In most cases, the increase in cost due to the forming of transitions during the initial construction is less than the continuing cost of maintenance were the work left harsh and angular.

The reduction in cost of maintenance is due primarily to reduction in erosion. There are other attendant savings, such as the elimination of some of the hand mowing, and greater facility in keeping the road open in winter.

Transitions improve the appearance of a road greatly, since the forms of natural hillsides are approximated more closely.

Broad shallow gutters and a flowing roadside promote 'rideability'. The psychological effect produced promotes safer operation of vehicles. The absence of angularities and artificialities makes the road more attractive, it satisfies the traveller better. Such a highway is a 'Sunday Road' every day in the week.

SLOPE DESIGN PRACTICE IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

F. W. Cron, Senior Highway Engineer
Public Roads Administration

Good conservation policy requires that roads in National Parks shall be inconspicuous and create a minimum of scar and disfigurement of the landscape. The results of 16 years of road construction in the Great Smoky Mountains National Park demonstrate that these requirements can be met without prohibitive cost and without sacrifice of essential traffic service by adherence to proven roadside design and construction practices.

Most of the roads in this area lie in rough mountain terrain covered by dense forest. Plentiful rainfall insures rapid growth of vegetation but also presents serious erosion problems. Roadside use by the public is an important factor in the design of roads as great crowds of people flock to the Park on summer weekends.

Experience has shown that roadway slopes of $1\frac{1}{2}$ horizontal to one vertical, or flatter are quickly covered with volunteer vegetation, while steeper slopes remain naked for years due to erosion and ravelling under frost action. The natural mountain slopes usually range from $1\frac{1}{2}$ to 1, to $2\frac{1}{2}$ to 1, so that slope design is necessarily a compromise between the desirable and the practical. In steep terrain the desired maximum of $1\frac{1}{2}$ to 1 for earth cuts cannot always be attained economically and in these circumstances a steeper slope, usually 1 to 1, and, rarely, 3/4 to 1 must be used. In sound, solid rock a vertical cut slope is the ideal condition since it creates the least scar on the landscape when viewed from a distance.

With all materials so far encountered in the area structurally stable embankments can be made on slopes of $1\frac{1}{2}$ to 1; and these slopes are standard design for mixed materials in steep country.

In mountain construction, where the road crosses a steeply sloping spur or nose, a through cut as a rule creates an isolated hillock on the downhill side. The size of the hillock may vary greatly with different cuts; and where it is very small the practice in the Smokies is to "daylight", or cut it off flush with the grade.

Hillocks even of considerable size may be daylighted to secure borrow, either in the original design or during construction. The daylight area then becomes a roadside-use area where motorists may pull out and park or picnic. If the area is exceptionally large, or if the view from it is very fine it may be developed into a formal parking area or overlook, separated from the main traffic stream by a mounted turf island.

Where the residual hillock is too large to daylight as a matter of routine and the material is not needed for embankment, the slope is usually made 2 to 1, 3 to 1, or even flatter to improve sight distance and to impart variety to the roadside.

The reverse of the residual hillock situation occurs when an embankment crosses a steep-bottomed ravine. Here a basin or pocket is trapped on the uphill side between the embankment and the grade contour of the ravine. Usually the standard $1\frac{1}{2}$ to 1 fill slope is held on the downhill side of the embankment but the pocket on the uphill side, if small, may be entirely filled up. If the pocket is large the slope will usually be flattened to 2 to 1, or 3 to 1 to minimize the feeling of insecurity which a high, through fill creates in the mind of the driver. Even comparatively large pockets are sometimes filled completely to dispose of surplus excavation; and these are always popular as roadside-use areas, especially if they occur where running streams exist. The practice of using pocket fills sometimes increases drainage cost, but usually culverts can be placed at the down-grade ends of the pockets where the fill is narrow.

Before the recent war low unit prices permitted rather liberal use of masonry retaining walls to reduce landscape scars by intercepting fill slopes close to the roadway. Since the war masonry prices have advanced so much that use of walls has been greatly restricted; but exceptionally fine stands of trees are still saved by use of retaining walls; and walls are often unavoidable on valley locations where embankments must be protected from stream erosion.

Tunnels are occasionally used to avoid the landscape scar created by very large through cuts, especially at places where the cut would be viewed from a distance as a notch on the skyline.

The intersections of earth cut and fill slopes with natural ground are well rounded. Rounding tends to blend the artificial slope into the natural slope and reduces ravelling at the tops of cuts. Very little can be done with rock cuts in the way of rounding other than to slope back and round the earth overburden. In addition to rounding, earth slopes are transitioned by gradually flattening the slope as the cross section changes from cut to fill. This treatment when combined with rounding, is intended to merge the construction into the natural contours in a gradual manner, avoiding unnatural "knife-edge" effects.

