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CHANNEL CHANGE ADJACENT TO FOREST HIGHWAY IN OREGON

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CHANNEL CHANGES ON FOREST HIGHWAYS

Reported by H. D. FARMER, Senior Highway Engineer, and A. B. LEWELLEN, Chief Engineering Inspector-Superintendent, District 1, Bureau of Public Roads

DURING the past 6 or 8 years numerous forest highways in Washington, Oregon, and Montana, have been designed and constructed that involved channel changes to improve the alinement. Prior to this time alinement standards had been lower and there was little need to dispute the right-of-way with streams. It was obviously safe and conservative to leave the streams in their long-established courses and build around them or bridge over them when conditions became critical. In those years the use of 20- to 56-degree curves was common and was considered acceptable practice in mountain road location.

With the advent of faster traffic, the former alinement standards quickly became obsolete. The traveling public demanded roads capable of serving more safely faster moving vehicles. With the further improvement of motor vehicles, this demand became more and more insistent. Obviously, one important factor in the solution of the problem was the reduction of curvature to a practical minimum.

Many of our primary forest highways are in mountainous country where the most economical location, and often the only feasible one, follows the course of some tortuous stream. Characteristically, such streams alternately flow through narrow, winding mountain valleys and through sharply defined canyons. The general problem of location in such situations is simple since the stream is the major control. The solution involves establishing a proper grade line, fitting the alinement within the limitations imposed by the high-water elevation and the topography of the valley, and determining to what extent, if any, crowding or diverting the stream or crossing it is justified in order to obtain satisfactory alinement.

In deciding whether to introduce channel changes or to leave the stream in its natural bed and use bridges, landscape values must not be overlooked, especially within the national parks or national forests. Bridges of harmonious design with adequate waterways, in general, do little violence to natural topography, but all such structures entail special and perpetual maintenance costs. Of even greater importance, however, is the high first cost of bridges. In contrast, channel changes generally cost less to construct than bridges. The saving is effected chiefly by the use of modern methods of machine excavation. In spite of introducing some additional scar into the landscape, economy and better alinement are more often possible with channel changes; therefore, highway engineers of the Northwest have carefully studied the advantages and disadvantages of using channel changes instead of bridges in locating certain roads.

Channel changes require careful study, especially if a sizable stream is involved. The streams have followed the line of least resistance in eroding their present channels, and equilibrium resulting from all the factors of friction in the channel has been established. Where this equilibrium is disturbed by constructing a steeper and shorter channel, provision must be made for the increased erosive capacity of the stream.

Since the carrying power of moving water varies as the sixth power of its velocity, it is obvious that any change resulting in an increase in velocity caused by shortening and straightening a stream cannot be undertaken in a haphazard manner. The energy of the water must be dissipated in such a way as to prevent destructive erosion. The transportation of channel debris to downstream points where it might be deposited and build up the stream bed enough to flood the roadway and adjacent property must be prevented. The problem is one of duplicating, so far as possible, the friction head in the original channel, or of providing a channel capable of resisting the greater erosive force if a higher current velocity is to be permitted.

SEVERAL PRINCIPLES INVOLVED IN DESIGN OF CHANNEL CHANGES

As applied to forest highway construction in Washington, Oregon, and Montana, the ordinary principles involved in channel change construction are briefly summarized as follows:

1. The highway is located well above maximum high water, allowing a margin of safety to cover factors difficult to evaluate.

2. Material excavated from the channel is used in constructing the roadway.

3. The stream side of embankments and the channel slopes are protected by a 4- to 6-foot layer of angular rock obtained either from the roadway excavation or borrowed and placed as loose riprap. This rock protection is usually placed outside of the finished roadbed prism and thus widens the shoulder on the stream side. The additional width, if considered necessary, may be utilized to support a guardrail, although the extra width in itself is a margin of safety. Seventy-five percent of the riprap material ranges from one-half cubic foot to 1 cubic yard in size. The largest rocks are placed at the bottom and are moved roughly into place with crowbars.

4. Unless ample room is available to effect a wide separation between the channel change and the roadway prism, the roadway embankment slopes are usually designed as part of the channel slopes so that the slope is continuous from the road shoulder to the stream bed. Berms are seldom used between the roadway and the channel because erosion is apt to occur along the berm unless it is carefully protected. The heavy course of loose riprap provides sufficient material so that any undercuts at the toe of the channel slope that may be eroded by the stream are immediately filled with the coarse material, thus effectively preventing further erosion.

5. The channel designed has sufficient width and depth to provide adequate carrying capacity. The bottom of the channel is made sufficiently rough to duplicate the original friction head or is of resistant material that will permit the higher velocity without erosion. Data are taken on the original channel above and below the proposed change, and the new channel is fitted into the old smoothly.

6. If conditions permit, the bank of the new channel opposite the road is cleared and grubbed for a width of 20 to 50 feet to weaken the bank so that if the channel provided proves inadequate the stream will erode that bank rather than the roadway embankment. In areas containing large timber this practice insures that erosion will not undermine the standing timber, causing log jams and consequent destructive erosion.

7. After construction, maintenance is carefully supervised to see that any deficiencies that develop are corrected. In some instances increased friction is provided by placing impediments such as large, angular rock in the channel bed. In other cases the channel is widened to reduce the velocity and also increase the friction.

It must be borne in mind that stream flow is a powerful force very difficult to evaluate. It would be surprising if some failures were not caused by the extreme floods that occur once in 20 to 50 years. It has been the history of railroads and highways that such floods take toll of bridge structures as well. It is, therefore, to be expected during critical floods that some small failures of channel revisions will be experienced. Failures of channel changes are most likely to be minor in character and can be repaired at small expense. After repair the weak features will have been eliminated and the road should be safe for many years.

On roads of high standards in difficult terrain it is sometimes cheaper to construct channel changes than to build bridges, and, if large savings in first cost are possible, assumption of the additional risk would seem to be warranted. Even though they may be damaged in some degree by occasional, unusual floods, it is often sounder economic policy to build highways at moderate cost, making use of channel changes where reasonably safe, than to build expensive, ultra-conservative roads and bridges that will withstand all floods. Since obsolescence is an important factor influencing the useful lives of highways and future traffic demands are often difficult to foresee, it will usually result in ultimate economy to design roads and bridges to withstand floods normally to be anticipated and rebuild them after damage by infrequent, abnormal floods. The large mileage of roads needing improvement and the limited funds available favor this policy.

In any locality, the inclusion of channel changes in highway design will depend on a thorough understanding of the characteristics of the streams involved and of the tributary watershed. While channel changes have proved their economic worth on many projects in the Northwest where small or moderate-sized streams are involved, and where the regimen of the stream is not too severe, it is recognized that there are many locations where channel changes would be distinctly hazardous. Channel changes cannot be used indiscriminately.

Preservation of landscape values should be a cardinal principle in any highway design. It is recognized so far as appearance is concerned that seldom can man-made water courses improve on nature. Careful planning, however, can minimize the artificiality of channel changes. Vegetation, encouraged by ample rainfall, will quickly cover the more noticeable construction scars, but some of the attractive characteristics of a natural stream unavoidably will be lost. It is obvious, therefore, that if an alternate location exists comparable in standards and costs which does not involve channel changes, the alternate is to be preferred.

EXAMPLES SHOW ECONOMY OF BUILDING CHANNEL CHANGES INSTEAD OF BRIDGES

The following examples (projects A and B), for which alternate design data are available, are cited to give interesting comparisons. Both are on important routes where high standards of alinement were considered justified. Design data are included for a third example (project C) involving major channel changes, but no comparable alternate location was possible due to the terrain.

Project A.—This project is on both the Federal-aid and Forest Highway Systems in Oregon on one of the more important transmountain highways. It is the shortest and easiest route from the Willamette Valley and points north to California and probably will divert a portion of the traffic now carried by other parallel routes. It is estimated that this highway will carry from 500 to 1,000 vehicles per day.

The original design for the section discussed here involved curves of 10 degrees or less without channel changes. The alinement on each side for some distance consisted of long tangents and long-radius curves. A period of several years intervened between the original location survey and construction. When the section was finally proposed for construction alternate designs were studied with the result that, although the cost was increased by approximately $11,000 per mile, the benefits derived by using channel changes were considered to justify the additional expense on the 1.8 miles affected. The original design involving the sharper curvature was considered dangerous and inadequate.

Table 1 gives a comparison of the two lines. A rough estimate showed that a design using bridges and minor channel changes would have cost an additional $28,000 per mile.

Five channel changes on project A will be illustrated and described briefly.

TABLE 1.—*Comparison of curvature data for project A (1.8 miles long) as originally surveyed and as finally constructed*

Line	Total curves	Total angle[1]	Maximum curve	Number of curves of—						
				2°	3°	4°	7°	8°	9°	10°
	Number	*Degrees*	*Degrees*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Original[2]	9	378	10	1	------	1	------	2	2	3
Constructed[3]	6	194	7	1	2	1	2	------	------	------

[1] All curves on the constructed line are spiraled, and spiral angles are included in the total angle for the constructed line.
[2] Without channel changes.
[3] With channel changes.

Figure 1, A shows the original terrain, looking upstream from station 1725, and figure 1, B shows the completed channel change and road. The road has a curve of 6°20′ and a grade of 5.5 percent. The grade of the road exceeds the grade of the stream bed so that the road gradually rises above the stream.

The channel is 38 feet wide at the bottom, and its slopes are 1 to 1. The highway fill slopes are 1½ to 1. Sufficient angular rock for slope protection was obtained from the adjacent excavation without expense other than the cost of the unclassified excavation involved. The new channel required approximately 5,000 cubic yards of excavation and is 600 feet long.

Figure 2, A shows the original terrain looking downstream from station 1728, and figure 2, B shows the completed channel change and road. The road has a curve of 6°30′ and its grade increases from 3.5 to 5.2 percent. The grade of the road exceeds the grade of the stream bed so that the road gradually rises above the stream.

