3. Road Construction

Introduction

The purpose of this chapter is to assist practitioners in meeting forest road construction and modification requirements under the Forest Practices Code. Successful construction involves building roads that are appropriate for the expected service life (see Chapter 1, "Road Layout and Design") while minimizing adverse impacts on other forest and non-forest resources.

Since road construction activities can have adverse impacts on fisheries resources, particular care must be exercised when work is under way near riparian management areas and at stream crossings. Timing construction to use instream work windows, and scheduling operations so that construction is carried out without undue delay, will help to minimize these impacts.

The following topics are covered in this chapter:

- road corridor preparation activities during removal of timber from the corridor, including establishing and laying out clearing widths, establishing pilot trails, and felling and yarding within the clearing width
- grubbing and stripping operations within the road corridor and disposal of slash and debris
- subgrade construction activities, including:
  - construction surveys, and methods to make modifications to the road layout and design
  - sidecast and full bench construction techniques
  - endhauling practices, example swell factors to convert from bank volumes to loose volumes, and drilling and blasting
  - overlanding techniques for construction in swampy terrain, borrow pit locations, and winter construction of permanent roads
  - protecting erodible fills located within floodplains
  - requirements for the use, storage, and disposal of litter, petroleum products, and other waste products.
- stabilizing the road subgrade and surfacing the road to support traffic loading
- construction and use of snow and one-season winter roads, and construction of 5-year roads
- surface erosion and sediment control techniques
- road works shutdown indicators and procedures.

Road corridor preparation

Establishing clearing widths

Clearing widths are established to facilitate the construction, use, and maintenance of forest roads. The objective is to minimize the width of the clearing, yet accommodate:

- 1–3 m of width between standing timber and any excavation to avoid undercutting roots that may create dangerous trees and destabilize the top of road cut (see Figures 7 and 8)
- the road prism, including widenings for curves and turnouts
- subgrade drainage structures
- landings and slash disposal without piling wood or excavated material against standing trees
- borrow pits, gravel pits, quarries, and waste areas
- safe sight distance for user safety
- snow removal
- fencing and other structures that are ancillary to the road
- other special operational requirements.

For natural slopes up to 60%, clearing widths can be conveniently determined from the tables in Appendix 5. For slopes greater than 60%, or in areas of moderate or high likelihood of landslides, clearing widths should be determined from the geometric road design.

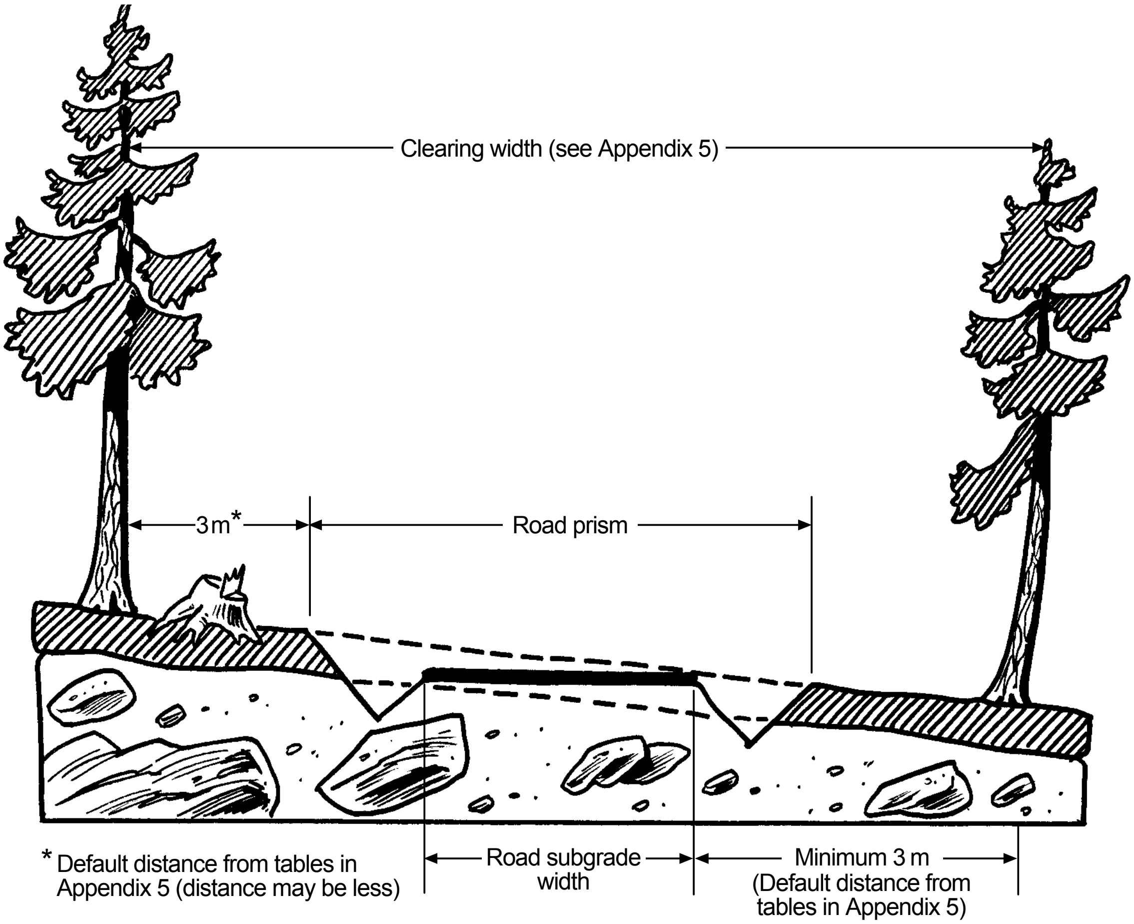

Figure 7. Typical roadway on gentle slopes with no additional clearing.

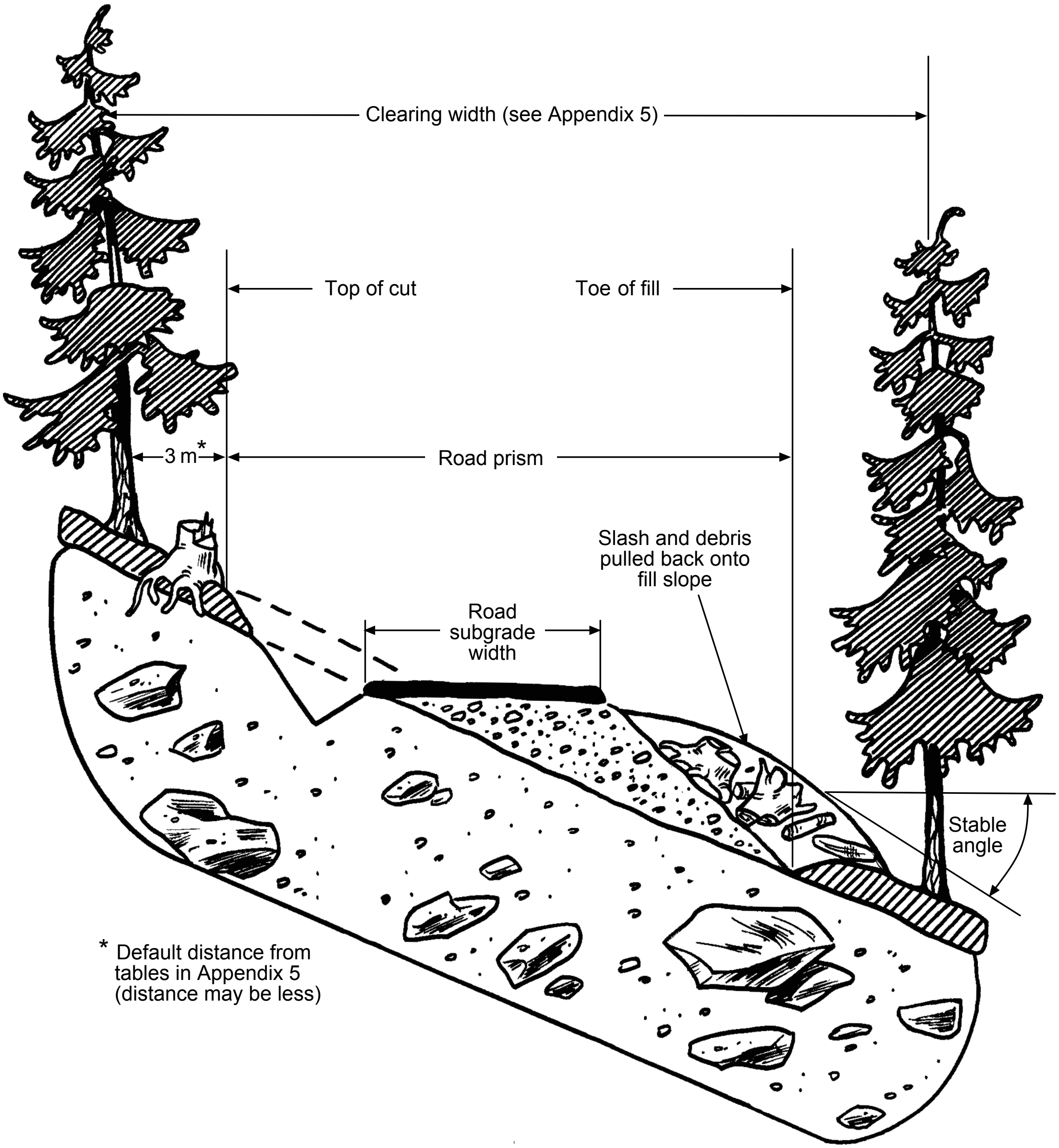

Figure 8. Typical permanent roadway on moderate slopes (best practice).

Laying out clearing widths

Clearing limits should be marked in the field with flagging tape. The clearing boundaries should be sufficiently flagged to be clearly visible for machine operators or hand fallers to follow.

Flagging should be hung on trees and shrubs that will remain after the clearing operation is completed. Trees that are on the boundary should be left standing unless the roots will be undermined by operations within the clearing width. Where slope staking is not required, the flagging can be used as an offset line to establish the top of cut for grade construction.

Establishing pilot trails

Frequently, pilot trails or tote roads are built within the clearing width before falling begins. These trails are to provide easy access for the faller (hand or mechanical), a route for skidding felled timber to a landing or collection point, and temporary access along the road corridor.

Terrain and soil conditions will govern the location of the pilot trail within the clearing width. Generally, the trail is constructed below the flagged centreline on side hills, near the lower clearing width limits. This allows for easy access to skid fallen timber, and allows for the toe of the road fill to be keyed into the slope. Where drilling for blasting is required, the trail may be built above the road centreline, just below the upper clearing limit, to permit vertical drilling of the rock cut.

Care should be taken during pilot trail construction to minimize damage to any timber and to ensure that unsafe conditions are not created for fallers. Excavators are superior machines for constructing trails because they can push down, remove, and place trees along the trail for easy removal later.

Pilot trails are often constructed to allow trucks to remove the merchantable timber within the clearing area. This is desirable where there is insufficient room to construct large landings for timber storage.

