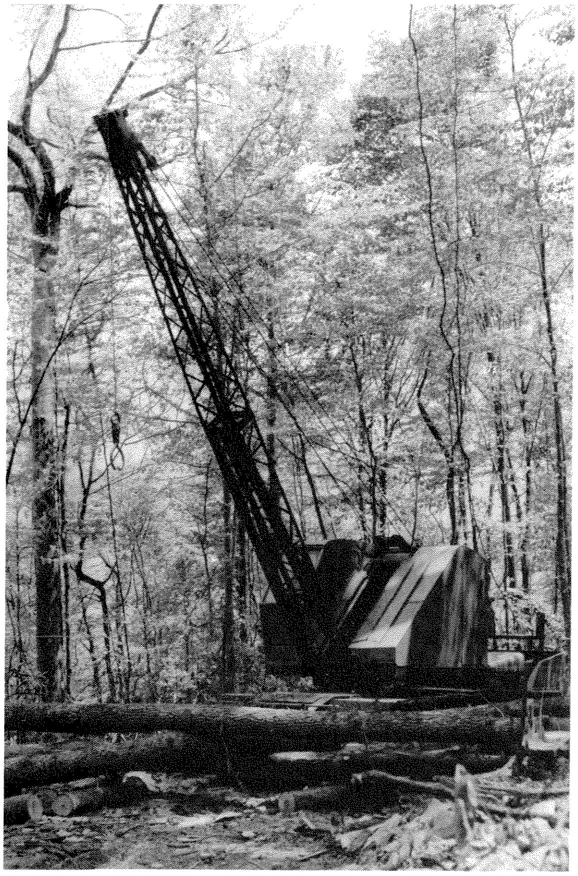
ODC 375.1, 461, 116.28, 661



Costs and Environmental Impacts of Harvesting Timber in Appalachia with a Truck-Mounted Crane

by J. N. Kochenderfer
and G. W. Wendel

FOREST SERVICE RESEARCH PAPER NE-456
1980

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
370 REED ROAD, BROOMALL, PA 19008

The Authors

J. N. KOCHENDERFER and G. W. WENDEL are long-time Research Foresters at the Northeastern Forest Experiment Station's Timber and Watershed Laboratory in Parsons, West Virginia. Kochenderfer's major research interests are in forest hydrology, Wendel's are in timber management.

MANUSCRIPT RECEIVED FOR PUBLICATION 7 DECEMBER 1979

Abstract

A truck-mounted crane was used to yard and load timber from a 30-acre sale in a 140-acre watershed in the mountains of north-central West Virginia. A total logging cost, excluding road costs, of $44.35/M bm for logs delivered to a mill 20 miles away was comparable to that reported for wheeled skidders. Road costs with gravel would add $55/M bm, without gravel $26/M bm. Roads built to these standards held sediment production within the range (0.05 to 0.10 ton/acre/year) expected for undisturbed forested watersheds. Residual stand damage caused by this system was also comparable to other systems and was concentrated on small trees.

