4. Road Drainage Construction

Introduction

To minimize negative impacts on the environment, forest road drainage systems should maintain surface drainage patterns. This is accomplished by installing drainage structures and ditches that are sound, functional, and stable.

This chapter discusses:

- maintaining surface drainage patterns, both during and after construction
- temporary stream crossings
- ditch construction considerations
- cross-drain culvert location and installation
- backfilling and compaction around pipe culverts
- log culvert design and construction
- ford design and construction on non-fish streams.

Maintaining surface drainage patterns

To maintain surface drainage patterns, water should be kept in its own drainage area, unless moving it to another area is necessary to avoid unstable or sensitive soils.

The potential for adverse upslope, downslope, and downstream impacts should be considered before culvert locations and outlet controls are determined. Measures to accomplish the latter include installing flumes or rip rap, or carrying drainage flow farther along the ditchline to discharge it onto stable slopes.

Drainage systems are used to intercept and manage surface or subsurface drainage. If the soils are easily erodible, the ditch gradient, alignment, or cross-section may need to be changed, or extra culverts added, to reduce the distance over which water will have to be carried.

To minimize sediment delivery to streams, the water conveyed in ditches and cross-drain culverts should not discharge directly into streams. These flows should be allowed to settle out through the natural vegetation on the forest floor before reaching any stream. Alternatively, these flows can be filtered in other ways, including the use of settling basins or geosynthetics, until vegetation can be re-established.

Drainage systems, whether permanent or temporary, should be constructed concurrently with subgrade construction. For a tote road or pilot trail, these should be functional to accommodate surface and subsurface drainage runoff throughout the construction period. Permanent structures should be installed during the construction period, and temporary structures removed.

Temporary structures, such as cross-ditches, swales, and open-topped culverts, should be constructed as water is encountered. Such structures should be capable of accommodating the peak flows likely to be encountered during construction. If the site is left unattended and a storm takes place, the in-place drainage structures should handle the runoff without damage resulting to the road or other resources.

Practices to control drainage during construction:

- Stockpile an adequate supply of culverts, rip rap, geotextiles, silt fencing, and grass seed on-site for immediate and future use, and to avoid construction delays.
- As water is encountered, establish adequate drainage to ensure flows are controlled and, where required, water quality is maintained should a peak flow event occur.
- Construct the final drainage structures as early in the construction process as practicable.
- Construct silt traps, armoured ditch blocks, and aprons as construction progresses or as soon as soil conditions allow.

Practices to protect water quality:

- Avoid working in areas of ponded water or saturated soils where this could result in negative impacts on other forest resource values.
- Construct stable cut and fill slopes.
- Avoid in-stream work as much as possible. Where in-stream work is necessary, obtain appropriate agency approval before starting the work.
- Install sufficient cross-drains and ditch blocks to keep ditchwater from eroding the ditchline.
- Install erosion-resistant aprons at the inlet and outlet of culverts.
- In ditches, use armouring, geotextile or silt fencing, blocks, or traps to minimize erosion.
- Revegetate exposed erodible soils as soon as possible. Seeding cut slopes and ditchlines is a very effective erosion control technique.

Silt fencing, straw or hay bales, and silt traps are maintenance-intensive, temporary construction measures and should be removed when no longer required.

Temporary stream crossings

This discussion applies only to non-fish streams. Pilot trails (tote roads) are usually required for harvesting merchantable timber within the road clearing width. Landings should be located to minimize skidding across drainage structures. If temporary stream crossings are required, the district manager's approval must be obtained, and the crossings constructed in accordance with applicable timing windows and measures provided in writing by a designated environmental official. For construction of snow or one-season winter roads, it may be acceptable to construct crossings using snow fills with or without culverts, depending on expected flows.

To reduce adverse impacts on the stream bed and its banks, it is expected that the temporary crossing will be in the same location as that of the permanent structure. If the temporary crossing will be in a different location, a separate approval by the district manager is required as part of the overall harvesting approval.

Refer to the *Fish-stream Crossing Guidebook* for requirements for temporary crossings of fish-bearing streams.

Depending on the season the crossing is constructed and used, there are options as to the type of temporary crossings installed. These may include snow fills, fords, log bundles, and log skid or portable bridges. The structure must be able to handle peak flows during the period of time it will be in place without causing negative impacts on the stream bed. It should ensure flows are confined to the stream channel, which is particularly important where, if water escaped, it would continue down the road grade. The permanent structure is to be installed as soon as conditions permit.

Other points to consider concerning temporary crossings:

- Structures that clear-span the stream and its banks—such as portable bridges or log skid bridges—have the least chance of causing negative impacts.
- Temporary culverts with brow logs can be used to protect the culvert ends if skidding is planned.
- During periods of low stream flow, it may be appropriate to carefully place two parallel rows of boulders across the stream channel, with each row beneath the full width of the equipment tracks to provide suitable support of equipment loads.
- Logs placed longitudinally (in the direction of stream flow) across the base of the stream channel to support equipment tracks above the water level may be acceptable during low stream flow.

Temporary in-stream structures should be removed in accordance with the road layout and design and with any deactivation measures, which may include full rehabilitation of the secondary crossing.

Ditch construction considerations

Several factors should be considered in construction of ditches so that both surface and subsurface flows do not cause excessive ditch or roadway erosion. These include ditch soil conditions, gradient, alignment, cross-section, ancillary works, ditch stabilization, and alternatives to ditching where ditching is inappropriate.

Ditch soil conditions

Ditch soil conditions will influence erodibility. Finer textured, non-cohesive soils will be more readily eroded than coarser materials, or cohesive soils.

Ditch gradient, alignment, and cross-section

How a ditch is configured, as shown on a plan profile and cross-sectional design, is critical to ensuring that water flow can be managed properly. Both gradient and path should be considered.

Ditch gradient:

- The ditch gradient is largely dictated by the vertical alignment of the road. Ideally, the gradient should be a minimum of 2% to ensure that water will flow and not pond. Lower gradients can still be effective, but may require a higher-than-routine level of inspection and maintenance.
- Under certain conditions, ponded water can lead to a saturated subgrade. This can contribute to severe roadway rutting, siltation, and possible failure of the roadway prism, as well as sediment deposition and plugging of cross-ditch culverts—negative impacts that can occur in both gentle and steep terrain.
- Ditch gradients in granular soils should be just steep enough to keep intercepted water moving to relief culverts without carrying excessive sediment.
- Steeper ditch gradients in erodible soils generally increase the likelihood of erosion and sediment transport. More frequent culvert placement and armouring should be considered.

In general, mid- and upper-slope roads require shorter ditch lengths than do valley-bottom roads, primarily because of the steeper ditch gradients and fewer well-defined stream channels on the slopes. On valley bottoms, by comparison, ditch gradients are usually gentler and downslope erosion concerns pose less of a problem. Drainage systems should be evaluated across the slope to review adequacy of flow paths created by the ditch and cross-drain network down the slope.

Ditch alignment:

- Abrupt water flow changes should be avoided. Sharp angles in the ditch alignment, or flow obstructions in the ditch, such as boulders or rock outcrops that can potentially deflect water into the subgrade or cut banks, can result in erosion of the subgrade or undermining of the cut bank.
- Sometimes it is necessary to carry a ditch farther than what would be ideal to limit ditch erosion, such as in areas of through cuts, or across areas of sensitive downslope soils where concentrating water could lead to small or mass failures. To limit ditch erosion, for example, it may be necessary to:
  - armour the ditch with angular shot rock
  - line the ditch with an appropriate geosynthetic
  - construct an erosion-proof check dam, or series of check dams within the ditchline, where velocity is also a concern. If not properly designed, however, check dams can create severe erosion holes below the dams and may require a high level of maintenance.
  - vegetate ditches (see "Ditch Stabilization," below).

