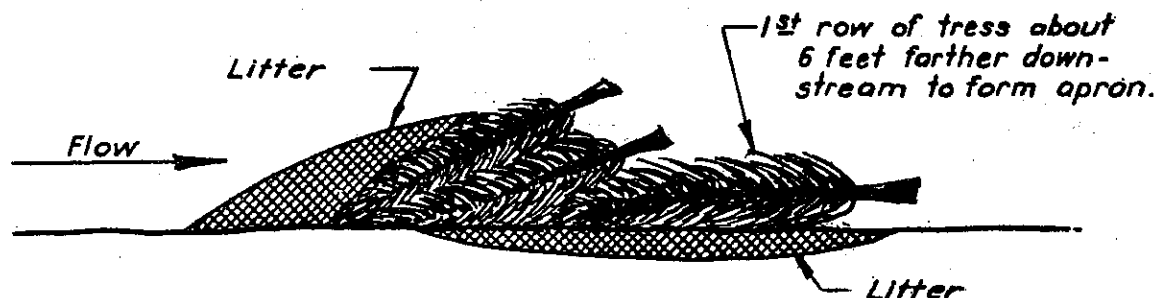


Figure 36  
Side section of tree dam.

#### Construction procedure

1. Slope banks back if nearly vertical. Throw the loosened earth upstream from the dam.

2. If needed, lay a 6-inch layer of "litter" along the bottom and sides of the gully for a distance of about 8 feet. This should be under where the first row of trees is to be placed for the apron.

(Note: The layer of litter under the apron is unnecessary if there is a good cover of sod on the gully bottom.)

3. Lay the first row of trees, butts downstream, across the gully and up the sides to provide the apron.

4. As shown in figure 36, lay several layers of trees, butts downstream, across the gully bottom and up the sides so that the butt-ends are up on the apron trees and the top ends are in the gully bottom. They should be piled 3 to 4 feet high in the center and several feet higher on the banks.

5. The effectiveness of the dam will be improved if a layer of litter is placed against the upstream face of the dam.

## Structure No. 12 - Simple Tree Dam

(This is a simplification of the tree dam constructed without an apron. It is suitable where an apron is unnecessary, (1) because of a solid rock bottomed gully, or (2) because the dams are placed close enough together so that the crest of one is on a level with the bottom of the next one above, and the gully bottom is heavily sodded. The dams are not impervious. The water all seeps through the dam, which is not overtopped until the basin behind has completely filled with sediment. While the water percolates through the dam, the sod is sufficient to prevent erosion, and after the delta has been created and water flows over the crest, the basin of the dam below acts as a cushion to break the force of the waterfall. These simple tree dams are useful where the height of the dams is to be increased year by year.)

Materials required: Small green trees, 2 long logs or poles, and litter.

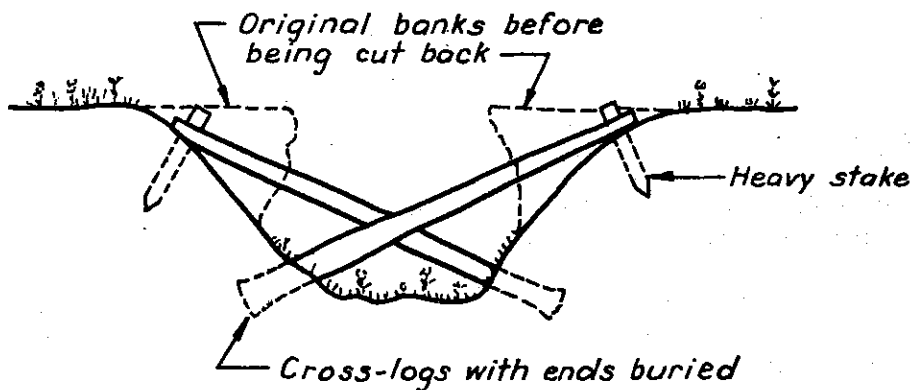


Figure 37

Sectional elevation of gully showing cross-logs placed for a simple tree dam.

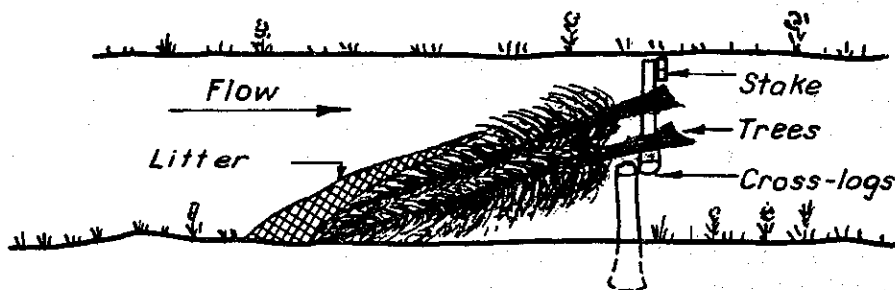


Figure 38

Side section of gully showing simple tree dam.

### Construction procedure

1. If banks are steep and unstable, cut back as shown in figure 37.
2. Place two stout cross-logs (or poles) across the gully, burying the butt-ends as shown in figure 37.
3. Drive stout stakes in the ground on the downstream side of the logs near the top of the banks, as shown in figure 37. Willow stakes should be used, if available. They should be at least 3 feet long and about 4 inches in diameter.
4. Place the butt-ends of the trees up on, and extending 2 or 3 feet over, the cross-logs. The top ends should rest on the gully bottom upstream from the cross-logs. Pile in sufficient trees to make a dense dam. They should be extended on up the sides of the gully so that there will be no danger of side-cutting.
5. The dam will often be somewhat more effective if a layer of "litter" is placed against the upstream face.



### Structure No. 13 - Loose Rock Dam

(Suitable where there is ample rock and very little brush.)

Materials required: Rock and litter.

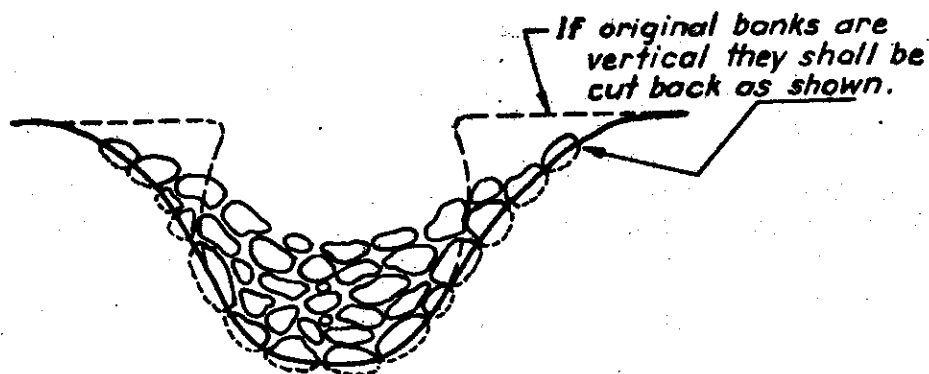


Figure 39  
Section of gully showing loose rock dam.

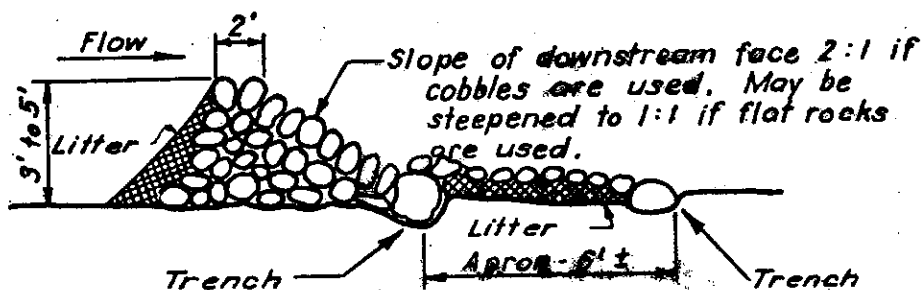


Figure 40  
Side section of gully showing loose rock dam.

