Designing & Building Road Systems

9

Forest Operations Manual

The Conservation Forestry Program

Designing & Building Road Systems

CHAPTER 9

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9.1 The Nature Conservancy Philosophy

Carefully designed, well-constructed roads are perhaps the most critical element of any timber operation from a conservation standpoint. As earlier chapters explain, damage to forestland, particularly in terms of erosion, most often results not from forest management activities themselves, but from roads that were improperly designed and laid out, poorly constructed, poorly maintained, or not closed correctly. By making proper road design and construction a high priority, forest managers will not only minimize erosion damage and protect water and soil quality, but also help promote a new standard for timber operations in southwest Virginia and northeast Tennessee.

Not every area requires roads, of course. Areas closed to motorized vehicles and timber harvesting may not need road access. Consideration will also be given to the potential adverse effects of roads on wildlife. But any place where people can bring vehicles, whether for recreation or for logging, requires well-designed roads.

Recreational roads are typically permanent additions to the landscape, and are particularly important for creating access for visitors who may not otherwise be able to enjoy the beauty and serenity of our forests. Logging roads, in contrast, are often temporary, built just before or during the timber harvest and closed as soon as harvesting ends. In some cases, though, these roads may remain open for recreation, fire fighting, pest control, or related management goals as appropriate.

Regardless of the road type, forest managers will always carefully design, build, and maintain roads to prevent erosion and protect the overall health of the forest.

9.2 Key Strategies

To create ecologically sound access, forest managers will:

- ❑ Know and follow the professionally accepted specifications for building landings, haul roads and skid roads.
- ❑ Build roads that are compatible with local soil and geologic stability.
- ❑ Design roads with sufficient drainage.
- ❑ Limit road use by heavy equipment when the soil is saturated.
- ❑ Choose equipment that causes the least soil disturbance.
- ❑ Adequately maintain roads.
- ❑ Close roads that are no longer needed.
- ❑ Monitor the effectiveness of erosion controls

9.3 Designing the Road System

Careful planning is essential for minimizing the environmental impact of any road system. A well-planned system should:

- ❑ require fewer miles of roads
- ❑ require less time to build
- ❑ lower construction costs
- ❑ increase hauling efficiency
- ❑ minimize damage to residual trees during harvest
- ❑ decrease the maintenance required
- ❑ maximize usability in bad weather
- ❑ look better, and thus enhance public image
- ❑ provide for future access
- ❑ result in better pollution and sediment control

To meet these goals, forest managers will plan roads that fit the terrain and take into account property boundaries, timber concentrations, stream locations, water and soil quality concerns, equipment needs, and future harvests. This planning process involves three major steps:

1. **FIELD RECONNAISSANCE.**

Before actually surveying the land to locate roads, forest managers will carefully inspect the area and examine the terrain to 1) locate potential landing sites, 2) identify factors that either limit or support road construction, 3) determine preliminary routes, and 4) identify the types of roads required. During this inspection, managers should mentally locate, and even lightly flag, proposed landings and roads to help design the most efficient, ecologically sound network.

Factors that **limit road building** include:

- ✓ property lines
- ✓ entry and exit points
- ✓ rights-of-ways
- ✓ special or unique habitats
- ✓ gas and power lines
- ✓ rock bluffs
- ✓ stream crossings
- ✓ ponds and lakes
- ✓ excessively steep terrain
- ✓ unstable soils

The forest manager will either avoid or adequately protect these areas when designing the road system.