Ditch cross-section:

- Ditches should be of sufficient depth and flow capacity to transport anticipated drainage flows.
- In cross-section, ditches should be sloped to a stable angle and designed to have adequate hydraulic and minor debris-carrying capacity, and should limit water velocities to prevent accelerated ditch erosion.
- Additional capacity for water flow, sloughing, and minor debris can be obtained by widening ditches.
- The ditch should be adequate to provide drainage of the uphill slope, the roadway surface, and minor debris (leaves, twigs, and small woody debris).
- U-shaped ditches should be avoided because the almost vertical sides tend to ravel or slough, undermining the cut slope and the shoulder of the roadway.
- Ditches should have a uniform cross-section for safety and ease of maintenance. Wide ditch bottoms facilitate grading operations where side borrow methods are used.

Ancillary works

The following features are associated with ditches:

Inlet armouring to protect the road fill from erosion as the water flows into the cross-drain culvert inlet.

Inlet basins are depressions dug at the inlet of cross-drain culverts. They are intended to trap material that could, over time, restrict the intake flow or infill and plug the culvert. Properly installed, inlet basins can reduce maintenance frequency. They are required where fine-grained sediments are anticipated from ditch erosion or minor sloughing, and where woody debris movement is expected along ditches in harvested openings.

Sediment settling ponds differ from ditch inlet basins in that they are designed to allow sediment to settle for later removal. They are generally located downslope of the roadway, but in some instances may be incorporated into sections of ditchline. They are effective only under low-velocity water conditions. The configuration and depth of settling ponds should be adequate to allow sediment to settle and to facilitate cleanout. The backslope of unstable settling ponds can be armoured with placed shot rock or stabilized with placed large boulders.

Settling ponds are a temporary measure to protect water quality during construction. If designed for long-term use, access is required to facilitate routine maintenance. Ponds may be vegetated to assist filtering sediments.

Ditch blocks are installed to direct flows into the culvert inlet. They are constructed of erosion-resistant material, with the crest being approximately 0.3 m lower than the adjacent road grade. This elevation difference is critical because if the culvert becomes plugged and the water rises above the ditch block, then the flow will continue down the next section of ditchline rather than being directed onto the roadway surface.

Where ditches converge, ditch blocks are not required.

Take-off or lateral ditches are constructed leading away from the culvert outlet to ensure there is a positive flow away from the roadway. Their design should be in keeping with existing drainage patterns, to ensure that the flow is dissipated or controlled.

A take-off or lateral ditch is required where a minimum grade is needed to ensure that water will carry fines away rather than depositing them at the culvert outlet and restricting normal flow.

Where it is neither practical nor environmentally sound to disperse ditchwater immediately before the ditch reaches a stream, and where sediment transport is anticipated, the construction of a check dam, settling pond, silt fence, slash filter windrow, or other sediment catchment device should be considered. These sediment catchment facilities require routine maintenance to be effective.

Ditchwater should be dissipated through cross-drain culverts and a vegetated filter zone before the flow can reach a stream. Care should be taken to select an outflow location that will not destabilize the gully sidewalls and so create a larger sediment source.

Ditch stabilization

In addition to armouring ditches with shot rock or lining them with a geosynthetic, other options are available to minimize ditch erosion.

- In erodible soils, the ditchline can be seeded or an anti-wash vegetation fabric installed. This can be very effective under low-velocity flow conditions and on soils that are erodible, and it usually helps to establish grasses. In erodible soils, it may be necessary to widen the ditch, as well as slope the sides more gently than normal.
- In some cases, polymer stabilizers (soil binders) can be sprayed within the ditchline. The manufacturer's assurance should first be obtained that use of the stabilizer will not result in adverse impacts, such as leaching, on stream water quality.
- If soils upslope of the ditchline are sensitive, then ditchline erosion treatments can be incorporated at the same time. The prescriptions may or may not be identical.
- In rare situations where the stabilization options described above do not work, consideration could be given to armouring.
- It is important that grader or other machine operations do not disturb the ditchline stabilization measures. Should this occur, the ditch should be re-stabilized as soon as practicable.

Alternatives to ditching

In some instances, ditches may be inappropriate:

- on sites where there is a need to minimize bench cuts for stability or economic concerns (e.g., to reduce the volume of blasted rock)
- on sites where there is a need to minimize the amount of site degradation
- on ridge or hilltop roads where natural drainage occurs
- along one-season winter roads.

Nevertheless, cut slope and roadway drainage should still be accommodated in the above situations, with the use of:

- subdrains (such as French drains) in place of ditches
- French drains in place of ditch relief culverts
- road surface drains such as dips and swales
- road insloping or outsloping
- open-top ditch relief culverts
- erosion-resistant surfacing.

Cross-drain culvert location

How far water should be carried in a ditch before being dissipated away from the road prism depends on: water volume and velocity, soil types, hillslope aspect, elevation, vegetation, rainfall intensity, the incidence of rain-on-snow events, and downslope conditions. With so many factors influencing placement of cross-drain culverts, it is not recommended that spacing tables be used unless the designer has experience and augments the tables with consideration of site-specific conditions.

Typical locations for cross-drain culvert placement are:

- at the top of a steep gradient—the intent is to prevent accelerated ditch, subgrade, or cut bank erosion by dispersing ditchwater before its volume and velocity increase downgrade
- at seepage zones
- at zones that have localized overland flow with no defined channels—it is critical to ensure that ditchwater is dissipated at the downgrade side of these zones—otherwise water flow will carry on to the next segment of the ditch, thereby increasing the flow at the start of the next section of ditchline and increasing the potential for erosion and natural drainage pattern disruption
- at any location where accelerated ditch erosion could potentially begin—again ditchwater volume and velocity should be dissipated to prevent build-up and the risk of adverse impacts on improvements and other resources
- at low points in the road profile
- where ditchline bedrock approaches the elevation of the finished grade
- immediately prior to sections of cut slope instability or ravelling
- prior to large through cuts that may be drainage divides
- at any other location found necessary during construction, or evident during maintenance inspections.

Cross-drain culverts and ditches at switchbacks often need site-specific consideration.

For forest road construction, unless soil and runoff conditions require increased sizes, recommended minimum pipe culvert diameters are 400 mm for dry sites and 600 mm for wet sites. The culverts addressed here have a design discharge of less than 6 m^3/sec and a diameter of less than 2000 mm. Culverts larger than this must be designed by a professional engineer. Refer to Chapter 2, "Design and Construction of Bridges and Stream Culverts" for more information.

Cross-drain culvert installation

Proper installation of cross-drain culverts—regardless of the material used—is critical to ensuring that road stability will not be compromised by ineffective drainage.

- To prevent drain water from being directed over erodible fills, construct settling ponds adjacent to every cross-drain culvert.
- Make culverts long enough to ensure that the inlet and the outlet cannot become blocked by the encroachment of road embankment fill.
- Protect unstable or erodible fill at culvert outlets with flumes or other erosion-resistant material, and protect inlets to prevent scour and erosion.
- Install cross-drain culverts at a gradient of 1–2.5%. Shallower gradients may allow silt to build up inside the pipe. If the gradient needs to be steeper than this, consider providing outlet protection.
- To encourage smooth entry of ditch flows, skew cross-drain culverts to the perpendicular to the road centreline, by 3 degrees for each 1% that the road grade exceeds 3%, to a maximum of 45 degrees.
- Excavate unsuitable materials beneath the pipe and replace them with suitably compacted fill to provide a firm and uniform foundation.
- Install seepage barriers or collars where necessary.
- Remove large rocks or ledges and replace them with suitably compacted fill before the pipe bedding is prepared.

Backfilling and compaction around pipe culverts

The ability of a pipe to maintain its shape and structural integrity depends on correct selection, placement, and compaction of backfill materials, and adequate depth of cover for the pipe material selected.