Drainage structures should be installed concurrently with pilot trail construction. Temporary stream crossings may be required during the road construction phase until the permanent crossing is commissioned. Ideally, to minimize the impact on the stream, the temporary crossing should be situated in the same location as the permanent crossing, but this may be impractical. For further details, see Chapter 4, “Road Drainage Construction.”

Felling and yarding within the clearing width

Felling methods

Several methods for falling trees within the clearing width are available, depending on terrain, soil conditions, timber size, and total volume.

Mechanical methods:

- feller-bunchers (tracked, high flotation tired) used for merchantable and non-merchantable timber and on terrain suited to the safe operation of such equipment
- crawler tractors/excavators used for non-merchantable timber or to assist hand fallers where hang-ups or faller safety dictates such action.

Hand methods:

- hand falling to avoid site impacts associated with mechanical falling
- directional falling of leaning timber, using jacks, excavators, or hydraulic log loaders.

Explosives:

- use is restricted to falling large dangerous trees that cannot be removed safely by other means
- if used adjacent to streams, explosives must first be approved by the appropriate resource agencies
- the person using explosives must have a valid Workers' Compensation Board Blaster's Certificate.

Further information about falling is contained in the British Columbia Occupational Health & Safety Regulation and the Workers' Compensation Board of B.C. *Fallers' and Buckers' Handbook*.

Techniques for protecting stream banks during felling operations

Before falling begins, ensure that streams and their associated riparian management areas and the "machine-free zones" identified on operational plans are flagged in the field, and use appropriate directional falling techniques to protect these areas.

Where felling timber across a stream is unavoidable, buck the tree carefully into shorter lengths and lift it out of the stream or off the stream banks. Avoid skidding the tree across the stream. For further information, refer to the *Riparian Management Area Guidebook*.

Techniques for protecting stream banks during yarding operations

Stream bank destabilization resulting from yarding operations should be avoided. This is best accomplished by yarding away from streams, not across them. Options for avoiding stream bank damage include:

- using overhead systems or hydraulic log loaders or excavators to lift, not drag, the felled trees away from the stream
- where machines are used to lift trees away from the stream, minimizing equipment movement and removing any puncheon placed to support the machine as the machine moves
- using temporary crossings (skid bridges) or installing a permanent structure before yarding; refer to Chapter 4, "Road Drainage Construction" for more details on temporary stream crossings.

Removing debris from streams

Where debris is accidentally introduced into the stream, clean-up should take place concurrently with clearing operations. Any stream bank damage, outside of designated crossings, should be reported to the appropriate resource agency immediately so that any mitigative prescriptions can be approved and carried out without delay.

Dangerous trees

All dangerous trees outside the clearing width but deemed hazardous to road workers or users should be felled concurrently with the felling phase of site preparation.

Grubbing and stripping

After all standing trees and dangerous trees have been felled and removed, the road prism should be grubbed and stripped of all topsoil and unsuitable mineral soils. Grubbing includes the removal of stumps, roots, logging slash, and downed or buried logs. Stripping includes the removal of topsoil, or other organic material, and mineral soils unsuitable for forming the road subgrade.

Where grubbing operations have removed all organic soil, no stripping is required unless other unsuitable soils are encountered.

Organic material, such as stumps, roots, logging slash, embedded logs, topsoil, and otherwise unsuitable soils may be left within the subgrade width where one-season winter use or snow roads are constructed, or where overlanding techniques are applied.

Disposal of slash and debris

Slash and debris must be disposed of by burning, burying, scattering, or end-hauling. The method selected should:

- meet objectives of higher-level plans (such as those for smoke management, aesthetics, or pest management)
- be compatible with terrain conditions
- consider the slash volume, loading, species, and piece sizes
- not alter natural drainage patterns
- be compatible with other resource values.

Disposal sites must:

- be sufficiently stable to support the debris
- have very low potential for failing into a stream (such as by landslide or snowslide)
- have little or no impact on other forest resource values.

Under no circumstances may slash be placed within the high-water mark of a stream, or in a manner likely to cause the material to fall into a stream.

Best practice is to remove all organic debris from within the road prism width (Figure 8). However, where the road **does not** cross areas having a moderate or high likelihood of landslides as determined by a TSFA, stumps, roots, and embedded logs may be incorporated in the road prism as follows:

- stumps, roots, and embedded logs may be left or placed **outside the road subgrade width** on the downhill side (Figure 9)
- for a 5-year road (Figure 10), stumps, roots, and embedded logs may be left or placed **within the road subgrade width**. For more information about 5-year roads, refer to “Construction of 5-year roads” later in this chapter.

For each of these two situations above, the person responsible for constructing the road must provide a statement that indicates that leaving or placing stumps, roots, and embedded logs in the road prism will not significantly increase the risk of a failure of the road subgrade.

In all cases of road site preparation, topsoil must be removed from within the road prism width.

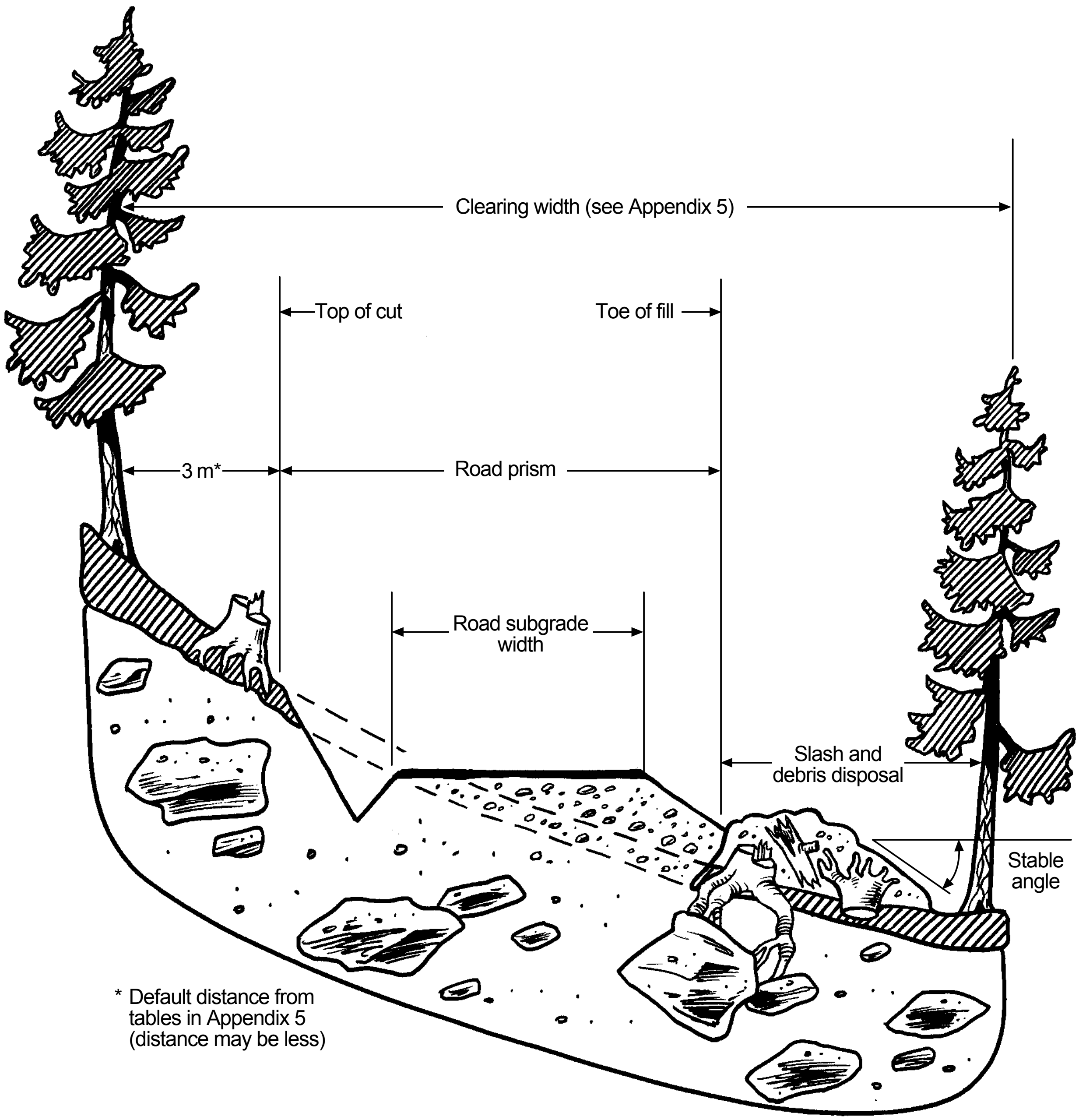

Figure 9. Permanent road in low likelihood of landslide terrain (acceptable practice).

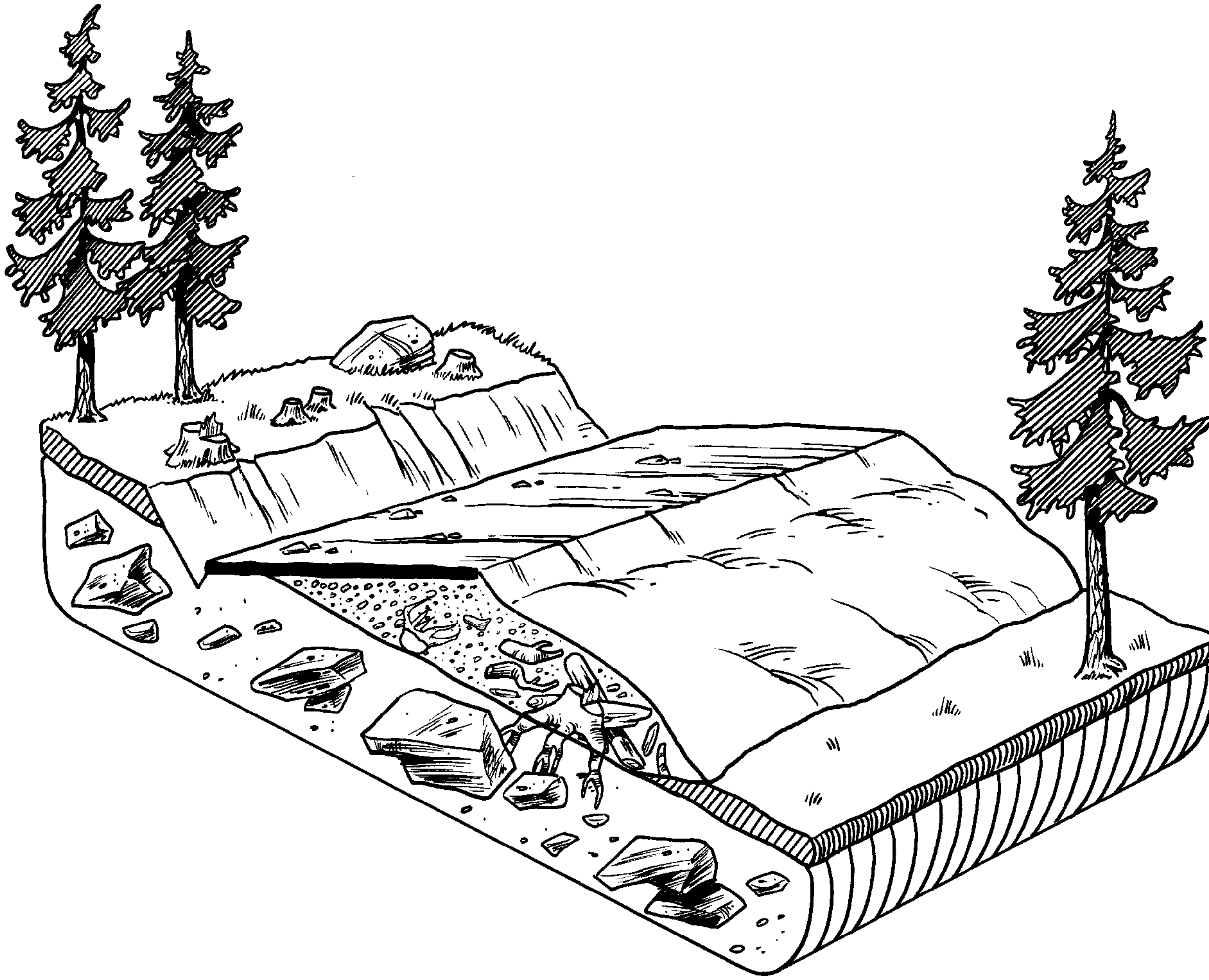

Figure 10. Typical 5-year road showing debris placement.