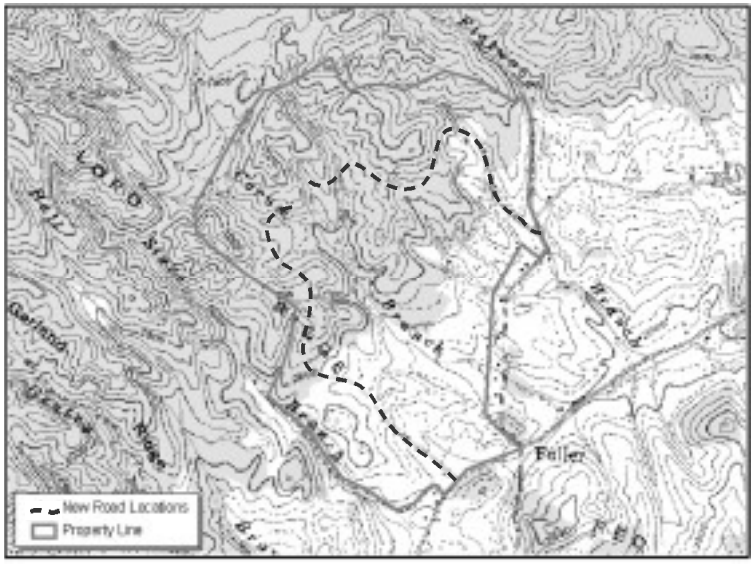
Factors that **support road building** include:

- ✓ reasonable side slopes
- ✓ desirable stream crossings
- ✓ saddles and areas suitable for switchback construction

Such features will become "control points" that the preliminary route will pass through.

2. DESIGN DRAINAGE METHODS.

No matter how carefully foresters design a road, without adequate drainage it will not remain serviceable for long. Good drainage helps rapidly dispose of surface water without scouring or puddling, and virtually eliminates erosion and sedimentation. The most common drainage structures for forest roads are water turnouts, water bars, broad based dips, culverts, low water bridges and simple span bridges.



3. **LOCATE ROADS on the GROUND.**

To correctly account for grade, obstacles, and other considerations, forest managers will always locate roads on the ground before construction begins. Foresters or road surveyors will walk the entire length of proposed roads and flag the potential mid-line, as well as proposed drainage locations. This process may require several trial runs to get a satisfactory grade; often the job is easiest when the leaves are off the trees.

In some cases, this on-the-ground work requires preliminary planning on paper; the larger the size and quantity of timber harvested, the better the roads must be, and the more expertise and time required. When planning large, permanent road systems for heavy use, forest managers may first need to design the route on topographical maps in the office. The map should mark proposed roads and landings, drainage or water control structures, bridges, culverts and dips, outslopes or inslopes of roads, grade breaks, and critical areas to be graveled. Shorter, temporary, less critical road systems on easy terrain often do not require this preliminary step.

Section 9.4 provides detailed specifications for landings, roads, stream crossings, and drainage systems on managed lands. For additional information on road building, consult T.A. Walbridges' publications and Virginia's Department of Forestry's Best Management Practices guidelines.

9.4 Design Specifications

A forest road system typically includes:

- **Landings**, where forest products are collected for loading and shipping
- **Main haul roads** that lead from the landings to the tract's public road access to allow foresters, loggers, and other workers, along with their equipment, to access the area and move logs and other forest products to market
- **Skid trails** through the forest that allow loggers to move logs from the felling point to the landings

In addition, a well-designed road system includes clear specifications for stream crossings and effective drainage control measures. The following sections layout guidelines in each of these areas.

LANDINGS

Landings (also called decks) are areas where logs are gathered, processed, sorted and loaded prior to shipping. Because they serve as central hubs for the road system, these areas should be located first; location and size depend upon:

- ✓ Size of the harvest (area and total timber production)
- ✓ Size of the logging operation (number and size of skidders, loaders, and log trucks using the landing at any one time)
- ✓ Skills and abilities of equipment operators, particularly in small areas
- ✓ Available area and terrain suitable for landings
- ✓ Tract access to public roads

Because they experience consistent, heavy traffic, landings are subject to severe compaction and its associated run-off problems. The landing design, and preharvest plan, harvest monitoring plan, and the closing must all address this issue to minimize damage.

Specifications:

- ❑ Locate landing sites before designing and building roads.
- ❑ Locate landings at least 75 feet from any Riparian Management Zone.
- ❑ Locate landings on well-drained soils, which dry out quickly, or on dry places like ridgetops or small flats.
- ❑ Construct landings with a 2-5% slope for drainage.
- ❑ Construct a diversion ditch around the uphill side to intercept flowing surface water and direct it away from the deck.
- ❑ Make landings large enough so that loggers do not need to pile waste wood within any adjacent Riparian Management Zones.
- ❑ When landings border Riparian Management Zones, include precautions such as haybale barriers or silt fences to keep runoff out of stream channels.

