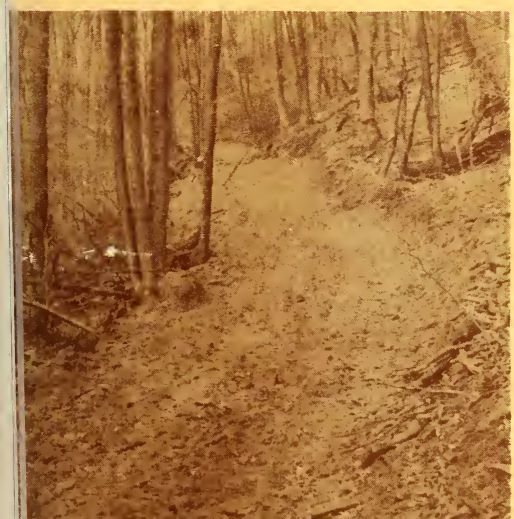
PERMANENT LOGGING ROADS FOR BETTER WOODLOT MANAGEMENT



Division of
STATE and PRIVATE FORESTRY
FOREST SERVICE EASTERN REGION
U. S. DEPT. OF AGRICULTURE
UPPER DARBY, PA.

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By Richard F. Haussman

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1960

PREFACE

Availability of professional guidance in forest management coupled with a continuing demand for forest products makes intensive mangagement feasible for timberland owners. Ready access to all parts of a timber-producing area is prerequisite to intensive management, adequate protection, and successful harvest operations. Roads and trails, well located and constructed to sufficiently high standards, provide the necessary access just as do streets and walks in the city.

This principle of access applies to small properties as well as large. Providing access for the farm woodlot does not usually involve difficult engineering problems but, even so, the location and design of roads and trails warrant careful consideration. Roads may serve a variety of useful purposes. Good location and design facilitate operations; poor location and design may handicap them and may even induce undesirable effects such as soil erosion and siltation.

This handbook has been prepared to meet the need for proper directions in the construction and maintenance of a transportation system on a typical woodlot. It applies specifically to situations most commonly encountered in the Northeast and is designed to provide a set of principles for a generally applicable type of low-cost, low-speed road. Good judgment must, of course, be used in applying those principles because of the wide variety of topography, soils, climate, and other factors which prevail in different parts of the Northeast.

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for
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LOCATING THE ROAD

BASIC CONSIDERATONS

Topography will often dictate the approximate location and extent of a road system necessary to bring timber out of the woods. In other cases, property lines, economic limits on skidding, and other features may determine to what point a truck road shall be extended into the timber. Generally the haul road should be planned to the farthest point consistent with good economics and sound operating principles.

Here are some items to consider in planning and locating a logging road:

1. **Grade:** Logging roads in mountain country are usually too steep. Excessive grades increase maintenance and trucking costs and frequently make it too expensive to keep roads intact. Grades should be kept below 10% except for short distances where this limit may be exceeded to a maximum of 15% to 20%.

   Long, steady grades permit the build-up of drainage water and increase the erosion potential unless adequate drainage structures are installed. To facilitate natural drainage, occasional breaks to level or adverse grade may be planned.

   Likewise, it is well to avoid long, level sections of road because such sections are difficult to drain properly. Grades of 3% to 5% are desirable.

Figure 1 — Logging in terrain such as this requires careful planning. Proper location of roads is imperative. (Courtesy Caterpillar Tractor Co.)

2. **Slopes:** Side-hill locations permit good cross drainage and also provide the construction advantage of balanced cross sections which involve a minimum of earthmoving. Where slopes exceed 60% to 70% in grade, this advantage is lost because the road bed must be placed in solid material with all of the excavated earth going over the side as waste. (See Road Cross Sections and Slope Chart in Appendix.)

3. **Obstacles:** Rock outcrops, ledges, swampy places, and other features which are apt to present difficulties in construction should be avoided.

The exact location of such obstacles must be known because they constitute control points that will influence the final location of the road. Occasionally, however, they are not encountered until the preliminary location is made.

4. **Distance from Streams:** Streambeds do not make good roads and should not be used for that purpose. Road surface drainage should be kept out of streams by locating the road far enough from a stream to provide sufficient filtering area.

TABLE I

Recommended widths for filter strips Between Logging Roads and Streams

Slope of land between road and stream	Width of filtration strip
Percent	Feet
0	25
10	45
20	65
30	85
40	105
50	125
60	145
70	165

Figure 2 — Poorly located logging road with no facilities for drainage.

5. **Stream Crossings:** Stream crossings should be made at right angles where possible regardless whether the crossing is by ford, culvert, or bridge. Where water values are high, as in the case of domestic use, live water courses should always be bridged. If a stream is forded, sufficient adverse grade should be provided on the lower approach section to confine the stream to its channel even during periods of high water.

METHOD OF LOCATING ROAD

It is assumed that the road locator has some knowledge of the area to be served by the road and of the terrain and the approximate location on which the road is to be built. The distribution and volume of the timber which is to feed into the road should also have been determined.

The proposed road should become a permanent improvement to

serve either as a continuously passable road or to be used at periodic intervals. It should be planned to assure adequate coverage of the whole area even though the area might contain blocks of timber not now operable. This can be done most effectively by plotting or sketching the road on an aerial photo or on a map.

The next step in the location process is to walk the entire length of the proposed road to become familiar with the topography and ground conditions. All control points should be established at this time with only a minimum of marking necessary to indicate the route traveled.

Then follows the preliminary location survey which can best be done by a two-man crew. Working in a downhill direction affords a better view of the terrain. The procedure usually followed is for the instrument man, with Abney Level and from the starting point, to line in the headman or flagman at a visible point in the direction of the survey. The grade is then checked with the instrument. If the grade between these points is excessive, the flagman moves uphill or downhill until the desired grade is obtained. The two points are then tied in with markers, and the same process is repeated from the advanced station. Marking can be done with axe blazes, paint, strips of cloth, or weatherproof marking tape fastened to trees. The entire course should be marked as the survey progresses, with the marked line constituting the center line of the right-of-way.

If, in following a predetermined fixed grade, the locator misses the desired road terminus, he should work back from that end and connect the two surveys at the most convenient point. It may be necessary to repeat this grade survey .

A road locator working alone can establish and maintain a desired grade by tying a flag or leaving a readily visible mark at eye-level height at the starting point of the survey, then taking a backsight with the instrument from the next point in the survey. This method is repeated for every shot between intervisible points along the course.

Curves and switchbacks must be of sufficient radius for trucks to negotiate easily. The radius should be not less than 35 feet and on as flat a grade as possible. Turnouts should be provided to permit the passing and parking of vehicles. It is desirable that they be intervisible. Advantage should be taken

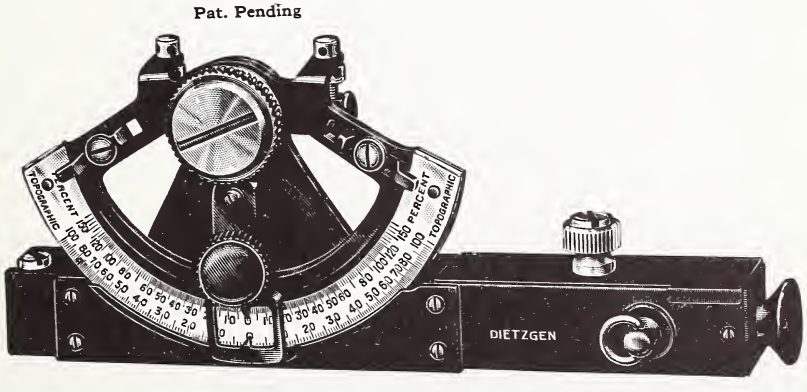


Figure 3 — Abney Hand Level with combination percentage of grade and topographic (rise in feet per chain) scale. (Courtesy Eugene Dietzgen Co.)

of topography that provides natural passing places which require little movement of materials. Curves and turnouts should be staked during the location survey.

The most convenient, low-cost surveying tool for road grade layout is an Abney Hand Level with a percent scale. This instrument should be used because it is extremely difficult even for experienced people to estimate grade correctly. Other equipment needed for use in the field is a measuring tape, flagging material, axe or brush hook, and hand compass if bearings are desired. Aerial photos or map of area should be carried for reference.

THE USE OF GRADE AND SLOPE STAKES

Should circumstances dictate that a more highly engineered road be built than is possible from a center line location survey, it may become necessary to set grade and slope stakes.

In that event, grade stakes must be placed along the location survey line, at 50 feet, 100 feet, or even greater intervals, depending upon the uniformity of the topography. At sharp curves, stakes may be set as close as 25-foot intervals in order to assure uniform curvature. (See Suggested Method for Laying Out a Curve.) On tangents, the grade stakes should be placed in a reasonably straight line.

A grade stake marks that point on the ground and represents that point in the cross section of the road where the "cut" and "fill" sections meet and are reduced to zero. Slope stakes mark those points in the cross section which represent the outer limits of construction, namely: the top of the cut bank and the toe of the fill bank. However, slope stakes are normally set only on the cut side for the type of road considered here. (See Slope Stake Sketch in Appendix.)

The setting of slope stakes follows the "grade" survey as a separate operation. These are placed on the uphill side of every grade stake. The principal steps in setting slope stakes are as follows (see Slope Stake Sketch and Slope Stake Table):

1. With Abney Level determine the average percentage of slope by taking readings to the right and to the left of grade stake. (Example: right 36% left 32%, average 34%).
2. From Slope Stake Table under 1/4:1 Slope (or whatever bank slope is desired), and opposite 34%, determine "S" (6.8 ft.). Measure this distance from grade stake and at right angle to road and set slope stake.
3. From same table find "C" or depth of vertical cut (2.2 ft.) and mark this figure on slope stake.
4. Find distance "B" from table (5.9 ft.) and measure off horizontally from grade stake and set rough stake at this point.

The Slope Stake Table is so constructed that reasonably close balance will be obtained between cut and fill if the indicated dimensions are followed during construction.

CONSTRUCTION

After the survey has been completed, it is important that the road be properly constructed. Building of logging roads does not generally require the services of a highway engineer, but certain basic construction principles must be followed in the process.

Figure 4 — Bulldozer at work on road construction.

Depending upon the skill and road building experience of the equipment operator, it may be necessary for a qualified man to provide some supervision during the period of construction. Before the heavy equipment is engaged and put to work, the road location should be well marked and all preparatory work within the right-of-way should be completed. This will permit immediate and steady use of the machinery and will result in prompt completion of construction at minimum equipment costs.

