Forest Practices Technical Note Number 4

Version 1.0

Fish Passage Guidelines for New and Replacement Stream Crossing Structures

Effective May 10, 2002

Introduction

The objective of this note is to provide the essential information that will enable landowners and operators to install stream-crossing structures that have a high likelihood of providing fish passage. The Oregon Department of Forestry (ODF) regulates fish passage on state and private forestlands consistent with ODFW guidelines, and has produced regulatory guidance on how to design structures that are likely to pass fish under various stream conditions. OAR 629-625-0320 describes the requirements for stream crossing structures relevant to fish passage that the guidelines herein are designed to achieve (see Technical Note #5 for guidelines on passing a 50-year peak flow):

> ***629-625-0320 Stream Crossing Structures***
> ***(2) Operators shall design and construct stream crossings (culverts, bridges, and fords) to:***
> ***(a) Pass a peak flow that at least corresponds to the 50-year return interval. When determining the size of culvert needed to pass a peak flow corresponding to the 50-year return interval, operators shall select a size that is adequate to preclude ponding of water higher than the top of the culvert; and***
> ***(b) Allow migration of adult and juvenile fish upstream and downstream during conditions when fish movement in that stream normally occurs.***
> ***(3) An exception to the requirements in subsection (2)(a) of this rule is allowed to reduce the height of fills where roads cross wide flood plains. Such an exception shall be allowed if:***
> ***(a) The stream crossing site includes a wide flood plain; and***
> ***(b) The stream crossing structure matches the size of the active channel and is covered by the minimum fill necessary to protect the structure;***
> ***(c) Except for culvert cover, soil fill is not placed in the flood plain; and***
> ***(d) The downstream edge of all fill is armored with rock of sufficient size and depth to protect the fill from eroding when a flood flow occurs.***

The guidelines described in this document supersede all past guidance documents for fish passage on state and private forestlands. Forest Practice Foresters (FPF) and forestland owners and operators should consider this technical note as their primary source of guidance information. For individuals interested in more detailed technical material that goes beyond the essential information presented here, references are provided.

Physical Conditions Necessary for Fish Passage

Movement of fish throughout a watershed is necessary for a number of life-stage needs. Providing for access to spawning grounds, migration during summer low flows necessary to avoid warm water temperatures, and migration into side channels during winter to escape flood flows are an important part of maintaining healthy fish populations. Requirements for fish passage design in Oregon is based on the weakest species or life stage present that requires upstream access and should accommodate the weakest group within that species. In most cases this will mean providing passage for juvenile fish that are about two inches in length or greater. For juvenile fish, ODFW guidelines specify a maximum jump height of six inches and an average water velocity no greater than two feet per second to ensure that passage will be provided. Accordingly, all of the strategies described below are designed to provide for these physical conditions. For some of the key definitions of terminology used throughout this guidance for describing conditions around culverts and stream crossings, refer to the "terminology" section at the end of this note.

Collecting Information on Stream Characteristics

Before it is possible to decide on the appropriate strategy for providing fish passage, the following specific information on the stream characteristics in and around the crossing should be collected:

1. Streambed gradient
2. Streambed material
3. Depth of streambed material
4. Active channel width

1. STREAMBED GRADIENT

Determining the stream gradient outside of the influence of an existing stream crossing structure is extremely important. The preferred method for determining stream gradient is to use the stream profile. The stream profile is the streambed elevation measured at a series of points up and down the stream from the road crossing. It can be measured using a hand level (or similar instrument that can be re-calibrated before each use) and stadia rod that will give a fixed elevation above the streambed. These tools will estimate the stream grade to a precision of $\pm$0.5%. The use of a tripod level improves the precision greatly (to 1/10 of a percent), and is preferable for stream gradients in the range of 1-4%. In this range a small difference in slope can mean the difference between using a bare culvert or a streambed simulation strategy. A clinometer should never be used because it lacks the precision needed and cannot be re-calibrated before each use.

Often the stream profile immediately above and below the existing road crossing is artificial due to an existing culvert installation. Scour at the outlet and deposition upstream of existing undersized culverts is common. Because the stream gradient in and around an existing crossing can be significantly different than the 'natural' profile, it is preferable to measure a long profile between two points at least 200 feet upstream and downstream from the influence of the existing road/stream crossing (400 feet total). There are cases where a profile shorter than 400

feet should be used, such as where an abrupt change in the channel morphology and/or valley form occurs. There are other cases where a longer profile should be used, such as where the upstream deposition due to the existing crossing extends for a long distance and the channel morphology and/or valley form remain relatively unchanged. Taking a long profile can be especially important in determining design criteria for streambed simulation culverts or bare culverts placed at a zero grade, where relatively small errors in estimating the natural stream bed elevation can make the difference between success and failure in terms of providing fish passage.

