The Use of Wattles in Prevention of Erosion

by

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A Thesis

Presented to the Faculty

of the

School of Forestry

Oregon State College

In Partial Fulfillment

of the Requirements for the Degree

Bachelor of Science

June 1941

Approved:

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Professor of Forestry

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Acknowledgment

Acknowledgment is hereby made to J. S. Horton of the California Forest and Range Experiment Station at Glendora; to T. H. Dennis, Maintenance Engineer for the Department of Public Works of the State of California; to Sidney Walsh, Landscape Engineer for the Department of Highways of the State of Washington; to George H. Otten, Landscape Engineer for the Oregon State Highway Commission, for the generous assistance which they gave me in the solution of my problem.

INTRODUCTION

The need for erosion control is very evident in view of the damage done annually by erosion's devastating work. A conservative estimate of the annual monetary cost of erosion in the United States is at least $400,000,000 in terms of lost productivity alone.[2] (1) Added to this figure are millions of dollars more for losses outside of the agricultural field: loss of water resources; loss and damage to property caused by flood; loss of lives and personal injury due to flood; loss due to washing out of roads.

Much of this erosion is taking place on slopes that are barren, devoid of vegetation. Heavy rainfall causes the soil to become saturated and then causes water to rush unchecked down the slopes. The run-off gains in volume, erosion begins, becomes worse as sheet erosion, gullies, and slides take place. An example of the devastating effects of erosion on bare slopes may be seen in the results of the Montrose Flood which occurred in southern California in December 1933. A fire the previous summer had burned off the foothill slopes and during a heavy two-day rain during the latter part of December a flood resulted, causing tremendous damage, and moving 659,000 cubic yards of earth or 90,000 cubic yards per square mile.[3] (2.)

It is on the fill slopes of many mountain roads that there is a need for erosion control measures. Within the

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1. Bennett, H. H., Soil Conservation; p. 11.

2. Cecil, Geo. H., Flood Control and Water Conservation in South Coastal Basin of S. Cal.; p. 9.

last ten years the speed of travel for the motoring public has been doubled and the increase in volume of travel over mountain roads has been even greater. The result of this increase in speed and in volume is a demand for more and bigger mountain roads -- wide roads with a minimum grade and a minimum degree of curvature. But here it should be recognized that many mountain roads are built largely for recreational use. In such a case there should be as little disfigurement of mountains and forests as is possible. The ideal mountain road will fit well into the landscape. On the other hand, there are modern highways which pass through mountainous country or even hilly country where it is necessary to cut through the hills and to put in fills so that the motoring public may be provided with a highway that can be traveled safely under all conditions. Such highways have low gradients and improved alinement and improved cross-sectional designs and they thus expose large areas of subsoil which are very susceptible to erosion.[4](1.) To cite an example of erosion and damage caused by improper protection of or loss of protection for road fills, let us again turn to southern California. The Rim-of-the World Drive in the San Bernardino National Forest is a scenic highway which passes through very spectacular mountain landscapes. Due to its construction, the Waterman Canyon section of this road shows huge scars and large fills. Because the huge

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1. Davis, Arnold M., Erosion on Roads and Adjacent Lands.

fills on steep mountain sides were left bare and unprotected, large quantities of earth from these fills were washed down the slopes by heavy rains. The streams below were filled with debris. The flow of mud and boulders caused this damage: (1) broken off or uprooted were whole groves of alder trees which were deposited 2 miles down the canyon as jagged and splintered logs; (2) 2-ton boulders were rolled down the canyon by the stream; (3) a small bridge was wrecked and carried away several times; (4) attractive stream banks were left ruined when the flood receded; (5) a series of debris dams was filled almost overnight with rubble and for two years thereafter they were refilled almost as soon as they were emptied; (6) each time a flood occurred the city of San Bernardino, at great expense, had to clear mud and boulders from channels and ponds which constitute their system of water conservation.[1]

Many examples of this type may be found upon investigation of road conditions and damage therefrom in many sections of the country. Erosion control measures should be practiced here for the protection of the road and for the protection of the landscape. It is under such conditions that wattles are of great importance.

Control of erosion damage may be accomplished through the establishment of adequate vegetative cover. Such a cover protects the soil from the impact of rainfall. With a

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1. Kraebel, Chas. J., Erosion Control on Mountain Roads; p. 28.

proper vegetative cover, when the water does come in contact with the underlying mineral soil, the conditions are such that maximum percolation takes place. When there is no cover, the rain falls directly upon bare soil and it carries the soil particles into the interstices of the soil and percolation is thus prevented. When such a condition exists, the upper soil layer becomes so saturated with water that the whole of it moves down the slopes, increasing in velocity and volume on its way. The result is obvious: a serious form of erosion. Another function of vegetative cover, besides aiding percolation, is performed by the roots of the plants making up the cover. They bind the rough soils to the slopes and hold them in place, preventing washing. There are other minor functions of vegetative cover, including the fact that (1) leaves and branches intercept precipitation and afford protection even where the cover of the soil has been destroyed; (2) it protects the burrows of animals, which accelerate the process of percolation; (3) roots, through chemical and mechanical action, disintegrate and break up rock particles underlying the soil and in this manner roots build up and increase the depth of soil; (4) evaporation is retarded because the movement of winds is reduced and because the direct rays of the sun are prevented from striking the ground; (5) transpiration takes place and increases the humidity of the atmosphere;[3](1) (6) vegetation

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1. Cecil, Geo. H., Op. Cit.; p. 10.

supplies nutrients for many micro-flora and fauna.[10](1)

This thesis deals with the problem of establishing this necessary vegetation on barren slopes, on road fills, on meadows suffering from the effects of erosion, and along banks of streams where they are being or where they have been undermined. Where other methods of establishing plant life might fail, wattling is successful. Wattling may be termed an introductory method of plant establishment as it serves for erosion protection as well as development of subsequent plant growth. Wattles are constructed so that natural vegetation may gain a foothold and may begin to grow and become established upon unfavorable sites.

