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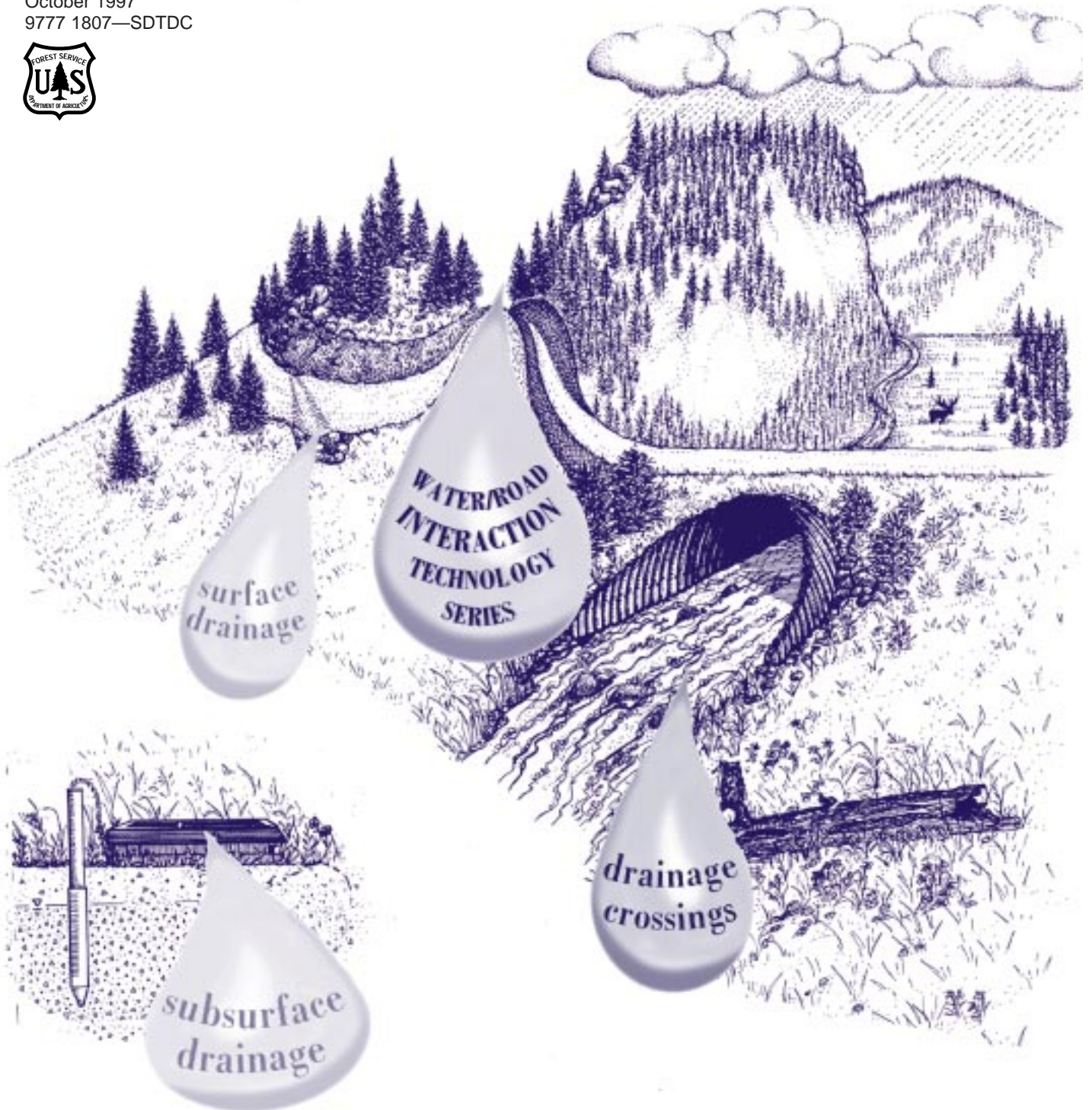
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Field Indicators of Inlet Controlled Road Stream Crossing Capacity



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FIELD INDICATORS OF INLET CONTROLLED ROAD STREAM CROSSING CAPACITY

INTRODUCTION

Most road stream crossings in wildland environments exhibit physical evidence of past crossing performance that can be readily observed in the field. These observations, together with more intensive watershed inventory and assessments, are useful in determining where crossings are likely to fail and where crossing upgrades or road decommissioning may be needed to reduce adverse effects to aquatic and riparian ecosystems.

Typically, culverts will possess a suite of identifiable field features that indicates their past performance. These features are useful for screening sites for possible upgrade or removal. They are intended to add supporting field evidence to more rigorous inventories and assessments. These features have been observed around inlet-controlled culverts (usually where pipe gradient is greater than 2 percent). Caution should be used when applying the parameters to outlet-controlled culverts.

The indicators discussed here are:

- Channel width versus culvert inlet diameter
- Inlet basin geometry
- Terrace development in the inlet basin
- Crushing and plugging of the inlet.

