

Corrugated steel pipe fish ladder completes first field trial

By Ray Wilcock

Throughout North America, perched culverts and similar hydraulic impasses represent a big problem for migrating fish. Perched culverts are ones with an outlet elevated above the downstream water surface. “Fish ladder” is a term used to describe fishway conveyances intended to help alleviate this difficulty. They generally consist of a stepped series of sequentially elevated water pools, separated by weirs or baffles. Replacing a perched culvert is rarely an economically viable solution.

Despite the fact that these obstacles are widespread, little work has been done to scientifically analyze the performance of existing fish ladders in order to improve them.

Under the auspices of the Natural Sciences and Engineering Research Council of Canada (NSERC), a small



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group of concerned industry colleagues has been collaborating on a project to design and test an innovative corrugated steel pipe (CSP) fish ladder that will enhance the safe passage of migrating fish. Following the analytical /design stage of the project phase, the first prototype has now completed its first field trial.

Overseeing this project are: Dave Penny, Corrugated Steel Pipe Institute (CSPI); Jason Duguay and Jay Lacey, University of Sherbrooke; and Ken Hannaford, Government of Newfoundland and Labrador.

The idea for this research project came about in 2012, when Penny described a concept that Hannaford had for an innovative and improved fish ladder. Penny had learned of this while showing him how using polymer coated structural plate corrugated steel pipe would offer a great base for fabricating these structures. Its corrugations naturally reduce the velocity of water flowing through it, particularly along the edges of the pipe. In fact, the deeper the corrugations, the greater the decrease in



Perched culverts are just one of many elevation obstacles that can stop the passage of fish migrating upstream.

velocity.

Previous solutions have been devised to address the problem, including Denil fish ladders. Inside these, numerous metal fins act as deflecting barriers to slow water flow. However, the fins have sharp edges and, if poorly configured, can create excessive turbulence in the

pools. Moreover, they provide only small zones of calmer water that fish need for resting, before they proceed to the next pool. Sharp baffle edges and excessive turbulence can injure or even kill fish, especially those that are exhausted from swimming against the combined forces

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Ad to Come**

of gravity and flowing water.

Unfortunately, many of these types of fish ladders are ineffective, non-permanent and non-portable devices, and can become plugged with debris, branches, etc.

Penny, Lacey and Duguay collaborated to secure funding from NSERC, which promotes and supports scientific innovation and collaboration among academic experts and industry.

“We needed funds to support our work and purchase numerical modeling software to determine the effects of specific design changes on water velocities and turbulences within the fish ladder,” explains Duguay.

The team had to ensure that its new design could develop spatial distributions of water velocity and turbulence similar to those of other designs recommended by the Department of Fisheries and Oceans Canada (DFO). They employed a 3D computational fluid dynamics program to analyze and design a baffle that would deliver equal or better results, while providing easier, safer fish passage over a wide range of flow rates.

“We wanted to ensure that our baffle would respect the minimum criteria laid out in the DFO recommendations and, hopefully, improve upon a few deficiencies that Hannaford saw in the DFO design,” explains Duguay. “First, the DFO design features aligned passages in the centre of each baffle. This channels flow straight down the centre, creating excessive turbulence as the flow enters the next downstream pool. This effectively reduces the area of calm water available in the pool where fish can rest. A lack of effective resting areas can increase the chance of fatigue, injury and rates of mortality during ascent.”

“Ken Hannaford came up with the concept of using curved forms, rather than angular ones. Also, by sequentially alternating the baffles on either side of the corrugated steel pipe, I immediately saw its potential to relegate high velocities and reduce overall turbulence in each pool of the fish ladder. Also, the corrugated walls of the pipe help to reduce flow velocities,” explains Duguay.

“We were also concerned by numerous reports of debris blockages in the

DFO design. We believe that the curved form of the baffle could also limit debris snags and reduce maintenance costs,” says Duguay.

One principal objective of the design study was to make the new fish ladder passable for as many kinds of fish as possible. This meant that they needed to ensure fish had access to larger recirculation areas of relatively calm water and low velocities near the passageways.

The DFO design recommends a minimum of 200 mm between the lowest part in the slot and the CSP corrugations, which results in little buildup of water depth in pools. That is a weakness, because deeper water will further reduce turbulence. Conversely, the innovative curves of this new, arched baffle produce significant increases in pool depths during higher flow rates, to minimize turbulence.

“I would run simulations and send them to Hannaford,” explains Duguay. “Then we’d discuss the findings via email and proceed to suggest new refinements that might further improve the results we were getting. That was the iterative,

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collaborative process through which we developed the final design. Historically, other hydraulic simulations generated by the software have proved it to be a very accurate tool for predicting real-world measurements. So, we're pretty confident that our numbers are good; however, we still want to compare results with a real-world model," he concludes.

The curved baffles of the new design provide a primary slot for fish passage, but also a smaller, secondary slot on the opposite side of the baffle. Primary and secondary slots are fixed on alternate sides of each successive baffle, so that flow moves through the primary passageway just above the secondary passageway of the next downstream baffle. In this fashion, velocities through the pools are decreased, which translates into improved passage performance.

The primary passage is wider, allowing more water to flow through. This in turn gives fish a larger opening through which they can jump. Previous scientific studies have shown that increased passageway width directly improves jumping success rates. The secondary

passage serves as an alternative slot during high flow rates, not only for fish, but also for debris.

Findings

Fish ladder simulations were tested at typical seasonal flow rates of streams in which a number of important North American fish species are commonly observed. These include brown trout and cutthroat, as well as Sockeye, Coho and Chinook salmon. Results demonstrate that the new baffle design helps lower the global turbulence in each pool and confines the regions of high velocity to the side of the ladder. This leaves a large portion of the pool free for fish to rest in before continuing upstream.

Additionally, the high protruding arch of the baffle helps build pool depth as flow rates increase. This keeps turbulence and velocities within reasonable levels. The increased pool depths observed at higher flow rates also decrease the vertical drop that fish need to overcome between adjacent pools. In some instances, fish may be able to swim directly between pools without resorting to jumping.

The design still needs to be verified for its ability to pass smaller juvenile fish, as well as fish species with weaker swimming abilities. To this end, the team is currently expanding its research, in order to analyze, understand and address the additional needs of these types of fish.

In November 2014, the Ministry of Transportation Ontario (MTO) came forward with a culvert replacement/fish passage project under HWY 21, on Saugeen Ojibway Nation land. CSPI began work with the MTO design team. The HWY 21 project, completed in December 2015, has become part of their ongoing research and will be presented in detail at the 2016 Canadian Society of Civil Engineers Conference in London, Ontario, June 1-4.

Ray Wilcock is Executive Director of the Corrugated Steel Pipe Institute. For more information, visit www.cspi.ca

To see more photos and watch the fish ladder in action, visit: www.esemag.com/fish-ladder

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