Definition of wattling: wattling consists of packing lengths of material into "thick cables partially buried across a slope at regular contour intervals and supported on the bottom by stakes."[7](2) The material used in making up the wattles is varied. Most commonly wattles consist of brush, sod, hay, or pine needles. Of course other materials may be utilized in making the "cables" to lay in the contour trenches. Many times a combination of materials is used depending upon ground conditions, degree of slope, availability of materials, extent of project, cost of materials. In any case, no matter what materials are used, the fundamental process in construction of the wattles is the same.

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1. Lowdermilk, W. C., The Role of Vegetation in Erosion Control and Water Conservation.

2. Kraebel, Chas. J., Op. Cit.; p. 13.

In its simplest form the treatment of contour wattling consists of (1) preparing the slope by smoothing existing gullies and removing loose rock; (2) anchoring the slope surface mechanically by use of a system of contour trenches, embedded wattles, with stakes and spacing best suited to soil conditions and to site; (3) sowing cereal grains or other fast-growing annuals which will bind the soil by means of their fibrous root system; (4) planting suitable trees and shrubs -- willow, baccharis, elderberry and other species which sprout -- to cause the establishment of a complete vegetative cover on the slope and to effect a permanent soil control."[1]

Purposes of contour wattling:

Contour wattles act as stabilizers in fixing the upper layer of soil. Generally, this stabilization takes place to a depth of 6 to 10 inches. The trenches, the wattle material in the trenches, and the stakes, all contribute to the stabilizing influence brought to bear upon the soil.

Contour wattles intercept the soil and form barriers against the downward gullying of slopes during heavy rains. Barren slopes are very susceptible to erosion from water. The soil becomes saturated with water and the particles are

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1. Murphy, F. D., "Slope Planting and Contour Wattling;" The Highway Magazine; May 1940.

carried into the interstices and further percolation of water is stopped. This means that any additional water coming in contact with the soil will not permeate into the soil but will run down the slope. Under such conditions it is inevitable that soil particles will be carried along down the slope with the water. As this process continues, more and more soil is moved down the slope. The water begins to follow a definite pattern in its gravitational flow and numerous rivulets will be formed. The water, flowing steadily downward and continually carrying with it the soil particles, gradually wears gullies in its path. The more rapid is the flow or the greater is the volume of the flow, the more rapid is the gullying or the more intensive is the gullying. With contour wattles on the slope, the water is checked in its course downward and it more easily is able to percolate into the soil. The soil particles that are carried down are stopped by the wattle barriers.[1]

Slides are prevented from occurring through the use of wattles. The wattles prevent the top layers of soil from breaking loose and from sliding down en masse. There are instances of such occurrences having taken place. Many of the cases are large-scale. There is an instance of an entire hillside being moved within the city of Los Angeles. A bare hillside within what is known as Elysian Park, began to shift downward. A main thoroughfare, handling heavy

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1. Kraebel, Chas. J., Op. Cit.; p. 13.

loads of motor traffic, extends through a system of tunnels, through the hill. The slide occurred directly above the tunnel and as the entire hillside inched downward there was fear, in the event of a heavy rain, of an avalanche covering up the mouth of the tunnel and of the road being blocked. Costly structures were erected to save the highway and to hold the layers of soil lest they slide down too far. Much danger and much added expense could have been spared had a method of soil fixation, a method of binding the soil to the slope, been employed. Vegetative cover should have been established. Wattles could have been used in this instance to great advantage.

On road fills, contour wattles are especially important in preventing slides. In the construction of these fills, the earth in them becomes more and more compacted as each successive layer adds its weight to the structure. This compacting effect takes place up to the upper layer of soil. Here, because of the lack of tamping action which was effected by the earth on the layers beneath, there is a relatively loose layer of earth. The action of the sun and the wind also helps to keep this upper 15 to 30 inches of soil loose. Until vegetation begins to grow and until the roots of plants can bind this loose top layer to the more firm soil beneath, some mechanical means of holding it in place is necessary in many cases. If such steps are not taken, this loose upper soil layer may soak up so much moisture from rains and heavy storms that it will be severed by

force of gravity from the firm soil beneath and it will slip down from the top of the fill over the lower slope. Slides of this type are prevented in a large measure by the contour wattling and the numerous stakes which are driven into the compact lower soil layers and which serve to anchor down the upper layer of soil on the fills until plant roots afford a permanent bond.

Another important function of wattles, and probably the basic function, is that of making it possible to grow vegetation on bare slopes. The cheapest type of blanket protection is a vegetative cover. Miniature terraces are formed by the wattles and these terraces then act as resting places for seeds. Cereals and other quick-growing annuals can be planted and they will serve as the starting vegetative cover. These grains and annuals will hold the ground by breaking up the force of run-off and erosion. Green stakes of sprouting species are used wherever possible and they will grow and develop into bushy cover which will continue to hold the ground until native vegetation can become established and until the native species take possession. Such a succession should take place: the ultimate cover should be of the native type -- shrubs, herbs, or trees -- and it should be growing upon a firm slope showing no evidence of gullying or serious soil movement. For instance, a road fill which has been treated in such a fashion will prevent damage to property below it; it will serve its purpose at a minimum cost of upkeep; it will not deface a

landscape which ordinarily would show the scars of a modern road. The process of introducing permanent vegetation through the use of wattles can also be used to advantage on sloped-off banks; where there are side gullies or where side gullies are apt to start; where there is run-off from meadows or from the slopes above. It may be used on banks which erode during the melting of snow. It may be used on wide or on deep gully heads. It may be used to reinforce check dams; to prevent side-cutting of stream banks; to protect meadows not controlled by dams if there is rapid run-off.[7](1)