### Construction procedure

1. If banks are too steep, slope back as shown in figure 39. Throw loose dirt upstream from the dam.
2. Cut a 4 to 6 inch trench across gully and up the sides to anchor the heavy rocks on the downstream toe of the dam.
3. Place a row of large rocks along this trench to form the downstream toe. Build back from this row. The rocks, especially on the downstream face, should be toed upward so that they will be keyed in place, as shown in figure 40. Note that the flatter rocks are used on this face.
4. About 6 feet downstream from the downstream toe of the dam cut a 4 to 6 inch trench across the gully, as shown in figure 40.
5. Lay a row of heavy rocks in this trench across the gully.
6. Place a 4-inch layer of litter in the space between this row

of rocks and the row at the toe of the dam. Extend this layer well up the banks.

7. Cover the litter with a solid pavement of rock.

8. Place a thick layer of litter over the upstream face of the dam when completed.

#### SUMMARY

The 7 types of check dams above described are believed, from experience, the most economical and best adapted to the control of erosion in mountain meadows. It is not believed that they are entirely suitable for the wide arroyos, washes, and gulches of semi-arid and arid regions, and they are not recommended for such localities.

The importance of "brush" and "litter" in the dams cannot be stressed too greatly. Massive materials, such as logs and rock, used alone are dangerous because of the tendency of water to form "pipes" along the sides of the material, which often cause the structures to be undercut or permit low flows to carry away gradually the deltas formed in times of flood. Brush and litter, on the other hand, gradually become wedged in the cracks and "pipes" and seal the dam as the basin fills with sediment.

Light weight brush dams, without stakes, posts, or rocks, to anchor them, might float downstream under water pressure; so all designs provide at least temporarily for such anchorage. However, the filling of the spaces between the brush with silt soon anchors the dams and binds them in place.

## Chapter VI

### CHANNEL CONTROL

Mountain meadow channel control consists, essentially, in stabilizing the banks of well established gullies and stream channels which traverse or border the meadows. Meandering streams requiring control with jetties, riprap and similar structures are seldom, if ever, encountered in mountain meadows. The control work, therefore, consists mainly of (1) bank fixation by sloping back and stabilizing eroding banks, (2) planting willows and other vegetation along the banks to stop cutting, (3) the building of light structures to break the force of the water and (4) filling washes with logging slash or similar material such as tree-tops, branches and trash left from the cutting of posts.

#### Bank fixation

Bank fixation consists in sloping back the banks of gullies and streams to the natural angle of repose of the soil, so that they will be sufficiently stable to be covered with vegetation either naturally or artificially. Normally banks of about 70% slope are stable, but some soils may be stable at steeper angles. Most meadow gully banks will become overgrown naturally when sloped back. Where artificial vegetation is required, sod should be planted or the slopes seeded. Instructions for doing this are given in Chapter VIII, SOD PLANTING, and Chapter X, ARTIFICIAL SEEDING. Where the channel sides become loose and erode during rains, "wattles" should be constructed to stabilize them. This work is described in Chapter IX, WATTLE CONSTRUCTION.

#### Protection against side cutting

Normally, in mountain meadows, vegetation planted along a gully bank furnishes sufficient protection against side cutting in meandering channels. Vegetative methods usually employed consist in planting the slopes with willows, mule-fat (*Baccharis*), or other similar shrubs, and in seeding the slopes with grass or planting sod. Methods employed in planting cuttings are found under Chapter VII, PLANTING CUTTINGS; methods employed in seeding are described in Chapter X, ARTIFICIAL SEEDING. SOD PLANTING is described in Chapter VIII.

In case the cutting is so rapid that mechanical means must be employed to protect the vegetation until it becomes established, brush and trees can be anchored to the eroding banks, or fences can be built to break the force of the current and possibly cause it to deposit silt. Typical illustrations of such control are shown in figure 41. The methods to be employed depend so much upon the conditions encountered and on the materials available that detailed directions cannot be given.

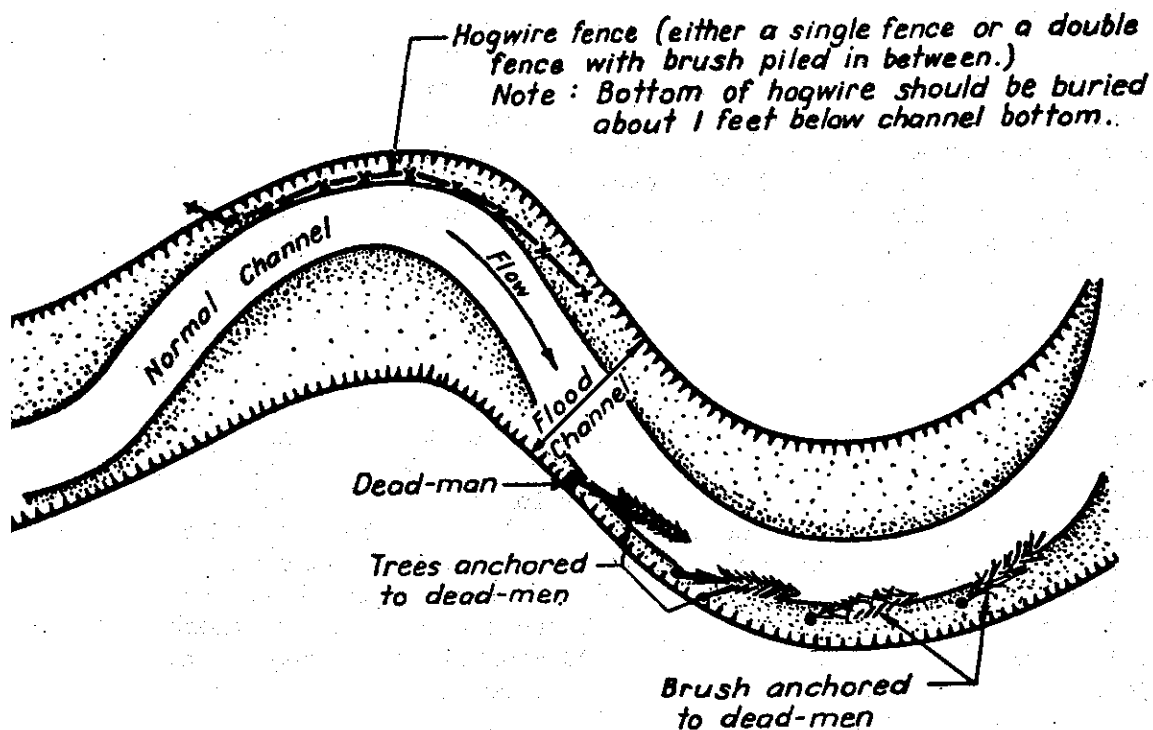


Figure 41

Plan of meandering stream channel showing several types of mechanical obstructions to control bank erosion.



Figure 42

Disposal of snags in a meadow gully. The channel has been completely filled to force flood flows to spread out and irrigate the meadow. Carmen Valley, Tahoe National Forest, California.  
 Photo No. 279012  
 Pillsbury 7-17-33

### Slash disposal in gullies

Where, in the progress of other improvement work, considerable brush and snags are accumulated, this material can well be used in channel improvement and control. Sometimes such material is used in the construction of check dams, but where check dams are not needed or where the material is not suitable, it can still be used for channel improvement.

In general, the method consists in spreading the material along the channel, care being taken to adhere to the following principles:

1. Do not make haphazard dams, but pack the material uniformly along the bottom and sides of the channel. Crude dams are liable to wash out and cause considerable damage. Sometimes it pays to drive a few stakes to keep the material in place.

2. The tops of the branches should always lie upstream. In such position they become more readily silted in place and there is less danger of forming "pipes".

3. Do not fill the gully unless it is desired to spread the water over the meadow area.

4. Weight down light material with heavy material.

5. Cut up stiff brush into small pieces.

6. Pack the trash higher on the sides of the channel than in the center.

## Preface to Chapters VII, VIII, IX, and X

### USE OF VEGETATION

Structures built to control gullying in mountain meadows are, in general, of a temporary nature. Vegetation must be depended on to make this control permanent. Ordinarily, controlled gullies will revegetate naturally in time, but, to hasten vegetative growth and to make it more effective, planting and seeding should be resorted to in many places.

Chapters VII, VIII, and X deal with the planting of cuttings, the planting of sod, and artificial seeding, respectively. These are the principal vegetative methods employed in erosion control in mountain meadows, and it should be emphasized that such of these vegetative methods as are appropriate to the locality should be included in all projects as a most desirable supplement to check dam or other mechanical control methods.