INTRODUCTION

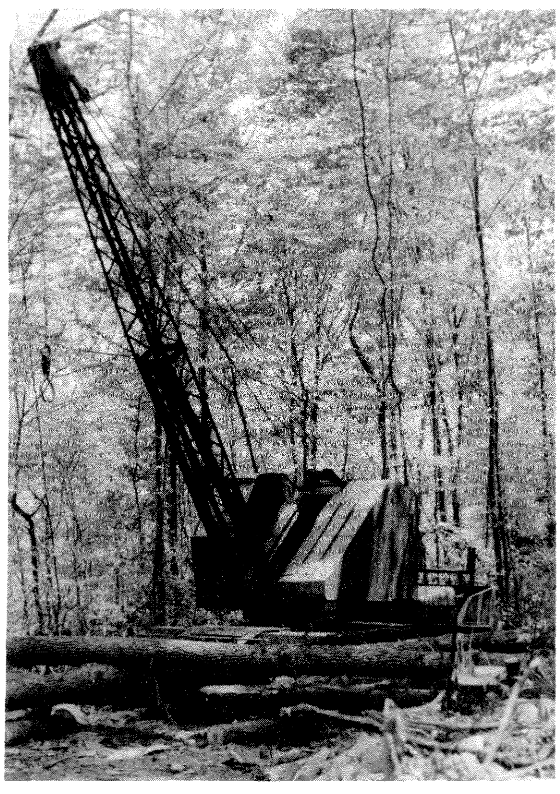
IN THE APPALACHIAN MOUNTAINS most timber is harvested by some form of ground skidding. Wheeled skidders appeared in the late 1950's, and are now the most widely used. In our opinion, the major problem with wheeled skidders is their requirement for a dense network of roads. Bulldozed skidder roads, often improperly planned and poorly constructed, also may be esthetically unacceptable. The customary practice is to space roads 100 to 150 feet apart, thus reducing the distance the winch line must be pulled to trees. Skidders usually log about 20 acres per mile of road, exposing about 10 percent of the soil surface in roads and log landings (Kochenderfer 1977).

The public is concerned about the environmental impacts of timber harvesting, especially muddy streams and hillsides crisscrossed with numerous bulldozed roads. The reduction of these impacts often increases logging costs in proportion to the volume and value of the timber harvested. In the West, where the volumes per acre harvested are high and the land ownerships generally large, highly sophisticated cable systems are used. These require fewer roads and are environmentally more acceptable than ground skidding systems. In the East, with relatively small ownerships and generally low value-volume stands as compared to the West, little is known about the economics of cable logging (Kochenderfer and Wendel 1978).

This article describes a simple cable system used for several years by a logger in the north-central part of West Virginia. It is a truck-mounted crane used for both yarding and loading. The crane is self-propelled, a desirable feature where ownerships are small and scattered. Kochenderfer (1977) reported that this machine operated from roads spaced at about 250-foot intervals, logged about 31 acres per mile of road, and exposed about 8 percent of the soil surface in bulldozed roads and landings.

The cost of the second-hand, truck-mounted crane, plus the necessary modifications, was less than $10,000. The original crane was removed from its 20-ton carrier and replaced with a smaller 6-ton crane with a 25-foot boom (Fig. 1). This modification provided a stable base for yarding and reduced the overall machine weight, yet permitted the machine to operate on narrow roads (12 to 15 feet wide). The machine has two drums, but only the one carrying 400 feet of 3/8-inch cable is normally used. Most of the logs are yarded tree length and then bucked in the road. In yarding, the cable is pulled out to the logs, tongs are set, and the log is pulled to the road. The swing boom helps to guide logs around obstacles while they are being winched and

Figure 1.—Truck-mounted crane.



then decks them on or along the roads, eliminating the need for large landings. The lift provided by the boom raises the front of the log off the ground, which results in less ground disturbance and damage to road berms. Also, logs are usually cleaner than those pulled by ground skidders.

A typical access system for this machine consists of a climbing road with contour roads branching off at 250- to 300-foot intervals. Generally, the truck-mounted crane operates best on roads with a grade of less than 10 percent.

