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Planning, Design and Construction of Fish Friendly Stream Crossings



This web page was developed as an informational resource for people involved in planning, designing and constructing stream crossings on small streams less than 20 feet wide.

For a brief preview of a culvert replacement project, click [here](#) to view the 18 Mile Creek Culvert Replacement Video (7:13 seconds 23 mb)



Building a fish-friendly stream crossing requires an understanding of not only fishery biology but also basic engineering and construction principles as well as fluvial geomorphology (that is the processes that form and maintain stream habitat).

Our intent in developing this web site was to provide the tools needed to plan and construct a fish passage structure that will be efficient, safe and conducive to fish passage.

The procedures we suggest were derived from best practices recommended by public and private agencies and were selected to provide practical guidelines for designing long lasting, stable road crossings that will have minimum adverse affect on fish and their stream habitats.

A number of state, federal and municipal agencies may have jurisdiction and permit authority over construction activities on streams and wetlands. Any person involved with planning, designing and constructing a stream crossing improvement should consult with the appropriate federal, state and local agencies from a very early stage within the planning process and comply with permit and construction regulations.

Through this web page, we hope you will learn about:

- How to identify problem fish passage structures.
- How to evaluate a site for possible fish passage remediation.
- How to design and install replacement fish passage structures that are friendly to fish and their habitats.
- Where to find additional resources for planning, designing and construction of fish friendly stream crossings.



Background:

Early in our history, rivers ran wild, and fish followed them according to their needs. This was a time when our fishery resources



seemed abundant and without end.

Since then, millions of culverts, dikes, stream diversions, dams, and other artificial barriers were constructed for transportation, to impound and redirect water for irrigation, flood control, electricity and drinking water. Many of these alterations have changed the open access features of rivers and streams and have taken their toll on our fishery resources. Improperly designed or damaged stream crossings are by far the most common cause of these problems.

~ Restoring fish passage benefits people, fish and the environment ~

The vast majority of crossings are culverts or bridges on small streams. Nearly all culvert installations are intended to serve the purpose of providing vehicle access, however, many also have an unintended function - they can block the migration of fish up or down streams.

They also alter the geomorphic processes by which river channels form and maintain habit over time. For example, they may block or constrict the passage of sediment and large wood being transported by the river, and prevent channel migration.

Fish movements within streams are vital for maintaining healthy populations. Spawning migrations like those made by trout and salmon may be the most visible and dramatic, but seasonal (or even daily) movements upstream or downstream to find food supplies, refuge from predators, preferred temperatures or cover may also be critical.



Where fish habitats are divided into small segments (fragmented) by man-made barriers, whole populations may be eliminated, reduced or genetically damaged through the effects of isolation and inbreeding. The consequences can be disastrous for fish populations and other aquatic organisms within a watershed. It is a fundamental fact, fish need to move. For example, many fish need to move between feeding and spawning areas and make other seasonal movements to important habitats.

Please select from the links below 

 Start Here .. About the Program	Choosing Options for Replacement Structures
Cautions to Consider	Final Site Preparation and Structure Installation
What is a Fish Barrier ?	Erosion Control
Evaluation of Your Work Site	Quick Guide to Culvert Installation
References and Web Links	



To print the information contained in this web site, please set your "printer setup" preferences to landscape mode.



Click [here](#) to download this presentation

(1.7 mb).

- [Ashland NFWCO Home Page](#)
- [Region 3 Fisheries](#)

The U.S. Fish and Wildlife Service, Ashland Fishery Resources Office has developed this webpage as an informational resource only. The U.S. Fish & Wildlife Service does not accept legal responsibility for any of the information contained within. The consultation of professional engineering and geomorphology expertise is recommended before starting any stream crossing improvement project.

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What is the U.S. Fish Wildlife Service Fish Passage Program?



The Fish Passage Program provides technical assistance and Federal funds to:

Remove, replace, or retrofit artificial barriers; design and construct fishways; support biological surveys of important watersheds; and monitor the effectiveness of these activities. Fish passage projects can be engineered on either private or public lands, but cannot be used on hydroelectric projects licensed by the Federal Energy Regulatory Commission (FERC).

All projects are voluntary, and are performed in cooperation with agencies, private organizations, and landowner partners.

The goal of the Fish Passage Program is to restore native fish and other aquatic species to self-sustaining levels by reconnecting habitats that have been fragmented by artificial barriers, where such reconnection results in a positive ecological effect.

In 1999, the U.S. Fish and Wildlife Service initiated the [National Fish Passage Program](#). The Program uses a voluntary, non-regulatory approach to remove and bypass fish barriers. The Program addresses the problem of fish barriers on a national level, working with local communities and partner agencies to restore natural flows and fish migration. The Program is administered by National and Regional Coordinators, and delivered by [Fish and Wildlife Management Assistance Offices](#), with their 300 biologists located across the Nation. Appropriations for the Program support the Coordinators, in-the-water fish passage projects, and the Fish Passage Decision Support System.

Click [here](#) to learn more about the fish passage projects completed with the assistance of the U.S. Fish & Wildlife Service

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(503) 231-6217

Region 2 - Southwest
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P.O. Box 1306
Albuquerque, NM 87103-1306
(505) 248-6471

Region 3 - Great Lakes-Big Rivers
(IA, IL, IN, MI, MN, MO, OH, WI)

Federal Building
1 Federal Drive
Fort Snelling, MN 55111
(612) 713-5114

and Region 3 Fish Passage Program

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(404) 679-7324

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Hadley, MA 01035-9589
(413) 253-8405

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Planning, Design and Construction of Fish Friendly Stream Crossings



Cautions that should be considered before initiating any fish passage project:

Not all barriers are bad!

While removing barriers to fish migration at road crossings is important, there are situations where barrier removal may NOT be beneficial.

Some barriers at road crossings may be keeping out unwanted or harmful exotic species.



