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#### **Publication Date**

2001-09-24

## CULVERT DESIGNS FOR FISH PASSAGE IN PENNSYLVANIA

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Abstract: Pennsylvania contains approximately 83,000 miles (133,547 km) of streams and 119,000 miles (191,471 km) of public roadways. Fish movement can be impeded by highway culvert designs that create sheet flow or increased current velocity within the culvert barrel, and/or perched outlet conditions. The Pennsylvania Fish and Boat Commission and the Pennsylvania Department of Transportation reviewed performance measures of existing culvert designs and conducted a literature review to develop culvert designs that enhance fish passage. Design guidelines were established for pipe culverts and statewide design standards have been adopted for single cell and twin cell box culverts. Pipe culverts can be depressed at varying depths below streambed elevation depending upon the upstream drainage area and the diameter of the pipe. Single and twin cell box culverts are depressed twelve inches (305 mm) below streambed elevation. Box culverts installed in waterways with a stream slope less than four percent are constructed with a different baffle design than those installed with stream slopes greater than four percent. Stream flows are directed to the primary cell of the twin cell box culvert structure while the secondary cell is designed only to accept storm flows. All culvert structures are installed parallel to stream gradient and riprap used to protect the inlet and outlet is placed to match the invert elevation of the structure.

### Background

Prior to the 1970s, there were few environmental regulations in place to prevent adverse impacts to aquatic resources from highway construction activities. The Pennsylvania Department of Transportation (PennDOT) and the Pennsylvania Fish and Boat Commission (PFBC) developed a memorandum of understanding in 1968, which allowed for environmental reviews to occur during the proposed highway development process. In 1969, the National Environmental Policy Act was legislated and allowed for all Act 120 agencies to review and comment on proposed highway projects.

Fish passage designs were first included within the PennDOT's Design Manual for box culvert construction during the early 1970s. The early designs included several baffle configurations or a notch placed within the culvert floor. These designs were rarely installed, and there was minimal documentation as to their success. Throughout the 1990s, the PFBC recommended that the invert of the box culvert bottoms be installed six to twelve inches (152-305mm) below streambed elevation to allow for fish passage in perennial streams that contained fish populations. These "depressed" culverts were frequently installed across Pennsylvania and often included baffles.

In 1999, several personnel from PennDOT and the PFBC formed a task force to develop fish passage designs for both pipe and box culvert installations. Measurements and physical observation were conducted on hundreds of depressed box culverts that were installed during the 1990s. These data and an extensive literature review were used to develop the culvert designs for fish passage.

### Accomplishments

#### *Pipe Culverts*

In Pennsylvania, pipe culverts are normally used in highway drainage for ephemeral, intermittent and small perennial stream channels. The guidelines that were developed for pipe culvert installation are dependent upon the diameter of the pipe and upstream drainage area (Table 2).

Table 2.  
Standards for Installation of Pipe Culverts

PHYSICAL CRITERIA	INVERT DEPRESSION
<b>Pipe Diameter &lt; 8.0 feet (2.4 m)</b> <u>Drainage Area</u> ≤ 100 acres (0.405 sq km) 100 to 640 acres (2.59 sq km) ≥ 640 acres	None Required 0.5 feet (152 mm) 1.0 feet (305 mm)
<b>Pipe Diameter ≥ 8.0 feet</b>	1/5 Pipe Diameter

Additional guidance for the installation of pipe culverts includes the following:

- Pipes shall be installed parallel to stream slope so that both the inlet and outlet is depressed at specified depths.
- The hydraulic capacity of depressed pipes shall be computed assuming no flow in the depressed area of the pipe.
- The value of Manning's n for the pipe shall be a weighted average of the wetted perimeter of flow. Assume the pipe fills with natural stream material to the level of the natural streambed. Refer to Appendix B of *Hydraulic Design of Highway Culverts, Hydraulic Design Series No. 5. Report No. FHWA-IP-85-15*, Federal Highway Administration, Washington, D.C.
- Riprap used to protect inlets and outlets of drainage pipes shall be placed so that the height of the riprap matches the inverts of the pipe culvert. Excess natural streambed material could be used to choke the riprap and to finish backfilling the streambed to the natural grade line.
- There may be unusual circumstances (i.e., bedrock) in which the standard design guidance for pipe culvert depression may not be practicable. In these cases, the PFBC should be contacted for specific guidance at the earliest opportunity.