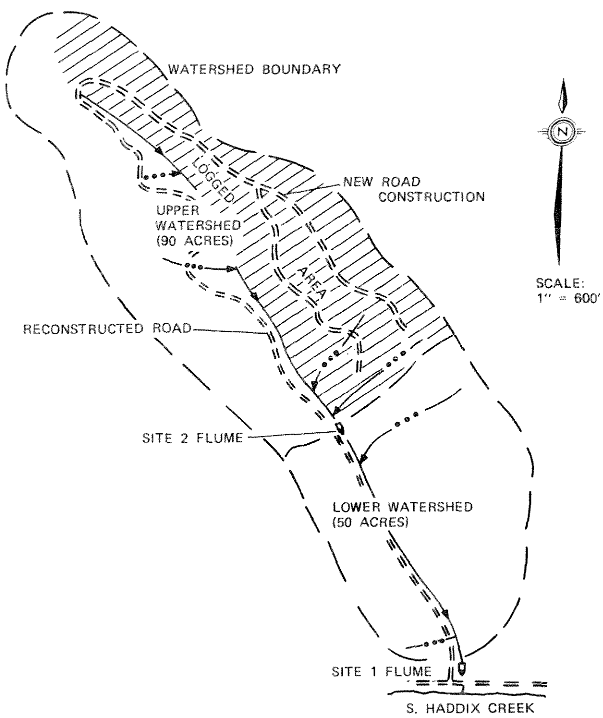
STUDY AND METHODS

In the spring of 1977, we set up a 30-acre timber sale in a 140-acre watershed on the Monongahela National Forest near Parsons, West Virginia, to be logged with a truck-mounted crane. Our objectives were to determine logging and road building costs, and to measure the impacts of truck-mounted crane logging on the residual stand and stream quality.

Logging costs were determined from a daily tally of man and machine hours, from the start of road building until the last log was delivered to the mill. The costs do not include allowances for profit and risk or cost of stumpage. The assumption is that the stumpage was purchased by someone else and that the logger contracted to cut and move the timber to the mill, the common practice in this section of Appalachia. Road costs included bulldozing, construction of drainage dips, culvert installation, and graveling. During logging, we tallied man and machine hours separately for yarding, trucking, and felling.

Streamflow was measured at two sites using H-type flumes equipped with FW-1 water-level recorders: site 1 at the mouth of the watershed, and site 2 at the stream just below the boundary of the cutting areas (Fig. 2). Some pertinent watershed dimensions are listed in Table 1. Five-tenths of 1 percent of the flow through each flume was sampled by a Coshocton wheel and 10 percent of this was stored in a 600-gallon tank (Fig. 3). A sample of the tank contents was taken weekly, more often during high flows. Sedi-

Figure 2.—Map of the study area on the Monongahela National Forest.



ment was determined by a standard filtering method (AAPSE 1972). Streamflow was determined from recorder charts and rating tables for H-type flumes (Holtan et al. 1962). Coarse sediment (bedload) collected in the flume approach box at site 1 was periodically weighed and added to the total. This material consisted mainly of sand and larger size particles. Finer sediments in the collection tank were mostly silt and clay. Some storm flows were sampled at 15-minute intervals, using ISCO automatic samplers equipped with a floating intake at site 1.

At 40 randomly selected points, a 10-factor prism was used to tally all residual trees larger than 1.0 inch in diameter at breast height (dbh), and these were examined for damage. Damage to residual trees was classed as abrasion, skinned, root damage, or destroyed.

For the logging operation, 4,300 feet of existing road were reconstructed and upgraded to provide access to the sale area (Table 2) which lay 460 feet above the watershed outlet. An additional 4,300 feet

Table 1.—Watershed dimensions

Watershed	Area: Watershed	Stream channel	Roads	Sediment source area[a]
	Acres			
Upper	90	.53	3.56	4.09
Lower	50	.28	.82	1.10
Total	140	.81	4.38	5.19

[a]Area is the acreage of stream channel and roads.

Figure 3.—The 3-foot H-type flume and 2-foot Coshocton wheel at site 1.

of new road was constructed within the sale area (Fig. 2). About 67 percent of the climbing (existing) road had a grade of 10 percent or less, while 81 percent of the new road had grades of less than 10 percent.

Metal culverts were placed at crossings of all live streams and seeps. All other drainage was taken care of by broad-based dips, spaced at 200-foot intervals, patterned after those of Hewlett and Douglass (1968) and Cook and Hewlett (1979).

RESULTS

Road cost

The cost for the reconstructed road was $5,855 per mile, including 600 tons of 3-inch clean stone surfacing at $5.74 per ton. The D-6 tractor time was 20.5 hours (25 hours per mile), with 6 of these hours used to construct 19 broad-based drainage dips. Spreading gravel and final dip shaping required 23 hours (28 hours per mile) of JD 450 tractor time. Installation of two culverts required 5 hours of labor. Road reconstruction without stone would have cost $1,061 per mile.