- An example is the Atlantic sea lamprey that invaded the Great Lakes and decimated fish populations. Sea lamprey spawn and develop in streams before going downstream to the lakes to prey on rough and gamefish. Denying them access to spawning streams by installing low head dams (barriers) is one common method of controlling lamprey populations. Some road crossing barriers may currently be serving this function. It's always important to consult with federal or state natural resource officials before planning any fish passage project.
- Diseases of concern to fish health and differences in fish population genetic structure above and below barriers are also reasons why not all barriers are bad and why not all should be removed.
- Another very important consideration is the potential for geomorphic effects, in particular, channel incision. Channel incision or down-cutting of the streambed tends to propagate upstream by means of migration of a headcut. Often, this headcut migration is arrested when it encounters a culvert. If the culvert is replaced, the headcut may then proceed onward upstream, spreading channel incision, and inducing a period of channel destabilization and habitat degradation.

Click [here](#) to review the document (pdf) *Geomorphologic Impacts of Culvert Replacement and Removal: Avoiding Channel Incision.*



It isn't just fish that you are helping!



Culverts also provide moist shady habitats and pathways and may serve as attractive temporary homes for frogs, toad's, snakes, mink, otter and a host of other desirable species.

Think Safety!

Work sites at culverts can be dark, wet/slippery and hazardous. Exercise caution, wear protective gear and be aware of dangers. The rusted and jagged metal edges shown in this image are typical hazards often found in culvert restoration projects.



There are a number of safety issues that must be considered when performing earthmoving & culvert installation projects:

- Mobile equipment working near roadways.
- Control of traffic near work areas.
- Shoring & bracing during trenching operations.
- Stability of backhoe/excavator during operation: use of outriggers & blocking.
- Working around heavy equipment: pinch points and staying in view of equipment operators.
- Proper hand signals for equipment operators.
- Lifting loads: cable/sling inspections and load ratings, proper hookups and working near overhead loads.
- Proper use of hand tools.
- Physical hazards: proper lifting techniques, sprains, cuts & abrasions.
- Hazards of working outdoors: working in cold environments, heat illness, sunburn, insect bites, ticks, poison ivy and snakes.
- Environmental hazards: slippery and wet conditions, working on slopes and in stream beds.
- Review Personal Protection Equipment (PPE) requirements.
- Follow all OSHA standards.

Each specific project may have a number of safety related hazards. Therefore, a preliminary construction project safety review is necessary. Be aware of the potential worksite hazards, and take the proper steps to prevent accidents and injuries.



Beware of critters in the work place!

Some culvert users may have a bad attitude.... [click](#) image to enlarge.

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What kinds of structures at road crossings create fish barriers?

High vertical drops at culvert outlets

Excessive water velocities inside culverts

Debris barriers

Lack of jumping pools or inadequate pool depths

Click on the Windows Media Player icon to download and view a short video showing different structures that create passage barriers for fish.

Windows Media Player 7.0 or greater, may be needed to view this video.

Click [here](#) to download Windows Media Player.



(Windows Media Player Video 15MB, 3 minutes)

Downloading Hints: During the initial download of this file, if your viewer starts to play, press the pause button to stop the video. Play the video only after the download process has been fully completed.

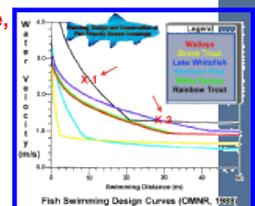
To save this video to your computer, right mouse click the link below and select "Save Target As." Then select a folder on your computer to save the file.

- [15.0MB](#) ~ small screen version or
- [33.5MB](#) ~ large screen version

Water Velocity Barriers and Fish Swimming Performance

Use this table to determine the swimming ability of some adult fish species. For example, note that rainbow trout (X-1) can swim through a 10 meter culvert with a flow velocity of 2.4 meters per second (7.9 feet per second). However, in a 30 meter culvert (X-2), rainbow trout can only manage a velocity of 1.4 meters per second (4.6 feet per second).

This performance table only applies to large, adult game fish swimming between resting points. The swimming abilities of small or juvenile size fish will not result in these same values.



Generally, when flow velocities through a culvert exceed .6 meters (or 2.0 feet) per second, some sizes and species of fish will be blocked.



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Evaluation of your Work Site



This site has excellent spawning habitat for a variety of fish species including steelhead, coho salmon and white suckers.

Evaluating a Problem Road Crossing for Remedial Action:

1. Is there important fish habitat in the stream on the work site? What is the composition of the material on the stream bottom? Gravel or cobble size rock are spawning habitat for many fish species. Groundwater or springs are too. These are important habitats and must be protected from disturbance and sedimentation during and after construction.



These culverts are severely perched, damage habitat and block fish passage.



Too short a culvert, soft, sandy soil and excessively steep banks spelled disaster for this installation. Replacing it correctly will approximately double the cost of the initial project.

2. Evaluate and record soil types at work site. Soil and available fill composition are important factors in determining how slopes may be contoured to stable configurations. Cohesive soils such as clay are less prone to erosion or slumping than sand. Slope or bank ratios include a number of considerations:

- Consider the bank slopes needed for a stable configuration.
- What is required by county, state and federal highway and safety authorities?
- For keeping installation costs down and for fish passage, how can the slope and total culvert lengths be kept to a minimum, while maintaining a safe and lasting structure?

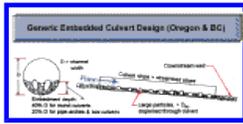


3. Note and record potential erosion or sediment sources entering the work site. Are there ditches or banks contributing significant amounts of water flow or sediment to the site?

[Plan an approach to sediment control !](#)



In this example, a roadside ditch is contributing suspended red clay to this trout stream.



Slope determines the type of culvert or bridge that may be used.

Critical Stream Measurements:

1. What is the slope of the stream bottom? Slope determines the type of culvert or bridge that may be used. Measure stream slope from a point 100 feet above the existing culvert to a point 100 feet downstream. Measure elevations from bottom of the stream bed.



Culvert designers need to measure profile (i.e. elevations and longitudinal distances of a series of points on the streambed), not just slope through the pipe. This requires extending the survey far enough upstream & downstream to get a representative profile of the channel away from the area affected by the culvert itself. For some projects, this may be more than 100 ft (some authorities recommend a distance of 10 bankfull channel widths in each direction).