Chapter IX deals with the construction of "wattles" which offer both vegetative and mechanical protection to slopes which cannot feasibly be controlled in other ways.

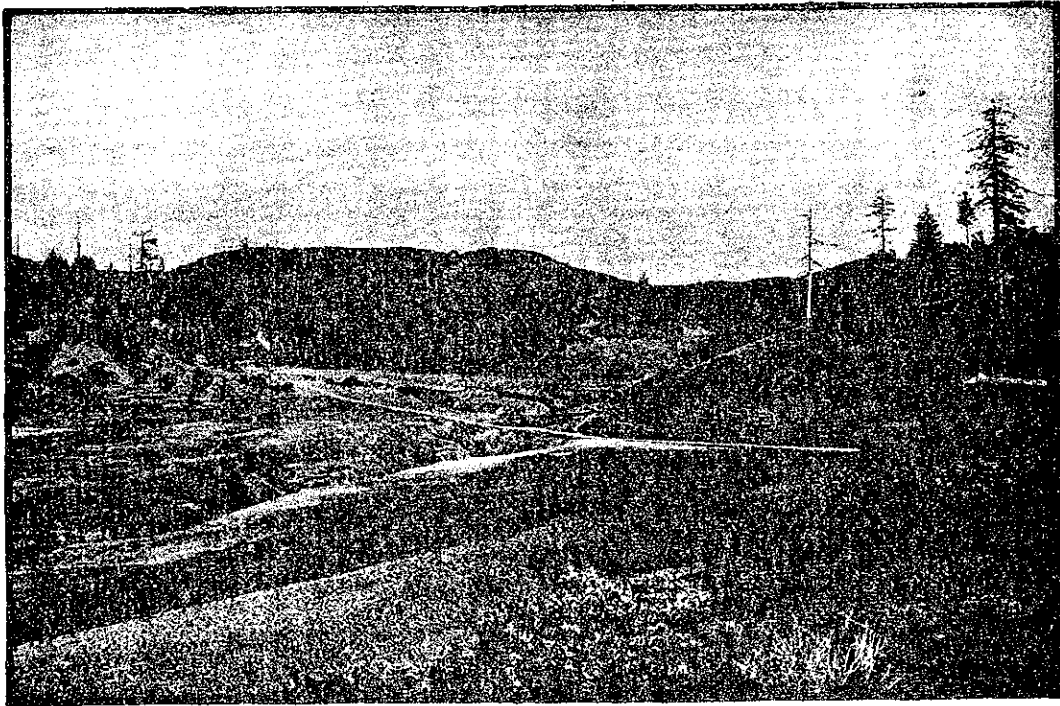


Figure 43

A gullied mountain meadow grazed heavily by sheep. It is surrounded by a chamise chaparral covered watershed wherein there are remnants of a sugar pine stand. Sheep men regularly burn over the watershed at 3 or 4 year intervals to "maintain the grazing capacity of the range", but such burning, coupled with heavy overgrazing, has undoubtedly caused the draining of this once valuable meadow area. Bendmore Valley, Lake County, California. W-1322 Wieslander 4-15-34

## Chapter VII

### PLANTING CUTTINGS

A quick and effective means of securing a vegetative cover for the control of soil erosion is the planting of willow cuttings. It is well known that most willows, poplars and cottonwoods will grow readily from cuttings when these are set in rich moist soil, as in streambanks and wet meadows. What is not so well known is that several species of willow will grow from cuttings in much less favorable soils such as new road fills and the gullies in bare denuded land. Even in very unfavorable sites willow cuttings will often grow vigorously for a few years before they die out. In the meantime they will have served the important function of stabilizing the soil and so enabling other plants to become started.

In California, willows are used almost exclusively for cuttings, and in this chapter the use of willows alone is discussed. The climate is characterized by a short wet winter and a long dry summer, and willows thrive in such a climate. An ample supply of willow cuttings can usually be secured in the immediate vicinity of the meadow to be controlled. This is an important factor not only in regard to cost, but also because of the assurance that the species is suited to the locality. Very little is known of the ability of woody plants other than the willow group to grow from cuttings under these conditions in the open and without care. If other plants are so tried, the principles herein given for willows will apply. Considerable success has been experienced with cuttings of elderberry and mule-fat (*Baccharis viminea*).

#### Selection of species

Wherever possible vigorous native brush species of willow should be used. Species having long, straight stems are much easier to cut than those with crooked stems, and provide stakes that are easier to drive.

In general, it is preferable to use species which have browse value, but in meadows which are very heavily grazed a plantation of palatable willows may be completely destroyed by grazing animals. In such cases non-browse species should be mixed with the browse species. In each locality a little observation will determine which willows are eaten most readily and which are left untouched by grazing animals. Deer usually do little damage in comparison with domestic livestock.

#### Time to plant

Stakes should be cut and planted when the willows are dormant. This period extends from the time the leaves start to turn yellow in the autumn until the time when growth starts in the spring. In moist soils, willow stakes can sometimes be successfully planted during the summer season, but usually this should not be attempted. If necessary to do so, use cuttings that already have roots, and plant them like trees instead of driving them.

### How to cut stakes

In general the stakes should be  $\frac{1}{2}$  to 2 inches in diameter, and about 18 inches long. Larger sizes are even better, but much more expensive to cut and plant.

Stems up to  $1\frac{1}{2}$  inches in diameter can best be cut from the bush with two-handled brush pruning shears. Larger branches can be cut with axes.

The quickest method to cut the stems into the 18-inch lengths is to use a sharp hand ax or a sharp chisel-edged machete and a chopping block. It may be convenient to have markers on the chopping block 18 inches apart or to set up a back-stop board 18 inches from a mark on the block, so that the proper length can be quickly gaged. When no chopping block is available, the stems can be readily cut with heavy brush pruning shears.

It is important that the stakes be piled, as cut, with the butts all at one end of the pile. This should prevent the cuttings from being planted wrong side up. Bundles of stakes can be bound together with baling wire for transporting to where they will be used. The stakes should be planted as soon as possible after they are cut and should be protected from excessive drying at all times, if they are expected to grow. It should be remembered that they are living plants even though cut to look and drive like stakes.

### How to plant stakes

1. The cuttings must be planted right side up; i.e., with the butt-ends in the ground.
2. Set cuttings as deep as possible up to  $\frac{3}{4}$  of their length.
3. In fairly soft soil the stakes can be driven with a wooden maul, constructed as shown in figure 44. Do not use an ax or a sledge.
4. In hard soil holes should be prepared for the stakes with a crow-bar to prevent excessive stripping of the bark.
5. Cuttings should be set at a slight downstream angle rather than vertical. This lessens the chance of their being uprooted by the current.

### Where to plant willow stakes

1. To reinforce check dams.

For strengthening check dams, willow cuttings should be planted as shown in figure 45. Normally, the stakes should be spaced 1 foot to 18 inches apart. On large dams willows should also be planted at the points marked "secondary" on the drawing. This secondary planting consists in extending the willows part way around the upstream face of the dams, and in planting another row about 2 feet downstream from the apron.



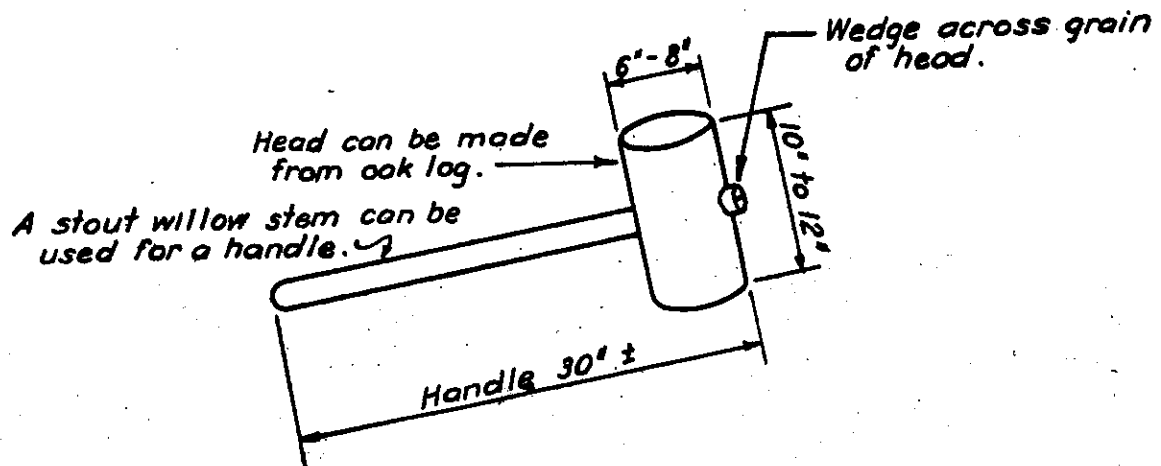


Figure 44  
Wooden maul for driving willow stakes.