The newly constructed road cost $3,673 per mile, including 200 tons of gravel. Only the softer fills and a few of the dips were graveled. Approximately 46.5 hours of D-6 tractor time (57 hours per mile) were required to bulldoze the road and construct 22 dips. Spreading gravel and final dip shaping required an additional 7.5 hours of JD 450 tractor time. Constructed without stone, this road would have cost $2,078 per mile. Each drainage dip took about 20 minutes to construct and required about 20 tons of gravel.

Table 2.—Average dimensions of the road system

Road	Cut bank height	Bottom of cut bank to: Edge of berm	Bottom of cut bank to: Toe of fill	Drainage dip intervals[a]	Side slope	Road grade
	Feet				*Percent*	
Newly constructed	3.9	15.2	20.2	225	39	7
Reconstructed	5.7	17.0	23.7	200	48	9

[a]Distance between low points of two adjacent dips.

The total cost of a graveled dip averaged $128.

To reduce road building costs, cut banks were not sloped. Clearing and grubbing were done in conjunction with road building, and slash was simply pushed away from the road.

Logging study

It took 724 man hours (90.5 man days) to cut, log, and transport the 140 M bm (International 1/4-inch Kerf rule) to the mill. The five-man crew averaged 7.7 M bm per day or 38.5 M bm per week at the mill, located about 20 miles from the logging area. Total labor cost at $6 per man hour was $31.02 per M bm (Table 3).

Generally, the trees were yarded as they fell. Thus the feller was not continuously cutting trees, but assisted in bucking, yarding, and loading. Trees most distant from roads were felled first to avoid yarding them through slash. To determine machine costs, we divided total hours of operating time by volume logged for each piece of equipment and then multiplied that product by the hourly machine rate. Total machine cost, not including road construction, was $44.26 per M bm. Costs for the graveled road system added about $55 per M bm, about $26 if no gravel was used. Thus, the total logging cost from the stump to the mill was $99.26 per M bm on graveled roads. If no gravel had been used, the usual case in Appalachia, total costs would have been $70.26 per M bm — plus any additional cost resulting from operation on ungraveled roads.

Sediment production

Sediment production was monitored continuously for 2 years. Since these data include the period during road building and logging, they probably include the period of maximum sediment production.

As expected, most of the sediment was produced during occasional large storms. One major storm spanned a 2-day period, producing 47 percent of 1977-1978 sediment discharge. Two other major storms spanned a 6-day period, accounting for 50 percent of the 1978-1979 sediment discharge. Most of the sediment during both years was exported when peak flows approached or exceeded 2.6 ft^3/s. In both

Table 3.—Summary of logging costs and time, using a truck-mounted crane

Item	Hours/M bm	Cost	
		Per hour	Per M bm
		Dollars	
Labor			
Felling & bucking	1.87	6.00	11.22
Yarding	1.34	6.00	8.04
Loading	0.91	6.00	5.46
Hauling	0.94	6.00	5.64
Maint. & Repair	0.08	6.00	0.48
Final road work	0.03	6.00	0.18
Total			31.02
Machine time			
Felling & bucking	1.87	0.69	1.29
Yarding & loading	0.97	3.36	3.26
Hauling (incl. loading time)	1.26	5.98	7.53
Case 310 (final road shaping)	0.03	20.00	0.60
Crew pick-up	0.20	2.82	0.56
Total			13.24
Total logging cost			44.26
Road cost			
With stone	—	—	55.00
Without stone	—	—	26.00

years of record, 90 percent of the sediment from the 140-acre watershed was exported in only 5 percent of the time.

