A Test Bed for Juvenile Salmonid Passage Through Culverts

Basic Premise: Juvenile fish pass culverts at higher mean velocities than their swimming performance indicates because they utilize low-velocity pathways and adaptive behaviors to accomplish the passage.

Questions:

- What new culvert and retrofit designs pass juvenile salmonids?
- For such designs, how do hydraulic conditions and culvert characteristics influence the extent or degree of passage success?
- How does passage success vary with fish species and fish size?

Solution: A fish-passage research program using a specially fabricated test bed is being used to identify retrofit culvert designs and associated hydraulic conditions that allow successful upstream movement of juvenile salmonids at different life stages. A full-scale testing apparatus represents a regional and national asset for the long-term development and testing of culvert designs. A fish passage research program will save time and money through optimizing

- retrofit culvert design
- materials
- construction
- installation
- hydraulic conditions

for enhanced juvenile salmonid passage success.

The engineered culvert test bed allows studies on variations in

- slope (0 to 10%)
- flow (up to 24 cfs)
- culvert type and size (up to 6' round or 81" pipe arch)
- bed configurations and materials
- cues (light, temperature, flow changes, chemosensory)
- test species and life stage (salmon and trout)

THE NEED: The passage of juvenile salmonids and other fish through culverts is a significant Endangered Species Act (ESA) issue throughout the Pacific Northwest and now in other areas of the nation. Much of recent research and engineering has focused on increased passage of returning adult salmon; however, juvenile salmonid movement both up and downstream throughout the year is now recognized as substantial and is a key area in which future research promises practical returns. Because a large percentage of the culverts beneath roads in the Pacific Northwest are judged as blocking juvenile salmon from thousands of miles of habitat, determining appropriate hydraulic and fish-passage designs for retrofitted culverts before installation has both substantial cost and environmental implications.

THE PROGRAM: To address these issues, the Washington State Department of Transportation (WSDOT) leads a partnership that includes the Washington Department of Fish and Wildlife (WDFW), Alaska Department of Transportation, Alaska Department of Fish and Game, Oregon Department of Transportation, California Department of Transportation, and the Federal Highway Administration. The partnership has undertaken a phased program conducted by an interdisciplinary team of scientists and engineers from the Pacific Northwest National Laboratory (PNNL) to address the hydraulic and behavioral issues associated with juvenile salmonid fish passage through culvert systems. This program addresses the testing and assessment of full-scale physical models of culvert systems deployed in an experimental test bed. Experiments in the test bed have begun and will measure the hydraulic conditions (mean velocity, turbulence, and water depth) associated with various culvert designs under various slopes and flow regimes, and then relate these measures to repeatable, quantitative measures of fish-passage success.

The culvert test-bed program is a one-of-a-kind capability designed to provide scientifically sound information that can be used to develop better designs for retrofitted culvert installations. Compared with field studies or temporary installations, the facility promises fast results, scientific and statistically controlled evaluations, an ability to quickly discern optimum engineering principles, and elimination of expensive trial-and-error approaches of field installations.

THE CALL: The test bed has been installed and experiments are beginning. WSDOT and PNNL are seeking to enlarge the partners in this endeavor. If you are interested in evaluating specific culvert designs or other studies in the test bed, please contact:

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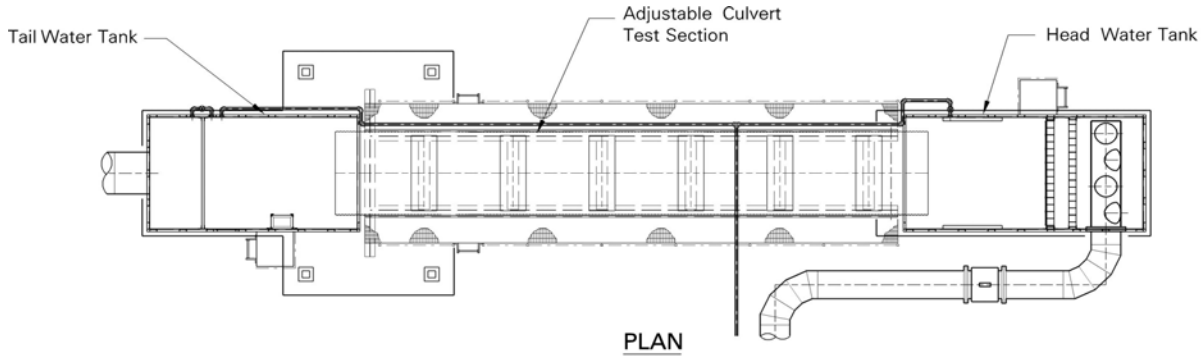
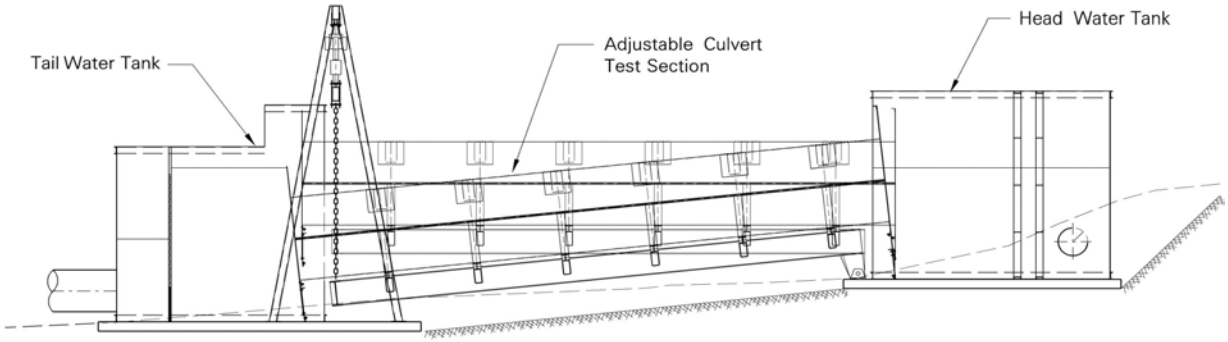
Operated by Battelle for the U.S. Department of Energy

Test Bed for Evaluation of Passage of Juvenile Salmon through Culverts



PLAN



ELEVATION

TEST BED: At the request of WSDOT, PNNL and Montgomery Watson Harza (MWH) have designed a test bed to identify the culvert designs and associated hydraulic conditions that allow successful upstream movement of juvenile salmonids at different life stages. The test bed is installed and has capabilities to

- Accommodate 40-foot round, oval, and box-shaped culverts from 2 to 6 feet in diameter
- Enable testing of different bed configurations, including gravel configurations
- Enable testing at culvert slopes from level to 10%
- Measure and control water flows from 0.5 to 20 cubic feet per second
- Enable fine-scale measurements of hydraulic conditions, including turbulence in the boundary layer
- Relate the success of fish passage to hydraulic measurements and culvert and bed characteristics.

Designed for the Washington State Department of Transportation by

MWH
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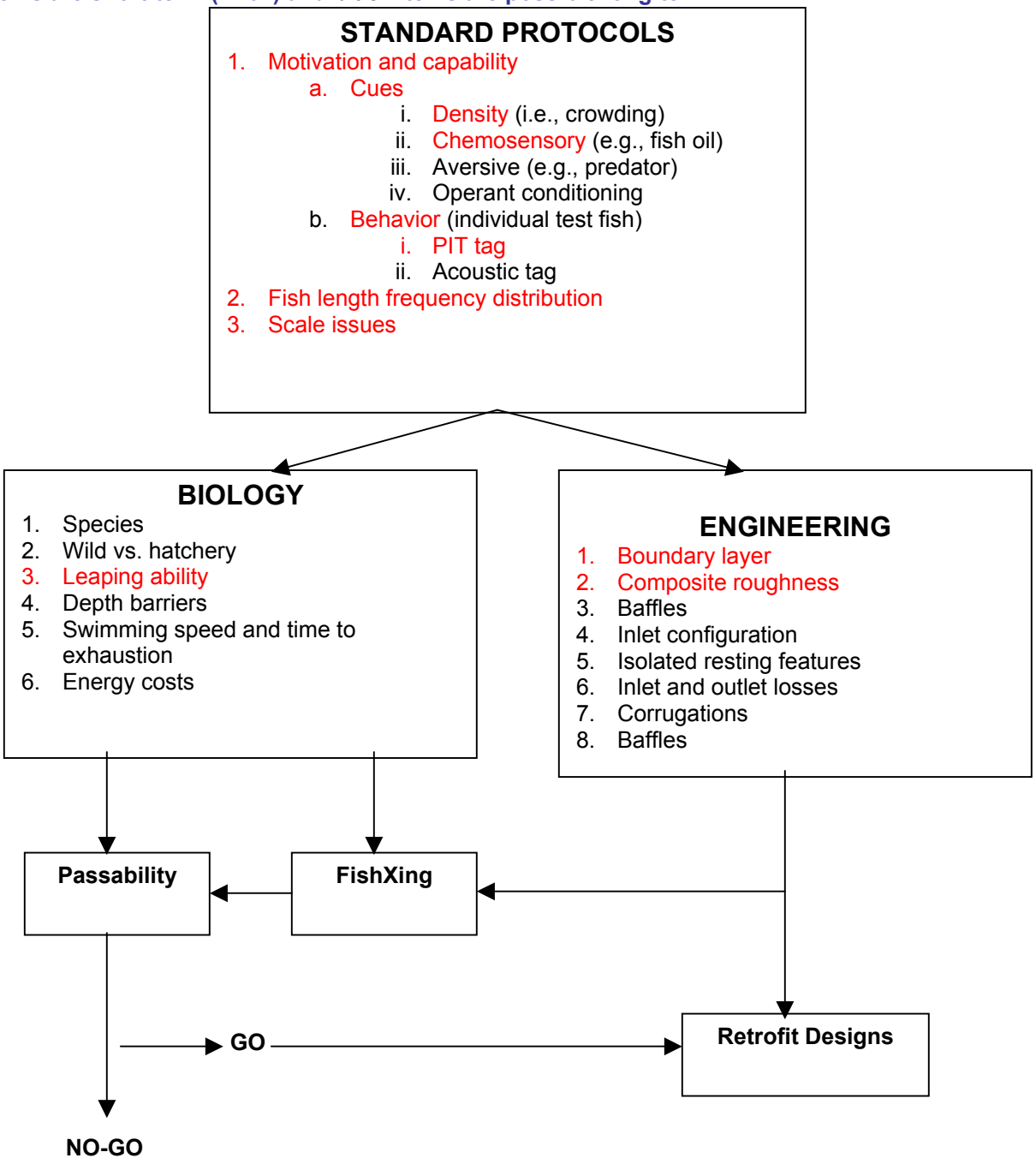
Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