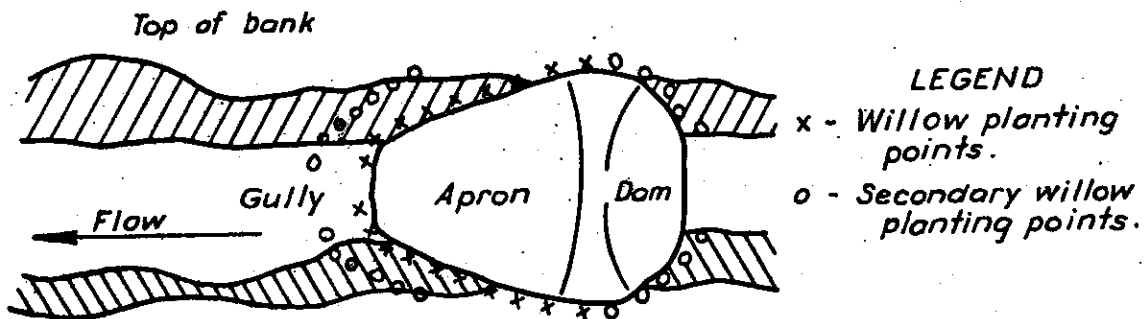


Figure 45  
Plan of gully check-dam showing points for planting willows.

2. To reinforce gully-head plugs and mattresses.

For the strengthening of gully-head plugs and mattresses, willows should be planted as shown in Figure 46. The stakes should be spaced 1 foot to 18 inches apart.

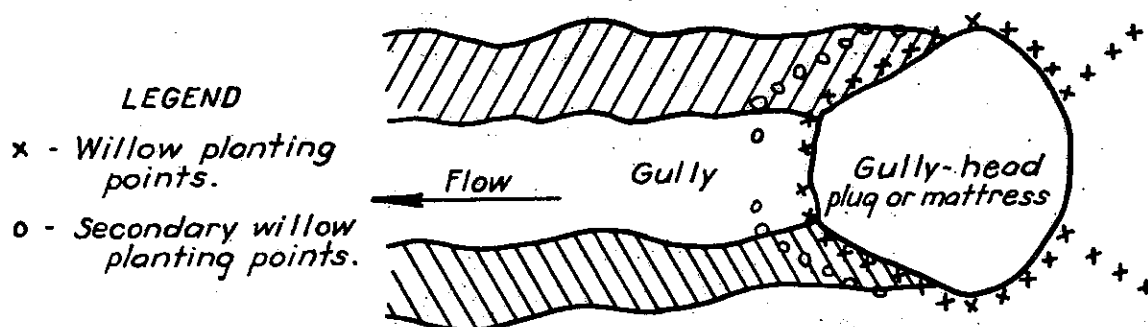


Figure 46

Plan of gully-head plug or mattress showing points for planting willows.

3. For staking wattles in gully heads and banks.

"Dry" gully heads and banks should usually be controlled by sloping back the banks and heads to the natural angle of repose of the soil. To hold this slope during periods of runoff until natural vegetation has it stabilized, wattles of cut brush pegged down with willow stakes can be constructed. The use of willow cuttings for this purpose is discussed in Chapter IX, WATTLE CONSTRUCTION.

4. To prevent side-cutting of stream banks.

In dry gullies in which water flows for only a part of the year a row of willow stakes should be planted along the toe of the bank slopes where the banks are eroding. Where there are perennial streams flowing in the gullies, the rows of willow stakes should be planted at least one foot above the low water line. This is necessary because vigorous roots will not develop in a continuously saturated soil. The stakes should be spaced about 18 inches apart in the row. The outside curves of sharp bends in the streams will often be found to be eroding, and in need of such protection.

5. For protection of meadows not controlled with dams.

Some gullies cannot be satisfactorily controlled by the construction of dams. Either the gully is relatively shallow, or the slope is too great for the safe use of check-dams, or both. In any case, the planting of willows in clusters at intervals along the gullies will be found beneficial. Figure 46 illustrates the method of planting one cluster. The distance between willow clusters normally depends upon the gradient of the gully bottom. The steeper the gully grade, the closer together the clusters should be. Usually the spacing can vary from 500 feet with a gully gradient of 1%, to 25 feet with a gully gradient of 20%.

In the rows of willows shown in Figure 47, the stakes should be 1 foot to 18 inches apart in the rows and the two rows should be about 4 feet apart. The rows should extend from the top of the bank downstream to the toe.

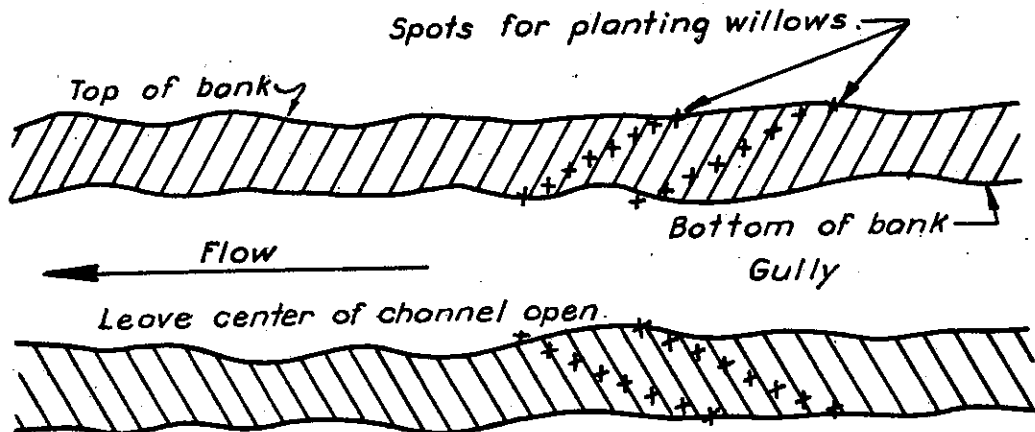


Figure 47  
Plan of gully showing planting points of a willow cluster.

6. To control small side gullies.

In small "V"-shaped side gullies, willows should be planted in a continuous row along the bottom of each gully, spacing the cuttings about 2 feet apart and somewhat staggering them in the row.

## Chapter VIII

### SOD PLANTING

The heavy sod usually found in mountain meadows is an excellent protection against erosion. Strips of such sod, planted in key spots or in contour strips, will soon spread and form a strong cover for the soil. Care should be used to dig sod from level places in the meadow where there is no danger of starting fresh erosion.

Sods should not be planted until just before or during wet seasons, except when planted in soil that is continually damp. Where the soil is always damp, the sods may be planted at any time. As a rule, it is best to obtain the sod from the immediate locality in which it is to be planted. Plant the sod as soon as possible after cutting. If it is necessary to delay planting for a day or two, keep it moist. The sod is most readily cut with an axe-mattock or spade, and lifted with a square-pointed shovel. Sod should be planted so that the ground surface of the sod is slightly below the surface of the ground in which it is being planted. Where grass is already growing in a gully, it is of course unnecessary to plant sod.

Sod is used as follows:

1. In constructing wattles (discussed under Chapter IX, WATTLE CONSTRUCTION).

2. In gully head controls.

Blocks of sod about one foot square should be placed at 3-foot intervals around gully head controls in such a position that it is protected from the full force of heavy floods.

3. On check-dams.

Strips or patches of sod about one foot wide or square should be planted in open spots between the gully bank and the dam and apron to prevent undercutting. Similarly, strips of sod planted in a contour line one foot wide along the sides of the basin, upstream from the dam, will hasten the revegetation of the slope and the surface of the expected fill above the dam.

## Chapter IX

### WATTLE CONSTRUCTION

Most meadow gullies have vertical sides with rims of overhanging sod. Unless corrected, this condition continues by constant undercutting of the sides. This process is most rapidly checked by cutting down the vertical slopes to a natural angle of repose.