There is no way to pinpoint the sources of this sediment. But since overland flow does not occur on most well-vegetated forest land (Hewlett and Hibbert 1967), the roads and stream channels are the only sediment sources possible. The area above site 2, which includes the logged area, produced the least sediment while the 50-acre area between sites 1 and 2 produced the most. When loss is expressed as tons/acre of source area, sediment export was at least twice as great from the lower part of the watershed. Part of this increase is attributed to disturbance during construction of the flume at site 2. Sediment production also was greater on the lower watershed since it contained 1,600 feet of reconstructed road, located at some places on a 60-percent side slope and within 50 feet of the stream. Some of the overcast material from this road slid to within a few feet of the stream during reconstruction. Although the road is close to the stream, gravel and closely-spaced, broad-based dips have protected the road surface from erosion and dispersed runoff. There was no observable movement of soil to the stream, even where recommended filter strip widths did not exist.

Sediment yield for the 2-year period is summarized in Table 4. This yield compares favorably with the 0.007 ton/acre-inch/year suggested as a base rate for undisturbed, well-stocked pine types in the Coastal Plain (Ursic 1977). Douglass (1975) concluded that normal erosion from fully stocked forests is generally less than 300 pounds/acre/year and results mainly from normal geologic erosion on stream channels and banks. The highest yearly rate we measured was from the lower watershed, 0.005 ton/acre-inch (46 ppm) or 208 pounds/acre. Expressed as tons/acre/year, these yields are similar to those summarized for undisturbed forest plots and small watersheds in the Eastern United States (Patric 1976). These rates are much less than the 1 to 5 tons/acre/year under which economic agriculture can be sustained on farmland (Klingebiel 1962).

Coarse sediment accounted for 24 percent of total sediment exported at site 1, only a negligible amount of coarse material was exported at site 2. The gravelly nature of the stream channel between sites 1 and 2 and the larger volume of flow in it probably account for this difference in coarse sediment export. Stream gradient above the two sites is not much different, averaging 10 percent above site 1 and 9 percent above site 2.

Organic matter comprised 25 percent (by loss on ignition) of the fine sediment measured in the collection tanks. Only 3.4 percent of the coarse sediment measured in the approach box at site 1 was organic matter. Twenty-one percent of total sediment production at site 1 was composed of organic matter.

The enormous variation of sediment production over time is illustrated in Figure 4. The hydrograph was generated when about 1.5 inches of rain fell during 2 days on 18 inches of melting snow. Sediment export peaked slightly ahead of streamflow. Fine sediment export was 2,304 pounds

Table 4.—Annual sediment production for 1977 and 1978

Watershed	Total per period		Per acre-inch of streamflow		Annual yield per acre of watershed		Annual yield per acre of sediment source area[a]	
	Tons							
	1977	*1978*	*1977*	*1978*	*1977*	*1978*	*1977*	*1978*
Upper	4.274	4.334	.002	.002	.048	.048	1.045	1.060
Lower	5.173	4.511	.005	.004	.104	.090	4.703	4.101
Total	9.447	8.845	.003	.003	.068	.063	1.820	1.704

[a]Area is the acreage of stream channel and roads.

Figure 4.—Relationship between sediment and streamflow with time for a 2-day period in February at site 1.

