SECTION 5
GUIDELINES FOR FOREST PRACTICES HYDRAULIC PROJECTS

PART 1. INTRODUCTION

The 2012 Washington State Legislature amended laws to integrate hydraulic projects associated with forest practices into forest practices application (FPA) review and approval.

As amended, RCW 76.09.040 directs the Forest Practices Board to:

- Incorporate applicable fish protection standards from the hydraulic code rules into the forest practices rules; and
- Establish and maintain technical guidance in the forest practices board manual to assist with implementation of those fish protection standards.

The resulting rules for *s* (FPHPs) can be found in chapters 222-12, 222-16, 222-20, 222-24, 222-30, 222-34, and 222-50 WAC. This board manual section contains the required technical guidance.

The guidelines in this board manual section are provided to help forest landowners and managers plan and design hydraulic projects that will protect *fish life* and water quality. However, they will not address every situation. You are encouraged to consult with the Department of Natural Resources (DNR) and the Washington Department of Fish and Wildlife (WDFW) while planning projects to make sure you are considering and addressing all important factors on a particular site. DNR and WDFW contact information is shown on the region maps in figures 1 and 2 below. Tribes may be consulted for additional expertise.

Figure 1 Washington Department of Fish and Wildlife contact information

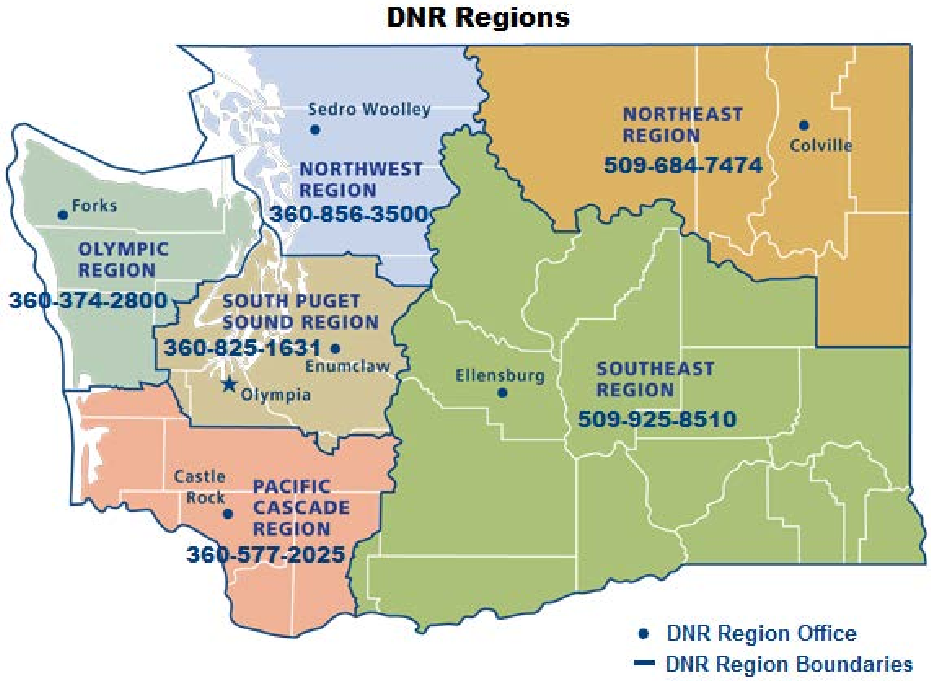


Figure 2 Washington Department of Natural Resources contact information

Certain technical terms throughout the guidance are defined in the glossary on pages B5-57 and B5-58. Each is italicized once per major part. For guidance on forest practices road construction and maintenance, please see Board Manual Section 3 Guidelines for Forest Roads.

PART 2. FISH PROTECTION STANDARDS

Fish protection standards are included in forest practices rules for specific FPHP types. The primary objectives of the fish protection standards are to:

- Protect *fish life*;
- Achieve *no-net-loss* of productive capacity of fish or shellfish habitat;
- Minimize project-specific and cumulative impacts to fish life; and
- Mitigate for unavoidable impacts from FPHPs to fish life and fish habitat.

Using the best management practices (BMPs) in this manual will increase the likelihood that your project will achieve the standards and result in approval of your application.

In general, you will need to:

- Restrict and mitigate for any disturbances from FPHPs to the existing stream channel, banks, and riparian vegetation;
- Preserve spawning and rearing habitat (examples: preserving recruitment and transport of bed load and large woody material downstream; preserving opportunities for natural rates of channel migration within the floodplain);
- Preserve fish life during the project;
- Preserve water quality and unobstructed flow;
- Ensure free and unimpeded adult and juvenile fish passage; and
- Design and maintain structures to withstand the *100-year flood level*.

Mitigation

"Mitigation", as defined in WAC 222-16-025, means actions required as provisions of FPHPs to avoid or compensate for impacts to fish life resulting from the proposed project activity.

Mitigation is achieved for most FPHPs in the forested environment through the proper use of forest practices rules and BMPs in this board manual section. Additional mitigation may be required for site-specific unavoidable impacts depending on the nature of the project. Therefore, DNR and WDFW should be consulted prior to FPA submittal. Affected tribes will also review proposed activities and can provide helpful technical input for minimizing and mitigating for unavoidable impacts to fish life or habitat.

The type(s) of mitigation required will be considered, and implemented where feasible in the following sequential order of preference:

1) Avoiding the impact altogether by not taking a certain action or parts of an action;
2) Minimizing impacts by limiting the degree or magnitude of the action and its implementation;
3) Rectifying the impact by repairing, rehabilitating, or restoring the affected environment;
4) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action;
5) Compensating for the impact by replacing or providing substitute resources or environments; or
6) Monitoring the impact and taking appropriate corrective measures to achieve the identified goal.