Relationship between the three topic areas and the overall goals.

Figure 1. Relationship between Standard Protocols, Fundamental Science, and Design Data for the Retrofit Design and Culvert Assessment at the Culvert Test Bed. Potential research items identified in Table 1 are embedded. Red items are short-term (FY04) and black items are possible long-term.



Summary of potential tests that could be performed using the flume.

Table 1. Potential Tests with Fish Passage Bed Identified at the Steering Committee Meeting in February 2004

Category	Item	Description
Overall	Passability	Passability is the fundamental parameter in assessment of whether to fix a particular culvert or not, i.e., the "go/no-go" decision. Hydraulic measurements, field observations of fish distribution, and modeling, e.g., FishXing model, are used to assess passability.
	Assessment problem (is there a barrier or not?)	This is the same as passability.
	Cost benefit of research and various solutions	The steering committee felt that culvert owners should perform a cost benefit analysis to demonstrate the value of research in the test bed.
Standard Protocols	Motivation and capability	A fundamental issue in culvert research is how much the passage results reflect the capability of fish motivated to move upstream. For example, assume observed passage success was 25% (e.g., 25 in headwater tank out of 100 released in tailwater tank). Observed passage success would be 100% if 75 of the 100 fish had no motivation to swim upstream while the other 25 fish were motivated. This item affects the interpretation of both design and assessment research results, and constitutes one of the most important elements yet to be established for the standard protocols.
	Fish density in tailwater tank	Fish density in the tailwater tank during the passage tests of spring of 2003, although informally assessed, was approximately 100 or 200 fish per 10 m^3. Fish density at sufficient levels results in crowding, which may serve as a cue to motivate upstream movement. Crowding effects have been observed in the wild and would constitute a new experimental factor relative to the issue of motivation.
	Fish length frequency distribution	To investigate passage success, length frequency distributions for the population successfully moving upstream through the culvert and the population left in the tailwater tank should be compared. This item involves more in-depth analysis of the biological monitoring data and requires used test populations with subsets of fish with distinctly different size ranges.
	Scale issues	Scale issues have to do with the temporal and spatial scales over which the hydraulic data are collected and analyzed. The steering committee recommended that measurement scales for the hydraulic data be more clearly explained. This item entails more in-depth reporting of the hydraulic data.
Biological Science	Species other than coho	Coho salmon are typically raised at the Skookumchuck facility. Other species can also be raised there in isolation pens or raceways, including steelhead and cutthroat trout. Testing species other than coho salmon would broaden the applicability of the results. This item would be a new experimental factor.