by R.L. Rothwell*

How to design logging road drainage systems

A well-planned drainage system is an important element in the design of logging roads.

Besides providing longer road life and reducing road maintenance problems, good drainage will minimize soil erosion and deterioration of the surrounding watershed. Excess water on roads weakens grades, erodes surfaces and slopes and causes slides.

This article provides guidelines for the design of logging road drainage structures. The recommendations are based on an extensive literature survey of research findings and common practices in North America.

The primary function of a drainage system is to intercept, collect and remove surface and subsurface runoff from roads.

The design of road drainage systems is an integral part of the road plan and should not be considered as a separate task. Many drainage problems can be minimized in road location by avoidance of clay beds, seeps, springs, concave slopes, muskegs, ravines, draws, and stream bottoms. For control of runoff, roadside ditches, intercepting ditches upslope, culverts, and cross drains can be used.

Design and installation of culverts

Culverts should be installed at all points where natural drainages intersect a road and along grades, at intervals sufficient to prevent excessive build-up of runoff on road surfaces and in roadside ditches. Unfortunately, very little quantitative information exists on the spacing of culverts or cross drains which collectively considers soils, topography, and precipitation. The general rule of dividing 1000 by the road gradient can serve as an initial guide for spacing culverts.

Culverts should be large enough to carry peak flows from drainage areas and discharge from roadside ditches. If culverts are too small they become overtopped or clogged, resulting in ponding of water, flows over road surfaces, and eventually, road failures.

A survey of existing culverts on a watershed can provide useful information for determination of the size of culverts needed for a new road. Where a parallel road does not exist, examination of areas with similar rainfall, topography, vegetation, and soils is helpful.

When such surveys are made, the diameter, length, and slope of culverts, the age of culverts, and high-water marks relative to culvert inlets should be noted. Also, signs or erosion at culvert outlets from high velocity exit of runoff or sedimentation in culverts from low velocity flows should be considered. If possible, culverts should be inspected at high water and low water stages.

Culvert size required to drain a given area can be determined by empirical formulas. Talbot's formula is often used for forest roads:

$$A = (C)(M)^{3/4}$$

C = runoff coefficient which incorporates factors of soil, topography, and rainfall

M = drainage area in acres

The formula is for a maximum rainfall intensity of 4 in. per hour and a velocity flow of 10 feet per second.

When culverts are installed, trenches should be prepared with an even grade and free of rocks that might damage the pipe when the trench is filled and compacted. Culverts should be covered with well-tamped fill, equal in depth to half the diameter of the pipe but never less than 12 in. Fig. 1 shows a poorly installation culvert.

Fill material should not be humped to cover culverts for this is ineffective and poor workmanship. Minimum grade for a culvert should be 3% and not less than the road above it. A useful guide is that a culvert should be inclined 2% more than the road grade above it. Where large amounts of silt are expected, a grade of 20% may be desirable to make the culvert self-cleaning. However, the grade should not be too great as water can back up and cause road damage.

Culverts should have sufficient camber or bend to compensate for the settling of fill material. The weight of settling fill will cause culvert ends to bend slightly upwards or tear apart at the joints.

Debris control at culverts

The inlets and outlets of culverts should be protected to prevent them from becoming clogged or damaged. Conditions that require debris control around inlets are:

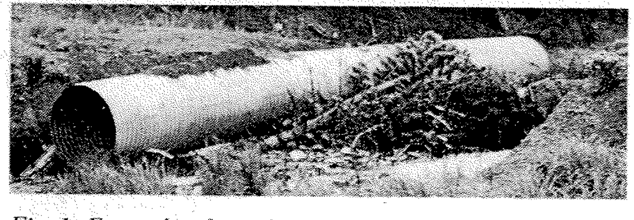

Fig. 1: Example of poorly installed culvert with inadequate fill covering it. Organic material like the trees seen in the photograph should not be used as fill, since extreme settling and washouts can easily occur.

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existence of present or future logging slash upstream, sandy or silty stream bottoms, and erodible soils. Fig. 2 shows different structures that can be used to control debris.

Culvert outlets should be provided with aprons of rock or resistant material to reduce the energy of outflow. For prevention of erosion on large fills, aprons and downspouts may be necessary to transport water over unstable soil materials.