For projects with potentially significant impacts, a mitigation agreement may be required prior to approval.

Possible unavoidable impacts and potential mitigation measures to compensate for those impacts are found for particular FPHPs within this manual (site restoration, beaver dam removal, logging cable suspension, and stream bank protection). The activities, possible impacts, and potential mitigation alternatives are not comprehensive but can be used to guide the development of proposals. Potential mitigation measures are best formulated and determined on site. Alternative mitigation measures not listed for particular FPHPs in this manual may also be deemed necessary on a case by case basis.

Consider the following points during the development of compensating mitigation proposals:

- Utilizing onsite materials where they are available and provide adequate function.
- Capitalizing on operational efficiency by implementing compensating mitigation measures in the same time period as the project.
- Coordinating early and often with DNR, WDFW, and affected tribes to plan for site-specific conditions.

PART 3. GUIDELINES FOR APPLICATION PREPARATION

The purpose of this part is to help applicants prepare and complete applications that include an FPHP. FPA instructions specify the required information for FPHPs. The instructions are available at http://www.dnr.wa.gov/programs-and-services/forest-practices/review-applications-fpars/forest-practices-forms-and

FPA review time for applications that include FPHPs is described in detail in WAC 220-110-085, WAC 222-20-017, and WAC 222-20-020. FPAs containing the following types of FPHPs will take up to 30 additional days for approval or disapproval:

- Culvert installation or replacement, and repair at or below the *bankfull width* in fish bearing streams that exceed five percent gradient;
- Bridge construction or replacement, and repair at or below the bankfull width of fish bearing *unconfined stream*s;
- Fill within the 100-year flood level of unconfined fish bearing streams.

The additional time for these FPHPs is required for concurrence review by WDFW. During the concurrence review, WDFW may contact the applicant requesting clarification or additional information, or to discuss changes to the project designs provided in the application to improve compliance with fish protection standards. The consultation process is limited to a maximum of 30 days, and therefore thorough planning is critical and pre-application consultation is encouraged.

3.1 Pre-application consultation

Landowners are encouraged to consult with WDFW biologists and DNR forest practices foresters prior to submitting an FPA to ensure project plans and specifications meet fish protection standards. Tribes may also be consulted for additional expertise.

Pre-application consultation should take place well before submitting an FPA to DNR. It will save time in the long run and increase the likelihood of approval.

3.2 Considerations before completing an application

FPHP design often depends on the water type; therefore, you should verify the water type with DNR prior to submitting an application.

FPHPs involving construction in fish bearing or flowing waters are usually conducted during times of low summer flow conditions outside of fish migration, spawning and incubation periods. Timing is site-specific and varies by fish species and stream location. Therefore, it is critical to contact WDFW for specific guidance on project timing.

If an FPHP is proposed for a Type S Water, any requirements of the local government's shoreline master plan must be reflected in the FPA; if the local government requires a Substantial Development Permit, a copy of the permit must be included with the FPA.

You should also determine:

- Your proposed start and end date;
- How the work will be sequenced; and
- All equipment that will be needed and how it will be used.

Depending on the potential impacts to *fish life* and water quality, all hydraulic projects will involve some combination of rule-required specifications and best management practices (BMPs) for the activities listed in Table 1. To prepare a complete plan, see Parts 4 through 10 as applicable to your project.

Table 1. Best Management Practices (BMPs)

Project Activities	BMP Locations	Parts
Controlling sediment and erosion	Water quality Equipment operation Dewatering Project site preparation Site restoration Culvert, bridge, ford installation and maintenance Water crossing structure maintenance and repair Temporary culverts Logging cable suspension activities Large wood placement, removal, and repositioning Stream bank protection	4.3 4.3 4.3 4.3 4.3 4.5, 4.6, 4.7 6 7 10.2 10.3 10.4
Clearing vegetation , minimizing disturbance, and replanting exposed areas	Project site preparation Equipment operation Site restoration Water crossing structure maintenance and repair Temporary culverts Water Crossing Removal and Abandonment Beaver dam removal Logging cable suspension activities Large wood placement, removal, and repositioning Stream bank protection	4.3 4.3 4.3 6 7 8 10.1 10.2 10.3 10.4
Operating and staging of heavy equipment	Water quality Equipment operation Project site preparation Site restoration Fords (Type N Waters) Water crossing structure maintenance and repair Beaver dam removal Large wood placement, removal, and repositioning Stream bank protection	4.3 4.3 4.3 4.3 5.3 6 10.1 10.3 10.4
Addressing oil or gasoline spills or leakages	Project site preparation Water quality Equipment operation Fords (Type N Waters) Water crossing structure maintenance and repair	4.3 4.3 4.3 5.3 6
Bypass methods to be used in flowing water	Dewatering Construction BMPs (Type N Waters) Water crossing structure maintenance and repair Fish capture and exclusion	4.3 5.2 6 9
Keeping fish life out of the work area, including fish capture and exclusion (Type S and F Waters only)	Fish capture and exclusion Dewatering Beaver dam removal	9 4.3 10.1

Project Activities	BMP Locations	Parts
Ensuring fish passage after project completion (Type S and F Waters only)	Culverts Bridges Temporary culverts Water crossing removal and abandonment	4.5 4.6 7 8
Considering the passage of woody debris and sediment (all typed Waters)	Culverts Bridges Construction (Type N Waters) Water crossing structure maintenance and repair	4.5 4.6 5.2 6

Alternatives to the BMPs in Parts 4 through 10 may be considered if they can be shown to meet or exceed fish protection standards. Alternative methods that haven't been demonstrated for their effectiveness in meeting fish protection standards are likely to require additional review.

