5.8 Road Drainage Construction

In this chapter, drainage consists of:

- surface drainage works, including ditches and cross drain culverts as well as any ancillary works; and
- stream crossings, including metal culverts, log culverts and fords.

Ensure that any permanent culvert materials are fabricated in accordance with the current Canadian Standards Association specifications.

5.8.1 Maintaining Surface Drainage Patterns

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

Consider the potential for adverse upslope, downslope and downstream impacts before culvert locations and outlet controls are determined. Measures to limit these impacts include:

- installing flumes or riprap; 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, consider changing the ditch gradient, alignment, or cross-section, or adding extra culverts, to reduce the distance over which water will have to be carried.

To minimize sediment delivery to streams, do not discharge the water conveyed in ditches and cross-drain culverts directly into streams. Allow these flows to settle out through the natural vegetation on the forest floor before reaching any stream. Alternatively, filter these flows in other ways, such as through the use of settling basins or geosynthetics, until vegetation can be re-established. For more information about sediment control techniques, see Soil Erosion & Sediment Control.

5.8.2 Drainage Practices & Water Quality

Install drainage systems, whether permanent or temporary, concurrently with subgrade construction. Consider constructing temporary structures, such as cross- ditches, swales, or open-topped culverts (e.g., cattleguards and similar structures), as appropriate, where water is encountered, to accommodate the peak flows likely to be encountered during construction. Ensure that, if the site is left unattended and a storm takes place, the in-place drainage structures can handle the runoff without damage resulting to the road or other resources. For a pilot trail or tote road, ensure that these can accommodate surface and subsurface drainage runoff throughout the construction period. During road construction, remove any temporary drainage structures that were previously installed to facilitate machine access and install permanent structures in their place.

To ensure proper drainage during road construction:

- stockpile an adequate supply of culverts, riprap, 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 water quality is maintained (where required) should a peak flow event occur;
- construct the final drainage structures as early in the construction process as is practicable;
- construct silt traps, armoured ditch blocks, and aprons as construction progresses or as soon as soil conditions allow.

To protect water quality, utilize the following techniques, where applicable:

- avoid working in areas of ponded water or saturated soils where this could result in negative impacts on 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;
- ensure that machinery used in in-stream work is free of deleterious materials that might be deposited into the water; clean the machine undercarriage and tracks before doing in-stream 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; and
- remove maintenance-intensive temporary construction measures such as silt fencing, straw or hay bales, and silt traps, when not required any longer.

5.8.3 Ditch Construction Considerations

Ensure that surface and subsurface flows do not cause excessive ditch or roadway erosion. Consider such factors as:

- ditch soil conditions;
- gradient;
- alignment;
- cross-section;
- ancillary works;
- ditch stabilization; and
- drainage alternatives where ditching is inappropriate.

Expand All | Collapse All

Ditch soil conditions

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

Ditch gradient

The ditch gradient is largely dictated by the vertical alignment of the road. Ideally, construct the gradient at a minimum of 2% to ensure that water will flow and not pond. Lower ditch 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-drain culverts. Such negative impacts can occur in both gentle and steep terrain.

However, keep ditch gradients in granular soils just steep enough to keep intercepted water moving to cross-drain 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.

Ditch alignment

Avoid abrupt water flow changes. Sharp angles in the ditch alignment or flow obstructions in the ditch (such as boulders or rock outcrops) can potentially deflect water into the subgrade or cutbanks and can result in erosion of the subgrade or undermining of the cutbank. Where there are impassable flow obstructions, consider installing additional cross-drain culverts.

Ditch cross-section

Ensure that ditches are of sufficient depth and flow capacity to transport anticipated drainage flows. The ditch should be adequate to provide drainage of the uphill slope, the roadway surface, and minor debris (leaves, twigs, and small woody debris). Slope ditches to a stable angle, design them to have adequate hydraulic and minor debris-carrying capacity, and limit water velocities to prevent accelerated ditch erosion. Obtain additional capacity for water flow, sloughing, and minor debris by widening ditches. Avoid u-shaped ditches because the almost vertical sides tend to ravel or slough, undermining the cut slope and the shoulder of the roadway. Wide ditch bottoms facilitate grading operations where side borrow methods are used.

Ancillary works

The following features are associated with ditches:

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

Culvert 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. Use them where fine-grained sediments are anticipated from ditch erosion or minor sloughing, and where woody debris movement is expected along ditches in harvested openings. Periodically, clean out inlet basins.

Sediment settling ponds differ from culvert inlet basins in that they are designed to allow sediment to settle for later removal. Generally, locate them downslope of the roadway, but in some instances incorporate them into sections of ditchline.

They are only effective under low water velocity conditions. Ensure that the configuration and depth of settling ponds are adequate to allow sediment to settle and to facilitate clean-out. Consider armouring the back slope of unstable settling ponds with placed shot rock or stabilizing them with placed large boulders.