Piling and burning

Piling and burning (Figure 11) may be considered as an alternative to burying in areas with flatter terrain, heavy slash loading, and moderate to high pest or fire hazard, and where smoke management objectives can be met. Where possible, use natural openings and landings.

- pile slash and debris at least twice the width of the pile away from standing timber
- to facilitate efficient burning, ensure that the slash pile contains as little soil as is possible
- ensure that slash is piled tightly, using a brush blade or excavator
- excavate a fireguard down to mineral soil around each burn pile to prevent ground fire escape
- ensure that a Burning Reference Number has been obtained before initiating the burn.

The use of burning racks can be very useful to ensure that a hot clean burn results. This eliminates the need to push in or re-pile debris that does not burn cleanly.

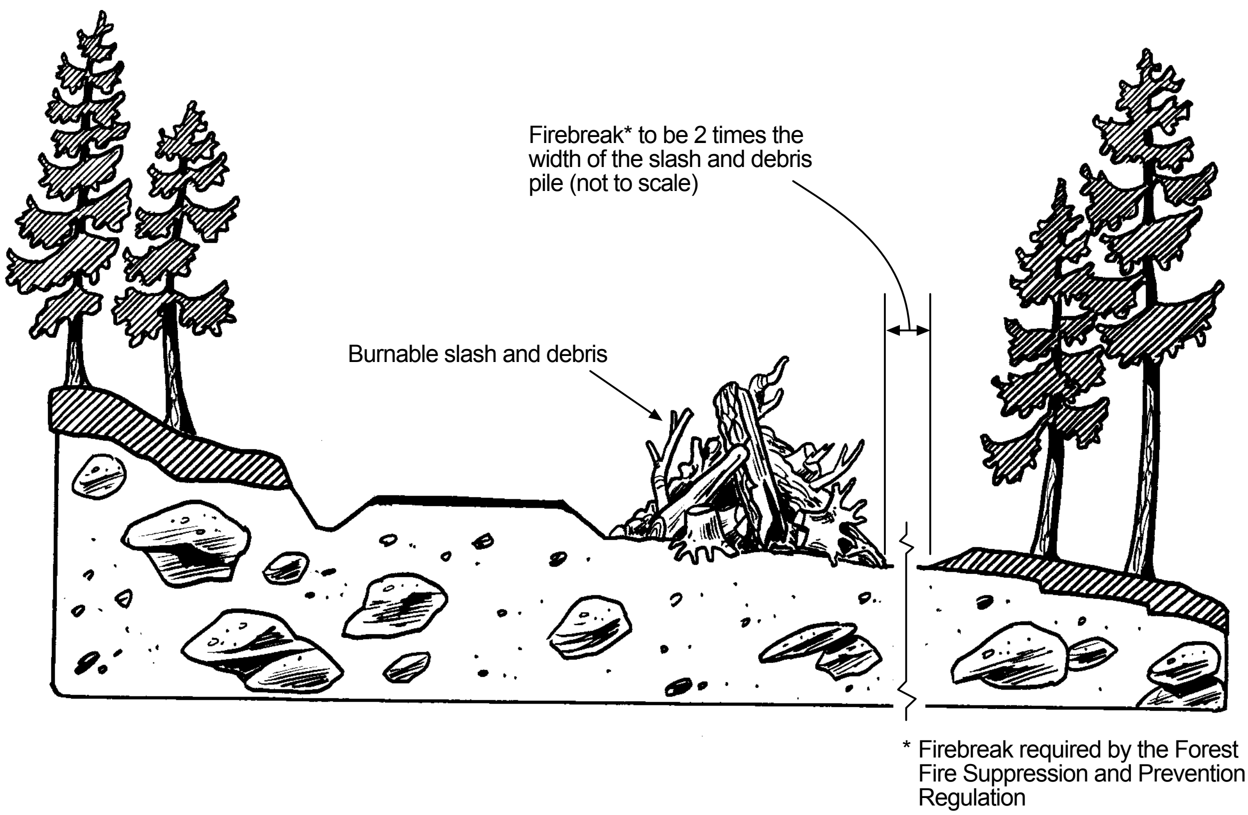

Figure 11. Slash and debris disposal by piling and burning.

Burying

Burying is usually the preferred practice and there are three methods for burying slash and debris with overburden material: trenching, mounding or windrowing, and creating pushouts.

The volume of slash and overburden should first be calculated per lineal metre of road. Generally, for every cubic metre of debris, a metre of clearing is required for disposal (Figure 12). When excessive slash volumes are encountered, other disposal methods should be considered.

Buried material should:

- be compacted before being covered with soil
- be covered with a minimum of 300 mm of soil
- be placed so as not to interfere with roadway or other drainage, utilities, planned road improvements, snow removal, design sight distance, future developments, or standing timber
- not interfere with any watercourse.

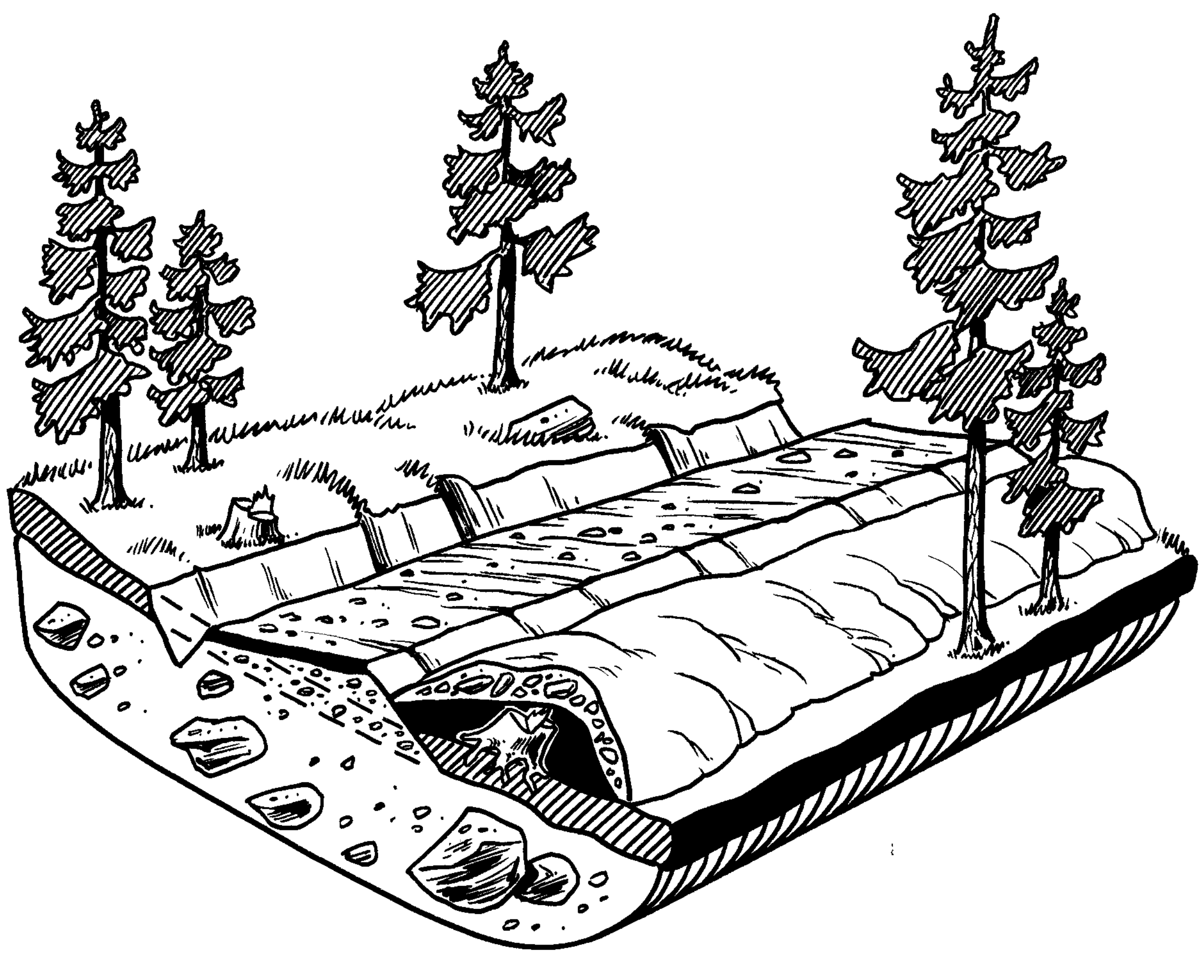

Figure 12. Slash and debris disposal by burying.

Trenching

This is a type of burying in which slash and debris are placed in a trench rather than being spread over the ground surface. The volume of debris should determine the size of the trench. To minimize the size of the cleared area, a deep, narrow trench is preferable to a shallow, wide trench (Figure 13).

To prevent undermining tree roots, 3 m of cleared width should remain between any standing timber and the trench. The trench should lie parallel to the roadway and may be continuous or intermittent, depending on the volume of debris. The woody debris is placed on the bottom of the trench and compacted before being buried with topsoil and other strippings from the road prism.