Using the stream profile method for measuring the stream gradient is done by starting at a point well upstream of where the existing crossing has altered the 'natural' stream gradient, or about 100 feet, whichever is greater (can be a lesser or greater distance, depending on site-specific conditions). With one person holding a hand level and another holding a stadia rod one to two channel widths further upstream, record either the slope or elevation as well as the measured distance over which the slope or elevation measurement was taken (i.e. distance between the two individuals). Walk upstream to the point where the stadia rod was being held for the first measurement and repeat the process. Continue taking measurements in this way until you have covered a distance of at least 100 feet (can be a closer or farther distance depending on site-specific conditions). Then go downstream to a point below the influence of the existing crossing and repeat the same process in the downstream direction. With this information the average stream gradient above and below the crossing can be calculated and used to estimate the 'natural' stream gradient through the section of the stream where the new stream crossing structure will be constructed.

2. STREAMBED MATERIAL

The type of streambed material that is present is critical, especially for strategies that depend on culvert sinking. For the streambed simulation strategy to be successful there should be an ample supply and diversity of sediment (i.e. fine and coarse gravel; small to large cobble) that will embed the culvert and remain stable over time. Use the following categories to classify the streambed material, in 10% increments (e.g., "30% fines/sand; 50% gravel and cobble; 0% boulders; 20% bedrock."):

Bedrock.....>13 feet diameter	Bigger than a car, or continuous underlayer
Boulders.....>10 inches to 13 feet	Basketball to car size
Cobble (small to large).....>2.5 in. to 10 inches	Tennis ball to basketball
Gravel (fine to coarse).....>0.1 inches to 2.5 inches	Ladybug to tennis ball
Fines/sand..... Particles not visible to 0.1 in.	Silt clay, to visible as particle (gritty).

3. DEPTH OF STREAMBED MATERIAL

It is also important to estimate the depth of streambed material outside of the influence of the existing culvert installation. This is also referred to as valley fill, and consists of the layers of unconsolidated gravel, sand, cobble, and other sediment that lie over the top of the bedrock. If little fill is present, then culvert sinking/embedding strategies become impractical because of the difficulty of sinking into bedrock. On the other hand, placing an open arch in a place where there is deep valley fill would require either excessive excavation or an excessive span so that

the footings are well outside of the active channel. Either situation could make an open arch design impractical because of the potentially high cost. If there is uncertainty about the presence or absence of bedrock when considering sinking a culvert into an existing streambed, assume that bedrock is present and chose a strategy accordingly. A far too common problem with sunken culverts is that during the installation unexpected bedrock is discovered and the culvert cannot be sunken adequately to achieve fish passage.

5. ACTIVE CHANNEL WIDTH

New and replacement stream crossing structures should have an effective width equal-to or greater-than the active width (also sometimes referred to as 'bankfull width') of the stream. This will prevent abrupt changes in stream velocities at the inlet and outlet that create fish passage barriers (inlet and outlet drops; bed scour; higher stream velocities through the crossing that prevent sediment from depositing in the culvert; etc.). The active channel width corresponds to a peak streamflow that occurs on average once every one to two years. Locating the active width, while generally based on scientific principles, requires judgement when making a determination in the field. In alluvial streams (i.e. in low gradient streams in wider valleys) that have not been incised (i.e. downcut), the active mark is usually where the bank slope moderates from being steep to being more gentle or almost flat (Figure 1).

Abrupt changes in vegetation are good clues to help determine the active channel width. Abrupt changes in texture of the bank material may also be clues. The active width is measured from one stream bank mark to the other. Features like large islands that would be dry even under active conditions need to be subtracted out. The active width is determined by taking the average of at least 10 cross-section measurements, spaced one to two channel widths apart, upstream of the location where the crossing is being installed. Start taking measurements upstream of the crossing, beyond the point where the old crossing has influenced channel characteristics.

