

Forest Road Design

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Introduction

A well planned, designed, constructed, and maintained system of forest roads is essential to facilitate forest management and protection of natural resources. Road design is the process of determining the “what, where, when, and how” for a new road construction, road improvement, or extra-ordinary road maintenance project. It begins after careful planning has determined that the project is necessary.

The designer of a project will consider the following factors:

- The purpose and intended use of the project. Included in this factor are length of use (temporary or permanent), amount and timing of use, and type of use (commercial, recreational, or administrative).
- The physical conditions affecting the project. Included in this factor are soils, topography, high landslide hazard locations, streams, wetlands, bedrock, weather, etc.
- Environmental conditions affecting the project. Included in this factor are fish bearing streams, threatened and endangered species, environmentally sensitive sites, scenic values, recreational use, etc.
- Benefits, costs, and risks associated with the project. Included in this factor is the consideration of alternative designs and locations for the project. The design will strive for maximizing benefits and minimizing costs and risks.

Goals of Road Design

1. Design roads that meet access needs.
2. Design roads to meet or exceed all Forest Practices Act road design rules to minimize environmental impacts on natural resources.
3. Design roads that are economical to construct and maintain.

Objectives of Road Design

1. Facilitate building roads in the best locations to meet forest management needs and minimize impacts to natural resources.
2. Ensure that the proper standard of road is constructed to facilitate the projected use without overbuilding or excessive cost.
3. Provide drainage that removes water from the road prism before it can cause problems and that will:
 - Allow the use of roads during the seasons of desired use.
 - Minimize the impact on water quality and aquatic habitat that is caused by roads.
 - Maintain the stability of forest slopes that are impacted by roads.
 - Minimize the disruptions to natural drainage patterns.
 - Reduce the amount and cost of road maintenance.
 - Minimize the impacts if drainage failures occur.

4. Provide project direction that will aid efficient, economical construction of the project.
5. Provide road designs that contain accurate information to facilitate:
 - Clear communication of specifications and expectations for road projects. The written specifications should help project administrators and contractors construct projects as designed.
 - Accurate, fair cost estimates for construction projects, which will support doing the project as planned.

Road Design Strategies

Road design strategies are the specific actions and standards that will lead to achieving the goals and objectives of this section of the manual.

Engineering Procedures

The engineering procedures listed in this section are the minimum standards of engineering design work that will be utilized when designing road projects. The road designer should go beyond the minimum engineering procedures when circumstances dictate.

Generally, the engineering procedures that are utilized are dependent upon two factors. The first is the level of risk to natural resources posed by the road. The higher the chance that serious damage could occur to a natural resource as a result of the road project, the higher the level of engineering procedures that should be used to design the project. The second is the grade and alignment of the road. Steeper grades and more difficult alignments require higher levels of engineering procedures.

The road designer should visualize the desired finished road and determine what engineering procedures are needed to be sure that the project can and will be completed as desired. Unneeded engineering procedures waste time and energy in designing projects and may require wasteful construction practices. Likewise, not using adequate engineering procedures can result in the project not meeting objectives and damaging natural resources.

The road designer must be familiar with and understand the relationship between engineering procedures (this section) and road design standards (the following section). Engineering procedures and road design standards are not interchangeable. For example, to design a spur may require upper level engineering procedures if a portion of the road crosses a high landslide hazard location.

Base Level Engineering Procedures

Base level engineering procedures are applicable when all of the following criteria are met:

- Spur roads, usually less than ¼ mile in length, often temporary use.
- Gentle road grades that are less than 10%.
- Gentle side slopes of less than 35%, or ridgetop roads.
- High landslide hazard locations or other Natural Resource concerns are not involved.

Base level engineering procedures include:

- Reconnaissance.
- Flag or stake centerline.
- Reference beginning and ending points and other control points as needed.

Mid-Level Engineering Procedures

Mid-level engineering procedures are applicable when one or more the following criteria are met:

- Spur roads longer than ¼ mile, usually permanent.
- A portion of the road has grades that exceed 10% but are less than 17%.
- A portion of the road is located on slopes greater than 35% but less than 60% and high landslide hazard locations or deep seated landslides are not involved.

Mid-level engineering procedures will be applied to any portion of the road meeting the above criteria. Mid-level engineering procedures include:

- Reconnaissance of P-line(s) and topography.
- Run grade line.
- Field design final centerline location.
- Mark centerline with paint on stumps and hang flagging
- May be slope-staked, but generally reference tags are adequate (see section on “Referencing Centerline”)

Upper Level Engineering Procedures

Upper level engineering procedures are used when one or more of the following criteria are met:

- Mainline roads.
- Portions of the road:
 - a) Are located on slopes over 60%, or
 - b) Cross a high landslide hazard location, or
 - c) Cross a sharp “V” draw, or
 - d) Cross a sharp ridge and horizontal and/or vertical curves are a concern, or
 - e) Have sections of “through cut” or fills where the fill or cut heights exceed 10 feet, or
 - f) Cross fish bearing streams, or
 - g) Have long stretches of continuous road grades greater than 16%, or
 - h) Require end hauling, or
 - i) Require critical alignment, or
 - j) Cross through or are adjacent to environmentally sensitive sites.

Upper level engineering procedures will be applied to roads or portions of roads meeting the above criteria. Upper level engineering procedures include:

- Reconnaissance.
- P-Line.
- Grade Line.
- Plan.
- Profile.
- Office-locate L-line.
- Cross-section.
- Slope stake or reference L-line. (See section on “Referencing Centerline Location”)

Where a planned road has segments that meet the criteria for upper level engineering procedures and the remainder of the road meets the criteria for base or mid level engineering procedures, a combination of procedures may be used. For example, a permanent spur road has moderate grades and is located on moderate slopes. However, it crosses a fish-bearing stream. The stream crossing will be designed using upper level engineering procedures, while the remainder of the road can be designed using mid-level engineering procedures.

Road Design Standards

Roads on state-owned forest land will be designed to meet the planned use of the road. The design will limit the alteration of natural slopes and drainage patterns to that which will safely accommodate the anticipated use of the road, protect water quality and aquatic habitat, and maintain site productivity. The standard of road will be consistent with good safety practices, while keeping construction and maintenance costs to a minimum.

When determining the road design standard, the following factors will be evaluated:

- The volume of traffic that will use the road at any given period of time and that will be expected to use the road over its duration.
- The type of vehicles that will use the road.
- The topography and soils where the road will be located.
- Duration of use (permanent, temporary, seasonal, or year around).
- Public use(s) of the road.
- Sensitive natural resources that may be affected by the road.
- Future road maintenance requirements.

Design Standards for Spurs

Description: These are generally roads that are used for a short term, intermittently and/or have a low traffic volume. Use may be heavy during periods of log hauling but minimal at other times.

Design standards:

Subgrade	12 to 16 feet wide, may have a 2 foot ditch
Running Surface	12 feet wide
Drainage	out-sloped, in-sloped, or crowned with ditch, dips, waterbars, may have temporary stream crossings (removed after road use is completed)
Surfacing	optional (consider pit or jaw run)
Minimum curve radius	50 feet plus curve widening
*Grade limitations	up to 35%, roads over 20% will be closed after use

Design Standards for Collectors

Description: These are permanent roads that access multiple logging units and may receive moderate use by the public during portions of the year.

