TECHNICAL NOTES

USDA-Natural Resources Conservation Service
Boise, Idaho

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The attached technical note provides guidelines on how instream structures should be installed to provide fish passage.

The publication was developed by the Idaho Department of Lands.

File this in the Biology section of the Technical Notes, Section VI of the Technical Guide.

IDAHO DEPARTMENT OF LANDS

State Forester Forum

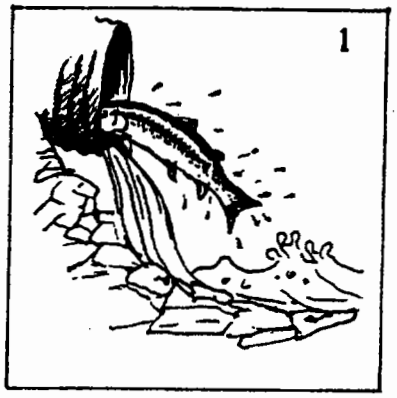
FISH PASSAGE GUIDELINES WHEN INSTALLING STREAM CROSSINGS

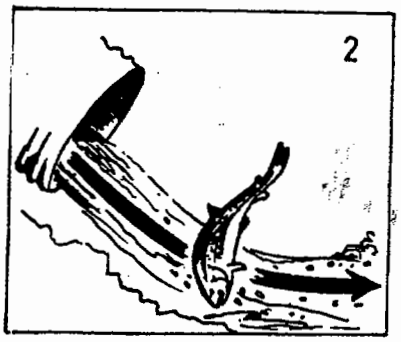
Under the Idaho Forest Practices Act and the Stream Channel Protection Act, all stream crossings on fish bearing streams must provide for fish passage. Unfortunately, few guidelines exist that describe how stream crossings should be installed so they do not inhibit fish passage. As a result, numerous crossings have been built that either block or delay fish passage. This Forester Forum provides guidelines that will help individuals design and install stream crossings that will not impede or delay fish passage. These guidelines were developed in cooperation with the Idaho Departments of Fish and Game and Water Resources.

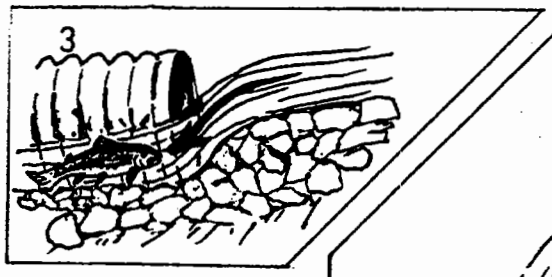
Minimum Requirements by Law

Currently, the only specific guidelines on how stream crossings should be installed to provide fish passage are found in Idaho's Stream Channel Alteration Rules. These rules state that in streams where fish passage is of concern, the following provisions must be complied with to insure that passage will not be prevented by a proposed crossing.

1. Minimum water depths shall not be less than 3 inches during fish migration.
2. Maximum water velocities shall not exceed the swimming ability of fish for more than a 48 hour period during fish migration (see Figure 1).
3. No drop into a culvert's entrance (inlet) will be permitted.
4. A maximum drop of 1 foot is permitted from a culvert's outlet when a holding pool is provided.







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These provision, although specific in nature, do not clearly indicate how a stream crossing must be installed to provide unrestricted fish passage. The following section discusses and depicts various stream crossing alternatives including how they should be installed to provide unrestricted fish passage.

Choosing and Installing an Appropriate Stream Crossing that Provides Fish Passage

When designing a crossing that provides fish passage, the fish species present, the life stages to be impacted and the timing of their migrations must all be considered (see Table 2 for timing of fish migrations). Fish passage designs should be based upon the weakest species or life stage present. On occasions fish passage may be designed to protect important fish populations by preventing upstream invasions of an undesired species (e.g. brook trout in bull trout habitat). If necessary, consult a fish biologist for additional fisheries information.

Stream crossing alternatives include various culvert designs, bottomless arches, fords and bridges. These alternatives vary in their ability to pass fish, cost, durability, and ease of installation and maintenance. Table 1 and Figure 2 discuss and depict these alternatives and can be used as a guide when planning and installing a stream crossing to insure it provides fish passage. When deciding which alternative to use at a proposed stream crossing, one should consider the following steps.