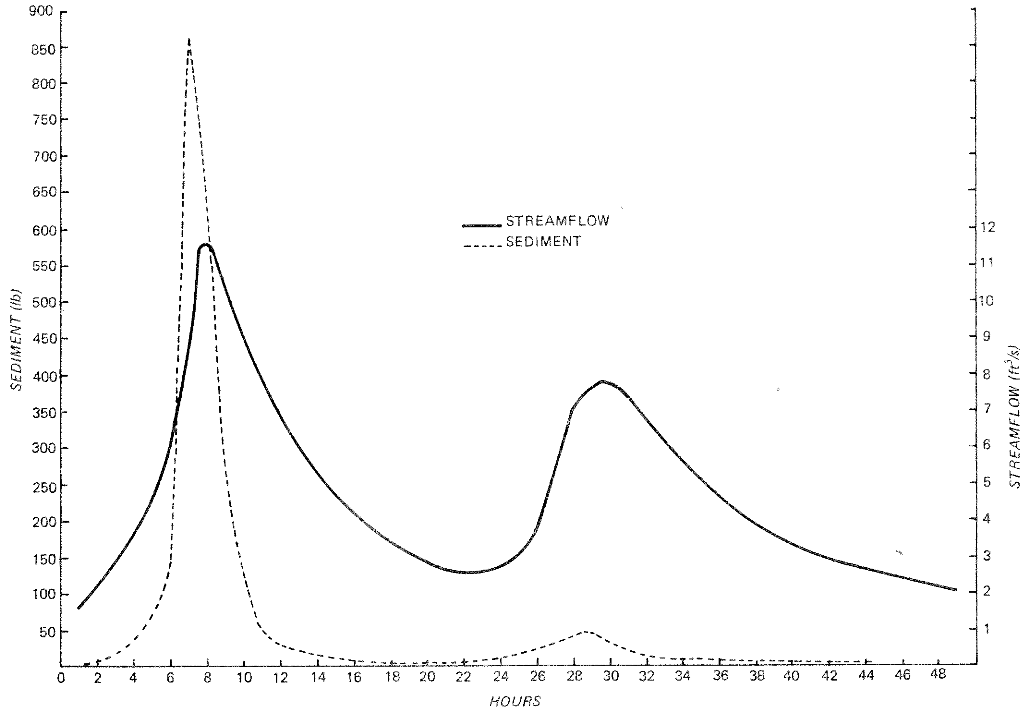
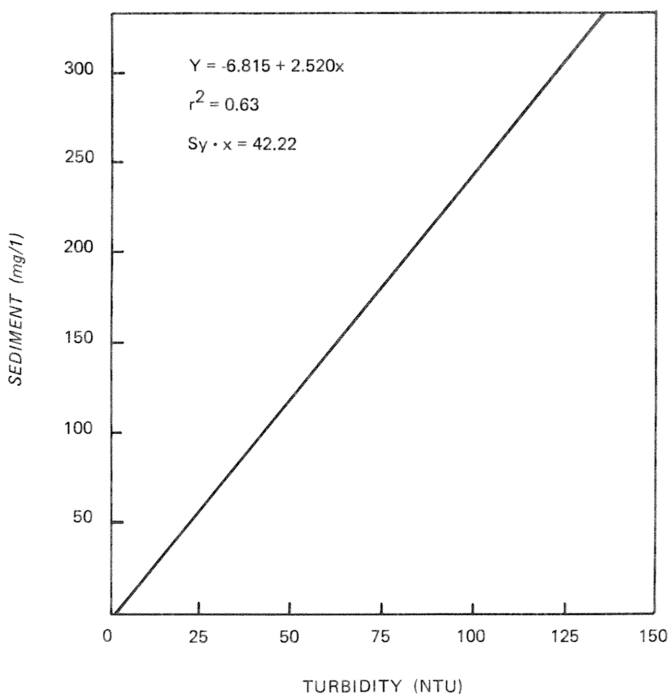


Figure 5.—The relationship between sediment concentrations and turbidity.



during the first 22 hours. The next 22 hours, when the second peak occurred on the hydrograph, only 263 pounds of fine sediment were exported. This illustrates a "flushing out" phenomenon commonly observed on all of our experimental watersheds. In addition to storm size and intensity, the interval between storms is an important variable influencing sediment loads on a given watershed. There were also 1,244 pounds of coarse material deposited in the approach box at site 1 during this 44-hour period. Most of this material was probably deposited during the first peak on the hydrograph. During periods when ISCO samplers equipped with a floating intake were used in conjunction with the Coshocton wheels, there was a close agreement in fine sediment export between the two sampling methods.

Turbidity of a water sample is the optical property that causes light to be scattered and absorbed by suspended and colloidal matter rather than being transmitted through the sample. Figure 5 shows the relationship between sediment concentrations and turbidity. It is based on about 1,000 samples having turbidities up to 130 NTU. The validity of turbidity measurements as estimators of sediment concentration has been questioned by some authorities. The American Public Health Association (1975), for example, states that "Attempts to correlate turbidity with weight concentrations of suspended matter are impractical." Kunkle and Comer (1971), nevertheless, found a reasonably consistent relationship in Vermont, and Costa (1977) found a good correlation between turbidity and sediment concentrations in Maryland. Both authors pointed out that the relationships should be verified for the streams in question. The correlation on this graph is less than ideal but it does provide rough estimates of sediment concentrations on this watershed and perhaps for other watersheds having similar soil. Its reliability must be verified before use at other locations. Since turbidity measurements can be readily made in the field, this relationship affords a quick way to estimate sediment concentration, for example, in evaluating erosion control measures on logged areas.