The channel is 38 feet wide at the bottom. The new channel is 500 feet long and required 2,100 cubic yards of excavation. Rock for slope protection was obtained

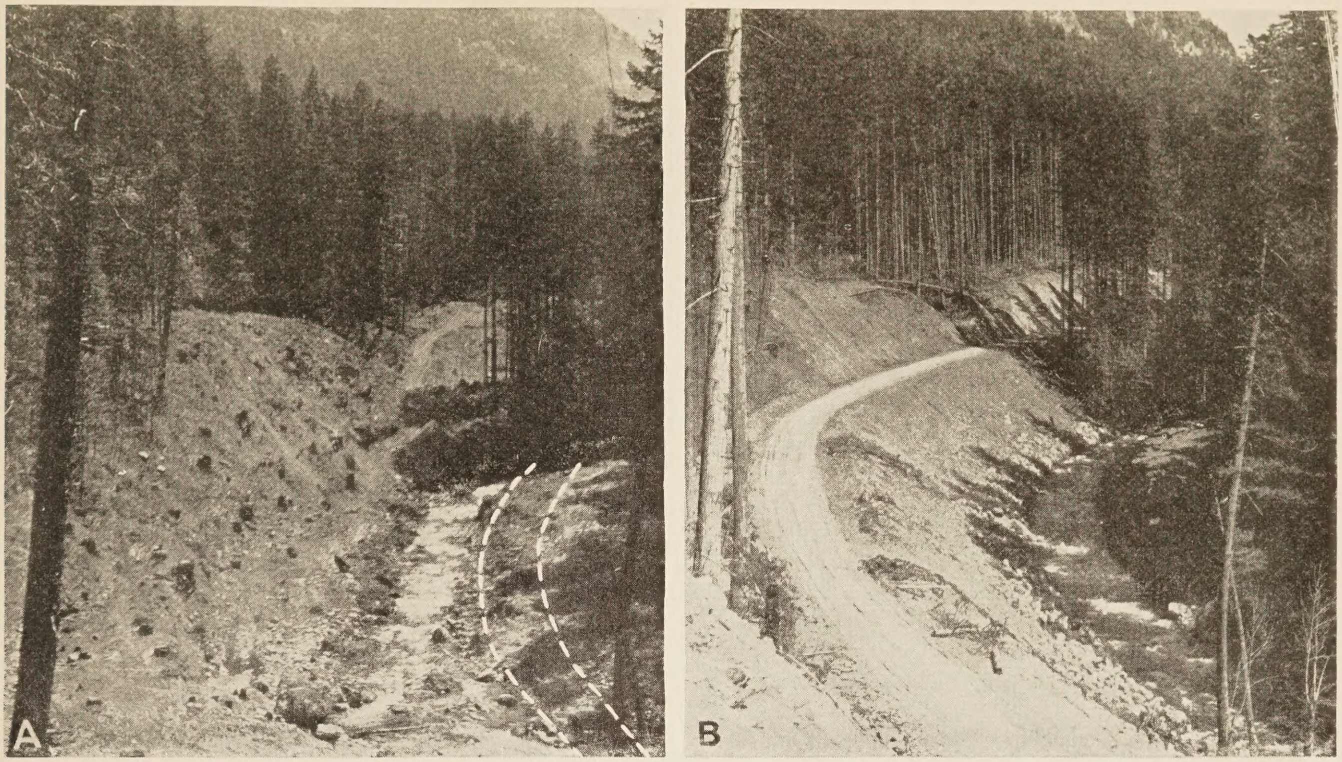


FIGURE 1.—ORIGINAL TERRAIN AND COMPLETED ROAD AND CHANNEL CHANGE. A, THE DOTTED LINES MARK THE CHANNEL CHANGE LOCATION. B, THE HIGHWAY FILL SLOPE IS RIPRAPPED AT THE BOTTOM WHERE IT SERVES AS ONE BANK OF THE STREAM.

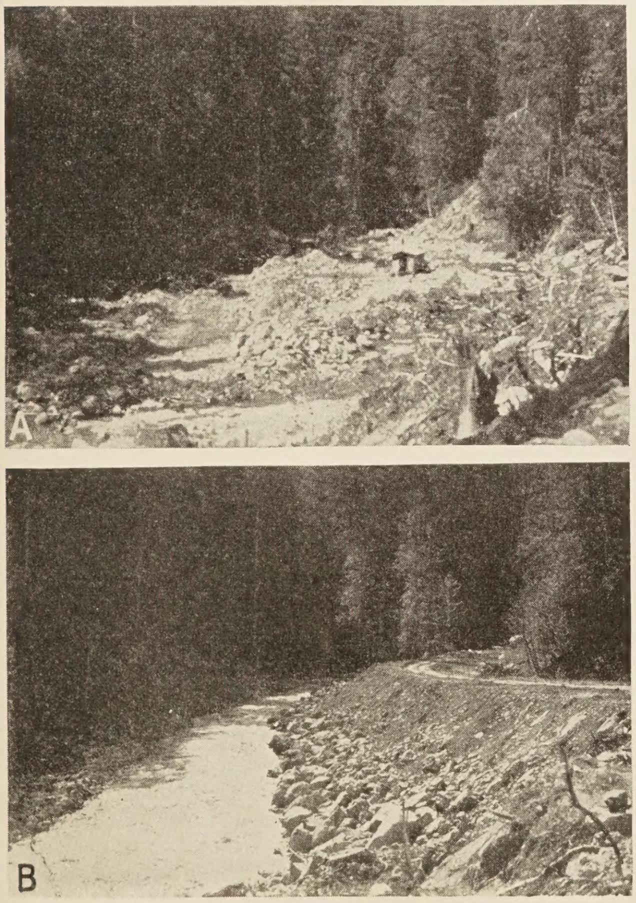


FIGURE 2.—A, ORIGINAL TERRAIN; AND B, COMPLETED CHANNEL CHANGE.

FIGURE 3.—A COMPLETED CHANNEL CHANGE THAT DIVERTS THE STREAM FROM ITS ORIGINAL CHANNEL ENTIRELY.

from adjacent roadway excavation. The stream was diverted entirely from its original channel.

Figure 3 shows a completed channel change looking downstream from station 1738. This channel change, which diverted the stream from its original channel entirely, is 1,100 feet long and involved 22,000 cubic yards of excavation. The channel change cost approximately $9,000 and made possible an alinement that otherwise would only have been possible by constructing two bridges at a probable cost of $25,000.

Figure 4, A shows the original terrain, looking downstream from station 1766, and figure 4, C shows the completed channel change and road. Figure 4, B shows operations during construction of the new channel.

This channel change is 600 feet long and required about 6,000 cubic yards of excavation. Most of the rock for slope protection was obtained from adjacent

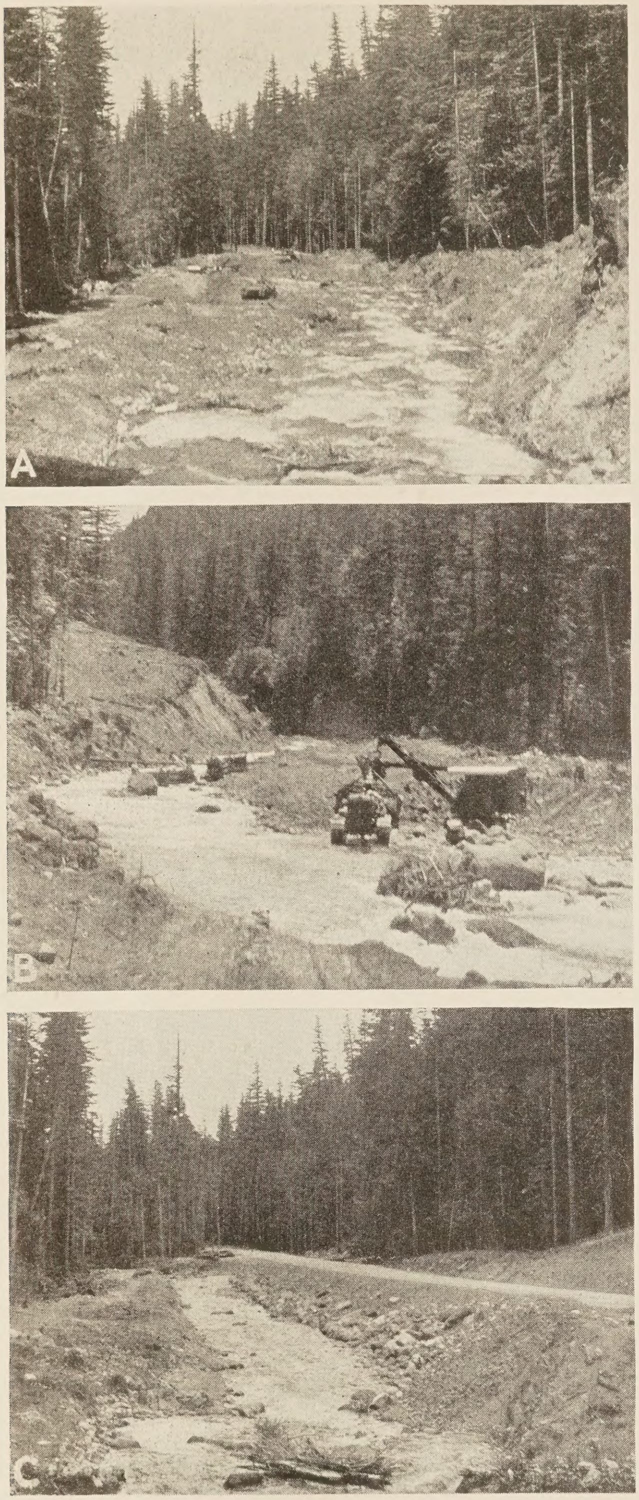


FIGURE 4.—A CHANNEL CHANGE AT VARIOUS STAGES OF CONSTRUCTION: A, ORIGINAL TERRAIN AS CLEARED OF TREES AND UNDERGROWTH; B, CONSTRUCTION OPERATIONS; AND C, THE NEW CHANNEL COMPLETED.

cuts. The left bank of the stream (fig. 4, C) has been cleared and grubbed for a width of about 50 feet.

The completed channel change shown in figure 5, A is 4,000 feet long. This picture shows the channel change looking upstream from station 1943. About 50,000 cubic yards of roadway embankment were required, 30,000 cubic yards of which were obtained from the channel excavation, and 20,000 cubic yards from cuts at each end.

About 3,000 cubic yards of loose riprap were placed in addition to rock brought from adjacent cuts. The riprap (fig. 5, B) is a conglomerate rock of fair quality, ranging in size from one-half cubic foot to one-half cubic yard. This rock was dumped by trucks and moved into place by crowbars.

Note how the channel has widened and material has been deposited at the lower end (foreground, fig. 5, A). This was caused by flattening of the stream grade and by drift. It is expected that the next floodwaters will scour the channel enough to remove this deposit.

CHANNEL CHANGES OFTEN ECONOMICAL MEANS OF ATTAINING HIGH STANDARDS OF ALINEMENT

Project B.—This project is on a route that crosses the Cascade Range. It follows practically a water grade from the Willamette Valley to a point 3 miles from the summit of the Cascade Range, which it climbs on a 5.5-percent grade, and then descends for 5 miles on a 5-percent grade to the central Oregon Plateau. This route affords one of the most favorable crossings of the Cascades and is expected to carry considerable traffic.