ROADS

A timber harvest generally involves two types of roads, as noted earlier: haul roads, which run from public roads to landings, and skid roads that run from the landing through the harvest area.

When choosing among various classes of truck roads and skid roads, forest managers must consider:

- ✓ road purposes (all-weather for intensive management or secondary access for harvesting)
- ✓ expected traffic speed and volume
- ✓ vehicle and load size
- ✓ access privileges (private and locked or open to the public)
- ✓ tract size
- ✓ economics (i.e. is the cost of the road standard chosen justified)

Balancing these factors involves both engineering and management decisions; forest managers should always choose road classes first, before beginning preliminary surveys or design. In general:

- ❑ Tracts under intensive management and over 100 acres in size should have a well-built, permanent truck road for primary access.
- ❑ Tracts under intensive management and under 100 acres should have a lower class truck road for primary access.
- ❑ Further subdivisions throughout the management area should then use roads of the same or the next lower standard.

See *Walbridge* (1991) for more detail on road standards recommended for various uses.

Haul Roads

Most importantly, whether haul roads are permanent or temporary, they must support the size and weight of loaded log trucks (often tractor-trailers).

Specifications:

- ❑ Locate major haul roads on sunny south and west slopes whenever possible because these dry more quickly than shady north and east slopes.
- ❑ Locate haul roads on side slopes and avoid level ridgetops and flood plains where good drainage is difficult to establish.
- ❑ Design haul roads to follow the contour of the land as much as possible, with 2-10% grades. Use steeper gradients (exceeding 15%) only for distances less than 200 feet.
- ❑ Change grade frequently to minimize erosion problems; water is difficult to control on long, steep, straight, continuous grades because options for drainage structures are limited.
- ❑ Minimize cuts and fills as much as possible during design and construction.
- ❑ Properly stabilize slopes exposed by road construction to prevent erosion and runoff. If necessary for stability and successful revegetation, backslope tall cut slopes to a 3:1 slope.
- ❑ At the entrance to state and county roads, use gravel, wooden mats, geotextile fabrics, or other measures to keep trucks from tracking mud onto the hardtop or state road.
- ❑ Make roads wide enough to accommodate the expected traffic safely.
- ❑ Construct drainage structures sufficient to move surface water off of the road bed, especially on steep grades.
- ❑ Locate and construct stream crossings properly.
- ❑ Cut trees back along the road to allow full sunlight on its surface and ensure better drying conditions after wet weather.
- ❑ Prohibit skidding on haul roads.

Skid Trails

Skidding is simply the process of dragging logs through the woods from the felling point (where they are cut down) to the landing. Harvest operations require skid trails when the terrain is too steep for dispersed skidding, in which equipment operators may drive skidders freely across the harvest area so that they do not use the same trail more than once.

Because dispersed skidding leaves a more complete root mat and organic layer on the forest floor after the harvest, and thus creates more favorable revegetation conditions, forest managers will use this method whenever possible. If dispersed skidding is not possible, forest managers should consider alternate methods to limit the amount of mineral soil exposed such as requiring extra cable lengths on skidders or the use of cable yarding systems.

Skid trails, like other roads, pose potential erosion and compaction problems, though secondary trails that branch off the main route typically experience lower use and thus less compaction. To minimize damage, forest managers must plan these trails carefully, in light of the specifications below and the considerations outlined in *Chapter 2: Protecting Water Quality* and *Chapter 5: Protecting Soil Quality*

Specifications:

❑ Keep skid trail gradients below 15% except for short, steeper segments needed to avoid boundary lines, sensitive areas, or other areas not accessible using skid roads of lesser grades. (Dispersed skidding, which limits mineral soil exposure, may use steeper grades.)

❑ If a trail does require steeper grades, sufficient drainage measures must be installed along the trail to keep concentrated water flow from reaching streams.

❑ Approach the landing at the lowest grade possible to minimize water flow into a landing.

❑ Space skid trails as far apart as practical. Typically, a skidder cable can reach 150-200 feet, but skid trails spaced approximately 200 feet apart on a hillside are reasonable (trees are felled towards the closest trail).