After the slope has been cut back, it is usually necessary to protect it until vegetation becomes fully established. The prevention of side cutting by the stream in the gully bottom has previously been described. However, such methods do not stop erosion caused by water flowing down the slope into the gully, a condition particularly noticeable where side gullies are forming, and in "dry" gully heads subject to erosion only during infrequent floods.

A system of contour "wattle" construction as used on road slopes, can be adapted to the control of these gully slopes. A wattle is a continuous bundle of cut brush, hay or other vegetation packed into a small contour trench to hold the soil and interrupt the flow of any water down the slope. It is necessary to space such wattles every 2 to 4 feet, slope distance.

#### Locations where wattles can be used

1. On banks which have been sloped back, and where side gullies have started, or are apt to start, from runoff from the meadow land above.
2. On banks which erode during the melting of snow. Such banks are characterized by a loose soil, by very little vegetative cover, and by being already sloped to the natural angle of repose of the soil.
3. On wide or deep gully heads, too large for the ready construction of the usual gully-head controls.
4. On gully heads where the headward erosion is caused more by the loose condition of the soil than by severe floods.

#### Common types of wattles

Type A. Sod wattles: These consist of continuous strips of sod cut from the overhanging banks or from flat areas further back in the meadow where there is no danger of starting fresh erosion spots. The strips should be about 10 inches or one foot wide, and spaced about 30 inches apart, slope distance. For this planting actual terraces need not be made; the strips of sod are bedded firmly into the slope as shown in figure 48.

It would, of course, be somewhat better to plant the sod in a solid mat over the slope. But the costs involved in doing so make it prohibitive, and contour strips provide almost equal protection. The strips will spread and make a solid mat in a few years.

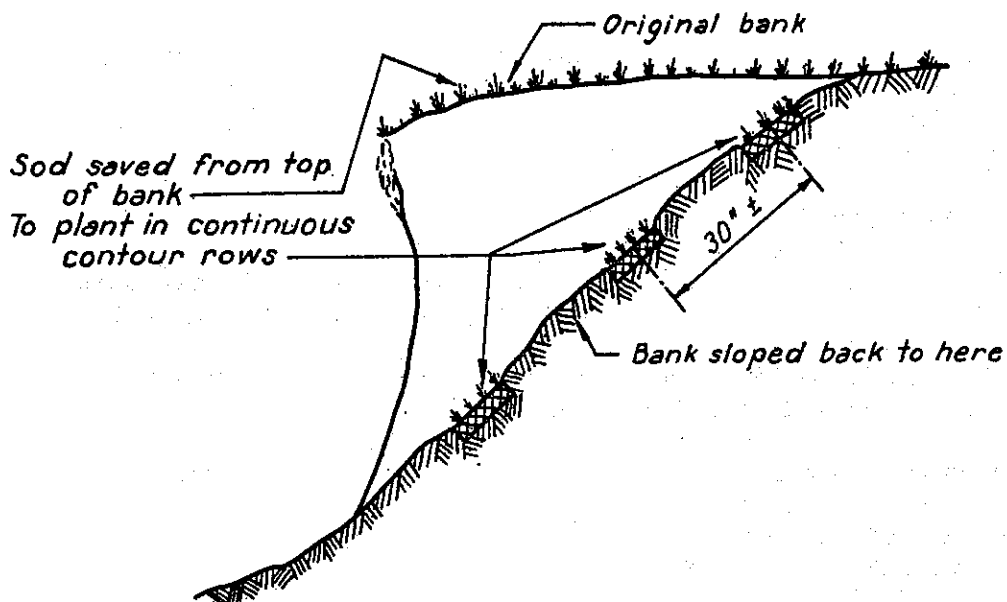


Figure 48  
Sectional elevation of gully bank showing sod wattles.

Type B. Hay or pine needle wattles: Constructed, as shown in figure 49, by cutting small trenches around the slopes on the contours and by filling the trenches with continuous "ropes" or bundles of pine needles or hay. These "ropes" are made by merely bundling the loose hay or pine needles together with the hands, and tucking it into the trenches. The "rope" should be 2 or 3 inches in diameter. Earth from the slope above will work down and partially cover the material. These wattles should be spaced about 30 inches apart, slope distance.

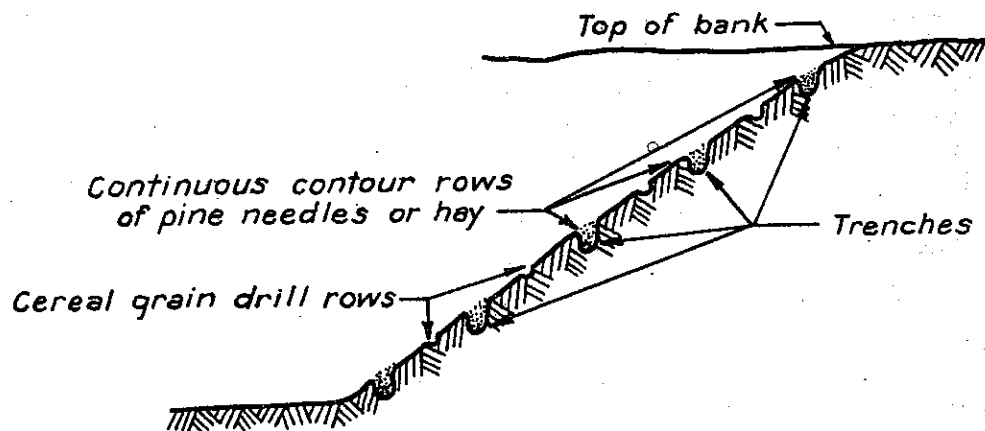


Figure 49  
Side elevation of gully head showing Type B gully wattles.

Type C. Wattles constructed of willow stakes and pine needles or hay: This type, illustrated in figure 50, is constructed as follows:

1. About 30 inches up from the bottom of the gully drive a row of willow stakes along the contour. These may be the standard willow cuttings, 18 inches long, but on very loose slopes longer lengths may be more satisfactory. They should be driven at least  $\frac{2}{3}$  their length. They should be spaced 8 inches to one foot apart.

2. With a hoe, cut out a small trench immediately behind the willow stakes. This trench should be 3 or 4 inches deep.

3. Bundle loose hay or pine needles together with the hands making a continuous "rope" immediately behind the stakes about 2 or 3 inches in diameter. Earth from the slope above will work down and partially cover the material.

4. Cereal grain should usually be planted in a row just above the hay or needles, and covered with a thin layer of earth.

5. The men can walk on this wattle while working on the next one above, and so on. The wattles should be spaced about 30 inches apart, slope distance.

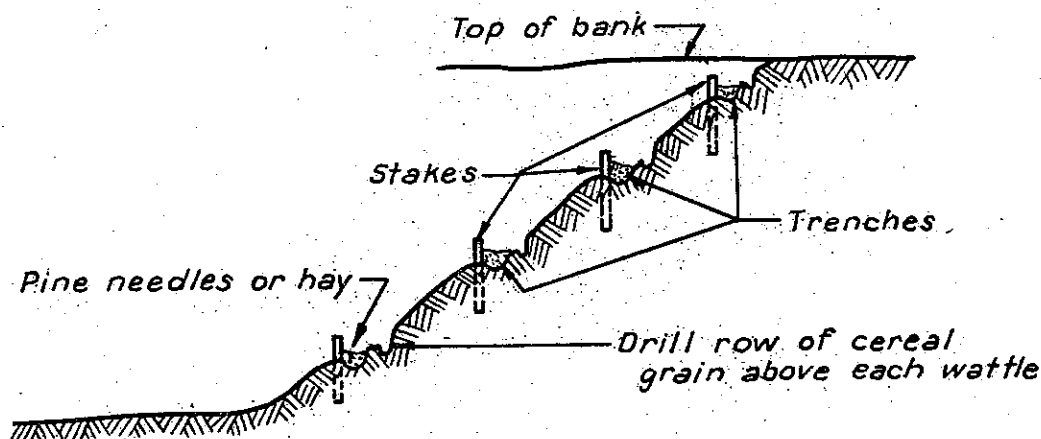


Figure 50  
Side elevation of gully head showing gully wattles, Type C.