Common types of wattles:

Sod wattles[8](2) are continuous strips of sod. This type of control is used in meadows or near meadows where sod is plentiful. The sod may be cut from overhanging banks or from flat places in meadows where there is no danger of erosion. Terraces are sometimes made, but in most cases this practice is not necessary. The strips of sod are imbedded into the slope. In some cases stakes are used to hold the wattles more securely to the slope. This type of wattle is restricted to use on soil that is not subject to rapid erosion. The soil in which it is used must be moist throughout the year. Conditions favorable for the use of this type of wattle are found along stream channels through a meadow

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1. Kraebel, Chas. J., Op. Cit.; pp. 13-15.
2. Kraebel, C. J., Use of Vegetation for Mountain Meadows.

where the banks have been eroding slowly away; where the stream bed is widening. After wattling has been done, sod will spread itself out and will cover the entire slope and afford it protection against erosion.

Litter, hay, or pine needle wattles[8(1.)] are bundles of this type of material made into cable-like strands which are laid into small trenches cut along the contours of the slope. The bundles of material should be two or three inches in diameter. Wattles should be spaced about 30 inches apart on the slope. (Under very favorable conditions staking the hay or pine needles to the slope is unnecessary, but control by this method will be strengthened greatly by staking the slope with live willow or baccharis cuttings.) Cereal grain seeds and permanent cover seeds should be sown before the litter or the hay of the pine needles have spread. If conditions deem it desirable, nursery-grown trees or shrubs can be planted at any favorable time throughout the litter. For the wattles, combinations of material may be used depending upon the type of material at hand. Of course a type of material or mixture of materials should be used which will check run-off and which will encourage percolation. Using this type of wattle, the spacing between contours should be about 30 to 40 inches slope distance for best results. Litter, hay, or pine needle wattles can be used on soil that is too dry to

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1. Kraebel, C. J., Op. Cit.

grow sod and where erosion is slow.

Stakes and pine needles or hay[8](1) use the same system of trenching and laying-in wattle material, as is explained in the foregoing paragraph. In addition, however, and this practice is done first, stakes are driven in along the contour rows. Stakes should be of live material, preferably; of course, if live, sprouting material is scarce and hard to obtain, inert stakes must be used; but to facilitate fast development of vegetative cover, inert stakes of split wood or other material should be interspersed with live cuttings wherever possible. The rows of wattles should be about 30 inches apart and the stakes within the rows should be spaced approximately 8 inches apart. Again, in this system, cereal grain or fast-growing annuals are seeded in behind the wattles in order to obtain quickly a vegetative cover on the bare slopes. This system is used where the soil is not subjected to heavy flow but erodes easily. In many cases it is not necessary to stake every row of wattles, so the staked rows may be interspersed with unstaked rows.

Baffles are a type of wattle that is being used by the State of Washington Department of Highways, and may be seen 6.5 miles east of the City of Olympia on Primary State Highway #1 (U.S. 99). This type of wattle is used here on a cut 95 feet high and 1000 feet long. 1½" x 2" x 24" split cedar stakes are driven into the slope along contour rows.

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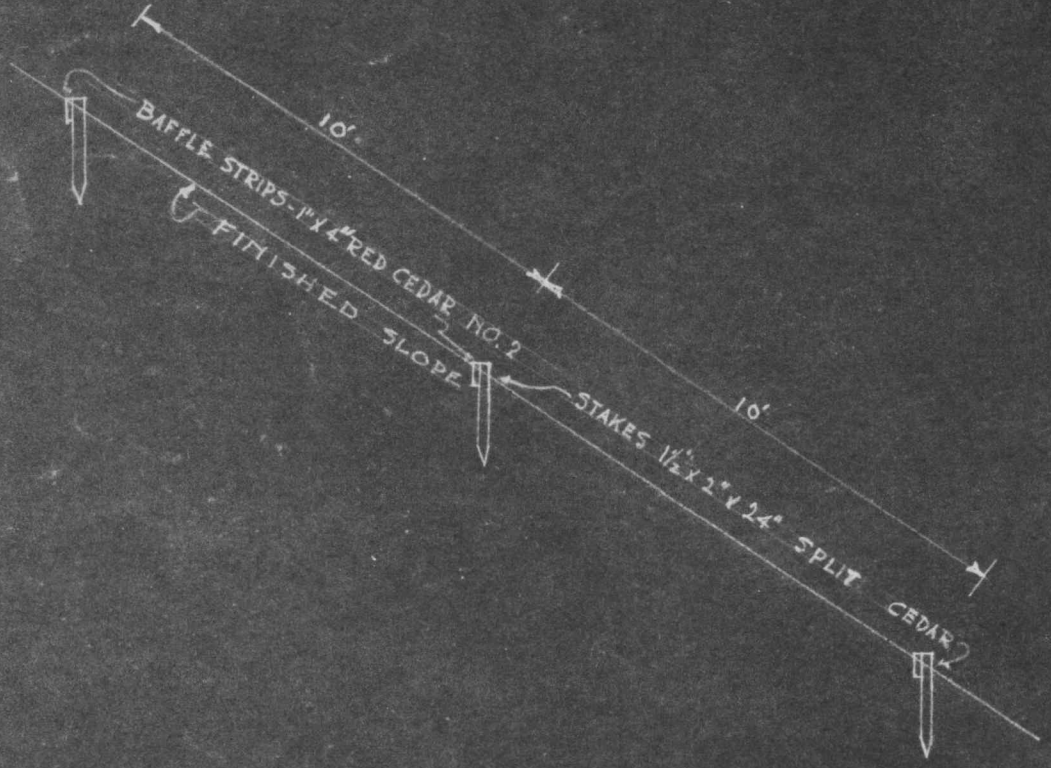
1. Kraebel, Chas. J., Op. Cit.; p. 15.