The likelihood of a culvert failure increases with a lack of adequate compaction during backfilling. Consideration should be given to suitably compacting the culvert backfill during installation, especially for 1200 mm pipes and larger. In general, the procedures below should be followed:

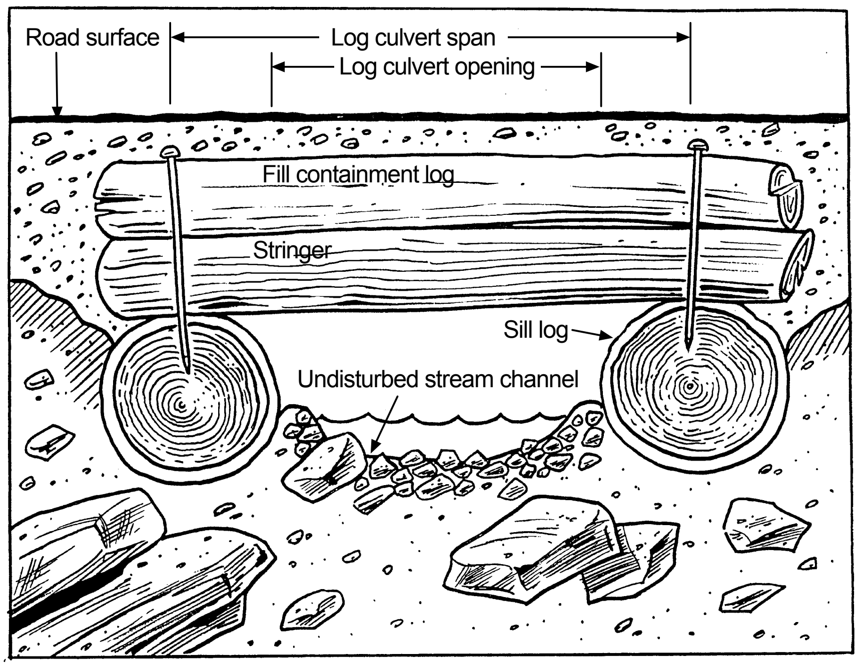
- Select good backfill material.
  - A granular non-saturated backfill material should be used. Pit-run gravel or coarse sands are usually satisfactory.
  - Cohesive materials may be used as backfill material if careful attention is given to compaction at optimum moisture content.
  - Avoid placing large angular rock, boulders, snow, or ice within the backfill material.
- Ensure adequate compaction under haunches.
- Maintain an adequate width of backfill.

- For culverts 1200 mm and larger, place backfill material in layers of 150–200 mm.
- Balance the fill height on either side as backfilling progresses.
- Compact each layer before adding the next layer.
- Adequate compaction will help to maintain the manufactured shape and help minimize cross-sectional deformations.
- Do not permit construction vehicles or equipment to cross the structure until the minimum allowable depth of cover has been placed.

Log culvert design

A log culvert is a log structure having a span of less than 6 m between bearing points and an abutment height (if constructed as a log crib) of less than 4 m measured between the underside of the lowest crib log to the underside of the stringers.

Elevation view



Notes:

- Opening size: must pass peak flow for 100-year return period plus minor debris.
- Road width: varies with road curvature.
- Log culvert length (as measured parallel to stream): varies with road width, height and type of fill, culvert gradient and skew.
- Sill logs: place outside stream channel and below scour level; species can vary. Minimum diameter should be about 300 mm; long enough to support stringers, fill containment logs, and road fill.
- Non-woven geotextile (filter cloth)
- Stringers (puncheon): match in diameter and taper, and be free of decay and excessive crook or sweep; spiral grain should be less than 1 in 8. Knot size in middle should not exceed 125 mm. See Table 8 for sizing.
- Fill containment logs: minimum diameter 400 mm. See Figure 20. If lashing is used, inset the cable to protect it from damage by road maintenance equipment.
- Connections:
  - – stringers to sill; 12 mm spiral drifts
  - – fill containment log to sill: 19mm spiral drifts or four wraps of 19 mm diameter 6 × 9 fibre core wire rope.
- Inlet control: place shot rock to protect against fill erosion below the design flood level.
- Outlet control: place rock as required to prevent outlet scouring and undermining of the sill logs.
- In the case of a skewed log culvert, the span of the stringers for design purposes is measured from bearing to bearing along the stringers and not at right angles to the sill logs.

Figure 19. Simple log culvert.

Log culverts are used, for example:

- for streams where other resource agencies require the stream banks or stream bed to be undisturbed
- on steep-gradient streams.

Where the planned service life of the road is less than the life expectancy of the crossing components, log culverts may be used:

- as temporary structures on tote roads or pilot trails
- on short-term, or permanent, roads where ongoing minor debris problems are anticipated
- on permanent roads as temporary drainage structures at the clearing or subgrade construction stage, until the permanent drainage structures are installed.

Each log culvert design should address the following:

- opening size for design flow and debris management
- culvert length and fill and surfacing requirements
- superstructure design (stringer or puncheon sizing)
- substructure design (sills, mud sills, and foundation logs)
- inlet and outlet protection requirements.

Log culvert opening size

All log culverts for streams must be designed to pass the 100-year return peak discharge and should be situated so that the structure, including its sills, is outside the design flood level. To determine this value, refer to "Estimating design discharge for streams" in Chapter 2, "Design and Construction of Bridges and Stream Culverts."

In addition to passing the Q_{100} peak discharge, log culverts should be designed to manage anticipated debris. Options may include, but are not limited to:

- increasing the opening size—height, width, or both
- allowing debris to pass over the approaches
- trapping debris with a specially fitted trash rack or other device
- combining these and other options.

Debris catchment devices should be inspected frequently and cleaned as required. This aspect of the design is a site-specific consideration and may require professional input. Debris problems may be identified from terrain hazard maps, air photo interpretations, field investigations, and reports for the area. Use of the *Gully Assessment Procedure Guidebook* is recommended.

The convention for specifying the opening size (inside measurements) of a log culvert is height (vertical distance between the deepest point along the channel floor and the soffit of the stringers) followed by width (horizontal distance measured at right angles between the inside face of the sill logs).

Log culvert length

Culvert length, as measured in the direction of the stream or watercourse, is determined by considering the following:

- road width
- depth of road fill over the log culvert, and fill slope angles
- type of fill over the log culvert
- inlet and outlet treatments
- culvert gradient
- culvert skew.

Road width

If the culvert is located within a horizontal curve, extra road width to accommodate side tracking of logging trucks and hence additional culvert length is required. The required width can be found in Table 2 in Chapter 1, "Road Layout and Design."

Depth of road fill

Use of deep road fills on top of the log stringers is not recommended. Should a failure occur, there is a potential for large volumes of sediment-producing materials to enter the stream channel. Measures to reduce road fill depth include:

- use of a longer span culvert, or a bridge for V-shaped channels
- increasing the culvert height, by use of log cribs
- relocation of the road to a more suitable crossing.

Log culverts requiring road fill depths greater than 2 m should be reviewed by a professional engineer, and deactivation plans should address fill removal measures that prevent material from entering the stream's wetted perimeter. Log culverts should be sufficiently long to contain the fill and prevent material from entering the stream. As the fill height increases for a given roadway width, so should the culvert length.

Road fill containment measures should be incorporated into the design. This can be achieved by making the culvert extra long (at least 1 m per side beyond the toe of the road fill), and securing a large containment log (at least 400 mm diameter) at the toe. See Figure 20.