Design Standards:

Subgrade	16 to 20 feet wide including a 2 to 3 foot ditch
Running Surface	12-16 feet wide
Drainage	Normally crowned with ditch, relief culverts, and stream crossings.
Surfacing	Crushed rock
Minimum curve radius	60 feet plus curve widening
*Grade limitations	up to 20%, usually under 18%

Design Standards for Mainlines

Description: These are permanent roads with high traffic volumes, higher speeds, movement of heavy equipment and/or a high level of public use during portions of the year. They are useable by a lowboy truck, which is a key design vehicle. They may have high public and recreational usage during parts of the year.

Design Standards:

Subgrade	20 to 24 feet wide including 2 to 3 foot ditch
Running Surface	16-20 feet wide
Drainage	Crowned, with ditches, relief culverts, and stream crossings including bridges
Surfacing	pit run, jaw run or crushed rock for base and crushed rock for driving surface
Minimum curve radius	70 feet plus curve widening
*Grade limitations	up to 14%

**Grades over 20% require assist vehicles (OAR 437-80-065). Rock surfaced grades over 16% require special surfacing design to alleviate traction problems (consult geotechnical specialist or staff engineer).*

Road Design Criteria

A number of criteria must be considered in designing roads. These are discussed in the following paragraphs.

Coordinated Planning and Location of Roads

Forest management operations planning and planning for forest transportation are dependent on each other. These two plans must be coordinated to provide for an efficient and effective overall plan. Professional foresters, roads specialists and engineers with knowledge, skills and abilities in the access requirements for forest management operations and the design, construction, and maintenance of forest roads make these important decisions. Management activities will be planned to take advantage of existing road systems when appropriate. Environmental and economical evaluations of both planned management operations and planned road construction/improvement will be performed to achieve the optimum design combination for the two activities. Careful planning and location of roads will ensure that roads are located where potential impacts to natural resources such as water quality and aquatic habitat are minimized. The areas served by each road will be maximized where possible; thus minimizing the amount of road needed to meet management objectives.

Reconnaissance

Reconnaissance involves reviewing the area and then identifying and evaluating the best locations for roads, landings and logging settings. Aerial photos, maps, and local knowledge as well as walking the ground are used to determine the best locations for the road. This is the time to identify potential control points such as landing locations, ridgetops, stream crossings, benches and other locations that may be desirable locations for the road. Location/reconnaissance will include a route assessment of alternatives and ending location(s). Sensitive natural resources on or near these routes will be identified. These include all streams (with special recognition for Type F(ish) and Type D(omestic), wetlands, slopes over 50 percent (especially high landslide hazard locations), and wildlife sites. To avoid these resource areas, the road location will use grade and alignment changes up to the upper limits as defined in the road design standards. Where the sensitive natural resources cannot be avoided, minimize the length of road in these areas and direct the road away from them as quickly as possible. In addition, when it is necessary to cross these areas, the appropriate technical specialist(s) will be consulted (geotechnical specialist, wildlife/fish biologist, hydrologist, staff forest engineer, etc.).

Road Location

Road locations should minimize the risk of materials entering waters of the state and minimize disturbance to stream channels, lakes, wetlands and floodplains. Where viable alternatives exist, avoid locating roads on steep slopes, slide areas, or high landslide hazard locations, and in wetlands, riparian management areas, channels or floodplains. When possible, avoid locating roads parallel to and in close proximity to streams because they have a higher than normal potential to deliver sediments directly into the channel. Roads that are close to and parallel streams also displace part of the riparian management area. Stream crossings will be as close as possible to a right angle in order to enter and

exit the stream zone and the adjacent riparian management area as quickly as possible. Use variable grades and alignments to locate roads on the most suitable terrain.

Alternative road locations will be considered where natural resources are impacted. Locations will be favored that provide the best combination of meeting objectives and minimizing economic and environmental costs.

Make use of good, existing roads to reduce the duplication of road systems and associated ground disturbance. Where roads are present on an adjacent ownership and the roads will adequately serve the planned forest management operation, investigate options for using those roads before constructing new roads.

Road Prism Design

Roads will be no wider than necessary to accommodate the anticipated use. See the ranges listed in the road design standards.

Roads will be designed to be constructed with a balanced cut and fill cross section where possible and where this does not pose a risk of slope instability. Where a balanced cross section is not used, excess excavation material should be used in the road design, when possible, and not wasted. Designs will call for full bench construction and end-hauling of excess excavation material when roads are located on steep slopes, high landslide hazard locations and deep seated landslides

To prevent fill failures, road designs will provide for stable fills by using compaction, buttressing, subsurface drainage, rock facing or other effective means.

Road Drainage

Good road drainage is one of the most important features designed into a road. The prompt removal of water from the road prism will help avoid many problems related to road construction and maintenance. Water is a critical factor affecting:

- Subgrade load bearing capacity (poor subgrade strength results in potential rutting caused by traffic)
- Slope stability
- Stream sedimentation

It is inevitable that roads will intercept, interrupt and interact with natural water flow patterns. The management of this interaction between roads and water is critical to a successful road system. Establishing proper drainage of water from roads and passage of water through roads is one of the most important techniques to minimize adverse impacts on water quality and aquatic habitat.

Surface Drainage

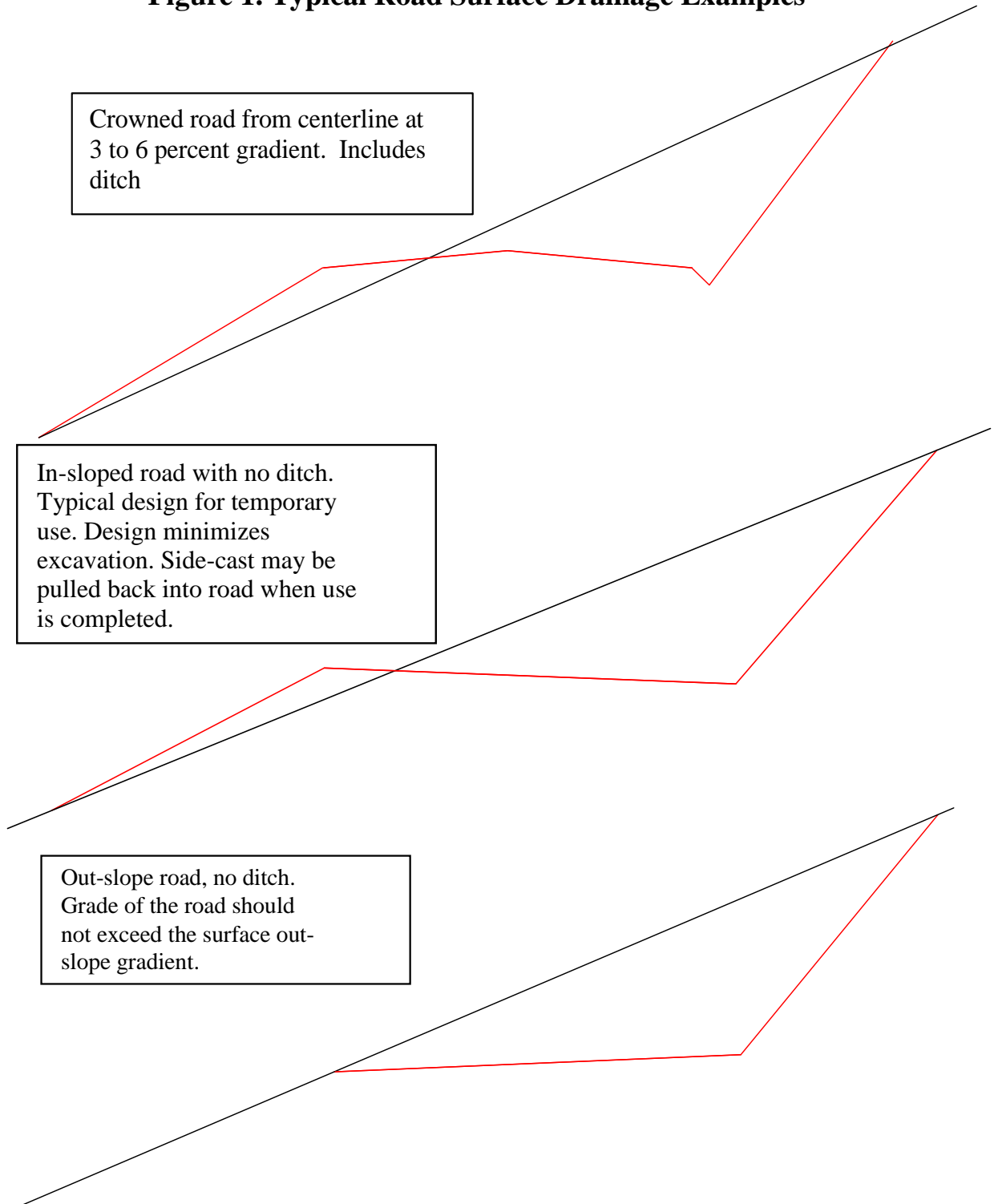
Good road surface drainage is important for keeping siltation to a minimum and to keep subgrades firm and stable to support the designed loads. Water intercepted by roads will be returned to natural flow processes as quickly as practical. Methods of achieving this are listed below.