CLEARING

Merchantable trees in the right-of-way are cut down and bucked into logs ahead of construction. Logs and tops should be moved far enough off the right-of-way so they will not interfere with construction.

Logging roads on small woodland properties are usually constructed by the logging contractor, sawmill operator, or by a contractor who rents out equipment or contracts jobs. These often use whatever size of equipment is most readily available even though it is important economically that equipment of the proper size be used. A D-6 or D-7 or equivalent is best suited for road

jobs of 10 feet or 12 feet in width, with larger machines for wider roads. Machine rental rates normally include the services of an operator.

Stumps which will be covered by a foot or more of fill material should be cut low and need not be removed. All other stumps and roots over 3 inches in diameter should be dug out of the ground. This is usually accomplished by leaving a stump about 3 feet high to facilitate its removal with the bulldozer blade.

Figure 5 — Right-of-way clearing is the first step in the construction of a woods road.

Figure 6 — Completed section of low service, low-speed timber haul road. Note steep slope of cut bank.

If the right-of-way supports only brush or young timber, or where a sufficiently heavy tractor-dozer is engaged, no felling need be done and all material can be cleared by machine. Trees which are so moved by bulldozer should not be permitted to lean or be left suspended above the ground. They present a hazard which should be eliminated at the time of construction. Snags which may fall into the road from outside should also be felled. Blasting of rocks and boulders may be necessary on rare occasions although this need can usually be avoided at the time of location. Even after construction is under way, it may be possible to by-pass such obstacles by minor changes in alignment.

If the road has a dead-end, sufficient space should be cleared and bulldozed off to provide for easy equipment turn-around.

DESIGN AND STANDARDS

The design and standard of a logging road are determined by certain basic economic considerations. These are the original construction costs and the costs of trucking as affected by the road.

Because the former is more readily determined, the latter consideration is often neglected. Yet, just as the size of the load is determined by the size of the truck, so is the total hauling expense affected by the proportionate time the equipment spends on the logging road and by the ease with which the road is traversed. In other words, road design and standards have a far greater effect upon the economics of a logging operation than is represented by origi-

nal road construction costs. Excessive road maintenance and trucking expenses may more than offset savings in construction.

Figure 7 — Completed section of road in steep terrain. Note inslope of road bed and slopes of road banks.

Figure 8 — Clearing to inadequate widths retards drying out of road surface. This road has been in existence for a number of years. Note how crowns of trees have closed in over right-of-way. Some "daylighting" is desirable here.

The desired width of single track haul roads is from 10 to 12 feet, with greater widths at curves and turnouts. However, construction cost for a 12-foot road on a steep side slope may be as much as one-third higher than for a 10-foot road on the same location. The difference is represented by the high volume of earth to be moved out of the additional 2 feet.

Road banks may be cut just as steep as the stability of the material will permit. Bank slopes may range from 1/4:1 on stable material to a 1:1 ratio in erosive soil. (For details on design and standards refer to Appendix.)

DRAINAGE

It is difficult to over-emphasize the importance of adequate drainage in the construction of any road. Provision must be made not only for passage of surface water from adjacent slopes; rapid drainage of the road bed itself is necessary to keep the road in good, serviceable condition.

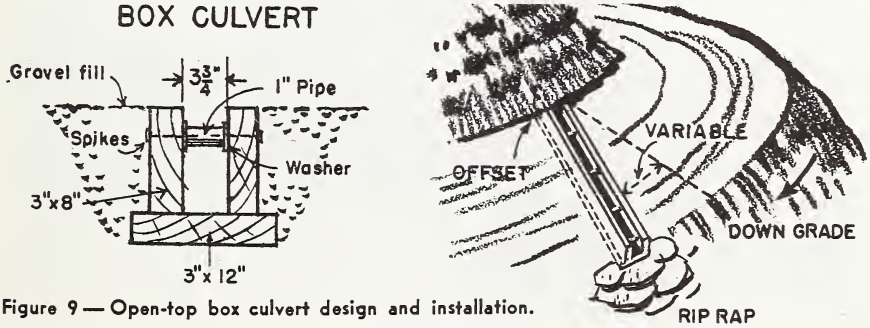


Figure 9 — Open-top box culvert design and installation.

Where side ditches are necessary, provision must be made to divert the water across the road at frequent intervals by means of culverts or dips. Open-top culverts are generally used on roads of this type. They are cheap to construct and quite serviceable when properly maintained. Open-top culverts can be constructed of poles or from sawn timbers. If made of durable wood or treated material, box culverts give many years of service.

Figure 10 — Open-top box culvert properly installed in road.

TABLE II

Recommended distances between open-top culverts

Road grade	Spacing
Percent	Feet
2-5	300-500
6-10	200-300
11-15	100-200
16-20	100 —

Note: Actual distances between culverts will depend upon the nature of the road surface material and its tendency to erode.

Figure 11 — "Thank-you-ma'am" drainage structure.

"Thank-you-ma'ams" are frequently used on logging roads, especially where the volume of water is not expected to be great enough to wash them out. These, as well as culverts, should be placed across the road at an oblique angle in the direction of the waterflow. On mountain roads, this angle placement not only makes it possible for the culverts to clear themselves of dirt, stones, and debris, but also makes for safer truck travel in that two front wheels of a truck do not cross the drainage structure at the same time.

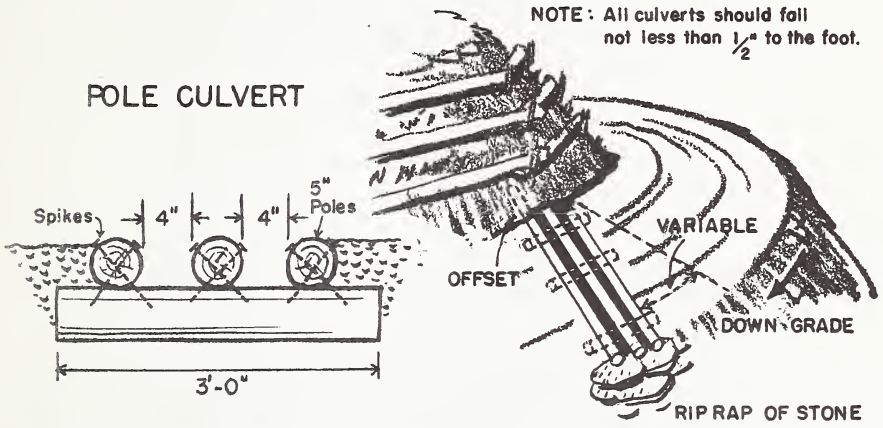


Figure 12 — Open-top pole culvert design and installation.

Figure 13 — Open-top pole culvert installed in logging road.

Outsloping the entire width of the road towards the fill bank provides good surface drainage and may reduce the number of culverts needed, and hence the construction costs. The outslope should only be enough to divert the water, generally 1/4 inch to 3/8 inch to the foot. If the slope is apparent to the eye, it is usually too great. A road should not be outsloped, however, in steep country, or if it becomes slippery when wet or frozen. Truck travel becomes hazardous under such conditions.

Insloping the road toward the cut bank may be done to prevent erosion, or as a safety precaution on slippery soils. An insloped road requires the installation of culverts unless the water will seep through pervious material.

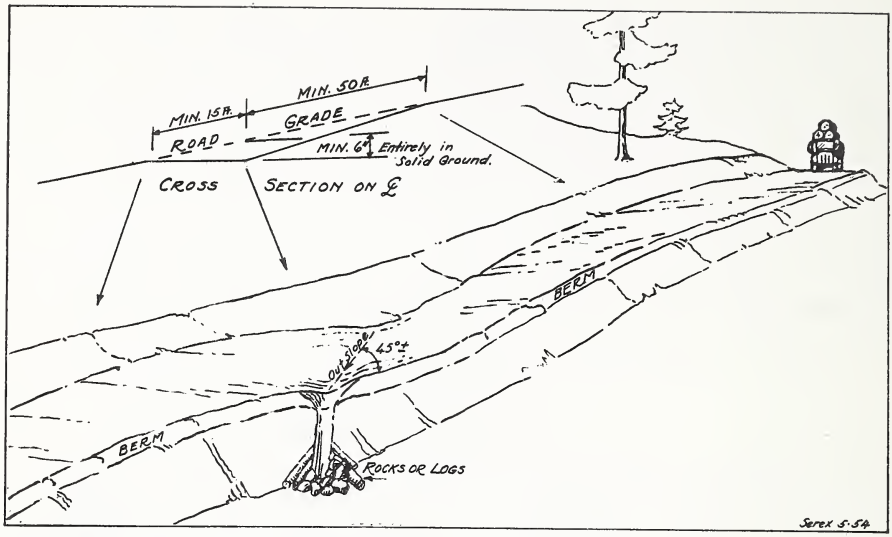


Figure 14 — Typical drainage dip installation.

A frequently used drainage structure on insloped roads is the intercepting dip. This is a carefully outsloped section of road which acts as a water catchment and drainage channel. It must be constructed accurately. Length and depth must be adequate to provide drainage, yet not excessive to endanger traffic at normal speeds. Dips should not be installed to handle live (constantly running) water.

Figure 15 — Abandoned logging road in light soil now seriously eroding. Simple protective measures could have prevented this.

On occasion, it becomes necessary to prevent surface water from entering a stream—as on downgrade approaches to a bridge. This may be done by installing a culvert just ahead of the bridge and diverting the water into a sump hole between road and stream. Such a catchment can usually be dug out with a bulldozer.

If long-time use of the road is anticipated after completion of the immediate logging job, it is more economical to install drainage structures of corrugated metal or concrete pipe, rather than to risk costly maintenance and early replacement of temporary culverts.

BRIDGES — GENERAL CONSIDERATIONS

Careful consideration should be given to alternate road locations before deciding that a bridge is really necessary to transport timber out of a certain tract of woodland. It may be cheaper in the long run to move the timber out in another direction over a longer route rather than to build a bridge. In any case, a bridge should not be constructed if a crossing can be made by less expensive means such as a culvert pipe or ford, unless water values rule out the latter.

A word of caution about the use of fords as a stream crossing. Fords should have solid approaches on both sides of the stream. On occasions this condition can be achieved by a heavy application of gravel or shale to the approach sections.