Settling ponds are a temporary measure to protect water quality during construction. If designed for long-term use, ensure that access is provided to facilitate their cleaning out. Consider vegetating settling ponds to assist filtering sediments.

Install **ditch blocks** to direct flows into the culvert inlet. They are constructed of erosion-resistant material, with the crest being approximately 0.3m 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. Do not provide ditch blocks where ditches converge; however, take into consideration the effects of the increased water volume on the drainage structures.

Use a **take-off or lateral ditch** where a minimum grade is needed for the water to carry fines away rather than depositing them at the culvert outlet and restricting normal flow. They ensure there is a positive flow away from the roadway. However, dissipate or control the flow.

Ditch stabilization

Where 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 gullies or areas of sensitive downslope soils where concentrating water could lead to small or mass failures, limit ditch erosion by:

- armouring the ditch with angular shot rock;
- lining the ditch with an appropriate geosynthetic;
- constructing an erosion-proof check dam, or series of check dams within the ditchline, where velocity is also a concern (note: if not properly designed, however, check dams can create severe erosion holes below the dams and may require a high level of maintenance); or
- vegetating ditches.

Drainage alternatives

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; and
- along one-season winter roads.

Nevertheless, accommodate cut slope and roadway drainage in the above situations using:

- subdrains (e.g., French drains) in place of ditches;
- French drains in place of cross-drain culverts;
- road surface drains such as dips and swales;
- road insloping or outsloping;
- open top cross-drain culverts (e.g., cattleguard-like structures); and
- erosion-resistant road surfacing with a material such as shot rock.

5.8.4 Cross-Drain Culvert Location

How far water should be carried in a ditch before being left to dissipate 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.

Typical locations for cross-drain culvert placement are:

- near the top of a steep road gradient – the intent is to prevent accelerated ditch, subgrade, or cutbank erosion by dispersing ditchwater before its volume and velocity increase downgrade;
- at seepage zones;
- at zones that have localized overland flow with undefined channels (ensure that ditchwater is dissipating at the downgrade side of these zones; otherwise water flow will carry on to the next segment of the ditch, 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, ensure the dissipation of ditchwater volume and velocity 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 before sections of cut slope instability or raveling;
- before large through-cuts that may be drainage divides; and
- 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.

5.8.5 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. In wet areas, particularly along steep road segments, consider decreasing the spacing between cross-drain culverts to decrease ditchwater flow volumes and minimize ditch erosion.

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 minimum gradient of 1%. Shallower gradients may allow silt to build up inside the pipe. Consider the need to provide outlet protection, particularly if the culvert gradient exceeds 3%.

To encourage smooth entry of ditch flows, skew cross-drain culverts to be perpendicular to the road centreline by 3 degrees for each 1% that the road grade exceeds 3%, to a maximum of 45 degrees. This skew will increase the overall length of the culvert, a fact that needs to be taken into consideration when culverts are being ordered for installation.

Excavate unsuitable materials beneath the pipe and replace them with suitably compacted fill to provide a firm and uniform foundation. Assess whether seepage along the outside wall of the pipe could cause internal piping erosion (loss of fines and gravel, resulting in voids forming channels or “pipes”) that could impair the stability of the culvert installation and road prism. If this is a concern, consider using suitable geotextiles or other seepage control measures (such as sand- bagging or installing pre-fabricated anti-seep barriers or collars at right angles to the pipe) along the pipe wall near the inlet to retard longitudinal seepage along the pipe. Remove large rocks or ledges and replace them with suitably compacted fill before the pipe bedding is prepared. Backfill and compact around the culvert in the same manner as for stream culverts (see Construction of Open & Closed Bottom Metal Culverts on Non-Fish Streams).

5.8.6 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. Ensure that the design is in accordance with the requirements set out in Chapter 3: Log Culvert Design. Use the following procedures to lay out and construct a log culvert:

- mark the location of the substructure on the ground before and after the site- clearing operation;
- particularly for those log culverts with high fills or requiring skewing, ensure that the sill logs be cut to the correct length and placed in the proper position;
- lay two evenly sized sill logs parallel to and clear of the wetted perimeter of the stream, and on solid bearing;
- excavate a trench for the sill logs below the scour depth of the stream or construct a non-erodible foundation pad of large angular shot rock;
- pin the outside stringers to the sills with drift pins or lashing, or place them in neat notches; avoid sharp notches or slabbing of the stringer ends that will result in unacceptable stress concentrations or degradation of the shear strength;
- place a layer of non-woven geotextile filter cloth over the stringers.

5.8.7 Temporary Stream Crossings

Temporary stream crossings are used to provide access until the prescribed access structures are in place. Depending on the season that the stream crossing structure is constructed and used, there are options as to the type of temporary crossings that should be installed. The range of options depending on site conditions and type of road construction may include snow fills, fords, log bundles, log culverts, and log skid or portable bridges. Ensure that a temporary structure can handle peak flows without causing negative impacts on the streambed. Install the permanent structure as soon as conditions permit.