Six years ago a survey was made and a design prepared that involved no major channel changes or bridges. This design required several curves ranging from 14° to 22° and represented the best alinement possible without using bridges or major channel changes. In later surveys, consideration of possible stream crossings or channel changes revealed that much better alinement was possible. The best obtainable alinement was obtained by making major channel changes. and cost less than the design involving bridges.

No direct cost comparison with the original design is available since the surfaced road widths in the designs were different. It is estimated that the road as constructed cost approximately 50 percent more than if it had been constructed according to the original design for the 5.6 miles where the stream was the control. To improve the original alinement appreciably without bridges or channel changes was impracticable. The alinement of the highway on both sides of the section for several miles is very good and to have constructed a road with the alinement first considered would have resulted in a bottle neck that would retard traffic. Table 2 compares the alinement for the three designs.

The line as originally surveyed followed the stream closely, thus reducing construction costs but necessitating sharp curves. The maximum curvature on the revised line was 6°, but this line required four bridges and several channel changes. Additional channel changes were made to eliminate the bridges on the constructed line.

Figure 6 shows a channel change on project B during construction and after completion. Figure 7 shows several completed channel changes. Figure 8, A shows a channel change and highway fill nearly completed, and figure 8, B shows a completed channel change and highway fill protected by riprap.

Project C.—This project is on the road between Canyon City and Bear Gulch, Oreg., and follows the floor of Canyon Creek for a distance of 8 miles. In many places there is scarcely room for both the stream and the highway. It was impracticable to work out any acceptable alinement without channel changes. Even with extensive channel changes the best alinement that could be obtained involved 26 curves ranging from 10° to 28°, with 6 curves exceeding 20°.

Material excavated from the channel change was used to construct the road.

Coarse rock helps prevent erosion of the highway fill.

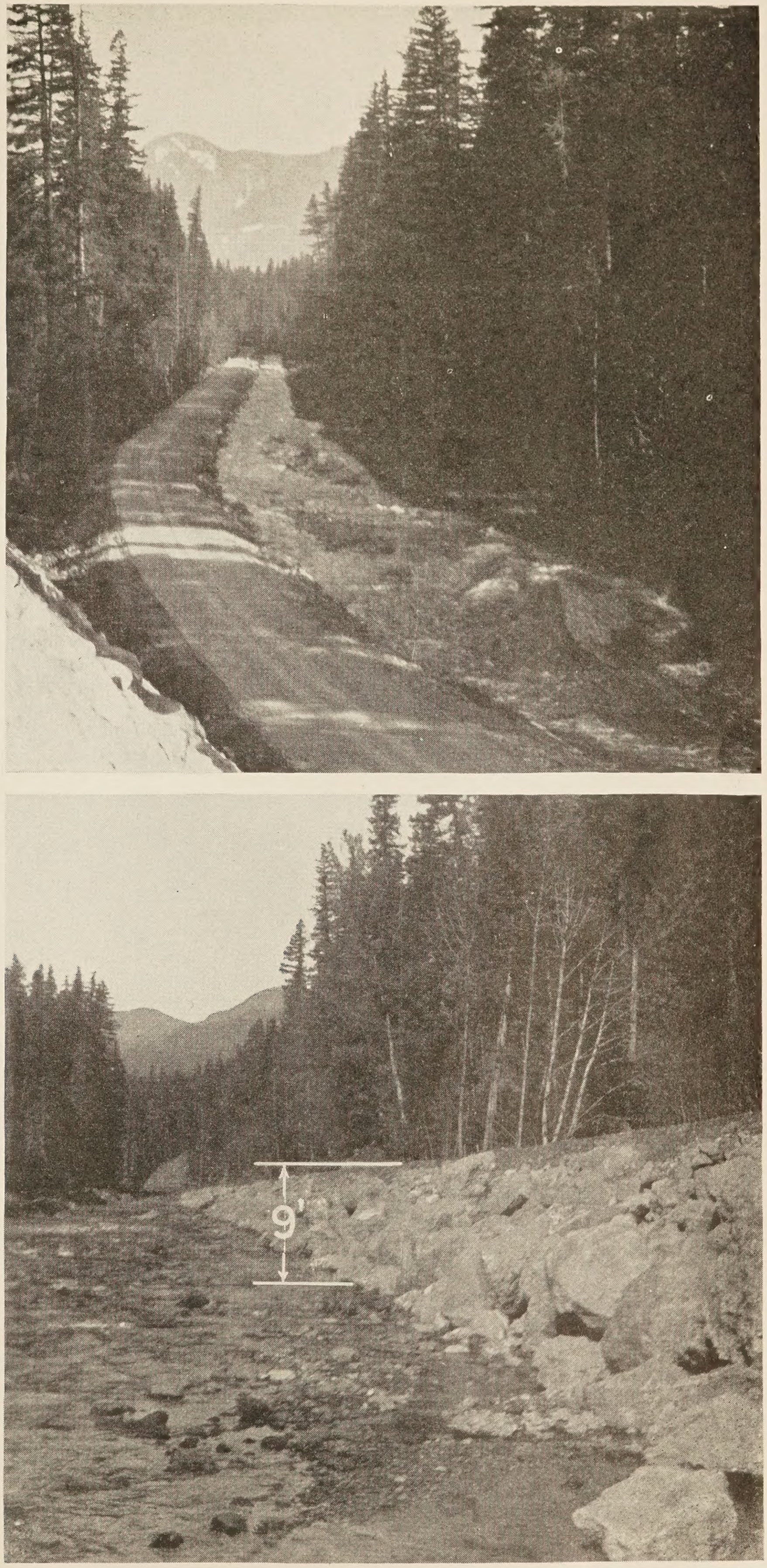
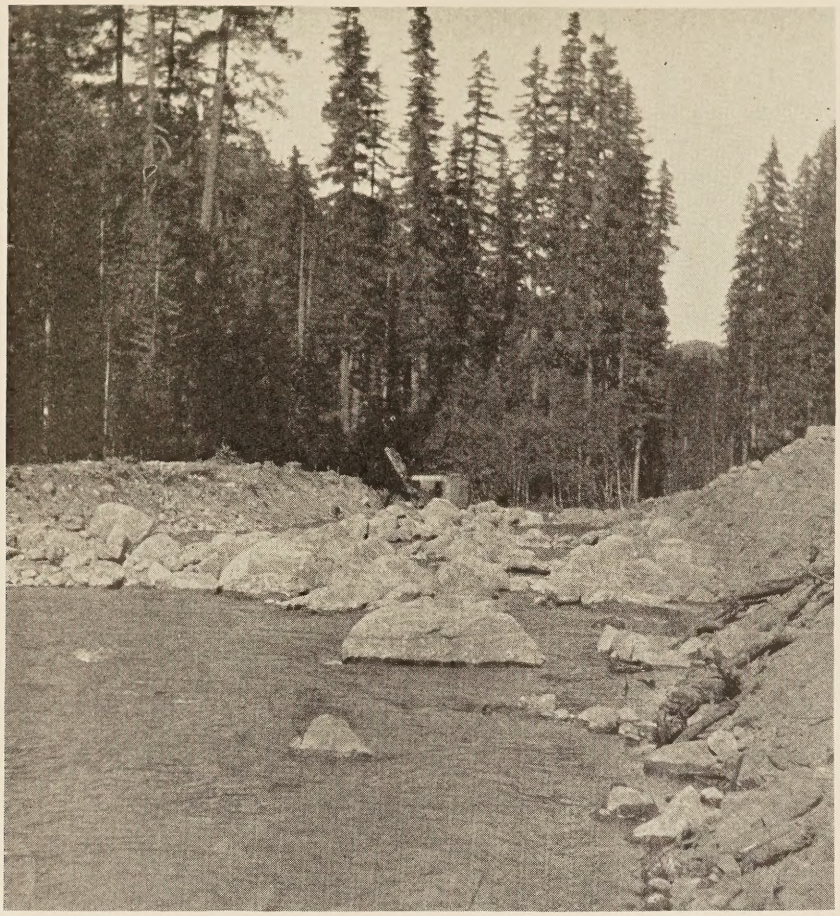


FIGURE 5.—TWO VIEWS OF A COMPLETED CHANNEL CHANGE.



The large boulders remaining in the stream were later used for slope protection.

Lower, the left bank of the channel is cleared of vegetation to permit erosion.

Figure 6.—Progress During Construction of a Channel Change.

FIGURE 7.—TYPICAL CHANNEL CHANGES USED TO BENEFIT ROAD LOCATIONS.

The grading of the road was completed in 1931 and it has now gone through 6 years of winter and spring floods without signs of damage. However, there have been no unusually high floods.

No data are available as to comparative costs of alternate designs. The material from the channel excavation was used in building the roadbed. It was largely gravel and boulders and was handled with power shovels and trucks at a contract price of approximately 40 cents per cubic yard. The adjacent hillside material is largely rock which at the time the work was done would probably have cost approximately 75 cents per cubic yard to move. Quantities on the adopted design were much lighter than could have been obtained by sidehill construction. It is obvious that the cost of the road as built was considerably less than would have been the case with sidehill construction and bridges, and the alinement is better. Figure 7 shows several channel changes on this project and the loose rock protection used on the highway fill slopes extending into the stream.

(Continued on page 182)

EXPERIMENTAL EROSION CONTROL ON FOREST HIGHWAY FILLS

BY DISTRICT 2, BUREAU OF PUBLIC ROADS

INTEREST in the development of practical methods of erosion control has grown tremendously during the past several years. Until recently a relatively unexplored field as related to highways, engineers are now experimenting with various methods of preventing erosion on highway fills.

Experimental work on forest highway fills in California, though somewhat limited in extent and so recent that conclusive evidence of the effectiveness of the various types of control is not yet available, nevertheless gives some indication of the results to be expected. The purpose of this work has been to determine the most practical methods of preventing erosion and encouraging revegetation on newly constructed fill slopes under varying soil and climatic conditions. Types of treatment have varied, from broadcasting grain and other seeds on the slopes or covering with forest duff, to more extensive methods using various types of revetments or wattling.

The landscaping of roadsides to eliminate unsightly construction scars and to give the roads a more pleasing appearance has, within the past decade, been stimulated in all States by a provision of highway legislation enabling Federal funds to be spent for such purposes. This landscaping has included the planting of desirable vegetation along roadsides. The plantings have served to help prevent erosion, though in this work the erosion control effect was generally subordinated to the roadside beautification objective.

Work of this character was performed on a project in the Tahoe National Forest, in Sierra County, Calif. Crested wheat seed was sown broadcast on two fills late in the fall of 1935. Figure 1 shows one of the fills 8 months after planting. The soil in the fills was not very erosible, and the chief value of the planting was to screen the bare earth and thereby improve the appearance of the roadside.

