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Relining Culverts Can Reduce Hydraulic Capacity

Relined culvert - reduced cross sectional area.
This CSP culvert under Highway 407 in Ontario was relined after less than 20 years in service. The designer specified the appropriate rip rap protection to prevent erosion.

The following statement is made in a research paper that was presented at both the Transportation Association of Canada Annual Conference in Halifax in September 2010, and again at the Transportation Research Board Annual Meeting in Washington D.C. in January 2011.

"Improved Flow Characteristics: *Another advantage of HPDE culvert relining is the potential to increase the culvert flow capacity and velocity. In many cases, HDPE liners will increase the flow capacity, even though the cross-sectional area will be reduced from the host pipe. Despite the reduction in area, the flow capacity can be maintained or improved because of the smoothness of the lining walls.* ***Provided the culvert is outlet controlled, the reduction in flow resistance will counteract the reduced cross-sectional area."***

This type of statement can be misleading especially if the final sentence (bolded for emphasis in this article) in the paragraph above is overlooked. What does "*provided the culvert is outlet controlled*" mean?

Inlet and Outlet Control: Culverts are classified according to which end controls the discharge capacity, the inlet or outlet.

Inlet Control: If water can flow through and out of the culvert faster than it can enter, the culvert is under Inlet Control. Flow capacity is controlled at the entrance by the headwater depth, cross-sectional area and type of inlet edge. The roughness, length and outlet conditions are not factors in determining capacity. Flow is therefore controlled upstream and is limited to what can enter the culvert.

Outlet Control: If water can flow into the culvert faster than it can flow through and out, then it is under Outlet Control. Culverts under outlet control can flow either partially full or full. In this case water is relatively deep and slower. Therefore, flow is controlled downstream and limited to what the pipe can carry. In this case friction and roughness in the culvert are significant in the flow through a culvert and the difference in head-water and tailwater depth represents the energy which conveys flow through the culvert.

Inlet and outlet control are set by the slope of the stream, it is not a designed feature. Generally speaking, when culverts are designed, calculations are made assuming both inlet and outlet control and comparing the headwater depth under both conditions. Designs for low headwater depths

Canadian Concrete Pipe and Precast Association 447 Frederick St, Suite 200, Kitchener, Ontario N2H 2P4
T: 519.489.4488 F: 519.578.6060 TF: 1.800.435.0116 www.ccppa.ca

reduce pipe diameter and fill material, but risk overtopping and often result in undersized culverts when exposed to natural conditions. Conversely, designs for higher headwater depths are more conservative and generally govern design.

Factors affecting Inlet and Outlet Control:

Outlet Control	Inlet Control
Headwater Depth	Headwater Depth
Tailwater Depth	N/A
Inlet Edge	Inlet Edge
Cross Sectional Area	Cross Sectional Area
Shape	Shape
Slope	N/A
Length	N/A
Roughness	N/A

Reducing the diameter of a culvert reduces the cross sectional area. If a culvert is in inlet control the hydraulic capacity of the culvert WILL BE REDUCED regardless of the roughness co-efficient (Manning's n) of the liner when it is relined. This can have serious consequences such as overtopping and erosion.

Engineers and public works superintendents are encouraged to develop an understanding of inlet and outlet control before designing and constructing a culvert relining system.

Do it right the first time.