On a recent Park project this treatment was supplemented by "bell-mouthing" of cuts and flaring of the ends of fills with good effect. The bell-mouth technique is especially appropriate where the road intercepts steep ravines and short, abrupt ridges; and it imparts a more natural effect than simple transitioning in such terrain. One advantage of this treatment is that it leads the gutter away from the fill and reduces erosion at the point where the fill meets natural ground. It also creates the opportunity to disperse the ditch water by substituting a wide shallow gutter for a narrow V-ditch at the point of exit, so that paved gutters are seldom needed.

Rounding, transitioning and bell-mouthing do not materially increase the overall cost of the job if they are taken into account in the original design; and in the long run they reduce costs by savings in maintenance expense. Varying the slopes in residual hillocks or pocket fills, or daylighting hillocks and filling up pockets permit a considerable degree of flexibility in balancing cut and fill volumes, both in the design stage and during construction. Sometimes it is more economical to waste by filling a nearby pocket than to overhaul the material to a distant fill, while often the latter fill can be made more cheaply by daylighting a point within free-haul distance.

In grading slopes no attempt is made to get a "sandpaper finish" on cuts or fills, or to stringline the shoulders. Projecting rocks and other irregularities in the slopes if solidly anchored tend to impart variety and assist in catching topsoil, and thus promote quick growth of vegetation. Topsoil from rounding the overburden at the tops of rock cuts is drifted down on the face of the cut where much of it lodges in crevices and on ledges. Often seedling trees take root in these crevices.

Recent grading contracts have included fertilizing, seeding and mulch protection for all freshly-graded slopes. The seedbed is kept moist and protected from the impact of raindrops by the mat of hay or straw mulch which in turn is held down by brush and stakes. A great improvement in the roadside has been effected by permitting the contractor to obtain his brush by selectively thinning the forest adjacent to the highway. This thinning diminishes in intensity as the distance from the road increases, creating a gradual transition from the denuded condition of the newly-constructed slopes to the undisturbed natural forest.

Except on slopes of 3 to 1 or flatter which can be maintained by machine mowing seeding is considered only as a temporary protection to retard erosion and create favorable conditions for native vegetation to establish itself.

In all road construction in National Parks great care is taken to conserve usable materials in the roadway prism and to protect adjacent trees, streamsides, rock outcrops and other natural features from damage. Suitable topsoil is stripped, stored and later placed on the shoulders and slopes; merchantable timber is sawed into logs and saved; locust and cedar logs are saved for sign posts and guardrails; suitable rock in cuts is used for masonry or crushed for base course material; weathered boulders are used for guardwall. Specimen trees are saved and protected by building tree wells around them and covering the roots with a blanket of porous rock. Pay items are provided in the contracts for this work. Non-merchantable logs from the clearing are laid along the toes of embankments to prevent damage to standing timber by intercepting rolling rocks. These barricades are left in place and eventually rot away. Where roads are relocated the remains of the old road are carefully obliterated under the grading contracts.

Figure 1. In Moist Climaté of the Great Smoky Mountains National Park Volunteer Vegetation will Grow on Slopes of $1\frac{1}{2}$ to 1 or Flatter (center) but Ravelling Removes Seedlings from 1 to 1 and Steeper Slopes (right). Ravelling is very Active Due to Numerous Cycles of Freezing and Thawing. This slope is 12 years old.

Figure 2. Removal of Residual Hillock Often Increases Sight Distance.

Figure 3. Relatively Small Daylight Areas Can be Developed Into Attractive Overlooks and Roadside-Use Areas.