Compute stream slope using this formula:

$$\text{Slope} = \text{Length (200 + length of Culvert)} / \text{elevation change}$$

For example: If the existing culvert is 80' long and we measure from 100' above to 100' below, the total length equals 280'. If the elevation change is 9', then $9'/280' = .032$ or 3.2% slope.



Bankfull stage is the vital measurement for properly sizing culverts.

2. Determine the width of the **bankfull stage** of the channel. This measurement is a good, on-the-ground indicator of flow levels in the stream over a long period of time. It may be used to determine **culvert sizing** that will be capable of handling peak flow levels, but, it must be measured accurately.

The important element in determining the bankfull stage is the presence of the depositional (floodplain) surface. This surface may be correlated to a transition in vegetation type (e.g. presence of certain species, transition from moss to rooted plants or annual to perennial woody plants), or transition in substrate texture (e.g. gravel to sand or silt), but these secondary indicators need to be locally calibrated by correlating them to the "point of incipient flooding".



Determining the Bankfull Stage is the most important measurement for establishing culvert size in handling peak stream flows.

Advantages to having a culvert somewhat wider than bankfull include:

- Better ability to pass sediment, large wood and debris without scour or blockage.
- Less constriction of the flow during high water, and thus less increase in average velocity during peak flow development of a natural channel edge within the culvert, which promotes a more extensive low-velocity zone (technically, the hydraulic "boundary layer"). Small fish typically hug this zone to stay out of high-velocity water when moving through a culvert.

Measure and average channel width at 10 locations above the existing crossing (crossings often alter the normal channel below the installation). Measure from the first rooted, and established vegetation on each side of the channel as shown in this diagram.



Planning, Design and Construction of Fish Friendly Stream Crossings



In this program, we recommend the [Stream Simulation Design Method](#) because it provides maximum benefits to stream habitat and is a practical and effective method to design and build stable road crossings.

Structures installed using the [Stream Simulation Design Method](#) include natural stream substrate bottoms that will maintain habitat values and provide for passage of all fish.

Preferred Alternatives And Crossings

Before design work begins, the following alternatives and structure types should be considered. In order of preference they are:

1. No Action: Is this stream crossing really necessary? Can the road be realigned to avoid crossing the stream?
2. Bridge: Spanning the entire stream is best for the stream environment, but is it practical?
3. Streambed Simulation Strategies: Bottomless arch or embedded culvert design.

At some sites, it may be impractical or cost prohibitive to employ the [Stream Simulation Design Method](#).

In those cases other techniques may be required such as:

Non-embedded Culvert:

This is often referred as a hydraulic design, associated with more traditional culvert design approaches and is limited to low slopes for fish passage. Non-embedded culverts must be set deep enough into the stream bed (at least 10% of their diameter) to provide adequate water depth for fish to swim and to keep flow velocities down.

The culvert in this photo is set too high, resulting in excessive flow velocity and depth too shallow for fish to swim.





Natural stream substrates like gravel, rock, sand and woody debris, provide habitat features that support plant and animal stream life; including shelter, food and spawning areas. These substrate types are just as valuable when contained within culverts.

Baffled Culvert, or Structure Designed with a Fishway:

Used for steeper slopes and not usually recommended for new installations, this technique may be used to retrofit existing structures.

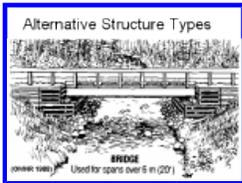


When first installed, this box culvert was a velocity barrier to fish passage on an important brook trout, steelhead and coho salmon spawning stream. The recent installation of a series of jumping pools, (essentially a fish ladder-on the left of the picture) now provides fish passage to 4 miles of quality habitat upstream. The cost of this retrofit fish passage project was about \$35,000. If the original installation had been a bottomless culvert, the extra cost of the retrofit would not have been necessary and habitat values at the site would be better.

Structure Options for Stream Crossings:

Two types of structures are generally used for stream crossings, they are:

1. Span Bridges:



Span bridges are recommended for sites on streams that are more than 20 feet in width (bankfull stage width measurement) or with slopes more than 3%, or where important spawning habitat is present.

This inexpensive, prefabricated bridge is a good solution for low traffic (one lane) crossing and maintains high quality fish habitat in the trout stream it spans.

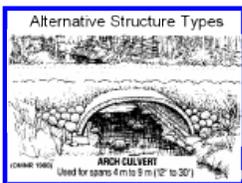


2. Culverts:

For sites on streams that are less than 20 feet in width (bankfull stage width measurement) or with slopes less than 6%, and where important spawning habitat is not present, culverts may be considered. Four general types of culverts may be used; round, ellipse, box or bottomless arch. All are readily available from manufacturers in a wide range of sizes and lengths.

A. Bottomless Arch Culverts:

Bottomless arch culvert installations are an excellent choice from an environmental and fisheries viewpoint.



The typical design for installation of a pre-cast concrete, bottomless arch culvert is shown in this line drawing. It is mounted on footings (poured-in-place) that extend below the scour line. Like a span bridge, they allow for natural stream channel processes that will maintain favorable habitat and fish passage under the structure.

Bottomless arch culvert installations also have the low profile advantage of an ellipse type culvert. Bottomless arch structures may be used at sites with slopes ranging from 0% to 6%, but bottom materials inside the culvert should include boulders large enough to withstand current flows. On sites with slopes from 3% to 6% this means

utilizing D_{90} * size rock (D_{90} size material refers to the largest 10% of naturally occurring boulders in the stream). In some installations special preparations (like rock placement) are needed to address possible scour erosion of the stream bed that could undermine the culvert footing.



In this photo, the flange footing type, bottomless arch culvert is being lowered onto the prepared streambed. Note the placement of D_{90} (or larger) boulders in the channel to provide resting places for migrating fish.

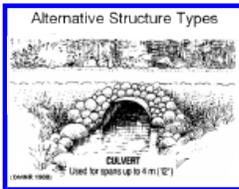
* The term D_{90} refers to the size of the boulders in the vicinity of the crossing.

The size of a D_{90} boulder is equal to the average of the largest 10% of the boulders in the stream bed.

This corrugated metal, bottomless arch culvert is provided with a metal flange footing and rests on a cement base. It is a highly functional installation, does a great job of maintaining fish habitat and is competitive in price with a round culvert installation.