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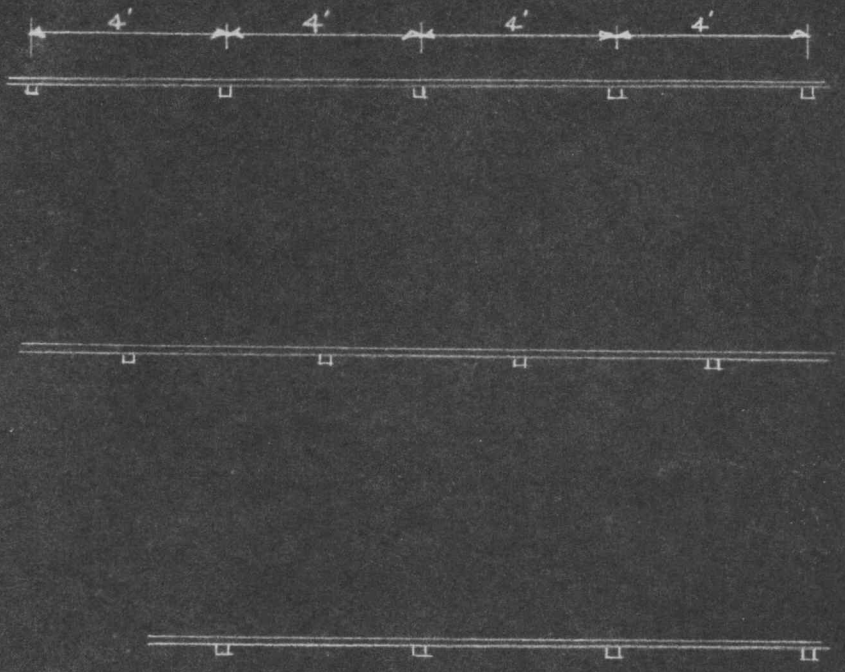

ELEVATION

DETAILS OF EROSION CONTROL SLOPE BAFFLES

SCALE 1/4" = 1'

Figure 3

Baffle strips of #2, 1" x 4" red cedar are fastened to the stakes and the strips are partly buried in the soil along the contour of the slope. Stakes are driven into the slope at a distance of 4 feet apart along the contour and the slope distance between rows of stakes is 10 feet.

The cost of constructing these wattles, or "baffles" as they are called, was approximately $.037 per linear foot.

This type of wattle is very practical on steep cuts where loose material is to be kept off the road. Should it be used on such slopes where the growing of plant life is practicable, it would be a good practice to seed in the bare slopes. The baffles would prevent the seeds from washing away.

Scotch broom wattles (Cytisus scoparius) have been employed and they have proven to be very satisfactory in preventing erosion by the wind, along the southern Oregon coast.

Stakes and brush type of wattle is the most sturdy of them all and finds its use under the most severe of conditions. Because this type of wattling is the most highly developed and because the other types are really modifications of this method, it will here be explained in detail.

The following method is one used in California and is described by Kraebel:[7](1)

Work on each slope is begun on the bottom of that

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1. Kraebel, Chas. J., Op. Cit; p. 15.

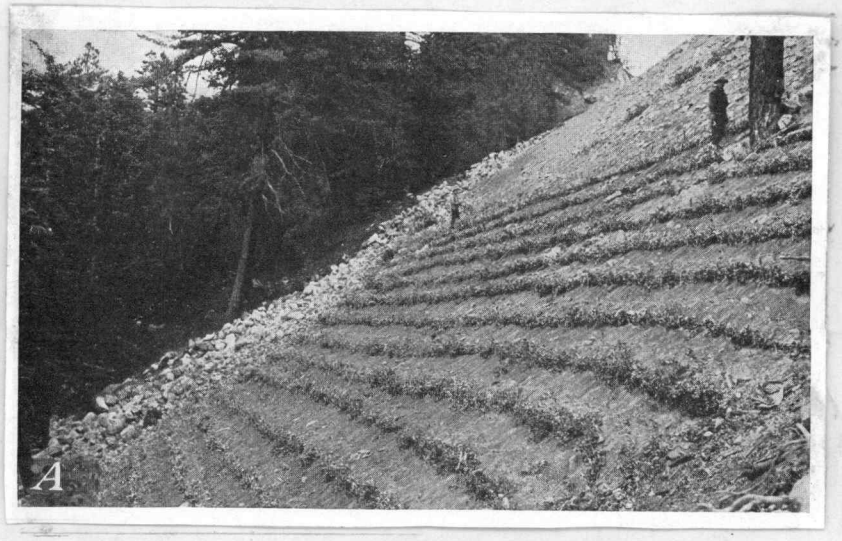

Figure 1, a 77-percent slope controlled by contour wattling. Wattles are well buried and stakes are set deeply. (Mill Creek Road, San Bernardino National Forest-- from Kraebel).