Type D: Wattles constructed of willow stakes, brush, and sometimes also anchor "pegs". This type, illustrated in figure 51, is constructed as follows:

1. About 30 inches up from the bottom of the gully drive a row of willow stakes along the contour, spacing the stakes 18 inches to 2 feet apart. These may be the standard willow cuttings 18 inches long, but if the soil is very loose, somewhat heavier and longer stakes should be used. They should be driven in the ground at least  $\frac{2}{3}$  of their length.

2. With a hoe, cut a small trench immediately behind the willow stakes. This trench should be 4 to 6 inches deep.

3. Bundle loose brush together with the hands, making a continuous "rope" in the trench immediately behind the stakes. This "rope" should be 3 to 6 inches in diameter.

4. Holding the brush down with one hand, drive in the anchor pegs horizontally, as shown in the drawing, to keep the brush in place. These pegs are necessary only when stiff brush is used, like oak, which cannot be held down by earth alone.

5. Cereal grain should usually be planted in a row just above the brush and covered lightly with soil.

6. The men can walk on this wattle while working on the next one above, and so on. The wattles should be spaced about 30 inches apart, slope distance.

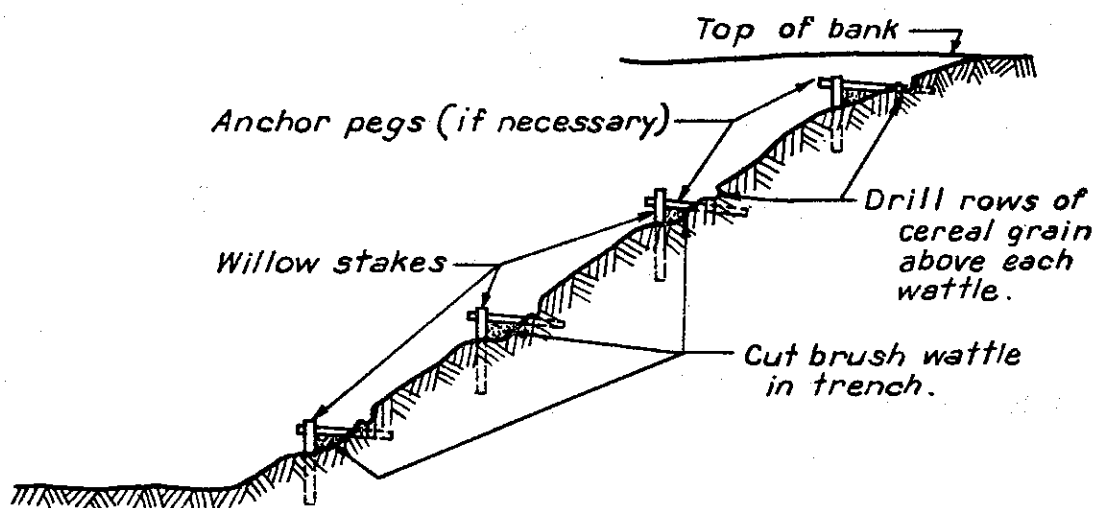


Figure 51  
Side elevation of gully head showing gully wattles, Type D.



### Selection of types of wattles to be used

The choice of the method of wattle construction to be used depends on the soil type, looseness of the slope, soil-moisture conditions throughout the year, and on what flood flow might reasonably be expected. Normally a combination of wattle types is used, so as to get the best protection of the slope at the least cost. Illustrative combinations for different conditions are given below:

1. On a soil moist enough throughout the year to grow a heavy sod:

- a) Where the soil is not subject to rapid erosion use Type A wattles alone. This condition frequently exists along a main channel through a meadow where the banks have been slowly eating back and broadening the stream bed. It should be noted that the sod will ultimately cover the entire slope and protect that slope also against floods along the channel parallel to the wattles.
- b) Where the soil is not subjected to a heavy flow, but is of a type which erodes easily, use Type A and Type C alternately. Usually Type C wattles can be spaced 4 to 5 feet apart, slope distance, with the sod (Type A) planted midway between.
- c) Where the erosion is relatively rapid and the soil is light, alternate Type A and Type D. The Type D wattles can be spaced 3 to 5 feet apart, slope distance, with the sod (Type A) midway between.

2. On a soil too dry to grow a good sod:

- a) Where erosion is slow, use Type B, spacing the wattles 30 to 40 inches apart.
- b) Where the erosion may be expected to be somewhat faster, use Type C alternated with Type B.
- c) Under severest conditions use Type D.

3. To supplement the wattles grass or cereal grain seed can be sown for quick temporary control. For details see Chapter X, ARTIFICIAL SEEDING.

### Selection of material to be used for wattles

1. Willows: For the stakes, which form the main support of the wattles, use ordinary willow cuttings, 18 inches long and  $\frac{1}{2}$  to 2 inches in diameter. On very long, loose slopes it may be necessary to use somewhat longer and heavier stakes. Where pegs are needed to peg down the wattles use willow twigs and stems 18 inches long and  $\frac{1}{4}$  to 1 inch in diameter. If willows are scarce, some scrap lumber can be used, but there should be a willow stake at least every 4 or 5 feet along each contour wattle.

2. Hay: Any hay with long stems is good. Wheat, alfalfa or oat hay should be satisfactory. The hay should be fairly free from weeds. Special care should be taken to avoid introducing Russian thistle (tumbleweed) and Napa or star thistle.

3. Pine needles: The needles should be long, such as those from ponderosa and jeffery pine trees.

4. Brush: Brush should be used that has a dense leaf system and which will pack relatively flat in the contour trench. The following are listed as suggestions:

- a) Fire sprouts of the live oak
- b) California laurel
- c) California coffeeberry
- d) Chokecherry
- e) Holly-leaf cherry
- f) Incense cedar
- g) Any small, heavily leaved branches of pine or fir

## Chapter X

### ARTIFICIAL SEEDING

As previously mentioned, a seeding program in conjunction with other work is recommended for meadow erosion control, except where there is already a good stand of vegetative growth on the gully banks. The main purpose of sowing grass seed is to hasten the revegetation of banks which have been sloped off as part of the control work. In moist mountain meadows perennial grass seed will thrive and produce a thick sod that is excellent for erosion control. Among the most promising species for this purpose are timothy, redbud, Kentucky or Canada bluegrass, meadow foxtail, and red, alsike and white clovers alone or in mixtures. Crested wheatgrass, and the perennial brome grasses will also thrive. Crested wheatgrass is probably the most important grass in the drier meadows. For more detailed information on this subject consult references Nos. 6, 7, and 8 as given in the bibliography, page 69. It should be emphasized that for success any seeding in connection with meadow erosion control must be protected from all grazing for a long enough time to permit the new grass to become firmly established. If grazing is permitted in seeded areas the effort will be wasted.

The sowing of cereal grains in contour drills on fresh bare slopes is intended only as a temporary control until the natural meadow grass can recover the slopes. The cereals make very rapid growth and leave a fibrous root system in the ground even after they die. It is usually best to use a mixture of several grains: oats, rye and wheat or barley, rather than only one species. The grain should be sown at the rate of  $\frac{1}{2}$  pound per 100 feet in furrows or drill rows, on contours midway between the Type B wattles or just above the Type C and D wattles. Broadcast sowing is less effective because grain seed does not grow well from surface sowing and because seed sown on the surface is too easily found by birds and rodents.

Cereal grain may be sown in a special manner on freshly sloped banks of dry gullies which may be subjected to flood flows. Plant the grain in drill rows at an angle of 45 degrees to the direction of flow as shown in figure 52. This method is used supplementary to or in place of the planting of a row of willows along the toe of the bank slopes.

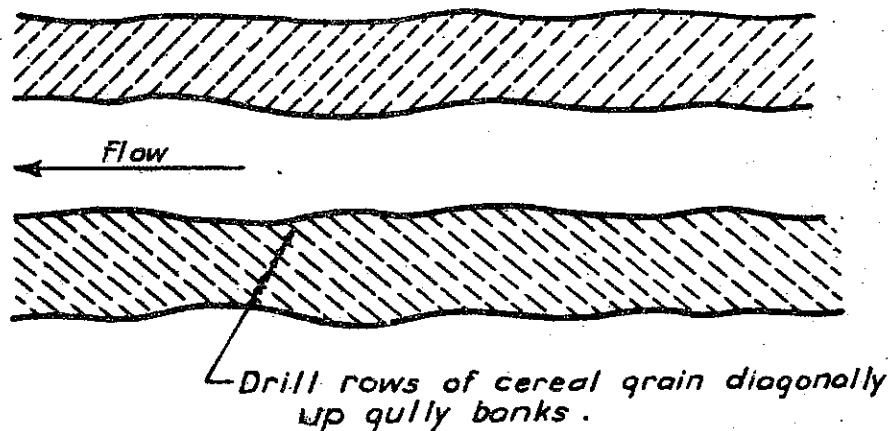


Figure 52  
Plan of gully showing planting of grain rows.