This method works well where usable subgrade material occurs fairly continuously below a veneer of unsuitable soil. The excavated trench material can

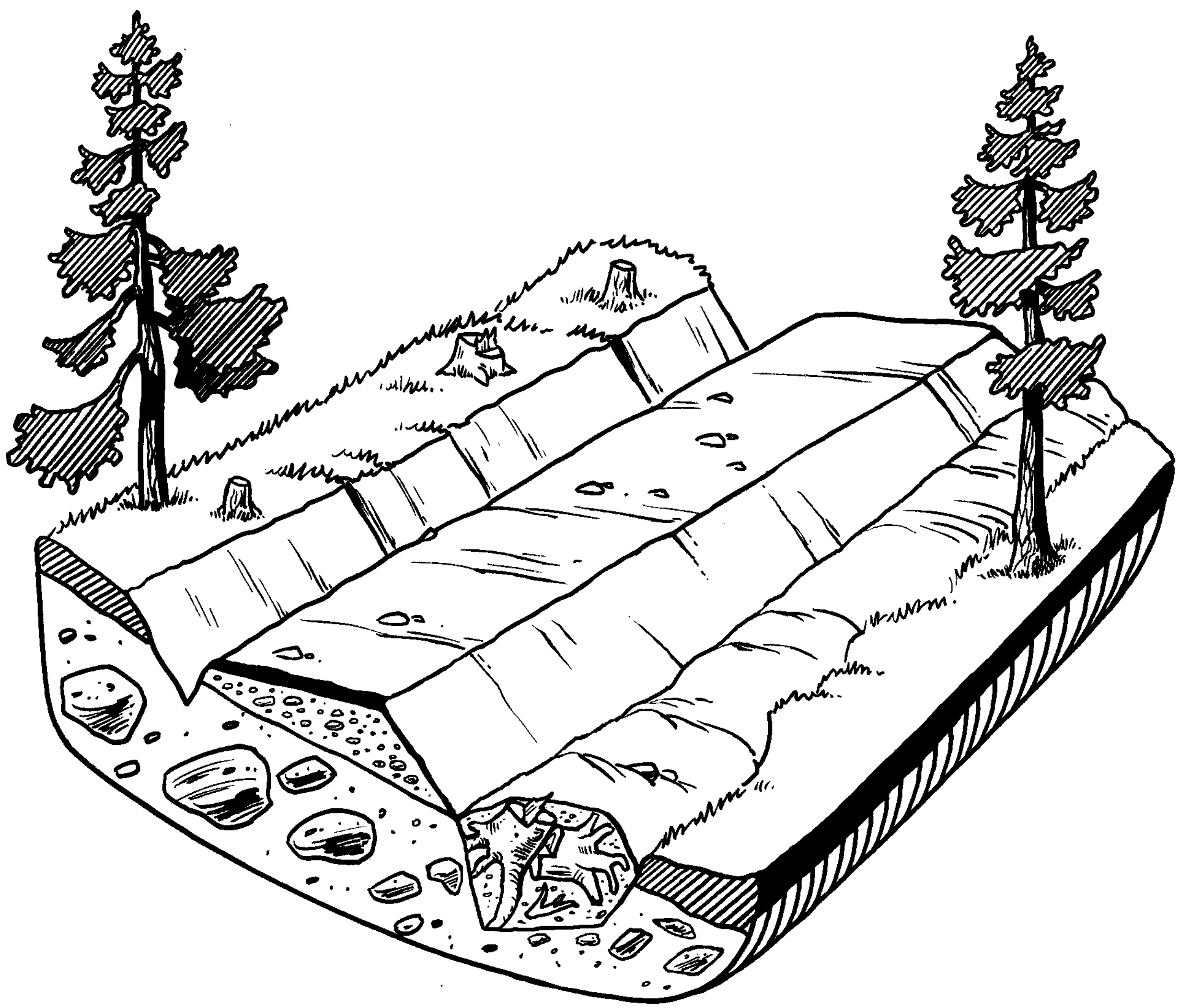

Figure 13. Slash and debris disposal by trenching.

be used to raise the subgrade above the normal groundline. Trenching should not be used on natural slopes with greater than 20% gradient, as it could undermine the road surface, causing long-term subgrade instability.

Mounding or windrowing

With this technique, all slash and debris are accumulated along one side of the cleared width between the road prism and the standing timber. The woody debris is placed first and compacted by the grubbing equipment. Stripping material from the road prism is used to cover the slash with additional mineral soil, used as required to ensure that a minimum of 300 mm of soil cover is achieved. Because of the difficulty of maintaining an adequate soil cover on the downslope side, the results of this method on natural slopes with greater than 50% gradient are not easy to control.

Pushouts

Pushouts should be located in natural openings along the cleared area and should be appropriate for the volume of material to be disposed of. Debris should not be pushed into standing timber, and the piles should be properly groomed to be stable and visually acceptable.

Scattering

This process is similar to mounding and windrowing, but does not require the slash to be buried (Figure 14). In low-density stands, debris may be spread among the standing timber in natural openings along the cleared area, thus reducing the clearing width required for disposal. Care must be taken to avoid damaging the standing timber.

Scattering should be considered where:

- sidecasting slash and debris will not increase the likelihood of landslides
- fire and pest hazards are low and aesthetic concerns are not an issue.

Incidental burying may occur, but is not an objective. The material may be bunched or spread, but any continuous accumulations should be breached to accommodate drainage, snow removal, and wildlife passage.

Slash and debris can also be chipped, or ground up, and blown along the cleared area or into the standing timber, away from watercourses. In addition, chipping may limit erosion of exposed soils and facilitate revegetation.

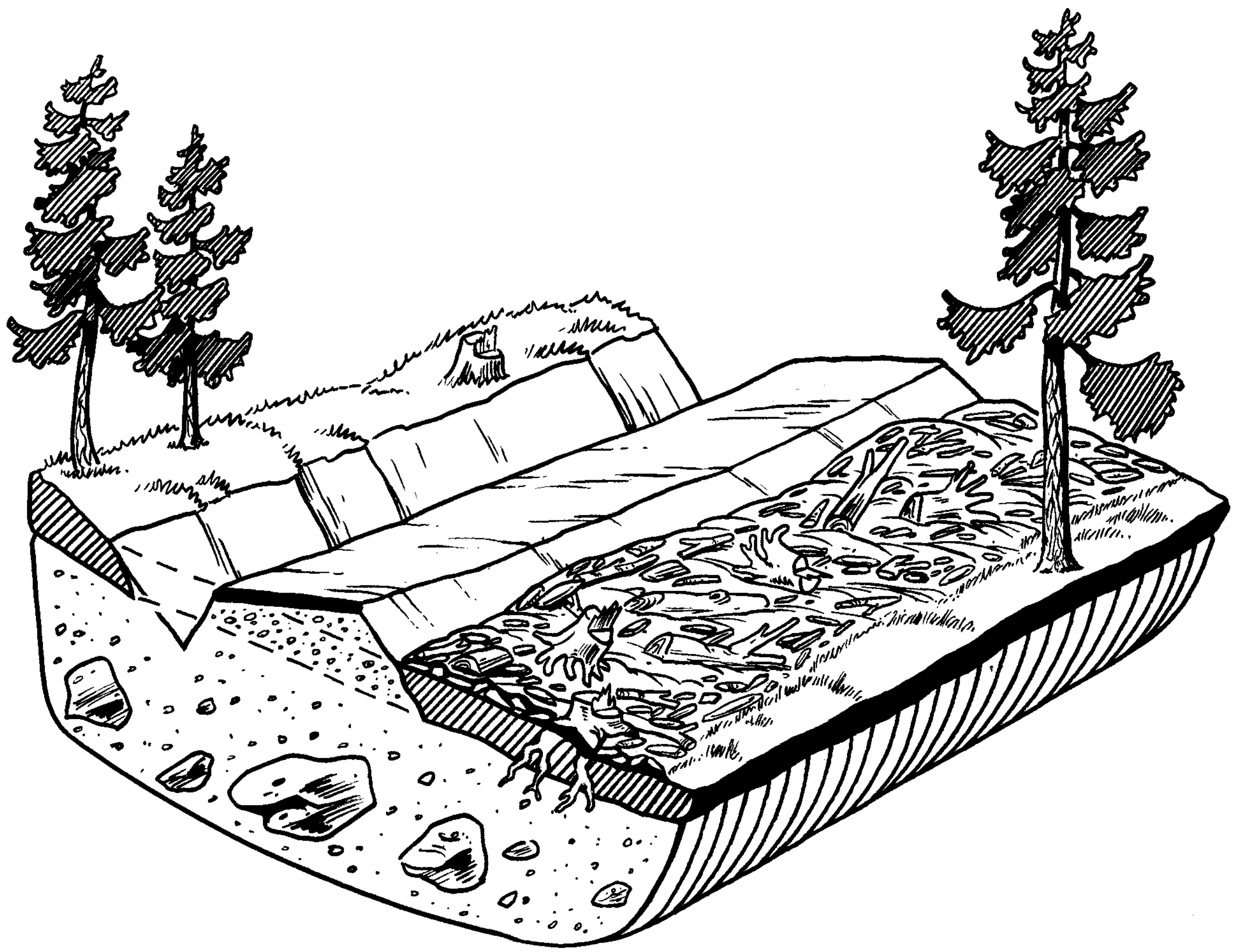

Figure 14. Slash and debris disposal by scattering.

Endhauling slash and debris

Endhauling slash and debris from the road corridor is required in steep or unstable terrain where this material must be removed to maintain slope stability. It may also be required in areas with high recreational value where aesthetics may be an issue.

The approved waste area should be stable and well drained, isolated from streams or wet sites, and have a minimal adverse impact on other forest resources. Overloading of slopes should be avoided. Once endhauled, the slash and debris should be disposed of by burning, burying, or scattering.

Where possible and practical, stockpile organic and fine-textured soils for placement over abandoned borrow and waste areas to facilitate revegetation. All waste areas should be identified before construction.

Regardless of the disposal method used, ensure that the top of any remaining spoil material is below the road surface (to allow for snow ploughing and sight distance) and placed in a manner to allow surface water to drain away from the road.

Subgrade construction

Storm and rapid snowmelt events should be anticipated during construction, and the associated surface runoff and intercepted subsurface flows should not be allowed to damage the subgrade or other resources. This means that ditches, cross-drain culverts, and any permanent or suitably sized temporary drainage structures should be constructed as water is encountered. Refer to Chapter 4, “Road Drainage Construction.”

Construction surveys

Construction surveys are conducted to re-establish the road centreline, and to determine the limits of the cut and fill slopes. They are also carried out to provide grade control during construction. Preferably, construction surveys are carried out after clearing and grubbing operations, but before primary excavation begins.

In some instances, construction surveys are mandatory. They are required for roads that will cross areas with a moderate or high likelihood of landslides as determined by a TSFA. An exception to this requirement occurs when a qualified registered professional will provide on-site inspections during construction and a statement of construction conformance after completion of construction indicating that the measures to maintain slope stability, stipulated in the design, were implemented.

All excavation equipment operators should be familiar with the use of construction survey stakes. Properly conducted, the construction survey ensures that excavation volumes are minimized and that the measures to maintain slope stability are correctly implemented.

Construction surveys normally include:

- marking of the clearing width boundaries
- establishment of new reference trees where the existing reference trees are located within the clearing area
- accurate establishment of the road centreline
- slope staking of cut and fill slopes based on actual site conditions (field calculation as opposed to following the design staking table)
- centreline location, design, and slope staking as needed to adjust for unforeseen site conditions.

When a forest road is being built in steep and broken terrain, the opportunity to construct a pilot trail ahead on the road right-of-way is often limited. Therefore, it may not be possible to completely separate the grubbing, stripping, and subgrade excavation phases. Under these conditions, slope staking should be done prior to any equipment activity. This requires flexibility to adjust the limits for excavation if material conditions are different from those assumed in the road design.