### *Box Culverts*

Single and twin cell box culverts are normally installed on perennial stream channels in Pennsylvania for highway drainage. Perennial streams contain benthic macroinvertebrate communities and in most cases support fish populations. The task force decided to depress the invert of the floor of all reinforced concrete box culverts types twelve inches below streambed elevation to enhance fish passage. The intent of this design feature is for the natural stream bottom substrates to "fill in" the newly created channel depression and eventually form a natural channel through the culvert barrel.

Baffles were incorporated into the box culvert designs to enhance fish passage immediately following construction and to promote the collection of natural stream substrates within the culvert barrel. Observations of existing depressed culverts indicated a need to develop different baffle designs for stream gradients less than or greater than four percent. For stream gradients less than four percent, alternating eight-inch (203mm) high baffles are constructed within single cell box culverts at lengths and spacing dependent upon the existing stream channel width (see figure 1, end of paper). Subsequent to project completion, these eight-inch high baffles should eventually be covered by natural stream substrates.

A different type of baffle design was developed for the construction of a single cell box culvert on streams with gradients greater than four percent. The baffle height drops from twelve inches to six inches at a location dependent upon existing stream width (see figure 2, end of paper). This full-length baffle design is recommended for steeper gradient streams to promote stream substrates to collect within the culvert barrel, and to maintain channel stability both upstream and downstream of the culvert placement location.