## Chapter XI

### COST RECORDS

Cost data are essential on erosion control projects as on any other type of work because (a) costs should be estimated before the work starts, and (b) the project should be of proven economic feasibility. Present data on the costs of control measures are, at best, exceedingly meager and unreliable. Although it may occasionally be justifiable, for asthetic reasons, to incur greater expense in pursuance of such measures than the present amount of erosion damage seems to warrant, they should, on the whole, be of proven economic worth.

Because of the great variations encountered in the character and extent of gullying, in the availability of suitable materials, and in the accessibility of the meadows, reliable data are difficult to obtain. It is necessary, therefore, that all cost data be qualified with full descriptive information. The necessary information should include:

1. Description of meadow, including location, type and size of gullying, and character of vegetation.
2. Character and quantities of material available for structures, and accessibility to meadow, including distance and conditions of haul.
3. Record of structures built, including size, spacing, and type. To obtain a simple yet quantitative unit of size applicable to dams, plugs, and mattresses, the "size multiple" is proposed. The number of "size multiples" in any structure is obtained by multiplying the crest length (horizontal distance across the gully level with the center crest of the dam) in feet, times the center height of the structure above streambed in feet. By totaling the size multiples of all structures and dividing that amount into the total cost, a standardized unit cost is obtained.
4. Record of area, spacing, and types of wattle work.
5. Description of vegetative control measures, including area covered, species, etc.
6. Records of any other work such as sloping back banks, slope protection, etc.
7. Complete records of all labor and supervision segregated according to type of work done. Because of the differences in rates of pay on different projects, the total man-hours of labor should be kept as well as labor costs.
8. Records of the rental value of all tools and equipment used. This should include truck hire, and should show truck-days as well as costs.
9. Cost of overhead and supervision.

Cost forms Nos. 5, 6, 7 and 8 are intended to be used in keeping all necessary records on the costs of mountain meadow dams, plugs, and mattresses. Samples of these forms are herein included, on which typical entries have been made to illustrate their use. These forms will also serve satisfactorily for such control measures as snag disposal, wattle construction, and the sloping back of the gully banks. Cost form No. 9 is for use on vegetative control work.

A description of the use of these various forms follows:

Cost form No. 5 - Description Sheet:

This sheet is intended to describe the meadow to be controlled. The principal item to be included thereon is a sketch of the meadow area showing all the gullies and side gullies and other physical features. It is not essential that the sketch map be drawn accurately to scale, but all gullies should be numbered so that they can be readily identified later. Short side gullies branching off the main gullies should also be shown, and lettered for identification.

It will usually be sufficient to estimate the area of the meadow, but if it is possible to make a rough survey, that should be done.

At the bottom of the sheet space is provided to write down any observations such as the condition of the vegetation, apparent causes of the erosion, presence of willows in the gullies, and previous control work. Any other features should also be noted here.

Only one of these sheets is required for each meadow, and it should be filled out before the work starts.

Cost form No. 6 - Record of Structures:

Each structure built should be given a number for identification. So that structures can always be identified in the field, it is important to start numbering at the extreme upper end of each gully, and to give structures on down the gully consecutive numbers.

In the form the following should be listed for dams, plugs, and mattresses:

1. The number and size of the gully in which each structure is built.
2. The number of the structure (numbering downstream consecutively from the head of the gully).
3. The structure type number (as given in this manual) and name.
4. The length of the crest in feet.
5. The center height of the crest in feet.

6. The distance and slope to the center of the next structure upstream.

When the form is used for making a record of wattle construction the following information should be written in:

1. Banks sloped back to \_\_\_\_% slope.
2. Type \_\_\_\_\_ wattles (as given in this manual), spaced \_\_\_\_\_ ft. apart.
3. Total slope area \_\_\_\_\_ ft. x \_\_\_\_\_ ft. = \_\_\_\_\_ sq. ft.

Items 1 and 3 above should be included when the bank is sloped back, but wattles are not constructed.

When the form is used for slash disposal, a record should be made of:

1. Gully number and size.
2. "Structure" number.
3. Description of methods.
4. Depth.
5. Length along gully of slash disposal.

Notations should also be written in on this sheet to show the locations where vegetation is planted or seeded.

#### Cost form No. 7 - Labor Record:

This form is used to keep a record of all labor on each structure. Supervision is also included, as well as truck-haul (including a driver). The form can also be used to record labor on vegetative control work.

#### Cost form No. 8 - Structure Cost Summary:

This form is to be used to summarize costs on each structure. A separate form should be used for each type of structure built. Inasmuch as materials will be purchased only occasionally, the small space provided on this sheet should be ample to make a record of any purchases for a certain type of structure. Except for poultry netting and wire, material is seldom purchased for any of these structures.

Special care should be taken that each foreman understands what a "size multiple" is. This amount, for any one structure, is the horizontal distance across the gully at the center crest of the structure, (the crest length) in feet, times the center height of the structure in feet. It is an arbitrary figure used to compare the size of the

structures. To get the total size multiples for all structures, merely add the size multiples for each dam together.

Cost form No. 9 - Vegetative Control Costs:

This sheet is used to summarize labor and material costs on vegetative control measures. If convenient, the original labor records can be kept on form No. 7, and summarized on this sheet when the job is complete.

Summary: The cost forms herein shown should be sufficient for most mountain meadow erosion control work. However, if peculiar conditions exist, or if there are unusual features involved, the foreman should make special note of these. In any event, data are desired of such completeness that accurate cost figures can be obtained.

R-CAL  
Special  
ECW  
Erosion Control

California Forest Experiment Station  
331 Giannini Hall, Berkeley, Calif.

Project: \_\_\_\_\_

Cost Form No.5

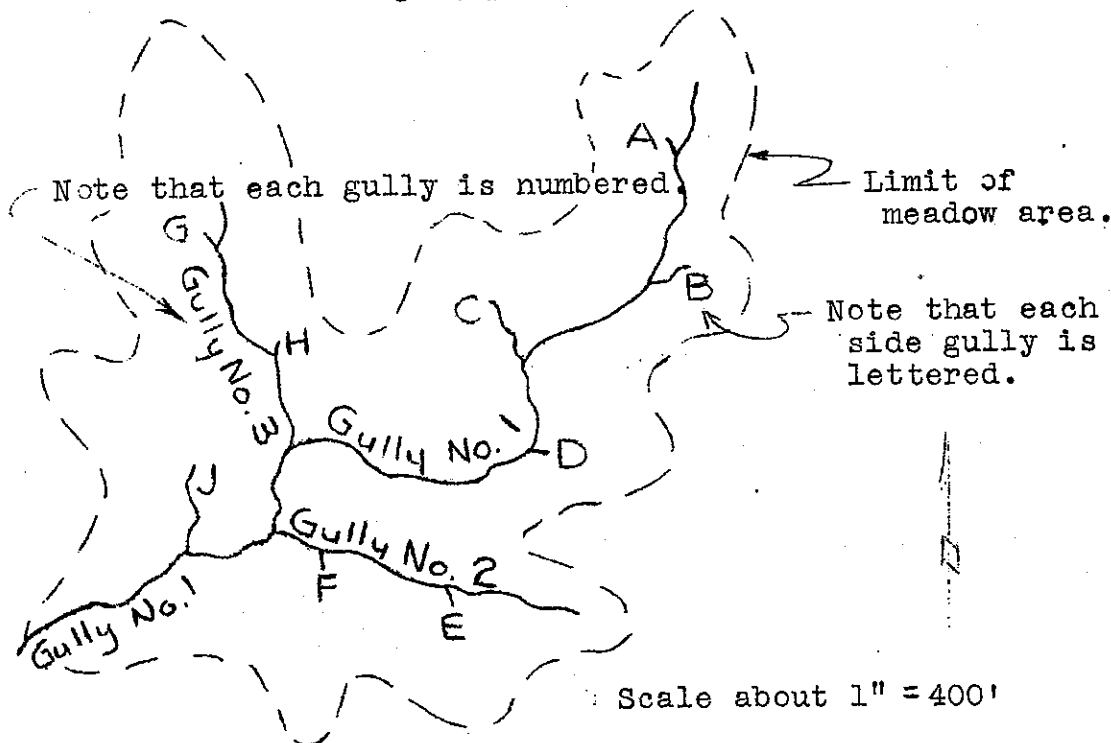
DESCRIPTION SHEET - EROSION CONTROL IN MOUNTAIN MEADOWS

Name of meadow Blank Valley, National Forest Tahoe

Location: Section 1, T. 22 N, R. 13 E, M D B & M and extending  
into Sections 2, 35 and 36

Meadow area, 230 acres. Date May 12, 19 34

Sketch of area: (Note: Number main gullies, and letter branch gullies for reference, and show relative positions on this sketch. Number each structure put in, starting at the head of gully #1 and work downstream.)