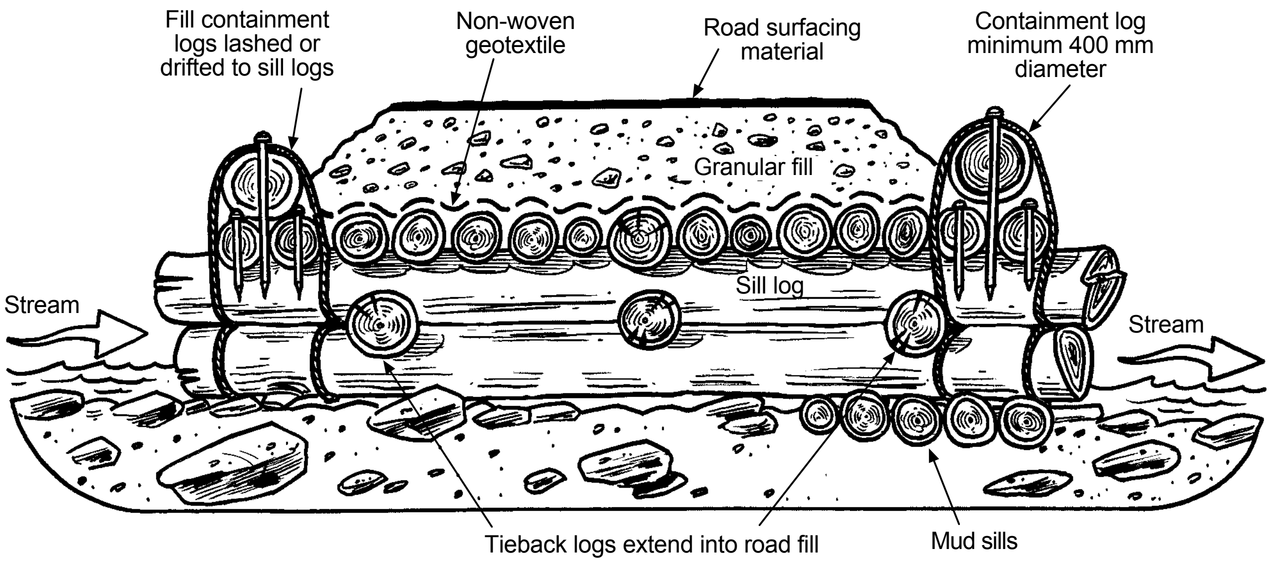


Figure 20. Fill containment for log culvert.

In addition, the design should include provisions that prevent road fill materials from encroaching on the 100-year flood level. For fills up to 1 m thickness, the sill logs—providing they are long enough—will serve this purpose. For higher fills, other site-specific measures should be incorporated into the design.

Type of road fill

To maximize fill slope angles and minimize culvert length, fill over a log culvert should be shot rock or granular pit-run material. Use of silty and clayey materials should be avoided because these (1) require flatter fill slope angles (and therefore longer slope lengths) to maintain fill slope stability, and (2) increase the potential for sedimentation.

Log culvert gradient

For stream gradients less than 10%, it is standard practice to place the stringer soffit (culvert soffit) at 0% grade or at or near the same gradient as the stream. Should the proposed stringer installation gradient exceed 10% (**culvert** soffit gradient, not the **stream** channel gradient), other structural considerations may apply.

Channel gradients less than 10%

A cross-sectional sketch of the culvert and the fill, and a profile of the stream bed, provide the best tools for determining log culvert length. The required length can be directly measured from a sketch drawn to scale.

Channel gradients greater than 10%

Again, the preferable method is to measure the length directly from the cross-sectional sketch for the stream.

Inlet and outlet treatments

Headwalls or sill logs may be incorporated into log culvert design, allowing vertical end fills and therefore reduced culvert length.

Length for skewed culverts

Where a culvert crosses the roadway at other than a right angle to the road centreline, allow for the increased culvert length caused by this skew.

Log culvert stringer selection

Stringer sizing involves selection of the appropriate log diameter and species to be used for the stringers (puncheon). Table 8 presents stringer sizing for log culverts, as a function of span (see Figure 19), total fill depth, logging truck axle loads (e.g., L75), and log species. In Table 8, which was developed by professional engineers, the total fill depth is the combined thickness of road surfacing and underlying road fill materials that extend down to the top of the stringers. The total fill depth ranges from a minimum of 300 mm to a maximum of 2 m. The log diameters given in Table 8 are to be considered as minimum mid-diameters, which are measured at mid-span under the bark.

Use of oversize logs is encouraged to account for unseen flaws, to give added strength for overloads and general heavy use, and to extend the service life of the structure. For maximum service life, it is recommended that sound western redcedar be used. Fill containment logs are required to contain the fill or road surfacing and can be structural or non-structural. A geosynthetic should first be placed over the puncheon to prevent surfacing or fill material from migrating between the stringers and into the watercourse.

Table 8. Log culvert stringer sizing table—log diameters are mid-diameters, in millimetres.

Span (m)	Total Fill Depth (m)	L60 D.Fir/ Larch	L60 Other	L75 D.Fir/ Larch	L75 Other	L100 D.Fir/ Larch	L100 Other	L165 D.Fir/ Larch	L165 Other
1.5	**0.3**	*250*	*250*	*250*	*275*	*250*	*325*	*350*	*450*
	1.0	*250*	*250*	*250*	*225*	*225*	*250*	*250*	*300*
	2.0	*250*	*250*	*250*	*250*	*250*	*250*	*250*	*275*
3.0	**0.3**	*350*	*425*	*375*	*475*	*400*	*475*	*650*	*800*
	1.0	*250*	*300*	*275*	*300*	*275*	*325*	*350*	*400*
	2.0	*250*	*325*	*275*	*325*	*300*	*350*	*375*	*450*
4.5	**0.3**	*460*	*575*	*500*	*625*	*575*	*675*	*700*	*825*
	1.0	*325*	*400*	*350*	*425*	*375*	*475*	*500*	*600*
	2.0	*375*	*425*	*400*	*475*	*425*	*475*	*525*	*625*
6.0	**0.3**	*550*	*675*	*600*	*725*	*650*	*775*	*800*	*950*
	1.0	*425*	*525*	*450*	*550*	*500*	*575*	*600*	*750*
	2.0	*475*	*575*	*500*	*625*	*525*	*650*	*625*	*825*

Notes:

1. Other refers to cedar, spruce, lodgepole pine, jack pine, and hemlock.
2. Sizes are based on sound logs, with no allowance for decay.
3. Logs should be free of cracks, excessive taper, sweep, damage, or large knots.
4. Reverse the taper of adjacent logs.
5. Spans over 3 m should be lashed at mid-span.
6. Logging truck axle loads in accordance with B.C. Ministry of Forests standards.
7. Axle loads allow for unbalanced 60%–40% wheel loading.
8. Fill depths greater than 2 m should be designed by a professional engineer, or designed from tables prepared by a professional engineer.

Log culvert substructure design

The substructure required depends on the bearing capacity of the foundation soils and the length and diameter of the logs available. Choice of substructure requires first an estimate of the bearing strength of the soil at the site. From this, the size (diameter and length) of the logs needed to support the design loads can be determined. Refer to FERIC's *Log Bridge Construction Handbook* (1980) for a detailed explanation of this topic.

Single sill logs

Single sill logs may be used as culvert foundations if the ground is firm and the sill log provides sufficient clearance for the design flood and debris passage. The minimum diameter for sill logs should be about 300 mm. For short service-life culverts (planned for less than 3 years use), almost any species of wood will suffice for the sill logs, provided it is sound throughout.

The expected service life for sill logs is as follows:

- Cedar (sound, with preservatives applied to cut surfaces): 20 years plus
- Douglas-fir: 8–10 years
- Spruce, hemlock, and balsam: 4–6 years
- Hardwood species: Variable but probably less than 4 years

Mud sills

If the natural ground will not support the culvert loads on a single sill log, the load-bearing area can be increased with the use of mud sills. These are short logs, 250 mm (or larger) in diameter, and 1–6 m in length, placed at right angles under the sill log for the entire length of the sill.

For crossings on soft ground, on non–fish-bearing streams, another option is to extend the mud sills completely across the channel to and beneath the other sill log. This increases the stability of the structure. It is important that the mud sills be placed below the scour level.