CHANNEL WIDTH VERSUS CULVERT INLET DIAMETER

Channels develop their particular form in response to their long-term regime of water, debris, and sediment. Channel dimensions are thus a good indicator of the range of water, debris and sediment yields in the channel. Stream bed width—the zone of annual scour—(Lisle 1986) is a readily observable feature for most low-order channels. Traditionally, bankfull or active-channel width has been used for assessing channel dimensions (Keller and Tally

1979). However, for many upland, forested channels, confinement of the channel by hillslopes precludes development of bankfull terraces. Stream bed width is a more consistently observable feature.

Plugging of culverts by woody debris is common in woodland settings; however, traditional analysis techniques do not address debris passage. Small culverts on relatively wide stream channels are at a greater risk of plugging with floating wood than culverts that do not restrict the channel width. The role of channel width in controlling the size of fluvially transported debris is well documented (Keller and Swanson 1979, Bilby 1985, Robison and Beschta 1990). Often, the diameter of the culvert is less than the stream bed width. For example, a survey of 140 road stream crossings in the North Fork Eel River watershed in Northern California revealed that 9 percent of the culverts had a diameter less than half the stream bed width. This width constriction is a favorable place for the accumulation of woody debris. As culvert diameter increases, longer pieces of woody debris are required to initiate culvert plugging (Flanagan, in review). Thus, the ratio of culvert diameter to stream bed width provides one indication of plugging potential in woodland settings (figure 1).

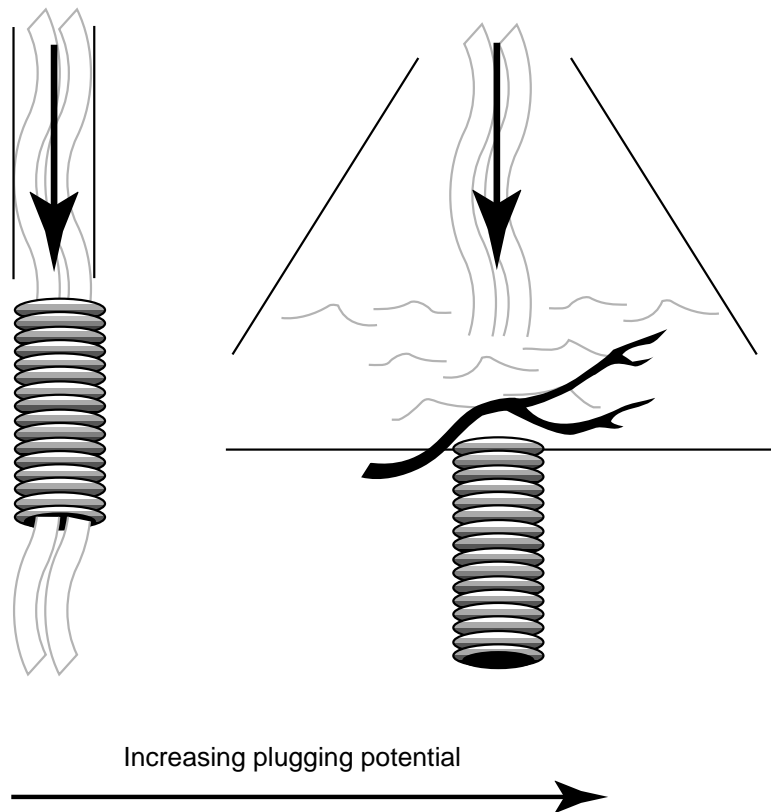
INLET BASIN GEOMETRY

Debris plugging is more likely where channel confinement decreases and channel width increases towards the inlet. During peak flows, the water spreads laterally promoting debris rotation and accumulation in the turbulent eddies of the widening flow (figure 2). Pieces oriented perpendicular to the inlet most often become lodged across the inlet thus initiating plugging. Normann et al. (1985) suggest straight, narrow channel approaches promote debris passage.

Similarly, high angle channel approaches promote plugging by debris (Garland 1983 and Piehl et al. 1988). Wood in transport, oriented parallel to the channel, is unable to rotate when it approaches the inlet due to forward momentum and/or lack of rotational space (figure 2).



Figure 1—When compared with the bed width, the zone of average annual bedload transport, this culvert is undersized. Hydraulic calculations show this pipe unable to pass a 10-year design discharge. Also note terrace development. Such physical features often coexist and provide evidence for inadequately sized culverts.



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Figure 2—Inlet basin plan view. Inlet basins that maintain the natural channel configuration promote debris transport and passage through the culvert. Where the flow is allowed to spread laterally, debris can accumulate and increase the chance of plugging. Furthermore, debris rotation is promoted in the turbulent eddies of the widening flow. Similarly, where the channel abruptly changes direction, wood lodgment is enhanced. This is a common scenario for cross drains.