1. Determine which fish species and life stages require upstream passage and the timing of their migrations.
2. Determine the slope of the stream channel at the proposed crossing site.
3. Based on the stream's slope and the fish requiring passage, use Table 1 to determine which type of stream crossings will allow upstream fish migrations.
4. Taking into account cost, technical difficulty, potential for failure, low flow problems and maintenance needs, choose a stream crossing that will allow fish passage at the proposed site.
5. Refer to Figure 2 for culvert installation instructions, if necessary.
6. If unfamiliar with installing any of these alternatives, consult someone with experience.

As a general rule, culverts greater than 50 ft long will cause fish passage problems for adult spring migrating trout (6-12 inches) if installed at over a 0.5% gradient. Culverts less than 50 ft long can be installed up to a 1% grade. Culverts installed at steeper grades than this will probably have water velocities through them for more than a 48 hour period that will exceed the swimming ability of spring migrating fish. In certain situations (trout > 15 inches, steelhead and salmon), a migratory run of fish may have stronger swimming abilities than these guidelines were developed for. If larger migratory fish are the weakest swimmers in a stream, a stream crossing can be installed at a steeper gradient than indicated above. Where upstream passage of juvenile fish is important to the survival of a fish population, culverts must be installed at flatter gradients than indicated. Consult a fish biologist if in question about which fish passage should be provided for.

With special designs (e.g. fish ladder), culverts can be installed on streams with slopes up to 7% and still provide adult fish passage (Table 2). Stream slopes over 7% usually require a ford, bottomless type culvert or bridge to provide fish passage. All culverts should be installed so no drop occurs from the outlet. If a drop is unavoidable due to physical site limitations, it should be kept as small as possible and never more than 1 ft. Stream gradients at which the various alternatives can be installed, and provide fish passage, were determined through widely accepted formulas, published research, and discussions with experts in the field.

Continuous (over ½ a mile) stream gradients over about 15% have been found to block cutthroat trout passage in the Coeur d'Alene River drainage. However, fish can flourish in streams with gradients over 20% if there is a good step-pool configuration. Consult a fish biologist if in question about the ability of a stream to support fish. Streams that have sufficiently steep gradients may not require fish passage at stream crossings.

FIGURE 1. Swimming capability of migrating salmon and trout (Alaskan Curve)