PART 4. WATER CROSSING STRUCTURES IN TYPE S AND F WATERS

Whenever a roadway crosses a stream it creates some level of risk to fish passage, water quality, or specific aquatic or riparian habitats. Generally, the risk increases the more the roadway confines and constricts the channel and floodplain. When siting a water crossing structure, all practical alternatives should be investigated to prevent or minimize these risks. However, additional mitigation measures may be necessary to address unavoidable impacts from FPHPs to *fish life* and fish habitat.

Family Forest Fish Passage Program (FFFPP)

Small forest landowners may be eligible for the FFFPP, a state cost share program to help pay for fixing fish passage barriers. For information see *Family Forest Fish Passage Program* in Board Manual Section 3 Guidelines for Forest Roads, and go to www.dnr.wa.gov/fffpp, or contact any DNR region office.

When designed and constructed properly, water crossing structures in Type S and F Waters will protect fish life and habitat, and will meet fish protection standards by:

- Providing for unimpeded passage for all species of adult and juvenile fishes;
- Ensuring that the physical and biological characteristics of the natural stream channel are preserved throughout the water crossing structure, as well as the adjacent channel both upstream and downstream;
- Passing the *100-year flood level*; and
- Providing opportunity for passage of expected bed load and associated large woody material likely to be encountered during flood events.

Starting your design planning process with a site assessment will help you determine the appropriate water crossing structure for your site. The two primary options for water crossing structures are bridges and culverts. The appropriate option depends on the size and configuration of the stream channel; the size, character, location, and elevation of the watershed; and the frequency and timing of use. Generally, bridges are the preferred structure to ensure free and unimpeded fish passage, culverts are used to cross smaller streams, and fords are used for temporary purposes under limited circumstances.

For more information on culvert design, please see the guidelines in the WDFW publication, *Design of Road Culverts for Fish Passage* (Bates et al. 2003), which can be found at http://wdfw.wa.gov/publications/00049/.

4.1 Basic Application Information for FPHPs Involving Type S and F Waters

Applications that include FPHPs require the following basic information:

- Vicinity map and other drawings that show the project in relationship to the *channel bed width* or the channel migration zone, whichever is greater, and the 100-year flood level if a floodplain exists at the project location.
- If possible, the GPS-derived location for the project site expressed in terms of decimal degrees.
- Accurate drawings with dimensions of the plan view, cross section view, and channel profile view. Examples are shown in figures 3, 4, and 5.
- Establish and show the location of benchmarks, also known as reference points, at the project site as identified on the site plan. These are typically used to establish exact critical elevations and locations relative to the design plan and channel survey for upstream and downstream culvert elevation (*invert*), bottomless culvert footings, bridge abutments, etc. The reference points need to be durable and located on persistent objects like old growth stumps, large trees, or boulders that will survive the construction activity, and durable enough to facilitate post-project monitoring.

Figures 3, 4, and 5 are examples of a plan view, culvert cross section view, and channel profile view.

- The plan view shows a crossing structure in relation to road and stream alignment;
- The culvert cross section view depicts a crossing structure perpendicular to the axis; and
- The channel profile view shows the lengthwise dimensions of the crossing structure.