B. Round Culverts:



Round culverts of corrugated metal, pre-cast concrete or plastic are by far the most commonly used structures at road crossings in the United States. They are suitable for use where slopes range from 0% to 3%. At slopes > 3%, it is very difficult to maintain natural substrates on the metal or concrete bottom.

When properly installed and embedded, they can be both fish friendly and the least expensive option. Unfortunately, many existing culverts are not properly sized or installed correctly and cause damage to stream habitats, fish and other stream organisms.



These round culverts are set too high or “perched” and makes for a difficult jump, even for mature fish. Assuming that fish could leap into these culverts, excessive flow velocities will stop their upstream spawning migration here.



The best design of a round culvert will include natural stream materials in the bottom of the culvert that help to minimize and alter water flows, thus allowing for easy fish passage.



C. Box Culverts:

Box culverts are commonly used where traffic loads or higher fill levels place heavy stresses on the structure. They are suitable for use where slopes range from 0% to 3%. At slopes > 3%, it is very difficult to maintain natural substrates on the metal or concrete bottom. They are usually made of concrete and may be purchased as pre-fabricated units of various

lengths, or poured in place.

This poured-in-place box culvert has a number of problems: A vertical jump, water too shallow for fish to swim, and at higher flow levels, it may generate water velocities that act as a fish barrier. Replacing this structure under a major highway would be an extremely expensive project. However, retrofitting the structure with current deflectors and by raising the level of the plunge pool may be possible to enhance the fish passage function of this culvert.



D. Ellipse or "Squashed Arch" Culverts.

Ellipse culverts are a viable choice where a lower profile (and less fill cover) is required.

They are suitable for use where slopes range from 0% to 3%. At slopes > 3%, it is very difficult to maintain natural substrates on the metal or concrete bottom. This ellipse culvert handles water flows well, but should have been sized larger and set lower (embedded) in the stream to allow natural stream bed materials to line the bottom and provide fish habitat.

Each of the culvert types described above have advantages and disadvantages in terms of cost, ease of installation and its effects on stream habitat and fish passage. Choice of structure type is an important consideration, but the placement and installation are just as critical for the success of the project.

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Stream Simulation Design Method

The Stream Simulation Design method is a design process that is intended to mimic the natural stream processes within a culvert. Fish passage, sediment transport, flood and debris conveyance within the culvert are intended to function as they would in a natural channel.

Determination of the high and low fish passage design flows, water velocity, and water depth is not required for this option since the stream hydraulic characteristics within the culvert are designed to mimic the stream conditions upstream and downstream of the crossing.



The structures for this design method are typically open bottomed arches or boxes but could have buried floors in some cases. These culverts contain a streambed mixture that is similar to the adjacent stream channel. Stream simulation culverts require a greater level of information on hydrology and geomorphology (topography of the stream channel) and a higher level of engineering expertise.

Click [here](#) to download the Adobe pdf file "GUIDELINES FOR SALMONID PASSAGE AT STREAM CROSSINGS" that discusses this method of fish passage.

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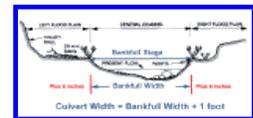
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In the previous sections we measured the bankfull width and slope of the stream bed at the planned crossing.

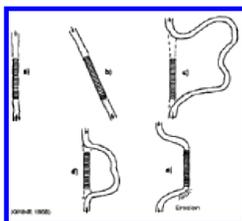


The Bankfull Width measurement determines the width of the new culvert (all types) using the following formula:



$$\text{Culvert Width} = \text{Bankfull Width} + 1 \text{ foot}$$

We have also determined whether important fish spawning habitat occurred on the site. Based on these factors, we decided which of the four culvert types to install. The final dimension of the culvert, length, is determined by measurements made on the site. The measurements needed are the desired, final width of the road bed and the slope of the embankments. The design width of the road bed (at the culvert) should be at least the width of the existing road. However, in some cases it should be set at the width of any planned or expected improvements that might occur during the life of the structure.



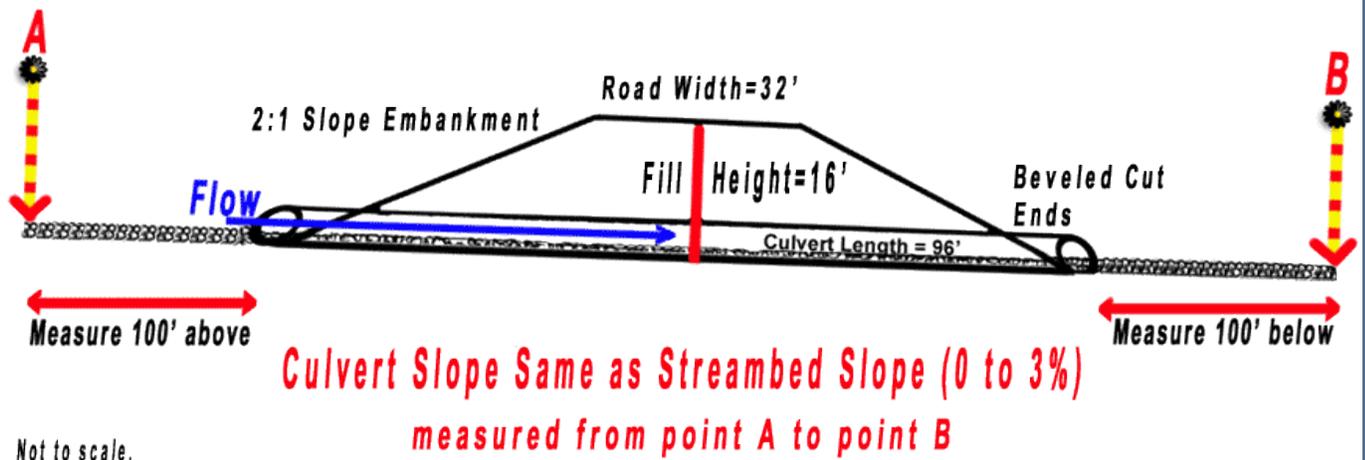
The new culvert should be aligned with the existing stream channel. Sharp turns in the channel above or below the structure will direct currents into banks, eventually causing undercutting and collapse. However, if stream bends adjacent to culverts can't be avoided, it is preferred to locate culverts so they are aligned with the downstream channel. Even if there is a sharp bend upstream.