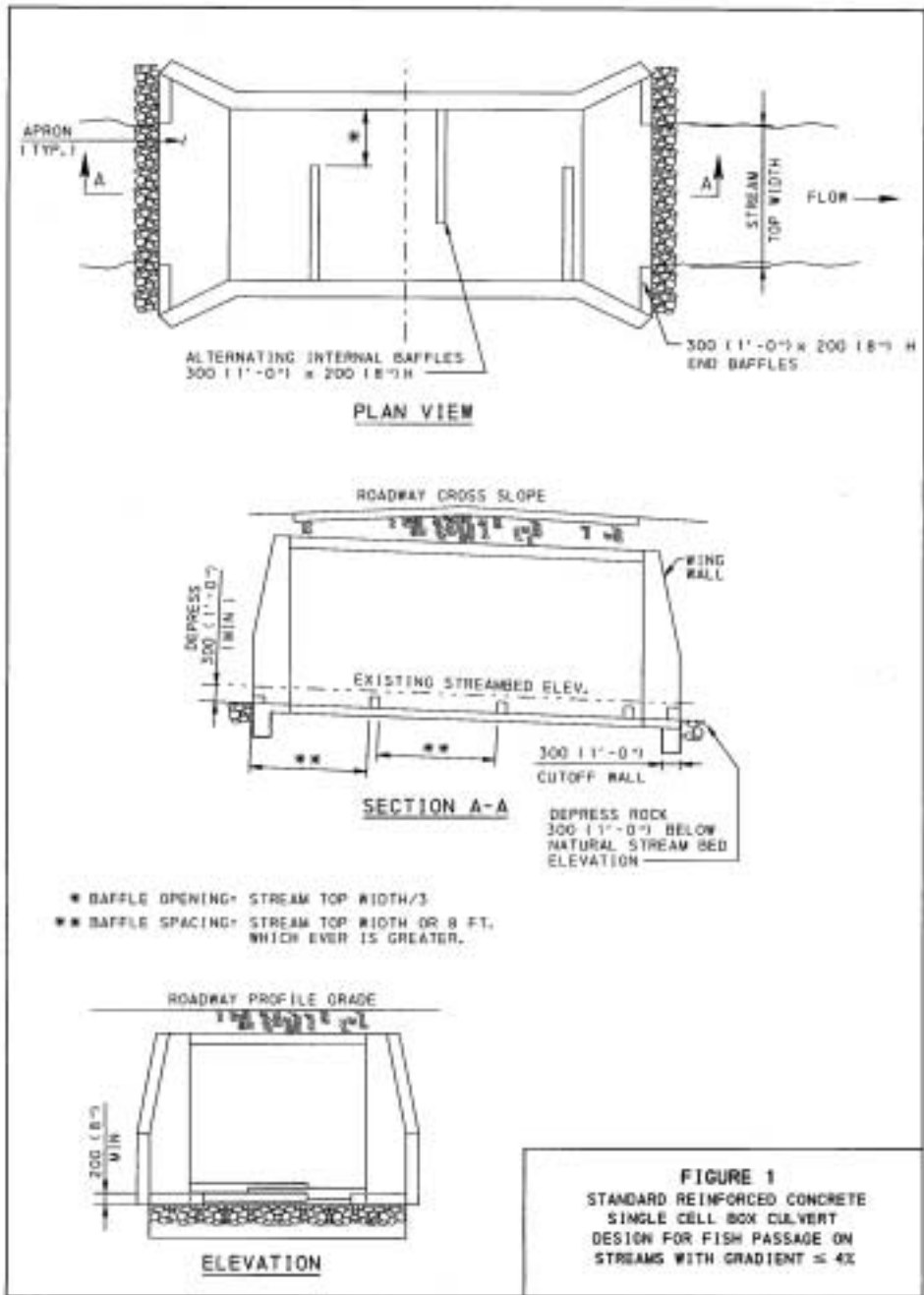
Twin cell box culverts are designed to be installed offset to the configuration of the stream channel (see figures 3 and 4, end of paper). The primary cell is aligned to accept normal stream flows while the secondary cell has

an eighteen-inch (457mm) high weir on the upstream end, and is designed only to transport excess flows during storm events. Baffles within the primary cell of the twin cell structures should follow the design criteria as previously described for single cell culverts on stream gradients less than or greater than four percent.

