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# Cost of and Soil Loss on "Minimum-Standard" Forest Truck Roads Constructed in the Central Appalachians

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## Abstract

A "minimum-standard" forest truck road that provides efficient and environmentally acceptable access for several forest activities is described. Cost data are presented for eight of these roads constructed in the central Appalachians. The average cost per mile excluding gravel was $8,119. The range was $5,048 to $14,424. Soil loss was measured from several sections of a minimum-standard road. Traffic was regulated the first year and unrestricted the second year. Losses ranged from 44 tons per acre on ungraveled road sections to 5 tons per acre on graveled sections. Soil loss from the graveled sections on the minimum-standard road was about the same as that from higher standard graveled roads.

## Introduction

Traditionally, there have been many opinions on the standards to which forest access roads should be built. As a result, such roads have ranged from poorly located ones with little or no water control to well-located and constructed ones with excellent water control. Koger (1978) pointed out several problems in attempting to describe roads in terms of standards. Major variables that have affected standards for forest roads are road costs, projected current and future use, and varying degrees of concern about environmental impacts. Regardless of intended road use, basic standards should include provisions for controlling water, maintaining moderate grades, and good aligning of roads.

Forest roads are a principle concern of land managers in the Appalachian mountains because they represent a significant portion of logging costs and are the source of most environmental concerns during logging operations. Overdesign and some construction practices such as right-of-way clearing, slash disposal, and excessive sloping of banks not only can increase costs but often contribute little to road utility or environmental protection. Because most timber harvesting operations in Appalachia are on private land, forest-road systems should allow a profitable operation, protect other resources, and provide residual value to landowners. Therefore, standards for forest access roads must be realistic and economical with regard to utility and environmental protection.

Since 1977 we have been constructing roads that we call "minimum-standard" truck roads (Kochenderfer and Wendel 1980). Our objective has been to construct roads to the lowest standard that we believe will provide a desirable level of utility and environmental protection at an acceptable cost.

## The Minimum-Standard Road

Figure 1 shows a section of a minimum-standard road. These roads are suitable for the large tri-axle trucks commonly used to haul logs in Appalachia and for vehicles with clearances equivalent to those for pickup trucks. Construction costs for a minimum-standard truck road were based largely on the following:

- Roads were constructed from a flagged centerline. There was no formal road design or construction staking.
- Operators experienced in forest-road construction used nothing smaller than a D-6 bulldozer or its equivalent.
- All machines were hired with an operator on an hourly basis. An experienced supervisor-helper remained with the machine operator most of the time.

Figure 1.—Newly constructed minimum-standard truck road on the Fernow Experimental Forest.

- All right-of-way clearing was done with the bulldozer in conjunction with road building. Standing trees were pushed or pulled over and pushed away from the roadbed with the bulldozer. This was done because standing trees are much easier to push out than stumps, and because slash disposal is expensive and does little to improve utility or reduce impacts. Actually removing slash from fill slopes might create erosion.
- Cut banks usually were left vertical. However, if bank height exceeded 5 feet or a ditch line were involved, banks were rough-sloped or benched. Experience has shown that banks stabilize naturally over a 1- to 2-year period. Two to three feet of extra road width was allowed for bank sloughing.
- Culverts were used on all live and intermittent streams. Major seeps were also culverted and ditched as necessary.
- Broad-based dips spaced at intervals of about 200 feet were used to control surface water caused by precipitation (USDA Forest Service 1940; Hewlett and Douglass 1968). Natural grade breaks reduced the number of constructed dips needed.
- Seeding was done with a cyclone seeder since most of the exposed soil suitable for seeding was on the roadbed.

## Methods

Costs for road building were determined from a daily tally of man and machine hours on eight minimum-standard forest truck roads that were constructed by the procedures outlined. The hours include all of the delays and downtime actually paid for. Seven of these roads were constructed with a D-6 bulldozer; the eighth was constructed with a D-7 dozer. D-5 and JD-450 bulldozers were used to a limited extent on some roads; their time accounted for less than 5 percent of the total excavation costs on these roads. A backhoe was used to install some of the culverts on one road. Although some of the roads were graveled, gravel costs were not included. Data for each road are shown in Table 1. Width, cut bank height, road grade, and side slope are average values computed from observations made at intervals of 100 feet when the roads were measured. Measurements were made after most bank sloughing had occurred. All of the construction was based on a contracted hourly rate. In addition to making decisions concerning road construction, the road foreman also served as a helper to the dozer operator, e.g., pulling out the winchline, swamping, and installing culverts.