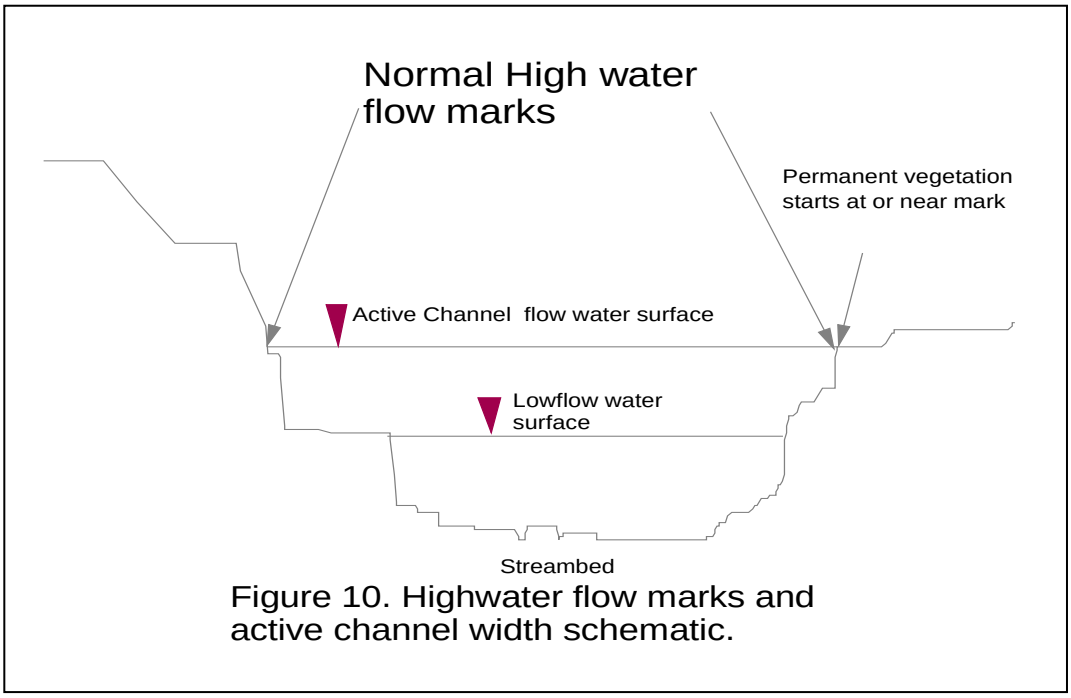

Figure 10. Highwater flow marks and active channel width schematic.

Figure 1: High water flow marks and active channel width schematic.

Fish Passage Design Strategies

Once the above information on stream characteristics is collected the fish passage design strategy can be determined. The specific strategy should be determined *prior* to evaluating the flow capacity of the stream crossing structure and ensuring that it will pass the 50-year peak flow. The size of the structure will be dependent upon the active channel width and whether or not an embedded design is used. Considering the streambed simulation strategy, for example, a culvert size will be initially selected that will allow for a culvert width *after* embedding that is equal-to or greater-than the width of the channel (i.e. the active channel width). Once the width and embedded depth specifications have been determined Technical Note #5 should be used to calculate the 50-year peak flow and check to see that the culvert will pass this peak flow. Field experience has shown that in general, culverts sized to the active channel width will be adequately sized to pass the 50-year peak flow.

Oftentimes there is more than one strategy that could be used at a given stream crossing location. For instance, on a relatively low stream gradient (i.e. 1-2% stream channel gradient) with deep valley fill and ample supplies of gravel and cobbles, a number of different strategies can work. A channel-spanning structure allowing for natural channel conditions, a bare culvert placed at zero-grade and backwatered, or a culvert placed at the stream gradient that simulates the streambed will all provide unobstructed fish passage.

As stream gradients increase, however, the number of strategies that will be successful in passing fish decreases. Culverts, unlike channel-spanning structures, tend to have problems if used outside of a given gradient range or under certain streambed conditions. Along with stream slope, the degree of valley fill material over bedrock is extremely important in deciding

between strategies. For instance, a streambed simulation design can easily be used for a crossing with a 5% stream slope. However if bedrock is present, the culvert can no longer be easily buried into the streambed and a channel-spanning structure becomes a preferred option. Stream size is another critical factor along with slope and valley fill depth (i.e. depth of material in the stream channel—see definition in terminology section). Small streams with active channel widths less than 10 feet can often be accommodated with culverts at a lower expense than bridges. But as active channel width increases, culvert installations become more costly and problematic. When culvert dimensions begin to require multi plate designs in excess of 10 feet in diameter (for round culverts) or 12 feet in span (for pipe-arches) the cost can approach that of a bridge, making a channel-spanning structure a more preferred design.

This guidance lays out six basic strategies to choose from for providing fish passage, which should be considered in the following order of preference:

1. Remove/abandon stream crossing (re-route the road; find an alternative route)
2. Channel-spanning structures (long and short-span bridges; open-bottom arches)
3. Fords (low-traffic crossings only)
4. Streambed simulation (sunken and embedded culverts)
5. Bare culvert placed at a zero grade (culvert at $\leq$0.5% gradient and sunken for backwatering)
6. Hydraulic design (weir and baffle culvert designs)

The guidelines below provide a detailed description of each strategy. Table 1 summarizes the criteria that should be included in written plans for the various fish passage strategies. Table 2 is a summary of the stream crossing installation criteria for each strategy:

1. REMOVE/ABANDON STREAM CROSSING

When considering the replacement of an existing stream crossing, review the existing transportation system and determine if it is feasible to remove and abandon the crossing. It's possible that a minor rerouting of the existing road can avoid the need for a crossing and be comparable in cost. Also consider other existing roads and whether or not a minor change along another portion of the road system can provide access. In many cases this strategy will not be a viable option, as the rerouting and/or building of a new road segment(s) can involve significant costs. However, where the cost of replacing the crossing is comparable to abandoning it entirely and using a different access route, this is a preferred strategy since it allows the reestablishment of natural stream conditions.