1. **Subgrade shapes.** The running surface and subgrade must be shaped to move water off the road. Road surfaces will be crowned, in-sloped, or out-sloped for drainage. A “crowned road surface” is often preferred since it provides the shortest distance for

water to travel off the road (from centerline to either road edge). Out-sloped roads can save on excavation and material costs since there is no ditch or cross drain. Outsloping will generally be limited to roads with grades less than 8 percent unless they are temporary and will be closed or vacated after use. Water bars and water dips can also be used on temporary roads and spurs in lieu of a ditch. See "Figure 1. Typical Road Surface Drainage Examples" in this section.

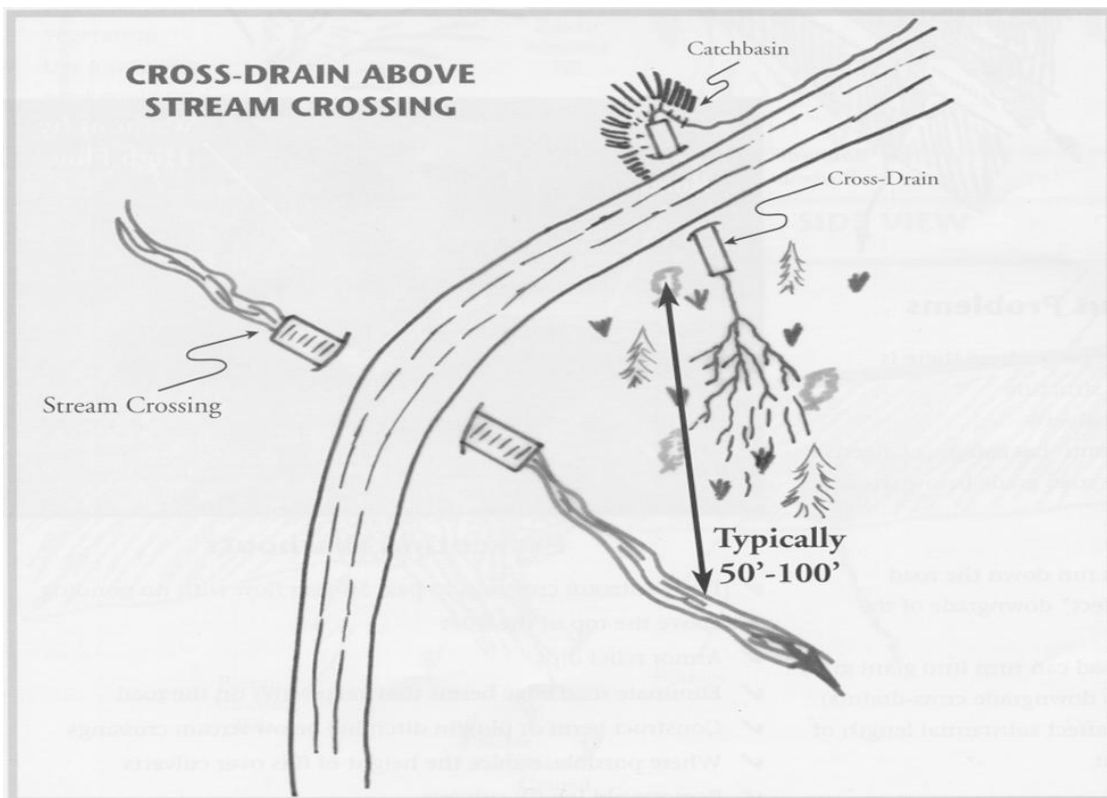
2. **Road Grades.** Road grades will be kept between 2% and 18% whenever possible. Flat grades will be avoided where possible; a minimum of 2% road grade will be favored to help to drain water out of the road prism. Steep grades above 15% should also be avoided. When steep grades are used, closer scrutiny of drainage for proper spacing of culverts, water bars, water dips, road grade reversals, and road surface maintenance is required.

Figure 1. Typical Road Surface Drainage Examples



3. **Drainage Structures.** A properly designed road will provide a drainage system using grade reversals, ditches, culverts, dips and/or water bars as necessary to effectively control and disperse surface water to minimize erosion of the road. Water will not be diverted from normal channels except as necessary to construct stream crossings. Drainage will be provided when roads cross or expose springs, seeps, or wet areas. Road drainage water should not be dispersed into headwalls, slide areas, or high landslide hazard locations.

Dips, water bars, or cross-drainage culverts should be located above and away from stream crossings so that road drainage water may be filtered before entering streams. Wherever possible, locate relief drainage 50 to 100 feet above stream crossings to eliminate the direct connection between road water and streams. The ditch-disconnect structure should be located in an area that will have at least 50 feet of filter distance to the stream.



Ditch relief culverts will be placed at appropriate distances and locations along roads to prevent large accumulations of water running down ditchlines and to prevent direct discharge of ditch water into streams. See "Table 1. Guide Table for Water Bar and Relief Culvert Spacing".

Table 1. Guide Table for Water Bar and Relief Culvert Spacing

Recommended Maximum Spacing in Feet of Lateral Drainage

ROAD GRADE in %	SOIL EROSION RATING*		
	High	Normal	Low
0-4%	800	1000	1500
5-9%	500	800	1000
10-14%	300	400	500
15-19%	200	300	400
over 19%	150	200	300

**High = Cohesionless fine-grained soil*

Normal = Sandy loam

Low = Rocky /gravelly soil

The table above will be used as a guide. The road designer should also examine other roads in the immediate area to find out how well ditches and existing culvert spacing are performing. If necessary, the spacing should be adjusted to fit the local conditions.

The smallest culvert used will be 18 inches in diameter. Culverts smaller than 18” plug easily and present maintenance problems. Smaller diameter culverts will only be used in temporary applications where the culvert will be removed at the end of the use of the road.

Culverts will be located away from high landslide hazard locations and deep seated landslides whenever possible, in order to disperse water on to stable locations (noses or ridges). When this is not possible, the geotechnical specialist will be consulted.