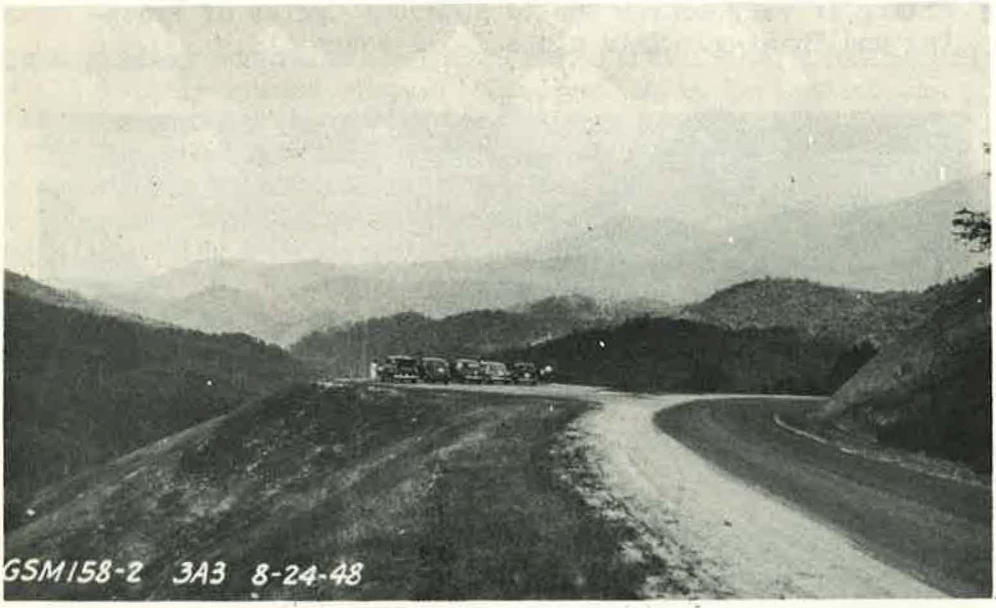

Figure 4. Unless Parking Facilities are Provided at Places of Outstanding Scenic Interest Traffic Congestion is Sure to Result.

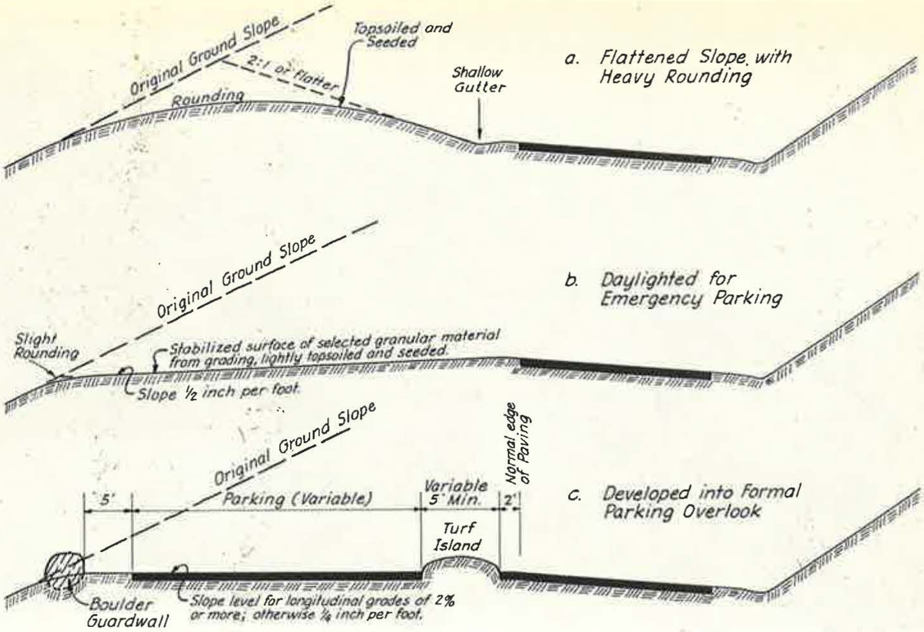

Figure 5. Treatment of Residual Hillocks.

Figure 6. Variety Can Be Imparted to the Roadside by Varying the Slopes of Residual Hillocks. Such Treatment Also Provides Flexible Source of Borrow.

Figure 7. The Hillock in Middle Distance is "Daylighted" or Cut Off Flush With the Grade. Note Seeded $1\frac{1}{2}$ to 1 Fill Slope in Foreground.