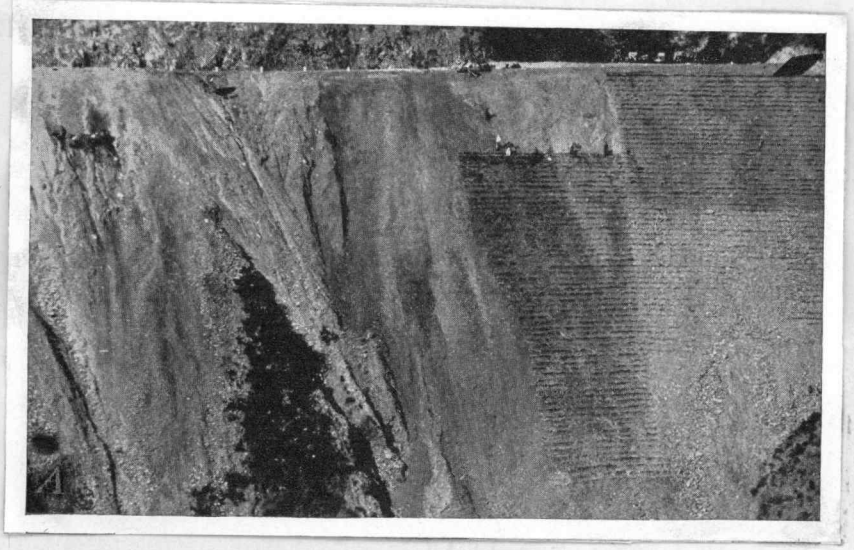

Figure 2, view of wattling crew working up slope with conveyor. To the left is a smoothed slope ready for wattling. (San Gabriel Canyon Highway, Angeles National Forest-- from Kraebel.)

slope. Contour rows are lined-in with an Abney level and sufficient guide stakes are put into the ground so that the workmen who follow can complete them easily and accurately. Next, stakes for the wattles are set in. The length of these stakes depends upon the depth at which compact soil is found. Usually, the minimum length should be 30 to 36 inches. Of this length all but about 3 inches is driven into the ground. Where the loose surface soil is greater than 2 feet deep or where the slope has a greater than 67 per cent angle, it is the safe thing to do to use longer stakes. Of course the longer are the stakes, the greater is the cost. However, in such severe cases it is many times possible to intersperse the long stakes with ones of shorter length. For instance, if every fifth stake used is a 4-foot stake and those between are 2½ feet long, the expense will be cut down and surface slides will be greatly prevented.

The spacing (slope distance) between contour rows should not be greater than 4 feet and for most cases 3 feet between rows would be preferable. Distances between stakes may vary but generally this distance should not exceed 18 inches. If the slope treatment is done in the dormant season, late fall, winter, or early spring, at least a quarter of the stakes used should be of green sprouting material, such as willow, baccharis, elderberry. If it happens that the treatment is made during the growing or dry season, provision should be made so that the necessarily-used inert stakes can be replaced by live ones in desirable places

during the next dormant season.

When a few rows of stakes at the bottom of the slope are set, the trenching and wattling crews begin work. The trencher follows the contour line marked out by the stakes. With a hoe he puts in a trench directly above the stakes. The size of the trench he makes depends upon the size of the brush bundles used. An average-size of trench would be approximately 6 to 10 inches deep and 8 inches wide. The trench should be so placed that the brush bundles will rest against the stakes. After the first two trenches have been put in, wattling begins. Now the trencher may follow the wattling crew and he may walk on the brush that has been laid down and work on the row above. Such a practice is desirable as it gives the trencher a firm footing and will prevent the soil between the trenches from being distrubed due to unnecessary trampling.

Crew organization:

Generally two men comprise a wattling crew. One man carries the bundles of brush and hands them to the other as he needs it. The other man bundles it and packs it in the contour trenches. They work from one side of the slope to the other. The packer walks along the wattle beneath the one on which he is working. He arranges the brush so that all the butt ends in every bundle are together; then he places the bundle in the trench so that the butt ends of the brush intertwine with the tops of the bundle previously laid down. In this way, there is a continuous overlapping

of tops and butts, which makes for holding strength to withstand the tendency of the soil to slide down the slope. Because it is only for the purpose of bridging the gap between stakes that brush is laid down, the brush need not be too carefully spliced together. No attempt should be made to weave it.

When the packer places the brush, he should put it into the trenches firmly so that soil may pack itself around the brush and hold it firmly in place. If the soil of the slope is dry, no special effort need be made to pack soil around the brush, as the workmen walking along the wattles will tamp down the brush and dirt will fill in and make firm the wattles without covering them completely. However, if the soil is damp or wet, the trencher will have to pull down soil from above the trench and firm the wattles. The man who carries the brush gives it to the packer in convenient bundles which have been prepared previously. With relatively uniformly-sized bundles the wattles are easily packed in place.

All the tasks of the crew fit together. After the first two rows have been trenched and the first row has been wattled, the packer stands on the wattles of the first row and packs the brush in the second row. Walking along the brush just laid down in the second row is the carrier, who throws down bundles of brush into the trench as they are needed and the packer fits them in. The trencher follows at some distance. He walks along the second row also while

making the trench for the third row. A method such as this one causes little interference among the workers; the tasks are coordinated; the brush wattles receive maximum trampling and become well-firmed in the trenches.

By no means is contour wattling an especially difficult process, but it must be done correctly in order that the desired results be obtained. The brush should not be so greatly exposed as to encourage undercutting by the run-off from storms, nor should it be so buried as to be over-run by water and by silt; but it should represent a slight terrace with twigs and leaves protruding from the lower edge. The unburied portion of the wattles should act as a safety factor against run-off and silt.