The length of the culvert for any installation is based on the total width of the road plus the distance added by the slopes of the embankments on each side of the road to the bottom of the culvert (see diagram below).

The road width is measured from the point on each side of the road where slope meets level road shoulder. The height of the fill is the vertical distance from the bottom of the culvert at the middle of the road to the finished level of the center of the road.

The actual slope of the embankments should provide a stable configuration and may be based on one-size-fits-all recommendations or requirements, or be determined by knowledge and experience with local soil and fill characteristics. General recommendations tend to be conservative and based on unstable fill materials such as sand. This can result in longer slopes and culverts than are really needed in applications where fill materials are more cohesive and stable (such as clay).

While the general rule approach may provide an extra measure of stability to slopes in some cases, it also results in longer culverts, higher costs and more habitat and fish passage problems. We recommend consultation with agencies with local expertise such as U.S. Natural Resources Conservation Service (NRCS), State natural resources agencies and experienced road building contractors. This point in the project development is an excellent time for consultation with regulatory agencies for both advice and information regarding regulations and permits.



In the example above, the fill height needed to maintain a level road at the crossing is 16 feet. Assume that we will use local fill materials that are fairly cohesive and capable of supporting strong plant growth for further stabilization. Based on the observations made in this example, we have assumed that a 2:1 bank slope is adequate for this site. We now have the information needed to determine culvert length by using the following formula:

$$\text{Culvert Length} = \text{Road Width} + 2(\text{Fill Height} \times \text{Slope})$$

$$\text{Culvert Length} = 32' + 2(16' \times 2)$$

$$\text{Culvert Length} = 96'$$

Establishing the elevations of the culvert inlet and outlet are critical elements in the installation using the Stream Simulation Method.

Determine the stream slope by surveying the vertical drop in the stream bed from 100 feet above the culvert (Point A) to 100 feet below (Point B). See image above. Set culvert inlet and outlet depths (embed) to the appropriate amount below the slope line. Round Culverts may be embedded from 20% to 40 %, ellipse or squashed arch culverts from 10% to 25%.

Note: The method described above is the simplest method for finding stream slope. However, a more complete profile of the stream slope may be needed in some cases. In so, several elevations are measured on the stream bed at points above and below the structure to create an actual bed profile (images right).

When using either method you will often note that the stream bed is elevated directly above the existing culvert. This typically occurs when the initial culvert placement is too high. Natural stream processes deposit sediment, rock and debris above the culvert to a level above the culvert inlet. When a new structure is placed at the correct depth, the sediment deposit may be considerably higher than the new culvert inlet. In most cases, the stream flow will quickly cut through and redistribute these materials downstream to normalize the channel.

The process is called "head cutting" and will change the upstream channel shape and configuration considerably. If the materials lodged above the old installation are clean sand, wood or rock, downstream deposition of these materials may not be a severe problem. However, if large amounts of fine silt/sediment are involved, fish habitat downstream may be damaged. In some cases, these materials can be removed mechanically before the flow is released through the new structure.

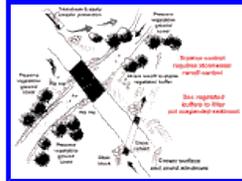


At this site, the original culvert placement was too high above the natural stream slope. Rocks and sand have accumulated at the upper end of the culvert blocking more than 50% of the opening and creating a fish passage barrier.

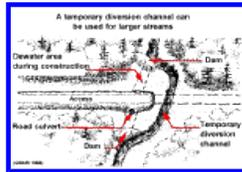


Only a few hours after installation of a new culvert (embedded 20% below the slope line), head

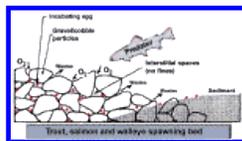
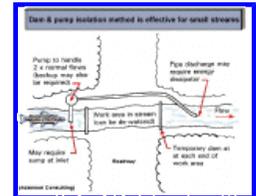
Culverts may be purchased with square or bevel cut ends that match the bank slope. Bevel cut ends (see diagram) are thought to be less prone to blockage by debris washing downstream. Placing rocks in the bottom of culverts will also help to simulate the natural stream bed.



With an outline diagram of the planned project, we are now ready to plan the final steps before permits are requested. Requirements for construction permits are highly variable among jurisdictions. In most cases however, the project diagram will need to be supplemented with an erosion control plan and a description of sediment control during construction. This image shows one example of an erosion control plan for a small stream.



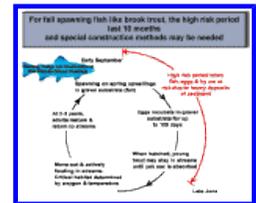
A plan to control sedimentation of the stream during construction is often required. This plan should describe how stream flow will be handled during the construction period. In very low flow streams, simply damming the stream with clean fill above the work site may provide time for the installation. On streams where flows are too large for this technique, water may be pumped around the work site, or a temporary diversion channel may be required.



Construction scheduling for stream work can be very difficult. Work must be done during low stream flow periods to minimize sediment deposition and transport, but must also consider the life stages of fish present in the stream. Adult fish are usually not highly vulnerable to the type of sediment depositions created by culvert projects. However, fish eggs and fry developing in spawning beds are extremely vulnerable to being smothered by sediment.



Culvert installations should be scheduled when no fish eggs or developing fry are in substrates downstream of the project site. Most fish species spawn either in spring or fall. These diagrams outline life cycles of some common game fish. They also help to illustrate, that when spring and fall spawning species are present in a stream, the construction window may be limited to the months of July and August. In this situation, some jurisdictions will only issue construction permits during that time frame. Be sure to check with your local offices of the U.S. Fish and Wildlife Service and state Natural Resource Departments to determine what fish are present in the stream and permitting requirements.



Permits are usually issued for a certain time period, such as 60 or 90 days. Within that time it will be the builder's responsibility to schedule the work when streams are low and work can be completed under good conditions. Often this means keeping some flexibility in work schedules to provide for contingencies such as equipment problems or severe weather events.