When a pilot trail is built, underlying material types can be examined and confirmed to match the road design. If the soil types differ, re-design of the geometric road design may be required to adjust the cut and fill slope angles as well as the movement of materials. Changes in soil types often result in a shortage or surplus of materials that can be remedied by a re-design.

Before primary excavation begins, ensure that the construction survey has been completed and any necessary re-designs have been incorporated into the slope staking. Slope stakes should include the horizontal and vertical offset to the designed centreline; cut or fill slopes, station chainage, and roadbed width.

Provide adequate protection of the slope stakes by offsetting and painting them with high-visibility florescent paint. Reference points should remain intact. Staking may be substituted by flagging or spray-paint as appropriate for the site conditions; for example, in areas where shallow organic soils overlie bedrock. For detailed procedures for construction surveys refer to *Manual for Roads and Transportation* (BCIT 1984).

Modifying the road layout and design

If the road design does not reflect the field conditions actually encountered, then the road design may be modified to address those unforeseen conditions. Should a professional prescription not reflect actual field conditions, or if the layout and design revisions affect a prescription to maintain slope stability, then any design changes must be reviewed and approved by a qualified registered professional before construction begins.

Where the changes made to a previously approved layout or design could have a negative impact on forest resources, and these forest resources were protected under the original approved road layout and design, then the revised design must be approved by the district manager before construction recommences. Examples of changes include, but are not limited to, amending:

- the construction techniques, where the likelihood of landslides may be increased if they are not amended
- the location of the road outside the approved clearing area
- the construction technique within riparian management areas
- the number of crossings of a stream
- the design of a drainage structure affecting a fish-bearing stream

- the design of a major culvert or bridge
- the construction technique such that the road classification changes from a permanent to 5-year road
- the road width or design speed.

Changes to road design to address unforeseen conditions

Where site conditions not anticipated by the design are encountered, work should be stopped at that location until:

- the extent of the problem is identified and recorded
- all resource impacts are re-assessed
- a plan for modifying the design to suit actual site conditions and to protect other resource values is developed
- the district manager's approval of the design modifications is obtained, if required.

Situations where the hazard is low, and the risk of damage is low:
Where the road **is not** in areas of moderate or high likelihood of landslides and the proponent determines the risk of adverse impacts on other forest resources to be low:

- note the road name, stations, and changes to the design on the drawings or road file and retain for future reference
- begin work with the amended design.

Situations where the hazard is moderate or high, and the risk of damage is low:
Where the road **is** in areas of moderate or high likelihood of landslides and the proponent determines the risk to other forest resources to be low:

- record in detail the problem and course of action taken, noting the discrepancy in the design and possible consequences to resources
- if changes to any professionally prepared prescriptions are required, obtain approval for them from a qualified registered professional, preferably from the original designer
- obtain the approval of the district manager for the changes to the design where the likelihood of landslides may not be reduced by the change
- mark the changes to the design on the drawings and retain them for future reference
- begin work following the approved, amended design.

Situations where the hazard is moderate or high, and the risk of damage is high:
Where the proponent determines the risks to other resource values to be high or very high, in addition to the above:

- in consultation with appropriate resource agencies or qualified registered professional, schedule an on-site review to determine a suitable course of action, and amend the design
- obtain written authorization from the district manager to continue work using the amended design
- monitor the construction continuously until the work through the high-risk area is complete to ensure the amended design is followed
- complete necessary professional statements, if required, for the professional designs.

Sidecast construction

Sidecast—also known as cut-and-fill, or partial bench construction—is the most common forest road building technique. Excavated material from the uphill slope is pushed, or cast, onto the downhill slope to form a fill to support the outside portion of the running surface of the road (Figure 8).

Topsoil and slash, together with saturated and other unsuitable soils, should not be used as road fill. These materials should be removed because they have a very low strength and readily fail under vehicle loading. However, stumps, roots, and embedded logs may be placed outside of the subgrade width in areas of low likelihood of landslides (Figure 9).

Crawler tractors and excavators are often used for sidecast construction. Soil is pushed or cast down the slope from the top of the road cut until the desired subgrade width is achieved. If this fill material is not properly compacted, settlement will likely occur, leading to slumping at the shoulders, and settlement or tension cracks in the road surface.

The fill material should be "keyed-in" or "notched" into the slope, after all organic material and unsuitable soils have first been removed from the road prism. The notch should be sufficiently wide to allow equipment to work. The fill should be built up in shallow lifts and compacted using the road-building machinery, or, ideally, roller compactors. Properly compacted fills have a higher load-carrying capacity, and tend to shed water rather than absorb it. This results in a more stable, erosion-resistant subgrade, which requires less maintenance while minimizing the potential for adverse environmental impacts.

Full bench construction

Full bench construction is a measure often used to maintain slope stability. The excavated material will be hauled away (see "Endhauling," below) to an approved waste area, not wasted along the slope below the road unless specified by a qualified registered professional.

Excavating the outside edge of the road prism last can minimize spillage. By pulling the remaining material into the road prism, only inconsequential volumes of material will spill down the slope.

Endhauling

Endhauling is a road construction practice often used to maintain slope stability, when done in conjunction with full bench construction. It can also apply in gentle terrain where road cuts, such as through-cuts, produce a surplus volume of material. Endhaul is the transportation of surplus excavated material from the construction site to an embankment area or waste area (also known as a spoil site) situated on stable terrain. Endhauling is an integral part of the road-building operation, rather than a distinct phase of construction, as site conditions dictate how and to what extent this practice must be adopted.

Location of waste areas

While surplus excavated material should be used in road fills, excessive volumes should be hauled to waste areas. Potential waste areas should be identified during the field reconnaissance and incorporated into the road design. Waste areas should be located outside riparian management areas. They should take advantage of swales, depressions, benches, and shallow slopes; ideally, they should use old borrow pits or quarries. It is important that they maintain natural drainage patterns. Waste areas should not be located in areas of moderate or high likelihood of landslides, or at the crest of a slope or top of an escarpment.

If waste areas are located where there is moderate or high likelihood of landslides, they must be identified in the measures to maintain slope stability. The qualified registered professional should prescribe treatment of the waste area (such as fill slope angles and height of fill) to ensure slope stability is not compromised.

Care must be taken when placing waste material in the selected sites to ensure stability of the waste pile and to minimize erosion. Consider:

- placing the coarse material on the bottom and the finer-grained material on top
- using topsoil to cover the pile to aid revegetation and limit surface erosion

- not exceeding the natural angle of repose of the material
- "benching" the sides of the pile when heights exceed 5 m
- crowning, sloping, and grooming the pile to ensure that the surface does not pond water
- installing sediment control devices below the waste area to capture and prevent sediment transport beyond the waste area until the pile is revegetated.

Loose (trucked) material volume

As discussed in the section "Correction factors to adjust for swell and shrinkage of materials," in Chapter 1, "Road Layout and Design," soil and rock material increases in volume when excavated from the bank (refer to Figure 3). Therefore, to estimate the loose volume (sometimes referred to as **trucked volume**), the bank volume, as measured from road cross-sections, must be increased by applying a suitable **swell factor**, according to the soil or rock type.

Examples of swell factors to convert from bank volumes to loose volumes are:

1.05 to 1.15 for sand and gravel,

1.15 to 1.35 for mixed soils, and

1.50 to 1.65 for blasted rock.

Refer to equipment supplier handbooks on materials handling and earthmoving to obtain representative swell factors for specific material types encountered during road construction.

Example

Loose volume = Bank volume × Swell factor.

Example: If the bank volume of a proposed rock cut is 9 m^3 measured from drawings, what will the loose volume be, or in other words what volume will have to be trucked? Assume a swell factor of 1.50.

Solution: Loose volume = 9 $m^3 \times 1.50 = 13.5$ m^3

Drilling and blasting

Blasting operations

The drilling and blasting techniques used should:

- minimize disturbance to forest resources and existing improvements
- minimize the potential for landslides or slope instability.

Many disturbances come directly from flyrock, such as:

- rocks embedded in trees, presenting hazards to fallers and mill workers
- trees blown over or otherwise damaged by air blast and flyrock
- carpeting of the forest floor with rock fragments, making reforestation difficult
- pile-up of blasted rock against trees
- physical damage to powerlines or other structures
- detrimental impacts to watercourses, creeks, or streams
- rocks hung up on slopes, presenting hazards downslope.

Blasting can create excessive site disturbance or increase hazards for slope instability in a number of ways:

- blast vibrations during periods of unusually wet soil conditions may lead to potential slope failures
- rock fragments may be projected outside the road prism and beyond the clearing width
- material may pile up or run out beyond the clearing width, especially on unstable slopes
- overbreak of uphill slope may create instability
- overbreak may induce rock fall or potential for rock fall later.

The objective of blast design is to fracture the rock mass in a controlled manner and permit the rock to move in successive stages toward a free face. Over-confinement of the rock at any point within a blast may lead to poor fragmentation and cause flyrock. Blasters should be able to assess rock and site conditions, formulate appropriate blast designs, learn from previous results, and immediately revise field practices to reflect changing conditions.

Where site conditions are complex or beyond the experience of the blaster, or the risk is severe, guidance from a specialist explosives engineering consultant should be sought. Good blast design considers the following:

- rock type and structure, including rock hardness, stratification, joint and dip orientation, and block size
- borehole diameter, length, and orientation—vertical drilling versus horizontal drilling—as appropriate to the blast objectives
- groundwater conditions
- burden and spacing
- weight and type of explosives
- collar length and stemming

- detonation method
- delay pattern
- measures for flyrock control.

Flyrock, or excessive throw, can originate at different points in a blast. It can come from:

- the forward movement or throw of the entire round
- the borehole charge breaking through the burden
- gas pressure forcing fragments into the air from within or around the collar of the borehole.

The degree or threshold of rock movement that constitutes flyrock varies depending on the blasting application. The Forest Road Regulation defines flyrock as “airborne rock displaced beyond the road prism by blasting.” Thus, the goal of blasting operations on forest roads is to minimize the amount of rock that is cast beyond the road prism.

It may be difficult to eliminate all flyrock from every blast because rock conditions and excavation requirements vary and can change frequently along the road location. Nevertheless, blasting crews and supervisors should be able to demonstrate that the practices they adopted were appropriate for the observed conditions, and that their practices were altered in subsequent blasts in response to changing rock conditions.

Causes of flyrock

Flyrock can be caused by:

- excessive amount of explosive
- inadequate burden
- faults and cracks in the rock
- inadvertent loading of explosives into voids or fissures in the rock
- spacing and burden that exceeds the depth of borehole
- inadequate type or amount of stemming
- over-confined shots
- inappropriate drilling and loading patterns
- poor selection of delay sequences.

Measures to minimize flyrock include:

- precisely orienting and drilling boreholes to maintain desired burden and spacing

- determining the appropriate quantity of explosive charge and distribution of this charge within and between boreholes
- specifying a firing pattern and selecting the delay sequence.

Where the rock hardness, weathering, and jointing is suitable, use of alternative rock excavation methods should be considered, such as rock breaking with a backhoe-mounted hydraulic hammer, and ripping by an excavator.