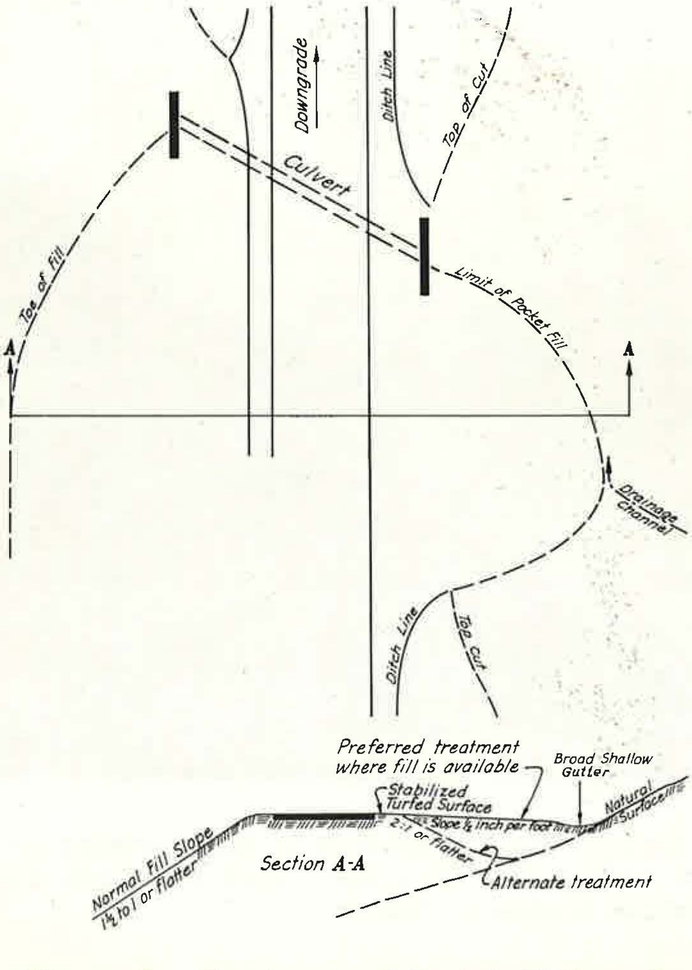

Figure 8. Treatment of Pocket Fills. By Placing Culvert at the Down-Grade End of the Pocket Its Length can Usually be Reduced.

Figure 9. Small Pocket Fill Right Foreground. Filling up Such a Small Pocket Often Obviates Need for Culvert.

Figure 10. Moderate-Sized Pocket Fill Built on 10 to 1 Slope From Shoulder. Tree in Background was Carefully Preserved During Construction Operations. Such Pockets are Convenient Places to Dispose of Surplus Excavation.

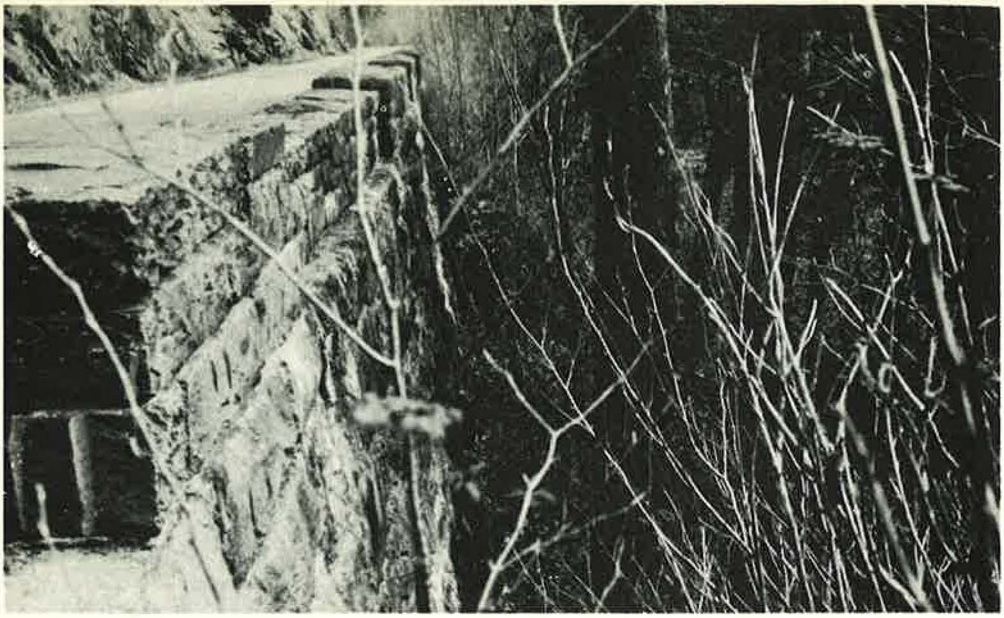

Figure 11. Retaining Walls are Occasionally Used to Intercept Long Fills on Steep Slopes and to Preserve Fine Stands of Timber.

