U. S. FOREST SERVICE

RESEARCH NOTE NC-37

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
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SIZE AND PLACEMENT OF METAL CULVERTS CRITICAL ON PEATLAND WOODS ROADS

ABSTRACT. — Culverts too small in diameter or poorly placed were major causes of timber flooding and tree damage. Placement problems were poor culvert slope, poor hydraulic approach, lack of gravel bedding, and too little soil covering the culverts.

A recent 7-county survey on roads used for logging and other woods work in northern Minnesota peatlands showed that backwater on 56 percent of wetland crossings had killed the timber or depressed its growth rate (Stoeckeler 1967). Furthermore, at high-water stages runoff water sometimes flowed over the road and eroded it. High levels of impounded water caused some road surfaces to become too soft and rut deeply after only a few passes of vehicles. Such roads are difficult for traffic and sometimes impassable, and require excessive maintenance. Lack of any culverts or poor placement of culverts were major reasons for this damage.

As a supplement to the survey, 41 metal culverts on 39 sites were studied to determine the factors that reduced their effectiveness. Thirty-seven sites had single culverts, and two had double culverts. Topography was such that the contours were somewhat parallel to, or within about 45 degrees of being parallel to, the road on 33 sites. These sites had considerable tree damage. There was no tree damage on the other 6 sites where contours were more nearly at right angles to the road so that drainage was less likely to be impeded (Stoeckeler 1965).

Culvert Size and Condition

Culvert size was related to tree damage from backwater and to the degree of siltation. Sites with culverts 21 inches or less in diameter had an especially high incidence of tree damage (table 1). Of these smaller culverts, 30 percent showed serious siltation; they were either plugged completely or silted up to one-third or more of their diameter. Plugged culverts contribute to a permanent backwater. Those partially plugged have a reduced capacity, and prolong temporary flooding from backwater. None of the culverts 24 inches or more in diameter were plugged, nor was their capacity seriously impaired.

Many factors affect the condition of culverts, but the number of years since installation is probably the more important one in culvert deterioration. Mueller (1955) cites 57 years as the average expected life of corrugated iron culverts in the United States. This life span, however, can be drastically shortened by various factors such as highly acid waters, the presence of organic reducing or oxidizing soils (Beaton and Stratfull 1959, 1962), or the presence of hydrogen sulfide (Lehmann 1964).

Table 1.—Tree damage on 33 sites with contours of the land somewhat parallel to the road

Culvert diameter group (inches)	Number of sites	Percent of sites with—[1/]			
		Undamaged stands	Damaged stands		
			Light to moderate	Severe	Total
12	5	0	20	80	100
15-21	15	20	40	40	80
24-30	6	67	0	33	33
36-60	7	71	15	14	29

[1/] See Stoeckeler (1967) for damage class definitions.

Field tests, based on the method of Beaton and Stratfull (1962), indicate that the pH of the water on 21 of the 33 sites with water flowing through the culverts is acid enough (5.0 or less) to reduce culvert life below the 57-year average. According to Forest Engineer Peter Meyer on the Chippewa National Forest in Minnesota, the average life of culverts in that area is only about 25 years. There, acid waters, which come mostly from certain types of peatlands, are probably a major factor in culvert deterioration. Asphalt coating would seem to offer a means of prolonging the service life of metal culverts in peatlands and should be tested.

In overall condition 53 percent of all 41 culverts in the study were rated as good, and 37 percent as fair. Ten percent were rated as poor owing to serious corrosion, severe bowing from frost lift, or other causes.

Culvert condition was also rated by the Mueller system, which deals with condition of the metal and its degree of corrosion. By this rating, only one culvert needed immediate replacement. Two more were rather close to the replacement stage.

Seven percent of the culverts were bowed and out of alignment, probably due to frost action; and another 7 percent had been damaged by road graders and snowplows — 4- to 12-inch pieces had been torn out, thereby accelerating rusting and weakening the culverts. Such breaks serve as entry points for surface gravel or soil and can thus reduce culvert capacity.

Installation Problems

About one-fourth of the culverts were classed as poor in the quality of hydraulic approach. Many inlets protruded too far, were choked by grass, brush, or siltation, or had large rocks impeding inflow of water.

The Minnesota Highway Department recommends a maximum slope of 1.0 percent and a minimum slope of 0.2 percent for culverts. For 34 culverts where slope was recorded, 27 percent were below the minimum and 44 percent were above the maximum:

Percent of slope	*Percent of culverts*
—0.1 to —1.0	6
0 to 0.1	21
0.2 to 1.0	29
1.1 to 1.5	26
1.6 to 3.0	9
3.1 and over	9

The culverts with slopes below the minimum standard averaged —0.7 percent slope — that is, they sloped *toward* the supposed inlet. Such culverts are especially prone to siltation. Twenty-six percent were in the 1.1 to 1.5 slope percent; although this is slightly greater than the maximum slope standard, it is not excessive for small-diameter culverts in narrow woods roads. Too little slope was a greater problem than too much.

Many factors can change the slope of a culvert after its installation. Some important ones are unequal soil subsidence and buoying (the lifting action by water) (Frederickson 1963) and frost heaving. Excessive projection of the intake side of the culvert probably accentuates both frost heaving and buoying.

Experts in soil mechanics and road construction (Casagrande 1936, 1938; Edgerton 1961) have emphasized the use of coarse gravel bedding under and at the sides of metal culverts to reduce frost heaving. Of the 41 culverts studied, only 48 percent were set on gravel or crushed rock. The lack of such bedding in the others undoubtedly caused some of the frost lifting, tilting, unequal subsidence, or culvert bowing. To reduce tilting or unequal subsidence, Davis (1961) suggests putting culverts in shallower peat on coarse bedding material extending to the mineral soil below, and for deeper peats (4 to 5 feet or more) placing the culvert on brush mat "corduroy," which holds up the mineral soil road surface fill.

Of the 41 culverts, 28 percent were not stabilized by rock or sod near the inlet. Sixteen percent had considerable sloughing on the road shoulder — a particularly serious problem near the smaller diameter metal culverts, which tended to get silted in. Seventeen percent had considerable erosion at the outlets, and 20 percent had some erosion at the inlets. Rock riprap or rock channel liners at inlets, or graded gravel and rock at outlets could serve as energy dissipators and reduce this erosion very substantially (Smith and Hallmark 1961).

The average soil depth over the top of the culverts was 1.1 feet. The depth of soil cover was especially thin (0.5 foot or less) on 35 percent of the culverts and rather meager (0.6 to 1.0 foot) on an additional 32 percent. Eighteen percent had a soil depth of 1.1 to 2.0 feet, and 15 percent had 2.1 feet or more. Deeper placement of culverts would seem highly desirable to increase the depth of soil over culverts and reduce culvert damage by traffic and by roadgraders and snowplows.

Apparently more care was taken in placing the larger diameter, more expensive culverts than the 12- to 21-inch size where most of the cross drainage and maintenance problems occurred.

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