In selecting a site for a bridge, attention should be directed to the alignment of the stream as well as that of the road. The crossing should be at right angles, with alignment of stream and road straight in all four directions. The stream bed should be straight and should also be of uniform profile to provide unobstructed flow of water. Approaches to a bridge should consist of the maximum practicable tangents, being not less than 50 feet in length on either side, if possible.

Piers and abutments should be in a direction parallel to the stream flow and must be imbedded in good foundation material. Skewed locations of bridge abutments and piers should be avoided when possible. The grade of the bridge should coincide with that of the road; i.e., if the bridge is to be built on a 2% grade, the approach should be the same grade for at least 50 feet at each end. Abrupt rises or falls in the grade line at the ends of the bridge are to be avoided.

Figure 16 — Approach to temporary bridge in logging road. Note uniform grade of approaches and bridge floor.

Figure 17 — Side view of same bridge. Note bridge components — log abutments, stringers, sawn timber decking, run-planks, and wheel guards.

For bridge material and design, refer to the "Round Stringer Bridge" plan in the Appendix. Native tree species are suitable for stringers in most bridges that need to be constructed on logging roads. Stringers should be large enough

and sound in order to meet the load specifications provided in the table in this plan.

The bridge floor consists of 3-inch-thick decking laid solidly across the stringers. Tops of the stringers should be hewn or adzed to provide a good bearing surface. The entire floor must be rigid enough to distribute the weight to all the stringers. Running planks, 3-inches thick, placed over the floor lengthwise and parallel to the stringers, serve as wheel tracks.

Large, uniform-size poles may be substituted for sawn bridge decking as floor material. Here, too, the poles are laid solidly across the stringers and fastened to them, and the running planks are installed on top of the pole decking. In either case, wheel guards of poles or sawn timbers should always be installed along the outer edges of the deck for safety.

MAINTENANCE

CURRENT

With properly located and well-constructed roads, maintenance problems are relatively minor. This is especially true if good judgment is used in keeping off the road during the spring break-up and extended periods of poor weather.

Much of the maintenance can be done by hand and may include opening drainage structures and ditches and their inlets, and removing slides, rocks, and material that has sloughed off the banks. After early use of a newly constructed road some subsurface weaknesses, dips, or holes may appear which will require spot surfacing with some suitable material.

Seasonal grading of the road surface is necessary to fill in wheel ruts and to shape up the road. This can best be done by a motor or tractor-drawn grader; however, such equipment normally is not available. A bulldozer may be used, but a more common piece of equipment used for this purpose is a road drag which is nothing more than a heavy platform built of timbers or iron members. It is usually weighted down heavily with stones and is pulled behind a truck or tractor, smoothing out the surface and filling in wheel ruts.

Figure 18 — Box culvert in this section of road has lost its usefulness. Too shallow side ditch and clogging of culvert resulted in heavy rutting of road. Drainage structures must be properly installed and maintained.

AFTER LOGGING

On logging roads that may not be used again for several years, certain steps should be taken to protect the road during this period of non-use.

Immediately after logging, the open-top culverts should be removed and

replaced with water bars, dips, or ditches—their number and spacing depending upon the grade of the road. All of these structures should be of sufficient size to carry maximum run-off volumes and to keep from getting washed out.

Natural revegetation of roads, ditches, and landings with grasses and weeds will prevent erosion. In easily erodible soil, roads, banks, and landings should be quickly seeded to protect them with a vegetative cover. Wherever possible, the road should be completely closed off to prevent use by unauthorized persons.

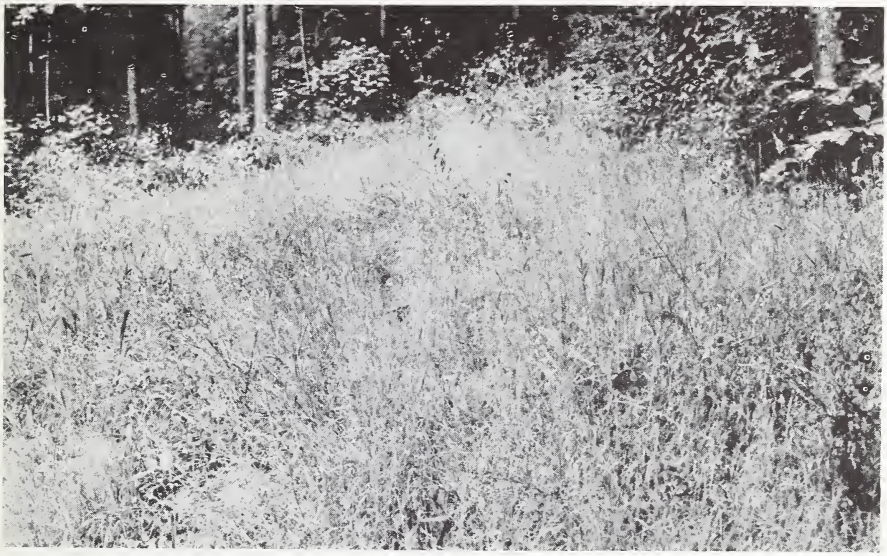


Figure 19 — Seeded log landing 1½ years after seeding. The site is now well protected from erosion.

Figure 20 — Similar log landing which was not seeded.

Because of the importance of a forest edge and openings in the woods to game birds and animals, preference might be given in seeding to such cover species that are recognized as beneficial to wildlife. Depending upon locality, climate and site, these might include some of the following species: Lespedeza, fescue, blue grass, timothy, clover (white, red top, ladino, alsike), birdsfoot trefoil, oats, wheat, and rye.

If it is decided that the road will be kept open after logging is completed, then it would be advisable to follow these simple rules to protect the road:

a) Keep travel at minimum
b) Use only during dry weather
c) Make periodic inspections and follow through with simple maintenance

RIGHTS-OF-WAY

Where woods roads cross lands of other owners, permission to cross should be obtained. For permanent access roads, however, it is advisable to obtain written agreements. Written and recorded rights-of-way are of mutual benefit and provide protection of the interests of all parties concerned.

A right-of-way agreement should define the road location, its points of ingress and egress, and width. All other pertinent information should be carefully noted. A simple survey may be desirable. Such conditions as the maintenance of fences, gates, cattle guards and other improvements should be clearly specified. Monetary considerations or other forms of payment requested by the grantor should also be made a part of the agreement.

Figure 21 — The common 1½-ton multi-purpose farm truck is used here for hauling logs. Its payload is limited but it is adequate for small woodlot operations involving short hauls.

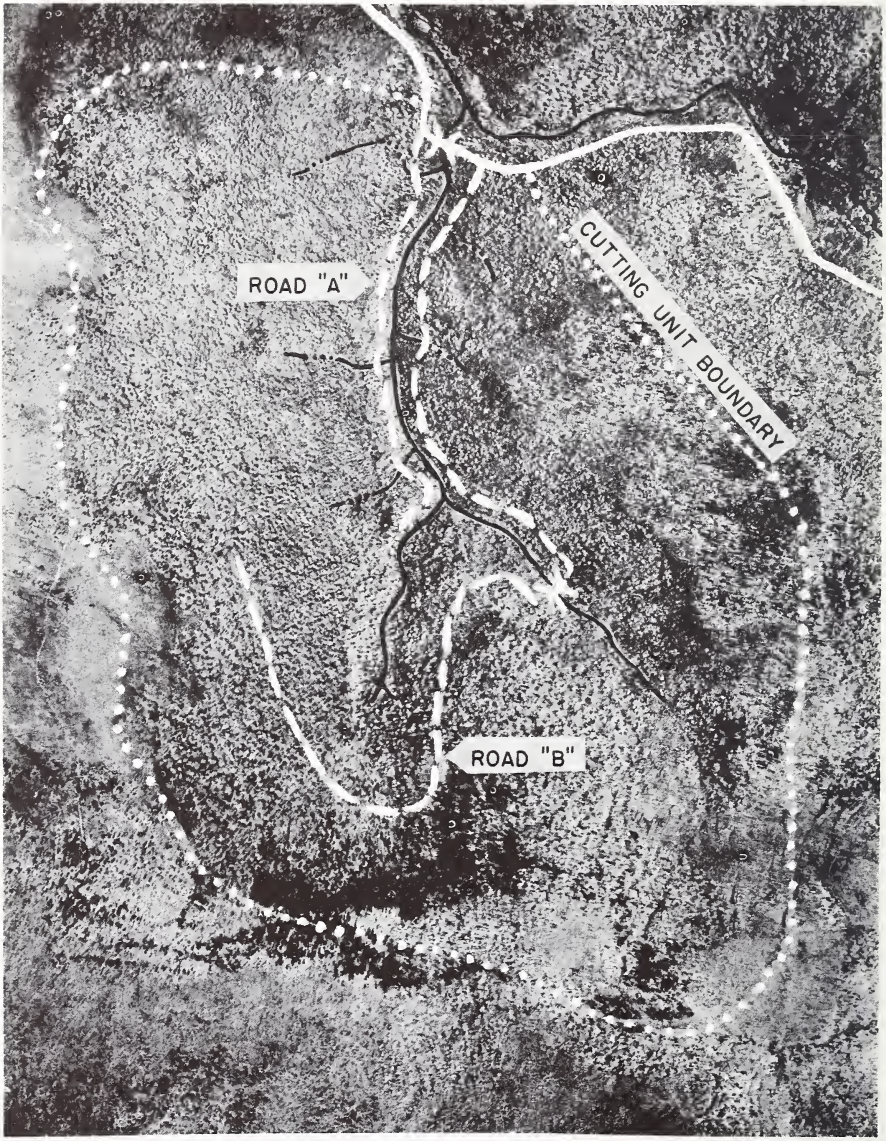
Should the woods road end on the right-of-way of a public secondary or primary highway, the local Highway Department offices should be contacted. Many State Highway Departments have strict rules and regulations governing the entry of private roads into public roads. Permits may be necessary.

Figure 22 — Tandem-axle trucks of a 30,000 to 35,000 lb. Gross Vehicle Weight size are a common log-hauling vehicle in the Northeast. They carry upward of 2,000 bd. ft. of logs and require well-constructed woods roads.