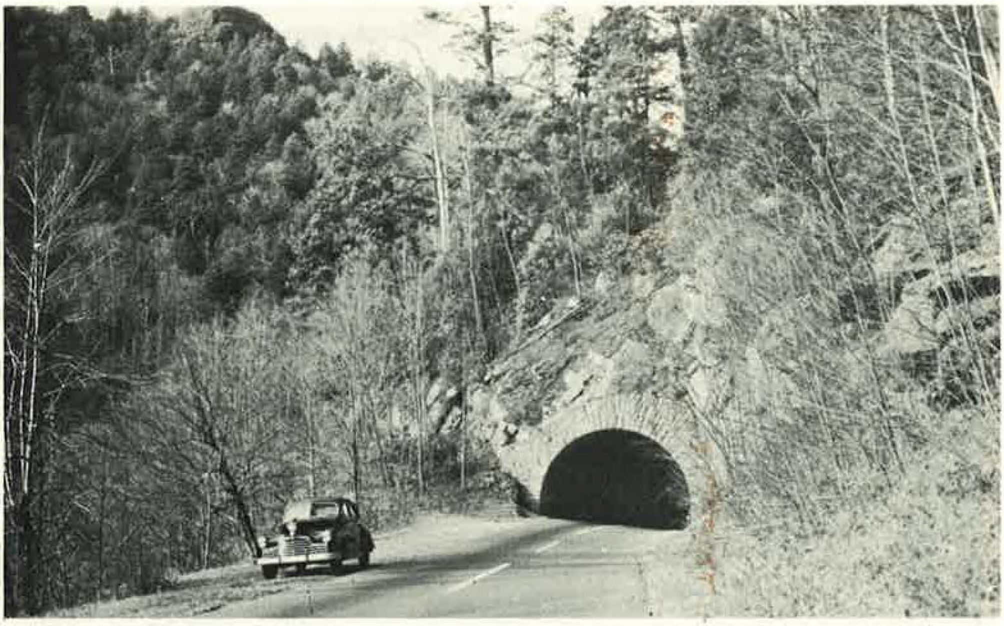

Figure 12. Severe Damage to the Landscape Can Sometimes be Avoided at Little Extra Cost by Tunnelling.

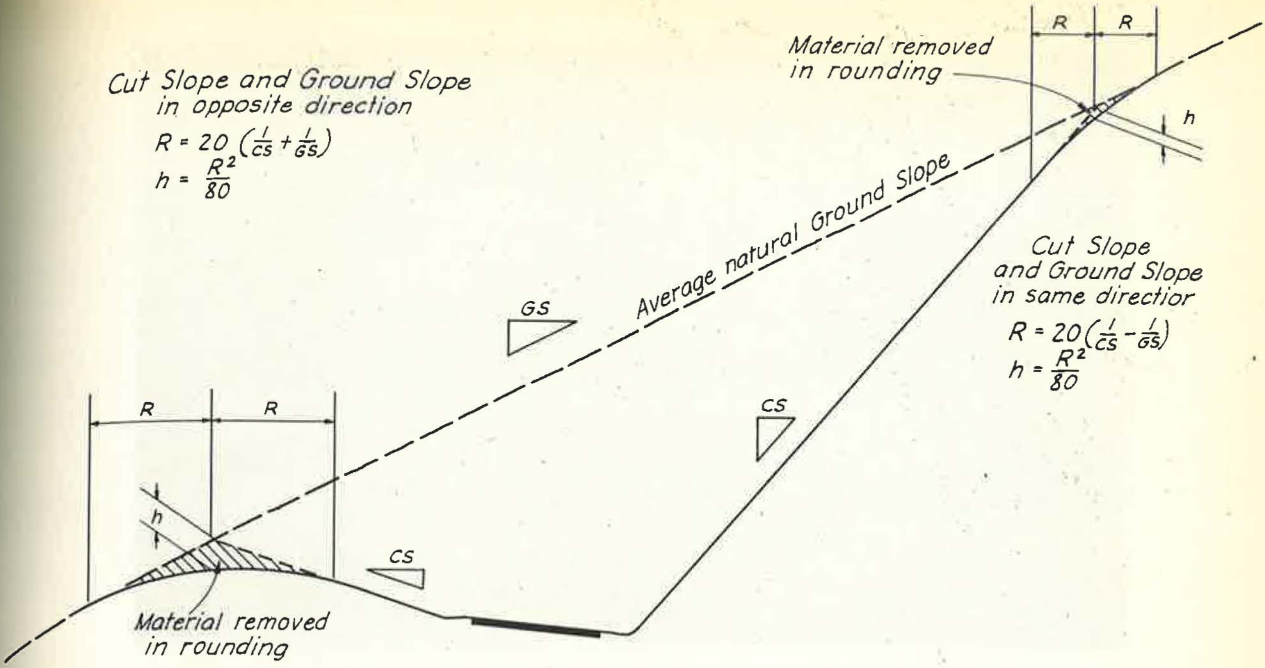

Figure 13. Formula for Rounding Slopes. Intersections of Graded Slopes With Natural Ground Surfaces are Liberally Rounded. The Curve Used is a Parabola. Slope Stakes for Rough Grading are Set at the Intersection of the Slope Line and the Ground Line. The Contractor is Given the Rounding Distance "R" and the Cut "h" and the Operation is Then Finished Largely by Eye. With a Little Experience, Foremen, Equipment Operators, Laborers and Inspectors Become Adept at Securing a Smooth Rounded Surface Merging With Adjacent Natural Contours, Which After All, is the Effect Desired. (This Figure Inverted Will Show Rounding Treatment for Fill Slopes.)