4. **Running surface.** The running surface of the road will be designed for the anticipated use. Rock surfacing can provide two important functions. First, a Layer of rock surfacing will help to spread vehicle tire loads over a larger area of the subgrade to help prevent rutting and subgrade failure. Secondly, a compacted layer of rock helps to seal the running surface, thus serving to move water away from the subgrade. Roads that will be open and used for hauling during wet weather will have rocked surfacing that will provide subgrade reinforcement and resist the erosive effects of water. Surfacing design is **found in Appendix 8** of this manual. There are a number of factors identified below that will influence the decision to use surfacing.

Advantages of rocking a road:

- Allows use of the road during wet periods
- Increases road subgrade strength, thus reducing the chance of wheel rutting during use.
- Provides a more stable, erosion resistant surface to the road, thus improving overall road drainage
- Provides base material (instead of dirt) that a grader can shape into a stable and longer lasting subgrade profile
- Reduces the amount of sedimentation produced by the road
- Reduces road maintenance needed to keep road performing properly
- Improves traction during wet weather
- All season access may increase the value of the area accessed for both commercial and non-commercial purposes. For example: reducing down time for wet weather could enhance the efficiency of a logging operation or a road could provide access for recreation throughout the year.

Disadvantages of rocking a road

- Cost, by far this is the single biggest factor - surfacing expense will often double the total cost of the road.
- May increase the cost to decommission the road in the future

Table 2 will be used as an aid in deciding when a road should be rocked and when it should not be rocked.

Table 2. Guidelines for Rocking a Road

Factors "for" rocking the road

Factors for "not" rocking

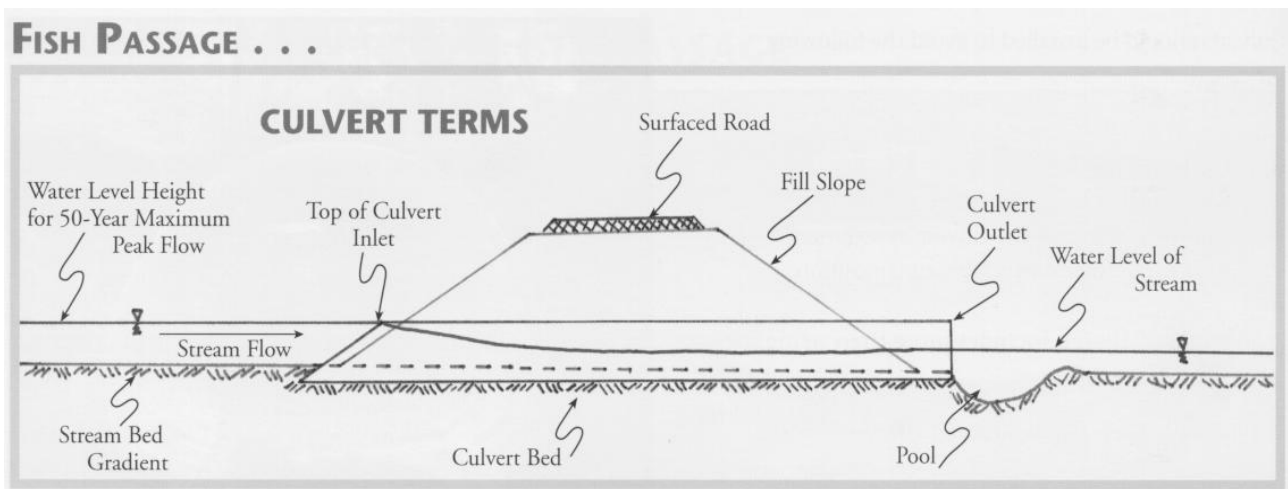
Road is in a coastal or valley climate	Road is in a dry climate such as Eastern or Southwest Oregon
Soil type is weak and poor draining, prone to erosion	Well drained gravelly soil
Grade of road is steep, any water will have potential to run down the road and erode the surface	Gentle road grade, less than 8%
Road is close to a stream and could deliver sediments easily	Road is not near streams and there are filtering opportunities for runoff from the road prior to entering a stream
	Road is located on a ridge or high on the hill slope and there is little risk of damage from sedimentation.
The road use is permanent and access is needed throughout the year.	This is a one time or one season road use that could be timed to occur during dry periods of the year
It is not practical or possible to close the road during un-needed periods	The road can be vacated or closed after short-term use.
Heavy use is planned for the road; several million board feet of timber will be hauled over the road.	Only a small amount of timber hauling anticipated on the road, part of one sale for example.
	Operations requiring this road could be shut down during wet periods and access to other parts of timber sale could be operated on at that time.
Rock is readily available and relatively inexpensive.	Rock is scarce, must be hauled long distances and is expensive to apply.
High use recreation area that would make it difficult to keep traffic off road during wet seasons.	Road can easily and effectively be blocked until weather permits use.

5. **Special Drainage.** Special drainage may be needed for areas containing springs or areas that have slope stability problems that are caused by subsurface water. The geotechnical specialist should be consulted for advice and assistance to design drainage structures that will help alleviate problems in these areas.

Design of Stream Crossing Structures

Stream crossing structures must protect aquatic and riparian habitats and provide fish passage, as well as preserve the stability and use of the road. The following requirements must be considered when designing stream crossings:

1. Streams will be kept in their natural channel and not diverted to crossing structures.
2. The number of acres in the drainage above the stream crossing structure will be determined from orthophotos, maps, aerial photography, or other comparable methods. This information is needed to determine the appropriate size for a stream crossing structure.
3. As a minimum, all new stream crossing installations or replacements of existing crossings will be sized to pass stream flow levels as predicted by the 50-year storm return interval. Oregon **Forest Practices Technical Note # 4** guidance provides a culvert-sizing design method that can be used for minimum design standards of stream crossings on state-owned forest lands.
4. Include design features that will minimize damage in the event the structure becomes plugged and fails. In many cases this is more effective than simply designing larger structures for larger storm events. Designed safety features may include some or all of the following:
 - Lowered fill heights to minimize back-watering effects and dam break floods.
 - Dips in the road, downgrade from the stream crossing, that would divert water off the road and onto the best available locations.
 - Armored fills at stream crossing and/or dip locations.
 - Overflow culverts
5. Road crossings over fish-bearing streams will be designed to allow fish passage. The design of stream crossings will follow the guidance in **Forest Practices Technical Notes 4 and 5**.
6. All permanent bridges will be designed and approved by a licensed civil engineer.



Temporary Road Design by Purchasers of Timber Sale Contracts

At times the purchaser of Department timber sale contracts will request and/or the Department will require that the purchaser locate, design, and construct temporary roads to facilitate the logging of Department of Forestry timber sales. This approach enables the purchaser to match road and landing locations with the planned yarding system. When this approach is used, the location and design of the roads and landings will be approved by the Department as part of the Operations Plan required by the timber sale contract. Roads and landings designed under this approach will meet all of the goals and objectives of this section of the manual. Variances from the procedures, standards and criteria set forth in this section of the manual must be approved the Department.

Since these roads are temporary, consideration will be given to vacating the road at the completion of use. If the Department does not need the road for management purposes (i.e. site preparation, reforestation, animal damage control, vegetation management, etc.), the Operations Plan should include the requirement for the purchaser to prepare the road for vacation. (See Section 8 on Forest Road Vacating)

Road Design by Easement Holders

At times adjacent landowners will be granted easements to construct roads across state-owned forest land in order to access their property. When these easements are granted, the Department will approve the location and design of the roads on state-owned forest land. The design of the roads will meet all of the procedures, criteria, and standards included in this section of the manual.