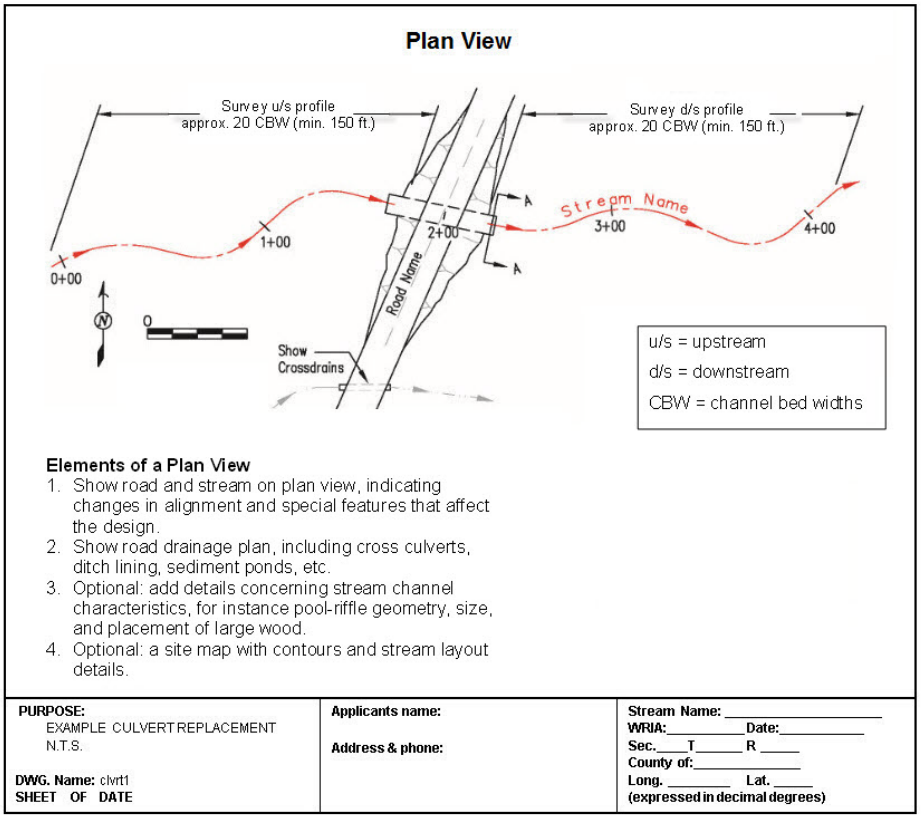


Figure 3 Plan view

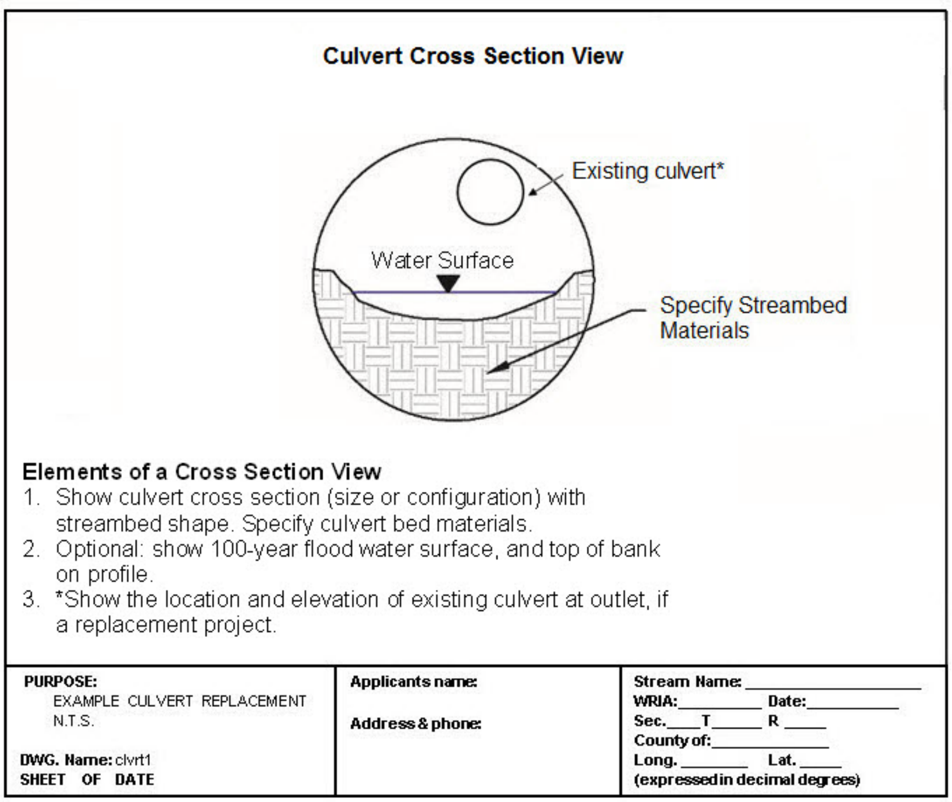


Figure 4 Culvert cross section view

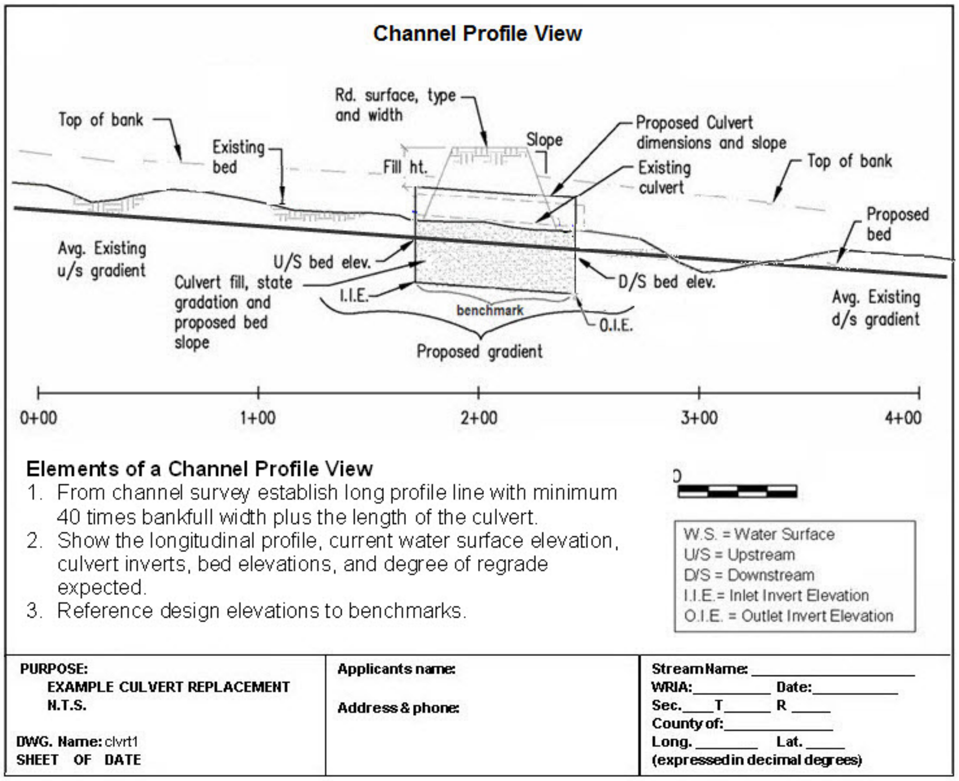


Figure 5 Channel profile view

4.2 Stream and Channel Assessment

Before designing a water crossing, you should verify the water type with DNR. Please refer to the water type definition in WAC 222-16-031, and refer to Board Manual Section 13 Guidelines for Determining Fish Use for the Purpose of Typing Waters.

The following stream characteristics should be assessed to determine an appropriate water crossing design:

- channel bed width/channel migration zone
- channel profile
- channel pattern
- vertical and horizontal channel stability
- condition of channel banks
- sediment transport and deposition
- potential debris loading and transport
- hydrology and hydraulics (watershed size, location, elevation, rain-on-snow zone, anchor ice, ice jams, etc.)

Part 4.2 provides concise information on stream characteristics and their relevance to a water crossing design. You can get help from WDFW to determine the scope of the evaluation necessary for your site. You may also refer to the WDFW publication, *Integrated Streambank Protection Guidelines* (Cramer et al. 2003) at http://wdfw.wa.gov/publications/00046/wdfw00046.pdf for in-depth guidelines on site assessments.