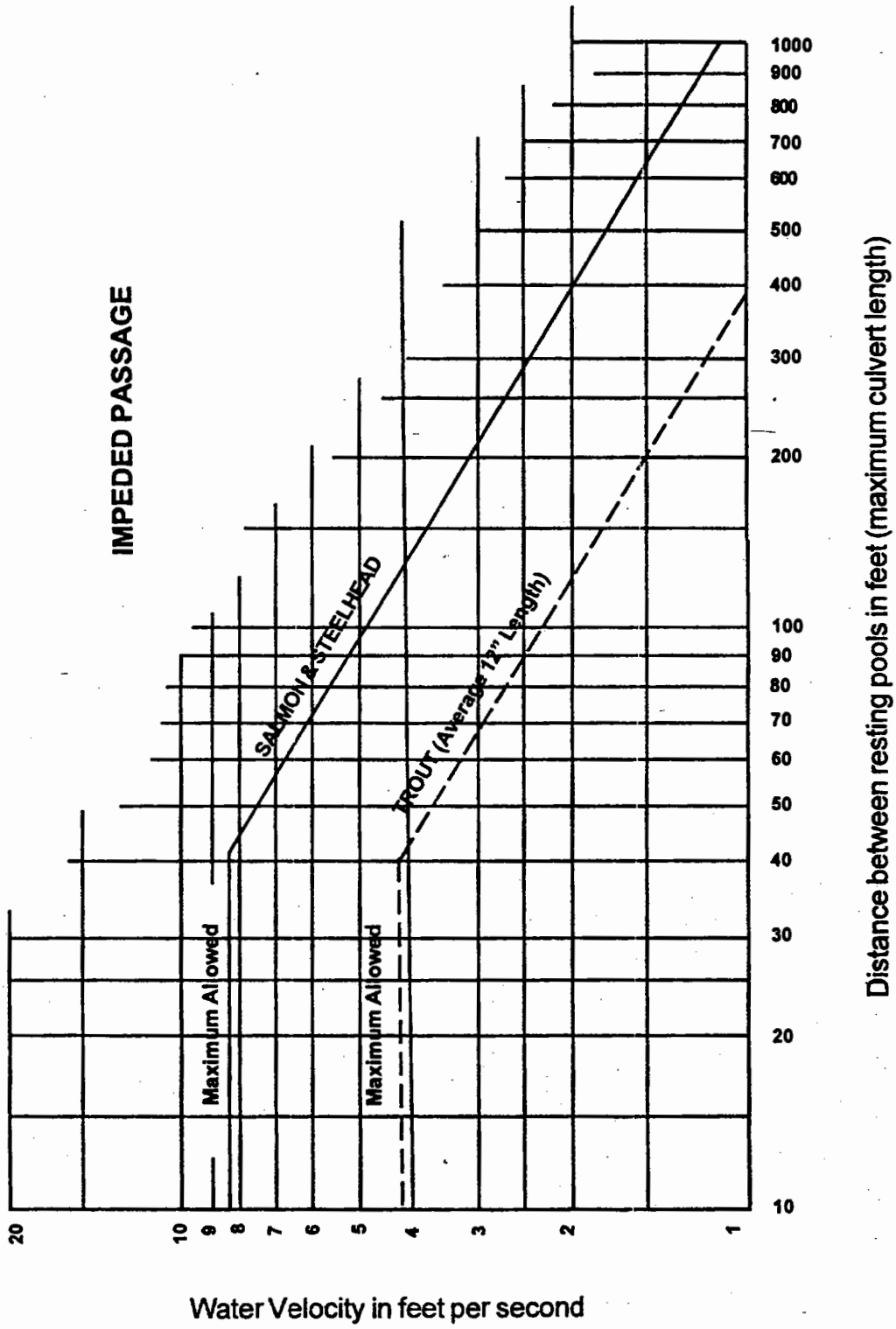


Table 1. Information on various stream crossing alternatives that provide upstream fish passage.

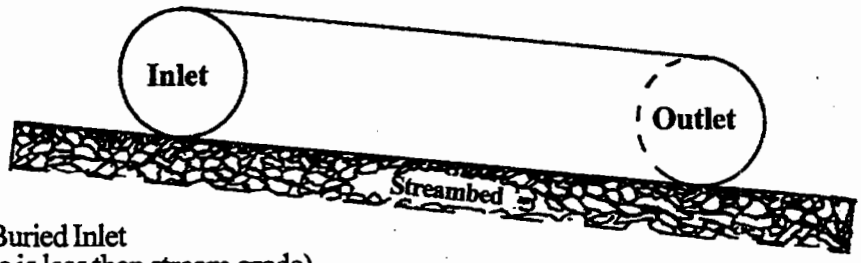
Stream Crossing Alternatives (See Figure 2 for details)	Maximum stream slope allowing fish passage*		Technical Difficulty (low/med/high)	Culvert Oversizing Needs	Potential of Plugging (low/med/high)	Problems with minimum depths during low flow	Additional Comments
	Adult	Juvenile					
1. Culvert installed at stream grade	culvert < 50ft 1.0% culvert > 50ft 0.5%	culvert < 50ft 0.5% culvert > 50ft 0.0%	low	no need to oversize culvert	medium	yes	If fish migrations occur at low flows (fall spawning fish) consider another alternative or installing a grade control structure down stream of the culvert's outlet to avoid problems with shallow water (see Alternative 5).
2. Culvert with buried inlet**	culvert < 50ft 3.0% culvert > 50ft 2.5%	culvert < 50ft 2.5% culvert > 50ft 2.0%	low	increase culvert size 1 diameter class	medium	yes	The purpose of burying the inlet is to reduce the slope through the culvert. The resultant grade should not exceed that specified in Alternative 1. An abundance of bedrock, sand, or silt substrate may limit the use of this alternative.
3. Culvert with buried inlet and outlet**	5.0%	3.5%	medium	increase culvert size 2 diameter classes	medium	usually not	Backfill culvert with cobble and boulder substrates. The culvert width should be similar to the width of the stream for substrate to remain in pipe. Arch pipes are recommended. This alternative may not work in streams dominated by boulder or bedrock.
4. Culvert with inlet buried more than outlet*	6.5%	5.0%	high	increase culvert size 2 diameter classes	medium	usually not	Backfill culvert with cobble and boulder substrates. The culvert width should be similar to the width of the stream. This alternative may not work in streams dominated by boulder or bedrock. The resultant grade should not exceed 5%.
5. Culvert with backwatering* **	4.0%	3.0%	medium	increase culvert size 1 diameter class	medium	no	This alternative can be combined with other alternatives to improve fish passage and can be used to reduce the drop height from a culvert's outlet. This alternative is often used to maintain water depths through a crossing during low flow.
6. Culvert with fish ladder or baffles**	7.0%	4.0%	medium	increase culvert size 1 diameter class	medium to high	no	The detachable fish ladder can be removed from a culvert if complications occur. Baffles are welded in place at the factory. Turbulence may restrict juenile fish passage at higher flows.
7. Open bottom culverts	any stream grade	any stream grade	high	culvert should span the entire stream channel	low to medium	no	Bottomless crossings that constrict the stream will have the same ability to pass fish as alternative 3. This alternative may not be practical on streams with fine grained substrates or where substantial fill cover height are required.
8. Ford	any stream grade	any stream grade	low-high depending on stream gradient	NA	low	no	Fords typically do not allow year-round use or heavy traffic. On stream gradients > 2%, special designs are required. Use of ford crossings may be limited by flow conditions and timing of fish spawning and egg incubation.
9. Bridges	any stream grade	any stream grade	high	NA	low	no	Although this alternative is often the most expensive, it is usually considered the best for fish passage.