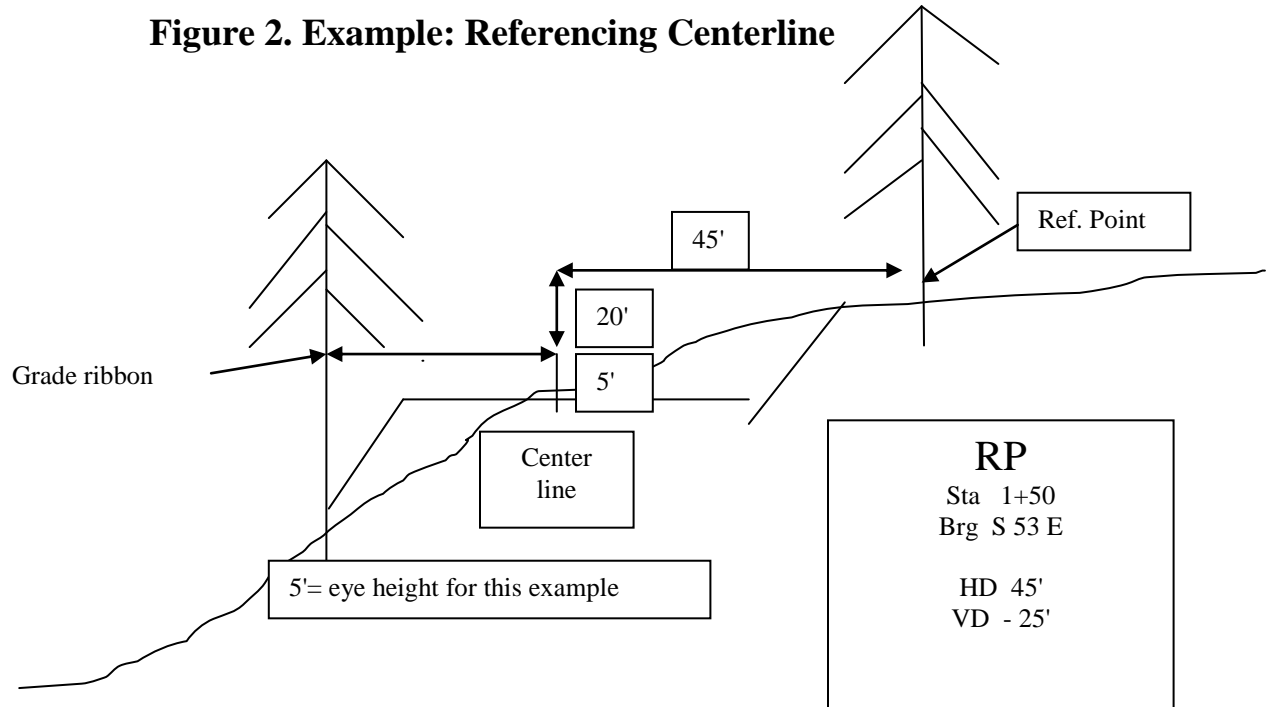
Road Construction

The design of a road construction or reconstruction/improvement project will include specifications that will minimize adverse impacts during the construction phase. Items to include are:

- Limiting construction activities to drier periods of the year, especially any activity involving exposed soil such as grubbing, excavation or grading.
- Curtailing activities on exposed soil during rain events, even when they occur during the dry season.
- Establish and maintain drainage throughout the construction phase.
- Take precautions to prevent siltation when rain is likely to occur. Precautions include hay bales, filter cloth, or other measures placed in ditch lines or other strategic locations to filter runoff water.
- When in-stream work is necessary, it should be accomplished during seasonal periods recommended by a fish biologist. A written plan is required by the Oregon Forest Practices Act and must be approved before working in a Type F (fish bearing) or Type D (domestic use) stream.
- Soils exposed by road construction or improvement that could enter streams will be seeded with grass or other vegetation to prevent erosion. These areas will be seeded at a time conducive to growing new grass and prior to the start of the wet season. Spring and fall periods are generally preferred for grass seeding.

Referencing Centerline Location Centerlines on new roads and road improvement projects are referenced so that the centerlines may be located at any time during or after construction. The number of reference points needed will vary and should be determined by the complexity and sensitivity of the project i.e. the more complex and/or the more sensitive the project, the more reference points that should be established.

Figure 2. Example: Referencing Centerline



A typical reference tag (4" aluminum tag) should have the following information or more if desired:

- Stationing.
- Bearing to centerline.
- Vertical and horizontal distance to centerline.

Reference spacing guidelines are:

- Slopes less than 50%: reference every 200 to 300 feet.
- Slopes greater than 50%: reference every 100 to 200 feet.
- Critical end haul areas: reference every 50 to 100 feet, or as needed.

The most common method of establishing road grade is to tie grade ribbons so that when your eyes are level with the ribbon your feet are on grade. In order to mark a reference tag you need to measure and calculate the following:

- Horizontal distance from tag to centerline.
- Vertical distance from tag to grade ribbon plus eye height.
- Bearing to centerline point and stationing.

The information on the reference tag will represent distances and bearings from the tag (not the ground) to the centerline of the designed road at the grade (ground) elevation.

Culvert Referencing

All culvert installations will be referenced with a 4" aluminum tag prior to the completion of road design work. The standard reference tag shall have the following information as a minimum:

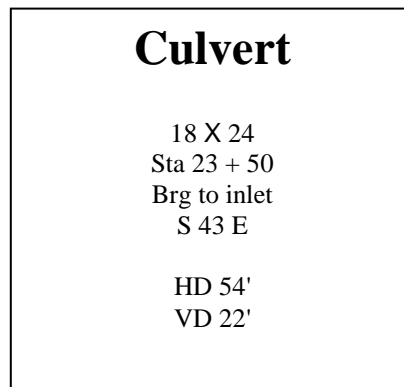
- Structure description, i.e., "culvert".
- Stationing.
- Size of culvert, i.e., "18 x 24'

Optional information:

- Attachments such as 1/2 rounds.
- Horizontal and vertical distance to culvert inlet, outlet.
- Bearing to either end of culvert
- Skew angle of culvert.

It is also a good idea to paint culvert information on the tree in case the tag falls off.

Figure 5. Example: Culvert Tag



Some surface drainage culvert locations are more apparent after the subgrade is constructed. The project administrator may relocate relief culverts in these instances.

Cut and Fill Slopes

The angle of the cut and fill slopes of a road can have a significant impact on the amount of ground taken up by the road and the stability of the hillside in the area around the road. The steeper the road slopes are, the less ground that is taken up by the road prism. The main problem with steep cut and fill slopes is that they can become unstable if they are constructed overly steep. The following table provides guidelines for cut and fills slope angles that will minimize slope instability and the foot print of the road on the hillside.

Table 3. Road Cut and Fill Slopes Angle Guidelines

Material	Compacted Fill Slope	Sidecast Fill Slope	Cut Slope
SOIL			
Silty sand No groundwater *High groundwater	1.5:1 2:1	2:1 3:1	.75:1 1.5:1
Soft clay, silts	Variable		
Sandy gravel No groundwater *High groundwater	1.5:1 1.75:1	1.5:1 1.5:1	.75:1 1.5:1
ROCK			
Solid – Fresh			** .25:1 to Vertical
Weathered – Stained			.25:1 to .75:1
Partially decomposed rock			.75:1 (with extra maintenance for ravel) 1.5:1 (slope with no ravel)
Cemented sands, silts, gravels			Vertical or .25:1

* May require special drainage, buttress, or other means of stabilization.

** With controlled blasting the back-slope will not shatter, and vertical slopes are usually the best design unless there is rock structure, bedding, jointing or fracturing which dips steeply out of the road cut. If this is the case, cut angle should be equal to the angle of the rock structure.