Debris plugging hazard at road stream crossings cannot be eliminated. Debris torrents, overhead blowdown, and fluvial transport of unusually large pieces can present pieces too large for the culvert to pass. However, recognition of the factors influencing the transport and orientation of debris coupled with simple, cost-effective designs can reduce the hazard substantially.

TERRACE DEVELOPMENT IN THE INLET BASIN

Crossings with a history of ponding water due to insufficient culvert capacity often produce terraces upstream of the inlet (figure 3). Sediment is deposited during ponded conditions. Terrace elevations can provide a clue to the magnitude of peak flows. Debris torrents that are slowed or stopped by the fill prisms also leave similar, but typically larger, undulating terraces. Terrace surfaces that project to near the road surface suggest peak flows have overtopped the fill. Terraces are rapidly colonized by vegetation and may require close examination of the inlet basin.

CRUSHING AND PLUGGING OF THE INLETS

Culverts with a history of plugging may have crushed or dented inlets from repeated excavation by heavy equipment. A crushed or plugged inlet will have an effective diameter corresponding to the degree of damage or plugging. For inlet-controlled culverts, reductions in the inlet cross sectional area result in a loss of hydraulic capacity. However, when expressed as a design storm capacity, reductions in inlet cross sectional area substantially reduce the design storm capacity of the pipe (figure 4). The percent reduction in inlet cross sectional area should be included in more detailed pipe capacity calculations. In the absence of maintenance, plugging is cumulative. The reduced aperture created by the plug promotes further plugging.

CONCLUSION

Stream crossing capacity can be assessed in the field using easily observable features. Relatively small culverts on wide channels are at risk of plugging by woody debris. Plugging hazard is increased where streamflow is allowed to spread



Figure 3—Terraces upstream of the culvert inlet indicate past ponded conditions. Channel dimensions and hydraulic capacity of this culvert should be checked.

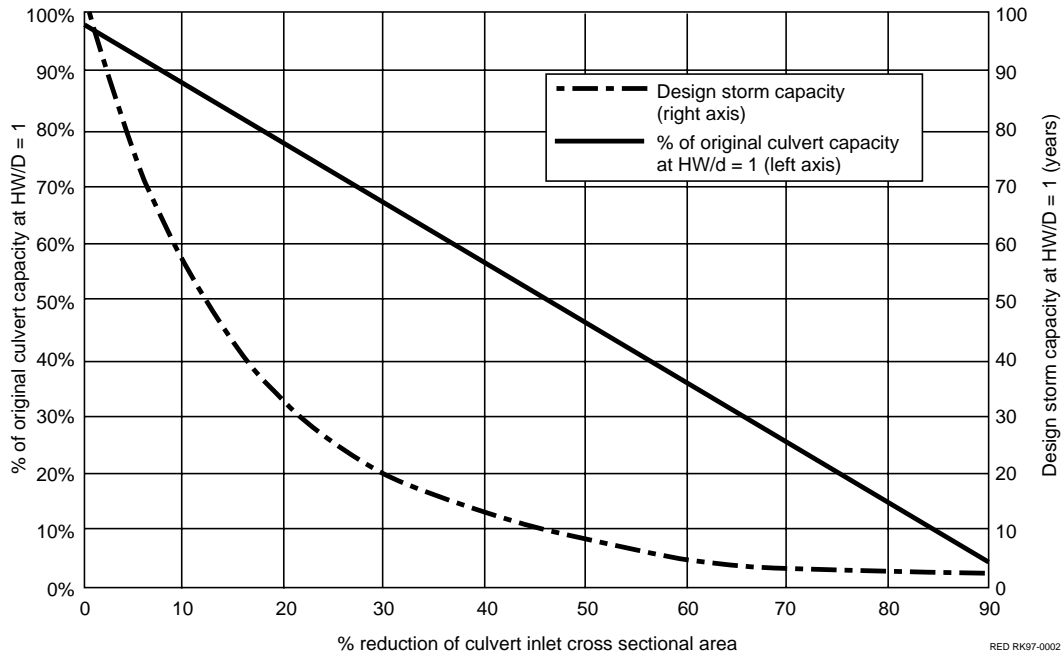


Figure 4—The percentage of cross sectional area reduced by crushing or partial plugging of the inlet is nearly equal to the percent of hydraulic capacity reduced (solid line). However, these reductions in capacity translate to large reductions in design storm capacity (dashed line). In this example from northwest California, a culvert originally sized for the 100 year design storm at HW/d=1 can only pass the 25-year storm with a 25 percent reduction in cross sectional area.

laterally in the inlet basin. Terraces deposited in the inlet basin are an indication of past failure(s) or a “near miss.” Crushed or partially plugged inlets can substantially reduce the design storm capacity of the culvert.

Site assessments are best accomplished as a ‘screening’ tool to determine those crossings that

pose the greatest chance of failure. The features recorded at one crossing should be compared to nearby sites to produce a ranked list of crossing capacity. The results of this screening can then be combined with an assessment of the consequences of failure and the downstream values at risk to produce a priority set of crossings to be evaluated for treatments.

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