<u>Channel bed width/channel migration zone</u>
The channel bed width of a stream is by far the most important parameter in any crossing design. Accurate measurements are critical for a successful project. The method for determining channel bed width is described below and the methods for determining whether a channel migration zone is present can be found in Board Manual Section 2 Standard Methods for Identifying Bankfull Channel Features and Channel Migration Zones.

Channel bed width, as defined here, is the stream's width metric for FPHPs involving Type S and F Waters. *Bankfull width* is to be used as the stream width metric for FPHPs involving Type N Waters.

The channel bed width is defined as the width of the bankfull channel. The bankfull channel is defined as the stage when water just begins to overflow into the active floodplain. However, determining bankfull width requires the presence of a floodplain or bench, and depending on physical or geographical conditions, some streams have neither. When determining bankfull channel width for a stream where a floodplain or distinct bench is not present, features used in the general descriptions of active channel and ordinary high water will aid the project designer in determining channel bed width.

"Active channel width" is used to describe the stream's recent or current discharges. Outside the active channel are indicators, such as soil development and permanent vegetation, which show stability and that overland flow is rare. Inside the active channel are features indicating normal stream flow processes such as sediment deposits and bed scour. The upper limit of the active channel may occur at a "break" in slope separating a steeper active slope and a gentler upland slope.

"Ordinary high water line" is usually identified by physical scarring along the bank or shore and the action of water so common that it leaves a natural line impressed on the bank. The line may be indicated by erosion, benching, change in soil characteristics, lack of terrestrial vegetation or the presence of vegetative litter or woody debris. Soil characteristics or seasonal vegetation may make finding the high water line difficult and several locations should be observed to ascertain the correct location of the high water mark.

The following features, taken from the descriptions of active channel width and ordinary high water line, can be used for measuring channel bed width when a floodplain or bench is not present:

- changes in vegetation or a lack of vegetation (especially the lower limit of perennial species);
- changes in slope or topographic breaks along the bank;
- changes in the particle size of bank material, such as the boundary between coarse cobble or gravel with fine-grained sand or silt;
- the presence of bank undercutting, which usually reaches an interior elevation slightly below the bankfull stage;
- the height of depositional features, especially the top of the point bar, which defines the lowest possible level for bankfull stage; and/or
- stain lines/marks or the lower extent of lichens on boulders.

Landowners and project designers are encouraged to use a combination of the indicators listed above to more accurately estimate the channel bed width. Since stream anomalies, drought, flooding, or seasonal vegetation can mask or accentuate the targeted channel bed width, it is recommended that applicants observe several locations when measuring the channel bed width to achieve an accurate calculation.

Channel profile

The channel profile is a longitudinal profile view along the length of the stream. An example is shown in Figure 5. It is critical for culvert design and forms the basis for the plan. It is developed by surveying the elevation of the bed or water surface along the stream reach that includes the water crossing, typically at least 200 feet upstream and downstream from the water crossing site.

The channel profile is used to determine stream slope, degree of upstream and downstream incision and deposition, the depth of pools, and the presence of *nick points*. Water surface measurements should be taken at the same flow level. The channel profile helps to determine the appropriate slope and elevation of the culvert and the strategy for dealing with channel regrade, including deposition, and incision. Channel elevation may respond when an existing in-stream structure is removed during the installation of a new crossing structure. Outfall drops and locally steepened sections immediately adjacent to the crossing structure are hallmarks of channel incision. Figure 6 shows the culvert invert, which is the bottom of the culvert at the inlet and outlet end, and which must be below the expected regrade line with an additional allowance for the necessary countersink.

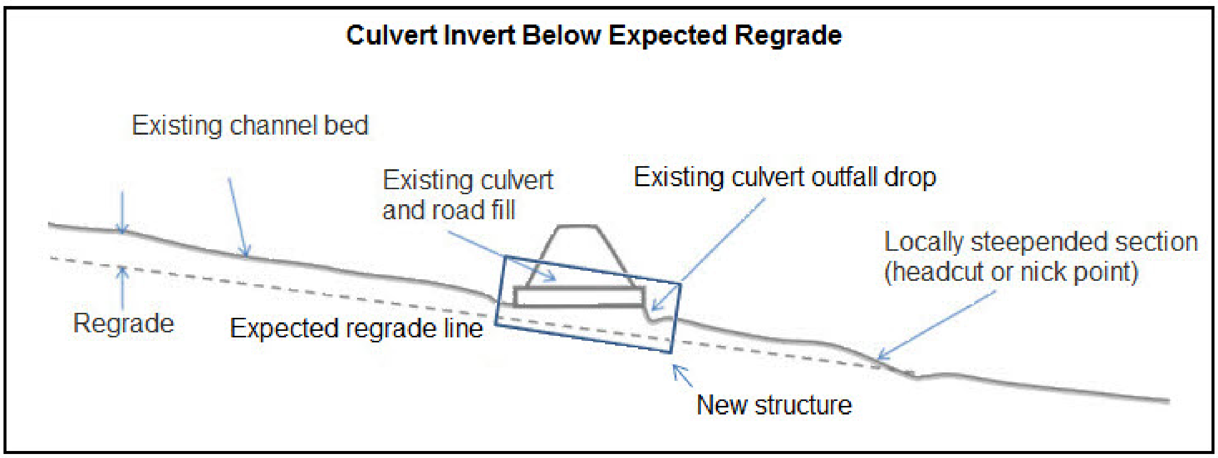


Figure 6 Culvert invert below expected regrade

Channel pattern

Recognizing the type of channel pattern is essential for the selection of an appropriate water crossing structure. Stream processes form variable channel patterns. The most common channel pattern type associated with culvert crossings is a confined, non-meandering channel. This greatly simplifies the analysis because these channels, if stable, experience limited lateral channel movement and have a limited floodplain. Unconfined alluvial channels are characteristic of channel migration zones and are more complicated because they tend to experience more lateral channel migration and larger floodplains. Please see Board Manual Section 2 Standard Methods for Identifying Bankfull Channel Features and Channel Migration Zones. Part 2.5 of Section 2 includes a technical discussion describing how riverine processes form channels; and 2.1 through 2.4 provide standard methods to identify whether a channel migration zone exists. It is recommended that DNR and WDFW be consulted when these complicated channel types are encountered. Tribes may also be consulted for additional expertise.