More extensive methods of erosion control were used on three other forest highways in California as follows: On route 20, in the Plumas National Forest in Plumas County; route 61, in the Angeles National Forest in Los Angeles County; and route 74, in the Sierra National Forest in Madera County. Conditions on these three projects represent almost the extremes where extensive erosion control methods appear feasible or desirable.

Conditions on route 20 may be considered to represent minimum needs. Clay predominates in the soil structure, though there is some rock that produces a certain amount of stability. Although the precipitation is heavy, it falls as snow which melts gradually and does not cause concentrated run-off.

Conditions on route 61 represent the other extreme. Here the soil is extremely erosible and most of the precipitation falls as rain in storms that are often cloudbursts. Furthermore, run-off from the highway enters streams that furnish water for irrigation and city water supplies, and it is imperative to avoid filling them with debris.

The methods of erosion control used on these three projects and the results obtained will be discussed in some detail.

Figure 1.—A Highway Fill 8 Months After Crested Wheat Had Been Planted.

WILLOW CUTTINGS PLANTED ON ROUTE 20

Route 20 is located in northeastern California, and immediately following the completion of the road in 1935 the erosion control work was started.

Climatic conditions in this locality are not ordinarily conducive to excessive erosion, as the snow melts slowly since warm rains are infrequent. The soil is chiefly clay, with some rock. From 35 to 55 percent of the soil passes a 200-mesh sieve. The large amount of fine material in the soil indicated that saturation of the newly constructed embankments might possibly result in the loss of considerable material by mud flows or slides. Surface scour was not considered an important factor because of the absence of heavy rainfall and the rapidity of reproduction of native vegetation.

In view of the favorable conditions existing on this road, the erosion control considered necessary involved stabilizing the fill slopes to an adequate depth below the surface. This was done by planting willow cuttings 3 feet long to a depth of 30 inches in the fill slopes. The cuttings were planted in rows following contour lines, spaced at vertical intervals of about 3 feet between rows. The spacing of the cuttings in rows varied from 1½ feet on the highest fills to 3 feet on small fills.

The appearance of one of the fills after planting had been completed is shown in figure 2.

For experimental purposes, on large fills the cuttings were supplemented by brush wattles placed in trenches directly above the cuttings. These trenches were 1 foot wide and 1 foot deep, and were filled with willow limbs and brush having an average length of 3½ feet and maximum butt diameter of 2 inches. The limbs were matted together to form a continuous chain along the trench, and were covered with a layer of small, newly cut fir limbs. Sufficient earth was then shoveled on top to hold all material in place. Further compaction was obtained by workmen walking on the wattles during construction operations. A fringe of the newly cut fir limbs was allowed to protrude above the surface in order to disperse surface run-off.

Approximately 0.4 slope acres of the total of 4.1 acres treated were supplemented with brush wattles. The fill slopes were then seeded with wheat and native dock.

The costs of the work for the various spacings of cuttings were as follows:

Spacing, feet	Cost per slope-acre
1½	$332
2	250
3	166

Willow cuttings spaced 1½ feet apart and supplemented with brush wattles cost $847 per slope acre.

In spite of the precautions taken some minor slips occurred. Figure 3, A shows minor slips on a fill after the winter season of 1935–36. Figure 3, B shows the same fill after having been repaired.

Excellent results were obtained on most of the fills planted with willow cuttings. Figure 4 shows a fill that had no failures. Although some of the plants shown in this figure may die, the majority should flourish and afford ample protection for revegetation by indigenous shrubs and small plants.

Figure 2.—Willow Cuttings Planted on a Highway Fill to Prevent Erosion.

BRUSH LAYERS PLACED IN FILL SLOPES DURING CONSTRUCTION

Route 61 is located in southern California. Soil and climatic conditions are such that extensive erosion has occurred on the fill slopes of nearby forest highways. Heavy rains and snowfalls, the latter melting quickly under warm rains and temperature, result in heavy and rapid run-off. Extensive erosion occurs even on the steep mountainsides despite native cover. Winds of high velocity also cause erosion in this locality.

It was thought advisable to perform the erosion control work during construction, since the unusually high fills proposed would expose large areas of loose material to the heavy rains common to the region. The work was performed during the winter and spring of 1935–36.

The soil with which the fills were constructed consisted of disintegrated granite and disintegrated schist, with some harder materials. It was found that the soils could be classified according to composition as follows:

Class 1.—Disintegrated schist or granite; 95 percent passing the 2-inch sieve; 35 to 56 percent passing the 200-mesh sieve.

Class 2.—Disintegrated schist or granite and rock; 50 percent passing the 2-inch sieve; 10 to 25 percent passing the 200-mesh sieve.

Class 3.—Rock; 25 percent passing the 2-inch sieve.

Figure 3.—A; Minor Slips of Wattles and Cuttings That Occurred on a Highway Fill. B; the Fill Shown Above After Having Been Repaired.

Fills composed of class 3 material were not treated. Three kinds of protection work were used on this project.

Method A.—Brush in fill layers.—All suitable brush obtained from clearing operations was stockpiled for future use in erosion-control work. This brush was placed, during construction of the fill, along the outer edge of the compacted layer in rows along contour lines. The distance between rows depended upon the height of the fill. In general, a 5-foot spacing was used on that portion of a fill lying less than 40 feet below grade; a 4-foot spacing was used from 40 to 70 feet below grade; and a 3-foot interval was used on all portions of fills lying 70 or more feet below grade.

Figure 4.—Appearance of a Fill 9 Months After Willow Cuttings Had Been Planted.

Each fill was compacted in layers with the outside edge slightly higher than the center. Brush was placed while the center of the fill was being compacted, thus avoiding interference with grading operations.

Long-stemmed brush or small logs were first placed along the edge of the layer, parallel to the centerline of the road. Brush was then placed with stems inward and at an angle of about 45 degrees with the edge of the fill. The branches protruded from 12 to 24 inches beyond the fill slope, and the stems extended into the fill from 2 to 6 feet, depending on the length of brush available. Small brush, roots, and small stumps were used to fill in and complete the mat. After the brush layer had been placed, a bulldozer was used to cover the brush out to the slope line.

The placing and covering of brush layers are shown in figure 5.

Particular attention was paid to extending the stems well into the fill to insure stability and prevent slipping or flowing of saturated surface material.

FIGURE 5.—A; PLACING A LAYER OF BRUSH. B; A BULLDOZER COVERING A BRUSH LAYER WITH EARTH. THE BULLDOZER IS PULLING A SHEEPSFOOT ROLLER USED TO COMPACT THE FILL.

Method B.—Brush in fill layers with hay mat.—Brush layers were first placed during construction of the fill, according to method A. The area between brush rows was then raked and smoothed, and alfalfa, barley, or oat hay was spread, beginning at the top of the fill and working downward by rows. After placing the hay, common rye seed was sown and a thin layer of earth was shoveled onto the hay from the area just below the brush row. The earth cover was intended to hold the hay in place, cover the seed, and discourage feeding by deer. After placing the earth cover, Italian rye and Australian rye seed were broadcast over the entire area of the fill slope.

Hay was spread at the rate of 6 tons per slope acre; common rye seed was sown at the rate of 100 pounds per slope acre; and Italian or Australian rye seed at the rate of 40 pounds per slope acre.

Method C—Stake and brush wattles with hay mat.—At locations where brush was not readily available during construction, fill slopes were treated after completion.

Fill slopes were first smoothed, and rows of 2-inch by 2-inch by 42-inch stakes were driven into the fill to a depth of 34 inches and normal to the slope. The rows were placed on contour lines at intervals of 3 to 5 feet, and individual stakes were placed 3 feet 3 inches apart in the rows. A level path approximately 1 foot wide was then excavated immediately above each row and brush was placed horizontally above the stakes to form a wattle.

The brush consisted almost entirely of manzanita, buck brush, mountain lilac, scrub oak, and greasewood. An effort was made to select brush with reasonably straight stems and a number of small, leafy branches. The length varied from 3 to 4 feet, and butt diameter from 1 to 2 inches. For some fills, suitable brush could be cut in the immediate vicinity; for others, it was necessary to haul it in by truck.

The brush was interlaced and compacted to form a wattle 1 foot wide and 1 to 1½ feet high. The entire thickness or height extended above the surface of the fill, and the wattle rested against the supporting stakes. After completion of the wattles the area between rows was covered with hay, seeded, and covered with earth as described under method B.

Table 1 shows the areas treated by each method and the costs.

Additional protection work not shown in table 1 was done in the summer and fall of 1936.

Method A was used in treating fills of class 2 soils, and methods B and C were used in treating fills of class 1 soils.

TABLE 1.—*Areas of fill slopes treated by three methods of erosion control, and cost per acre for each method*

Method	Area of slope treated	Cost per acre
	Acres	
A	2.7	$213
B	10.5	449
C	3.7	715

FAILURE OF BRUSH WATTLES CAUSED BY SLIPPAGE OF SURFACE MATERIAL

Some of the protection work was damaged by herds of deer. Probably because of the scarcity of forage in the surrounding mountains, the deer fed on the hay placed on the fills. In some locations this resulted in the complete loss of the hay mat and considerable damage to the rest of the protection work. It was deemed advisable to replace the hay and reseed the slopes prior to winter storms, so this was done. Also, approximately 300 Yerba Santa root cuttings were planted per slope-acre on slopes with southern exposures. This plant is native to the locality. Its growth was particularly vigorous under conditions similar to those existing on the fills where it was planted. All slopes were seeded with Italian rye and burr clover, with some acorns on slopes with northern exposures.

The protected fills were subjected to a severe test in February 1936 during construction. Approximately 10 inches of rain fell, at times approaching the rate of 1 inch per hour. After this storm, damage to protected and unprotected slopes was noted. (See figs. 6, 7, and 8.)

Fills protected by brush rows and hay mats eroded the least. Brush rows without hay mats were less effective protection, although they tended to break up small mud flows and prevent the formation of large channels.

Results to the middle of the winter season 1936–37, following unusually severe winter conditions, show considerable erosion of untreated fill slopes. There have

FIGURE 6.—APPEARANCES OF PROTECTED AND UNPROTECTED FILL SLOPES AFTER A HEAVY RAIN.

been some slips of wattled fills, but little erosion or loss of material has occurred on brush-treated fills. Figure 9 shows damage to fills protected according to method C. No protection work was performed on the upper sections of the fills shown in figure 9 because of the rocky material present.

The failure of wattles on some fills was probably caused chiefly by slippage of the surface material. Apparently the wattles were not as well anchored to the fill as were the rows of brush laid according to methods A and B.

The results obtained by the protection work, as determined by an inspection made in March 1937, are shown in table 2.