On large fill slopes a simple high-line conveyor system may be used to deliver the tied bundles to the wattling crew. If more than one crew is working on a slope, another man might be needed to deliver the bundles from the conveyor to the working crews. One or two men are also needed at the top of the slope to load and to operate the conveyor. The number of men here depends upon the number of crews working and upon the availability of the brush and upon the fact of whether or not the bundles are tied when they arrive from the field. Each project will have its own problems and the number of men and their placements must be worked out separately in each case.

Wattling Crews: Organization & Costs (Brush and stake wattles)

If work is done in the rainy season so that live cuttings can be used for stakes, the estimated labor for a typical crew used in constructing brush wattles is as follows:*

	Men
Cutting and preparing live stakes	5
Cutting and bundling brush	3
Truck-hauling brush and cuttings	1
Smoothing, staking, trenching, wattling slope	6
TOTAL	15

If work is done in summer, and inert stakes are used, the crew will be as follows (roughly):

Cutting and bundling brush	4
Smoothing slopes	4
Laying out and staking contours	2
Trenching contours	1
Packing wattles in trench	2
Carrying brush, and general utility	1
Truck-hauling of brush	1
TOTAL	15

Average small crew for small slopes:

Cutting and preparing brush	3
Cutting live stakes or smoothing slope	3
Staking, trenching and wattling	3
Trucking	1
TOTAL	10

*Larger or smaller crews may be employed, also. The size of the crew is naturally dependent upon site, source of materials, availability of labor and other factors. The organization for different jobs will vary.

Accomplishments of crews in terms of man-days per slope acre are dependent upon local conditions. Under average conditions, however, and with an experienced crew of 15, the entire procedure of stake and brush cutting, trucking, preparation of slope, running staked contours and wattling on one slope acre may be accomplished in 8 to 10 man-days. Where lumber stakes are used, the time of operation should be considerably less.

Vegetative factors controlling slope erosion:

On bare slopes that are to be protected from erosion, the aim is not for temporary but for permanent control. In order to arrive at this permanent control, it is oftentimes necessary to arrive at the desired end by stages. To arrive at permanent control by natural means many times takes far too long a time if it is even feasible. Especially is this true on fill slopes. The road may have been washed out or damaged many times before vegetation could have become established naturally on the slope to hold it. Kraebel classified the order of plants used for permanent control of slopes as (1) temporary plants; (2) semipermanent plants; (3) permanent plants.[7(1.)]

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1. Kraebel, Chas. J., Op. Cit.; p. 19.

Temporary vegetation:

The first class of plants used in quickly and effectively establishing a vegetative cover should be fast-growing, with fibrous roots to protect the loose soil against gullies and downward creeping. Its seed should be plentiful and cheap; the seed should germinate readily with the rains of early fall and it should develop rapidly before the winter's heavy rains occur; the root system should be dense and fibrous and it should bind the soil firmly and rapidly. In California, according to Kraebel,[1] the best plants are winter varieties of wheat, oats, barley, and rye. The roots and the stubble of these plants hold on and their effect upon the soil is felt even after the annuals (cereal grains) have died out. In other localities different plants may be better suited to local conditions and the best-adapted plants should be selected.

Again according to Kraebel,[2] the method of sowing as used in California is to begin after the first fall rains and after the wattles are completed. The cereal grains are sown in 5-inch contour strips which are about 1 inch deep and which are put in parallel to and a few inches above the wattles. The grain should be sown approximately 1 seed to a square inch of soil surface. It should not be sown too heavily, however, as the resulting crop may then rob the other vegetation of the moisture which it needs in order to

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1. Kraebel, Chas. J., Op. Cit.; p. 20.

2. Kraebel, Chas. J., Ibid.; p. 20.

develop. If contour wattles are spaced more than 3 feet apart, a strip of grain should be sown a few inches below the wattles, as well as above, to prevent gullying from percolated water."[1]

Semipermanent vegetation:

After the cereals have died down and before a permanent cover can be established, there is needed vegetation which will grow readily. Here the second class of plants, the semipermanent, comes into use. It must be a type of vegetation, however, which will yield to the species that is desired as the permanent cover. Species answering to the purpose of this semipermanent class include the common sunflower (Helianthus annus), desert ragwort (Senecio douglasii), rabbit brush (Chrysothamnus nauseosis), varieties of goldenbush (Aplopappus), and encelia (Encelia). All of these species can be started by broadcast seeding over the slopes after the wattles have been completed. Of a more hardy nature are species of willow, baccharis, and elderberry. These species will develop well from cuttings and will produce strong roots and hardy plants within one or two seasons. While willow and baccharis occur normally along stream banks, they have been found to grow vigorously from cuttings far from streams and from other sources of free water. The most economic and the most efficient method of introducing this vegetative cover, as has been brought out previously,

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1. Murphy, F. C., Op. Cit.

is to use the cuttings of willow, elderberry, baccharis, or whatever it may be, as stakes for the support of wattles. It must be remembered to do the wattling and staking in late fall, winter, or early spring, in that case.

In staking, willow has been found very successful. It is a very widely distributed genus and in practically every locality a species of willow is found. All species which have been tried so far have been proven successful. A common species is arroyo willow (Salix lasiolepis) which has been used much in California, as have been red willow (Salix laevigata) and Hind willow (Salix hindsiana). Lemmon willow (Salix lemmonii) gives good results at high elevations.

