FUNDAMENTALS OF CULVERT DESIGN
FOR PASSAGE OF WEAK SWIMMING FISH
Report No. FHWA-AK-RD-90-10

SOFTWARE DOCUMENTATION

INTRODUCTION

WELCOME to FISHPASS.EXE. FISHPASS provides the analytical capabilities to identify a culvert or parallel culverts that will pass weak swimming fish safely. The design procedure utilizes hydraulic formulas for profile drag, non-Archimedean buoyant forces, and virtual mass force to quantify the hydraulic conditions within a culvert that weak swimming fish can sustain without exhaustion.

Before using FISHPASS.EXE, read and be thoroughly familiar with the "Fundamentals of Culvert Design for Passage of Weak Swimming Fish", (Behlke et al. 1991. Alaska DOTPF Statewide Research Report Number FHWA-AK-RD-90-10). The required software data inputs and design results only will make sense if you are familiar with the underlying theory, foundation, and assumptions it explains.

SYSTEM REQUIREMENTS

Minimum: DOS 3.31 or higher with an 80286, 8088 or 8086 processor with 640 KB of RAM and a monochrome monitor is required.

A math co-processor will speed the computations up, but be aware that the program will run very slowly on an 80286, 8088, or 8086 processor.

Preferred: An 80386 processor, with a math co-processor, or an 80486-DX2 processor with a color monitor is recommended. The program is mouse-supported but can be run directly from the keyboard.

Disk Space: The FISHPASS.EXE file occupies 181,728 KB of disk space. 

CURSOR CONTROL

Select a Menu field or a Data Input field by using the <ENTER> key or by clicking on the field with a mouse.

A mouse, <SHIFT-TAB> or the left and right cursor control keys can be used to move between fields. The <BACKSPACE>, <INSERT>, and <DELETE> keys can be used to edit a field entry.

The <ESC> key will return the previous screen. Please note that if the <ESC> key is held down too long the initial FISHPASS.EXE menu screen will be returned, and the menu defaults and data input variables will have to be re-entered.

GETTING STARTED

FISHPASS.EXE can be run directly from a floppy drive or copied to the hardrive.

FISHPASS.EXE will also run under Microsoft Windows as a nonwindows application program.

To start FISHPASS.EXE from the DOS prompt, type "Fishpass."

Example: *A:\fishpass*

or

C:\<sub-directory>\fishpass

Press any key to bypass the title screen and access the menu screen (Figure 1).