❑ Climb upslope on a slant or zigzag pattern to break the grade whenever possible.

❑ Use fender logs or high stumps on the edge of skid roads on steep slopes, at turns, and on switchbacks to prevent logs from rolling off the skid road (causing more side casting of earth) and to protect adjacent standing timber.

❑ Construct drainage structures sufficient to move surface water off of the road bed, especially on steep grades.

❑ Minimize the number of skid trails by instructing skidder operators to winch logs to a trail instead of driving the machine to each individual stump.

❑ Locate and construct stream crossings properly. Do not skid logs through intermittent or perennial streams. If a skid trail must cross a perennial or intermittent stream, or a drainage ditch that leads to natural drainage, use an appropriately selected and installed structure.

STREAM CROSSINGS

Poorly planned or constructed stream crossings can adversely affect water quality by exposing soil at or near a stream channel. By properly locating and constructing these crossings, forest managers can prevent erosion and sedimentation problems both during the harvest and afterwards.

General Specifications:

❑ Avoid stream crossings whenever possible through careful planning.

❑ Cross streams at right angles whenever possible.

❑ Install culverts or small bridges at flowing streams and seeps (springs).

❑ Construct proper drainage for roads leading to stream crossings to avoid dumping water into the stream.

❑ Do not skid logs through flowing streams or down dry creek beds.

❑ Equipment crossing the stream should have no leaks of hydraulic oil, engine oil, or fuel.

❑ Do not allow drainage structures to impede fish, amphibian, crayfish, or other aquatic organism's passage or stream flow.

Stream crossings may be culverts, bridges, or fords, as described in the following sections.

Culverts

Culverts are the most common stream crossing, and are typically placed in all perennial and intermittent drainages. Although most culverts are temporary, we may design and install permanent culvert crossings. Importantly, though, temporary culverts must be removed after the harvest or they pose significant water quality problems.

Culvert size depends on purpose, duration required, and size of the watershed being drained. The Virginia's Technical Guide for Best Management Practices provides complete information on selecting the appropriate culvert size, along with installation specifications.

Bridges

Bridges are preferable for many jobs because their installation does not require in-stream work and they have less impact on fisheries than other methods. In addition, portable, temporary bridges typically require less time to install and can be used many times, making them more cost-effective than culverts.

Specifications for temporary bridges:

- ❑ The stream at the crossing should be straight and unobstructed, with uniform, stable banks.
- ❑ As with culverts, keep the approaches stable and at a right angle.
- ❑ Keep approaches straight to limit safety hazards and prevent logs, soil, and other debris from being deposited into stream by logs sliding over the edge of the bridge.
- ❑ Stabilize approaches with rock extending at least 50 feet from both sides of the stream edge if necessary, and underline the rock with geotextile cloth.
- ❑ As with temporary culverts, remove temporary bridges when logging is complete.
- ❑ After logging, stabilize approaches and stream edges with vegetation as needed to keep soil out of the stream.
- ❑ If the bridge is open for public use, have the design done or approved by a qualified civil or structural engineer.

For more detail, consult *Walbridge* (1991).

Fords

Although natural rock fords are acceptable, they are the least desirable stream crossing because they create continued stream disturbance.

Specifications:

- ❑ The streambed must have a firm natural rock base.
- ❑ Use fords only for temporary, low-traffic crossings.
- ❑ Water depth should be no more than 1 foot.
- ❑ Make crossing at right angles to the stream.
- ❑ Locate fords at low stream banks with stable approaches.
- ❑ Where necessary to avoid delivering sediment to the stream, stabilize approaches with rock a minimum of 50 feet from the water's edge on both sides of the stream. Underline rock approaches with geotextile fabric.