The following sample road right-of-way agreement contains the important provisions desirable in such an instrument. All of these provisions may

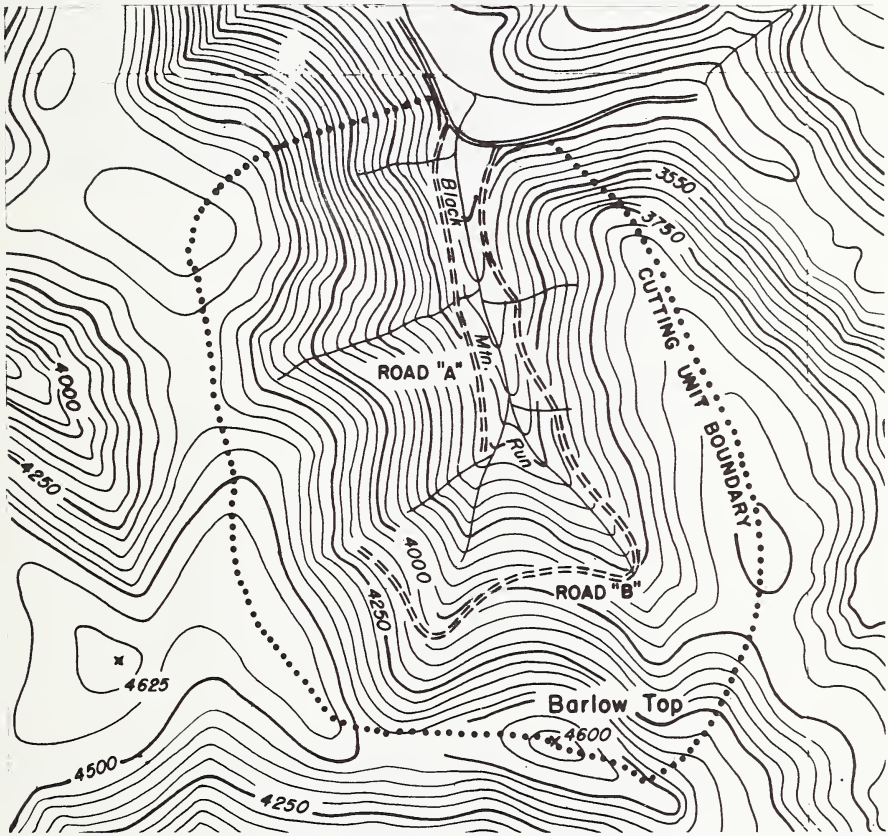
Comparision of logging road plan on an aerial photo and a topographic map of same area is provided on the following two pages. Lack of detail on topographic map permits only approximate location of road, but contour lines facilitate determination of road gradients.

AERIAL PHOTO OF LOGGING UNIT
SHOWING LOCATION OF PERMANENT ROADS



Area of operating unit	1,020 Acres
Volume of timber to be cut	3,600 M bd. ft.
Average cut per acre	3,500 bd. ft.

TOPOGRAPHIC MAP OF SAME AREA



Survey data on	Road A	Road B
Elevation at beginning	3,240 ft.	3,240 ft.
Elevation at upper end	3,510 "	4,150 "
Rise in elevation	270 "	910 "
Length of road	3,700 "	10,510 "
Average gradient	7.3%	8.7%

not be necessary in every case. It is suggested that before a right-of-way agreement is executed and recorded, a local attorney be consulted in order that the instrument conform with whatever legal state requirements may be in force.

Figure 23 — The tractor-trailer type of log truck makes for economic transportation but its use requires well-engineered roads.

RIGHT-OF-WAY AGREEMENT

THIS INDENTURE, MADE THIS ..... day of ....., 19 .....
Between .....
.....
.....
of the County of ....., State of .....,
grantor, party of the first part, and .....
.....
.....
of the County of ....., State of .....
party of the second part, WITNESSETH: .....
.....
that for and in consideration of .....
.....
receipt of which is hereby acknowledged; the party of the first part does hereby grant, bargain, sell, and convey unto the party of the second part and its assigns an easement and right-of-way for road purposes for a road to be located, constructed, operated and maintained across the grantor's premises located in the County of ....., State of ....., the said right-of-way to be in conformity with and located upon the ground according to a mutually agreed upon location which is described as follows:
.....
.....
.....
.....

1. PROVIDED: However, that if at any time this easement or any road constructed thereon shall be abandoned by the party of the second part, or its assigns, the rights and privileges hereby granted shall cease and terminate and the premises traversed thereby shall be freed from said easement fully and completely as if this agreement had not been made.

2. PROVIDED: However, that this easement shall become null and void and shall not extend beyond .....
3. PROVIDED: Also, that in the event of termination of this easement upon the satisfactory completion of the current period of use and enjoyment of its privileges by the party of the second part, another need arises for this right-of-way in the future, the party of the first part will consider favorably such a request by the party of the second part, its successors or assigns.
4. PROVIDED: That the party of the second part maintains and repairs fences, gates, and other improvements which have been damaged and broken as a result of the enjoyment of the easement and which are on the lands of the party of the first part and to the satisfaction of the party of the first part.
5. PROVIDED: That the party of the second part will not assign his rights or responsibilities under this agreement in whole or in part without the written consent of the party of the first part.

IN WITNESS WHEREOF; the said grantor and the said grantee have hereunto subscribed their name and affixed their seals the day and year herein above written.

Witness:

....

....

....

....

TRACTOR ROADS AND SKID TRAILS

Skidding of logs is performed in the Northeast in a variety of ways depending upon locality and the economic circumstances of the operator. Horses are still being used for "yarding" in parts of New England where we also find the timber "scoot" or log sled-tractor combination. The most common method, however, is skidding of one or more logs by wheel or crawler-type tractor, with the latter often accompanied by an arch.

Figure 24 — The seasonal logging operations in the farm woodlots of New England usually require simple road construction.

Figure 25 — Farm tractors are used extensively on woodlots of gentle topography. Road requirements here are minimum.

Tree-length skidding is becoming popular, especially so in connection with integrated sawlog and products operations. The recent development of fast and highly mobile rubber-tired tractors containing such features as four-wheel drive, power-steering, and oscillating axles is a notable improvement in logging equipment. These machines can operate successfully over steep terrain and on low-standard trails; they make long skids (a mile or more) economically feasible, which reduces or eliminates the need for truck roads on some jobs.

Figure 26 — Tractor roads in moderately steep country often require little preparation. (Courtesy Deere and Company)

Whatever method or combination of methods is contemplated in moving timber from stump to landing, each method requires its own particular type of skid trail or road. All of these, however, employ certain basic engineering principles in their location and construction.

Unfortunately, all too little attention has been paid in the past to the planning of an efficient skidroad system in the woods. These improvements are considered to serve a very temporary purpose and little thought is given to what happens to the land upon the completion of the logging operations. Oftentimes timber is skidded straight down the mountainside, no matter how steep, leaving in its wake eroding gullies and deposits of sediment at the foot of the slope and in the streams.

Figure 27 — Fast four-wheel power skidders such as this are well suited for tree-length skidding over long distances. They perform under many adverse conditions but operate most efficiently on well-located roads.

Figure 28 — Before this steep section of tractor road was seeded down it deposited much silt and debris in stream channel.

Figure 29 — Tree-length skidding with tractor and arch requires carefully located roads. Alignment of road is important.

In managing timberlands, some thought must be given to planning for repeated operations on the same area, and provision must be made for the protection and re-use of the major improvements after a lapse of a cutting cycle.. Also, whereas a haphazardly built system of truckroads, skidroads, and trails may disturb as much as 20% of the surface, a well-planned logging transport system need not occupy more than 10% of the land area. Here again, a map of the area or an aerial photo is extremely helpful. Tentative skidroad locations can be plotted on paper before final location and construction begin.

The frequent objection to tree-length logging for reasons of damage to residual trees can largely be overcome by the careful location of skidroads. In such cases, alignment of the road becomes of major importance. Where wheeled arches and tractors with angle blades are used in skidding, special care should be exercised in locating the road to prevent excessive damage to adjacent trees.

The primary difference between a tractor road and a skid trail lies in the degree of preparation prior to use. Main tractor roads should be flagged, cleared, and graded. Trails which are used to bring logs from stump to main skidroad are usually not graded and need only a minimum amount of clearing. Where skidding is contemplated by tractor equipped with a winch, logs are moved directly from stump to tractor road without prepared spur trails.

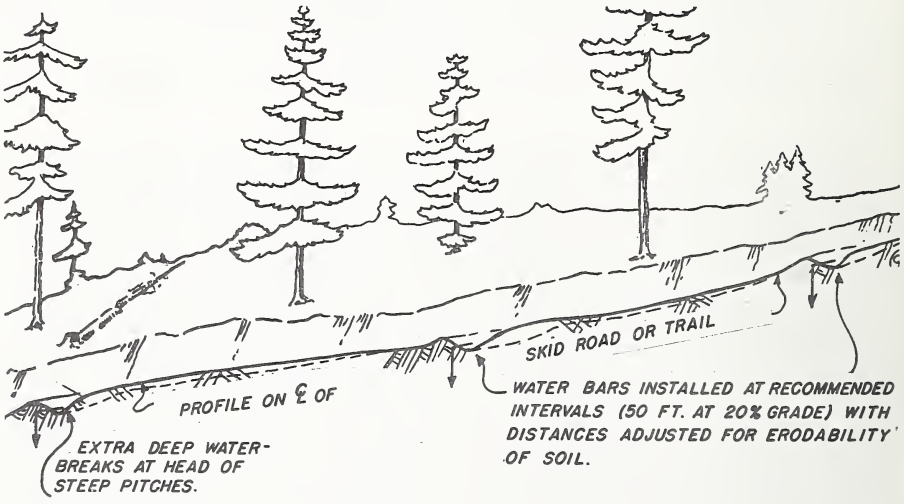


Figure 30 — Profile of skidroad showing water breaks.

With special attention to proper drainage and soil stabilization, the following points should receive consideration in developing a skidroad system on a logging job:

1. Locate landings first, and lay out tractor road approach with a low grade.

2. Keep grades as low as topography will permit. Do not go straight up the slope, but proceed slanting up the hill.

3. Avoid streambeds, rocky places, and adverse grades.

4. Cross stream courses at right angles.

5. Break the grade occasionally and avoid long, straight grades; these permit water to build up and cause erosion.

6. Wherever possible, build the tractor roads from the top on down—it is much easier.

7. Water turnouts should be installed on main tractor roads at intervals not greater than is indicated in Table II, which governs spacing of culverts on truck roads. It is also important to provide a cross-drain immediately above extra steep pitches in the road and below bank seepage spots

8. Construct small bridges or install culverts at live stream crossings, particularly on the main tractor roads and especially where water values are highly important.