TABLE 2.—*Results obtained on fill protection work on route 61*

Method	Treated area inspected	Area of failures	Percentage of failure
	Acres	*Acres*	
A	1.7	0.4	24
B	11.5	1.2	10
C	4.8	2.7	57

FIGURE 7.—FILL SLOPES PROTECTED ACCORDING TO METHOD A. PICTURE SHOWS A SECTION ABOUT 70 FEET BELOW GRADE.

EXTREMELY EROSIBLE SOIL IN FILLS ON ROUTE 74

Route 74, located in east-central California, was constructed during 1933 and 1934.

The soil on the fill slopes was not favorable to plant growth and this, together with erosion, prevented revegetation. The soil consisted of disintegrated granite with various percentages of hard rock particles. The soil was also micaceous in various degrees, the mica content ranging from a trace to a maximum of 20 percent, and was extremely erosible. The grading of the soil was approximately as follows:

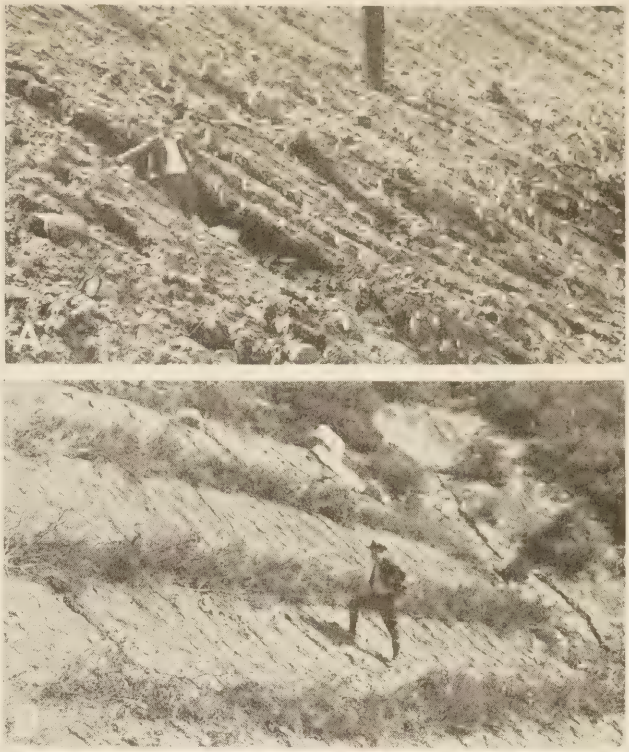


FIGURE 8.—SECTIONS OF FILL SLOPES ABOUT 70 FEET BELOW GRADE. A; EROSION ON AN UNPROTECTED FILL. B; A FILL PROTECTED ACCORDING TO METHOD A.

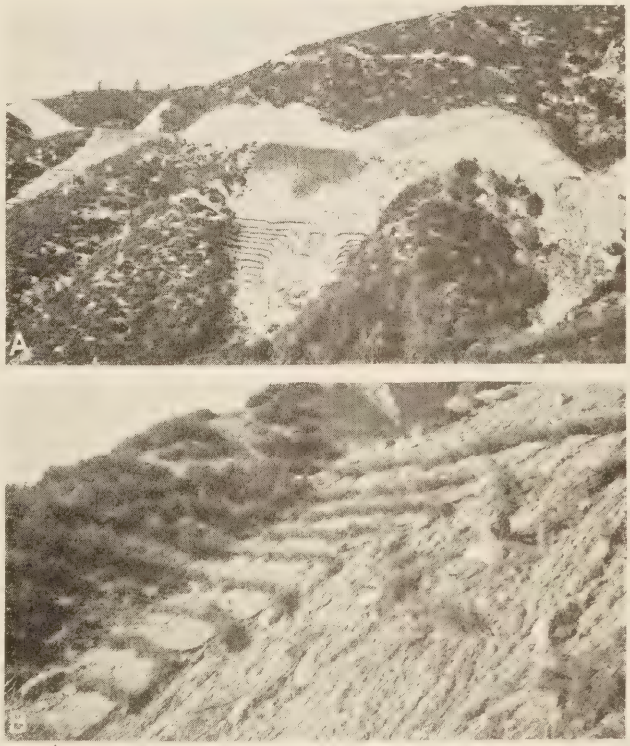


FIGURE 9.—DAMAGED FILLS THAT HAD BEEN PROTECTED BY BRUSH WATTLES (METHOD C).

	Percent
Passing the 2-inch sieve	75–100
Passing the 200-mesh sieve	20– 40

A typical example of gulley erosion in this type of soil is shown in figure 10. Practically all of the higher fills have northern exposures. Because most storms come from the north, erosion is greatest on the fills having northern exposures and least on fills having southern exposures.

An outline of the proposed control work on route 74 was prepared by the Landscape Division of the Forest Service, Region 5, and the work was done under the direct supervision of a Forest Service foreman with previous experience on similar work.

In general the methods of construction used were the types outlined in the May 1936 edition of "Specifications for Erosion Control Methods", Manual of Region 5 of the Forest Service. The types used will be described in detail.

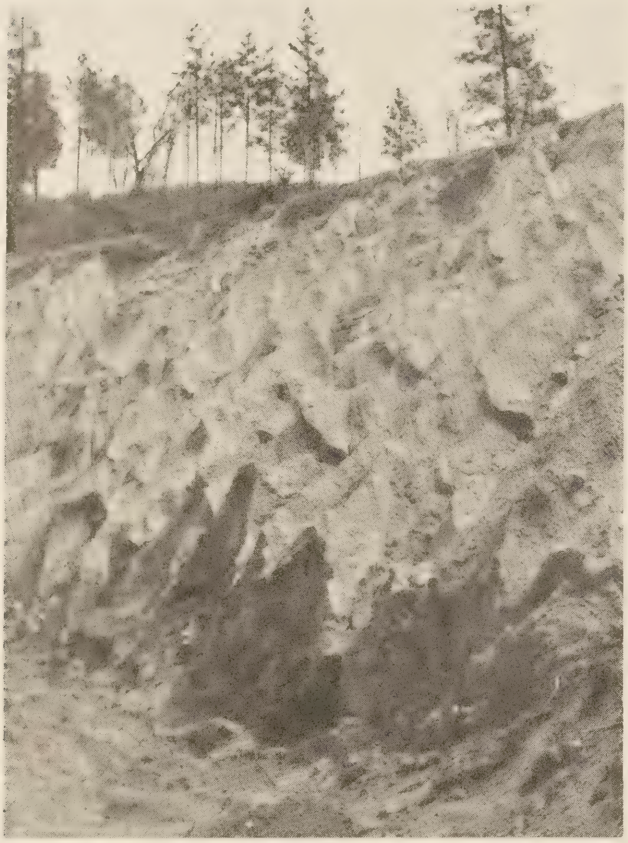


Figure 10.—Example of Gulley Erosion Occurring in Soil Similar to That on Fill Slopes on Route 74.

Wattling method A (*brush wattles and hay or straw*).—This method was used on the higher, more exposed fills and consisted of brush wattles anchored with 3-foot stakes driven 30 inches into the fill. The brush consisted chiefly of very leafy chaparral and mountain lilac, in lengths of about 4 feet and with a maximum butt diameter of 1 inch. A trench 1 foot wide and about 1 foot deep was dug immediately above the stake row. The brush was laid and compacted into a wattle 1 foot wide and 1½ feet thick. The completed wattle extended 6 inches above the surface of the fill slope. Sufficient earth was placed on the wattles after installation to hold the brush in place.

The spaces between wattles were covered with either hay or straw. Distances between rows of wattles and between stakes in the rows were varied. It was originally intended to space rows on contour lines 3½ feet apart and to place stakes 18 inches apart in the rows. This spacing was used on approximately 2 acres of the total of 3.6 acres protected by this method. Figure 11 shows stakes being driven in a fill and a fill with protection work completed.

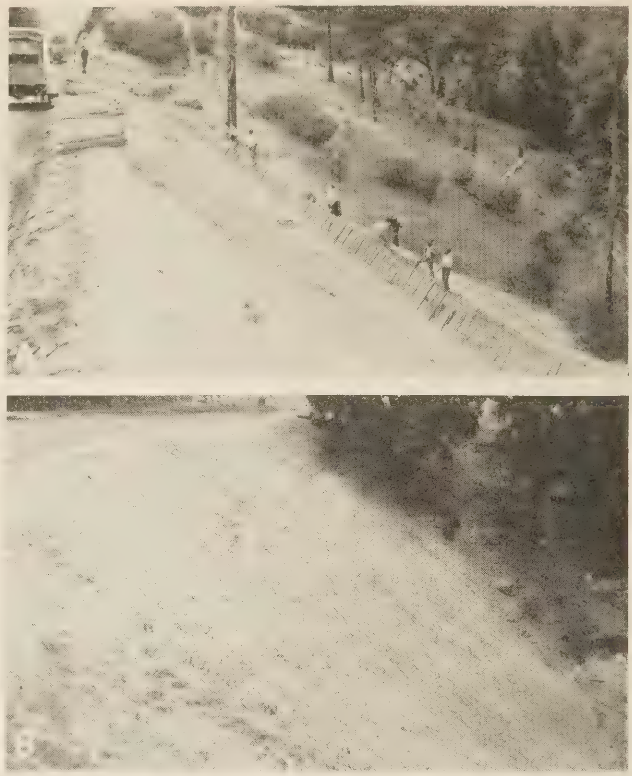


Figure 11.—A; Stakes Being Driven into a Fill in Building Brush Wattles. B; a Fill Protected by Brush Wattles and Hay.

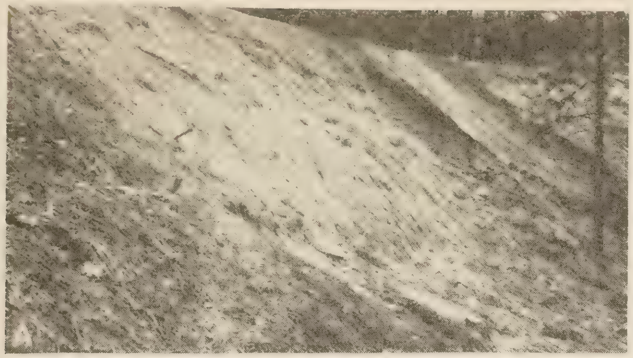
Because construction with the rows 3½ feet apart and stakes 18 inches apart was too rapidly depleting available funds, distances between rows and stakes on the remaining 1.6 acres were increased. The distance between rows was increased to 4 feet (on a few small fills to 4½ and 5 feet) and stakes were driven 2 feet apart in the rows.

Costs per slope acre were $828 for the closer spacing and $620 for the wider spacing.