Residual stand damage

There were 513 residual trees per acre larger than 1 inch dbh. Of these, less than 1 percent had abrasion wounds or root damage, 9 percent were skinned, and 1 percent were destroyed (Table 5). Sixty-three percent of the damaged trees were less than 6 inches dbh. Of the wounds on skinned trees, 52 percent were less than 6 in^2, 25 percent were between 7 and 25 in^2, and 23 percent exposed more than 25 in^2 of sapwood.

DISCUSSION

If we project the results obtained in this study, road construction costs on similar soils and topography will vary from about $2,000 per mile with no gravel and few culverts to about $10,000 per mile with complete graveling and more frequent use of culverts. In order to stay within these limits, the following rules of logging road construction should be observed:

- Use an operator experienced in forest road construction; use nothing smaller than a D-6 bulldozer or its equivalent.
- Use the bulldozer for right-of-way clearing.
- Make no effort to slope cut banks, sloughing off will occur naturally and road banks will eventually stabilize.
- Metal culverts and necessary ditching should be used on live streams and seeps; drainage from the road surface itself should be contained in broad-based drainage dips.
- Dips should be: constructed where road grades are 10 percent or less; flagged out after roads are roughed out; at least 100 feet long, i.e., from the start of the cut to the end of the fill; graveled with about 20 tons of clean, 3-inch stone except on rocky or shaley soil; and outsloped 3 to 4 percent at the low point to allow for drainage.
- If possible, allow newly constructed roads to settle several months before using.

Table 5.—Number of residual trees per acre damaged by yarding with a truck-mounted crane

Damage class	Dbh class (inches)			Total number per acre	Percent
	1 – 5	6 – 11	11 +		
Abrasion	0	< 1	0	< 1	< 1
Skinned	27	15	2	44	9
Root damage	0	0	< 1	< 1	< 1
Destroyed	5	0	0	5	1
Total	32	16	3	51	10

For this type of road, a bulldozer will often have to be used in conjunction with large trucks to spread gravel. Road rutting can be kept at a minimum by frequently changing wheel tracks when hauling.

In our opinion, the most important feature of this type of road is its residual value—it can be used for fuelwood harvesting, fire control, and a variety of other management activities. Roads built for rubber-tired skidders are often steep, poorly located, inadequately drained, and usually cannot be negotiated with other vehicles. Another value, frequently overlooked, is the good appearance of a properly constructed and drained forest road. Much of the criticism directed at timber harvest methods stems from objection to overly numerous, muddy, and generally unsightly logging roads.

The truck-mounted crane required fewer roads than the rubber-tired skidder; its mobility and swinging boom resulted in less damage to the residual stand, and provided a means for decking logs along the road. The boom lifted logs above the road berm, eliminating damage to the downhill side of the road. The logs were not skidded, so they were cleaner—important in bucking, and for mills with no debarker or other log-cleaning equipment. The investment probably was lower for a machine that both yards and loads than for a system requiring a skidder and a loader.

More extensive observation will have to be made to properly evaluate stand damage but we expect it to be at least as low as that observed on ground skidding systems.

Although topography dictated that the reconstructed road be located rather poorly in relation to the stream, sediment production was kept within limits expected for undisturbed forested watersheds. Erosion control on road sections adjacent to the stream was accomplished with additional gravel and close spacing of drainage dips. Allocating a larger percentage of available road funds to portions of the access that will receive the heaviest use—and to critical segments adjacent to streams—simply makes good sense. The rest of the access system was properly located relative to the stream and therefore could be built on a lower standard by using ungraveled dips and only spot graveling. This logging system lends itself well to winching trees away from the channel area and thus eliminates any need to operate equipment in this critical area.