DRAINAGE

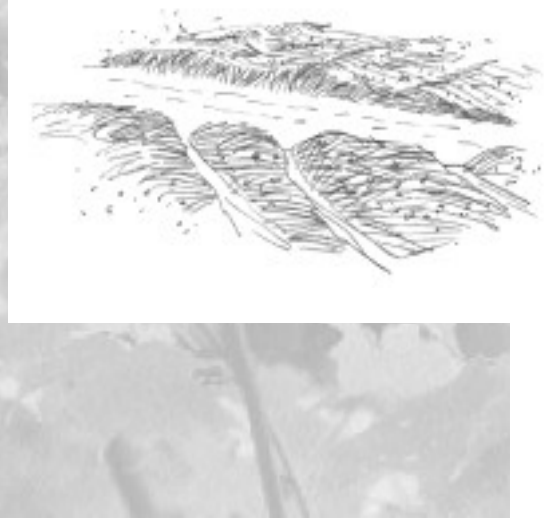
As noted earlier, good drainage is crucial to protecting soil and water quality in any forest road system. The following sections provide guidelines and specifications for the major drainage structures used by the Conservation Forestry Program.

Water kickoffs/turnouts:

Water kickoffs or turnouts remove water from road ditches. Because they are less expensive than culverts, but often equally effective, they will be used wherever possible.

Construction: Create water turnouts during the final stages of ditch construction. As the grader or bulldozer is finishing the ditch, operators should watch for an opportunity to lead the ditch away from the road into the woods and form a water-kickoff.

Operators must grade the kick-off to allow constant drainage and prevent excess soil from damming its end.



Water bars

When branch roads or spurs and skid trails have served their purpose, they are usually "put to bed," or closed. Building water bars on these roads at specific intervals reduces erosion and sedimentation. In addition, sowing these water bars can improve soil stabilization and create wildlife food plots.

Construction: Use a bulldozer to dig a trough about 2 feet deep and 4 feet wide at about a 30 degree angle across the road or skid trail. Pile the excavated dirt on the down hill side of the water bar for drainage.

The spacing depends on the road/trail gradient, as shown in *Table 9-1*.

Broad Based Dips

Another alternative to culverts are broad based dips.

Construction: Use bulldozers to dig a section of increased road gradient followed by a section of reverse gradient that brings the structure back to the original road subgrade. To create a water catchment and drainage channel, carefully outslope the bottom of the dip to about 3%, and line it with 2-3" of crushed stone.

Dip spacing depends on the gradient of the road, based on the formula:
Spacing = (400/Slope %) + 100 feet

Culverts

Culverts are the most commonly used drainage structures in forest roads. Ditch relief culverts move water under the road before the flow in the ditch gains sufficient volume or head to cause erosion.

Practically, culverts on forest roads should be at least 15 inches in diameter; if the situation requires a culvert larger than 48 inches, consider using multiple culverts instead. Space culverts using the guidelines for water bars (Table 9-1). On the down-slope end of a culvert, particularly when it projects out-slope well above the ground, place rocks to disperse the energy flow of water drainage to prevent erosion of the slope.

Manufactured Culverts: Use fabricated culverts for drainage on primary and secondary roads.

For more information on culvert selection, sizing, and installation, see *Walbridge* (1991).

Road Gradient	Spacing in Feet
2	250
5	135
10	80
15	60
20	45
25	40
30	35
40	30

TABLE 9-1. Suggested spacing of **Water Bars** for various gradients.

9.5 Constructing and Maintaining The Forest Road System

CONSTRUCTION GUIDELINES

To insure proper road construction, forest managers will:

- ❑ Meet with road building contractors on site **befor**e the contractors begin work to walk the proposed road locations and make sure the specifications are clear.
- ❑ Check the job daily once construction begins to monitor progress, catch mistakes or problems early, and help reroute roads that cannot be built as planned due to unexpected rock or other situations.

Maintenance Guidelines

To make sure forest roads are maintained properly, forest managers will:

- ❑ Control access by using a locked gate to prevent unauthorized use and unnecessary damage to the roads.
- ❑ Inspect roads at regular intervals to detect and correct maintenance problems, especially during rains when erosion and runoff may be problems.
- ❑ Keep drainage systems open at all times during logging operations by cleaning out culverts, dips, and ditches as needed to control water flow on the road surface.
- ❑ Regrade periodically to remove ruts and fill holes. Skidder ruts can cause water quality problems if they channel water into a stream; and severe ruts can also cause equipment malfunction and increased downtime.
- ❑ Restrict traffic during weather that makes the road unstable or highly susceptible to rutting and washing.
- ❑ Avoid using ditches on steep roads, and when necessary, line ditches with rock to prevent gullying and sedimentation.