Mulefat (Baccharis viminea) has been found to be excellent stock for road slope fixation. Sprouts from cuttings grow very rapidly. From a single cutting as many as three sprouts grow 7 to 10 feet high in one season. In southern California, Baccharis viminea is preferred over willow because it has better survival and growth and because it has the added advantage of being nonpalatable to deer.[6](1) In northern California several species of willow have been successful. Coyote brush (Baccharis pilularis) is used successfully in the Coast Range, which is its natural habitat. Water-wally (Baccharis glutinosa) is native from Owens Valley (Southern California) to Mexico and Texas and

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1. Horton, J. S.; Junior Forester, Calif. Forest and Range Experiment Station; private correspondence.

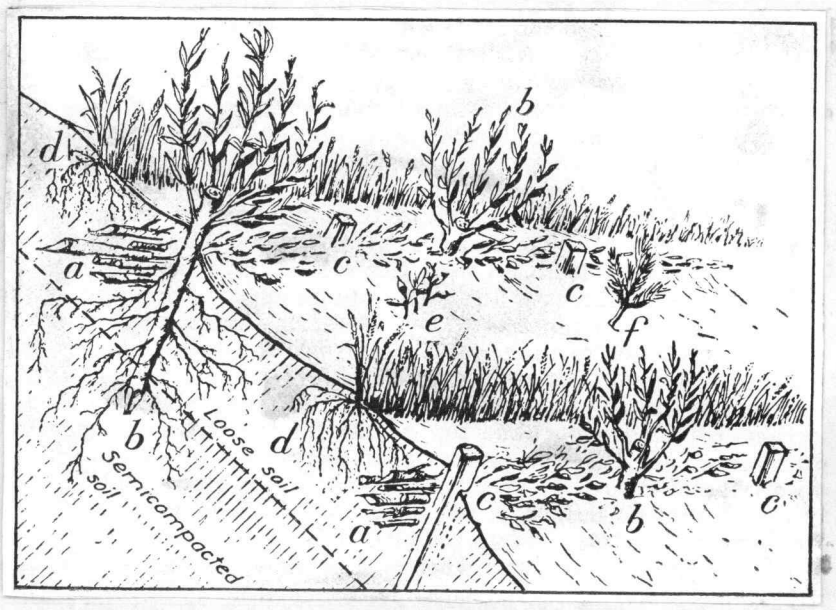

Figure 4, perspective of a section of treated slope: a, Stems of cut brush wattles imbedded in contour trench; b, live stake showing vigorous sprouts and good root system-- stakes set at right angles to slope, not vertical; c, inert stake; d, strip of cereal grain; e, cluster of shrub of herb seedling growing from a seed spot of permanent vegetation species; f, planted tree or shrub of permanent cover. (From Kraebel).

Figure 5, view of single live red willow stake which has produced 23 vigorous sprouts in 6 months. (Grizzly Boulevard, Berkeley Hills, California-- from Kraebel).

can be used in that area.

Elderberry is used for staking also, as it sprouts readily. Blue elderberry (Sambucus glauca) is the species that is used most commonly. It is desirable because it is well adapted to hillside conditions and because it will grow in the permanent cover as well. Elderberry has beauty to lend to the landscape, also, and its berries are attractive to the birds. One handicap in using blue elderberry, however, is that in only a few places does it grow abundantly enough to allow enough cuttings to be taken for slope fixation.

With research now being carried on in this problem, new shrubs and plants will doubtless be developed for use in furnishing good stakes to be used in the construction of wattles.

The stakes -- cuttings from whatever type of vegetation is used -- should be at least 18 inches long; however, they may be cut to any desired length up to about 5 feet. The butt ends of the cuttings should be pointed so that they may be driven more easily. Cuttings should be set deep. The deeper they are set -- up to three-fourths of their length -- the higher is the per cent of propagation. Shallow planting results in a shallow root system and too many leafy shoots above ground. Care must be taken not to loosen the bark from the wood as this injury will destroy the ability to sprout roots. In driving stakes a wooden maul or broad-faced sledge hammer should be used in order to prevent the stakes from splitting. Even though split stakes

often sprout, they are subject to disease and breakage by the wind. In handling cuttings the object is to prevent bruising and crushing as much as possible and to have proper contact of cuttings with the soil. When this care is exercised, there is more successful propagation and the sprouts have stronger and faster growth.

Permanent vegetation:[7] (1.)

The purpose of the cuttings (semipermanent vegetation) and of the temporary plants is to establish a permanent cover so soon as possible. By a "permanent vegetation" here is meant "an association of plants which are so well suited to the site that they will perpetuate themselves indefinitely and continue in full protection of the soil against erosion."[11] (2.) In choosing plants for this "permanent vegetation" it is well to look at the plants that make up the natural vegetation of that particular locality and to make selection from them. By reproducing a slope of the same type as the surrounding locality it will fit into the landscape as well as be adapted to local conditions, which factor will tend toward the permanency of the vegetation and of the slope.

As has been stated before, the objective in erosion control is to establish a vegetative cover upon the bare slopes to prevent this erosion. Wattling is one of the steps taken in arriving at a permanent vegetative cover.

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1. Kraebel, Chas. J., Op. Cit.; p. 23.

2. Murphy, Francis C., Op. Cit.

Many times it is necessary to wattle in order to establish any cover at all. At any rate, it gains the ultimate end more quickly and more efficiently. Thereby is justified the establishment of temporary and of semipermanent vegetation in arriving at a permanent soil cover. A permanent soil cover goes hand-in-hand with a fixed soil, and erosion-free soil; it goes hand-in-hand with a sound economy.

Stream bank erosion control:

Thus far the discussion on the use of wattles has been limited to bare slopes and road fills. Wattles are also used in preventing erosion of stream banks.