**Table 1.—Characteristics of eight "minimum-standard" forest truck roads constructed in the central Appalachians**

| Road no. | Road length | Road width | Cut bank height | Road grade | Side slope | Azimuth aspect | Number of dips[a] | Culvert | | | Ditch length | Turnaround | | Length of hard rock | Machine used |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Number | Size | Length | | Number | Size | | |
| | *Miles* | *Feet* | *Feet* | *Percent* | *Percent* | | | | *Inches* | *Feet* | *Feet* | | *Ft²* | *Feet* | |
| 1 | 0.81 | 12.6 | 3.9 | 6.9 | 39.0 | SW | 22 | 1 | 18 | 39 | | 3 | 4025 | | D-6<br>JD-450 |
| 2 | 0.38 | 15.5 | 4.0 | 4.8 | 33.1 | S | 12 | 1<br>1 | 15<br>18 | 32<br>37 | | 2 | 5580 | | D-6 |
| 3 | 1.08 | 16.9 | 3.9 | 6.7 | 29.7 | SW | 28 | 2 | 15 | 64 | | 5 | 19184 | | D-6 |
| 4 | 1.16 | 15.7 | 4.1 | 8.0 | 31.6 | NE | 14 | 7[b]<br>2 | 15<br>15 | 210<br>64 | 1604 | 1 | 2000 | | D-7 |
| 5 | 1.93 | 15.6 | 5.1 | 7.8 | 43.3 | SW | 41 | 8<br>2<br>2 | 15<br>36<br>18 | 236<br>86<br>64 | 662 | 5 | 18480 | 1100 | Backhoe<br>D-4<br>D-6 |
| 6 | 0.78 | 14.9 | 4.6 | 2.7 | 40.2 | S | 15 | 5 | 15 | 135 | 628 | 3 | 9690 | | D-6 |
| 7 | 0.34 | 15.1 | 5.1 | 3.7 | 47.3 | S | 5 | 2 | 15 | 64 | 432 | 1 | 2960 | 211 | D-6 |
| 8 | 1.25 | 15.3 | 4.4 | 2.6 | 38.6 | W | 30 | 0 | | | | 2 | 5115 | | D-6<br>JD-450 |

[a]Includes natural grade breaks where dozer work is required for outsloping.
[b]30-foot sections of gasline pipe.

## Results and Discussion

The eight roads on which data have been collected since 1977 represent many road-building conditions encountered in the central Appalachians. This area is characterized by steep mountains and narrow valleys. Much of the forest land is privately owned in small tracts, which places many constraints on road location. All of the roads were relatively short and located in areas that were unfamiliar to the road locators. Road costs are summarized in Table 2. Rates used for various machines, labor, and culverts are listed in the following tabulation (machine rates include an operator):

| *Item* | *Dollars* |
|---|---|
| Layout and construction | |
| Foreman | 15/hr |
| Labor | 8/hr |
| Machine used in excavation | |
| D-7 | 60/hr |
| D-6 | 50/hr |
| D-4 | 35/hr |
| JD-450 | 25/hr |
| Backhoe | 25/hr |
| Culvert | |
| 15-inch gasline pipe (30-foot sections) | 7.50/ft |
| 15-inch galvanized | 6.00/ft |
| 18-inch galvanized | 7.75/ft |
| 36-inch galvanized | 19.00/ft |

## Road Location

An average of about 40 hours was required to plan, reconnoiter, and lay out 1 mile of truck road. Layout often required rerunning grade lines two or three times until the "best" location was found. Road 5 required the most time to lay out, about 50 hours per mile. This road had several large rock outcrops which required changing the location several times. Silversides and Koroleff (1949) recognized the importance of road location: "Once a road is established it is seldom relocated so that if it is improperly located, the users suffer for years after." Road location costs accounted for 8 percent of total road costs.

**Table 2.—Cost summary for eight "minimum-standard" forest truck roads constructed in the central Appalachians[a]**

| Road no. | Road length | Road location | | Excavation | | Culvert cost/mile | Vehicle cost/mile | Labor cost/mile | | Total cost/mile |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Foreman | Other[b] | |
| | *Miles* | *Hours/mile* | *Dollars/mile* | *Hours/mile* | *Dollars/mile* | ---------*Dollars*--------- | | ---------*Dollars*--------- | | ------*Dollars*------ |
| 1 | 0.81 | 39 | 585 | 58 | 2,900 | 371 | 92 | 921 | 79 | 5,048 |
| | | | | 4 | 100 | | | | | |
| 2 | 0.38 | 42 | 630 | 84 | 4,200 | 1,264 | 127 | 1,267 | 169 | 7,657 |
| 3 | 1.08 | 37 | 555 | 69 | 3,450 | 356 | 111 | 1,028 | 74 | 5,574 |
| 4 | 1.16 | 35 | 525 | 93 | 5,580 | 1,696 | 291 | 935 | 332 | 9,359 |
| 5 | 1.93 | 50 | 750 | 25 | 625 | 1,839 | 156 | 2,606 | 647 | 14,424 |
| | | | | 143 | 7,150 | | | | | |
| | | | | 6 | 210 | | | | | |
| | | | | | 441[c] | | | | | |
| 6 | 0.78 | 41 | 615 | 84 | 4,200 | 1,043 | 155 | 1,256 | 536 | 7,805 |
| 7 | 0.34 | 48 | 720 | 113 | 5,650 | 1,143 | 134 | 1,696 | 286 | 9,629 |
| 8 | 1.25 | 39 | 585 | 79 | 3,950 | 0 | 36 | 686 | 0 | 5,457 |
| | | | | 8 | 200 | | | | | |
| | Mean | | 621 | | 4,832 | 964 | 138 | 1,299 | 265 | 8,119 |