Channel stability
Channel stability can vary greatly along a stream course. To the greatest degree possible, stream crossings should be placed in locations of high channel stability. Channel characteristics indicating stability include:

- Straight segments with no evident signs of recent bank erosion;
- A single channel with minimal floodplain and no high flow channels;
- Relatively coarse streambed material such as cobbles or boulders;
- The absence of sediment deposits such as significant gravel and sand bars that are exposed at low flows; and
- The absence of "stair step" features in the streambed within at least 200 feet of the crossing location.

Aligning the crossing structure at right angles to a relatively straight stream course can minimize the length of the structure (and the length of affected stream channel) and avoid the potentially destabilizing effects of forcing the channel through abrupt changes in direction and elevation.

Condition of channel banks
The condition of a channel's banks is indicative of channel stability. Raw, vertical banks are a sign of recent incision (cutting or vertical degradation) and may be a reason to increase the estimate of channel width to accommodate future channel widening. The channel may also continue to incise, forcing the design to a bridge or a more deeply countersunk culvert to accommodate the additional downcutting. Removing the existing culvert, if perched, may result in upstream incision and possible impacts to habitat and channel conditions. Figure 7 shows a perched culvert.

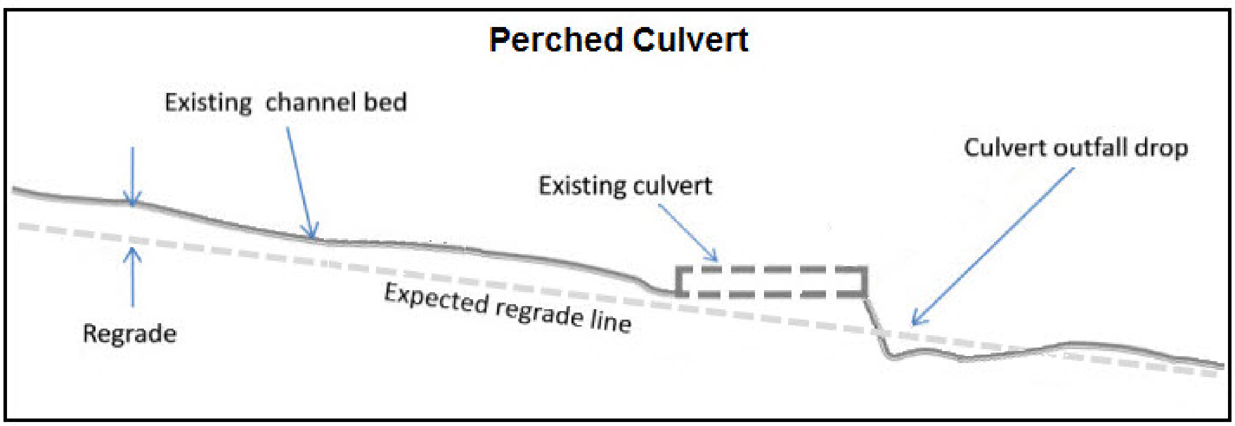


Figure 7 Perched culvert

Very low banks or no banks at all indicate heavy *aggradation*. The crossing is likely located at a gradient break or on an unconfined channel. This is a very challenging condition and the stream, without the road crossing determining the location of the channel, would move laterally to lower ground. Maintaining a static location often leads to designing a larger crossing to accommodate the sediment load, raising the road to allow sediment to build and scour, or using of alternative methods to maintain the crossing. For more information regarding alternative methods, please see the WDFW website at http://wdfw.wa.gov/conservation/habitat/planning/ahg/, Aquatic Habitat Guidelines.

Sediment transport and deposition

Sediment deposition, supply, and transport must be considered in selecting an appropriate water crossing structure. The resulting streambed at the crossing must be similar to the streambed upstream and downstream of the structure. Streambed composition can be measured in a variety of ways. See Figure 8. Another source of information on pebble count is available on the West Virginia Department of Environmental Protection website at http://www.dep.wv.gov/WWE/getinvolved/sos/Pages/SOPpebble.aspx.

