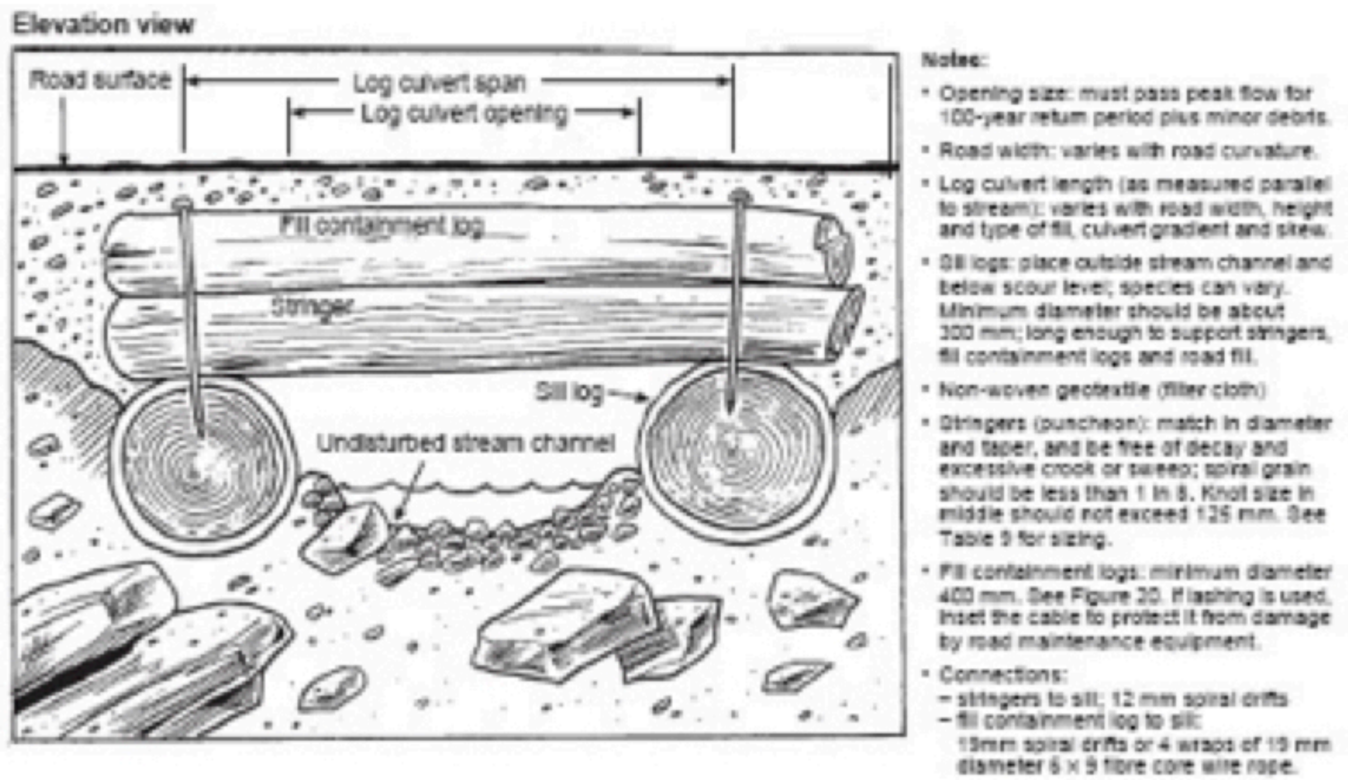
3.6.1 Log Culvert Design

For the purposes of this manual, the term “log culvert” is interchangeable with “woodbox culvert,” “log stringer culvert,” or “wood stringer culvert.”

A log culvert is a log crossing structure having a span of less than 6m centre-to-centre of bearing, and an abutment height (if constructed as a log crib) of less than 4m between the underside of the lowest crib log to the underside of the stringers, and is used to carry ephemeral or perennial stream flow in a stream channel from one side of a road to the other. A log culvert structure is covered with soil and lies below the road surface (Figure 3-14).

Figure 3-14 Simple log culvert



Notes Figure 3-14:

- Opening size: passes peak flow for 10-year or 100-year return period, (depending on the anticipated time that the log culvert will remain on the site) 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 the stream channel width and below scour level: species can vary. Use minimum diameter of about 300mm; 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 is less than 125mm. See Table 3-8 for sizing.
- Fill containment logs: minimum diameter 400mm. See Figure 3-15. If lashing is used, inset the cable to protect it from damage by road maintenance equipment.
- Connections:
- Stringers to sill; 12mm spiral drifts
- Fill containment log to sill: 19mm spiral drifts or four wraps of 19mm diameter 6 x 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, measure the span of the stringers for design purposes from bearing to bearing along the stringers and not at right angles to the sill logs.