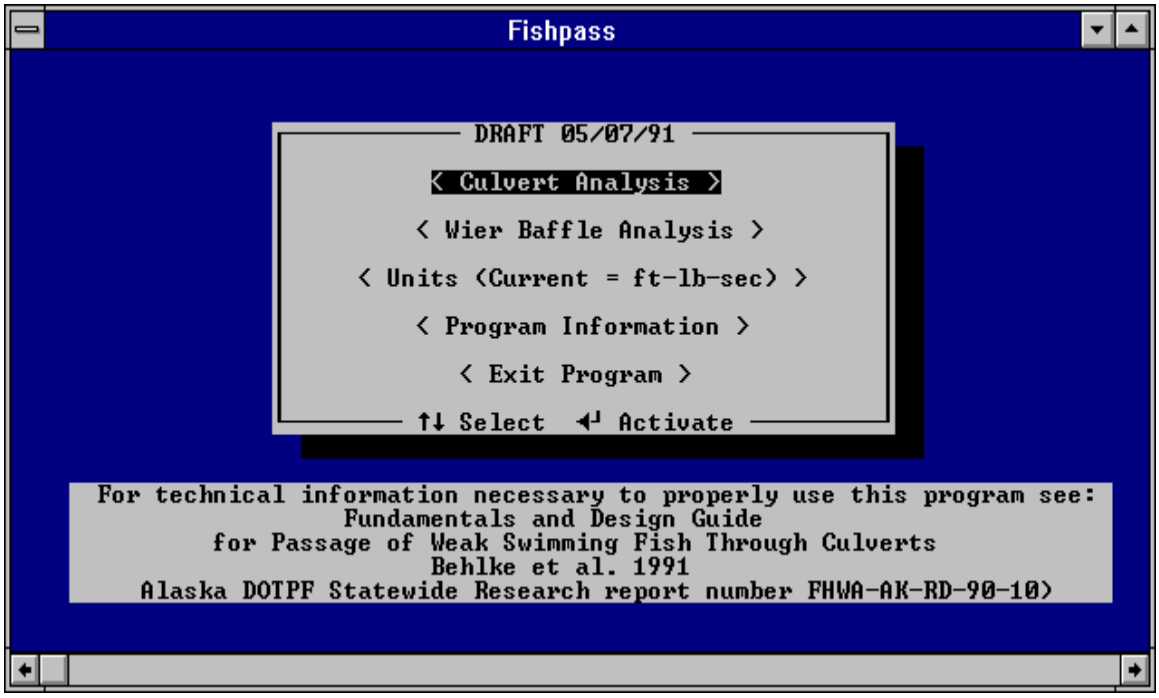

Figure 1. Menu Screen for FISHPASS.EXE.

You can select one of the following options from the menu screen:

MENU SCREEN OPTIONS

Culvert Analysis:	This program evaluates relatively flat sloping, circular culverts. The culvert may or may not have a depressed invert. Use it for original design work or retrofitting an existing culvert. **Restriction:** Culvert slopes must range between 0.1 to 10 percent. *At this time, the program will not evaluate elliptical culverts. A BASIC program has been developed that allows an approximate evaluation of elliptical culverts for water depths less than 3/10 of the culvert diameter. Please contact either Charles E. Behlke or Robert F. McLean (see listing under **Additional Information**) for further information.*
Weir Baffle Analysis:	The Canadian weir baffle design technique is used to evaluate fish passage when culvert slope or water flow is excessive and impedes fish passage. **Restriction**: Culvert slopes must range between 0.1 to 10 percent.
Units:	English foot–pound–second units are the system default. The SI metric system of units can be selected as an option.
Information:	Contains a brief description of the FISHPASS.EXE program.
Exit:	Returns you to the DOS prompt.

RUNNING "CULVERT ANALYSIS"

Prior to using "Culvert Analysis," select a culvert that meets the design flood requirements (generally the 50–year flood).

After the trial design flood culvert is selected, use the "Culvert Analysis" program to evaluate its suitability for fish passage at the fish passage design flood.

Menu Bar: The Menu Bar is located at the top of the screen. With it, select the help menu or define the printer options, culvert inlet type, calculation mode, and corrugation height (Figure 2).

Figure 2. "Culvert Analysis" Menu Bar.

The Menu Bar can be selected with the mouse or by typing <ALT> followed by the highlighted letter for each field.

MENU BAR OPTIONS

Help: General information or specific instructions for selected fields or calculated parameters can be obtained. Information on selected input data fields also can be obtained at any time by placing the cursor within that field and typing <F1>.

*Example: To activate the help menu for the "Minimum Flow Depth" output field, type <**ALT**> <**H**elp> <**C**alculated Parameters>, then use the cursor control keys or mouse to highlight "Min. Flow Depth." Press enter or click the mouse to obtain the help message in a box at the bottom of the screen.*

Print: Defines the printer options. Select to print either the current screen, the backwater curve, or both. Direct your printer output to either the LPT1 or LPT2 port.

Inlet: Select a projecting, flush headwall, or bevelled, flush headwall. The inlet type effects the drop in water surface elevation as the water enters the culvert and effects the fish's ability to exit the culvert at the inlet. The inlet type must be specified each time the program is run. If the stream is incised and the culvert diameter is approximately the same as the stream width, the "*flush headwall, beveled e*" inlet type should be used.

CalcMode: Defines the calculation mode. Select automatic, manual, or recalculation mode.