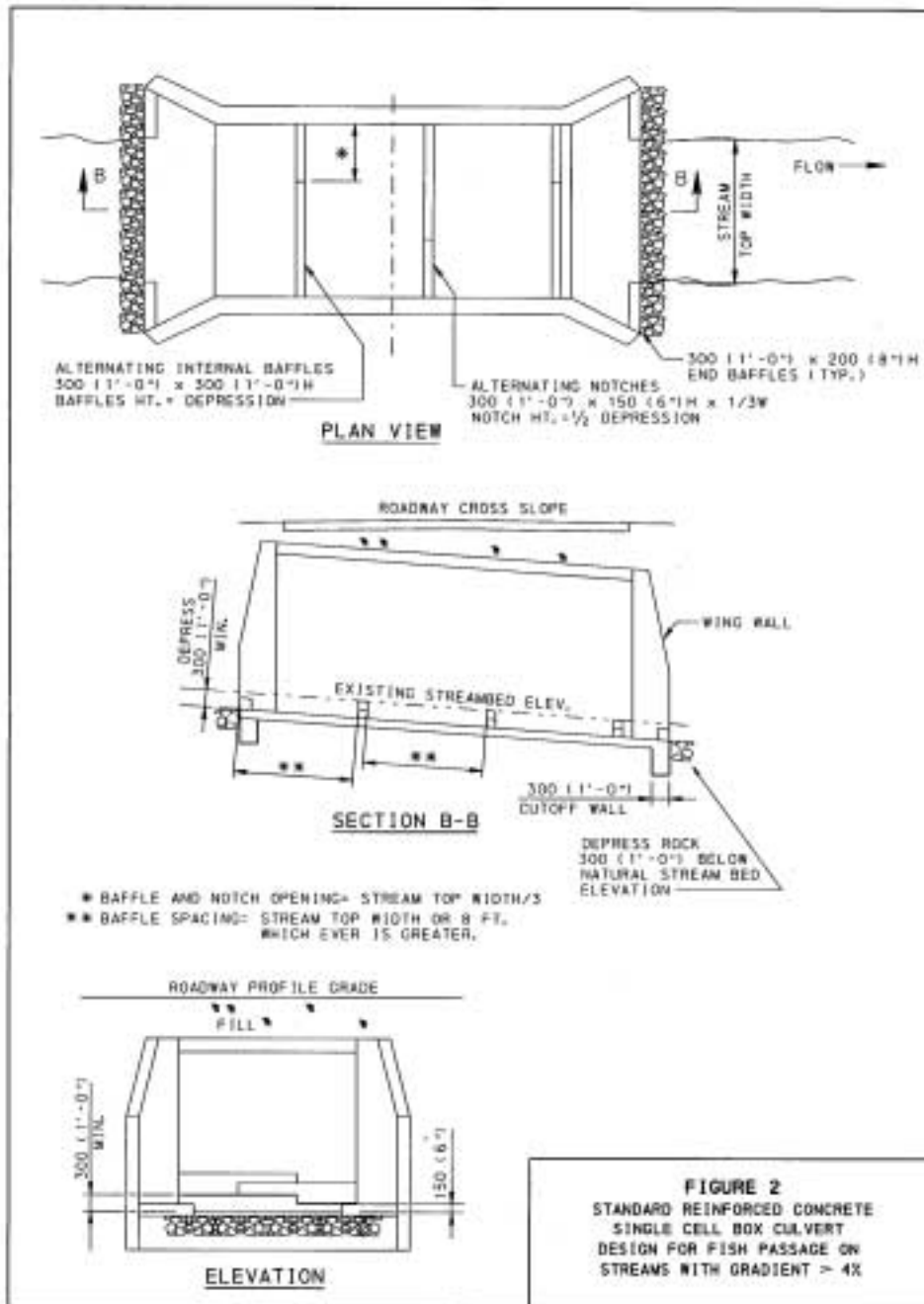
### Summary

The PFBC and PennDOT formed a partnership to develop culvert designs for fish passage. Box culvert designs (see figures 1-4) were adopted for statewide implementation by PennDOT, and are referenced as their Design Standard BD-632M. Additional details to the box culvert design standards can be located on PennDOT's Web site at <http://www.dot.state.pa.us/newproducts/index.htm>. Fish passage guidelines were also established for pipe culvert installation, however those guidelines have not been adopted for statewide standards to date. Other public road stakeholders such as the local municipalities, Pennsylvania Turnpike Commission, National Forest Service, and the Pennsylvania Department of Conservation and Natural Resources will also be encouraged to follow these fish passage designs for culvert construction on their respective roadways. We plan to conduct assessments of these new types of culvert structures as they are installed across the Commonwealth and will recommend design changes if necessary.