On secondary and temporary roads, drainage can be obtained inexpensively with open-topped culverts (Fig. 3). Open-topped culverts should be placed at angles across a road to provide gradient to the culvert and so no two wheels of a vehicle hit the ditch at once. This protects the ditch and helps keep it self-cleaning. This kind of culvert is economical and efficient for three to four years. Open-topped culverts can be built from many materials.

Ditch construction guidelines

Roadside ditches are equally important as culverts for controlling and dispersing runoff from roadways. Ditches should be large enough to carry runoff from moderate storms. A standard ditch used on secondary logging roads is a triangular section 1½-ft. deep, 3 ft. wide on the roadway side, and 1 ft wide on the cut bank side. Minimum ditch gradient should be 0.5% but 2.0% is preferred to ensure good drainage.

Runoff should be frequently diverted into culverts to prevent erosion or overflow. Ditches may have to be deepened for excessive rainfall and for draining ponds, springs, and swamps.

To determine the water carrying capacity of a roadside ditch, use Manning's formula:

$$Q = A\frac{1.486}{n}R^{2/3}S^{1/2}$$

Q = discharge in C.F.S.

A = cross-sectional area of the ditch in square feet

R = hydraulic radius which is equal to A divided by wetted perimeter of the ditch running full.

n = coefficient of roughness; for ditches in good condition n is 0.025, for poor, ditches 0.04.

S = slope of ditch in feet per foot.

Example calculation:

$$A = 2.0\text{ ft}^2 \quad S = 10\% = .1 \quad R = \frac{2.0}{\text{wetted}} = \frac{2.0}{4.9} = 0.436$$

$$n = 0.04$$

$$Q = (2)\left(\frac{1.486}{.04}\right)(0.436)^{2/3}(.1)^{1/2} = 13.58\text{ C F S.}$$

An alternative to larger roadside ditches is an intercepting ditch constructed upslope to reduce runoff entering roadside ditches. Intercepting ditches are built above the backslope, on a gentle contour grade to the nearest drainage channel above a culvert. Intercepting ditches also reduce slumping of road cuts by preventing soil from becoming water saturated.

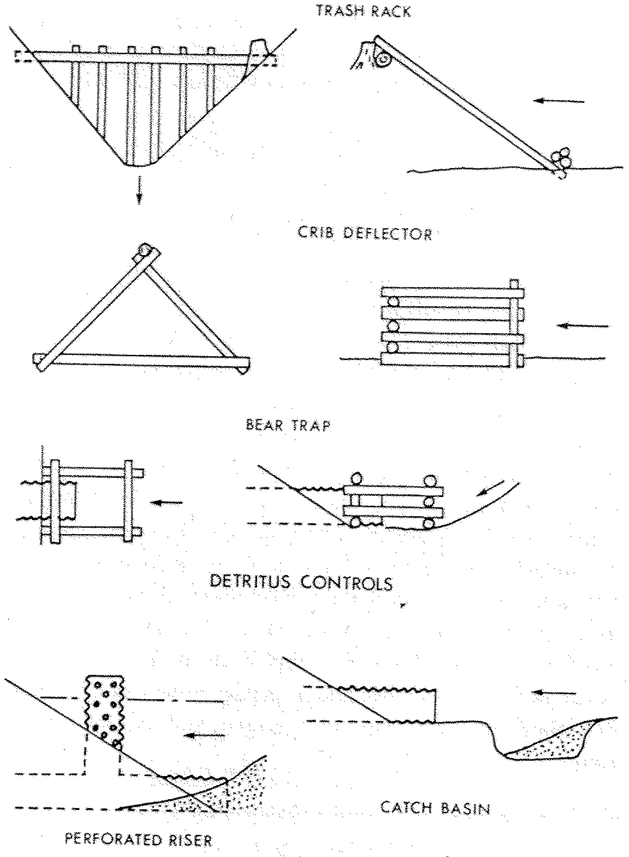


Fig. 2: Some common debris control structures.