Corrugation: Sets the culvert corrugation height. The program's default value is "Greater than 1.25 inches." This value must be changed if a 3–inch–by–1–inch or smaller corrugation is proposed. The corrugation height effects flow velocities near the culvert boundary (where weak fish swim), effecting how fast the fish must swim in the barrel of the culvert. Two-inch deep corrugations are highly recommended for fish passage culverts. This program does not apply to smooth-walled culverts.

Data Input Fields: After the appropriate values are entered within the Menu Bar for Inlet Type, CalcMode, and Corrugations, the cursor will drop down to the data input fields (Figure 3).

Figure 3. Data Input Fields for "Culvert Analysis."

The following input variables must be entered for each trial culvert design:

"CULVERT ANALYSIS" DATA INPUT VARIABLES

Fish Length: The fork length of the design fish must be entered in millimeters.

Note: The length always must be entered in millimeters even if the system default is set to English foot-pound-seconds. The length must be obtained from the resource agency responsible for managing the fish resources. Generally, the design length reflects the minimum size class for upstream migrant spawning fish.

Length: The length of the culvert must be entered in feet or meters.

Culvert Slope: Enter the slope of the culvert bottom as a percentage (i.e., 1% not 0.01).

Culvert Wall Manning *n* Value: Enter the Manning *n* for the culvert wall. Values from 0.02 to 0.05 can be entered. We suggest using 0.035 for two–inch deep corrugations.

Culvert Bed Manning *n* Value: Enter the Manning *n* for stream bed material that will be present within the culvert. Values from 0.02 to 0.05 can be entered.

A *non-zero value must be entered here and in the input field for the depth of bed material if you are analyzing a depressed invert culvert.*

(Continued)

"CULVERT ANALYSIS" DATA INPUT VARIABLES (Continued)

Q (cfs): Enter the fish passage design flow in cubic feet or meters per second.

Fish passage design flow is not the same as the culvert design or flood flow. The flood flow is the maximum discharge anticipated during the design life of the culvert. The fish passage design flow is the maximum discharge for which fish passage must be assured.

	In Alaska, this has been defined by the Alaska Department of Fish and Game as the mean annual, two-day duration flood ($Q_{2.33}$ - 2 day) for the specific time of the year that fish migrate upstream. For Arctic grayling, the design fish passage flow is the SPRING mean annual, two-day duration flood.
Diameter:	Input the diameter of the culvert barrel in feet or meters.
Bed Depth:	Enter the depth of the bed material above the culvert invert in feet or meters. *If the culvert is "bare" and will not contain bedload material, a red reminder notice will pop up. Ignore it by pressing <ENTER>.*
Outlet Depth:	Enter the tailwater depth in feet or meters. *The tailwater depth is the water surface elevation above the culvert invert and is used during the calculation of the back-water curve. Note that the culvert invert is the bottom of the culvert or the top of the bed material if the culvert is depressed and partially filled by such material. The value must be greater than the hydraulic critical depth for the design culvert diameter and discharge and less than the culvert diameter minus the bed depth.*

If the program is in the automatic calculation mode when the final input data is entered, the program will calculate the "Calculated Fish Parameters" and generate a backwater curve for the specified flow conditions. The screen will automatically shift to the backwater screen where the backwater curve is printed.

Please note that even for an otherwise suitable fish passage culvert some of the flow depths may be less than the "Safe fish passage flow depth." This is because the program calculates the "Safe fish passage depth" based on the minimum depth of flow required for the stated culvert diameter and discharge to maintain velocities at or below the maximum allowable fish passage velocity. This velocity threshold is based on the design fish's red muscle swimming power (sustained speed). If the program detects depths less than this depth at or near the culvert outlet, it runs until it finds that the swimming fish has run out of white muscle power or energy (burst speed), then it stops (as does the fish!).

The <ESC> key returns you back to the previous screen where the calculated hydraulic and fish swimming performance parameters are presented (Figure 4).