2. CHANNEL-SPANNING STRUCTURE

This strategy includes structures such as long and short-span bridges and open-bottom arches. Channel-spanning structures span the entire width of the stream and are placed on some type of abutments or footings. It is very important to properly size the structure or the stream bottom will scour (possibly to bedrock) leaving a chute with difficult fish passage. If the channel is constricted by the structure there is also an increased risk that undermining will occur, resulting in the physical failure of the structure.

This strategy can be both economically and ecologically the preferred strategy as stream size and/or slope increases. When culvert dimensions require multi-plate designs the cost of a channel-spanning structure can approach that of a culvert. Also, for higher gradient streams—especially those flowing over bedrock—a channel-spanning structure can be the preferred strategy as well. This strategy also includes 'low-height' structures that are low enough to the channel that they become overtopped during high streamflows. Low-height structures can be used where it is desirable and/or practicable to minimize the amount of fill material adjacent to the channel, and year-round access is not critical. While the fish passage aspects of channel spanning structures are relatively simple, the structural stability issues are more complex. The details of designing structures to bear loads are beyond the scope of this guidance and require civil engineering and/or geotechnical expertise.

3. FORDS

Fords can be a preferred strategy since they reduce the amount of fill material placed in or adjacent to the active channel and result in the lowest level of channel disturbance during installation short of using a channel-spanning structure or abandoning the crossing entirely. In general, fords should only be considered on small streams for low traffic roads that are private, gated, and have infrequent use. A reasonable measure of infrequent use is a level of traffic that does not cause a noticeable increase in turbidity (i.e. visible with the eye) that persists downstream of the crossing. Fords are best suited when the stream channel has larger cobble and bedrock material exposed. In designing a ford, the approaches should be at a 10% grade or less and hardened using coarse material (cobble and coarse gravel sized) for several hundred yards to allow the shedding of sediment as vehicles approach the crossing. Drainage structures should be used to deflect water away from the stream approaches. If the ford is hardened using cobbles in the stream, impermeable geotech fabric may need to be used to keep water on the surface so the ford does not become de-watered and impede fish passage.

4. STREAMBED SIMULATION

This strategy calls for sinking the culvert into the existing streambed at both the inlet and outlet, in streams with gradients up to 8% that are dominated by valley fill substrates several feet deep. For stream gradients above 8%, where this design can be more difficult to install with success, a further review by the ODF staff hydrologist is required. The effective culvert width (i.e. inlet width after sinking and embedding) should be equal-to or greater-than the active stream width. This design *will not work* if the stream is predominately bedrock or has extremely large boulders hampering culvert sinking into the streambed, unless measures are undertaken to properly embed the pipe. This strategy requires sinking the culvert to the same depth at the inlet and outlet so that the stream and culvert gradients are the same.

For stream gradients between 4% and 8%, consideration should be given to countersinking the culvert (the inlet buried deeper than the outlet), so that the resulting culvert gradient is 1.5 % less-than the stream gradient (Figure 2). Countersinking can help the culvert to recruit and maintain a simulated streambed for higher gradient streams where it can be more difficult to retain sediment in the culvert. Countersinking can also help where the channel is dominated by

fine materials that are more difficult to maintain in the culvert-bottom, as compared to an assortment of gravel and cobble of various sizes.

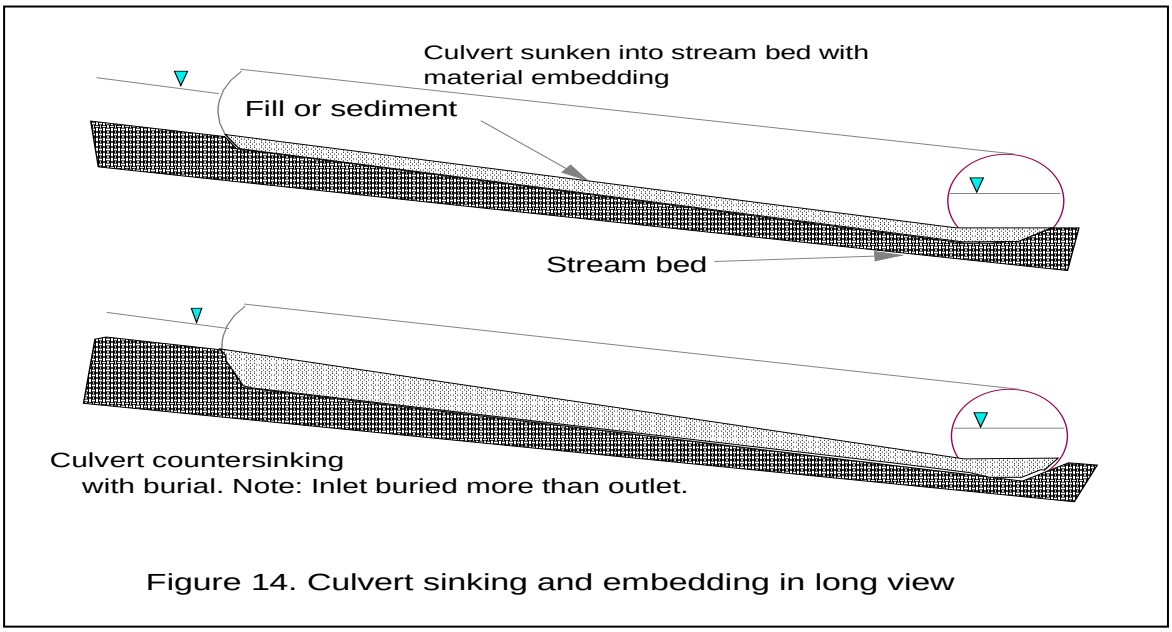

Figure 2: Culvert sinking and countersinking in long view.