* "Adult" refers to the maximum stream grade that will allow adult trout passage (spring spawners) and "juvenile" refers to maximum slopes that allow passage of juvenile trout and weak swimming fish species. Any design plans for crossings on stream slopes near the upper allowable li[illegible] should be preapproved by experienced personnel. Fish >15 inches in length and [illegible] that migrate du[illegible]wer flows (many fall spawning fish) can ascend steeper stream crossings than i[illegible]ed.

** Wi[illegible]sing any of these alternatives, culvert sizes may be increased to pass the design fl[illegible]

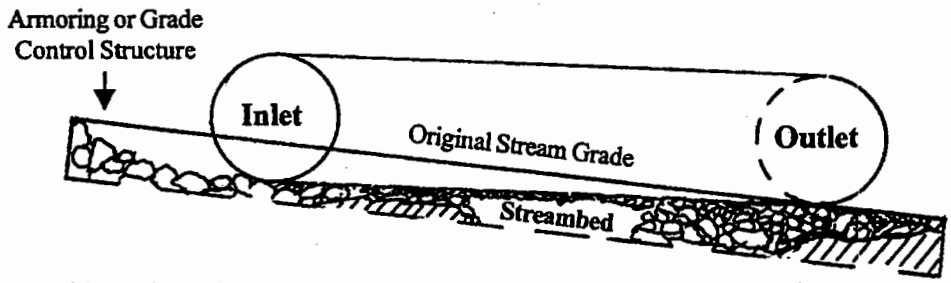
A. Culvert installed at stream grade

- A culvert should be selected that best fits the stream channel.
- The resultant culvert grade should be the same as the original stream grade.



B. Culvert with Buried Inlet
(Culvert grade is less than stream grade)

- The culvert will have to be oversized in order to pass the design flow.
- The culvert's inlet should not be buried over 2 ft. or ½ the diameter, whichever is less.
- There should not be more than a 2% difference in slope between the original channel and that of the culvert.
- The streambed should be armored just above the culverts inlet with angular cobble or boulders to prevent a drop from occurring into the culvert and to help prevent headcutting. Consult an experienced individual (e.g. hydrologist) if the stream substrate is composed of silt or sand.
- The resultant culvert grade should not exceed those specified in Alternative 1 of Table 2.



C. Culvert with Buried Inlet and Outlet

- The culvert will have to be oversized in order to pass the design flow.
- For pipe-arch culverts, bury both ends at least 1-2 ft (pipe-arches are the preferred type of culvert).
- For round pipes, both ends should be buried for 30% of the culvert's height.
- Armoring and/or a grade control structure upstream and downstream of the culvert will minimize erosion and help substrates remain inside the culvert.
- It is best to backfill inside the culvert with angular cobbles and boulders, although it will often fill naturally.