Culvert Installation, At last!

Be Sure to Review Your Final Checklist:

Contractor and machine operator are completely informed on the final installation plan, elevation requirements and sediment controls are in place.

The proper permits have been issued and the responsible natural resource agencies have been notified.

Electrical, gas and water utilities lines have been located or cleared at the site.

Project supervisor will be on-site throughout the construction period.

All construction materials are present and ready.

No bad weather forecast for today/tomorrow.



Excavate culvert and bypass channel. Elevations of inlet and outlet should be checked often to ensure they are positioned correctly.



Appropriate use of a flow bypass channel during placement of a large, multi-section box culvert. Note the clear water in the diversion channel and the alignment of the new culvert with the natural stream channel.

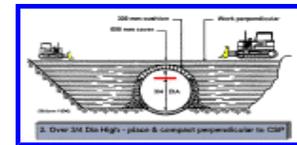
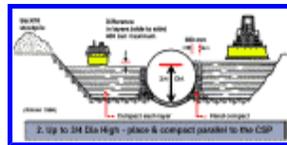
Water flow bypass during culvert placement.

The fill should be clean mineral soil and free of organic material, large rocks, tree roots or ice that will break down and leave holes. Bedding and filling around culverts is an important step in insuring that a culvert installation will not erode, settle or deform. It also prevents "piping" or the leaking of water around the culvert.

Compact the soil carefully using the process outlined below:



Bedding and compacting fill around the culvert.



When the culvert installation is complete, trim and stabilize the work site as soon as possible.



- Trim slopes to a stable configuration
- Apply grass seed or plantings
- Apply mulch or erosion control blankets

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Planning, Design and Construction of Fish Friendly Stream Crossings



Stream bank erosion and stream sedimentation at culvert crossing can be a major problem for fish habitat if the appropriate control measures are not adopted.

Soil erosion problems at fish crossings can be minimized if not completely eliminated, with advance planning. In all cases, the initial time/cost for preventing stream bank erosion, will be far less than if inadequate measures are taken and the project site needs additional repairs.

When erosion control measures are not used, or fail, roads and fish habitat are damaged. Gully wash and stream bank collapse are common and often result in the deposition of large amounts of sediment into streams. 



Best Practices to Control Erosion:

Protect vegetation and minimize the amount of disturbance of plants and soils by equipment

Work Fast! The less time disturbed soils are exposed, the better. One or two days should be adequate for most culvert replacement projects

Use coarse materials; they are less erodable than finer materials

Divert runoff away from exposed soils and into vegetated buffers

Disperse concentrated stream flows

Provide adequate run-off channels

Trim slopes to stable configurations and re-vegetate as soon as possible. Native vegetation is usually preferred

Cover disturbed soils

Rip-rap or “armor” around both ends of the culvert to protect splash areas or where stream bank is exposed to flow, as in the examples below: 



At crossings where small bridges are installed, rip-rap or armor banks to prevent bank erosion.

Road side ditches may be stabilized with rip-rap, sod or mulch-and-seed techniques.



Preventing Soil Erosion on Crossing Sites:

Plant roots stabilize the soil, and stems and leaves slow the water to give it time to percolate slowly into the soil profile. The potential for severe soil erosion exists after any culvert installation or enhancement project because it displaces or destroys plant material and the layer of litter on the surface. There are several steps you should take to reduce the amount of soil erosion at your work site.



Unstable soil surrounding this culvert has begun to erode away.

The **1st** step is to protect the work area long before the heavy construction begins:

The use of sand bags, silt fences, straw bales and straw wattles have proven benefits for small construction projects. Then as the project is progressing, it's important to leave in place, the greatest amount of existing vegetation as possible. Assuming the plants/trees do not threaten personal safety.

After the project is concluded, the **2nd** step is to reseed and protect any disturbed soils. Some good reseeding tips to protect your work site would include:

- If needed roughen the soil surface to provide a better seedbed by breaking through the hydrophobic layer. A steel rake works well for this, or, depending on the slope, a small tractor drawn harrow could be used.
- Add organic material (top soil or black muck) to ensure nutrients are available for seed germination. Add organic
- Broadcast the seed. Seeding rate depends upon the variety of seed used. Rake or harrow in ¼" to ¾" deep.
- If the area is small enough, roll or tamp the seed down to ensure good soil/seed contact.

- Spread certified weed-free hay straw as a mulch. If the area is small, crimp the hay into the soil with a shovel. This will help keep both soil and seed in place during a significant wind and rain event.
- Control weeds as needed by cutting off the flower before it can reseed
- Do not use herbicides for broadleaf weed control until after the grass has germinated and developed leaves.

The **3rd** step is to stabilize the upland area draining toward the stream crossing. This task can be safely accomplished by numerous means. The most commonly used methods are described below: 



Polypropylene Sand Bags are made of woven polypropylene and work well as a temporary solution to detour the path of unwanted runoff during the construction period. Biodegradable products should be used for all long term work.

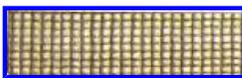
There are a variety of products available for erosion control.

Use biodegradable materials that will not interfere with long term vegetation development.



Silt fences are made of woven wire and a fabric filter cloth. The cloth traps sediment from runoff. These should be used in areas where runoff is more dispersed over a broad flat area. Silt fences are not suitable for concentrated flows occurring in small rills or gullies.

To install a (pre-assembled) silt fence, simply unroll, stretch and continue to drive stakes. If possible, each fence should be installed in a 6" deep trench to prevent sediment flow underneath the fence. Make sure that all supporting posts are on the downhill side of the fencing.



Fabrijute is a flexible open weave (holes approximately 1/8" x 1/8") geotextile designed to hold seeds and soil in place until vegetation is established. The natural looking, high strength polypropylene mesh protects the soil surface from water and wind erosion while offering partial shade and heat storage to accelerate vegetative development allowing uninhibited growth of wood plant species, grass, and ground cover.

QuickGrass is made from curled excelsior, 80% of the fibers are six inches or longer in length. Fibers expand as they come in contact with moisture. When water is released into the soil, the drying causes the fibers to contract. This process helps the fibers dig into the soil. The aspen fibers are biodegradable and add natural nutrients to the soil. The product breaks down in 9 - 12 months.