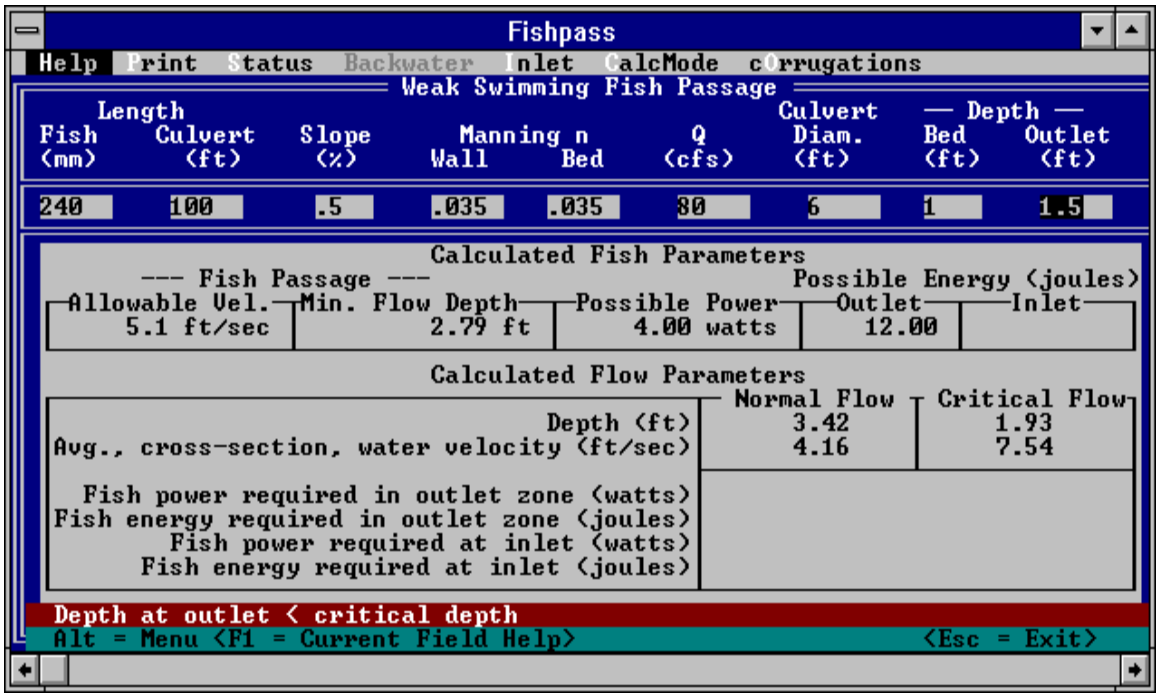

Figure 4. Calculated Fish Parameters Output Fields for "Culvert Analysis."

Status Bar: The red Status Bar is located on the next–to–last bar on this screen. A short message is included in this bar indicating that the culvert is acceptable for fish passage, or indicating the specific problem with the proposed culvert.

If the initial culvert is unsatisfactory, review the proposed installation and input a different culvert slope, diameter, entrance condition, depression, outlet pool elevation, or culvert bottom fill Manning *n* value. Change these parameters one at a time to obtain a culvert design that will pass fish successfully. Pay particular attention to the relative economics of one change versus another.

If the initial culvert is suitable for fish passage, in the interests of culvert economics try a smaller diameter, greater slope, less expensive culvert inlet, less outlet pool depth, etc. to determine the most cost-effective design that still provides acceptable fish passage. If unreasonable outlet control designs are required, consider trying a weir baffle design.

Some culvert designs allow fish to enter and pass through the culvert barrel but do not allow fish to exit the culvert inlet. This situation will be indicated on the red Status Bar and often can be solved by simply changing the culvert inlet condition (e.g., using a flush or bevelled headwall instead of a projecting inlet). If these adjustments do not solve the problem, a larger diameter culvert or more outlet pool depth may be necessary. When you have selected the proper geometry for fish passage, re-check the culvert dimensions for design flood flow.