After a blast design has been prepared, additional measures may be taken to reduce the residual risk of flyrock. These include covering the blast area or flyrock-prone portions of the blast area with backfill materials, or by using blast mats.

A rule of thumb is to backfill to a depth not less than the collar distance (minimum of 1 m) with granular overburden. Backfilling must be done with extreme care to prevent damage to any exposed components of the blast initiation system. If backfilling is not practical on sidehill rock cuts, blast mats or guard logs may be suitable alternatives.

Rubber blast mats, constructed from tires, and steel mats, constructed from wire rope or chain-link type materials, are available. To avoid inadvertent damage to the initiation system, blast mats must be placed with care and not dragged into position over the loaded blast area.

Guard logs, secured by cables if necessary, may be placed prior to, or after, drilling and loading operations. In remote locations they are a convenient, if somewhat less effective, alternative to backfilling or blast mats.

Secondary blasting

Small-diameter drilling equipment, such as hand-operated rock drills, may be useful for some special construction tasks. Alternative construction methods can eliminate the need for drilling and blasting altogether. Non-explosive rock fragmentation agents can also be used.

For blasting individual boulders, a device that uses the energy from a shotgun-type cartridge may be considered. A borehole is drilled in the boulder and filled with water. When the unit is fired, a pressure impulse is generated in the water column, cracking the rock. Another option is a directional-blasting cone. Hydraulic excavator-mounted rock breakers are useful tools for many construction situations and rock types.

Controlled blasting

Controlled perimeter blasting refers to a number of techniques that provide a competent, stable excavation in rock. These techniques, including pre-shearing, post-shearing, and cushion blasting, minimize overbreak—which is the fracturing and loosening of rock beyond the intended final boundary of the excavation.

The most common controlled blasting technique is pre-splitting, also known as pre-shearing. With this technique, a series of closely spaced holes, 600 to 900 mm apart, are drilled along the boundary of the excavation. These holes, usually 51 or 76 mm in diameter, are loaded relatively lightly and fired simultaneously just prior to initiation of the adjacent production holes. The objective is to crack the rock along the blast perimeter, reflect the energy of the production blast, and direct the fragmented rock mass away from the back wall. The holes are usually applied in downholing situations and require precise alignment. A number of explosives have been designed specifically for controlled perimeter blasting.

Overlanding

Overlanding is a construction technique in which road fill is placed on undisturbed organic soil, stumps, and vegetative material (Figure 15). The objective is to distribute vehicle loads over weak soils using the inherent strength of the vegetation mat to support the weight of the road fill without disturbing subsurface groundwater flows. It is important that the vegetative mat remain undisturbed to prevent the unsuitable saturated soils below the mat from mixing with the imported subgrade material.

When stump heights will interfere with the finished road surface, stumps can be inverted so that the root mat of the stump partially supports the fill material (Figure 16). Generally, overlanding is done on relatively low, wet flatlands or over shallow depressions on stable terrain with slopes less than 20%.

Ditching is not recommended, unless the ditch is located a sufficient distance away from the road to prevent weakening of the natural vegetation mat under the road. Furthermore, ditches should not be excavated to obtain the required road fill materials. The undisturbed mat should allow subsurface water to flow under the road prism. Any required fill material should be imported from a suitable borrow area.

Overlanding techniques can include placing a layer of unmerchantable trees, logs, stumps, roots, or branches—known as corduroy or puncheon—perpendicular to the road centreline to form a mat for the road fill. The mat separates the road fill from the underlying soil and supports the fill. It is important to separate the underlying soil from the road fill because infiltration of topsoil into the granular material will degrade the strength of the road fill. The corduroy should be completely buried to prevent decomposition.

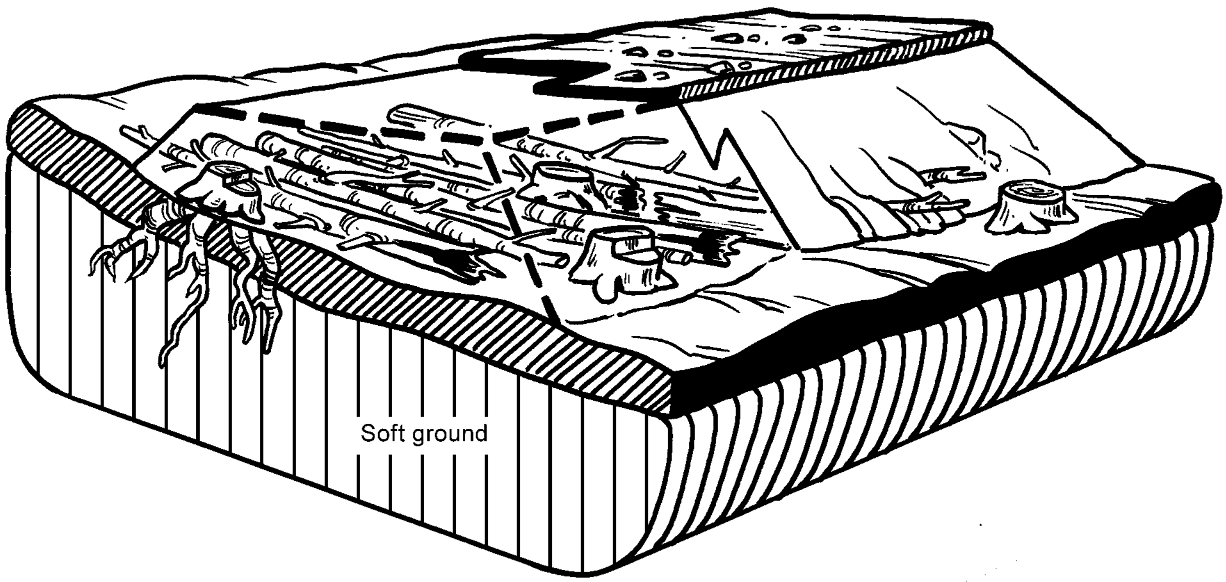

Figure 15. Overlanding cross-section with corduroy.

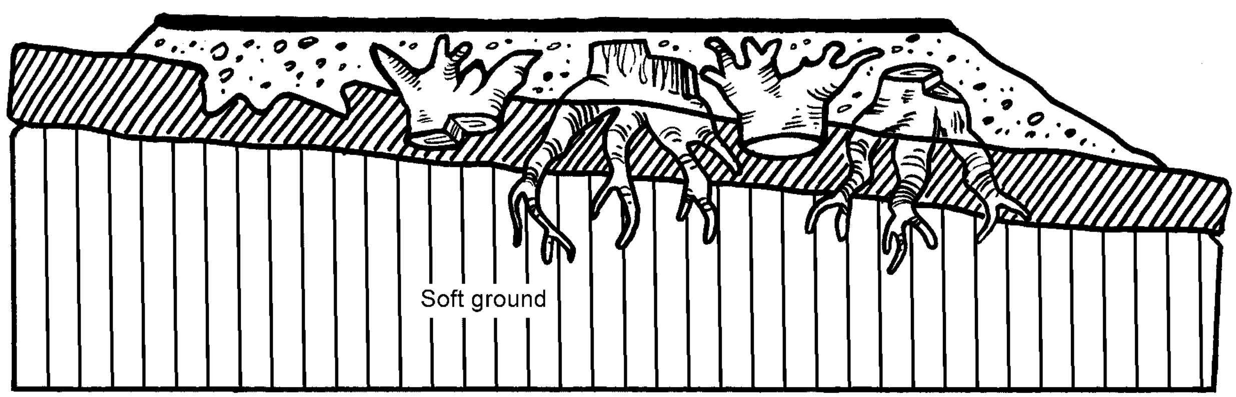

Figure 16. Overlanding cross-section with inverted stumps.

Geosynthetics can also be used to separate the underlying soil from the road fill. This is a method for separating materials and reinforcing the subgrade, but it requires careful preparation of the pioneer trail. A relatively smooth surface is preferred to prevent underlying debris and rock puncturing the geosynthetic. Where the risk of puncture is high, heavier geosynthetics are required to cover coarse ballast rock, or stumps.

Geosynthetics can also be used to reinforce the road fill structure. The subgrade and road fill must be built and compacted carefully to develop the necessary friction (or cohesion) between the fabric and adjacent material. The geosynthetic should be “anchored” within the structure to enable tensile forces to develop in the fabric under loading. This is difficult to achieve in the weak soil conditions typically found when overlanding. Therefore, in this application, the primary function of the geosynthetic is to separate the materials. Further information about the functions of geosynthetics and their application to forest roads can be found in *Basic Geosynthetics: A Guide to Best Practices* (Fannin 2000).

The amount of fill that is placed and compacted during overlanding must be sufficient for the anticipated loads. The depth of material is a function of soil properties (particularly bearing capacity), vehicle loading, season of use, and life expectancy of the road. The use of geosynthetics or puncheon can reduce the amount of road fill required and may also reduce future road maintenance requirements.

Borrow pit locations

Borrow pits and quarries must be excavated outside of riparian management areas. Ideally, they should be located where there is sufficient distance between the pit and the riparian management area to allow construction of sediment control devices that will minimize sediment transport beyond the pit.

The base of the pit should be sloped away from the stream, and drainage structures should be built to prevent water from entering the stream directly from the pit. Natural surface drainage patterns should be maintained.

Where the pit or quarry may encroach on the riparian management area, specific approval from the district manager, in writing, is required before works begin. Note that the district manager must first consult with the designated environment official regarding the approval of the pit.

If known acid-generating rock is encountered in pit development within a community watershed, further expansion of that pit should cease and backfilling to cover the acid-generating rock should begin. Drainage from the pit should be directed away from any stream. Acid-generating rock should not be used for construction purposes.

Winter construction of permanent roads

Where no other option exists, permanent roads may have to be constructed in the winter. Snow, ice, and frozen material should not be placed in the road fill. These materials cannot be easily compacted and settle when they thaw. This thawing then saturates the fill and creates voids that readily collapse. The resulting fill is not only unstable and low in strength, but also highly erodible and often a source of sediment, potentially causing severe damage to streams during the spring break-up period. Refer to “Construction and use of snow and one-season winter roads,” below, for use of snow, ice, and frozen material.

Protecting erodible fills located within floodplains

Where embankments must be constructed within active floodplains, action must be taken to prevent erosion of those embankments. The best way is to form the entire embankment of non-erodible material. Where this is not possible or practical, armouring of the fill is required.

Table 7 indicates the stream velocities that can erode different-sized materials.

If the embankment is to be formed by one of the materials in Table 7 and will likely be subject to velocities at least equal to those corresponding to that material, then armouring is required. There are several choices of armouring material:

- angular and durable rip rap
- sand bags (a short-term solution only, as bags break down over time)
- concrete: concrete blocks (quick, easy installation), sprayed concrete (shotcrete or gunnite), or poured-in-place concrete (uncured concrete products should be kept isolated from the stream until the concrete has cured)
- binwalls (for velocities less than 1 m/sec or in conjunction with rip rap and where suitable fill material—cobble, coarse gravel—is readily available)
- other commercial erosion control systems.