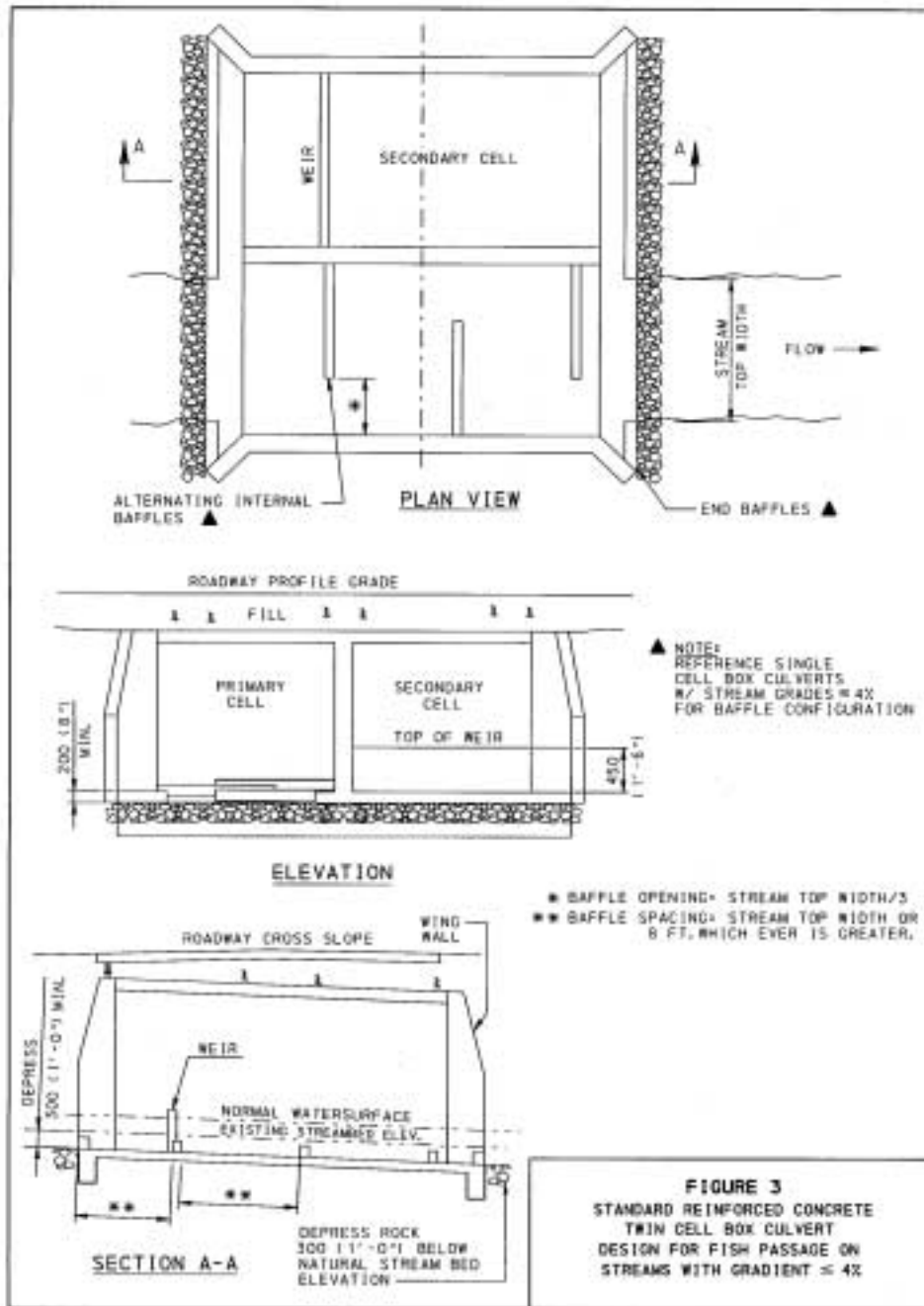
Biographical Sketch: David E. Spotts has been employed by the Pennsylvania Fish and Boat Commission for the past 22 years, and is currently serving as the Chief of the Watershed Analysis Section within the Division of Environmental Services. His primary responsibilities include the review and comment on statewide transportation projects, solid waste applications, and acid deposition issues. He has been an American Fisheries Society member since 1980, and has held many Pennsylvania Chapter offices including Chapter President in 1993. Dave graduated from Mansfield State University with a B.A. degree in biology and a minor in chemistry. He has received notable awards such as the Outstanding Service Award from the Pennsylvania Chapter AFS in 1992 and Vice President Al Gore's Hammer Award in 1996.