RUNNING "WEIR BAFFLE ANALYSIS"

For culverts so steeply sloped that no suitable culvert can be found using "Culvert Analysis," either relocate the culvert location to a stream segment with lower slopes or use the "Weir Baffle Analysis."

The weir baffle spacing for this program must be 0.6 times the culvert diameter (0.6 D). All weir baffled culverts designed using this program must have this weir spacing or the program results are meaningless. The two weir heights used are 0.1 D and 0.15 D.

NOTE: Please refer to Section IV.C.4.d of the background report for a better understanding of the weir baffle height and spacing requirements and for other baffle geometries not supported by this software.

Menu Bar: The Menu Bar is located at the top of the screen. With it, you can access the help menu, define the printer options, or obtain a status report (Figure 5).

Figure 5. Menu Bar for "Weir Baffle Analysis."

The Menu Bar can be selected with the mouse or by typing <ALT> followed by the highlighted letter for each field. The following options can be selected:

MENU BAR OPTIONS

Help:	You can obtain general information or specific instructions for selected fields or calculated parameters. Information on selected input data fields also can be obtained at any time by placing the cursor within that field and typing <F1>.
Print:	Defines the printer options. You can direct your printer output to either the LPT1 or LPT2 port.
Status:	Provides a status summary on the fish passage characteristics of the trial culvert design. This option is activated only after the data input parameters have been entered.

Data Input Fields: The following input variables must be entered for each trial weir baffled culvert design:

"WEIR BAFFLE ANALYSIS" DATA INPUT VARIABLES

Fish Length:	The fork length of the design fish must be entered in millimeters. NOTE: T*he length always must be entered in millimeters even if the system default is set to English foot-pound-seconds. The length must be obtained from the resource agency responsible for managing the fish resources. Generally, the design length reflects the minimum size class for upstream migrant spawning fish.*
Culvert Slope:	Enter the slope of the culvert bottom as a percentage (i.e., 1% not 0.01).
Culvert Wall Manning *n*:	Enter the Manning *n* for the culvert wall. Values from 0.02 to 0.05 are allowed. *We suggest using 0.035 for two-inch deep corrugations*.
Q Fish (cfs):	Enter the design fish passage flow in cubic feet or meters per second. *The fish passage design flow is the maximum discharge for which fish passage must be assured. In Alaska, the fish passage design flow has been defined by the Alaska Department of Fish and Game as the mean annual, two-day duration flood ($Q_{2.33}$ - 2 day) for the specific time of year that fish migrate upstream. For Arctic grayling, the design fish passage flow is the SPRING mean annual, two-day duration flood.*
Q Flood (cfs):	Enter the design flood flow in cubic feet or meters per second. *Unlike "Culvert Analysis," flood flow must be entered since the FHWA design software does not have the capabilities to analyze flows through this type of weir baffled culvert.*
Diameter:	Enter the diameter of the culvert barrel in feet or meters.

Status Bar: The red Status Bar is located on the next–to–last bar on this screen. A short message states that the culvert is acceptable for fish passage, or states the specific problem with the proposed culvert (Figure 6).