After being subjected to intense rains during the winter 1936–37, fills on which the closer spacing was used did not appear to be definitely superior to fills with wider spacing of rows. Failures or partial failures by slipping of the wattles amounted to approximately 18 percent on the closer spaced sections, and to 8 percent on the wider spaced sections. However, as the closer spacing was used on the more exposed and larger fills, these percentages cannot be directly compared. Failures of fills protected by brush wattles and hay are shown in figure 12.

Fourteen slopes on route 74 were protected by the brush wattles and hay or straw.

Wattling method B (*hay wattles*).—Hay wattles were placed on nine slopes having a total area of 1.3 slope acres. Six of these fills had southern exposures, and three were on stable-appearing fills having northern exposures. Stakes were driven on contour lines, with a vertical interval of 3 feet between rows; and were spaced 2 feet apart in individual rows. These stakes were 3 feet long and were driven 30 inches into the fill. A shallow trench about 1 foot wide was dug immediately



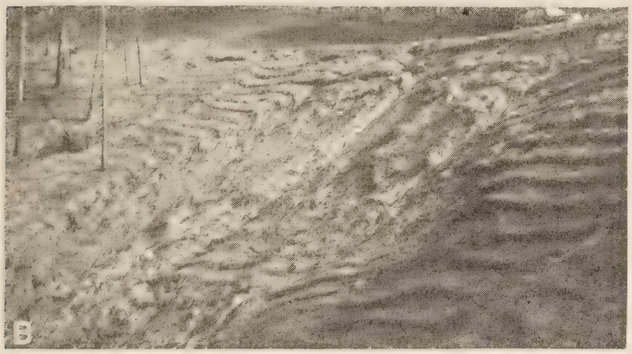


FIGURE 12.—FAILURES OF FILL PROTECTION WORK. THE FILL SHOWN IN B IS THE SAME FILL AS IS SHOWN IN FIGURE 11, B.

above each row and the wattle was placed in this trench. The wattles were formed by twisting and compacting oat hay and straw into a continuous bundle 4 inches in diameter. The wattles were lightly covered with earth to hold them in place. The entire slope was then covered with a layer of straw 4 inches deep.

The cost per slope acre was $256. Fills protected by this method withstood the winter rains remarkably well.

Some slipping occurred on one of the large fills having a northern exposure. This failure, which amounted to 25 percent of the area of the fill, represented less than 4 percent of the total area protected by hay wattles. Partial failure of a fill protected by hay wattles is illustrated in figure 13.

Although fills protected by hay wattles were more favorably situated than were those protected by brush wattles, the former proved satisfactory and might possibly give good results if used on more exposed fills.

Duff method.—In most cases the fills were trenched before duff or litter was placed. The duff consisted of pine needles, dead leaves, small twigs, small pieces of bark, grass, and leaf mold or other humus. This material was scraped from any available areas and spread on the fills to an average depth of 1 inch. As work progressed duff became increasingly difficult and expensive to obtain in sufficient quantity to complete the work.

The scarcity of material added somewhat to the cost, which was $337 per acre. Even if duff had been more readily available, it is doubtful that this method could be employed as cheaply as the hay-wattle method.

The duff method was used on 12 less-exposed fills having a total area of 1.7 slope acres. Only three of these fills had northern exposures. Very good results were obtained and failures during the first winter occurred on only two fills, both having northern exposures. The areas showing damage were but 5 percent of the total area treated by this method.

On two low fills, special effort was made to encourage the growth of native plants. Material on an area having a rich growth of native grasses and flowers was reserved for these fills, and all duff, litter, humus and a small amount of topsoil were removed. This material was transported to the fills and spread by hand methods to a depth of about 1 inch. Detailed costs were not kept on this work, but estimated costs were less than $200 per slope-acre. These fills showed but slight erosion after the first winter, and a very good growth of native plants had been established by the following spring.

Route 74 was, to a large extent, experimental in the use of various types of treatment recommended by the Landscape Division of the Forest Service. In general the results obtained were satisfactory.

FIGURE 13.—PARTIAL FAILURE ON A FILL PROTECTED BY HAY WATTLES.

CONCLUSIONS

Fills protected by the various methods on the three projects were subjected to severe weathering during the winter of 1936–37. An inspection made in March 1937 revealed that the greater part of the work successfully prevented excessive erosion.

In view of the good results obtained by planting willow cuttings on route 20, it is thought that their use alone, without wattles, would prove as satisfactory as the combination.

On route 61, a comparison of the costs and percentages of failure for the three methods used indicates that method B (brush in fill layers with hay mat) has been the most satisfactory in the types of soil encountered.

While the soils found on route 61 washed to some extent, the major difficulty was their tendency to absorb and hold large quantities of water. The extreme weight of the saturated areas caused slides. The ideal treatment for such soils would probably be some form of waterproofing to prevent saturation. This would generally be economically impossible, and the only known alternative is to stabilize the saturated areas by providing some form of anchorage. Considerable stabilization can be attained by compacting fills to their extreme edges, and by incorporating all available rock in the fill slopes. Of the various forms of anchorage tried, the most efficient was that of placing rows of brush during fill construction. In spite of some failures of fills protected by this method, it is believed that satisfactory results could be obtained by spacing the brush layers closer and by using long-stemmed brush.

The types of work done on route 74 cannot be directly compared because the different methods were used on fills subjected to different weathering conditions. However, the results indicate that the methods can be used as recommended with a fair assurance of satisfactory results on favorable types of soil.

Soils of the type and grading of those found on route 74 are subject to extreme erosion. These soils have little tendency to absorb and hold large quantities of moisture. Thus, while large slides do not occur on properly constructed fills, the surfaces ravel rapidly. The most suitable treatment for such soils is apparently the placing of some form of mat to hold the surface in place and prevent concentration of water in gullies. On low fills, where extensive concentration of water cannot occur, coverings of hay, straw, forest litter, or duff seem generally effective. On high fills anchorage of such coverings is necessary, and means of diffusing the water and preventing its concentration must be provided. Wattles and trenches, constructed in accordance with methods outlined in the Forest Service specifications, appear to be generally satisfactory for these purposes.

The results of the control work on these three projects have been of particular value in demonstrating the need of making thorough advance study of each proposed treatment and of adapting the methods to be used to each area treated. The fill soils should be studied to determine their reactions to the particular erosive forces to which they are exposed.

CHANNEL CHANGES ON FOREST HIGHWAYS

(Continued from page 175)

TABLE 2.—*Comparison of curvature data for project B (5.6 miles long) as originally surveyed, as revised, and as constructed*

Line	Curves	Total angle [1]	Maximum curve	Number of curves of— 1°	2°	3°	4°	5°	6°	7°	8°	10°	12°	14°	20°	22°
	Number	*Degrees*	*Degrees*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Original (1931)	29	1,230	22			5	3	2	5	1	2	4	3	1	2	1
Revised (1934)	17	666	8	2	1	2	6			1	5					
Constructed	14	558	6	1	1	4	5	2	1							

[1] All curves on the constructed line are spiraled, and spiral angles are included in total angles for both the revised and the constructed line.

FIGURE 8.—TWO CHANNEL CHANGES: A, THIS CHANNEL CHANGE STRAIGHTENS A MEANDERING STREAM. THE RIPRAPPED SLOPE BEARS THE FULL FORCE OF THE CURRENT AROUND THE CURVE. B, THE LARGEST ROCKS ARE PLACED AT THE BOTTOM OF THE RIPRAPPED SLOPE.