Whatever material is used, it should be:

- placed below the point of scour
- keyed in so that fill stability is maintained
- installed so as to prevent undermining of the fill
- sized to resist peak flow velocities
- graded to act as a filter to resist movement of underlying soil through the armouring material.

Table 7. Example erosion velocities.

Material	Diameter (mm)	Mean Velocity (m/sec)
Silt	0.005	0.15
Sand	1	0.55
Fine gravel	10	1.0
Medium gravel	25	1.4
Coarse gravel	75	2.4
Cobble	150	3.3

Litter, petroleum products, and other waste materials

All workers on the site should be familiar with the requirements for the use, storage, and disposal of litter and of equipment fuel and servicing products. Those most commonly associated with road construction are:

- petroleum products: waste oil, oil and grease containers, and spoiled fuel
- refuse: camp garbage, waste paper, old machine parts, and damaged culvert pipe
- batteries and battery acid
- sewage and litter: where camps are to be established, sewage disposal via permitted septic systems is required
- fuel storage: permit from the Department of Fisheries and Oceans is required for the establishment of fuel tank farms

Petroleum product spills are common and actions to contain the spill must be taken. Proponents should have a spill response kit on hand and ensure that all personnel are familiar with spill containment procedures.

Spill kit contents will vary by type of work, potential size of spill, and impact potential. Spill response equipment may be required for incidents from minor hydraulic leaks to major watercourse spills. At a minimum, each machine should have a spill kit with extra absorbents in the support vehicle.

As appropriate and in accordance with the *Waste Management Act*, waste and contaminated materials may be disposed of either by being:

- burned or buried, or
- contained and removed from the site to an approved disposal location.

Stabilizing the subgrade and surfacing the road

Ballasting

Ballasting is the use of rock to construct the road subgrade where other available material is incapable of supporting the design traffic load during the period of use.

Generally, suitable ballast material should:

- drain well
- form a structurally competent fill
- compact well
- resist erosion.

Surfacing

Surfacing the subgrade with pit-run gravel or crushed rock aggregate may be required for the following reasons:

- to form a driveable or gradeable surface
- where subgrade material is highly erodible and needs to be protected from water or wind action
- where subgrade material will not support traffic loading during periods of use.

Surfacing material selection

Surfacing materials include well-graded crushed rock and well-graded pit-run gravel aggregates. These materials should consist of inert, clean, tough, durable particles that will not deteriorate when worked (handled, spread, or compacted), or when exposed to water and freeze-thaw cycles. Aggregate particles should be uniform in quality and free from an excess of flat or elongated pieces.

The aggregate should be well-graded; that is, it should contain an even mix of all particle sizes. This is desirable for compaction as well as to ensure a durable wearing surface. Refer to the Ministry of Transportation *Standard Specifications for Highway Construction* for more detail and specifications for well-graded aggregates.

When the source material is a poorly graded material, screening the material to remove the excessive particle sizes or blending in the deficient material size should be considered.

Crushed aggregate is expensive to produce and should be protected with a base coarse stabilizer (e.g., calcium chloride or magnesium chloride, installed to the manufacturers' specifications) to prevent the loss of fines. Specifications for high fines crushed gravel should be obtained and rigidly applied when use of a calcium chloride or related stabilizer is being considered. Note that many stabilizers may not be acceptable in community watersheds or near licensed water intakes.

Surfacing compaction

Compaction of the subgrade and surface through the use of equipment designed for this purpose will increase the load-carrying capacity of the road bed and reduce the volume of surfacing material that will be required to maintain the road bed during its service life.

For optimum strength, the preferred material should be placed in uniform lifts compatible with the compaction equipment that is to be used. Each lift should be uniformly compacted before being covered with the next lift. To achieve the maximum compaction level, the material should be compacted at the optimum moisture content. A well-compacted material will generally resist human footprint depressions.

To achieve maximum compaction, moisture content is critical. Material that is too dry or too wet will have a lower compaction level. During the spreading phase, water should be added to dry material and the saturated material allowed to dry to achieve the optimum moisture content.

Construction and use of snow and one-season winter roads

Throughout much of the interior of British Columbia and in a few areas along the coast, winter climate conditions of frozen ground or deep snow fall, together with fine-textured soils and muskeg (bog) ground conditions, mean that forest operations are best conducted during the winter months. By using snow or frozen ground as the running surface, snow and one-season winter roads have a lower environmental impact than all-weather roads. The roads are constructed during the early part of the winter, so that harvesting can be completed before snowmelt and the break-up of frozen ground in the spring. If there is insufficient snowpack, these road types cannot be constructed.

Snow roads and one-season winter roads use the strength of ice and snow to produce a stable road bed that will support the design vehicle axle loads. In areas with heavy snowfall, the main reliance will be on the snowpack. Where snow is scarce, a small excavation may be required for the construction of a one-season road. In either case, weather is the essential and unpredictable factor in the construction process, and logistics are key to constructing and using winter roads effectively. Where mid-winter thaws are common, short spur roads can be constructed, used, and deactivated in a matter of weeks.

Generally, watercourses are frozen for the life of the road, and in many cases drainage structures may not be required. Snow fills are compacted across small streams and gullies with the use of log bundles to pass any seepage that may occur or to reduce the volume of snow required. Where mid-winter thaws are common, culverts may be installed in the snow fill to accommodate possible flowing water.

Deactivation of these road types should be co-ordinated with operations and be completed prior to the spring freshet. All natural drainage channels should be restored while road access is available. Logs should not be left in stream channels and snowfills should be breached to prevent the damming of watercourses. Though mid-winter thaws can disable even a well-built road, the high-risk period begins during the spring break-up period. In many areas during this period, snowmelt occurs very quickly, resulting in rapid overland flows of meltwater, high flows in watercourses, and an extreme softness of soil materials, which renders them highly susceptible to erosion. Any soils that have been mixed with snow become fluid and highly susceptible to mass erosion. Spoil material piled on top of a snow layer can become unstable on even gentle side slopes. For more information on deactivation techniques, refer to Chapter 6, "Road Deactivation."

Snow road construction

Snow roads are a form of overlanding construction in which clean snow and ice are used as fill (Figure 17). Suitability of materials is not critical because materials are frozen and can support the design vehicle axle loads. Snow roads are appropriate for providing access across gentle terrain to winter-harvest–only areas, which are located mostly in the Interior. Snow roads are limited to terrain with slopes less than 20%, unless there is a very deep snowpack. The surface is often built up with ice by using water in areas of flat terrain with a minimal snowpack.

No excavation is permitted (cut slopes or ditches) other than the removal of the occasional stump that cannot be readily covered with snow and ice. The road may be reconstructed and re-used each winter in the same location.

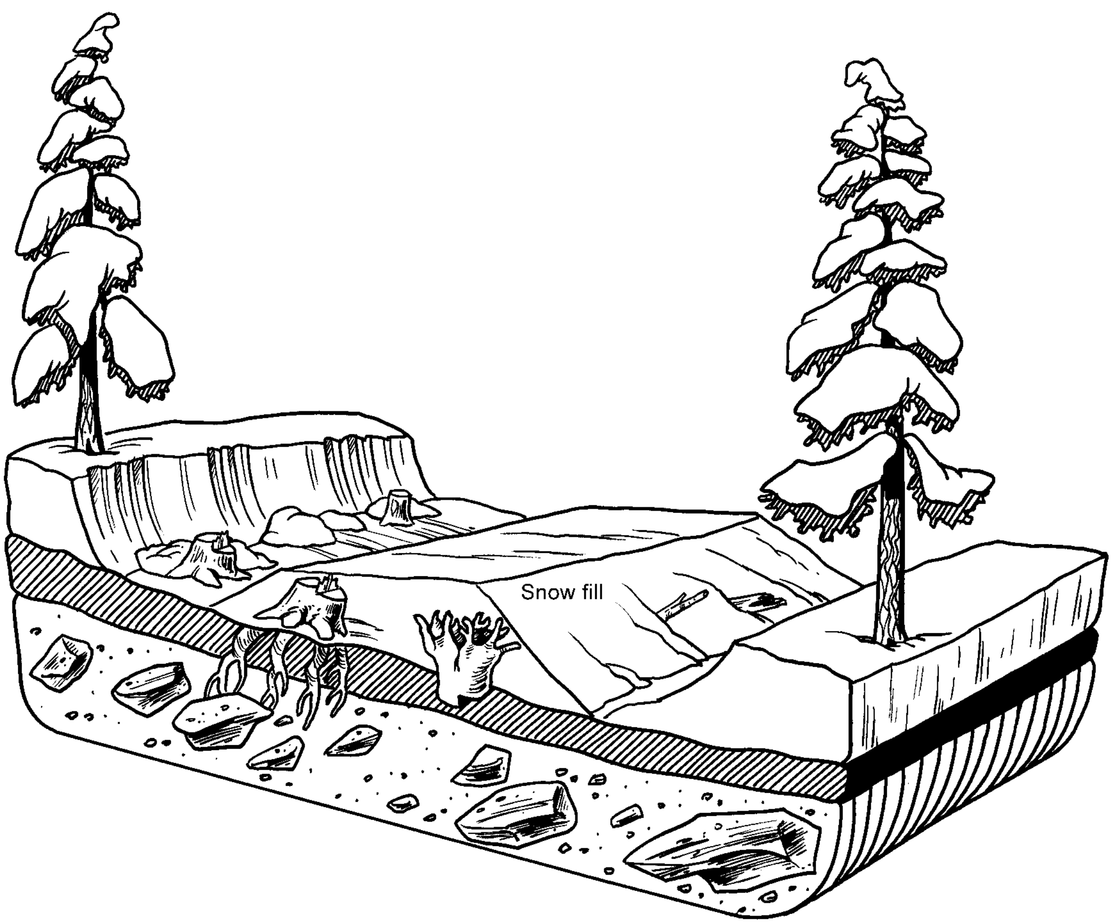

Figure 17. Typical snow road.

One-season winter road construction

Similar to snow roads, one-season winter roads are constructed mainly from snow and ice, with a minimal amount of soil (10–20%) to assist the freezing-in of the road, or to provide a more durable surface where infrequent mid-winter thaws may occur. They are suitable for temporary access to winter harvest areas for one season only and are not intended to be reconstructed.

Because of the high risk of sediment deposition during the spring freshet, soil should not be mixed with snow in the riparian management area of stream crossings. Log bundles and clean snow only should be used in gullies and riparian areas.

Stripping is to be limited to the removal of large stumps that cannot be easily covered with snow or ice. Cuts into mineral or organic soil should not exceed 300 mm in depth for sustained distances on slopes greater than 15% or 500 mm in depth for short distances on steeper slopes up to 35%. Figure 18 shows a finished one-season winter road.