Contact the geotechnical specialist for "special problem rock slope design recommendations."

Landings and Turnouts

Landing size requirements vary with size and kind of equipment, log size, loader configuration (heel boom, front end, etc.), sorting situation, cold decking vs. hot decking, the possibility of skidding logs to a different loading area, yarding configuration, lead (square, straight, V), and other factors.

Landing size should be:

- Large enough to heel and swing logs without striking standing timber, rigging, or other equipment or objects. Operators will be directed to keep landings as small as possible. The maximum size should not exceed 1/5 acre.
- Long and level enough so that at least 2/3 of the longest bucked log to be yarded will rest on the ground. (Exception: this is not intended to restrict the yarding or loading of logs for poles piling, or an infrequent long break or tree length, provided the log is secured before unhooking the choker.)
- See figures 6 and 7 (this section) for landing size examples.

Figure 6. Example of Road Bed Used as Landing

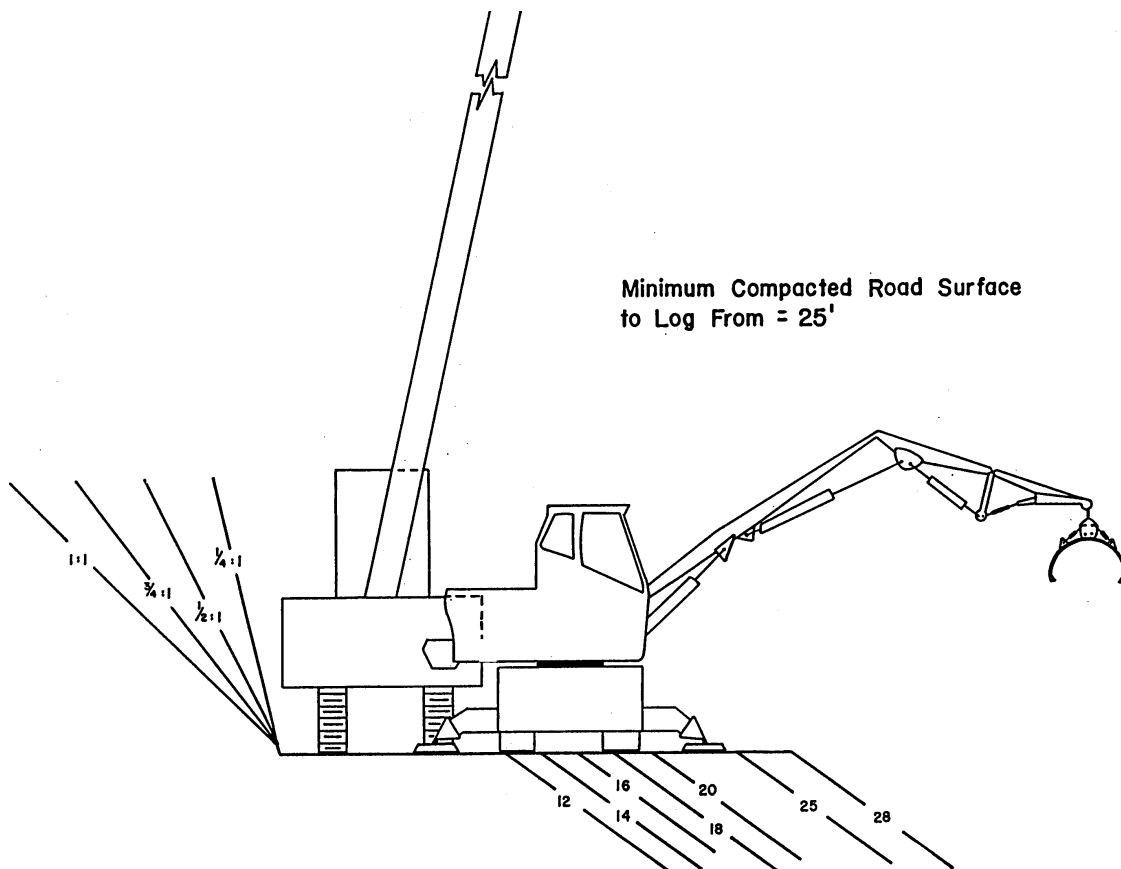
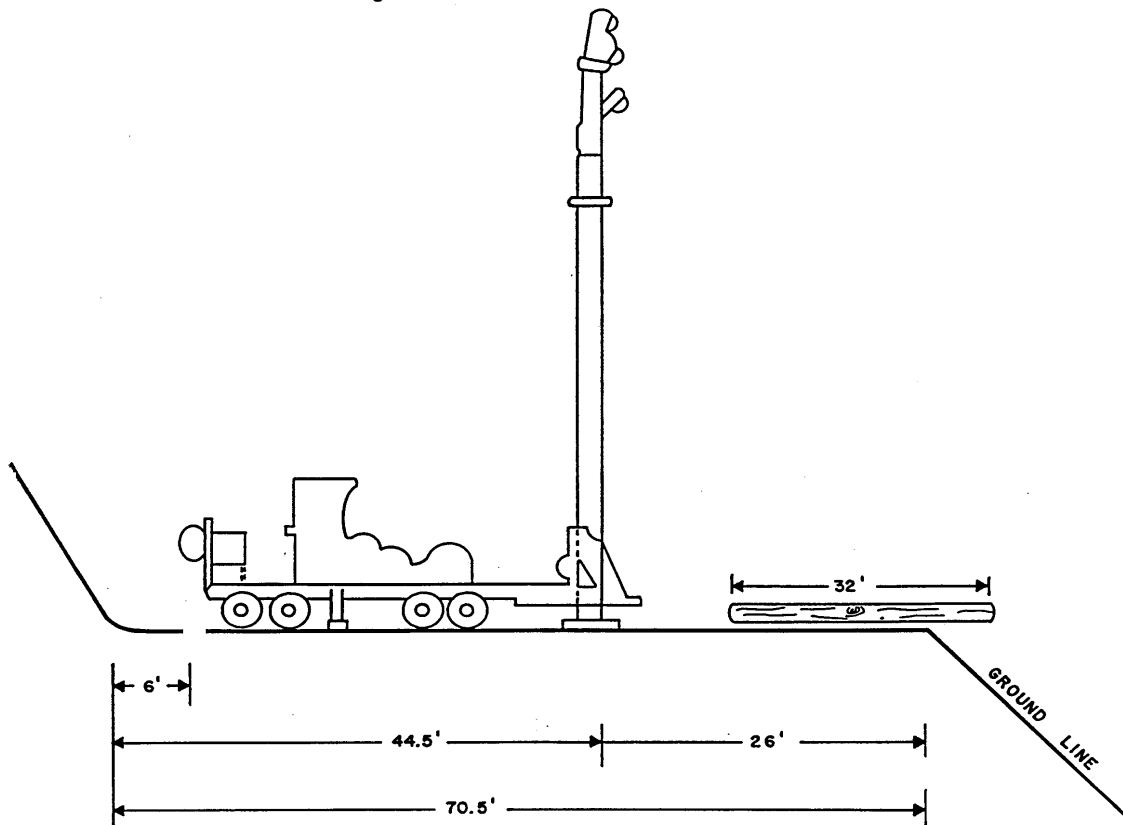