[a]Costs and time rounded to nearest whole number.
[b]Labor for culvert installation.
[c]Blasting cost.

## Excavation

Excavation as used here includes all the machine time used in construction. It includes all clearing, construction and installation of drainage structures, and all other earthmoving activities. Excavation time ranged from 62 hours/mile (Road 1) to 174 hours/mile (Road 5), and averaged 96 hours/mile. Road 1 was constructed on one of the best road-building soils in this area. No hard rock was encountered, and only one culvert was required. This road also was narrower (12.6 feet) than any of the other roads (Table 1). Road 5 was by far the most difficult of the eight roads to construct. A 1,100-foot section of hardrock, some of which required blasting, was encountered (Fig. 2). In addition, a considerable amount of time was spent removing several large trees on the right-of-way (Fig. 3). On average, excavation time accounted for 59 percent of the total road cost on the eight roads. Construction of broad-based dips was included in excavation costs. The average number of dips constructed was 22 per mile and this amounted to about 11 percent of excavation costs.

Figure 2.—Section on Road 5 where hard rock was encountered.

## Culverts

An average of four culverts/mile of road was used. The number of culverts ranged from none on Road 8 to 8 per mile on Road 4. Most were installed with rock headwalls. Road 8, which required no culverts, was located high on a mountain with a western exposure and on excellent road-building soil. Road 4 had a northern exposure and more active seeps and streams. Road 5 had the highest culvert cost per mile ($1,839). A large part of this cost was for two 36-inch, 40-foot culverts. Most of the culverts were used to drain live seeps. The minimum-size culvert used was 15 inches. Gasline pipe (15-inch) welded into 30-foot sections was used for seven culverts on Road 4. Culverts accounted for 12 percent of total road costs on the eight roads.

Figure 3.—Large tree removed on Road 5.

## Vehicles

Vehicle cost includes the machines used during road location and to transport the foreman and laborers. It also includes the vehicles used to haul culverts, tools, and rock for culvert headwalls. Vehicles accounted for 2 percent of total road costs.

## Labor

Labor costs include the foreman's wages and cost of other labor used to install culverts. Labor amounted to 19 percent of total road costs. When there is no set of road specifications detailing each phase of construction, the foreman must be able to make on-the-spot decisions concerning clearing limits, road width, culvert placement, ditch requirements, dip locations, and turnouts. Foreman costs averaged 16 percent of road costs while the cost of other labor (installing culverts) amounted to 3 percent of total road costs.

## Soil Loss

Reducing road standards does not necessarily increase erosion. On the Fernow Experimental Forest soil loss was measured from both graveled and ungraveled road sections on a newly built minimum-standard road where water was controlled with broad-based dips. Soil loss also was measured from a higher standard road ditched completely with metal culverts spaced about 300 feet apart. This road was graveled with 1-inch crusher-run gravel and the sloped banks have become well stabilized with vegetation since the road was constructed in the 1930's. Average road grades did not exceed 10 percent on either road.

Average annual soil loss on the minimum-standard road was 44 tons per acre on the bare sections and 5 tons per acre from the section graveled with 3-inch clean gravel. Average annual soil loss from the higher standard road graveled with 1-inch crusher-run gravel was 5 tons per acre. In addition to improving utility, gravel greatly reduced soil loss from road surfaces. On newly constructed roads, 3-inch clean gravel usually is used. If the road surface is firmer than normal, e.g., the road has been constructed and used before, 3-inch crusher-run gravel often is used. About 1,100 tons of gravel per mile are required to surface a road to a 4-inch depth. In our area, we use limestone gravel and this adds about $10,000 per mile to road costs. We believe that much of this cost can be borne by eliminating some of the design and construction features required for higher standard roads. In the central Appalachians, where precipitation occurs on average of 1 of every 3 days (Patric and Studenmund 1975) and roads usually do not remain frozen for extended periods, gravel can greatly increase the utility and reduce adverse environmental impacts. We believe that if a road is built at least 1 year before being subjected to heavy use, the amount of gravel required for stabilizing can be reduced. Groves et al. (1979) reported that if the disturbed subgrade is allowed to settle naturally for 6 months to 1 year, the amount of material needed for a 4- to 6-inch depth can be reduced.