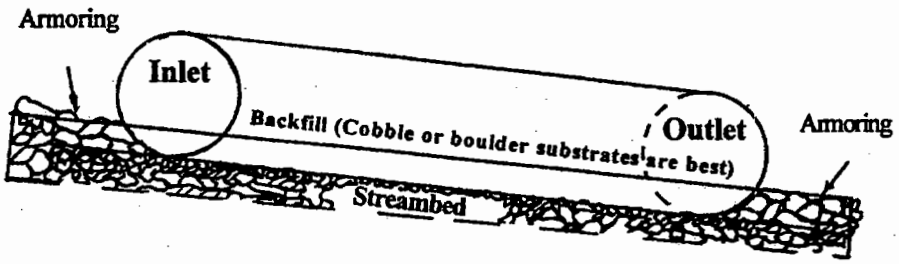
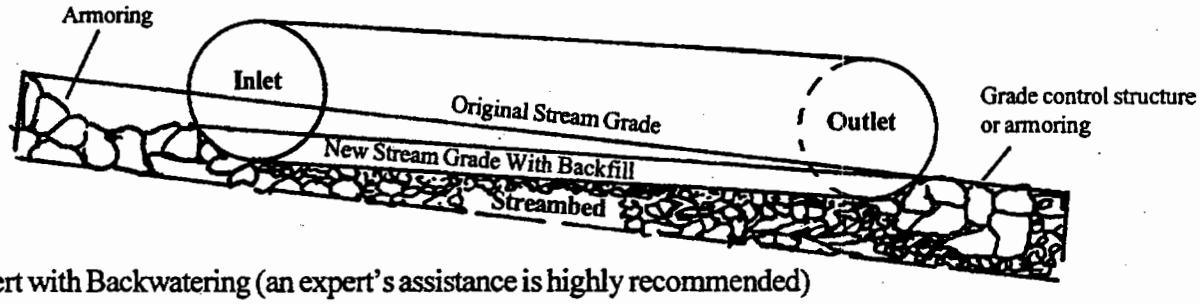


Figure 2. Details for installing various stream crossing alternatives.

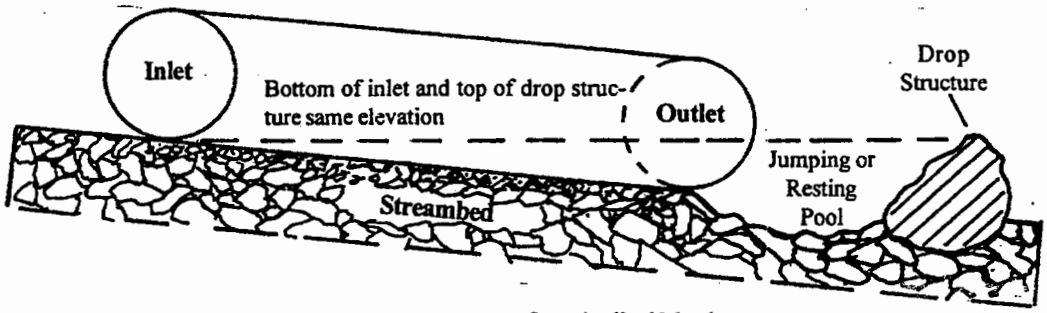
D. Culvert with Inlet Buried more than Outlet

- Rules from both alternative 2 and 3 apply here.
- The resultant slope of the culvert should not exceed 5% (3.5% for juvenile fish).



E. Culvert with Backwatering (an expert's assistance is highly recommended)

- The culvert will have to be oversized to pass the design flow.
- The drop structure (angular rock, logs or gabions) must be sized appropriately, keyed into the stream's banks, and excavated into the stream bottom to avoid failure.
- Place the most upstream drop structure two to three channel widths downstream from culvert outlet.
- The drop from the designed structure should not be > 1 ft. If the drop is > 1 ft., a series of drop structures should be constructed downstream to step down to the channel level in increments.
- This alternative is not recommended if the change in elevation between the culvert inlet and outlet is > 1.5 ft.