Log culvert inlet and outlet protection

Inlet and outlet protection for stream culverts

Inlet and outlet protection for stream culverts is not normally required because the sill logs are placed outside the stream channel and bedded below scour level. If there is a concern about erosion around the inlet or outlet, any erodible surfaces should be protected with rock to a level equivalent to the design flood. Some sites may require a settling or debris catchment basin at the inlet. Such features should be individually designed.

Inlet protection for cross-drain culverts

Inlet protection for cross-drain culverts will normally be achieved with a ditch block to ensure that ditchwater is directed into the log culvert and not past it. In most cases, a catch basin is required to trap sediment and debris. For cross-drain culverts on a steep road grade, lining the ditch block, catchment basin, and bottom of the channel with rock may be necessary to minimize scouring.

Outlet protection for cross-drain culverts

Log culverts should not be placed on top of erodible fills. It is preferable that ditch flows are directed onto erosion-resistant areas, or onto outlet protection such as flumes or rip rap aprons. Ditch water flows should never be directed onto unprotected sidecast material unless it is composed of rock or other erosion-resistant materials. On steeper slopes, erosion control at the culvert outlet is a design challenge. One option is to provide extensive outlet protection down the slope to an erosion-free area.

Open top log culverts

Open top culverts, constructed of logs, may be used to control road drainage on steep road grades or in situations where plugging of culvert inlets is a chronic problem.

Log culvert construction

Proper log culvert construction requires experience, skill, and good workmanship. Before construction begins, the crew should be made familiar with any particular installation requirements, including any design drawings. Construction should be in accordance with requirements of the "Log culvert stringer selection" and "Log culvert substructure design" sections above. In addition:

- The location of the substructure should be marked on the ground before and after the site-clearing operation. Re-establishing the road centreline may be necessary.
- For those log culverts with high fills or requiring skewing, it is important that the sill logs be cut to the correct length and placed in the proper position.
- Two evenly sized sill logs should be laid parallel and clear of the wetted perimeter of the stream, and should have solid bearing.
- The sill logs should be carefully bedded below the scour depth of the stream. If scouring is anticipated, a trench should be excavated below the scour level for the sill logs. Constructing a non-erodible foundation pad of large angular shot rock is a suitable alternative.
- The sill logs and stringers should be solid, good-quality wood, sized according to the design drawings or the stringer sizing table found in Table 8. Peeling the logs will normally extend their service life. For short-term roads, use of species that provide only a short service life is acceptable, provided the logs are structurally sound.
- A layer of non-woven geotextile filter cloth should be placed over the stringers.

The outside stringers should be pinned to the sills with drift pins or lashed to the sill log, or they should be placed in neat daps made in the sill log, and drift pinned, to prevent any shift or spreading of the stringers while the culvert is being backfilled. Avoid sharp daps, which will result in high stress concentrations, or slabbing the stringer ends, which will degrade shear load capacity.

Ford design and construction on non-fish streams

A ford is a dip in a road constructed to facilitate crossing a stream. The objective of a ford is to maintain drainage and provide a safe, erosion-free, and storm-proof crossing that requires little or no maintenance. In the past, inappropriate location and design of fords, and uncontrolled use, has led to a number of negative environmental impacts. These include increased sediment delivery to streams, and degraded water quality downstream.

In isolated locations where maintenance equipment may not be available on a continuing basis, properly designed and constructed fords require little maintenance, are storm-proof, and can be effective in reducing adverse impacts in drainage systems that are prone to debris torrents (Figure 21). Fords may also be considered for areas of low traffic and intermittent use. They should be considered as alternatives to bridges or culverts only where the crossings will not result in negative environmental impacts and where traffic use is confined to low-flow periods. A ford would not normally be considered if the crossing is expected to be subjected to extensive or year-round traffic.

Ford planning

Fords should be identified in the planning stage of road development to ensure that the required design and measures will include appropriate road grades leading into and out of the stream crossing.

- Prior to planning a ford, the stream should be evaluated to ensure that it is not a fish stream. Refer to the *Fish-stream Crossing Guidebook* for limitations on the use of fords on fish streams.
- When planning a ford, and establishing design criteria, determine if any of the following possible user safety restrictions (or combination of restrictions) will apply to the stream crossing:
  - the design vehicle will be able to cross the ford only during certain months of the year
  - the design vehicle will not be able to cross the ford during periods of specific maximum stream flows
  - only certain types of vehicles will be able to cross the ford
  - only certain specific road uses will be considered (such as industrial use only).

Each proposed ford design is unique, but the objectives of any design are to:

- pass the design peak flow
- minimize downstream erosion of the stream
- prevent sediment input into the stream from the approaches and associated ditches

- provide a suitable road profile to accommodate safe passage of the design vehicle
- ensure that the stream remains in its channel and cannot be diverted down the road or ditches
- ensure that the ford will either pass channel debris—the preferable option—or trap it

Non-standard crossing situations may require installation of weirs and other energy-dissipating structures upstream and downstream. Under these situations, design by a professional engineer, and agency consultation, may be required.

Ford design

For a ford, the road profile should dip into and out of the stream, creating a concave shape sufficient to ensure that the stream cannot be diverted away from its natural channel and down the road.

- Ensure that the anticipated design vehicle can negotiate vertical curves at the proposed ford. Where it is practical to do so, approaches should be at right angles to the stream.
- Check the debris flow history of the stream channel
  - on air photos
  - on terrain stability maps or terrain stability field assessments
  - in the field.

For further information, refer to the *Gully Assessment Procedures Guidebook*.

- If there is a debris flow problem, decide whether the ford should be designed to:
  - trap the debris, or
  - allow the debris to pass over the ford—the preferred option. If the debris is to be trapped, specialist consultation may be required to size the catchment basin.

The size and shape of the largest cobbles or boulders in the stream channel indicates the minimum size of rock required to resist movement when the stream is in flood, and thus provides a guide to the minimum size of rock to be used to construct the ford. The more angular the rock (such as shot rock), the more resistant it will be to moving.

In some situations, the use of a ford may be restricted to low-flow periods when the flow is subsurface. A low-flow culvert can be designed and installed to pass the anticipated low flow. With this design, peak flows and debris would flow over the top of the ford and some increased annual maintenance may be necessary. The running surface material should be of a size to resist erosion.

Design methods are available for determining flow rates through voids in rock fills. Such voids may plug, so the dip in the road profile should be designed to accommodate the Q_{100} peak flow, plus any anticipated debris.

Design approval requirements

Sketches of the ford design should be prepared, showing:

- the road profile, extending at least 50 m at each end beyond the wetted perimeter at Q_{100} peak flow
- the width and depth of the wetted surface during:
  - those months when use of the road is anticipated
  - Q_{100} peak flow level and an estimate of debris volumes to be passed or trapped
  - annual low-flow level, or the flow levels for the periods of anticipated use
- the range and average size of the material in the stream channel and its shape (angular, semi-angular, or rounded)
- the minimum width of the road running surface required to accommodate anticipated traffic
- the requirements for any erosion-resistant materials for the road running surface, such as shot rock and concrete cross-ties, including use of any geosynthetics, to help separate different types and gradations of road fill materials
- the rock source, size, and volume requirements
- the length, width, and depth of the upstream catchment basin if one is proposed
- the type and dimensions of the low-flow culvert, if one is proposed
- the length of apron to be surfaced with erosion-resistant material.