Consider log culverts for:

- streams where other resource agencies require the culvert to be open bottomed; and
- steep gradient streams.

Where the planned service life of the road is less than the life expectancy of the drainage structure components, consider using log culverts:

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

Ensure that a log culvert design addresses 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); and
- inlet and outlet protection requirements.

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Log culvert opening size

To meet current legislative requirements, design a log culvert to pass the highest peak flow of the stream that can reasonably be expected within the following return periods specified below for the length of time it is anticipated that the log culvert will remain on site (see FPPR section 74). For methods to estimate the value of Q10 and Q100, design discharge of a creek see Figure 3-3: High water estimation method for stream culverts in this chapter and Chapter 4: Design Discharge Criteria.

Table 3-8 Peak flows for various log culvert lifespans

Anticipated period that the log culvert will remain on the site	Peak flow return period
For a log culvert that will remain on site for up to 3 years	10 years (i.e., Q10)
For a log culvert that will remain on site for over 3 years	100 years (i.e., Q100)
For a log culvert within a community watershed that will remain on site for over 3 years	100 years (i.e., Q100)

A log culvert is a type of open bottom structure, designed to span the stream channel width. This is particularly important on fish-bearing streams to avoid impacts on fish habitat and fish passage - refer to the section on “Open bottom culverts” in the Fish-Stream Crossing Guidebook (PDF, 4.2MB) page 6.

In addition to passing the required peak flow discharge, design log culverts to manage anticipated debris. Options may include, but are not limited to:

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

Inspect debris catchment devices frequently and clean them as required. The criteria for design of any debris catchment device are site-specific and may incorporate professional input. Identify debris problems from terrain hazard maps, air photo interpretations, field investigations, and reports for the area - see the Gully Assessment Procedure Guidebook (PDF, 1.8MB).

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 the 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, is determined by 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; and
- culvert skew.

Road width

If the culvert is located within a horizontal curve, provide for extra road width to accommodate side tracking of logging trucks and hence additional culvert length. The required width can be found in Table 3-3: Curve widenings.

Depth of road fill

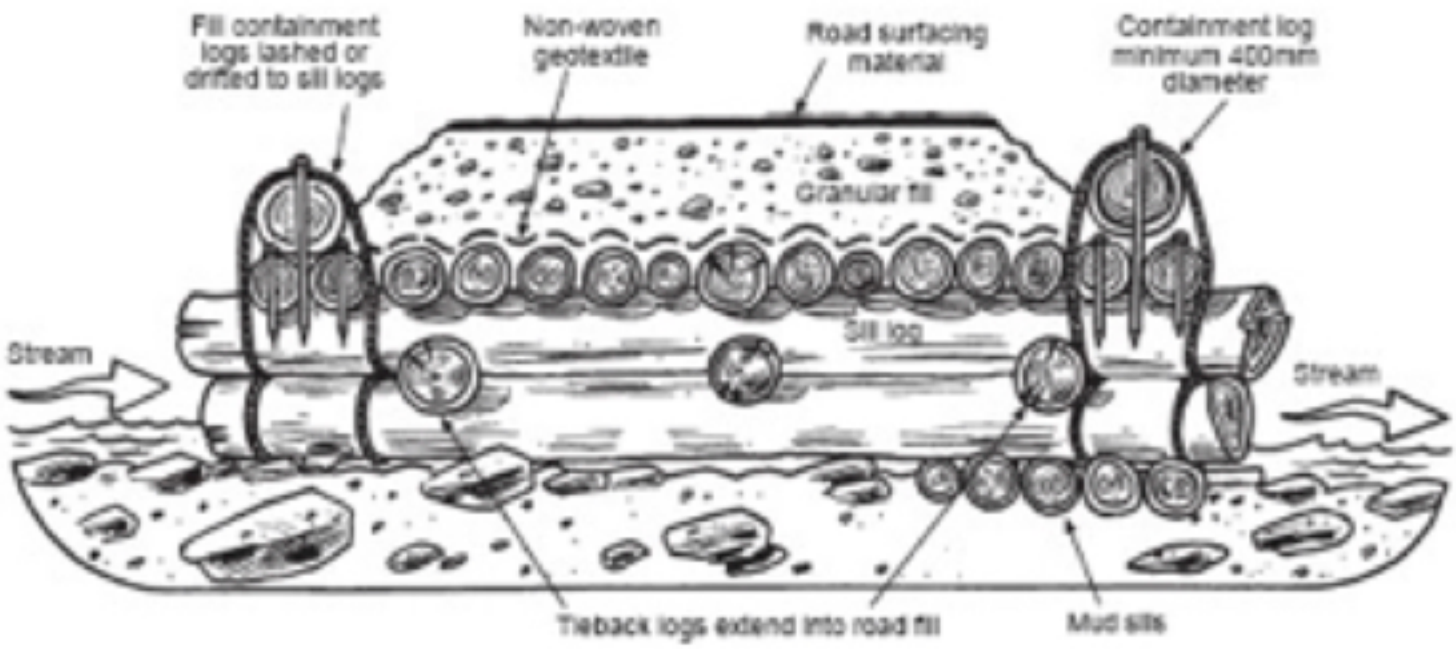
Road fills greater than 2 metres on top of the log stringers should generally be avoided. Should a failure occur, there is a potential for large volumes of sediment- producing materials to enter the stream channel. In addition, deep fills make culvert replacement, repairs or even inlet clean-out difficult. For fills anticipated to exceed depths of 2 metres, ensure that a professional engineer has been consulted or a design table produced by a professional engineer which captures the fill depth is used.