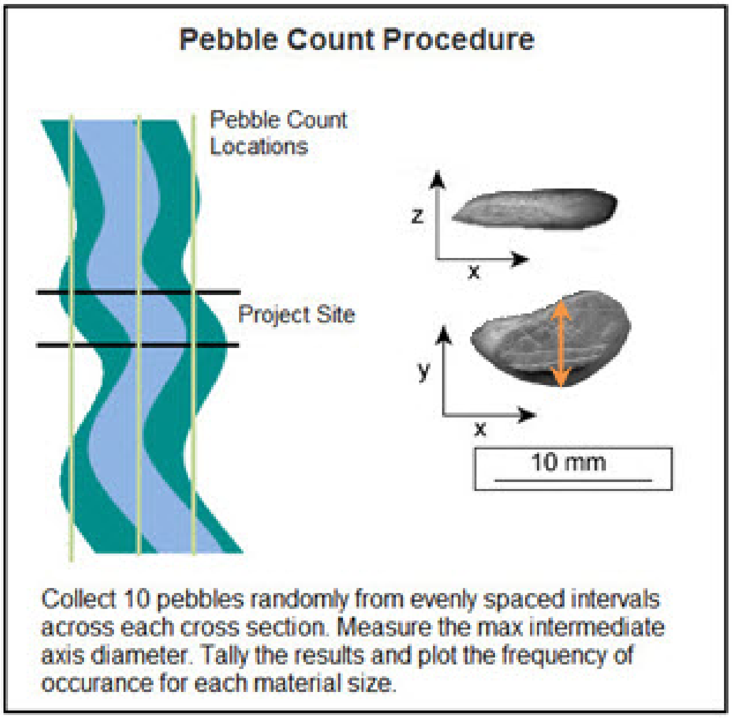


Figure 8 Pebble count procedure

Depositional areas, such as alluvial fans or where the channel gradient transitions from steep to flat, pose additional design considerations. A channel spanning bridge may be a better choice than a culvert for a stream crossing location with high sediment supply and deposition. A culvert located in a depositional reach may be overwhelmed with sediment, making it dysfunctional.

Similarly a channel spanning bridge may be a better choice for stream crossing locations with limited sediment supply where a culvert installation may eventually erode the outfall and result in the loss of fish passage.

Potential debris loading and transport

Large woody debris (LWD) is an important ecological and habitat-forming component in fish bearing streams, and serves as a sediment retention mechanism in fish and non-fish bearing streams. LWD includes boles, root wads, and whole trees. Delivery of LWD into the stream depends on factors such as tree proximity, lean and direction, and the degree and evenness of forest cover. Transport of LWD is dependent on the size and power of the stream. The potential debris loading and transport in the vicinity of the water crossing structure needs to be considered in order to design the proper size structure.

Hydrology and hydraulics

Water crossing structures should be designed to pass ice, debris and sediment likely to be encountered at the 100-year flood level. Bridges should have at least three feet of clearance between the bottom of the bridge structure and the water surface at the 100-year flood level. A clearance greater than 3 feet is typically necessary in locations of high transport of sediment and/or wood, or in locations where sediment and wood accumulate.

When designing a stream crossing, it is important to gather precipitation, forest hydrology, and peak flow data pertinent to the behavior of the stream. Hundred-year flood flows can be determined with gage data or regression analysis, allowing the determination of design discharge values. Methods to determine culvert sizing based on the 100-year flood level can be found in Part 5.1 Culvert Design. Also, it is important to consider the low flows in the channel to assure fish passage through the area of the water crossing structure. At the site of a structure it is essential to know the discharge and its variation over time.

Important considerations

Design crossings to allow for natural stream processes, including the transport of wood, water, and sediment, while maintaining the natural movement pattern of the stream.

- Cross streams at right angles to the natural flow of the stream. Avoid critical areas such as wetlands and spawning habitat.
- Avoid reaches showing signs of channel instability.
- Avoid areas that require constraining, re-aligning, or altering the natural channel.
- Consider possible mitigation measures for unavoidable impacts from FPHPs to fish life and fish habitat.

If you have a difficult situation such as a channel with no discernible channel bed width, a road that crosses a delta or high depositional area, or a tidal crossing, consider:

- Moving the crossing upstream of depositional area.
- Oversizing the culvert crossing or using a bridge to accommodate sediment deposition.
- For bridges, raising the crossing to allow for deposition and transport of wood and debris.
- Proposing an alternative design such as a ford or *vented ford*.

Finally, pre-application consultation with DNR and WDFW will help you evaluate and plan for construction or removal of your water crossing structures. Please refer to Part 1 for DNR and WDFW contact information. Tribes may also be consulted for additional expertise.

4.3 Construction BMPs

Use of the following BMPs during the construction of water crossing structures will minimize potential impacts to fish, fish habitat, water quality, and the riparian environment.

Project Site Preparation BMPs

- Minimize clearing limits associated with site access and construction to reduce disturbance of riparian vegetation, wetlands, and other sensitive channel features. Trimming and cutting is preferred to grubbing. Clearing limits for site disturbance should be clearly marked.
- Utilize established benchmarks for construction controls as described in Part 4.1.

- Establish staging areas (for construction equipment storage, vehicle storage, fueling, servicing, hazardous material storage, etc.) in a location and manner that will prevent erosion or contamination to typed waters.
- Prior to starting work in areas where the bank will be disturbed, install temporary erosion control measures such as a filter fabric fence or straw wattles to prevent sediment from entering the stream. During construction, cover erodible soils with a mulch or matting to prevent erosion, and slope erodible soils to route water into settling areas away from streams. Recommendations on the appropriate erosion control measures can be found in the Department of Ecology's stormwater management manuals at http://www.ecy.wa.gov/programs/wq/stormwater/manual.html (Western Washington); or http://www.ecy.wa.gov/programs/wq/stormwater/easternmanual/manual.html (Eastern Washington).
- After completion of work, but before removing the temporary erosion control measures, remove sediment accumulated during the project from behind the erosion control measures and deposit it in a location where it cannot enter typed water.

Fish capture and exclusion BMPs

Please see Part 9 for fish capture and exclusion BMPs. If personnel and resources are available, WDFW and affected tribes may assist with capturing and moving fish from the job site to free-flowing water. DNR can help identify affected tribes in a given area.

Dewatering BMPs

Construction site dewatering is often necessary to ensure the *protection of fish life* and habitat, as well as meet water quality standards. Dewatering of stream crossing construction sites is typically necessary because of potential impacts to the channel. Maintain clean water by diverting the stream before it enters the construction site and return the flow to the channel downstream from the project. Figure 9 illustrates this process.

- Passive gravity flow diversions are generally preferable to pumping. Pumps can be inefficient and unreliable, but may be necessary in some cases.
- Isolate the work area at both the upstream and downstream ends by placing coffer dams made of gravel filled bags, ecology blocks or a similar device and then diverting the flow around the work area before beginning any work in the channel.