The cheapest type of blanket protection is a vegetative cover and "the most effective type of cover under ordinary conditions is a stand of willow trees 4 inches to 6 inches in diameter."

Where temporary protection is needed along stream banks until a permanent cover can be established, brush-type wattles are used very successfully. It is true that under favorable conditions the willows will sprout with no trouble but under not-so-favorable conditions a system had to be developed to prevent the cuttings from being washed out. It took years of experimentation to determine the method that is best adapted to attaining permanency of the sprouts. Out of experimentation was developed a system known as the Scheifele system,[1](1.) which has been found to be quite effective

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1. Ayres, Quincy C., Soil Erosion and Its Control; p. 290.

on bare stream banks where undercutting of the banks is to be controlled. Experimentation was carried on along Coon Creek in southwestern Wisconsin.[5](1) This stream has, under normal conditions, a flow of 40.3 cubic feet per second and a silt content of 267 tons per day; but under flood conditions, caused by intense storms which were frequent during the summertime, Coon Creek had a flow of 8,110 cubic feet per second and a silt content of 36,800 tons per day. In this flood stage, the large addition of water and the continued addition of soil material to the water, caused the stream to cut deep gashes into the river banks and into the fields onto which the stream overflowed. The damage caused by this condition became of a serious nature, so control measures were developed. After the construction of brush wattles and the establishment of a willow cover, control was effected and damage was at a minimum. The system employed along the banks of Coon Creek has been used successfully along other streams throughout the country as well. The method employed will be outlined in the following paragraphs.

The eroded stream bank is given a 1:1 slope and most of the loose earth is placed above the bank. Shallow trenches are dug at four- to five-foot intervals from the edge of the water, up the slope to the top of the bank. Willow poles, $2\frac{1}{2}$ inches to 6 inches in diameter, are laid

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1. Fry, J. R., Willows for Streambank Control.

in trenches and the butts are shoved into the mud beneath the water. These poles extend the entire height of the slope. The trenches are filled with earth and only the upper third of the pole along its entire length remains exposed. Then the poles are made fast to the bank by means of willow stakes and number 9 smooth wire.

Now the exposed bank is thatched from the water level to the top with bundles of willow brush. In laying down the brush, covering the willow poles must be avoided as this operation would seriously hinder sprouting. The brush thatching and poles are covered with one or two widths of hog wire laid at right angles to the willow bundles. To tie the hog wire down to the slope, number 9 wire and willow stakes are again used. To prevent the stream from undermining the brush matting, the toe of the bank is riprapped with rocks. Loose earth from the top of the bank is scattered over the bundles of brush to fill up air spaces and to maintain the necessary sprouting moisture. In a short time the partially buried poles, willow stakes, and brush matting all produce sprouts and at the end of the second growing season these sprouts are an average of six feet tall and they are very well able to take care of themselves without further mechanical assistance.

Almost all species of willow have been used successfully. In the Coon Creek area, because it was the most available, sandbar willow (Salix longifolia) was employed the most extensively. White willow (Salix alba) has been

used extensively also in other areas. A brush type willow should be used if possible, however, because it grows very densely and its roots form a compact mass which binds the soil. Also, brush type willows bend over easily during a flood and they then form a protective thatching over the bank.

Incidental to the protection willow thickets give to eroding stream banks, they shade the water, which tends to lower the water temperature and to cause an increase in the amount of fish food. Also, these thickets provide excellent coverts for wildlife.

In many cases the construction of such a protective system may be simplified and costs may be reduced considerably. While riprapping is essential in the Scheifele system where poles are used, many times it may be possible to eliminate the hog wire and some of the poles.[5](1.) Where merely temporary protection is needed on stream banks, only a compact matting of brush need be laid down. If there is no danger from ice action or currents along the stream, the brush matting may be laid perpendicular to the current in order to encourage the deposition of silt. However, if there is danger from ice action or currents, the brush should be laid parallel to the current and it should be weighted down with rocks. For use in brush mattings, willow has been found preferable to any other genus because it is effective and economical even

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1. Fry, J. R., Willows for Streambank Control.

under severe ice conditions.[2] (1.)

The effectiveness of the Scheifele system may be seen from the results of an investigation made by a firm of consulting engineers from Omaha, Nebraska. These engineers investigated projects of the city of Buffalo, New York, where that type of protection was used on the banks of a dredged channel because of its aesthetic effect as well as its high protective value. They also investigated projects of the Ontario Hydro-Electric, the Canadian Pacific Railroad, and the Ontario Highway Department. Specimen willow poles removed were found to be alive and in perfect condition. Their extensive root system had protected and reinforced embankments against destructive erosion, seepage, and burrowing animals.[1] (2)

Wattling, then, is a method of establishing a vegetative cover on barren sites. It is a method which offers mechanical support to oncoming vegetation. It is a method which allows a permanent cover to become established, protecting the site against erosion until vegetation may gain a foothold.

In the future, wattling should find more extensive use. The practice is yet in its primary stages and new methods and modifications are likely to be found, which will probably mean a less expensive procedure. With further

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1. Bennett, H. H., Op. Cit.

2. Ayres, Quincy C., Op. Cit.

stress on necessary erosion control, wattles should enter into the picture with ever-increasing favor. On road fills, where wattles have been used with exceptional effectiveness, they will find even greater use with modern highways demanding the construction of huge fills and causing the exposure of large amounts of barren surface soil which will need protection against the devastations of erosion. Likewise, with further developments, wattles should be more extensively used on gullies; on meadows; on sloped-off banks; along streams to prevent side-cutting; to reinforce check dams.

Wattles are a definitely effective tool in the prevention of soil erosion and their efficient control should be put to greater use now and in the future.

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