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OFFICE OF TRANSPORTATION
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TECHNICAL SUMMARY

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PROJECT COST:

\$105,640



Instrumentation in the tilting flume in the laboratory collected water flow measurements.

Culvert Design Practices That Ensure Safe Passage for Fish

What Is the Need?

When roadways cross streams, they can cut off access to spawning, feeding and wintering areas for fish and other aquatic organisms. These barriers can threaten the populations of economically important fish like trout or northern pike.

While the Minnesota Department of Natural Resources prefers bridges as the best solution for roadway water crossings, recessed culverts are a less expensive alternative. However, culverts can become a barrier to aquatic organism passage if water flow through the culvert is significantly faster than in the rest of the stream, which can occur if the culvert has a smooth bottom while the rest of the stream bed is rough because of rocks and sediment.

Recessed culverts designed to facilitate fish passage are often installed with the assumption that the stream flow will naturally fill them with sediment, although recent research suggests that may not be true. As a result, MnDOT is working with the DNR to identify the conditions that determine whether a newly installed culvert will naturally fill with sediment, replicating surrounding streambed conditions, or whether a stream's water flow will transport sediment out of a culvert.

As Minnesota does not have a fish passage manual to provide guidance for culvert construction, research was needed to help outline potential design guidelines. Since Minnesota's freshwater fish behave differently from coastal, saltwater species, a simple adoption of coastal state manuals is not likely to provide an acceptable solution for the state.

What Was Our Goal?

This project aimed to determine in the laboratory the conditions under which a recessed culvert will fill with sediment after installation.

What Did We Do?

Researchers used an experimental flume to create a scale model of a stream channel containing MnDOT's standard box culvert design. Using this model, they created a laboratory simulation of several stream conditions, with variations in:

- **Stream gradient (slope):** Simulations include high, moderate and low gradient, all of which can be found in Minnesota.
- **Water flow:** Researchers tested both bankfull (equivalent to the start of flooding) and storm hydrograph flow (which varies over time from below-bankfull to overflow levels).
- **Initial culvert condition:** The culvert was initially either filled or unfilled with sediment. For high-gradient streams, researchers also tested the model filled with both sediment and large rocks.

Culverts can become barriers for fish if water flow through the culvert varies significantly from the rest of the stream, potentially resulting in serious economic and environmental impacts. This project tested various stream settings to determine the conditions under which a culvert will fill with sediment, which helps ensure aquatic organisms can pass through.

“Bridges are not always feasible from a budgetary standpoint, so we are working closely with the DNR to develop the best solution for culverts that protect public safety while protecting the environment.”

—Petra DeWall,
Assistant State Hydraulics
Engineer, MnDOT Office
of Bridges and Structures

“Minnesota has a strong interest in water resources and recreational fishing, so it is economically important to maintain stream connectivity and access to spawning habitats for species such as northern pike.”

—Jessica Kozarek,
Research Associate,
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Box culverts are less-expensive alternatives to bridges that allow fish and other aquatic animals to pass under a roadway. When the bottom of the culvert is significantly different from the rest of the stream, however, water flow will also be different, which can make the culvert a barrier to fish passage.

Researchers ran a series of simulations to monitor the sediment transport process through the culvert. Specifically, they sought to determine conditions that would cause an unfilled culvert to fill with sediment or that would cause water flow to transport sediment out of a filled culvert.

What Did We Learn?

Low-gradient waterways such as wetlands behave very differently from the high-gradient streams on the north shore of Lake Superior, so there is no single practice that applies to all situations. However, this research showed that the assumption that culverts will naturally fill with sediment until their base replicates the natural stream bottom is not necessarily accurate.

The laboratory simulations suggest that filling a culvert with sediment at installation rather than allowing it to fill over time is, with some exceptions, generally the best approach for low- and moderate-grade streams. Additionally, research results showed that culvert designs in high-gradient systems require a filled culvert with structures such as larger rocks to keep sediment in place. These structures also create steps, pools and riffles that enable fish to rest as they move upstream.

What's Next?

This research should be valuable in guiding culvert design to ensure culverts do not create barriers to fish and other aquatic organisms, although site-specific analysis of a waterway's flow and sediment mobility will be required for new culvert installations.

Further culvert research is underway to evaluate the impact of light conditions in culverts on the endangered Topeka shiner, specifically to investigate whether long, dark culverts may be a barrier to that species. Researchers are also testing whether mussel spat rope, which is normally used for farming mussels in oceans, can be used as an inexpensive retrofit to create a rough bottom that reduces water flow speed through existing box culverts that do not contain sediment.

Potential future research avenues include the impact of culvert width and multi-barrel culverts on sediment deposition.

This Technical Summary pertains to Report 2015-08, “Sediment Transport through Recessed Culverts: Laboratory Experiments,” published March 2015. The full report can be accessed at mndot.gov/research/TS/2015/201508.pdf.