Figure 7. Example of Landing for Large Yarder

**70.5 FT Wide Landing with Tower Set Up
for Straight Lead.**



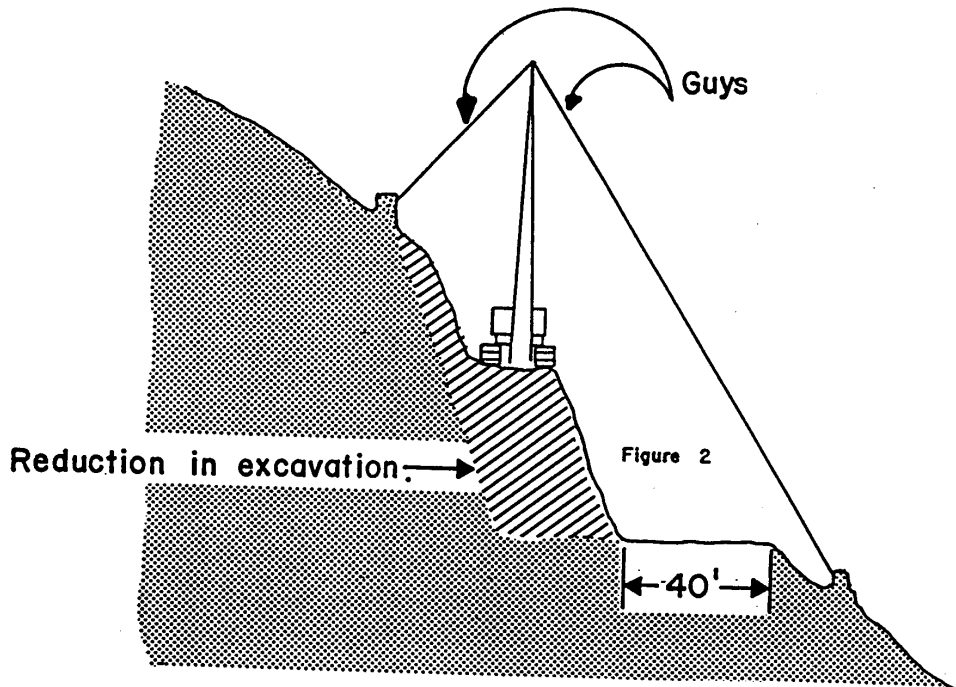
Landing construction should be:

- Reasonably level but with enough slope to provide drainage. Maximum slope should not exceed 8 %.

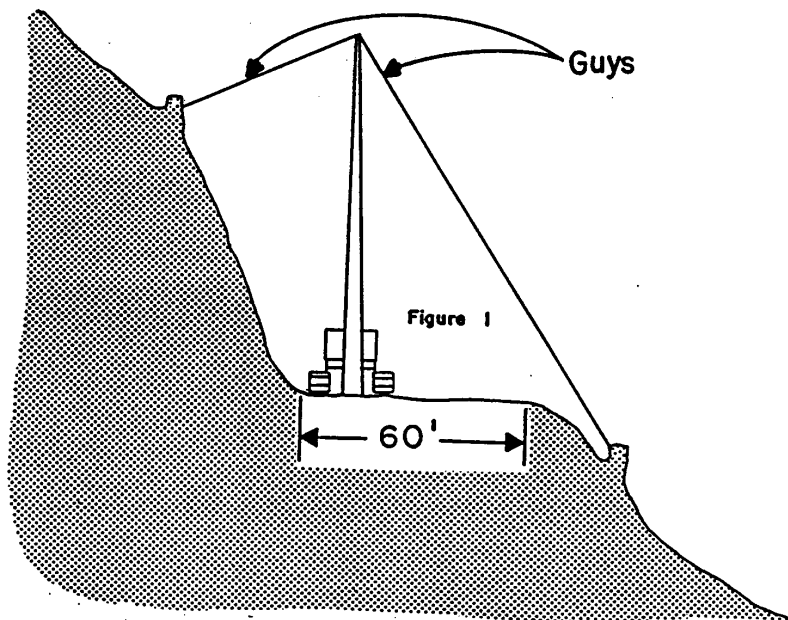
Usually an empty log truck ready for loading can start on about a 6 % grade, on a good crushed rock surface. If the truck has to maneuver on a steep grade, assistance may be needed.

- The slope in log chute areas can be up to 20 % if logs are decked perpendicular to slope. High decks will require flatter areas.
- Split-level construction can often save up to half the excavation required for a single level landing. See Figures 8 and 9 this section for example of split-level landing construction.

Figure 8. & Figure 9.



SPLIT LEVEL UPHILL SETUP



NORMAL UPHILL SETUP

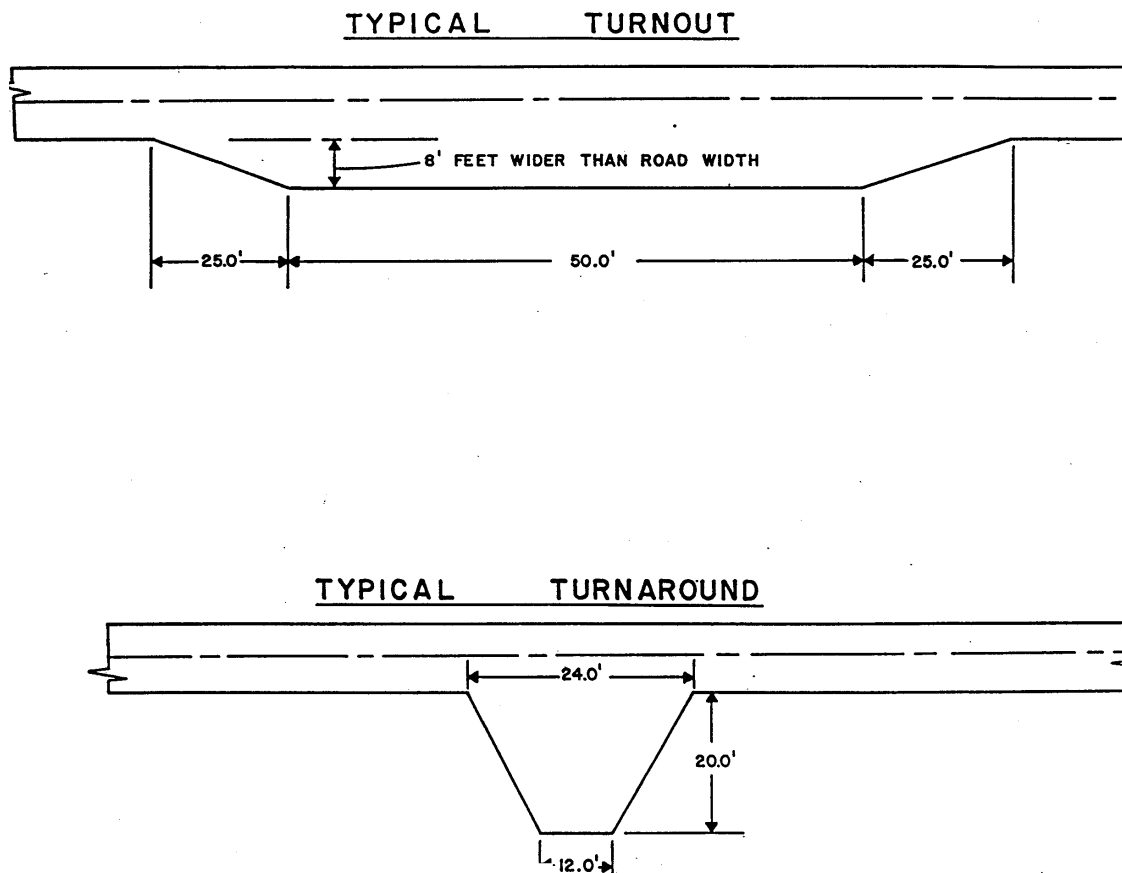
- Cut and fill construction can save excavation, but avoid landing fills on slopes over 50 % because of the likelihood for these fills to become overhangs of mixed dirt and slash during use. Such overhangs may slide out years after use, causing

soil and stream damage below. Consider end hauling the clearing and grubbing debris around landings where slopes are 50% or greater, due to the slope instability potential and safety hazard for the loggers working below the landing. Do not place landing fill on slopes over 65%.