The preferred method for determining the depth of sinking is to use the stream profile method (see previous section for a description) to estimate the natural channel elevation, and then sink the culvert relative to that elevation. An alternative method is to calculate the culvert sinking depth at the downstream end based on the elevation of the first downstream riffle and pool elevation below this riffle (see "sinking a culvert" in the terminology section below). Once the depth of sinking at the outlet is determined, the sinking depth at the inlet can be calculated based on the expected streambed elevation at the outlet and the intended slope of the culvert.

For circular culverts, the sinking at the inlet and outlet should be at least 40% of the culvert diameter or 2 feet, whichever is greater. For pipe-arch culverts, the sinking depth should be the greater-of 20% of the rise or 18 inches. There are two main reasons for the need to sink culverts to these depths when using this strategy. One is to ensure that after the culvert becomes embedded with streambed material, the effective channel width is similar to the widest part of the culvert. The second reason is so that as the channel elevation naturally fluctuates over time (rises and falls), the embedded depth is great enough to allow for this fluctuation without scouring down to the culvert bottom and resulting in a fish passage barrier.

Also important is the availability of streambed material to deposit in the culvert and making a determination as to whether manual embedding is not needed. Manual embedding may not be necessary if the upstream portion of the channel is expected to incise as a result of the newly placed culvert and a high volume of streambed material is expected to move into the culvert. However, if the streambed above crossing appears stable with little if any sign of bedload movement and/or sediment transport, manual embedding is needed. Indications of a stable

streambed include: highly decayed large and small wood in the active channel; thick layers of moss or other vegetation in the active channel; or other conditions that would not exist if there was relatively frequent movement of streambed material occurring.

When properly installed, the resulting streambed characteristics in terms of sedimentation sizes and distribution should be the same above, within, and below the culvert. For a migrating fish this would impose no changes or stress, and no delay in upstream migration. From a stream morphology perspective, the culvert will have a minimal effect on sediment transport dynamics, and there would be no sediment buildup upstream or deprivation downstream. Because the effective culvert width is the same as the active channel width, there is no flow constriction at the inlet and no flow concentration at the outlet. This will result in no increase in scouring or damage at the outlet.

5. CULVERT PLACED AT A ZERO GRADE

This strategy should *only* be used where the stream gradient is $\leq$ 2.5% and where moderate to deep valley fill is evident. The outlet should be buried at least six inches, and the inlet should be buried to a depth equal-to or greater-than six inches so that the culvert is placed at zero grade ($\leq$0.5%). The preferred method for determining the depth of sinking is to use the stream profile method to estimate the natural channel elevation, and then sink the culvert relative to that elevation (see previous discussion under strategy #4). **It is critical that the culvert be installed at a zero grade and at the proper elevation. Even a little slope can create a velocity barrier for juvenile fish, and culverts that are placed too high can be undermined by down cutting creating a jump barrier.**

To prevent channel constriction the effective culvert width should be similar to the active channel width. Also, sinking the culvert a minimum of six inches will ensure that the minimum water depth needed for adult fish passage will be maintained. Requiring the culvert to be placed at a zero grade will maintain the lower velocities through the culvert that are necessary for juvenile passage. Sizing the culvert similar to the active channel width will prevent risks associated with constricting the channel. An inlet or outlet constriction can create a hydraulic jump and a velocity barrier for juveniles. An outlet constriction can also cause the downcutting of the channel and the formation of an outlet drop that can prevent fish passage.

6. HYDRAULIC DESIGN

This strategy involves culverts with various types and configurations of weirs, or other flow obstructions, installed inside the culvert to either increase roughness or to create a series of pools with drops to increase depths and decrease velocity to aid fish passage. This design requires considerably more hydraulic engineering expertise than the other methods and may require outside consulting. **These designs need to have hydraulic calculations that indicate backwatering, velocities, and energy reductions are such that juvenile fish passage will occur. All hydraulic designs except those prepared by a licensed professional engineer require further review by the ODF staff hydrologist.**

This strategy can generally be used in streams with gradients up to 12%. This strategy might be feasible at higher gradients, however it can become more costly and difficult to design at higher gradients as the spacing of weirs within the structure is reduced. Because of cost and maintenance considerations this choice should only be used as a last resort. It can be a preferable strategy in places where there is a desire to preserve a sediment deposit or road fill-caused wetland by not installing a structure that allows natural sediment transport of the deposited material upstream of the culvert. It can also be installed in streams where deep valley fill is present, or in situations were the stream grade is at or near bedrock. This strategy is generally more expensive than installing a similar-sized culvert without baffles, even with sinking and embedding.