9. Install fender logs on outside edge of skidroad on steep slopes, also at turns and switchbacks to prevent logs from rolling off the skidroad and to protect adjacent standing timber from damage.

Figure 31 — Water bars installed in abandoned skid trail to prevent erosion.

Maintenance of skidroads during periods of use is usually confined to keeping the surface water drained off. However, immediately upon seasonal shutdown—or at completion of the operation—certain steps should be taken to protect the road against erosion. These are:

1. Install water bars at recommended intervals to provide for drainage.

2. Rocks, brush, and logging debris can often be used as water retardants on side trails, and should be so used.

3. Where skidroads cross streams or intermittent water courses, the streambeds should be cleaned of slash and restored to natural shape and grade.

4. Landings and trail sections of extreme grade should be seeded with grass or weed seed to provide early permanent vegetative cover.

TABLE III

Recommended distances between waterbars on skidroads which have been "put to sleep"

Grade of road	Distance between water bars
Percent	Feet
2	250
5	135
10	80
15	60
20	45
25	40
30	35
40	30

With the skidroads protected and "put to sleep" in such a manner, little attention will need to be given them during the ensuing years. And, when the time comes to remove another crop of timber from the area, the protected logging roads will result in lower operating costs and correspondingly higher timber prices to the landowner.

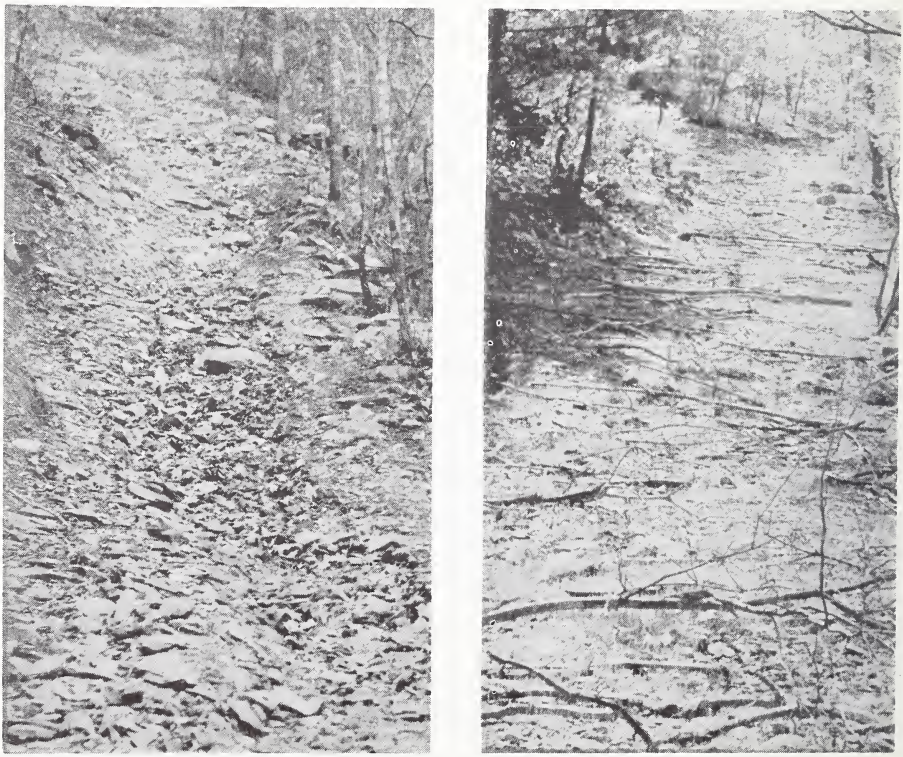


Figure 32 — Erosion on logging roads can be controlled. Before and after pictures of an eroding skidroad to which simple protective measures have been applied. Grade is about 25%.

BIBLIOGRAPHY

A guide to erosion reduction on national forest timber sale areas: Region 5, U. S. Forest Service, Dept. of Agriculture, 1954.

Forest road standards, surveys, and plans: Div. of Eng. Handbook, 1955, Region 6, U. S. Forest Service, Dept. of Agriculture.

Instructions for the location of temporary logging roads, Monongahela National Forest: Region 7, U. S. Forest Service, Dept. of Agriculture.

Laying out the skid-road: West Virginia Conservation, Cons. Comm. of West Virginia, June 1952.

Logging farm wood crops: Farmers' Bull., no. 2090, U. S. Dept. of Agriculture, 1955

Mitchell, Wilfred C., and Trimble, G. R. Jr., How much land is needed for the logging transport system?: Jour. of Forestry, vol. 57, no. 1, January 1959.

New Hampshire guides for logging roads and skid trails: Univ. of New Hampshire, Ext. Folder 35, January 1957.

Planning, location, design, and construction of timber access roads: Div. of Eng. (manual excerpt), Region 7, U. S. Forest Service, Dept. of Agriculture

Road handbook—standards, construction, maintenance, structures, transportation planning: Div. of Eng., U. S. Forest Service, Dept of Agriculture

Simmons, Fred C., Northeastern loggers' handbook: Handbook no. 6, Northeastern Forest Exp. Station, U. S. Dept. of Agriculture, 1951.

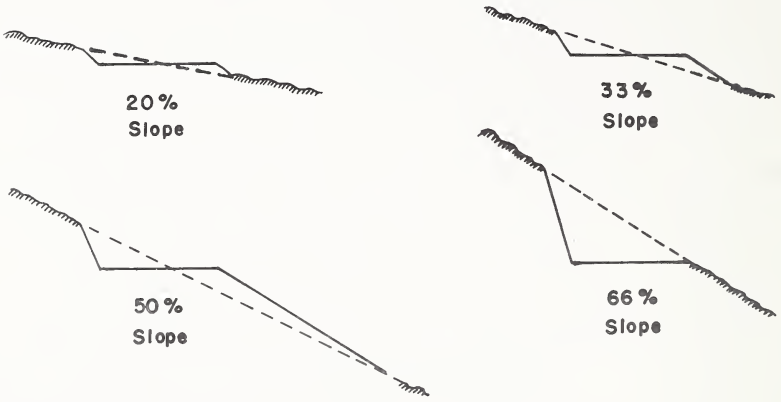
Timber haul costs, Monongahela National Forest: Handbook, 1957, Region 7, U. S. Forest Service, Dept. of Agriculture.

Trimble, G. R. Jr., and Sartz, Richard S., How far from a stream should a logging road be located?: Jour. of Forestry, vol. 55, no. 5, May 1957.

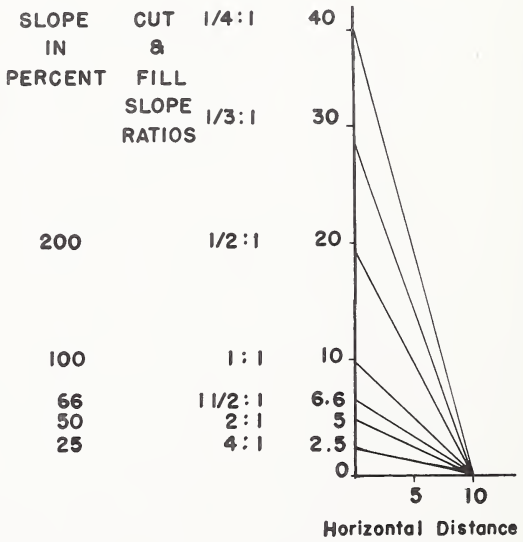
Weitzman, Sidney, and Trimble, G. R. Jr., Integrating timber and watershed management in mountain areas: Jour. of Soil and Water Conservation, vol. 10, no. 2, March 1955.

APPENDIX

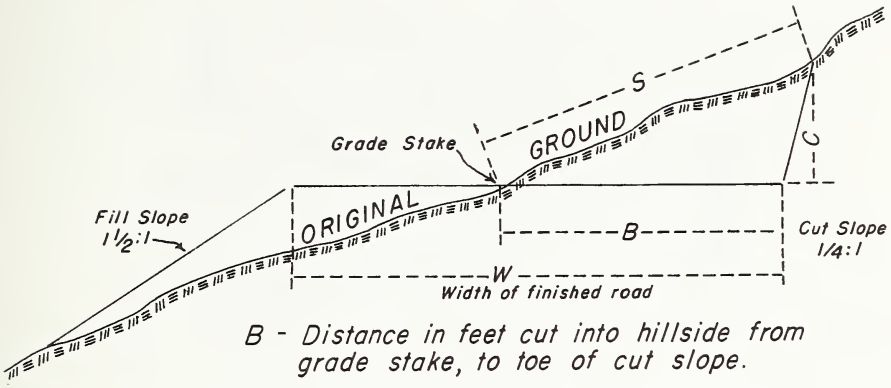
TYPICAL ROAD CROSS-SECTIONS
ON SIDE SLOPES OF VARYING DEGREES



SLOPE AND BANK CHART



SLOPE STAKE SKETCH



B - Distance in feet cut into hillside from grade stake, to toe of cut slope.

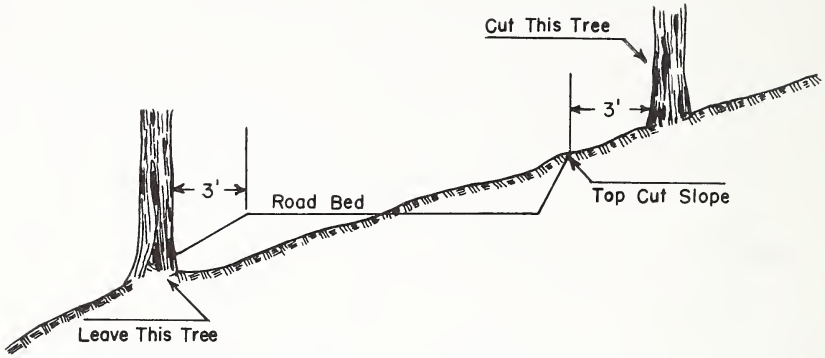
C - Vertical cut in feet, to be marked on cut stake.

S - Distance along slope to be measured from grade stake to cut stake.