9.6 Retiring Logging Roads and Landings

To promote *effective revegetation* and minimize erosion, forest managers will retire, or close, each logging road as soon as it is no longer needed to remove timber (i.e. rather than waiting until the entire job ends), and retire landings and other disturbed sites as soon as possible after the job ends, according to the following guidelines.

Retiring Landings:

- ❑ Smooth and grade for drainage, utility and appearance.
- ❑ Test the *soil* to determine the need for amendments for pH and nutrients.
- ❑ Plant a non-invasive cover crop on all exposed soil using lime, fertilizer, mulch and seed as needed; if soil compaction is severe, tractor disc the landing before planting. Preference will be given to using native seed mixes whenever possible.

Retiring Haul and Skid roads:

- ❑ Smooth and grade for drainage and utility.
- ❑ Clean permanent ditches and culverts.
- ❑ Pull out temporary culverts and bridges and regrade cross-ditches; make sure natural drainages are flowing across, not down, the road.
- ❑ At a minimum, seed steep roads and banks, especially near streams
- ❑ At state road access points, gate and sign the road entrances or use deep trenches to prevent public vehicle access if appropriate.
- ❑ On roads closed to vehicle use, install water bars or water-breaks at recommended intervals for proper drainage. Be sure the water bars span the entire road and the outlet ends are open.
- ❑ On gentle slopes, remove raised shoulders and outslope instead of installing water bars.
- ❑ Use rocks, brush, and logging debris as water retardants on skid trails where available.

Steve Linderman

Revegetating Bare Areas

❑ Use vegetation to stabilize areas with exposed soil that can erode into adjacent streams.

❑ Use vegetation to stabilize soil on areas exceeding 5% slope or on highly erodible soils.

❑ Stabilize bare areas immediately following harvest using the following recommendations:

✓ Prior to seeding, install all necessary water control structures such as water bars, broad based dips and turn outs.

✓ Select a seed mix appropriate for your conditions and the landowner's objectives for future use. See VDOF (1997) for seeding mixtures and guidelines for revegetation of critical areas. Use non-invasive native species where possible.

✓ Plan early! Most of the species recommended by VDOF are available through Virginia farm stores, but they must be ordered and take a week or two to come in.

✓ Seed immediately following harvest using the seasonal seed variety mixes and application rates given in VDOF (1997).

✓ Apply lime and fertilizer to an area according to guidelines recommended by a soil test.

✓ To control erosion, seeds must be able to germinate and grow, which in turn requires adequate seed bed preparation. To ensure good contact between seed and soil, disk, subsoil, or drag brush or a chain across the area first as needed.

✓ Broadcast seed using a broadcast seeder, drill or hydro seeder. Most seed varieties will successfully germinate when planted 1/8 to 1/4" below the surface.

✓ When broadcasting in dry summer months and fall, apply mulch to help germination and growth. Straw or hay mulch is effective and inexpensive, and rotten straw bales that the landowner cannot use for livestock are perfect sources.

Stabilizing Other Critical Areas

Severely disturbed or highly sensitive areas may require additional soil stabilization measures. Critical areas include eroding skid trails leading directly to streams, areas where culverts were removed or disturbed, or areas impacted by severe storms or floods. Always mulch critical areas at rates of 2 to 4 tons per acre. If planting occurs in mid-winter, consider mulch alone until the spring seeding period occurs.

Prepare the site as described under *Revegetating Bare Areas*; to foster growth, increase the seeding rate and include some of the fast-germinating grains and grasses as recommended for critical areas by the VDOF (1997).

9.7 Related Practices

Road design and construction is only one piece of the harvest operation. Adequately controlling erosion and preserving water quality involves applying all of the strategies listed in:

- *Chapter 2:* Protecting Water Quality and
- *Chapter 5:* Protecting Soil Quality.

In ADDITION, the guidelines outlined in this chapter work together with:

- Developing Management Plans (*see Chapter 7*)
- Timber Harvesting and Marketing (*see Chapter 10*)