A variety of similar products (generally called Erosion Control Blankets) are also available.

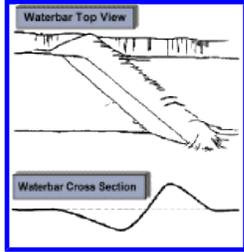


Straw bales placed in small drainages act as a dam – collecting sediments from upslope and slowing the velocity of water traveling down. Bales should be carefully placed in rows with overlapping joints (like building a brick wall). Some excavation is necessary to ensure bales butt up tightly against one another forming a good seal. Two rows (or walls) of bales are necessary and should be imbedded below the ground line at least six inches or held in place by stakes or rebar driven into the soil.

Straw wattles are extremely effective in controlling hillside erosion and serving as makeshift dams for blocking sediment into waterways and channels. They are constructed of long tubes of plastic netting packed with excelsior, straw, or other material. Wattles are used in a similar fashion to log terraces. The wattle is flexible enough to bend to the contour of the slope. Straw wattles last 3 - 5 years and can be left in place.



From a recent study, the U.S. Fish & Wildlife Service reported that out of 3,300 wattles placed in a particular year, only 10 failed from storm and animal disturbance. It was also reported that straw wattles are as effective as hand trenching, and they last much longer.



Water bars are berms of soil or bedded logs that channel water off roads and trails to avoid the creation of gullies. Water bars are angled down the slope to the outlet side. These bars can divert water to a vegetated slope below or redirect it to a channel that will take it to a culvert. On-site soil types and the road grade will dictate spacing requirements for protecting your site.

Water bars can only be used on abandoned roads or where very light vehicle traffic occurs.

Log terraces provide a barrier to runoff from heavy rainstorms. Dead trees are felled, limbed, and placed on the contour perpendicular to the direction of the slope. Logs are placed in an alternating fashion so the runoff no longer has a straight down slope path to follow. The water is forced to meander back and forth between logs, reducing the velocity of the runoff, and giving water time to percolate into the soil.



Logs should be 6 - 8 inches in diameter (smaller logs can be used) and 10 - 30 feet long. The logs should be bedded into the soil for the entire log length and backfilled with soil so water cannot run underneath. The backfill material should be tamped down.

Secure the logs from rolling by driving stakes on the downhill side. It is best to begin work at the top of the slope and work down. It is easier to see how the water might flow by looking down on an area to better visualize the alternating spacing of the logs.



Hydroseeding is a method where wood-based fiber products are used to spray on hillsides with unstable soils. Products of this type contain fiber mixed with a tacking agent, or binder. The liquid solution can be formulated to contain specific grass seed species so new vegetation can help stabilize the hillside.

Armoring, seeding and mulch cover have done a great job on this site. One year after installation, a heavy vegetative mat is established and the bank should continue to be stable.



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Planning, Design and Construction of Fish Friendly Stream Crossings



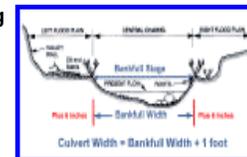
A Brief Summary in the Basic Steps for Choosing, Sizing and Installing Culverts at Stream Crossings

Please use this guide only as a quick reference to the material presented. Refer to the documentation presented throughout this web site for more detailed information.

1. We recommend a road crossing design process called the [Stream Simulation Design Method](#).
2. Generally, when [flow velocities](#) through a culvert exceed .6 meters (or 2.0 feet) per second, some sizes and species of fish will be blocked.
3. Measure bankfull width of the stream (average of 10 measurements).
4. Establishing the elevations of the culvert inlet and outlet are critical elements in the installation using the Stream Simulation Method.

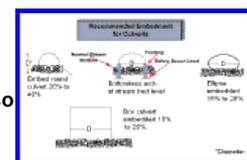
Determine the [stream slope](#) by surveying the vertical drop in the stream bed from 100 feet above the culvert (Point A) to 100 feet below (Point B). See images below. Set culvert inlet and outlet depths (embed) to the appropriate amount below the slope line. Round Culverts may be embedded from 20% to 40 %, ellipse or squashed arch culverts from 10% to 25%.

5. Determining the Bankfull Stage is the most important measurement for establishing culvert size in handling peak stream flows (refer to image).
6. If the Bankfull Width is more than 20 feet or if stream slope is more than 6%, use a [span bridge](#).



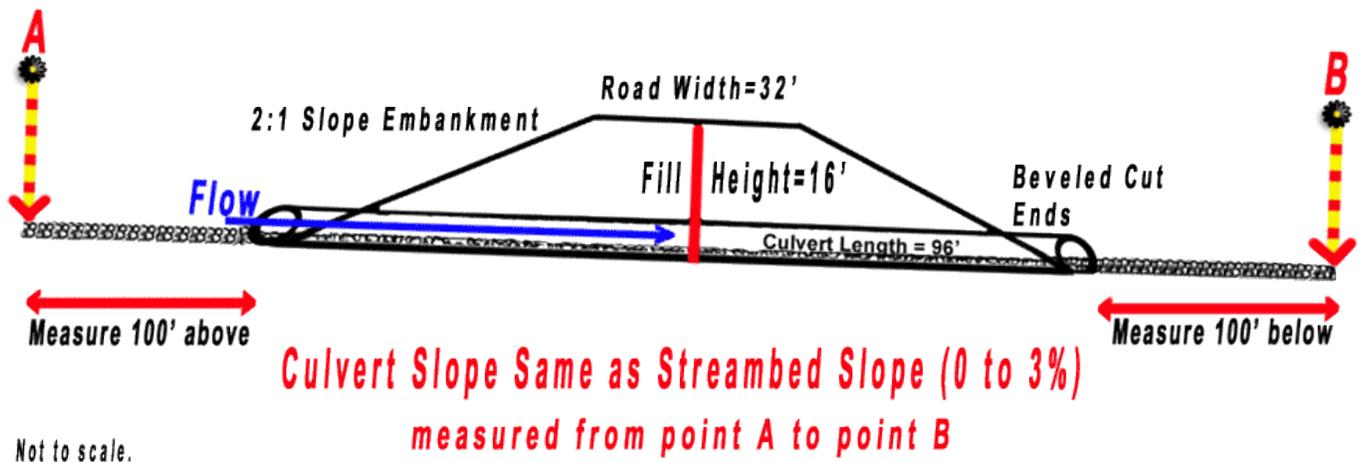
7. If the Bankfull Width is less than 20 feet and stream slope is less than 6%, a span bridge may be used or one of the four culvert types may be selected.