F. Culvert With Detachable Fish Ladder

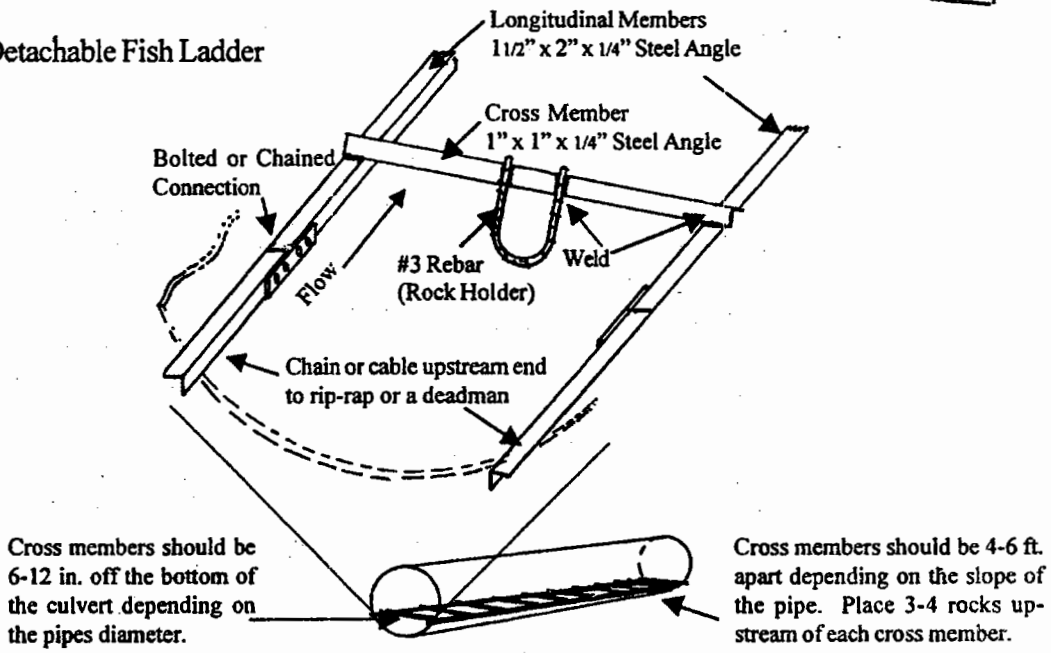


Figure 2 (continued). Details for installing various stream crossing alternative.

Table 2. Timing of migration and spawning of salmonids in Idaho.

FISH SPECIES	TIMING OF SPAWNING MIGRATION	TIMING OF SPAWNING
Rainbow Trout	Mid Feb. – Late June	Mid March – Late June
Cutthroat Trout	Early March – Early July	Late March – Early July
Chinook Salmon	Mid May – Late Sept.	Early August - Early Oct.
Bull Trout	Late May – Early Oct.	Mid August - Late Oct.
Brook Trout	Early July – Late Oct.	Early Sept. - Late Nov.
Brown Trout	Mid July – Early Jan.	Late Sept. - Early Dec.
Kokanee	Late July – Early Jan.	Early Sept. - Early Jan.
Lake Whitefish	Early Oct. – Late Jan.	Early Oct. - Late Jan.
Mt. Whitefish	Early Oct. – Mid Feb.	Mid Oct. - Early Feb.

GLOSSARY

Armoring: A layer of stone "Armor" placed on the stream bottom to protect erodible material lying underneath.

Backfill: Placing earth or a specified size of material in place of material removed during construction, such as in a culvert or trench.

Backwatering: The rise of water level upstream due to an obstruction or constriction in the stream channel.

Culvert Diameter Class: Culverts are built in certain sizes, which are classified in diameter classes. Each diameter class increases in six inch increments (18, 24, 30, 36, 42, 48, 54, 60, etc.).

Fill Cover Height: The height of soil placed over the culvert, which extends from the crown of the culvert to the top of the road surface.

Fish Ladder: Constructed angle iron placed into a culvert to improve fish passage.

Grade Control Structure: A structure placed across a stream channel used to prevent the stream channel from headcutting and used to raise upstream water levels.

Headcutting: The upstream erosion and displacement of stream bottom substrates. The stream channel erosion will often migrate in an upstream fashion.