Ford construction

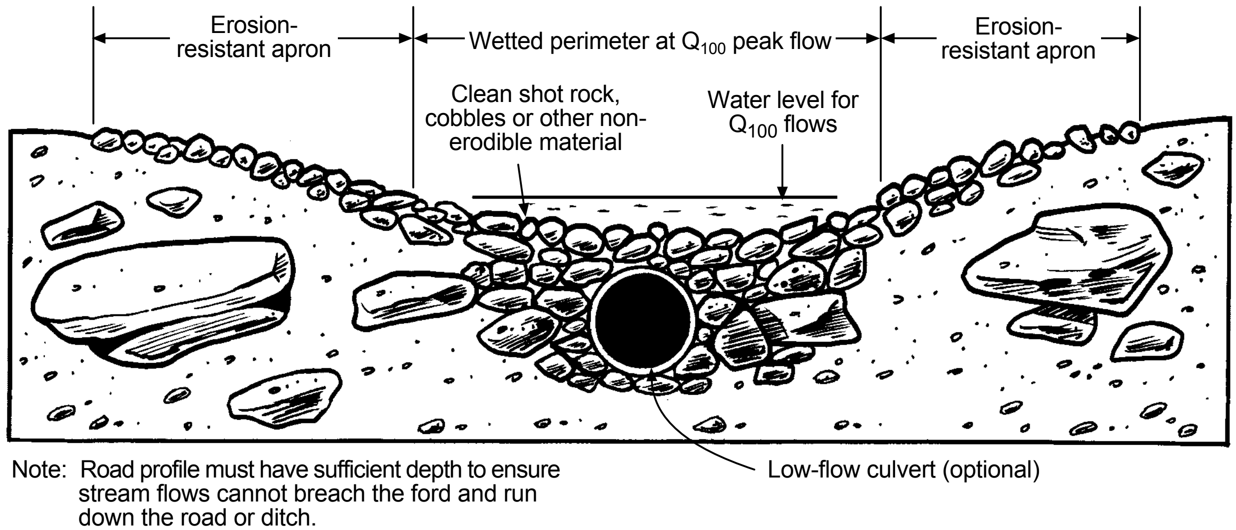
For low-flow streams, or for those that are dry in the summer, a properly designed and constructed ford should allow the stream flow to pass around and between the subsurface rock. For this, place the larger-size rock across the base and lower portion of the ford cross-section. For perennial streams where appropriate rock sizes are unavailable, consider the following alternatives:

- Construct a broad catchment basin, or upstream weirs, to slow the stream flow velocity and thus reduce the size of rock required for the ford to resist the erosion forces.
- For steeper-gradient streams, build up the downslope portion of the ford by positioning log cribs, gabions, lock blocks, etc. to contain the rock fill for the ford. In most situations, this will flatten the stream gradient at the crossing, thus reducing the stream velocities and permitting the use of smaller-size rock.

To prevent sediment delivery where approach drainage cannot be directed away from the stream, and to prevent sediment tracking by equipment and vehicles, the following procedures should be considered:

- armouring ditches with non-erosive material
- directing runoff into sediment basins or other sediment trapping device
- capping the road surface with erosion-resistant material on either side of the ford for an appropriate distance to protect the road and minimize sediment delivery to the stream.

Road profile (stream cross-section)



Road cross-section (stream profile)

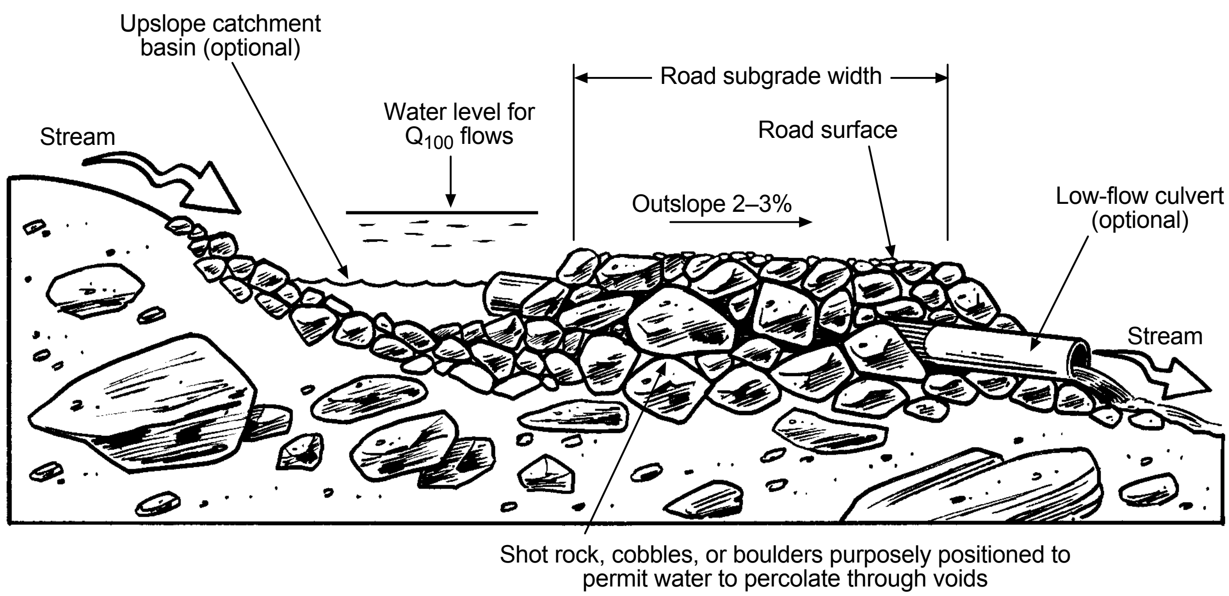


Figure 21. Plan and profile of a ford crossing.

Ford operating constraints

Once a ford is constructed, its use should be controlled to ensure that the integrity of the structure is maintained and that any potential adverse impacts on the environment are minimized.

- Nothing that could destroy the running surface of the ford should be dragged or skidded across it.
- Vehicles using the ford should be in good working order and not leaking fuel, hydraulic fluids, lubricating oil, or cargo.
- All excess soil should be removed from heavy equipment before it crosses a watercourse.
- The ford should not be used if the water depth is greater than the axle height of the vehicle. It may be appropriate to install a water-depth gauge clearly visible from the road.
- Should a ford become unsafe for traffic during high water, measures should be taken to warn and exclude users for that period.

Ford maintenance

Properly designed and constructed fords are usually low maintenance, stormproof structures. Nevertheless, the following activities may be required:

- Fords should be inspected at a frequency commensurate with the risk to users.
- Running surfaces, approach grades and aprons, ditches, and catchment basins should be properly maintained.

Suggestions for further reading

American Iron and Steel Institute. 1991. *Handbook of Steel Drainage and Highway Construction Products*. Canadian edition. W.P. Reyman Associates, Inc. New York, N.Y.

British Columbia Ministry of Forests. 2002. *Fish-stream Crossing Guidebook*. Victoria, B.C.

____________. 2001. *Gully Assessment Procedure Guidebook*. Victoria, B.C.

____________. 1999. *Forest Service Bridge Design and Construction Manual*. Victoria, B.C.

Nagy, M.M., J.T. Trebeth, G.V. Wellborn, and L.E. Gower. 1980. *Log Bridge Construction Handbook*. Forest Engineering Research Institute of Canada (FERIC), Vancouver, B.C.

5. Road and Structure Inspection and Maintenance

Introduction

Forest road and bridge inspection and maintenance involves the following activities:

- assigning road inspection priorities based on risk analysis
- road inspections
- bridge and major culvert inspections
- road prism maintenance
- structural maintenance of the subgrade
- clearing width maintenance
- ditch and culvert maintenance
- road surface maintenance
- maintenance of structures
- inspection and repair of deactivated roads.

Required maintenance activities should be determined from field information documented during formal inspections, and from information and incidents provided by road users. From this, a maintenance plan should be prepared to remedy the identified deficiencies.

The objectives of forest road maintenance are:

- ensuring user safety
- minimizing potentially adverse effects to adjacent forest resources from the use of the road
- maintaining safe fish passage at fish stream crossings
- maintaining water quality in community watersheds
- protecting the road infrastructure investment.