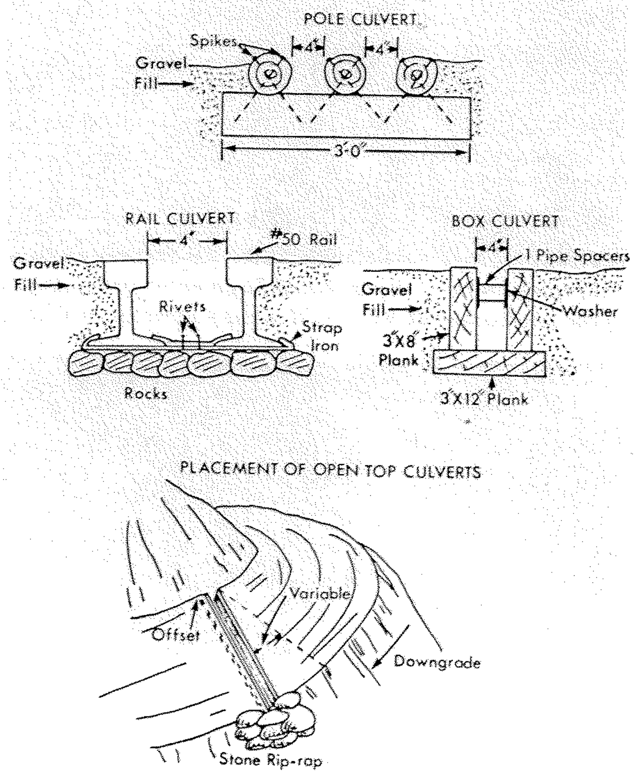


Fig. 3: Open top culverts (after Simmons 1951).

Road grading for runoff control

Outsloping and rolled grades are two other methods of controlling runoff on roads. Outsloping is grading the road so it slopes downward from the toe of the road cut to the shoulder. The slope should be just enough to move water off the road, about 3/8-½ in. per foot. If outsloping is apparent to the eye, it is too great.

Outsloping is preferable for use on contour roads where it will reduce the number of culverts for drainage. For safety, outsloping should not be used in steep country or where conditions are wet and slippery.

Rolled grades are a series of gently rolling dips constructed into a road to facilitate drainage (Fig. 4). It is essential that the dips be true dips with adverse slope on the downhill side. The bottom of the dips should slope gently from the cut bank to the road shoulder. Dips should not be used to carry constantly running water.

Sub-surface water is infiltrated water, which takes the form of seepage, springs, high water-tables, or capillary water. Drainage of sub-surface water is difficult and expensive so this problem is best avoided by locating roads on well-drained, high ground and by avoiding hollows, bottoms of slopes and deep road cuts. A good time to locate roads is in the spring when seeps and springs are most active and noticeable. Fig. 5 shows how slides can occur in fill sections because a seepage zone has lubricated the plane between the fill material and an impervious zone.

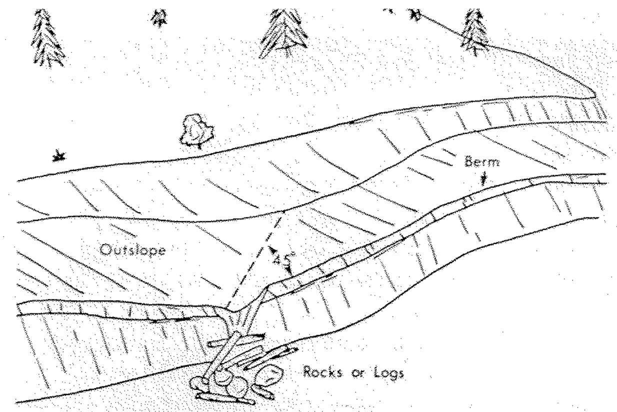


Fig. 4: Rolled grade and crossdrain (after Haussman 1960).

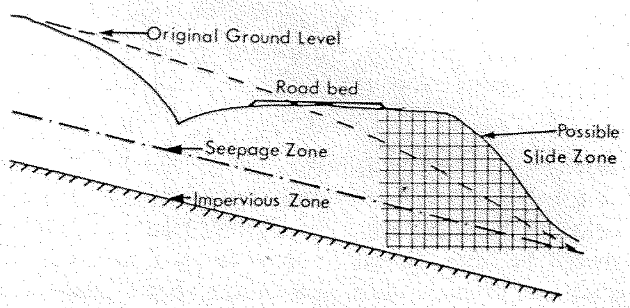


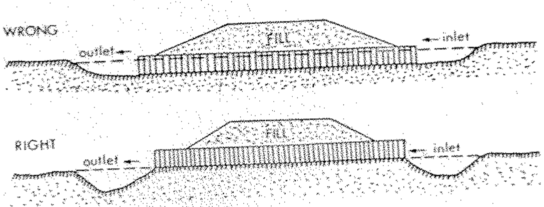
Fig. 5: How seepage can cause slides in fill section.