8. If slope is 3% to 6%, a span bridge is preferred but a [bottomless arch](#) culvert may also be used.



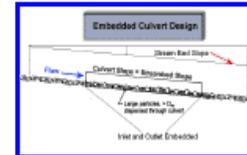
9. If slope is from 0% to 3%, bottomless arch, round, box or ellipse culverts may be used. If using a round culvert, the best design will include [natural stream materials](#) in the bottom of the culvert that help to minimize and alter water flows, thus allowing for easy fish passage.

10. Choice of the structure type is an important consideration, but the placement and installation are just as critical for the success of the project.



11. For all culverts, the width (D) of the opening will be the Bankfull Width of the stream, plus 1 foot.
12. **Length of the culvert** will be the total road width plus 2 times (fill height X slope).

13. Survey and establish the desired height of the culvert inlet and outlet.
14. Culvert should be embedded to correct for elevations at inlet and outlet.



15. Stream bank erosion and stream sedimentation at culvert crossing can be a major problem for fish habitat if the appropriate control measures are not adopted.
16. **Soil erosion problems** at fish crossings can be minimized if not completely eliminated, with advance planning. The 1st step is to **protect the work area** long before the heavy construction begins.
17. Another very important consideration is the potential for geomorphic effects, in particular, channel incision. Channel incision or down-cutting of the streambed tends to propagate upstream by means of migration of a headcut. Often, this headcut migration is arrested when it encounters a culvert. If the culvert is replaced, the headcut may then proceed onward upstream, spreading channel incision, and inducing a period of channel destabilization and habitat degradation.

Click [here](#) to review the document (pdf) *Geomorphologic Impacts of Culvert Replacement and Removal: Avoiding Channel Incision*.

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Planning, Design and Construction of Fish Friendly Stream Crossings



~ ■ ~ Acknowledgements ~ ■ ~



Developed by: Lee Newman ~ ■ ~ Web pages designed by: [Frank G. Stone](#)
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[Fish Passage Restoration and Five major fishway designs](#), Chesapeake Bay Program Office

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[Fish Passage](#), NW Hydro

[Fish Passage Barrier and Surface Water Diversion Screening Assessment and Prioritization Manual](#), Washington Department of Fish and Wildlife

[Fish Passage Improvement Program](#), California Department of Water Resources

[Fish Passage Short Course](#), Environmental Studies at U.C.Davis

[Fish Passage Through Culverts An Annotated Bibliography](#), Six Rivers National Forest Watershed Interactions Team

[Hydraulic Effects on Swimming Fish in Fish Passage Structures](#), American Society of Civil Engineers

[Landowner's Guide to Building Forest Access Roads](#), U.S. Forest Service

[Mannings Formula](#), Calculating Flow Velocity, Shows, Dearman and Waits, Inc.

[Natural fish passage structures in urban streams](#), University of California

[Pronounced Fish Crossing](#), AOP

[River Crossings and Migratory Fish: Design Guidance](#), Scottish Executive Consultations

[The Fish Passage Center](#), Northwest Power Planning Council

[Washington Department of Fish and Wildlife Fish Passage Technical Assistance](#)

[USDA Forest Service Water-Road Interaction Technology Series Documents](#)

[Upstream Fish Passage At Dams And Culverts](#), Washington Department of Fish and Wildlife

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The reference list below contains Adobe pdf documents that discuss various aspects of fish passage issues.



Click [here](#) to download the free Adobe Reader program to view these files.

[Assessment of Road Culverts for Fish Passage Problems on State and County Owned Roads](#) (34 KB)

[A Summary of Technical Considerations to Minimize the Blockage of Fish at Culverts on the National Forests of Alaska](#) (231 KB)

[Culvert Installation in Salmon Streams](#) (1,276 KB)

[Culvert Installation in Salmon Streams](#) (142 KB)

[Culvert Fish Baffles](#) (59 KB)

[Design of Road Culverts for Fish Passage](#) (5,335 KB)

[Elements of Fish Passage through Culverts](#) (12 KB)

[Geomorphologic Impacts of Culvert Replacement and Removal: Avoiding Channel Incision](#) (722 KB)

[Fish Friendly Culverts](#) (1,265 KB)

[Fish Passage Design At Road Culverts](#) (1,096 KB)

[Fish Passage Solutions](#) (699 KB)

[Guidelines For Salmonid Passage At Stream Crossings](#) (72 KB)

[How well are Oregon's Forest Landowners and Operators Complying with Fish Passage Requirements at Stream Crossings?](#) (304 KB)

[Lower Alameda Creek Fish Passage](#) (906 KB)

[Manitoba Stream Crossing Guidelines For The Protection Of Fish And Fish Habitat](#) (1,171 KB)

[National Fish Passage Program](#) (197KB)

[Overview Assessment of Fish Passage at Stream Crossings within Selected Watersheds](#) (1,661 KB)

[Policy and Guidelines for Fish Friendly Waterway Crossings](#) (229 KB)

[Recommendations for improving fish passage](#) (516 KB)

[Salmonid Passage At Stream Crossings](#) (61 KB)

[Fish Passage In Streams \(778 KB\)](#)

[Fish Passage Criteria \(44 KB\)](#)

[Fish Passage Restoration \(270 KB\)](#)

[Fish Passage Restoration \(232 KB\)](#)

[Fish Passage Through Culverts An Annotated Bibliography \(132 KB\)](#)

[Stonybrook Creek Fish Passage Assessment \(1,416 KB\)](#)

[The Use of Angled Bar Racks and Louvers \(1,085 KB\)](#)

[Upstream Fish Passage Technologies \(200 KB\)](#)

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"All things merge into one
and a river runs through it"

~~ Norman Maclean ~~