Road works shutdown indicators and procedures should be considered when forest road maintenance works are being carried out on active roads and when remedial works are being carried out on deactivated roads. These indicators and procedures are provided in Chapter 3, "Road Construction."

Assigning road inspection priorities

A person responsible for carrying out inspections on maintained roads and temporary and semi-permanently deactivated roads should "risk rate" roads using a simple, qualitative risk-analysis procedure.

Risk of damage to elements at risk = Hazard × Consequence

Assign maintenance inspection priorities based on the level of risk to elements at risk. Determine qualitative risk ratings (e.g., VH, H, M, L, VL) according to a combination of ratings for hazard and consequence, and then assign maintenance inspection priorities. Usually, roads that present the highest risk of damage to elements at risk also receive the highest inspection priority and frequency of inspection.

Table A10.1 in Appendix 10 is an example of a qualitative risk matrix. It combines a relative hazard rating and a relative consequence rating. Table A10.1 presents an example 5×3 matrix for landslide risk analysis, but a different qualitative method of risk analysis that uses a 3×3 matrix (three qualitative ratings for hazard [H, M, L] and three qualitative ratings for consequence [H, M, L]) is often satisfactory for assigning inspection and maintenance priorities.

Hazard, for assigning inspection priorities based on risk, is the likelihood of a particular condition with the potential for causing an undesirable consequence. Hazard events may include accelerated or uncontrolled soil erosion and sediment transport, slumping or sliding, or deterioration of structural elements within the road prism. These events may be caused, for example, by cut and fill slope failures, shoulder slumps, washouts, blocked ditches and culverts, road surface erosion, damaged guide rails or curbs on bridges, filled-in cross-ditches on deactivated roads, and events related to weather.

Consequence is the product of the element at risk and the vulnerability of that element at risk from hazard events described above. The term “vulnerability” refers to the fact that an element at risk may be exposed to different degrees of damage or loss from a hazard occurrence.

Tables A10.3–A10.11 in Appendix 10 are examples of landslide consequence tables that express consequence in terms of three relative qualitative ratings: H, M, and L. These tables, either in whole or in part, or some modified form of these tables as required to reflect specific road and site conditions and elements at risk, may be useful in determining consequences for the purpose of assigning inspection priorities based on risk.

The elements at risk included in these consequence tables include:

Table	Element at risk
Table A10.3	Human life and bodily harm
Table A10.4	Public and private property (includes building, structure, land, resource, recreational site and resource, cultural heritage feature and value, and other features)
Table A10.5	Transportation system/corridor
Table A10.6	Utility and utility corridor
Table A10.7	Domestic water supply
Table A10.8	Fish habitat
Table A10.9	Wildlife (non-fish) habitat and migration
Table A10.10	Visual resource in scenic area
Table A10.11	Timber value (includes soil productivity)

Refer to "Slope stability considerations," in Chapter 1, "Road Layout and Design," and to Appendix 10 for further general information on risk analysis.

When planning inspections and maintenance activities at fish stream crossings, refer to the *Fish-stream Crossing Guidebook*.

Road inspections

Inspections should focus on the structural integrity of the road prism, drainage systems, road surface, and sediment control. An inspection plan should be prepared based on inspection priorities assigned as a result of a risk assessment.

It is recommended that, as a minimum, all active roads receive one documented inspection per year. Roads should also be inspected following severe storms, before winter, and after the spring freshet.

After extreme weather events, inspections should be carried out as soon as possible. Aerial inspections, where adequate information can be obtained to determine a course of action, are acceptable. Culverts constructed or modified on fish-bearing streams after June 15, 1995, should be inspected to ensure continued provision of safe fish passage.

Inspection results should be recorded in a format that enables ready access for future reference. All staff who travel on forest roads are encouraged to report any road maintenance problems that they encounter in the course of their duties.

Road inspection records

Inspection records should cover key road elements and any deficiencies noted. Where major problems are identified, it is recommended that photographs be taken to accompany the inspection records. A sample road inspection and maintenance report is provided in Appendix 6.

The items to be assessed and evaluated when an inspection is carried out include:

- user safety
- structural integrity of the road prism and clearing width
- drainage systems
- potential for transport of sediment from the road prism
- road and bridge surfaces
- safe fish passage at stream crossings.

On completion of inspections, a maintenance plan should be prepared and maintenance works prioritized in accordance with risk. Inspection reports and maintenance records should be retained on file for review at the request of the district manager and for forest practice audits. Review of past reports and records can also assist forest road managers in identifying recurrent problems and identifying those road sections to be assigned a higher risk rating.

Remedial works

After a road inspection is completed, any deficiencies found must be remedied by the earliest of the following:

- a time period that is commensurate with the risk to the road, its users, and the environment,
- a time specified in the inspection report prepared by that person, or
- a time determined by the district manager.

The time frame for remedial action can and should be specified in the inspection report. "Reasonable time" will vary according to the specific site and problems identified. For example, waiting until equipment is in the area is inappropriate where the road fill is already failing into a stream. However, it may be appropriate to wait for equipment where a ravelling cutslope is filling in a ditch that has a low risk of transporting sediment to a stream.

Bridge and major culvert inspections

Bridge inspections

Bridge inspections can be broadly categorized into two types: routine condition inspections and close proximity inspections.

Routine condition inspections

Routine condition inspections involve visual and physical (non-destructive) testing of log stringer, steel, concrete, or glulam bridge components, or major steel culverts. These inspections can be completed by qualified inspectors, which would be those having appropriate training and experience to inspect bridge and major culverts and interpret the results. Inspectors should have adequate training and experience with the type of structures that they will be inspecting in order to be able to focus their attention in the critical areas for the types of structures encountered. Interpretation of results would involve evaluating inspection results as the inspection progressed.

For example, in review of wood components, if rot is found, the inspector should able to assess the significance of the rot to the structure's integrity. An inspector should be able to develop a conclusion of the components structural integrity considering the amount of rot, component being inspected, and location or rot on/in the component for the structure being inspected. Inspectors should be able to establish whether structural deficiencies require evaluation by professional engineers or can be simply rectified by specifying suitable repairs.

Close proximity inspections

Close proximity inspections would generally be carried out in review of complex, larger structures or where deficiencies have been noted in routine condition inspections. Typically, a close proximity inspection requires a higher level of expertise in interpretation of results as the inspection progresses. Close proximity inspections would generally involve the detailed inspection and review of primary structural components. Close proximity inspections would be carried out by a professional engineer or under a professional engineer's direct supervision.

Inspection frequencies

Unless a professional engineer specifies a longer period, bridges and major culverts composed of steel, concrete, and treated timbers must be inspected at least once every 3 years by a qualified inspector, and a record of the inspection made. If portions of the structural components (stringers, girders, or substructure) are made of untreated wood, the structure must be inspected at least once every 2 years.

In addition to regular scheduled inspections, structures should be inspected after severe storm events.

Inspection records

The inspection record of a bridge or major culvert must include all of the following:

- date of the inspection
- a condition assessment of the components of the structure
- a recommendation for any repairs that may be required and a schedule for those repairs
- the date of the next scheduled inspection
- the length of time a bridge has been at its current site
- a note about whether a bridge was designed and constructed to be at the current site for no more than 15 years.

Inspection records for major bridges and culverts must be retained for 1 year beyond the actual life of the structure at the site. Should a structure fail, these records will be useful in any subsequent investigation. These records can also be used as a reference to determine the type of structures that are cost-effective and environmentally suitable for similar stream crossings.

Structural deficiencies noted in inspections

The sequence of identifying and correcting structural deficiencies in existing bridges is as follows:

1. A qualified inspector identifies and records possible structural deficiencies.
2. A professional engineer carries out a field review of the structure, and confirms or recommends the following, as applicable:
   - the types of work that must be carried out to correct the deficiencies, or
   - the need to protect road users by either
     – installing signs detailing the load rating prepared by the engineer, or
     – closing or removing the structure.

