

Economic Culvert Design Using Fish Swimming Energy and Power Capabilities

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Abstract—Utilizing fish swimming power and energy capabilities and the hydraulic properties of culverts in those locations within culverts where fish actually swim, the writers have prepared a detailed manual of culvert design procedures for culverts which must provide safe passage of upstream moving, weak swimming fish (Behlke, Kane, McLean, and Travis, 1991). The design procedures utilize hydraulic formulae for profile drag, non-Archimedean buoyant forces, and virtual mass force to quantify the hydraulic conditions within a culvert that the design fish can sustain without exhaustion for various time durations. Final culvert design may then be selected on economic or other bases from the full range of trial designs that are hydraulically suitable for fish passage. This paper provides an overview of the analytical and biological methods used in the preparation of the design procedures and its associated software.

Introduction

A design species and size of fish must be selected as the basis for culvert design for fish passage. The design fish is the weakest swimming fish which must pass through the culvert being designed. Since fish usually do not move at all times of the year, flow conditions which occur during the time of expected fish passage are those selected for hydraulic considerations for fish passage. If fish passage delays of short periods are acceptable, flood peaks may be reduced for fish passage design purposes.

Following selection of the design fish and the associated maximum stream flows during times of passage, the culvert design process proceeds as follows:

1. Fish swimming capabilities of power and energy are determined.
2. Fish swimming behavior when stressed within the limits of its capabilities by a culvert must be defined.
3. Culvert hydraulics where the fish are expected to swim in the culvert must be determined.
4. A culvert is designed to pass the design flood and for which culvert hydraulics, where the fish swim, do not overstress swimming power and energy capabilities of design fish.

Fish Swimming Hydraulics And Capabilities

A satisfactory culvert for fish passage may have distinctly different types of flow occurring simultaneously at the outlet, inlet, and barrel. Typically, higher velocities of flow and/or water accelerations occur at the inlet and outlet, while smaller velocities of flow occur in the culvert barrel. It may, therefore, be necessary for a fish to utilize white muscle (anaerobic) power at the outlet and/or inlet while relying on red muscle (aerobic) power for passage through the culvert barrel. Thus, it is necessary to determine the design fish's swimming capabilities in each of these modes. Typically, white muscle mode swimming allows the fish to deliver much greater swimming