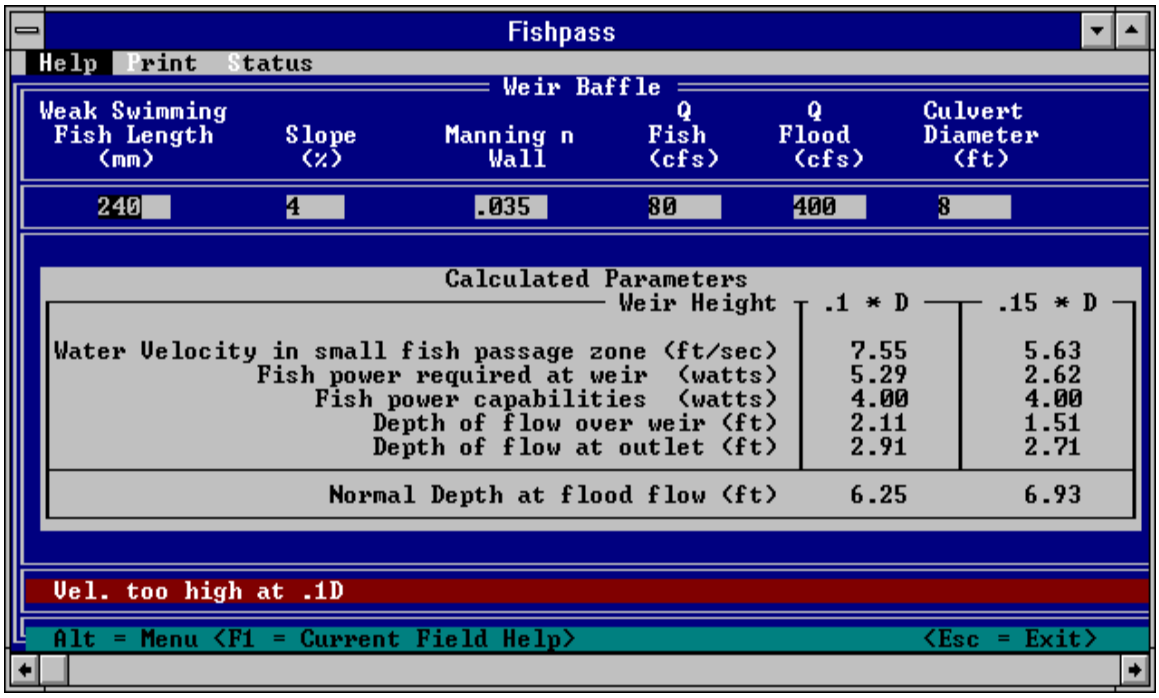

Figure 6. Calculated Parameters Output Fields for "Weir Baffle Analysis."

A NOTE ON CULVERT WALL CORRUGATIONS

Effective boundary roughness is virtually a necessity for effective fish passage. We encourage the use of culvert materials that result in relatively high Manning *n* factors. In particular, we recommend the use of corrugated structural steel plate pipes (SSP) with corrugations 6–inch–by–2–inch (15.2–cm–by–5.1–cm) or 9–inch–by–2.5–inch (22.9–cm–by–6.3–cm) for all fish passage structures.

Based on our field assessments, boundary zone water velocities in these rougher culverts typically range between 10–to–50 percent of the average cross-sectional water velocity (Q/A). In contrast, boundary zone water velocities for shallower corrugations (less than 1.25 inches) typically are 60 to 80 percent of the average cross-sectional water velocity. We particularly discourage the use of spiral (helical) and smooth–wall culverts due to their relatively small Manning *n* values.

This recommendation does not preclude the use of smaller corrugations; however, the maximum fish passage design discharge must be reduced or the culvert diameter increased from what these parameters would be for two–inch–diameter corrugations.

A NOTE ON DEPRESSED INVERT CULVERTS

The design program allows for, but does not require, installation of a depressed invert culvert. What the program does require is a tailwater depth elevation generally equal to or greater than the hydraulic critical depth (outlet control). Ideally, this should be achieved through design and construction of a downstream energy dissipation pool using generally accepted methods such as those outlined in the FHWA publication "Hydraulic Design of Energy Dissipators for Culverts and Channels" (1983). Dissipation of outlet energy is essential to prevent downstream erosion of the streambed and subsequent loss of the required tailwater elevations. Under extreme circumstances, excessive velocities will lead to a "perched" culvert.

In some cases, the culvert invert can be depressed to increase barrel roughness and enhance the tailwater rating curve. The deposition of course bedload material within the culvert bed can enhance fish passage characteristics. In other cases, a designer may opt to depress the culvert invert as a safety margin when there is uncertainty whether necessary tailwater depths will be provided or maintained over the life of the structure.

ADDITIONAL INFORMATION

If you have additional questions or if the program does not work properly, please call or write us. Also, please send your suggestions for improving FISHPASS.EXE to us at the following addresses:

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