STATUS OF FEDERAL-AID HIGHWAY PROJECTS

AS OF OCTOBER 31, 1937

STATE	COMPLETED DURING CURRENT FISCAL YEAR			UNDER CONSTRUCTION			APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR NEW PROJECTS
	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	Estimated Total Cost	Federal Aid	Miles	
Alabama	$ 163,700	$ 81,850	5.9	$ 2,557,661	$ 1,268,830	121.7	$ 3,108,900	$ 1,554,445	146.0	$ 4,942,055
Arizona	981,784	719,225	31.5	1,554,193	1,102,579	80.9	424,143	286,934	18.1	1,205,611
Arkansas	1,476,347	1,475,608	72.8	2,462,294	2,456,914	183.6	264,896	264,568	13.4	2,201,829
California	4,471,220	2,367,272	98.1	5,945,358	3,239,392	97.7	3,319,836	1,749,868	64.2	1,554,575
Colorado	2,234,049	1,248,194	87.4	1,260,853	696,448	33.9	494,404	260,018	16.0	2,166,805
Connecticut	710,998	353,096	8.7	231,110	107,923	1.3	72,610	36,300	.2	1,513,584
Delaware	231,150	115,530	5.8	281,162	140,537	13.7	243,905	119,934	14.8	1,107,687
Florida	301,250	150,620	8.2	2,716,172	1,358,086	65.2	508,170	254,085	7.8	2,648,148
Georgia	1,415,614	704,406	82.6	4,097,392	2,048,691	185.6	2,283,426	1,141,713	93.9	4,725,214
Idaho	1,639,071	978,378	140.6	1,271,274	759,487	78.3	194,020	115,570	20.3	1,112,436
Illinois	5,382,529	2,632,516	154.2	8,400,961	4,200,023	254.4	4,042,000	2,017,150	73.9	2,122,313
Indiana	2,527,473	1,258,071	53.3	5,091,782	2,545,770	148.9	1,206,198	603,099	24.4	2,120,799
Iowa	4,215,696	1,947,238	134.3	6,443,476	2,838,943	194.3	1,049,492	481,550	33.9	819,557
Kansas	2,575,957	1,260,617	146.6	3,694,085	1,846,943	125.7	1,900,812	949,133	98.1	3,276,079
Kentucky	904,102	452,051	25.6	3,914,808	1,907,404	115.2	1,845,164	922,582	88.0	2,401,247
Louisiana	213,312	102,519	5.9	6,724,240	1,514,885	48.6	5,293,838	836,455	12.5	1,729,722
Maine	1,316,680	658,340	34.7	2,143,566	1,071,783	52.7	690,599	345,295	16.3	203,604
Maryland	184,006	92,003	2.1	2,236,200	1,101,517	36.5	435,318	215,909	3.7	1,685,379
Massachusetts	926,641	463,320	7.3	4,039,654	2,019,826	15.2	1,484,726	742,363	.7	1,862,823
Michigan	4,829,650	2,414,825	126.1	5,882,030	2,941,515	145.4	2,417,309	1,133,829	37.3	228,478
Minnesota	3,861,230	1,919,018	175.3	3,782,371	1,879,941	164.3	1,528,426	628,328	59.6	1,741,332
Mississippi	804,200	402,100	40.0	4,696,100	2,347,730	216.5	1,362,200	680,050	58.3	3,203,296
Missouri	5,213,011	2,584,546	291.1	6,727,386	3,177,780	240.6	3,409,293	1,391,107	84.8	1,659,385
Montana	3,278,293	1,837,892	225.6	2,031,335	1,111,716	112.3	255,860	143,920	7.9	2,347,702
Nebraska	1,757,862	878,931	169.2	4,807,736	2,391,846	465.8	2,359,810	549,905	64.6	2,311,049
Nevada	1,333,105	1,146,790	74.9	1,454,212	1,255,676	61.5	328,489	284,859	36.5	682,069
New Hampshire	143,483	71,379	1.9	595,203	293,799	11.2	56,074	27,911	.6	1,039,780
New Jersey	689,590	267,500	5.7	1,808,138	903,749	16.5	124,870	62,435	.6	2,247,469
New Mexico	2,141,540	1,315,548	169.9	2,447,626	1,592,186	125.0	792,104	483,101	35.7	254,189
New York	6,833,274	3,162,558	119.4	17,878,354	8,498,916	300.5	3,583,890	1,790,445	49.3	565,736
North Carolina	2,086,699	1,043,289	163.1	6,076,383	2,825,491	300.2	1,592,280	697,390	61.3	2,538,696
North Dakota	925,760	925,760	173.4	1,281,430	1,260,920	90.5	236,822	236,822	36.4	3,298,731
Ohio	1,796,762	847,903	24.5	10,191,439	5,046,014	112.2	2,020,460	1,010,230	25.8	5,183,848
Oklahoma	2,119,328	1,112,698	90.7	2,829,097	1,464,273	118.5	1,859,295	976,663	82.1	3,123,267
Oregon	2,599,477	1,517,777	111.1	2,172,633	1,325,099	60.1	648,679	395,770	30.5	1,045,089
Pennsylvania	7,093,759	3,527,559	106.9	9,094,345	4,527,953	120.0	4,238,870	2,109,206	67.5	2,703,665
Rhode Island	536,250	266,814	5.7	1,097,274	548,637	13.7	257,230	128,615	1.7	760,655
South Carolina	1,927,691	820,202	167.2	5,068,911	2,049,055	229.7	1,694,090	630,135	71.1	1,357,311
South Dakota	1,853,022	1,057,041	148.0	1,905,350	1,053,580	214.0	549,730	303,940	83.5	3,132,700
Tennessee	932,278	459,194	42.7	1,539,764	769,882	41.5	803,300	401,650	29.5	4,888,945
Texas	6,730,726	3,362,428	486.9	10,373,623	5,168,332	525.0	3,988,591	1,945,434	183.6	5,862,276
Utah	491,434	353,242	44.6	1,445,090	1,030,780	130.1	154,270	108,800	8.5	1,096,863
Vermont	664,181	322,733	18.1	1,594,810	719,760	43.3	302,650	127,954	5.5	82,385
Virginia	1,736,001	868,001	90.6	2,829,382	1,375,276	78.6	1,151,502	551,316	40.2	2,125,909
Washington	1,266,828	665,300	62.1	2,871,529	1,500,679	44.9	1,007,410	527,225	8.9	796,634
West Virginia	708,835	354,418	20.5	1,466,674	736,830	42.7	628,902	464,851	18.1	2,136,392
Wisconsin	6,140,018	2,888,797	202.9	5,150,820	2,519,820	136.4	775,055	384,600	31.4	1,309,076
Wyoming	2,154,791	1,318,461	203.9	1,426,942	863,629	189.9	246,250	152,160	12.4	218,942
District of Columbia										
Hawaii	459,087	226,420	8.0	504,649	248,452	9.9	449,816	205,089	6.9	1,148,247
Puerto Rico				53,980	26,990	2.1	648,039	322,040	12.6	275,970
TOTALS	104,979,744	54,999,978	4,675.6	186,150,857	93,682,287	6,216.3	68,334,023	31,752,751	1,998.9	98,765,553

CURRENT STATUS OF UNITED STATES WORKS PROGRAM HIGHWAY PROJECTS

(AS PROVIDED BY THE EMERGENCY RELIEF APPROPRIATION ACT OF 1935)

AS OF OCTOBER 31, 1937

STATE	APPORTIONMENT	COMPLETED			UNDER CONSTRUCTION			APPROVED FOR CONSTRUCTION			BALANCE OF FUNDS AVAILABLE FOR NEW PROJECTS
		Estimated Total Cost	Works Program Funds	Miles	Estimated Total Cost	Works Program Funds	Miles	Estimated Total Cost	Works Program Funds	Miles	
Alabama	$ 4,151,115	$ 3,944,942	$ 3,907,392	136.9	$ 250,100	$ 243,478	7.8				$ 245
Arizona	2,569,841	3,125,360	2,453,294	194.8	38,548	38,548					77,999
Arkansas	3,352,061	3,143,188	3,123,140	350.5	181,216	180,523	9.7				48,398
California	7,747,928	7,545,686	7,194,317	257.5	572,929	515,656	6.4				37,955
Colorado	3,395,263	2,379,345	2,294,218	99.4	89,597	89,596	6.0	$ 8,200	$ 8,200		1,003,249
Connecticut	1,418,709	1,099,482	1,030,861	16.2	306,181	280,480	6.2	124,130	64,435	0.2	42,933
Delaware	900,310	627,224	601,492	53.8	257,585	257,585	13.0	26,712	26,712	4.4	14,521
Florida	2,597,144	2,584,572	2,521,530	99.1	38,957	38,957					36,657
Georgia	4,988,967	1,282,346	1,245,396	81.4	2,694,894	2,426,514	118.8	684,630	684,630	34.5	632,427
Idaho	2,222,747	2,252,832	2,151,909	185.6	49,205	49,131	.3				21,707
Illinois	8,694,009	8,034,975	7,803,546	456.2	764,590	764,590	32.0				125,873
Indiana	4,941,255	4,854,405	4,581,943	219.7	331,419	331,419	18.7				27,893
Iowa	4,991,664	5,218,382	4,865,314	526.3	124,300	117,465	2.3	3,474	3,470		5,415
Kansas	4,994,975	4,580,650	4,499,689	356.3	419,276	417,103	34.2	15,620	15,620	1.7	62,562
Kentucky	3,726,271	3,334,467	3,183,269	348.3	459,839	459,839	9.6	57,000	57,000	.6	26,163
Louisiana	2,890,429	2,473,382	2,212,488	163.0	604,151	543,516	4.6	97,087	97,070	10.4	37,355
Maine	1,676,799	1,573,431	1,560,841	72.0	118,557	115,958	4.1				
Maryland	1,750,738	637,876	631,089	23.5	581,095	581,095	11.6	193,134	159,302	6.4	379,253
Massachusetts	3,262,885	1,103,580	1,103,580	14.0	1,910,026	1,519,256	4.4	1,136,726	568,363	.8	71,686
Michigan	6,301,414	6,518,192	5,952,637	288.6	290,686	289,571	3.3	44,500	33,882	.3	25,324
Minnesota	5,277,145	6,384,622	5,170,637	895.7	111,965	92,862	6.1				13,646
Mississippi	3,457,552	2,831,756	2,827,119	197.9	541,746	540,706	37.8	8,900	8,900	.6	80,826
Missouri	6,012,652	5,298,465	5,157,460	774.5	802,370	747,248	3.2	34,391	32,294		75,650
Montana	3,676,416	3,618,384	3,562,698	202.6	95,385	95,385	.1	8,462	8,462		9,872
Nebraska	3,870,739	3,311,368	3,205,529	346.4	587,690	587,686	24.3	70,270	70,270	1.8	7,254
Nevada	2,243,074	2,290,966	2,207,403	110.1	33,646	33,646					2,026
New Hampshire	945,225	876,074	843,821	37.7	63,555	63,555	2.5	57,537	37,746	3.2	103
New Jersey	3,129,805	1,195,787	1,177,568	20.5	1,917,769	1,917,769	14.9				34,468
New Mexico	2,871,397	2,751,452	2,746,286	205.3	106,210	106,210	8.4	14,681	12,196		6,705
New York	11,046,377	10,786,792	10,331,736	170.0	125,700	85,700	.6	40,000	40,000		588,941
North Carolina	4,720,173	4,020,158	3,949,305	259.4	716,990	716,390	31.3	37,900	37,900	.5	16,577
North Dakota	2,867,245	2,490,916	2,459,240	378.9	107,799	107,799	1.2	280,295	280,295	36.0	19,911
Ohio	7,670,815	6,150,464	6,064,711	261.1	1,571,192	1,535,767	35.6	30,200	30,200	1.9	40,137
Oklahoma	4,580,670	4,329,543	4,202,267	391.5	330,110	330,110	13.7	77,400	35,307	3.8	12,986
Oregon	3,038,642	3,127,157	2,861,791	161.0	134,854	134,854	3.6	11,846	11,846	1.0	30,151
Pennsylvania	9,347,797	5,355,490	5,119,017	215.8	3,846,235	3,444,595	50.7	785,495	630,267	19.3	153,918
Rhode Island	989,208	1,111,600	989,136	18.8							72
South Carolina	2,702,012	2,261,423	2,111,864	224.6	627,419	545,752	24.9	9,664	9,664	1.5	34,731
South Dakota	2,976,454	2,532,822	2,529,342	467.0	432,947	432,947	37.6				14,165
Tennessee	4,192,460	3,173,312	3,141,998	126.1	1,020,913	1,020,913	24.6				29,549
Texas	11,989,350	12,599,090	11,528,578	1,105.8	382,509	285,584	5.9	159,161	143,575	13.3	31,614
Utah	2,067,154	2,053,065	1,842,753	204.2	196,775	196,775	4.5				27,626
Vermont	924,306	1,057,603	911,448	23.2	8,000	8,000					4,858
Virginia	3,652,667	3,345,780	3,264,377	1,020.5	188,931	182,932	14.6				205,358
Washington	3,026,161	3,356,252	2,940,122	164.3	45,392	45,392		25,465	20,845	.7	19,802
West Virginia	2,231,412	1,482,752	1,473,104	60.5	854,026	718,128	34.6	47,560	40,180	5.4	
Wisconsin	4,823,884	5,244,297	4,729,965	343.4	94,268	93,900	.3				19
Wyoming	2,219,155	2,185,929	2,180,273	152.4	33,287	33,287					5,595
District of Columbia	949,496	950,000	949,496	8.8							
Hawaii	926,033	678,560	655,700	10.4	277,293	215,689	7.0	10,000	10,000		44,644
TOTALS	195,000,000	173,166,196	164,052,689	12,501.5	25,338,127	23,579,861	681.0	4,100,440	3,178,631	148.3	4,188,819

U. S. GOVERNMENT PRINTING OFFICE: 1937

PUBLICATIONS of the BUREAU OF PUBLIC ROADS

Any of the following publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. As his office is not connected with the Department and as the Department does not sell publications, please send no remittance to the United States Department of Agriculture.