Figure 14. Bell-Mouthing of Cuts, Combined With Rounding and Transitioning Produces Natural Basic Ground Shape. Gutter at Exit of Cut in Foreground is Wide and Shallow to Reduce Erosion. Rounding is Clearly Evident on Dark Silhouette of Cut in Middle Distance.

Figure 15. Graded Surfaces are Seeded and Mulched. Mulch is Held Down by Saplings Obtained by Thinning Adjacent Forest.

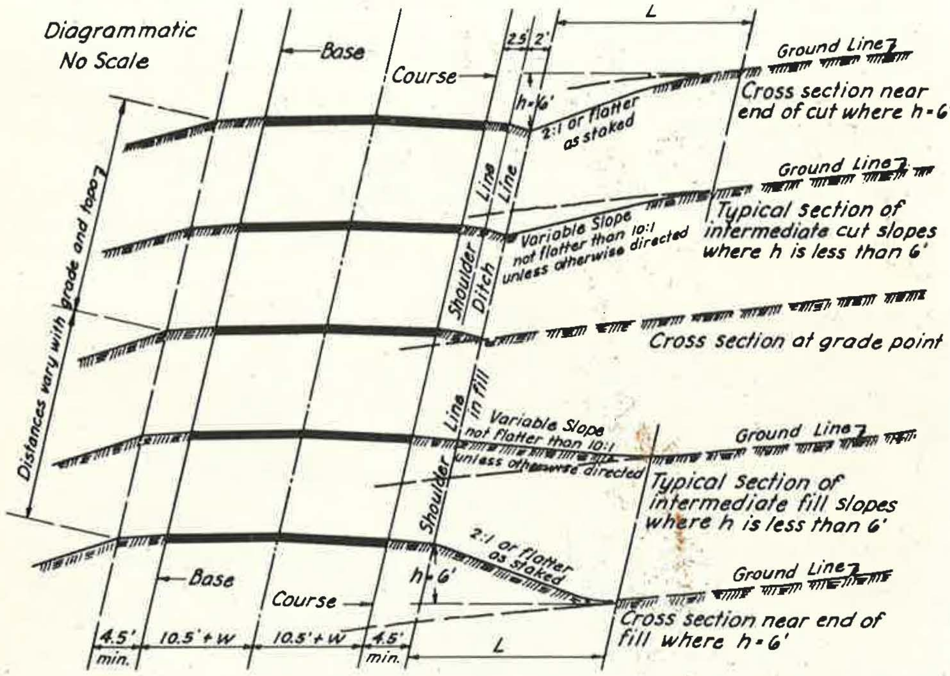

Figure 16. Pattern for Transitioning of Slopes from Fill to Cut. Distance L to be Maintained as Limit of Grading, Slope Rounding Included, to Establish Blend of Cut or Fill Slope Into Natural Ground Slope as Indicated. Applies to Earth Grading. A Smooth and Gradual Change from Cut to Fill is Desirable. After the Transition is Roughed Out by the Grading Machinery the Final Shape is Best Attained by Letting a Good Motor-Patrol Operator Work it Out by Eye.