Remarks on vegetation, apparent causes of erosion, etc.: Good sod covers  
most of meadow for 20' to 100' strips along gullies 1 & 3 -  
which strips are taken over by sagebrush Meadow heavily grazed,  
Watershed logged '27 to '29. Gullying started in '28.  
Previous control work: Gully No. 3 controlled in 1933 with  
structures type #1 and #9. Work by CCC crew under project  
C-27. All structures held, but insufficient rains to fill  
catch-basins.



R-CAL  
Special  
ECW  
Erosion Control

California Forest Experiment Station  
331 Giannini Hall, Berkeley, Calif.

Sheet 1 of 15 sheets

Project N-27

Cost Form No. 6

RECORD OF STRUCTURES - EROSION CONTROL IN MOUNTAIN MEADOWS

Name of meadow Blank Valley National Forest Tahoe

Foreman: John Doe Date May 12, 19 34

Gully				Structure				From next structure upstream		Remarks
No.	Depth ft.	Width ft.		No.	Type No. & Type	Crest Length ft.	Crest Height ft.	Dis- tance ft.	Slope %	
1	7	10	8	1	#5 Mattress	10	7	-	-	
1	7	10	8	2	#9 B&R dam	10	3	6	1	
1	7	12	9	3	#7 S.P. dam	10	4	100	4	
A	3	5	3	4	#1-Plug	5	3	-	-	
A	3	5	2	5	#9-Dam	3	2	3		
2	10	21	17	27	#2 Plug	21	10	-	-	
2	10	21	17	28	#8 D.P. Dam	12	4	8	2	
E	10	15	12	29	Sloped back to 70% slope and wattled					
				--	type C. 2' 6" c to c slope distance					
				--	Slope area = 27' x 17' = 460 sq. ft.					
1	Willow cuttings planted around structures #1 to 17 incl.									
1	Banks seeded with Timothy in drill rows between									
	structures 1 and 3. Rows spaced 2' c to c.									

California Forest Experiment Station  
331 Giannini Hall, Berkeley, Calif.

Cost Form No. 7

Sheet No. 1 of 23 sheets. Foreman: John Doe

[illegible]

R-CAL  
Special  
ECW  
Erosion Control

California Forest Experiment Station  
331 Giannini Hall, Berkeley, Calif.

Date: \_\_\_\_\_, 19\_\_\_\_

Project \_\_\_\_\_

Cost Form No. 8

STRUCTURE COST SUMMARY - EROSION CONTROL IN MOUNTAIN MEADOWS

Name of meadow \_\_\_\_\_ National Forest \_\_\_\_\_

Type of labor \_\_\_\_\_, Rates: per day: labor \$\_\_\_\_\_, supervision \$\_\_\_\_\_  
(CCC, Nira, CWA, or Regular)  
truck (with driver) \$\_\_\_\_\_. Working hours per day: \_\_\_\_\_

Type of structure: \_\_\_\_\_  
(Summarize each different type of structure used on a separate sheet.)

Number built \_\_\_\_\_. Total "size multiples" = \_\_\_\_\_ ft. = (sum of lengths)  
(x heights)

Cost of purchased materials:

Item	Quantity	Cost
		\$

Total cost of purchase material - - - - - \$

Labor: man-hours \_\_\_\_\_ at \$\_\_\_\_\_. per hour - - - - - \$

Truck-hours (with driver) \_\_\_\_\_ at \$\_\_\_\_\_. per hour - - - - - \$

Supervision: man-hours \_\_\_\_\_ at \$\_\_\_\_\_. per hour - - - - - \$

Rental value of tools & equipment - - - - - \$

Fixed Charges - - - - - \$

Total cost of \_\_\_\_\_ structures - - - - - \$

Cost: Per dam \$\_\_\_\_\_, per "size-multiple" \$\_\_\_\_\_

Remarks: \_\_\_\_\_

R-CAL  
Special  
ECW  
Erosion Control

California Forest Experiment Station  
331 Giannini Hall, Berkeley, Calif.

Project \_\_\_\_\_

Cost Form No. 9

VEGETATIVE CONTROL COSTS - EROSION CONTROL IN MOUNTAIN MEADOWS

Name of meadow \_\_\_\_\_, National Forest \_\_\_\_\_

Foreman: \_\_\_\_\_, Date \_\_\_\_\_, 19\_\_

Willow planting:

Preparing cuttings, man-hours labor \_\_\_\_\_ at \$ \_\_\_\_\_ per hr. \$ \_\_\_\_\_

Planting cuttings, man-hours labor \_\_\_\_\_ at \$ \_\_\_\_\_ per hr. \$ \_\_\_\_\_

\_\_\_\_\_ \$ \_\_\_\_\_

Sod planting:

Labor (man-hours) \_\_\_\_\_ at \$ \_\_\_\_\_ per hour \$ \_\_\_\_\_

\_\_\_\_\_ \$ \_\_\_\_\_

Seeding:

Labor (man-hours) \_\_\_\_\_ at \$ \_\_\_\_\_ per hour \$ \_\_\_\_\_

Seed used \_\_\_\_\_, wgt. \_\_\_\_\_ lbs. at \$ \_\_\_\_\_ per lb. \$ \_\_\_\_\_

\_\_\_\_\_ \$ \_\_\_\_\_

Supervision: man-hours \_\_\_\_\_ at \$ \_\_\_\_\_ per hour \$ \_\_\_\_\_

Rental value of tools and equipment \$ \_\_\_\_\_

\$ \_\_\_\_\_

\$ \_\_\_\_\_

Total \$ \_\_\_\_\_

Remarks: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

## BIBLIOGRAPHY

- (1) "Native California Rodents in Relation to Water Supply", by Joseph Grinnell. Journal of Mammalogy, Vol. 14, No. 4. November, 1933, pp. 293-298.
- (2) "Inexpensive Methods of Gully Control", by Ivan D. Wood. Extension Circular 741, University of Nebraska Agricultural Extension Service, Lincoln, Nebraska. June, 1933.
- (3) "Watershed Handbook for Emergency Conservation Work", Region 3, U. S. Forest Service (revised August 1, 1933).
- (4) "Gullies: How to Control and Reclaim Them", by C. E. Ramser. United States Department of Agriculture, Farmers' Bulletin No. 1234. February, 1932.
- (5) "Range Watering Places in the Southwest", by M. W. Talbot. United States Department of Agriculture, Department Bulletin No. 1358. January, 1926.
- (6) "Artificial Reseeding on Western Mountain Range Lands", by C. L. Forsling and W. A. Dayton. United States Department of Agriculture, Circular No. 178. August, 1931.
- (7) "Pasture Plants and Pasture Mixtures Adapted to Different Parts of the United States", by H. N. Vinall. United States Department of Agriculture, Bureau of Plant Industry, Division of Forage Crops and Diseases. Mimeographed, November 15, 1933.
- (8) "Suggested Soil-Improving and Erosion-Preventing Crops for Land Taken Out of Wheat, Corn, and Cotton, West of the 97th Meridian". Prepared by the Division of Forage Crops and Diseases, Bureau of Plant Industry, U. S. D. A., in consultation with the Replacement Crops Section, Production Division, Agricultural Adjustment Administration. Mimeographed, December 14, 1933.