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; and
- relocation of the road to a more suitable crossing.
- Ensure that log culverts are sufficiently long to contain the fill and prevent material from entering the stream. As the fill height increases for a given roadway width, increase the culvert length.

Incorporate road fill containment measures 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 (Figure 3-15.).

Figure 3-15 Fill containment for log culvert



In addition, include provisions that prevent road fill materials from encroaching on the design peak flow discharge flood level. For fills up to 1m thickness, use the sill logs-provided they are long enough-for this purpose. For higher fills, incorporate other site-specific measures into the design.

Type of road fill

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

Log culvert gradient

For stream gradients less than 10%, place the stringer soffit (culvert soffit) at 0% grade or at or near the same gradient as the stream. Should the proposed culvert soffit gradient (not the stream channel gradient), exceed 10%, then apply other structural considerations.

Channel gradients

Channel gradients less than 10%: A cross-sectional sketch of the culvert, the fill, and a profile of the stream bed provide the best tools for determining log culvert length. Measure the required length directly from a sketch drawn to scale.

Channel gradients greater than 10%: Measure the length directly from the cross-sectional sketch for the stream.

Inlet and outlet treatments

Incorporate headwalls or sill logs 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. Table 3-9 (PDF) is an example of a log stringer sizing table developed by a professional engineer. Table 3-9 presents stringer sizing for log culverts, as a function of span (see Figure 3-15), total fill depth, logging truck axle loads (e.g., L75), and log species. In this professionally engineered table, 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 log diameters given in Table 3-9 are minimum mid-diameters, which are measured at mid-span under the bark. The total fill depth ranges from a minimum of 300mm to a maximum of 2m for this table.

If the design discharge is 6 m3/sec or greater, or the road fill depth is greater than 2m, ensure that a professional engineer has been consulted or a design table produced by a professional engineer which captures the fill depth is used.

Use oversize logs 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, use sound western red cedar. Fill containment logs contain the fill or road surfacing and can be structural or non-structural. Firstly, place a geosynthetic over the stringers to prevent surfacing or fill material from migrating between the stringers and into the watercourse.

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 is based on an estimate of the bearing strength of the soil at the site. From this, determine the diameter and length of the logs needed to support the design loads. Refer to FPInnovations' Log Bridge Construction Handbook (1980) for a detailed explanation of this topic.

Single sill logs

Use single sill logs as culvert foundations if the ground is firm and the sill log provides sufficient clearance for the design flood and debris passage. Use a minimum diameter for sill logs of about 300mm. For short service-life culverts (planned for less than three years use), almost any species of wood will suffice for the sill logs, provided it is sound throughout. However, it is very important that the anticipated life-span of the road be well thought-out. If there is a good chance that the life of the road will be extended, design and construct a culvert with a longer service-life.

The expected service life for sill logs is as follows (subject to site-specific soil and climatic conditions):

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

Table 3-9 Log culvert stringer sizing table (PDF)

Mud sills

If the natural ground will not support the culvert loads on a single sill log, increase the load-bearing area with the use of mud sills. These are short logs, 250mm (or larger) in diameter, and 1m to 6m 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 mudsills completely across the channel to and beneath the other sill log. This increases the stability of the structure. It is important that the mudsills be placed below the scour level.

Log culvert inlet and outlet protection

Where the sill logs for log culverts are placed outside the stream channel and bedded below scour level, do not provide for additional inlet and outlet protection. If there is a concern about erosion around the inlet or outlet, protect any erodible surfaces with rock to a level equivalent to the design flood. Provide at some sites an individually designed settling or debris catchment basin at the inlet.

Inlet protection for cross-drain log culverts: Inlet protection for cross-drain log 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, use a catch basin to trap sediment and debris. For cross-drain culverts on a steep road grade, consider lining the ditch block, catchment basin, and the bottom of the channel with rock to minimize scouring.

Outlet protection for cross-drain log culverts: Do not consider placing log culverts on top of erodible fills. Direct ditch flows onto erosion-resistant areas or onto outlet protection such as flumes or riprap aprons. Do not direct ditch water flows 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.