Skid trails on steep slopes should be carefully pre-planned to minimize soil disturbance. A haphazard arrangement of trails, as in the photograph at left, could occupy upwards of 20% of the logged area. Coverage of 10% or less is desirable (right).

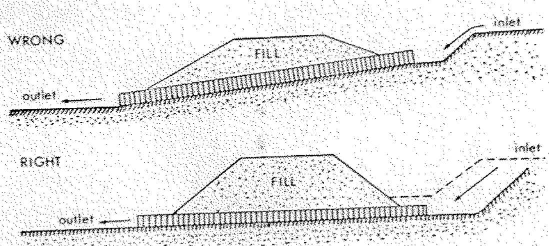
Skid trails should not be permitted to run straight up and down slopes, since serious erosion may occur and gullies may be formed, as at the upper section of the trail in this photograph. Trails should follow the contours. Slopes 12-18% are best for efficient tractor logging.

Skid trails should not be built on draws or creek bottoms. The trail in the photograph is too close to the small tributary and crosses the main stream without a culvert or temporary bridge. In any case, the gradient is too great for a stream cross and has no sediment trap.

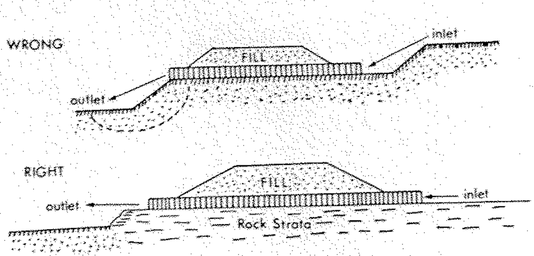
Dos and don'ts of culvert installation



Culverts should not be installed where ditches are lower on each side of the fill than the outlet. This will cause water to collect to a depth shown by the dotted line in top drawing and will cause the culvert to fill with sediment. The bottom drawing shows correct installation, which places the culvert on the natural flow line of water. Flow through and away from the culvert will not occur until the ditches are filled to the level indicated by the dotted line in the drawing.



The top illustration shows a culvert installed with too much fall. This will cause erosion at the bottom of the culvert and shorten its life. Correct installation is shown in lower drawing, where the ditch on the right has simply been lowered to the natural flow line, as indicated by the dotted line. Construction costs will likely be higher for the correctly designed culvert but maintenance costs will be lower and life-expectancy greater.



When a culvert is installed with the outlet high above the natural flow line, as in the top illustration, the fill will be washed away unless the outlet is extended beyond the toe of the slope. The bottom drawing shows a location where the fall below the outlet end is solid rock. Here the natural flow line is level with the rock.

CANADIAN

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COVER: International 3965 moves 8-ft bolts from Nesco slasher directly on to Sicard truck with custom-made Can-Car trailer. Slashing/loading productivity averages 27.4 cords per hour on this Thunder Bay, Ont. area logging operation of Abitibi Paper Co. Story on page 24.

Abitibi crews fell-skid up to 6 cords a man-day 24

Abitibi Paper Co. is getting good productivity and unexcelled machine reliability on its Thunder Bay, Ont. district logging operations. Man-day productivity is 5½-6 cords for three-man manual felling/wheeled skidding crews. Productivity in the mechanical slashing/loading phase exceeds 9 cords per man-hour. Machine availability through the operations is better than 90% average. Abitibi has participated extensively in developmental work on mechanical fellers and is keeping a close watch on progress with small-tree harvesters, but for the moment the company plans to stay with its highly productive partially mechanized logging system.

The life and times of Russian forest workers 30

Did you know that there are logging trade unions in the Soviet Union? How the Russian forest worker lives and how forest operations in the Soviet Union are organized is explained in this on-the-spot report by Canadian forestry consultant J.A. McNally, a former woodlands executive. The article is about activities in a typical Siberian forest village of 1,380 people. Loggers work Monday to Saturday and are entitled to a four-week vacation each year. Men and women get equal pay for equal work. Retirment age is 60 for men, 55 for women and they get a pension of 50% of pay at retirement.

How to design logging road drainage systems 39

A well-planned drainage system is an important element in the design of logging roads, extending road life and reducing maintenance costs. Good drainage also minimizes soil erosion and deterioration of the surrounding watershed. This article provides guidelines for the design of drainage structures.