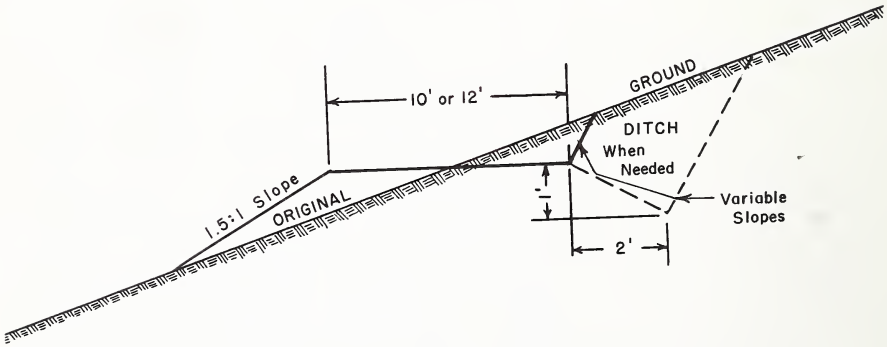
SLOPE STAKE TABLE
WIDTH FINISHED ROAD - 10 FEET
(SEE SKETCH)

SLOPE	1 : 1 Slope			3/4 : 1 Slope			1/2 : 1 Slope			1/4 : 1 Slope		
%	B	C	S	B	C	S	B	C	S	B	C	S
10	5.3	0.6	5.9	5.4	0.6	5.9	5.5	0.6	5.8	5.3	0.5	5.5
12	5.3	0.7	6.1	5.4	0.7	6.0	5.5	0.7	5.9	5.3	0.7	5.5
14	5.3	0.9	6.3	5.4	0.9	6.1	5.5	0.8	6.0	5.4	0.8	5.6
16	5.4	1.0	6.4	5.5	1.0	6.3	5.6	1.0	6.1	5.4	0.9	5.7
18	5.4	1.2	6.6	5.5	1.2	6.4	5.6	1.1	6.3	5.5	1.0	5.8
20	5.4	1.4	6.9	5.5	1.3	6.6	5.6	1.3	6.4	5.5	1.2	5.9
22	5.4	1.5	7.2	5.5	1.5	6.8	5.6	1.4	6.5	5.5	1.3	6.0
24	5.4	1.7	7.4	5.6	1.6	7.0	5.7	1.6	6.7	5.6	1.4	6.1
26	5.5	1.9	7.6	5.6	1.8	7.2	5.7	1.7	6.8	5.6	1.6	6.3
28	5.5	2.1	7.9	5.7	2.0	7.4	5.8	1.9	7.0	5.7	1.7	6.4
30	5.5	2.4	8.2	5.7	2.2	7.7	5.8	2.0	7.2	5.8	1.9	6.5
32	5.5	2.6	8.6	5.7	2.4	7.9	5.8	2.2	7.3	5.8	2.0	6.7
34	5.6	2.9	8.9	5.8	2.6	8.2	5.9	2.4	7.5	5.9	2.2	6.8
36	5.6	3.2	9.3	5.8	2.9	8.4	6.0	2.6	7.7	5.9	2.4	7.0
38	5.7	3.4	9.7	5.9	3.1	8.7	6.0	2.8	8.0	6.0	2.5	7.1
40	5.7	3.8	10.2	5.9	3.4	9.1	6.1	3.0	8.2	6.1	2.7	7.3
42	5.8	4.2	10.7	6.0	3.7	9.5	6.2	3.3	8.5	6.2	2.9	7.5
44	5.9	4.6	11.4	6.1	4.0	9.9	6.3	3.5	8.8	6.3	3.1	7.7
46	6.0	5.0	12.1	6.3	4.4	10.4	6.4	3.8	9.1	6.4	3.3	7.9
48	6.0	5.6	12.8	6.4	4.8	10.9	6.5	4.1	9.4	6.5	3.5	8.2
50	6.1	6.1	13.6	6.5	5.2	11.6	6.6	4.4	9.8	6.6	3.8	8.5
52	6.2	6.8	14.6	6.6	5.6	12.2	6.7	4.7	10.2	6.7	4.0	8.7
54	6.4	7.4	15.7	6.8	6.1	12.8	6.9	5.1	10.7	6.9	4.3	9.1
56	6.5	8.3	16.9	7.0	6.7	13.6	7.1	5.5	11.2	7.1	4.6	9.4
58	6.7	9.2	18.4	7.1	7.2	14.4	7.3	5.9	11.8	7.3	4.9	9.8
60	6.9	10.4	20.1	7.3	7.9	15.5	7.5	6.4	12.5	7.5	5.3	10.3
62	7.4	11.9	22.5	7.7	8.8	16.7	7.9	7.1	13.4	7.9	5.8	10.9
64	7.9	13.8	25.7	8.2	9.9	18.3	8.4	7.7	14.4	8.4	6.3	11.6
66	8.5	16.4	30.1	8.7	11.4	20.6	8.9	8.8	16.0	8.9	7.0	12.8

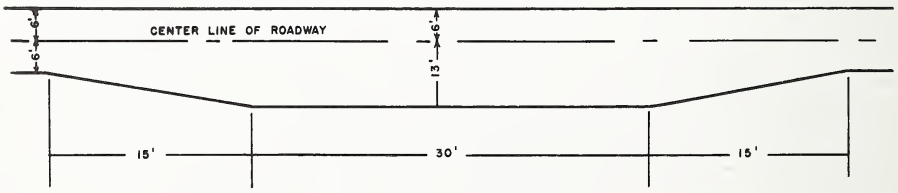
TYPICAL CLEARING SECTION



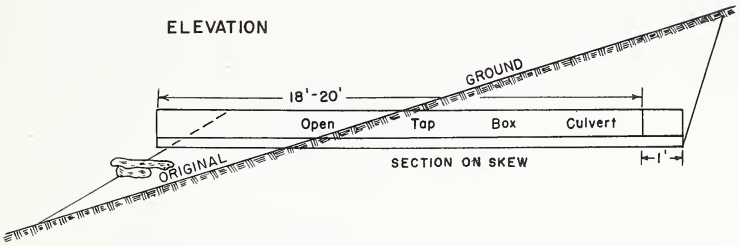
TYPICAL GRADING SECTION

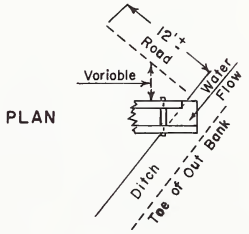


TURNOUT PLAN

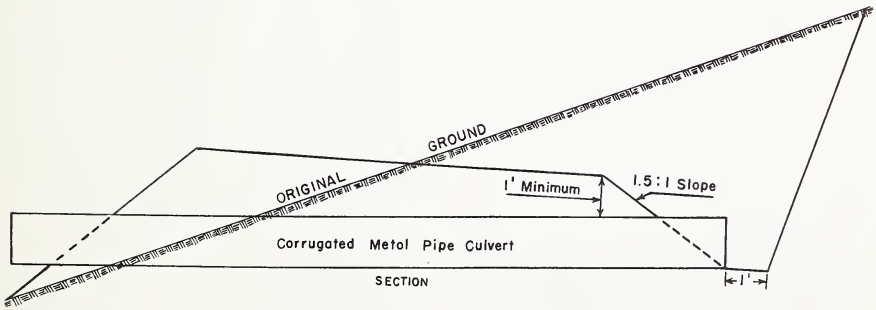


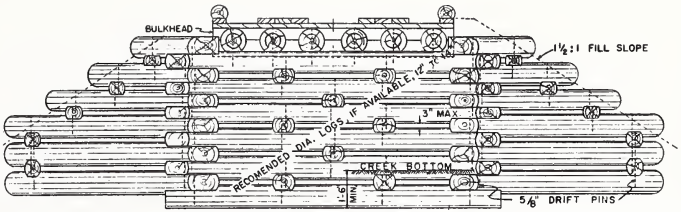
TYPICAL DRAINAGE INSTALLATIONS



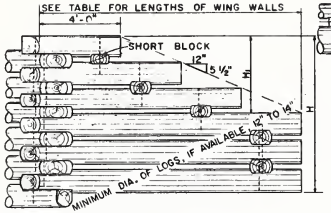


Recommended minimum slope of culverts is 5% and not less than the grade percent of the road.

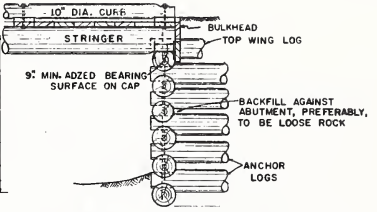




ABUTMENT ELEVATION

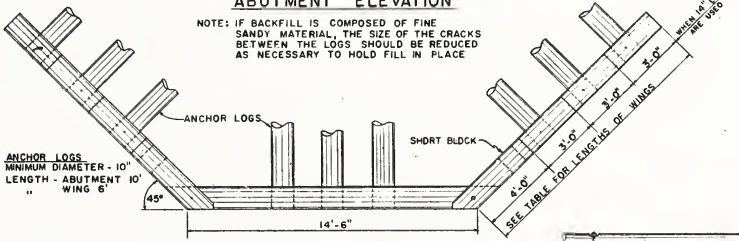


WING ELEVATION



LONGITUDINAL SECTION AT ABUTMENT

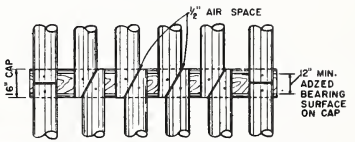
NOTE: IF BACKFILL IS COMPOSED OF FINE SANDY MATERIAL, THE SIZE OF THE CRACKS BETWEEN THE LOGS SHOULD BE REDUCED AS NECESSARY TO HOLD FILL IN PLACE



ABUTMENT PLAN

DIMENSIONS OF WINGS FOR VARIOUS HEIGHTS

H	H_1	LENGTH OF WING	NO. PINS FOR 12" DIA. LOGS
4'	1'-4"	7'	22
6'	2'-9"	10'	42
8'	4'-2"	13'	52
10'	4'-2"	13'	62
12'	5'-6"	16'	82
14'	7'-0"	19'	102



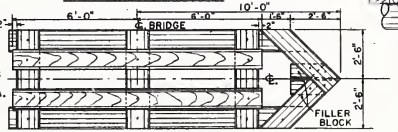
PLAN ASSEMBLY OF INTERMEDIATE BENT

NOTES – LOG CRIBS

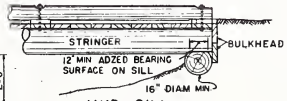
DRIFT PINS TO GO THROUGH TWO LOGS AND EXTEND NOT LESS THAN 4" INTO THIRD. HEADERS TO BE AT LEAST 10" DIA. AND STRETCHERS TO BE 12" DIA.