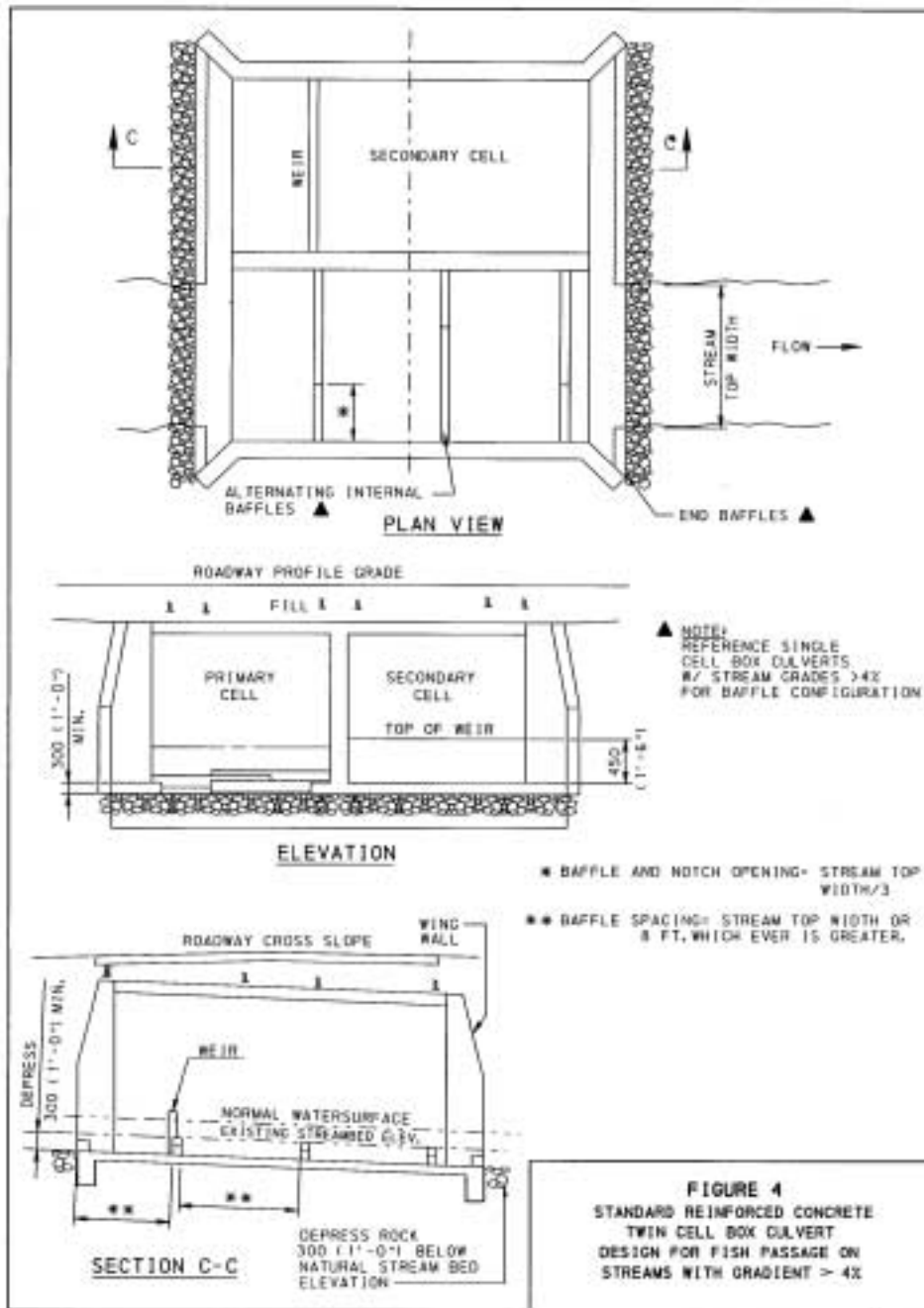
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