ANNUAL REPORTS

Report of the Chief of the Bureau of Public Roads, 1924. 5 cents.
Report of the Chief of the Bureau of Public Roads, 1927. 5 cents.
Report of the Chief of the Bureau of Public Roads, 1928. 5 cents.
Report of the Chief of the Bureau of Public Roads, 1929. 10 cents.
Report of the Chief of the Bureau of Public Roads, 1931. 10 cents.
Report of the Chief of the Bureau of Public Roads, 1933. 5 cents.
Report of the Chief of the Bureau of Public Roads, 1934. 10 cents.
Report of the Chief of the Bureau of Public Roads, 1935. 5 cents.
Report of the Chief of the Bureau of Public Roads, 1936. 10 cents.

DEPARTMENT BULLETINS

No. 583D . . Reports on Experimental Convict Road Camp, Fulton County, Ga. 25 cents.
No. 1279D . . Rural Highway Mileage, Income, and Expenditures, 1921 and 1922. 15 cents.
No. 1486D . . Highway Bridge Location. 15 cents.

TECHNICAL BULLETINS

No. 55T . . . Highway Bridge Surveys. 20 cents.
No. 265T . . . Electrical Equipment on Movable Bridges. 35 cents.

MISCELLANEOUS PUBLICATIONS

No. 76MP . . The Results of Physical Tests of Road-Building Rock. 25 cents.
No. 191MP. Roadside Improvement. 10 cents.
No. 272MP. Construction of Private Driveways. 10 cents.
No. 279MP. Bibliography on Highway Lighting. 5 cents.
The Taxation of Motor Vehicles in 1932. 35 cents.
Guides to Traffic Safety. 10 cents.
Federal Legislation and Rules and Regulations Relating to Highway Construction. 15 cents.
An Economic and Statistical Analysis of Highway-Construction Expenditures. 15 cents.
Highway Bond Calculations. 10 cents.

Single copies of the following publications may be obtained from the Bureau of Public Roads upon request. They cannot be purchased from the Superintendent of Documents.

SEPARATE REPRINT FROM THE YEARBOOK

No. 1036Y . . Road Work on Farm Outlets Needs Skill and Right Equipment.

TRANSPORTATION SURVEY REPORTS

Report of a Survey of Transportation on the State Highway System of Ohio (1927).

Report of a Survey of Transportation on the State Highways of Vermont (1927).

Report of a Survey of Transportation on the State Highways of New Hampshire (1927).

Report of a Plan of Highway Improvement in the Regional Area of Cleveland, Ohio (1928).

Report of a Survey of Transportation on the State Highways of Pennsylvania (1928).

Report of a Survey of Traffic on the Federal-Aid Highway Systems of Eleven Western States (1930).

UNIFORM VEHICLE CODE

Act I.—Uniform Motor Vehicle Administration, Registration, Certificate of Title, and Antitheft Act.

Act II.—Uniform Motor Vehicle Operators' and Chauffeurs' License Act.

Act III.—Uniform Motor Vehicle Civil Liability Act.

Act IV.—Uniform Motor Vehicle Safety Responsibility Act.

Act V.—Uniform Act Regulating Traffic on Highways.

Model Traffic Ordinances.

A complete list of the publications of the Bureau of Public Roads, classified according to subject and including the more important articles in Public Roads, may be obtained upon request addressed to the U. S. Bureau of Public Roads, Willard Building, Washington, D. C.

CURRENT STATUS OF UNITED STATES WORKS PROGRAM GRADE CROSSING PROJECTS

(AS PROVIDED BY THE EMERGENCY RELIEF APPROPRIATION ACT OF 1935)

AS OF OCTOBER 31, 1937

STATE	APPORTIONMENT	COMPLETED		NUMBER			UNDER CONSTRUCTION		NUMBER			APPROVED FOR CONSTRUCTION		NUMBER			BALANCE OF FUNDS AVAILABLE FOR NEW PROJECTS
		Estimated Total Cost	Works Program Funds	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	Estimated Total Cost	Works Program Funds	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	Estimated Total Cost	Works Program Funds	Grade Crossings Eliminated by Separation or Relocation	Grade Crossing Structures Reconstructed	Grade Crossings Protected by Signals or Otherwise	
Alabama	$ 4,034,617	$ 3,249,498	$ 3,231,948	44	1	12	$ 670,572	$ 670,572	5			$ 175,300	$ 109,000	4			$ 23,097
Arizona	1,256,099	1,113,686	1,072,656	13			185,468	163,059	2		3	6,403	6,403			2	13,981
Arkansas	3,574,060	2,826,690	2,819,516	51	6	4	570,659	570,224	4		8	149,214	148,944	1		21	35,376
California	7,486,362	7,153,440	6,966,322	45	8		470,205	470,204	2			10,000	10,000	5			39,836
Colorado	2,631,567	1,899,531	1,837,167	23	1		821,674	791,106	7	2	21						3,294
Connecticut	1,712,684	297,379	297,379	2	1	1	1,341,801	1,320,440	8								94,865
Delaware	418,239	130,000	130,000	1			277,993	277,993	2								10,246
Florida	2,827,883	2,271,833	2,252,939	28	5	2	250,124	249,518	3			128,320	128,320			72	197,106
Georgia	4,895,949	355,157	353,665	11	5	4	1,524,041	1,524,041	27	6	7	521,070	521,070	7	2	41	2,497,173
Idaho	1,674,479	1,333,866	1,323,563	20	2	9	318,696.	318,661	3		9	4,261	4,261			3	27,994
Illinois	10,307,184	8,062,094	7,986,847	62	8		2,212,294	2,205,890	11	2		127,000	78,000	2			36,447
Indiana	5,111,096	3,899,953	3,726,047	35	12		1,317,906	1,317,906	7		162						67,143
Iowa	5,600,679	4,362,927	4,263,256	94	9	8	1,332,589	1,326,781	12								10,642
Kansas	5,246,258	3,966,373	3,904,919	54		5	1,273,119	1,253,704	4	1		108,004	15,000	2			72,634
Kentucky	3,672,387	1,305,853	1,298,000	18	5		2,037,014	1,747,282	6	6		612,579	612,579	3	1		14,526
Louisiana	3,213,467	1,328,350	1,328,343	14	1		1,120,878	1,120,859	11	1		657,841	608,350	4	1		155,915
Maine	1,426,861	1,069,189	1,066,911	19		2	373,818	355,570	1	2		4,380	4,380			2	
Maryland	2,061,751	501,739	501,739	3	3	16	847,170	847,170	6	2	3	480,361	407,893	2	1	11	304,949
Massachusetts	4,210,833	2,139,608	2,137,178	19	4		1,617,761	1,617,761	7			249,991	249,991	1			205,903
Michigan	6,765,197	6,472,627	6,154,021	43	8		485,477	485,477	1			43,500	43,500		1		82,199
Minnesota	5,395,441	4,371,941	4,267,794	78	14	50	1,115,218	1,104,074	8								23,573
Mississippi	3,241,475	2,038,818	2,038,651	45	4	4	689,238	689,238	10	3	4	76,700	76,700	2		13	436,886
Missouri	6,142,153	3,014,620	2,940,676	31	1		3,293,571	3,190,761	18		1	1,650	1,650			1	9,066
Montana	2,722,327	2,589,093	2,532,574	37	7		245,576	185,931	1	1							3,823
Nebraska	3,556,441	2,651,081	2,615,327	73	3	19	713,266	713,266	8		1	214,916	189,878	5		4	37,971
Nevada	887,260	885,084	857,417	8	3		13,308	13,308				3,630	3,630			5	12,905
New Hampshire	822,484	737,902	737,857	8	4	6	106,670	82,521	2			2,106	2,106			1	
New Jersey	3,983,826	2,806,217	2,794,784	18	5	1	1,084,370	1,084,370	6	4		44,730	44,730		1		59,942
New Mexico	1,725,286	1,644,472	1,637,584	18	1		82,384	82,384	1								5,318
New York	13,577,189	10,043,525	9,769,001	31	39		3,537,000	3,537,000	14	10		94,000	94,000				177,189
North Carolina	4,823,958	3,297,724	3,277,598	45	18		1,405,139	1,405,139	15		108	32,870	32,870	2			108,350
North Dakota	3,207,473	2,820,675	2,817,055	56	4		389,012	389,012		1							1,406
Ohio	8,439,897	1,791,055	1,681,905	12	3	2	6,205,013	5,726,074	35	5	1	868,700	853,700	12		11	178,218
Oklahoma	5,004,711	3,582,337	3,575,085	56	7	4	1,436,634	1,303,534	9	5	3	102,170	102,170			34	23,922
Oregon	2,334,204	2,239,057	2,154,389	15	6	2	164,842	161,937	2								17,878
Pennsylvania	11,483,613	6,555,714	6,042,786	60	17	9	5,370,140	5,003,152	26	6		150,473	150,473	5			287,202
Rhode Island	699,691	698,074	695,860	4	3												3,831
South Carolina	3,059,956	1,500,273	1,481,282	29	10	8	1,074,226	1,066,796	16	5	22	205,667	205,667	1	1	18	306,211
South Dakota	3,249,086	2,263,266	2,262,574	45	6	53	770,289	770,289	20			269,350	210,392	17			5,831
Tennessee	3,903,979	1,305,258	1,296,577	25	3	26	2,201,440	2,201,440	20	1	1	155,070	155,070	1		12	250,892
Texas	10,855,982	9,774,780	9,767,329	125	14	65	560,011	548,167	2	2	9	223,121	223,121			75	317,365
Utah	1,230,763	931,508	924,612	12	1	1	290,423	290,423	5								15,728
Vermont	729,857	749,776	705,709	10	7	18	14,100	14,100			2						10,048
Virginia	3,774,287	2,493,195	2,383,324	42	15	14	1,340,098	1,333,473	10	5	2	49,660	47,646		1	8	9,843
Washington	3,095,041	2,733,615	2,710,650	22	11	11	368,494	368,069	1	1							16,322
West Virginia	2,677,937	749,099	749,099	6	1	4	1,847,604	1,845,636	20	2	2	78,855	78,855	2		1	4,348
Wisconsin	5,022,683	4,019,300	3,989,778	37	5		973,618	973,618		2		109,723	56,925			28	2,362
Wyoming	1,360,841	1,165,661	1,156,283	12			189,365	189,365	2								15,193
Dist. of Columbia	410,804	417,779	410,804	3													
Hawaii	453,703	284,891	284,005	3			226,162	158,370	2								11,327
TOTALS	196,000,000	133,895,583	131,210,785	1565	291	360	54,756,470	53,065,665	382	75	369	5,961,615	5,477,274	78	9	363	6,246,276