ALL NOTCHING TO BE ON LOWER SIDE OF LOG.

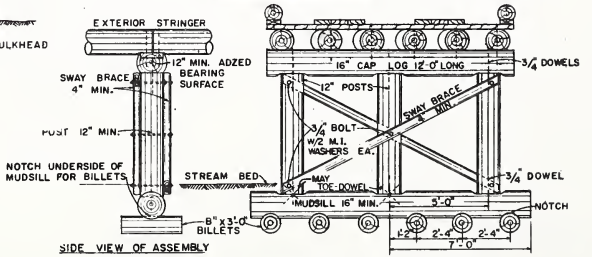
BACKFILL ADJACENT TO LOGS TO BE HAND PLACED



LOG CRIB PLAN
BATTER NOT SHOWN

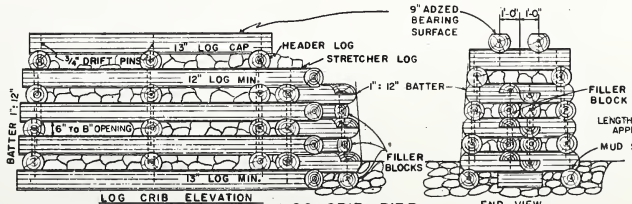


MUD SILL
(FOR STABILIZED BANKS)



SIDE VIEW OF ASSEMBLY OF INTERMEDIATE BENT

INTERMEDIATE BENT 6 STRINGERS



LOG CRIB ELEVATION
(FOR FAST FLOW STREAMS)

LOG CRIB PIER

END VIEW

BENT
(FOR SLOW FLOW STREAMS)

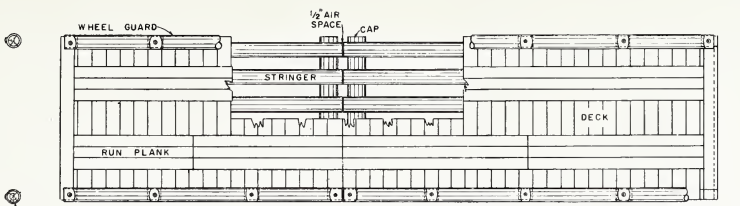
DESIGN: H-15 LOADING

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
REGION SEVEN
BOYD G. FISHER, REG. ENG'R

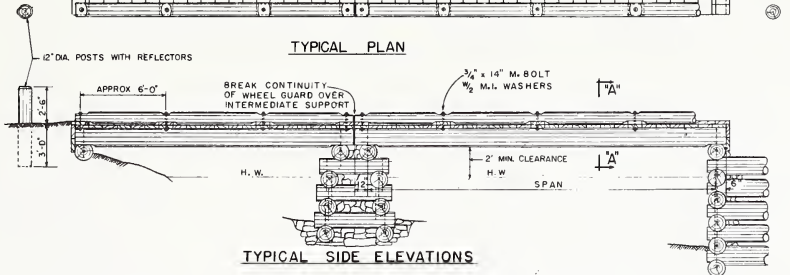
STANDARD
LOG SUBSTRUCTURES FOR ROUND STRINGER BRIDGES

DESIGNED
DRAWN
CHECKED
RECOMMENDED
APPROVED
REGIONAL ENGINEER

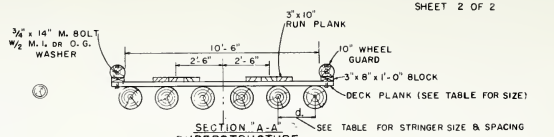
SCALE 1/2"=1'-0"
DATE 6-20-40
DATE 6-27-40
DATE 6-27-40



TYPICAL PLAN



TYPICAL SIDE ELEVATIONS



SUPERSTRUCTURE

DESIGN DATA

(1) LOAD DISTRIBUTION ACCORDING TO THE AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS SPECIFICATIONS - 1957
(2) BLACK LOCUST, SOUTHERN YELLOW PINE, OAK (RED OR WHITE), HICKORY, BEECH YELLOW BIRCH, SUGAR MAPLE, W ASH, 1300 #/□" UNIT STRESS IN BENDING
(3) SPRUCE (RED OR WHITE), EASTERN HEMLOCK, YELLOW POPLAR, NORWAY PINE, LARCH, 900 #/□" UNIT STRESS IN BENDING.

GENERAL NOTES

1) RUN PLANKS TO BE FASTENED TO FLOOR WITH TWO ½" x 5" LAG SCREWS AND CUT WASHERS IN EACH BOARD EVERY 4'-0" COUNTERSINK HEADS
2) ALL LOGS TO BE PEELED.
3) IN MEASURING ROUND TIMBERS DEDUCT ½ THE DEPTH OF SAP WOOD ON EACH SIDE OF THE HEART.
4) MEASURE DIAMETER OF LOGS AT ⅛ OF THE LENGTH FROM SMALL END.
5) ALTERNATE LARGE AND SMALL ENDS.
6) ALLOW NO LARGE KNOTS IN THE MIDDLE THIRD OF THE SPAN.
7) PLACE STRINGERS WITH KNOTS OR DEFECTS ON THE TOP SURFACE
8) HOLES FOR DRIFT PINS TO BE 1/16" UNDERSIZE.
9) FLOOR PLANK: - NUMBER GIVEN IN TABLE IS FOR 12" WIDTH, INCREASE NUMBER TO SUIT WIDTH USED.
10) LEAVE ¼" SPACE BETWEEN ALL FLOOR PLANKS.
11) BOLT HOLES TO BE BORED TO SIZE OF BOLT.
12) NAIL EACH PLANK TO EACH STRING WITH 2 NAILS

BILL OF MATERIALS FOR SUPERSTRUCTURE

DIAMETER OF STRINGERS H-15 LOADING

SPAN	UNIT STRESS=900 #/□" NUMBER OF STRINGERS 5	6	7	8	9	10	11	12	SPAN	UNIT STRESS=1300 #/□" NUMBER OF STRINGERS 5	6	7	8	9	10	11	12
8	13	12	11	11	10	10			8	12	11	10	10	9	9	9	
9	14	13	12	12	11	11	10		9	12	11	11	10	10	9	9	
10	14	13	13	12	12	11			10	13	12	11	11	10	10	10	9
11	15	14	13	13	12	12			11	13	12	12	11	11	10	10	
12	15	14	14	13	12	12			12	14	13	12	11	11	11	10	
13	16	15	14	13	13	12			13	14	13	12	12	11	11		
14	16	15	14	14	13				14	14	13	13	12	12	11		
15	17	16	15	14	13				15	15	14	13	12	12			
16	17	16	15	14					16	15	14	13	13	12			
17	18	16	15	15					17	16	14	14	13	13			
18	18	17	16	15					18	16	15	14	13	13			
19	18	17	16	15					19	16	15	14	14	13			
20	19	17	16						20	17	15	15	14	13			
21	19	18	17						21	17	16	15	14				
22	20	18	17						22	17	16	15	15				
23	20	18	17						23	18	16	16	15				
24	20	19	18						24	18	17	16	15				
25	21	19	18						25	18	17	16	15				
26	21	20	18						26	19	17	16					
27	22	20							27	19	18	17					
28	22	20							28	19	18	17					
29	22	21							29	20	18	17					
30	23	21							30	20	19	16					
d	2'-6"	2'-0"	1'-8"	1'-5"	1'-3"	1'-1"	1'-0"	11"	d	2'-6"	2'-0"	1'-8"	1'-5"	1'-3"	1'-1"	1'-0"	11"

LENGTH OF STRINGER	WHEEL GUARD 10" DIA. NO.	LENGTH	BULKHEAD NEW PLANK	FLOOR PLANK * NO.	SIZE	RUN PLANK 3"x10" NO.	LENGTH	¾" DIA DRIFT PINS NO.	¾" DIA 2 HOLE BOLTS NO.	¾" DIA. MACHINE BOLTS W/ 1¼" O.D. CAST WASHERS NO.	NAILS 8" NO.	NAILS 60d
9	2	9		9		6	9			6	12	40
10	2	10		10		6	10			6	12	40
11	2	11		11		6	11			6	12	45
12	2	12		12		6	12			8	16	50
13	2	13		13		6	13			8	16	50
14	2	14		14		6	14			8	16	55
15	2	15		15		6	15			8	16	55
16	2	16		16		6	16			8	16	60
17	4	10		17		9	12			8	16	65
18	4	11		18		9	12			10	20	70
19	4	11		19		9	14			10	20	75
20	4	11		20		9	14			10	20	80
21	4	12		21		9	14			10	20	85
22	4	12		22		9	16			12	24	90
23	4	13		23		9	16			12	24	90
24	4	14		24		12	12			12	24	95
25	4	14		25		12	14			12	24	95
26	4	14		26		12	14			14	28	100
27	4	15		27		12	14			14	28	100
28	4	15		28		12	14			14	28	105
29	4	16		29		12	16			14	28	110
30	4	16		30		12	16			14	28	115
31	4	17		31		12	16			14	28	120
32	4	17		32		12	16					

SEE TABLE - A

2 - 3"x10"x12'-0" FOR ALL SPANS

4"x12"x6'-0" FOR 5 AND 6 STRINGER BRIDGES
3"x12"x6'-0" FOR 7 STRINGER BRIDGES

2 - DRIFT PINS PER STRINGER

STRINGER BRIDGES, ONLY 6, 7, 8, 9, 10, 11 AND 12 STRINGER BRIDGES ONLY
NO. NAILS = NO. STRINGERS x 2 x NO. PLANKS + 10%
NO NAILS = NO. STRINGERS x 2 x NO. PLANKS + 10%

* SEE GENERAL NOTE 9)

TABLE - A

LOG DIAM.	BULKHEAD 12"d NO	SIZE	DRIFT PINS NO	LENGTH
8"	2	3"x12"		14"
9"	2	3"x12"		15"
10"	2	3"x12"		16"
11"	4	3"x8"		17"
12"	4	3"x8"		18"
13"	4	3"x8"		19"
14"	4	3"x8"		20"
15"	4	3"x8"		21"
16"	4	3"x10"		22"
17"	4	3"x10"		23"
18"	4	3"x10"		24"
19"	4	3"x10"		25"
20"	4	3"x10"		26"
21"	4	3"x12"		27"
22"	4	3"x12"		28"
23"	4	3"x12"		29"

DESIGN: H-15 LOADING

U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
REGION SEVEN — BOYD O. FISHER, REG. ENG'R