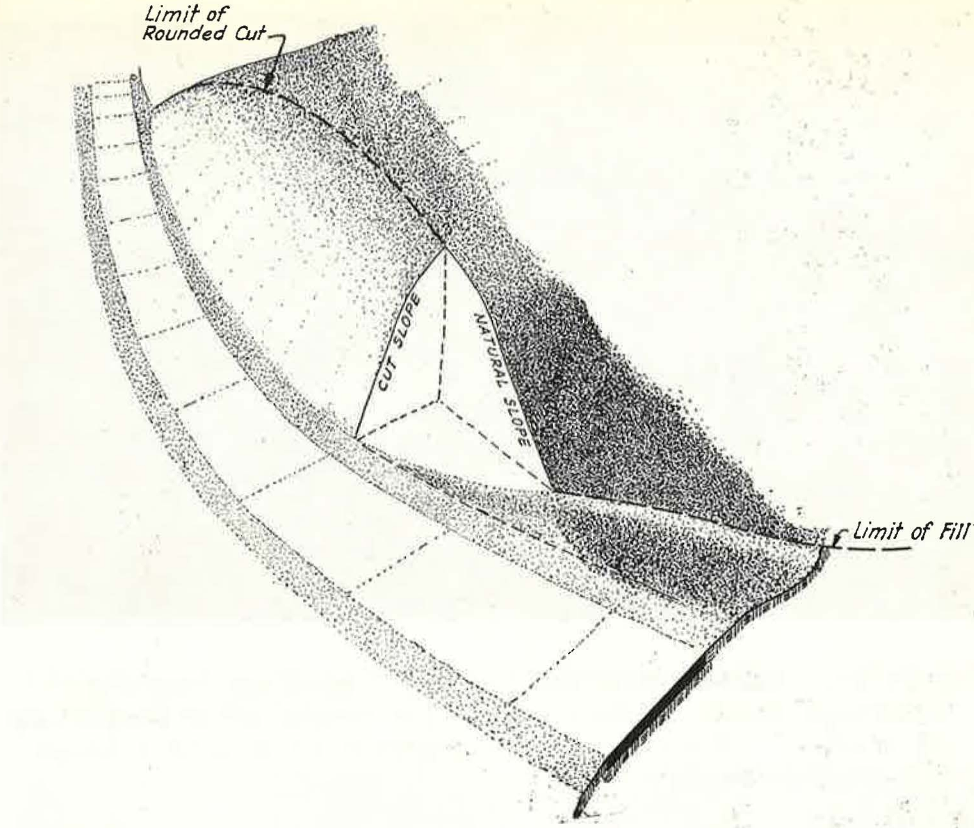

Figure 17. Bell-Mouth Treatment for Cuts. The Bell-Mouth Transition Provides a Gradual Change From Artificial Cut Slope to Natural Hillside.

Figure 18. In a Well-Designed Transition, Gutter is Led Away From Fill. Erosion Damage to Slopes is Prevented By Including Seeding and Mulching in Grading Contracts.

Figure 19. Bell-Mouthed and Rounded Transition Supports Luxurious Growth of Vegetation Five Months After Completion of Grading. Shale Slope in Background is on 1 to 1 Slope and Was Not Seeded.

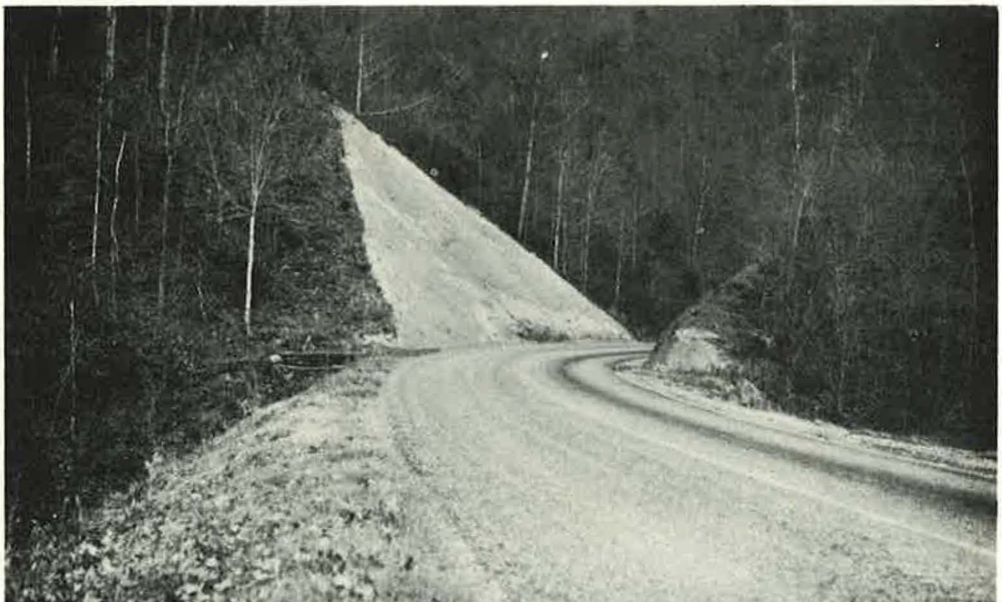

Figure 20. Nature has Difficulty Healing the Scars of Construction Without Assistance. This is a 1 to 1 Slope, Eight Years Old, Which has no Rounding or Transitioning.

Figure 21. Unfinished Borrow in Residual Hillocks Detracts From Attractiveness of Roadside.