Road prism maintenance

Maintenance is required to ensure user safety and stability of the road prism, and to minimize sediment transport from the road prism.

Methods to maintain the road prism include:

- stabilization of the road cut and fill slopes, repair of minor scours and washouts, and improvements of drainage systems before more serious problems occur
- removal of loose rocks, stumps, or other unstable materials (including dangerous trees) that present a hazard to road users
- seeding of all exposed soil that will support vegetation, by hydro-seeding or dry seeding, and reseeding of bare spots to fill in as required

The reasons why these problems are occurring should also be assessed and long-term corrective measures determined.

Subgrade maintenance

Subgrade maintenance is necessary to ensure that the road system will fulfill its designed function until deactivation. Measures to consider include:

- repairing chronic soft subgrade areas and problematic frost sections by excavating and replacing the weak soils with suitable granular material, including use of geosynthetics where appropriate
- modifying the road (may require an approved road layout and design)
- replacing or repairing the running surface if the road has chronic problems with ruts, potholes, and a broken surface that renders the road unable to support design loads
- cleaning up minor slumps, rock falls, and other sites where potential hazards are evident; and implementing measures to stabilize the site
- correcting the potential failure of stream crossing approach fills.

Clearing width maintenance

Brushing of the road clearing width should be carried out for vegetation control and to provide safe sight distances. For example, potential hazards exist where brush limits visibility at the inside of a curve or at bridge approaches, or where heavy snow loads on roadside trees may cause the trees to bend over the road surface, restricting use of the road and creating a safety hazard.

Ditch and culvert maintenance

Ditches should be cleaned and graded as necessary. However, grass or low vegetation lining the ditches is desirable to minimize scour and sediment transport. In domestic watersheds, ditch maintenance should be limited to removing rock falls and any slumping or ravelling material, while maintaining as much grass cover or other low vegetative cover as is practicable. Care should be taken to prevent blading material over the ends of culverts or undercutting cut slopes—a practice that will reduce their stability. Ponding of water in ditches should also be prevented, as it can saturate and weaken the road subgrade and lead to surface rutting.

Ditches should be kept unobstructed by tall vegetation, so that maintenance equipment operators can see the ditches and drainage structures. Culverts are often damaged because the grader operator cannot see the culvert ends through the vegetation growing in the ditches.

Additional routine ditch and culvert maintenance operations include:

- cleaning and repairing of culverts and ancillary drainage works to provide for flow of water
- repairing inlets, outlets, ditch blocks, catch basins, and flumes
- replacing cross-drain, flumes, and rip rap
- installing additional cross-drain culverts and ditch blocks where required, usually made evident by ponding of water or erosion (scour) in the bottom of the ditches.

These activities should be carried out at a time and in such a way as to minimize the potential for stream sediment delivery.

Road surface maintenance

Grading operations

A well-graded road should be slightly crowned, with no unbreached windrows. This will facilitate storm and meltwater drainage, minimizing erosion and transport of sediment from the road surface. A crowned road, however, is not always desired, as in the case of insloped or outsloped roads.

Roads should be graded where grading will be beneficial to maintaining structural integrity or will help protect the subgrade from damage. Grading can also add to vehicle efficiency and user safety. To protect the subgrade, roads should be graded before the surface:

- reaches severe stages of wash-boarding or pothole formation, or
- begins to trap water in windrows or ruts (windrows and ruts can result in water flowing down the road, scouring the surface, and potentially causing a washout when it reaches a dip in the road).

Restoring a severely damaged road surface can be a major undertaking and may require ripping the surface to below the pothole depth and recompaction of the surface material. Road grading should take place only when moisture conditions are suitable, and not when the road is either too wet or too dry. Preferably, no windrows should remain after the final pass; at the very least, those that do remain should be breached to provide for drainage. Grading material over the banks or into ditches should be minimized, as this material may be difficult to retrieve.

Resurfacing operations

Resurfacing of gravel roads is required when the existing surfacing material is no longer sufficient to support traffic loading or when there is not enough material available for grading purposes. Over time, surfacing material can break down and is lost from the road surface. Spot-gravelling of roads may be required where short sections of the road surface are failing or have a potential for failure, or where potholes that cannot be satisfactorily graded out are evident.

Information on surfacing roads is available in Chapter 3, "Road Construction."

Structure maintenance

Bridges and stream culverts

Bridge maintenance can be divided into two activities: structural and surface.

Structural maintenance of bridges

Structural maintenance involves repairing or replacing structural members of a bridge based on the results of inspections made by a qualified inspector. In some instances, the works will be carried out by or under the supervision of a professional engineer.

Examples of structural maintenance are:

- tightening the bolts connecting timber members
- installing shims to ensure adequate load transfer where there is loss of contact between piles, pile caps, stringers, crib timbers, needle beams, or other structural elements
- replacing stringers or girders.

Surface maintenance of bridges

Surface maintenance involves repairing or protecting parts of the bridges and approaches that do not directly affect structural integrity.

Examples of surface maintenance are:

- keeping the waterway opening free of logs and debris
- keeping the bearing surfaces, including plates, anchor bolts, and neoprene pads, free of gravel and dirt
- keeping wood stringers free of dirt accumulations
- resetting nails protruding from running planks
- replacing missing or damaged ties and running planks

- repairing or replacing damaged guide rails or curbs
- removing gravel build-up on concrete or timber decks.

Stream culvert maintenance

In addition to maintenance related to fish habitat covered in the *Fish-stream Crossing Guidebook*, stream culvert maintenance is carried out to ensure that the structure maintains its capability to conduct water under the road.

Examples of stream culvert maintenance are:

- repairing damaged inlets and outlets
- repairing armouring around inlets and outlets to reduce sediment transfer, particularly in community watersheds
- removing debris blocking or obstructing culvert inlets. If removing beaver dams, the Ministry of Sustainable Resource Management should be contacted for permission and advice. Installation of beaver protection devices should also be considered.
- replacing culverts where the bottoms are rusted out and when subject to damage from water seepage
- repairing major culvert headwalls and spillways when necessary, to protect the structures and the streams.

When replacing culverts at stream crossings, refer to the *Fish-stream Crossing Guidebook* for additional information.

Other structures

Cattleguards

Clean and repair cattleguards, or replace if repair is neither practical nor cost-effective.

Fences

Repair or replace range fences that have been damaged as a result of activities on the road. The range section in the local district office of the Ministry of Forests can advise on acceptable fence construction specifications and practices.

Signs

Repair or replace damaged or vandalized signs and posts.

Fords

Remove debris and sediment build-up on fords and approaches to minimize impact on downstream resources. Refer to “Ford design and construction on non-fish streams" in Chapter 4, "Road Drainage Construction," for additional maintenance information on fords.

Weirs

Where weirs are installed in a stream to maintain water levels for fish passage, they should be inspected and maintained to ensure that the fish passage objectives are being met.

Inspection and repair of temporary and semi-permanently deactivated roads

Inspections of temporarily and semi-permanently deactivated roads are to be carried out at frequencies commensurate with the risk to the road, its users, and adjacent forest resources. Their purpose is to assess the adequacy of bridges, culverts, and ditches, and to determine the need for further drainage work, road surfacing, and revegetation.

Where inspections identify inadequacies, remedial works must be performed to satisfy the requirements of the Forest Road Regulation.

A sample road deactivation inspection report is provided in Appendix 7.

Suggestions for further reading

British Columbia Institute of Technology (BCIT). 1995. *Surface Maintenance*. RRET 3328. Burnaby, B.C.

____________. 2001. *Bridge Maintenance*. RRET 3324. Burnaby, B.C.

____________. 2001. *Culvert Maintenance*. RRET 3322. Burnaby, B.C.

British Columbia Ministry of Forests. 2002. *Fish-stream Crossing Guidebook*. Victoria, B.C.