5.8.8 Construction of Open & Closed Bottom Metal Culverts on Non-Fish Streams

Intrusive excavation and local modification of channel conditions may be by- products of the construction of metal culverts on non-fish streams. However, ensure that the disturbance to the stream channel and the stream bank at the crossing are mitigated to the extent that the original conditions are reasonably restored. Also, ensure that despite the works at the crossing, the stream banks above and below the crossing are protected.

For non-fish streams, the choice of open or closed bottom metal culverts is generally one of economics, whether it be the cost of materials or the complexity of installation considering the required opening of the culvert and the streambed gradient and composition.

Use culvert outlet protection where discharge velocities and energies at the outlets of culverts, conduits or channels are sufficient to erode the immediate downstream reach. This practice protects the outlet from developing eroded pools. Protection against scour at culvert outlets varies from limited riprap placement, to protect the channel and redistribute or spread the flow, to complex and expensive energy dissipation devices. Preformed scour holes, approximating the configuration of naturally formed holes, dissipate energy while providing a protective lining to the streambed. When outlet velocities are high enough to create excessive downstream problems, consider using more complex energy dissipation devices. These include hydraulic jump-basins, impact basins, drop structures, and stilling wells. However, for small installations, where riprap will not suffice, it may be financially prudent to consider an open bottom culvert option or small bridge structure. In any event, where the culvert slope exceeds 10%, and scour will be an issue, retain a specialist professional to review the hydraulics at the site and determine the best site-specific solution to the scour issue.

Expand All | Collapse All

Constructing "in the dry"

Construct culverts “in the dry” whenever possible to prevent or minimize impacts on water quality and other biological resources. This typically enables faster construction of the culvert and reduces the potential for sediment transport into the stream.

Open bottom culvert foundation

Lay an open bottom culvert on a foundation that will prevent differential settlement over time that could compromise culvert functions and cause damage to overlying road. The foundation generally consists of parallel supports through the length of the culvert, and may be:

- continuous spread footings (generally precast or cast in place concrete); or
- footing pads (intermittent supports).

The size and complexity of culvert footings depend on the underlying soil qualities as well as the volume and size of traffic that will pass over the culvert. Bury the footings for open bottom culverts at a depth that will prevent the footing from being exposed by scour.

Limit the disturbance of the steam bed and banks to that necessary to place the structure, embankment protection and any required channel modifications associated with the installation. Revegetate disturbed areas to assist in reducing future surface soil erosion.

Backfilling and compaction

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. In general, utilize the procedures below:

- select good backfill material;
    - use a granular, non-saturated backfill material; pit-run gravel or coarse sands are usually satisfactory;
    - use cohesive materials as backfill material only 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 1200mm diameter and larger, place backfill material in layers to about 150-300mm loose thickness, depending on compaction equipment, materials being placed and the designer’s requirements;
- balance the fill height on either side as backfilling progresses;
- compact each layer before adding the next layer;
- do not permit construction vehicles or equipment to cross the structure until the

minimum allowable depth of cover established by the manufacturer or by a designer has been placed.

5.8.9 Construction of Open & Closed Bottom Metal Culverts on Fish Streams

Ensure that any culverts constructed on a fish stream do not impede fish passage or harmfully alter fish habitat. Because of the special precautions and limitations on instream work in fish streams, refer to the Fish-Stream Crossing Guidebook for information on the construction of such culverts.

5.8.10 Fords on Non-Fish Streams

Expand All | Collapse All

Ford construction

For low-flow or ephemeral streams, a properly designed and constructed ford allows the stream flow to pass around and between subsurface rocks. To accomplish 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 to enable the ford to resist the erosion forces; and
- 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.

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

- armouring ditches with non-erosive material;
- directing runoff into sediment basins or other sediment trapping devices; and
- 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.

Ford operating constraints

Once a ford is constructed, control its use to ensure that the integrity of the structure is maintained and that any potential adverse impacts on the environment are minimized. Do not drag or skid anything across the ford that could destroy the running surface of the ford. Where possible, ensure that vehicles using the ford are in good working order and not leaking fuel, hydraulic fluids, lubricating oil, or cargo. Remove excess soil heavy equipment before it crosses a watercourse. Do not use the ford if the water depth is greater than the axle height of the vehicle. Consider installing a water-depth gauge and a warning sign that are clearly visible from the road. Should a ford become unsafe for traffic during high water, take measures to warn and exclude users for that period.

Ford maintenance

Properly designed and constructed fords are usually low maintenance structures. Nevertheless, inspect fords at a frequency commensurate with the risk to road users and the environment, and properly maintain:

- running surfaces;
- approach grades and aprons;
- ditches; and
- catchment basins.