Hewlett (1979), after monitoring a forestry operation in the far more erodible soils of Georgia, concluded that most of the sediment export due to the forestry operation was directly attributable to bad roading and channel-area damage by equipment. Our findings support his conclusion because we took the necessary precautions in these potentially critical areas and sediment production did not exceed that normally expected from undisturbed forest land.

LITERATURE CITED

American Association of Professors in Sanitary Engineering.
1972. **Water chemistry laboratory manual.** Sec. 1. Univ. Nebr., Lincoln, 171 p.

American Public Health Association.
1975. **Standard methods for the examination of water and wastewater.** 14th ed. Am. Public Health Assoc., New York. 1,193 p.

Cook, Walter L., and John D. Hewlett.
1979. **The broad-based dip on Piedmont woods roads.** South. J. Appl. For. 3(3):77-81.

Costa, John E.
1977. **Sediment concentration and duration in stream channels.** J. Soil and Water Conserv. 32(4):168-170.

Douglass, James E.
1975. **Southeastern forests and the problem of non-point sources of water pollution.** *In* Non-point sources of water pollution. Southeast. Reg. Conf. Proc. Va. Polytech. Inst. and State Univ., Blacksburg, (1975)29-44.

Hewlett, John D.
1979. **Forest water quality: An experiment in harvesting and regenerating Piedmont forest.** Univ. Ga, Sch. For. Resour., Athens. 22 p.

Hewlett, J. H., and J. E. Douglass.
1968. **Blending forest uses.** USDA For. Serv. Res. Pap. SE-37. 15 p.

Hewlett, J. D., and A. R. Hibbert.
1967. **Factors affecting the response of small watersheds to precipitation in humid areas.** *In* International symposium forest hydrology proceedings, Pergamon Press, Oxford, England. p. 275-290.

Holtan, H. N., N. E. Minshall, and L. L. Harrold.
1962. **Field manual for research in agricultural hydrology.** U.S. Dep. Agric., Agric. Handb. 224. 215 p.

Klingebiel, A. A.
1962. Soil factor and soil loss tolerance. *In* ARS-SCS workshop on soil loss prediction in the Northeastern States. p. 25-26.

Kochenderfer, J. N.
1977. Area in skidroads, truck roads, and landings in the central Appalachians. J. For. 75(8): 507-508.

Kochenderfer, J. N., and G. W. Wendel.
1978. Skyline harvesting in Appalachia. USDA For. Serv. Res. Pap. NE-400. 9 p.

Kunkle, Samuel H., and George H. Comer.
1971. Estimating suspended sediment concentrations in streams by turbidity measurements. J. Soil and Water Conserv. 26(1):18-20.

Patric, J. H.
1976. Soil erosion in the eastern forest. J. For. 74(10):671-677.

Ursic, S. J.
1977. Water quality impacts of forest management practices. Pollut. Control Semin. South. For. Ind. Dallas, Texas, Sep. 28-29, 1977. 19 p.

Headquarters of the Northeastern Forest Experiment Station are in Broomall, Pa. Field laboratories and research units are maintained at:

- Amherst, Massachusetts, in cooperation with the University of Massachusetts.
- Beltsville, Maryland.
- Berea, Kentucky, in cooperation with Berea College.
- Burlington, Vermont, in cooperation with the University of Vermont.
- Delaware, Ohio.
- Durham, New Hampshire, in cooperation with the University of New Hampshire.
- Hamden, Connecticut, in cooperation with Yale University.
- Kingston, Pennsylvania.
- Morgantown, West Virginia, in cooperation with West Virginia University, Morgantown.
- Orono, Maine, in cooperation with the University of Maine, Orono.
- Parsons, West Virginia.
- Princeton, West Virginia.
- Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
- University Park, Pennsylvania, in cooperation with the Pennsylvania State University.
- Warren, Pennsylvania.