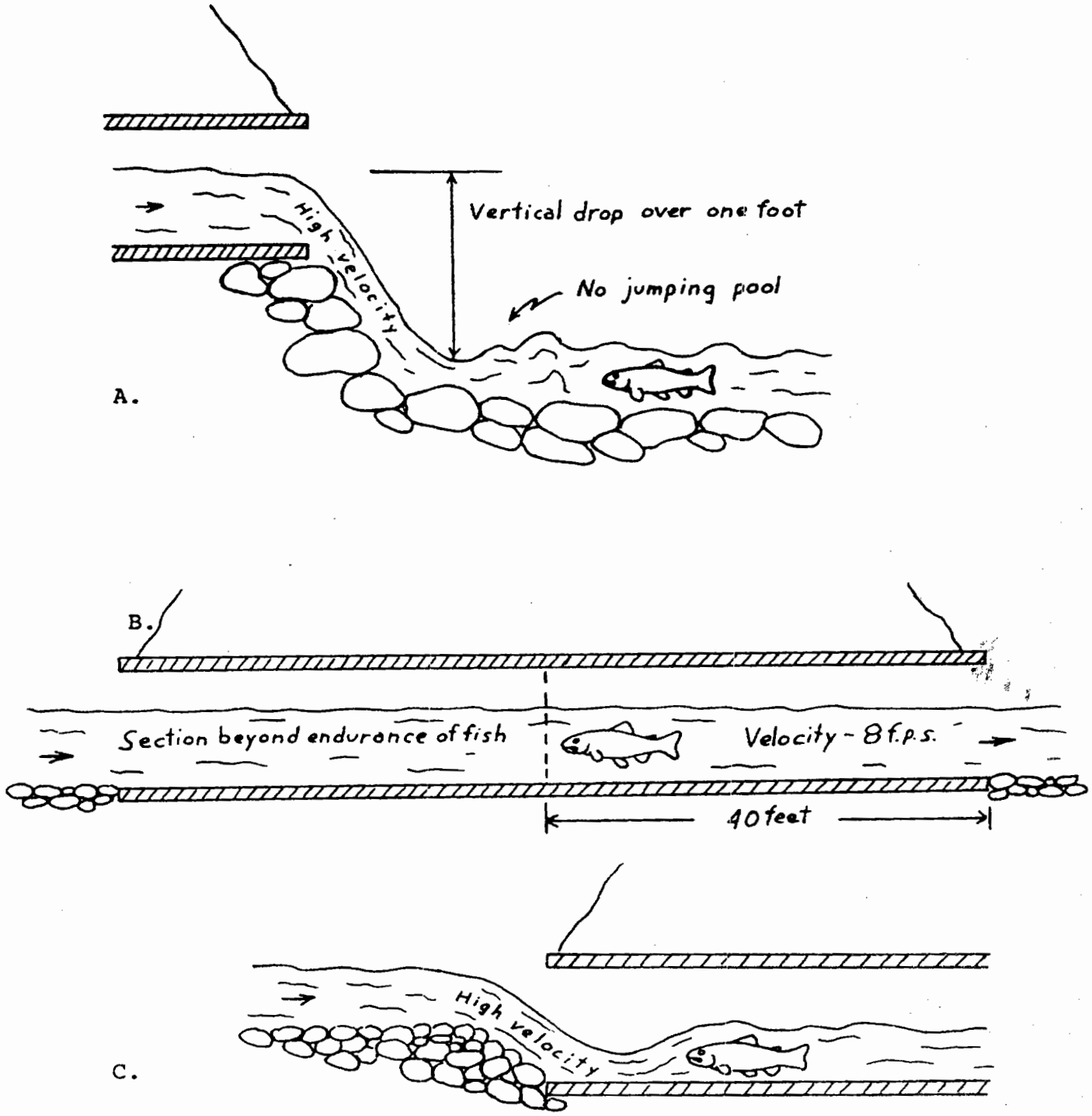
Inlet: Water flows into the inlet end of the culvert.

Outlet: Water flows out of the outlet end of the culvert.