To ensure fish passage with this design there are several checks that should be preformed which include depth of flow calculations for low and high design flows (must meet Oregon Department of Fish and Wildlife fish passage guidelines) and energy dissipation at high design flow. For many baffled designs there are no empirically developed methods for determining depth of flow calculations or energy dissipation because no experimental calculations have been done for different shapes and configurations of culverts. Therefore these calculations must apply experimental results from a situation that is different than the current design. This type of exercise requires considerable engineering judgement. For this and other reasons these designs should be developed by someone with expertise and experience in hydraulic engineering.

General Recommendations

In addition to the hydraulic design, any proposed design intended to provide for fish passage, consistent with OAR 629-625-0320, that falls outside of the guidelines requires further review by the ODF staff hydrologist. The one exception is if the hydraulic design (strategy #6) is prepared and stamped by a licensed professional engineer, in which case further review is not necessary. In all other cases, consistent with state statutes, the landowner and/or operator will need to demonstrate that fish passage will be achieved, and the proposed design will be evaluated accordingly. For example, there may be a design used in the past that is creating the conditions necessary to pass fish but does not fall under any of the specific strategies in the guidelines. So long as the design is documented by the landowner, a similar design in a similar type of stream channel may be acceptable and meet fish passage requirements. There also may be cases where a landowner proposes an experimental design (e.g. streambed simulation design at a gradient greater than 8%) that is untested but in theory is likely to pass fish, even though it is outside of the guidelines. Experimental designs may also be approved after further review and a site-specific evaluation. Stream crossing designs that are installed consistent with the guidelines set forth in this technical note and maintained over time are considered to have a high likelihood of providing fish passage and will be in compliance with the Forest Practices Act fish passage requirements. After determining which strategy will be used and the specific stream crossing structure dimensions, refer to Technical Note #5 to calculate the 50-year peak flow in order to ensure that the structure meets the peak flow requirement as well.

Table 1: Criteria that should be included in written plans for the various fish passage strategies.

Required Criteria to Include in the Written Plans	Strategy
List the strategy that is being attempted OR clearly describe strategy for a unique design.	All
Legal location (Township, range, section)	
Active channel width	
Stream gradient	4, 5, & 6
Streambed material	
Depth of streambed material (i.e. valley fill depth)	
Length of crossing (stream length)	
Elevation change over length of crossing	
Resulting culvert gradient	
Depth of inlet sinking	
Depth of outlet sinking	
Is it a low-traffic, gated road?	3
Hydraulic designs (requires further review unless prepared by a licensed professional engineer) • Baffle/weir configuration • Depth of flow calculations for low and high design flows • Energy dissipation calculations (velocity conditions) at design flows • Backwater length and depth at the outlet • Other calculations/diagrams pertinent to design	6
50-year peak flow calculation • Acreage or square miles, cubic feet per square mile (CMS) as chosen from ODF Peak Flow Map, and Design flow (CFS); OR • Complete calculation if using method other than ODF Peak Flow Map • For streambed simulation and hydraulic designs, account for culvert capacity losses at the inlet. • For bridges, diagram of cross-section and flow capacity calculations. • Where applicable, include adjustments for wide floodplains/overflow dips.	2, 4, 5, & 6

Table 2: Summary of stream crossing installation criteria for each strategy in the guidelines.

Strategy[1]	Channel Gradient (%)	Culvert Gradient (%)	Outlet Drop (ft)	Effective Crossing Width (Span) = Active Channel Width	Outlet Depth (ft)	Inlet Depth	Channel Bed Material	Valley Fill Depth
1.Crossing removal/ abandonment[2]	--	--	--	--	--	--	--	--
2. Channel-spanning structure	No limit	No limit	--	Yes	--	--	--	Shallow, near bedrock (for open-bottom arches)
3. Fords (only low traffic and gated)	--	--	--	--	--	--	Larger cobble and/or bedrock	None to moderately deep
4a. Streambed Simulation: Sunken evenly	≤8%	≤8% (Same as channel)	0 ft.	Yes	Round Culvert: Greater of 40% of diameter, or 24 inches Pipe Arch: Greater of 20% of rise or 18 inches	Round Culvert: Greater of 40% of diameter, or 24 inches Pipe Arch: Greater of 20% of rise or 18 inches	≤Cobble (few boulders)	Deep (no bedrock)
4b. Streambed Simulation: Inlet sunken more than outlet	>4%, up to 8%	1.5% less than channel	0 ft.	Yes	Round Culvert: Greater of 40% of diameter, or 24 inches Pipe Arch: Greater of 20% of rise or 18 inches	Outlet depth **PLUS** 1.5% of the length of the culvert, (e.g. 50-ft pipe installed at 1.5% less than channel % = (1.5% x 50), or an extra 9" in embedded depth)	≤Cobble (few boulders)	Deep (no bedrock)
5. Culvert at Zero Grade	≤2.5%	≤0.5% (Plan for 0%)	0 ft.	Yes	At least 6 inches	At least 6 inches, greater if stream slope is >0.5%. (e.g. Channel = 2%. For 50 ft pipe, depth = (2% x 50') + 6**"**. *Total inlet depth = 18"*)	≤Cobble (few boulders)	Moderately deep, to deep (no bedrock)
6. Hydraulic Design[3]	≤12%	≤12%	0 ft.	Yes	Sunken adequately to maintain backwatering to the top of the first weir/baffle	--	--	--