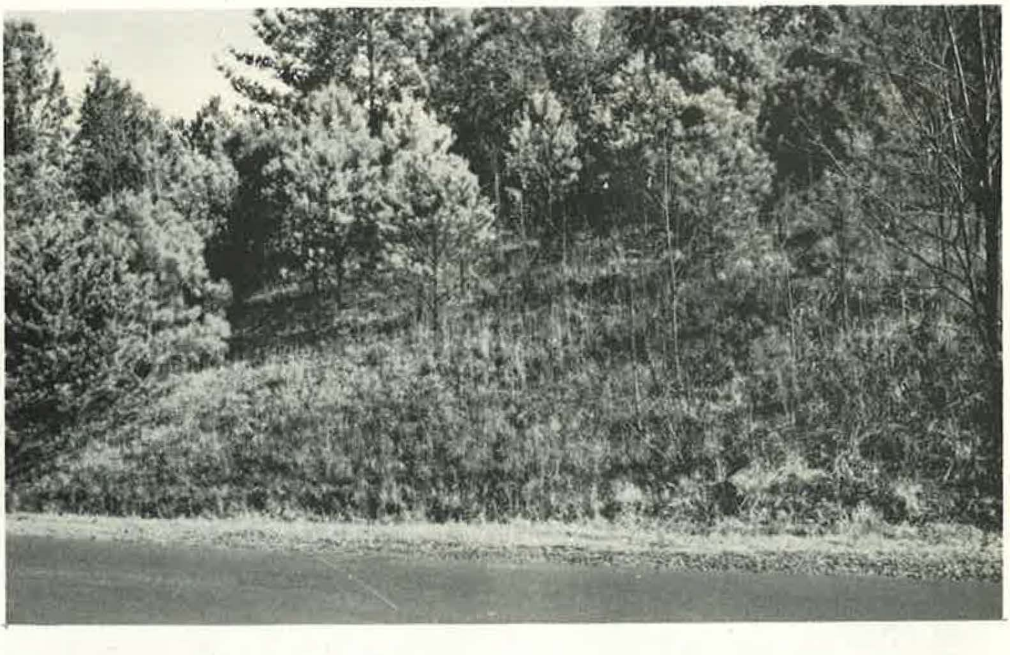

Figure 22. This Slope Has Been Completely Stabilized by Wild Grasses, Blackberries and Small Trees in a Period of 12 Years Without Seeding. Seeding Should Give Comparable Results in Much Less Time.

Figures 23A and 23B. Abandoned Roads are Obliterated.

Figure 24. Pocket Fills Often Become Attractive Roadside Use Areas. In the Smokies Such Areas are in Great Demand Due to Heavy Week-End and Holiday Visitation, and on Peak Days All Are Filled With Picnickers.

COMMENTS ON PAPERS BY MESSRS. DuBOIS AND CRON

Question:

Is all rounding of cross section on National Park and National Forest Roads included in the contract excavation item?

Answer: Yes. Rounding is a part of excavation, not an extra operation.

Question:

Will rounding cost more if the "bell mouth" system is used as compared with the "prism" or "rotary line" method?

Answer: All improvements cost a little more. They are considered in this case to pay for themselves in decreased maintenance costs. If rounding of the cross section is considered in original excavation yardage computations, then rounding costs very little.

Question:

Do your engineers have difficulty in getting contractors to do this slope and gutter rounding and warping?

Answer: Our engineers, landscape architects, and contractors have worked together for many years. All understand what needs to be done.

Question:

How are unit costs of earth excavation affected by the various methods of slope rounding and warping described?

Answer: Unit costs do not appear to be affected one way or the other. Cost for earth excavation on the job shown in these slides was 39 cents per cubic yard.

COMMENT

The work described by Mr. Cron was completed about 90 days ago. A good stand of protective vegetation has already become established on these rounded slope surfaces.

Question:

How about drainage? Are not those "pocket fills" difficult to drain?

Answer: Drainage by pipe drains is provided for in original plans.

Question:

How about the steep shale cut slopes shown in your slides. Can they be covered with vegetation?

Answer: We have some shale cuts about ten years old. Small pines and other growth are coming in on the talis material at bottom of the cut. This growth will screen the bare shale slope behind.

Question:

Is there a practical way of taking care of V ditches on existing highways with narrow rights-of-way?

Answer: Mr. Cron commented on this question by drawing diagram of cross section of typical National Park road. Relatively shallow, rounded ditch section is used, usually paved on grades of one or two percent or more. Frequent cross drains, never more than a few hundred feet apart, enable what might otherwise be considered an inadequate ditch, to function effectively.

COMMENT

It was suggested that a drawing be prepared for publication in Mr. Cron's paper showing, by means of contours, the difference between (1) the prism type of cross section grading, (2) the rotating line type of grading, and (3) the bell mouth method of grading.

Mr. Cron remarked that an attempt was made to construct an accurate scale model showing the "bell mouth" type of warping and rounding. Has anyone suggestions as to how this can best be done?

COMMENT

It was reported that plans for New Jersey parkways include contoured grading sheets showing proposed warping and rounding. The State, it was said, uses no regular standard slope section on its parkways. Transitions in slopes are made from station to station. Construction contractors, it was reported, have been trying to have all 2:1 earth slopes graded to 3:1 or flatter so that the most effective types of large excavation equipment can be used. 4:1 fill slopes are used wherever practicable, to avoid the cost of guard rail.

COMMENT

It was believed that rounding of toe and crest of fill slopes is just as important as rounding of cuts. The engineer must, it is thought, allow for the formation of a natural talis slope in computing his embankment quantities, particularly on steep slopes.