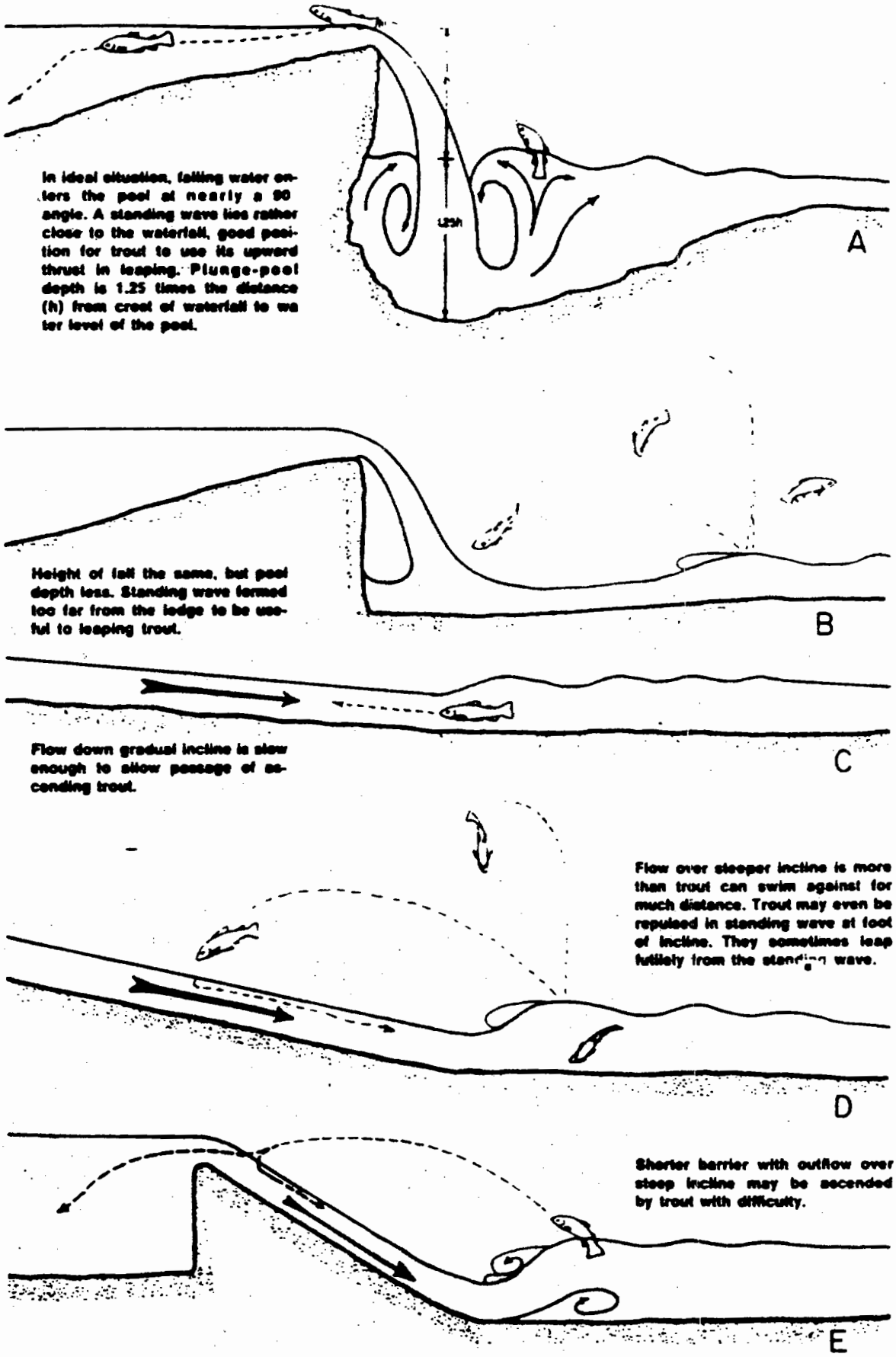
Resting Pool: A pool downstream of the outlet of a culvert that is deep and flows slowly to allow fish to rest before migrating through the culvert. If a drop occurs from the outlet of the culvert, the resting pool should be deep enough to allow fish to make a run before it jumps.

Salmonids: The family of fish including all trout, char, salmon and whitefish.

Substrate: Stream bottom sediments, which may include silt, sand, gravel, cobble, boulder, and bedrock.



Undesirable conditions for passage of fish through culverts.



MOVEMENT OF TROUT OVER OBSTACLES
(Diagrams drawn after Stuart, 1962)