Turnouts are to be intervisible with a maximum road distance of 750 feet between turnouts on mainline roads. Turnouts on shorter spur roads may be placed where the terrain allows. Since speeds are reduced on spur roads and most logging operations now use CBs it is not as important that turnouts be intervisible. They should be at least 8 feet in width and 50 feet long with a 25-foot transition at each end. (See Figure 10 for diagram of typical turnout and Figure 11 for diagram of typical turnaround)

Figure 10. & Figure 11.

LOGGING ROAD SPECIFICATIONS.



Curve Widening

The rear wheels of most vehicles will not track in the same path as the front wheels when traveling around a curve. This is called off-tracking. Extra subgrade and surfacing width may be necessary on the inside of the curve to accommodate the off tracking of the rear wheels. The amount of curve widening needed depends on the type of vehicle, the original subgrade width, the radius of the curve, and the central angle of the curve.

There are three critical types of vehicles that travel forest roads that may be impacted by curve width: the log truck, the logging yarder (on wheels), and the lowboy truck and trailer. The standard log truck tracks the best of these three, due to the configuration of the truck utilizing a stinger as the attachment point for the trailer. The logging yarder does not track as well as a log truck, due to its longer wheelbase. Finally, the lowboy truck will not track as well as the yarder, due to the long wheelbase of the truck and the longer wheelbase of the trailer. The trailer-mounted yarder pulled by a truck will usually off-track somewhere between the lowboy and self-propelled yarder. Sometimes yarders can be moved around corners with crawler tractors or other assist vehicles, which could improve their tracking ability on a temporary basis.

Since roads on state-owned forest land are designed as logging roads and not highways, not every factor will be evaluated in calculating extra curve width. The rule of thumb below, while not exact, will provide adequate curve width for the following vehicles.

Log Trucks and Yarders

Rule of Thumb: 400 divided by the radius = additional curve width

For a narrow subgrade (under 16 ft.), additional widening may be necessary, since the margin of safety or error for off-tracking on a narrow road would be less than on a wider subgrade. The amount of subgrade width less than 16' will be added on to the curve-widening formula as shown below.

Rule of Thumb: $(400 \div \text{Radius}) + (16' - \text{subgrade width}) = \text{additional curve width}$

Lowboy Truck and Trailer

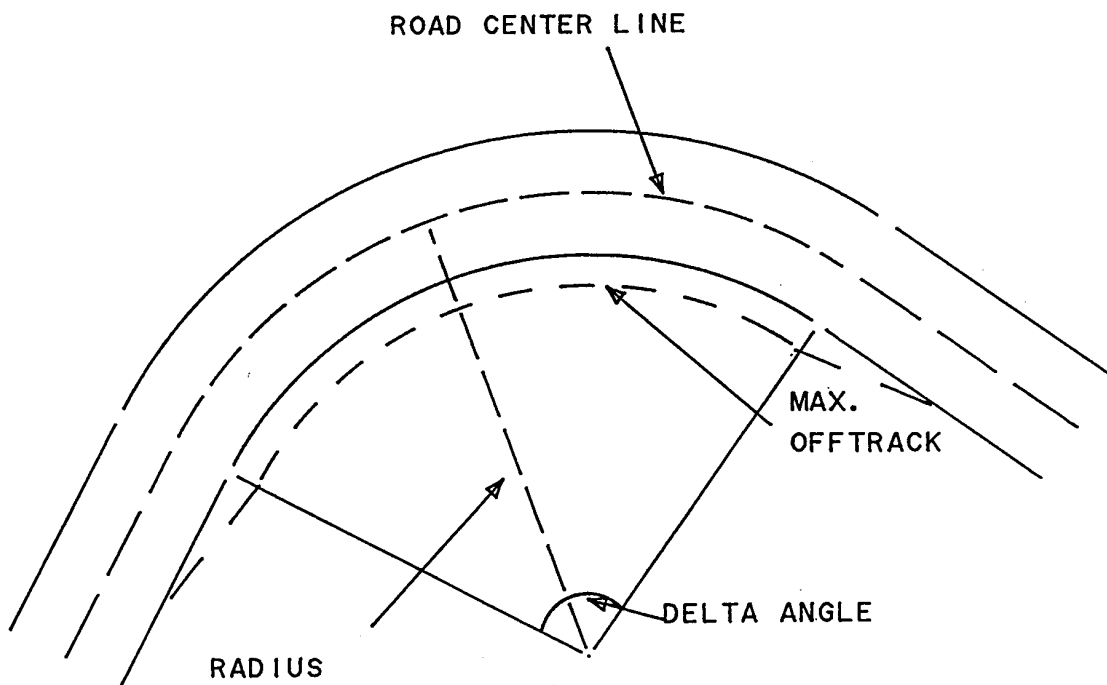
See Appendix 2 for Maximum Vehicle Off-Tracking for lowboy trailer (36'). The amount of off-tracking equals the amount of curve widening needed.

Good judgement and engineering skills must be used to design roads when vehicles with long overhangs will be traveling around curves. A vehicle such as a yarder with the tower down and traveling around a curve may have clearance problems with the cut-slope on the outside of the curve. This is particularly problematic for narrow roads with vertical cut-banks in solid rock.

Note: curve widening is normally added to the inside of the curve. If curve widening is to be put on the outside of the curve, the radius of the curve is effectively changed and the amount of road width needed for that radius curve will be calculated.

Figure 12.

MAXIMUM VEHICLE OFF TRACKING
ON SIMPLE CURVES



Maximum Vehicle Off-tracking on Simple Curves

Maximum Vehicle Off tracking

On Simple Curves

Vehicle: 36 ft. Lowboy Trailer

<u>Curve Rad. (ft)</u>	<u>Delta angle (deg.)</u>	<u>Off Track in ft.</u>
50	10	2
50	20	4
50	30	5
50	40	7
50	60	9
50	80	11
50	120	13
50	180	14

<u>Curve Rad. (ft)</u>	<u>Delta angle (deg.)</u>	<u>Off Track in ft.</u>
60	10	2
60	20	4
60	30	5
60	40	7
60	60	8
60	80	10
60	120	11
60	180	12

<u>Curve Rad. (ft)</u>	<u>Delta angle (deg.)</u>	<u>Off Track in ft.</u>
70	10	2
70	20	4
70	30	5
70	40	6
70	60	8
70	80	9
70	120	10
70	180	10

Maximum Vehicle Offtracking
On Simple Curves

Vehicle: 21 ft. BU-199 Yarder (self propelled)

<u>Curve Rad. (ft)</u>	<u>Delta angle (deg.)</u>	<u>Off Track in ft.</u>
50	10	1
50	20	2
50	30	3
50	50	4
50	90	4
50	180	5

<u>Curve Rad. (ft)</u>	<u>Delta angle (deg.)</u>	<u>Off Track in ft.</u>
60	10	1
60	20	2
60	40	3
60	70	4
60	180	4

<u>Curve Rad. (ft)</u>	<u>Delta angle (deg.)</u>	<u>Off Track in ft.</u>
70	10	1
70	20	2
70	40	3
70	180	3