STANDARD
SUPERSTRUCTURE FOR
ROUND STRINGER BRIDGES

DESIGNED [illegible] - K.J. Knight — SCALE 1/2" = 1'-0"
DRAWN K.J. Knight - A. Hanson — DATE 6-22-60
CHECKED J.W. & W.L.M. — DATE 6-22-60
RECOMMENDED [illegible] — DATE 6-27-60
APPROVED [illegible] — DATE 6-27-60
REGIONAL ENGINEER

METHOD FOR SIZING UP ROAD USE ON A PLANNED LOGGING JOB IN TERMS OF NUMBER OF LOADS THAT WILL BE HAULED OVER THE ROAD

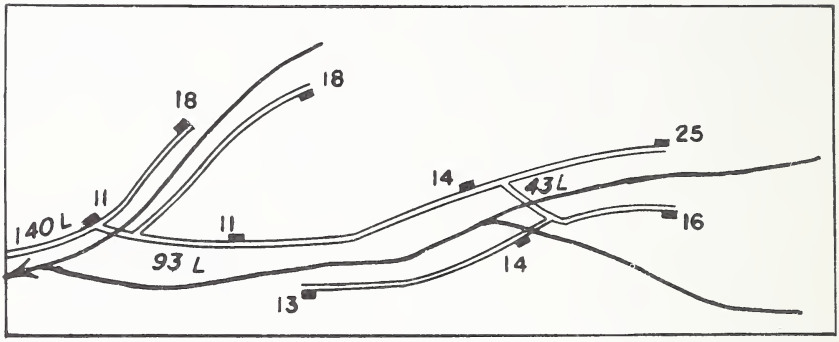


Illustration is based on a 100-acre tract with an average cut of 2.5 MBF per acre and trucks that will haul an average load of 1.8 MBF. Figures at landings represent the number of loads to be picked up at each point, and (L) figures represent total number of loads that will be hauled over the road past this point. Loads at landings are computed from estimate of timber that will be skidded to each landing. Where timber is uniformly distributed this can be determined from the area served by each landing.

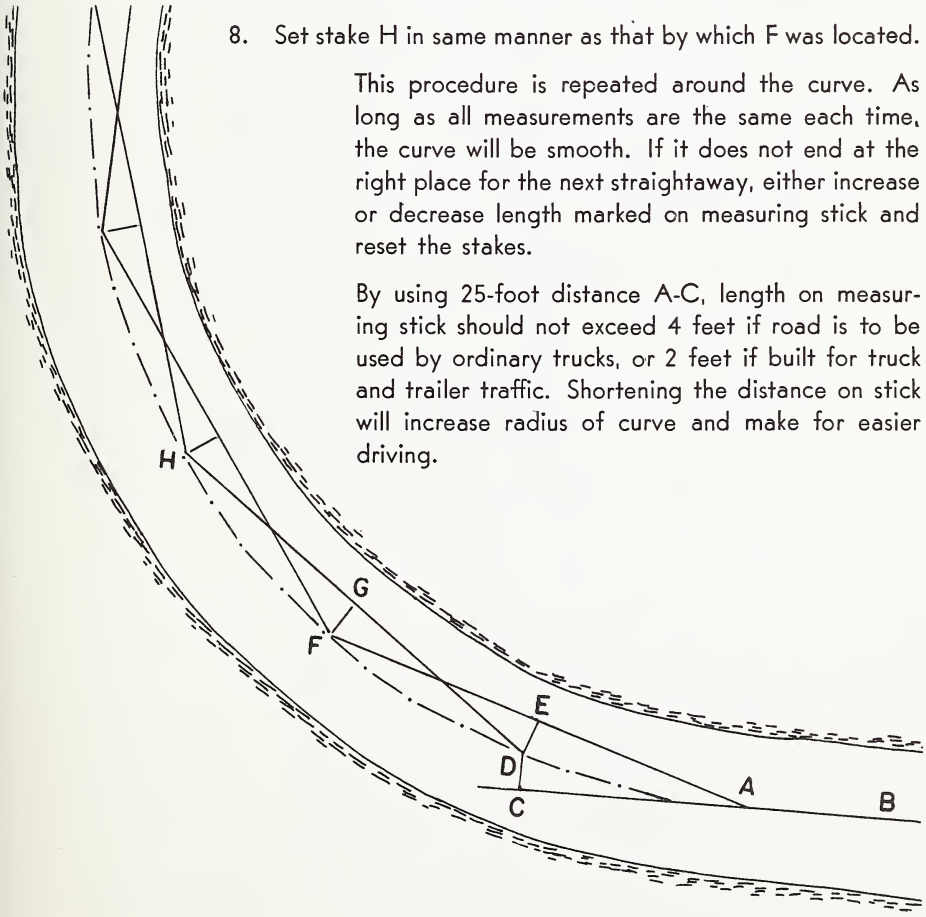
Expressing the proposed use of a logging road in terms of number of loads that will be hauled over it, can serve as a guide to the design and standards to which the various sections and spurs need to be constructed.

SUGGESTED METHOD FOR LAYING OUT A CURVE

1. Set a stake at beginning of curvature (end of straightaway)—point A.
2. Decide spacing of stakes in curve (distances from 25 to 100 feet are suitable for logging roads, with the closer spacing applicable to sharp curves).
3. Measure selected distance from A to C, in line with B.
4. At right angles to CA, set stake at D and mark distance CD on measuring stick.
5. Lay off same distance from D to E, and distance AC from A to E. Set temporary stake at E.
6. Double selected distance to F in line with AE and set stake at F.
7. Pull up temporary stake at E and set it at G by using measuring stick and tape in same way as at E.
8. Set stake H in same manner as that by which F was located.

This procedure is repeated around the curve. As long as all measurements are the same each time, the curve will be smooth. If it does not end at the right place for the next straightaway, either increase or decrease length marked on measuring stick and reset the stakes.

By using 25-foot distance A-C, length on measuring stick should not exceed 4 feet if road is to be used by ordinary trucks, or 2 feet if built for truck and trailer traffic. Shortening the distance on stick will increase radius of curve and make for easier driving.



DRAINAGE TABLE

BASED ON TALBOT'S FORMULA FOR A 2½" PER HOUR RAINFALL

AREA IN SQUARE FEET REQUIRED FOR WATER WAY

No. of Acres	Impervious 100% Runoff	Steep Slopes Heavy Soils Moderate Cover		Moderate Slopes Heavy to Light Soils Dense Cover		Gentle Slopes Agricultural Soils & Cover		Flatland Pervious Soils
	C = 1.00	C=.80	C=.70	C=.60	C=.50	C=.40	C=.30	C=.20
2	1.0	0.8	0.7	0.6				
4	1.7	1.4	1.2	1.0				
6	2.3	1.9	1.6	1.4	1.2	0.9	0.6	
8	2.9	2.3	2.0	1.7	1.4	1.2	0.9	0.6
10	3.4	2.7	2.4	2.0	1.7	1.4	1.0	0.7
20	5.8	4.6	4.0	3.5	2.9	2.3	1.7	1.2
30	8.0	6.3	5.4	4.8	4.0	3.2	2.4	1.6
40	9.8	7.8	6.8	5.9	4.9	3.9	3.0	2.0
50	11.6	9.3	8.0	7.0	5.8	4.6	3.5	2.3
60	13.4	10.7	9.2	8.0	6.7	5.3	4.0	2.7
70	15.0	12.0	10.3	9.0	7.5	6.0	4.5	3.0
80	16.6	13.3	11.5	10.0	8.3	6.6	5.0	3.3
90	18.2	14.6	12.5	11.0	9.1	7.2	5.4	3.6
100	19.7	15.8	13.5	11.8	9.8	7.8	5.8	3.9
150	26.9	21.2	18.5	16.0	13.3	10.7	8.0	5.4
200	33.2	26.8	22.9	20.0	16.7	13.3	10.0	6.6
250	39.5	31.5	27.1	23.8	19.7	15.7	11.8	7.9
300	45.7	36.1	31.0	27.1	27.0	18.0	13.5	9.0
350	51.0	40.6	35.0	30.5	25.3	20.2	15.0	10.1
400	56.0	45.0	39.0	33.9	28.0	22.2	16.7	11.2
450	61.7	49.7	42.0	37.0	30.6	24.2	18.0	12.3
500	66.8	52.8	46.0	40.0	33.2	26.5	19.8	13.2
600	77.0	61.6	52.5	46.0	38.2	30.3	22.8	15.3
700	86.0	68.4	59.5	52.0	43.0	34.0	25.8	17.2
800	96.0	76.1	65.8	57.0	47.5	38.0	28.5	19.0
900	104.0	83.0	71.7	62.2	51.9	41.5	31.1	20.8
1000	113.0	90.0	77.7	68.0	56.5	45.0	33.7	22.4

SIZES OF ROUND PIPE NEEDED FOR AREAS OF WATERWAY LISTED IN DRAINAGE TABLE

AREA	DIAMETER
Square Feet	Inches
1.25	15
1.80	18
3.10	24
4.90	30
7.10	36
9.60	42
12.60	48
15.90	54
19.60	60
23.80	66
28.30	72
33.20	78
38.50	84
44.20	90

EXPLANATIONS ON THE USE OF DRAINAGE TABLE

This table may be used in determining the size of drainage structures required to drain an area under run-off conditions resulting from a maximum rainfall of $2\frac{1}{2}$ inches per hour.

It is based on Talbot's Formula:

$$A = C \sqrt[4]{M^3}$$

Where: M = Acres of drainage basin

C = Constant factor based on a combination of soil absorptive capacity, slope and cover (.70 factor is adequate for most conditions prevailing in the Northeast. 1.00 represents complete run-off of precipitation.

A = Cross-sectional area of waterway required to carry run-off by bridge or culvert.

Example No. 1—Area to be drained, 70 acres.

Under C, opposite 70, find area required—10.3 square feet. Under the area table for round pipe, this falls between a 42-inch and a 48-inch pipe. Use 42-inch with an area of 9.6 square feet.

If a wood or other type box culvert is planned, one 3 feet x 3.5 feet would furnish the required area.

Example No. 2—Area to be drained, 450 acres.

Area of waterway required: 42 square feet.
This requires a 90-inch round pipe or a bridge of such dimensions that will furnish the required area; namely:
5 feet x 8 feet, or 4 feet x 11 feet, or 3 feet x 15 feet, etc.

SKID TRAIL EROSION CONTROL DEVICES