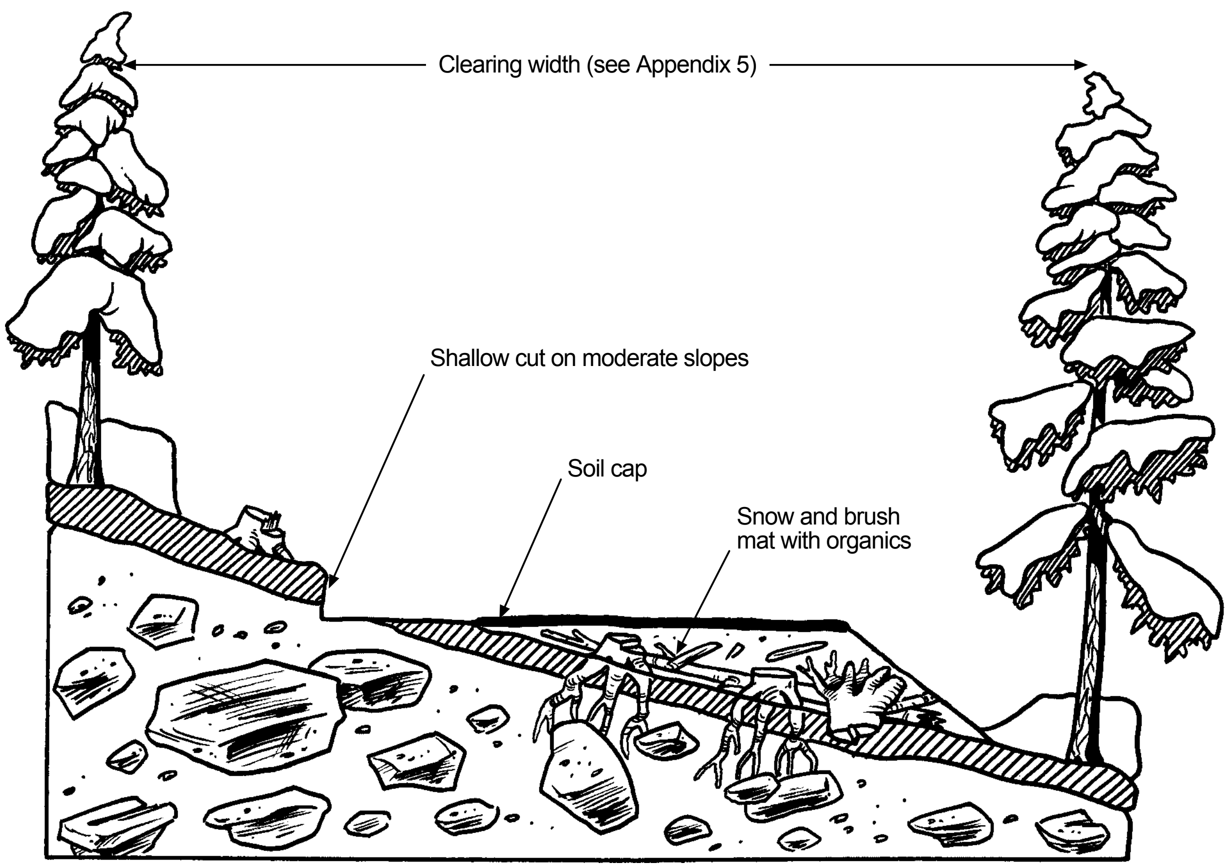

Figure 18. One-season winter road.

For one-season winter roads, a mixture of dirt and snow on the road surface can provide a stable roadway when frozen, but it becomes highly liquid during spring thaws. Any appreciable side slopes or gradients may result in mass erosion from the roadway. Waste areas constructed on top of snow can become unstable during melt periods, or can create a situation where meltwater on the roadway cannot run off the road but only run down it. To address these concerns, consider the following:

- plan for and install deactivation works during the original road construction wherever possible—this will help to decrease the amount of maintenance and deactivation needed during the summer months, when these types of roads are generally impassable
- construct swales, insloping and outsloping the subgrade, or install log-filled cross-ditches so deactivation requirements will be reduced
- where possible, overland the road with a brush mat and snow excavated from the clearing width
- use a small amount of unfrozen dirt as a freezing agent to construct the road surface
- breach berms and snowbanks at intervals of no more than 50 m
- smooth the road surface at the time of construction to avoid building in ruts and other irregularities
- construct waterbars on long grades
- remove fills in natural drainage channels
- pull back soil-contaminated snow fills in the vicinity of stream crossings
- take measures to prevent sediment from entering streams around crossings.

Road use

Mid-winter thaws are commonplace in the Interior and can disable even a well-built road. Because of heavy use and adverse weather, rutting and deformation of the road surface can occur as the subgrade begins to thaw. Roads should be used only in frozen conditions.

- Schedule night hauling when temperatures are expected to be above freezing during the day
- Strictly control all light traffic during unfrozen conditions.

Construction of 5-year roads

The introduction of stumps, roots, and embedded logs into the road fill under the travelled portion of the road reduces the long-term stability of the fill. The buried organic material will deteriorate over time and begin to settle. This removes support for the applied wheel loading and results in rutting of the road surface. Water ponding in the ruts may saturate the road fill and lead to failures. Thus, the use of roots, stumps, and embedded logs in the road fill should be restricted and the requirement to permanently deactivate these roads within 5 years of construction enforced.

The life of a 5-year road may be extended up to 10 years, but only if regular inspections indicate that the road fill is stable and can still support the design vehicle axle loads. If the road fill begins to show signs of failure, or after the 10 years have passed, the road must be permanently deactivated or reconstructed.

Surface erosion and sediment control

Control of surface erosion and subsequent sediment transport during road construction is a concern where there is direct or indirect connectivity to aquatic habitat or aquatic resources. Soil disturbance is inevitable from most road construction or modification activities. As erosion control has a generally higher level of effectiveness than sediment control, the primary goals should be, firstly, to minimize potentially damaging erosion of the disturbed sites, and, secondly, to limit the transport of sediment from these sites.

Surface soil erosion control techniques

The best way to minimize soil erosion is to cover all exposed soils with vegetation. This vegetative cover should be established as soon as possible to protect and hold soil particles from the erosive effects of rainfall. It should be applied as soon as slopes are completed, rather than after the entire road project is complete. Prompt revegetation not only helps for erosion control; it also helps to prevent the spread of noxious weeds.

Surface soil erosion control techniques include, but are not limited to, the following:

- confinement of sensitive operations to periods of dry weather and selection of equipment that will create the least disturbance
- compliance with local rainfall shutdown guidelines
- temporary diversion and/or impoundment of stream flow to reduce the exposure of disturbed soil to flowing water during stream-crossing structure construction
- installation of silt fencing or erosion control revegetation mats
- installation of rock check dams or placement of rip rap to reduce water velocity and scour potential
- installation of sediment catchment basins.

Refer to the Ministry of Forests *Best Management Practices Handbook: Hillslope Restoration in British Columbia*, and other references cited, for more detailed information on control of soil erosion and sediment transport.

Sediment control techniques

Consider the following measures to minimize sediment transport away from the road prism:

- apply grass seed as soon as practical following completion of an area of construction
- install silt fencing, hay bales, or erosion control revegetation mats
- install rock check dams or place rip rap to reduce water velocity and scour potential and to provide for temporary sediment retention
- install sediment catchment basins
- confine sensitive operations to periods of dry weather, minimize traffic through these areas, and select equipment that will create the least disturbance (e.g. rubber-tired or rubber-tracked machinery)
- for stream culvert installations, use temporary diversion or impoundment of stream flow to reduce the exposure of disturbed soil to flowing water (but obtain prior agency approval if required).

Refer to the Ministry of Forests *Best Management Practices Handbook: Hillslope Restoration in British Columbia* for more detailed information on control of soil erosion and sediment transport.

Revegetation

Grass seeding with a grass and legume seed mixture on exposed soil is the most common and usually the most cost-effective means of treating roads to prevent erosion.

There is a variety of erosion seed mixes available that provide for rapid germination and long-term growth to provide a solid sod layer. Care should be taken to ensure that the seed species selected are compatible with domestic livestock. For some areas, it may be desirable to select a seed mix that will not encourage grazing by livestock.

- Apply seed in accordance with vegetation specifications to all exposed soil that will support vegetation. For example, seed areas of road cuts, ditchlines, fill slopes, inactive borrow pits, waste areas, and other disturbed areas within the clearing width.
- Dry-broadcast seeding immediately following construction works is the most common means of applying seed, whether by hand using a handheld “cyclone” type seeder or by machine such as a vehicle-mounted spreader or a helicopter-slung bucket. In most cases, a light application of fertilizer will assist in initial establishment and growth.
- Hydroseeding (i.e., a mixture of seed, fertilizer, mulch, tackifier, and water applied as a slurry mix) can be used for revegetation of roads,

although it is more costly. It is the most effective method of obtaining growth on steep or difficult sites.

In some locations, natural revegetation may be appropriate. Note that this option requires the district manager's approval, but the proponent is still responsible to ensure that the area is completely revegetated within 2 years.

Road works shutdown indicators and procedures

This section describes the visible weather and soil-related conditions that proponents can use on site to help them determine when forest road operations should be shut down because works are causing, or may imminently cause environmental damage.

The objective is to reduce potential adverse impacts on forest resources such as:

- slope failure originating within the limits of the construction site or in the adjacent terrain
- surface erosion of exposed soils
- sediment transport to fish streams.

When a qualified registered professional develops a prescription for a road-related activity in areas of moderate or high likelihood of landslides, that prescription should contain site-specific, weather-related shutdown indicators, and start-up requirements.

Activities in saturated soils

Listed below are activities that may normally be conducted in areas of saturated soils:

Roadway construction:

- hand falling
- blasting in low landslide hazard terrain units
- installation of clear span stream culverts where sedimentation will not reach fish streams, fish lakes, marine-sensitive zones, or community water supply intakes
- installation of cross-drain culverts where sedimentation will not reach fish streams, fish lakes, marine-sensitive zones, or community water supply intakes
- placement of shot rock surfacing
- bridge construction (excluding instream works).

Under certain conditions, some works can be performed without adversely affecting resources. For example, machine falling or gravel surfacing may be done on competent well-drained soils.

Roadway maintenance:
Only in emergencies is it appropriate to carry out maintenance during high water flow or saturated soil conditions. For example, if a culvert is plugged and is starting to, or will imminently, wash out a roadway, fill, or structure, then the problem should be rectified immediately. Failure to carry out such works may result in loss of improvements and unacceptable impacts to other resources. If adverse impacts indeed occur during such maintenance work, the appropriate agencies should be notified at the earliest possible time.

Procedures for shutting down operations

Works should cease before soils are visibly soft or muddy and associated silty waters or sediment are flowing toward streams, lakes, or marine-sensitive zones or where such conditions are reasonably anticipated to develop. The equipment operator is usually in the position to first recognize signs of pending erosion on site.

Before shutdown, drainage should be controlled to ensure that no subsequent adverse impacts occur. Protective measures should be carried out in the localized work area, primarily on sites where works are not at a completed and controlled stage. Note the following general requirements:

- Minimize sediment delivery from stockpiled erodible soils.
- Leave drainage systems functional.
- Add water control measures such as cross-ditches and waterbars, where appropriate.

Limit use of the road to minimize adverse impacts

Traffic should be restricted where works are shut down because of saturated soil conditions. Temporary signs should be posted warning of the danger, and the district manager should be advised of the necessity to close the road to all traffic.

Suggestions for further reading

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