[1]All strategies must show complete calculations for the 50-year peak flow. This includes the watershed area, cubic feet per square mile (CMS), and final 50-year peak flow calculation in cubic feet per second (CFS) if using the ODF method; OR a complete calculation for an approved alternate 50-year peak flow estimation technique. If a bridge is being installed, a diagram and calculation of the capacity is required. All designs except for bridges must account for capacity losses at the inlet due to burying, sediment retention, or weir/baffle designs in the 50-year peak flow calculation.

[2]This option involves the removal of the old crossing and all fill material that is within the active channel. Road-fill adjacent to the active channel should be tapered back to minimize the risk of sediment entering waters of the state. See OAR 629-625-0650 for specific requirements related to vacating forest roads.

[3] All hydraulic designs except those prepared and stamped by a licensed professional engineer require further review by the ODF staff hydrologist. Expertise and experience in hydraulic engineering is required for this design. The written plan should include a diagram and description of baffle/weir configurations, depth of flow calculations, energy dissipation (velocity conditions) calculations at design flows, and other necessary information.

Terminology

The following are some key definitions of terminology used throughout this guidance for describing conditions around culverts and stream crossings. Some of the terms that are used in describing culverts are shown in Figure 1.

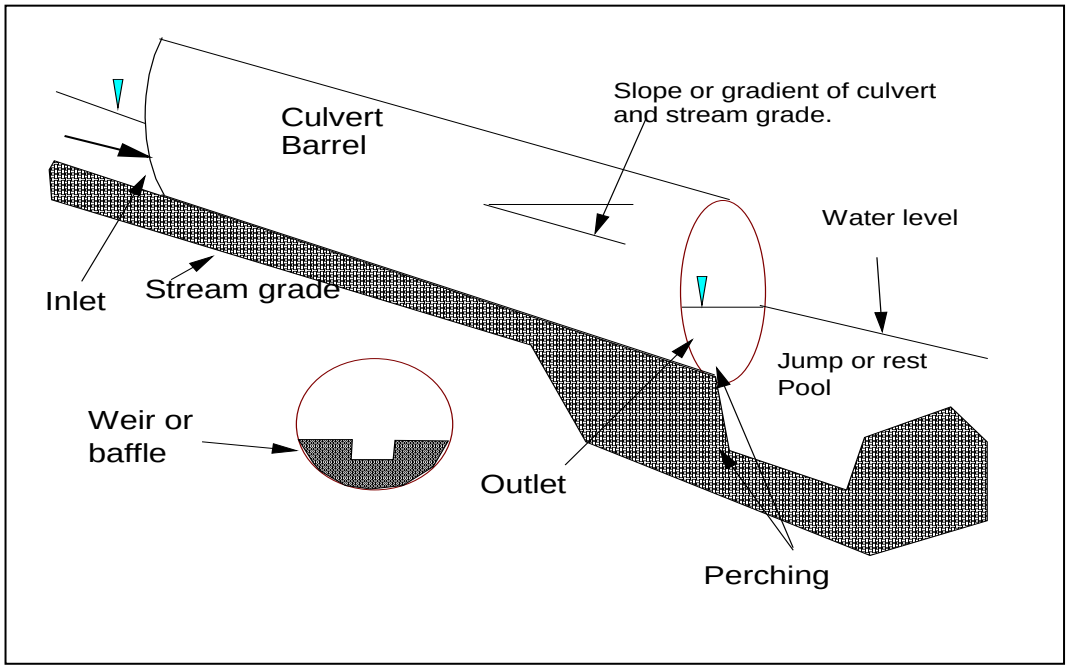

Figure 3. Culvert definition diagram.