In some soils, the content of natural coarse stone is high enough to prevent rutting without gravel during wet periods. Such a road is shown in Figure 4. This road was constructed in the fall, and drainage dips were installed at that time. Hauling was done the following April. Hauling the same volume of timber over an adjacent section of ungraveled road with low content of coarse fragment caused severe rutting.

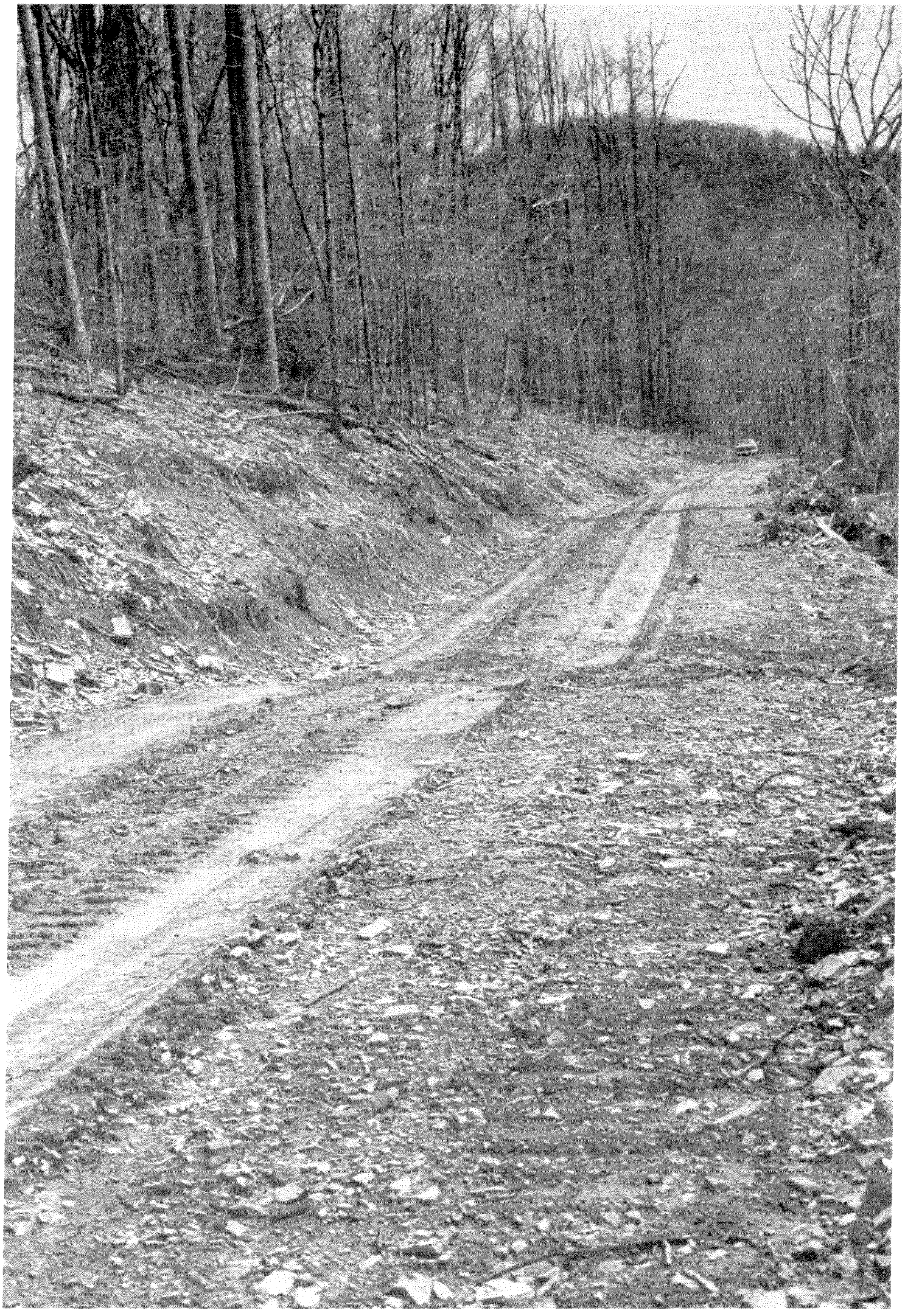

Figure 4.—Minimum-standard truck road with high content of natural coarse stone.

## Conclusions

The minimum-standard truck road fills a need between the "mud road" too often used in Appalachia and costly, higher standard roads. For roads constructed primarily for timber management activities, fire control, or hunter access, we believe that the "minimum-standard" is a good choice. When timber values and projected uses are considered, it is often difficult to justify a better road. The minimum-standard truck road provides a desirable level of utility and environmental protection at an acceptable cost. The average cost per mile for the eight roads, excluding gravel, was $8,119.

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