- **Inlet** refers to the culvert's upstream end.
- **Outlet** refers to the culvert's downstream end.
- **Perching or outlet drop** occurs at the outlet end when the culvert outlet is elevated above the downstream streambed.
- **Culvert Slope** refers to the culverts vertical rise from the outlet to the inlet divided by its length. It is usually expressed as a percent or in degrees.
- **Roughness** refers to the obstacles inside a culvert that reduces water velocities and diverts flow.
- **Sinking a culvert** refers to putting the bottom of the culvert in at a lower elevation than the existing streambed. It is measured from the estimated streambed elevation that will result after the old crossing is removed. One method for determining the degree of sinking is to use the elevation of the first downstream riffle below the existing crossing and the elevation at the bottom of the first pool below this riffle, and calculate the average of the two. This elevation is a rough estimate of the average streambed elevation at the culvert outlet. Using the measured stream grade and this elevation will allow for an estimate to be made of the streambed elevation at the inlet.
- **Countersinking a culvert** refers to when the inlet is sunk into the streambed to a greater degree than the outlet. This results in a culvert gradient that is less than the channel gradient.
- **Embedding a culvert** is to fill a culvert with larger and smaller sediment in a contiguous interlocking manner.

- **Culvert shape** refers to the cross-sectional shape of the culvert. The most common culvert shapes are round and pipe–arch (also called squash pipes). Culverts are commonly made of corrugated metal pipe (CMP) but can also be made from plastics and concrete. Plastic and concrete pipes, however, provide less roughness as compared to corrugated metal, making it potentially more difficult to retain sediment when using the "streambed simulation" strategy.
- **Streambed simulation** refers to the concept of trying to simulate natural stream conditions inside the culvert by sinking the culvert adequately so that it can be embedded with material similar to the natural streambed.
- **Active Channel width** refers to the stream width that occurs during a peak flow that occurs once every one or two years.
- **Effective width** refers to the width of the culvert or channel spanning structure after installation. Using the streambed simulation strategy as an example, this is the width of the culvert after it is embedded with streambed material. Since this dimension is dependent on the depth of sinking, it cannot be assumed that it will be equal to either the diameter (if using a round culvert) or width (if using a pipe-arch) of the culvert before sinking. This is the width of the culvert as measured at the streambed elevation once the stream has come to equilibrium with the sunken pipe.

Sources of More Detailed Technical Information

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Bell, M. C. 1986. Fisheries handbook of engineering requirements and biological criteria. Fish passage development and evaluation program, Corps of Engineers, North Pacific Division, Portland, Oregon. 290 p.

Oregon Department of Fish and Wildlife. 1997. Oregon Department of Fish and Wildlife *Guidelines and Criteria for Stream-Road Crossing*s. Portland, Oregon. 7 pp.

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White, D. 1997. Hydraulic performance of countersunk culverts in Oregon. Oregon State University, Masters Thesis.

Oregon Department of Forestry Field Offices

For more information about the Oregon Forest Practices Act or the Forest Practice Rules, please contact your local Oregon Department of Forestry office which can be found at http://www.oregon.gov/ODF/Working/Pages/FindAForester.aspx *or the headquarters office at 2600 State Street, Salem, Oregon 97310. 503-945-7200.*

APPENDIX A: WRITTEN PLAN EXAMPLE

Date: July 29**,** 2002

Project Name: X Creek (Notification #)
Legal: T xx R xx S xx
Protected Waters: X Creek

Stream Characteristics:

- X Creek is a Medium Type 'F' stream with a stream gradient of 3.5%.
- The stream gradient was measured upstream and downstream of the pipe using a handlevel and stadia rod, beyond the influence of the old culvert.
- The active channel width is 8.5 feet. This was estimated by averaging ten measurements taken above the influence of the old culvert, each about one channel width upstream of the other.
- The bed is comprised mainly of small to large cobbles.
- The bed material appears deep enough to countersink the culvert, since the crossing is in an area with deep valley fill material.

Installation Plan:

- No work will take place during wet conditions.
- The existing wood culvert will be removed and disposed of in an approved disposal site.
- Excess material removed from the fill will be placed in disposal site as shown on the map.
- Backfill material will be replaced in one-foot lifts and machine compacted across the entire width of the fill.
- All work will be done during the in-water work period between August 1 and September 30.
- All exposed soil will be seeded immediately after construction.

Pipe Installation:

- Alternate 4a in the fish passage guidance will be used (Streambed Simulation: Sunken evenly)
- A 60-foot long, 77-inch by 114-inch pipe arch will be placed in the crossing.
- The pipe will be placed on a 3.5% gradient, same as the channel gradient.
- The culvert will be buried 18 inches below the natural channel elevation at the inlet and the outlet.
- The elevation mid-way between the first riffle observed downstream of the old culvert and the first pool downstream of this riffle will be used as the reference elevation to determine the natural channel elevation at the outlet.
- The culvert will be manual-filled with material similar in size to what is seen in the stream channel above and below the crossing.
- Watershed area = 1565 acres, or 2.45 square miles.
- 50-year event, using ODF method: 94 cfs/square mile
- Estimated 50-year flow at the crossing: 230 (2.45 x 94)
- Culvert capacity, from ODF guidance: 340cfs
- Percent loss in capacity because of being buried 18 inches: 25%
- Effective capacity: 255 cfs (greater than the 50-year flow)