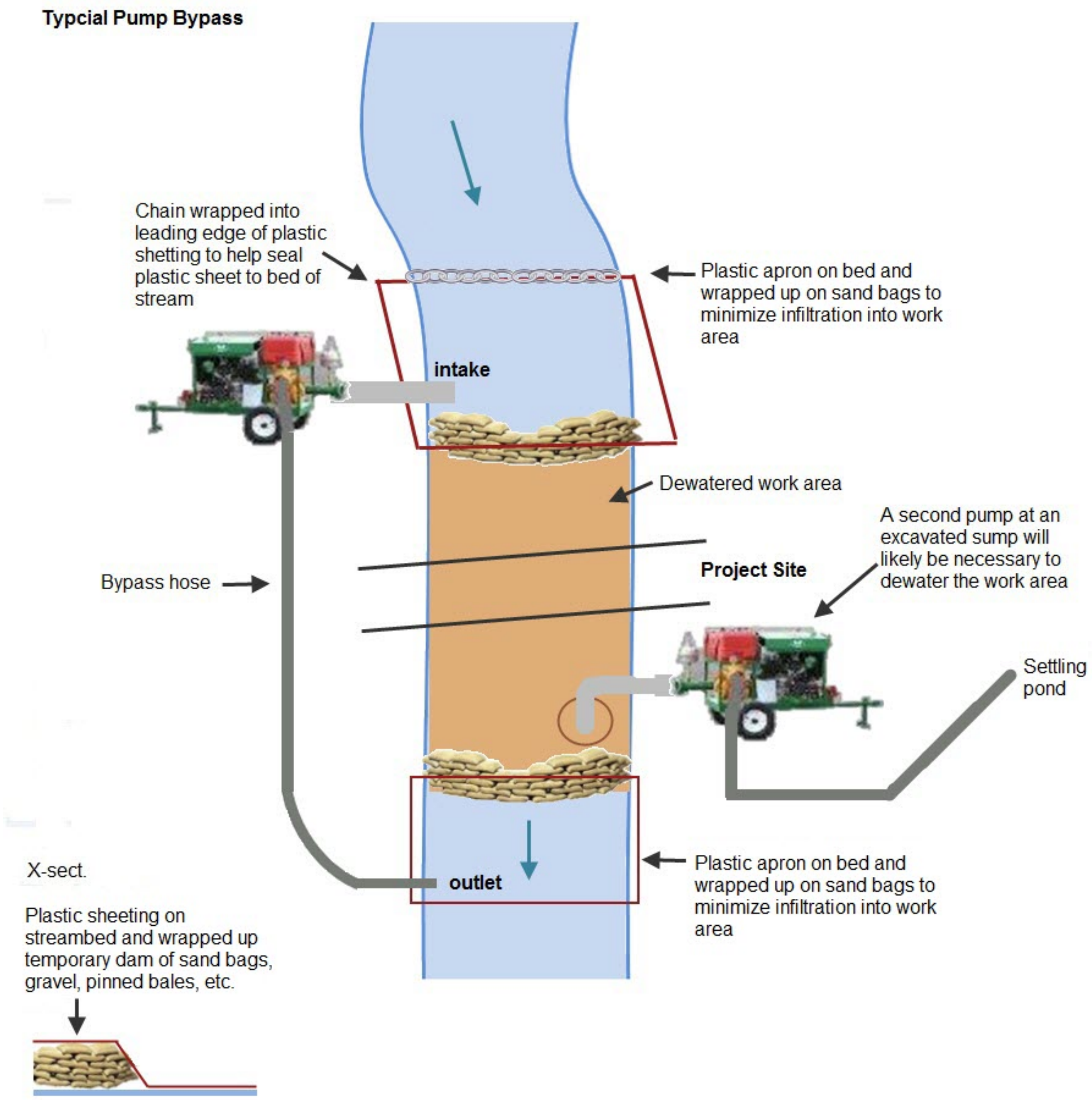


Figure 9 Typical bypass pump

- Coffer dams should be overlain with plastic or filter fabric on the upstream side to contain sediment. Accumulated silt should be removed with the filter fabric upon completion of the project.
- If gravel bags are used as coffer dams, after project completion the bags can be slit to allow the gravel to disperse downstream, provided the gravel is rounded and clean (e.g., pea gravel). Remove the bags and any associated debris from the site. If necessary, hand tools can be used to ensure stream flow and fish passage is not impeded by the gravel.
- Discharge clean diverted water back into the channel downstream as close as possible to the project site to maintain flows for fish and reduce the length of stream that needs to be dewatered.
- Stream beds typically have substantial subsurface water flow which must be captured and removed from the construction site. This dirty water (i.e., wastewater) cannot be discharged directly into typed waters. Install a *sump* within the work area for dewatering. Place pump

outlets upland a sufficient distance from the stream channel to allow the natural vegetation to filter sediments before waste water reaches the channel.

- Equip pumps used for dewatering the job site with screens to prevent injury of fish pursuant to RCW 77.57.010 and RCW 77.57.070. The pump intake must be screened by one of the following:
  - Perforated plate: 0.094 inch (maximum opening diameter)
  - Profile bar: 0.069 inch (maximum width opening)
  - Woven wire: 0.087 inch (maximum opening in the narrow direction)
- Ensure that the open area for all types of fish guards is a minimum of 27 percent and that the screened intake consists of a facility with enough surface area to ensure that the velocity through the screen is less than 0.4 feet per second.
- Keep the screen in place whenever water is withdrawn from the stream through the pump intake and maintain the screen to prevent injury or entrapment of juvenile fish.
- If pumps are used as the primary or secondary method of diverting flow around the isolated work area, plans should be in place for accessing additional backup pumps in the event of extremes in flow caused by weather or other factors. Once started, bypass pumps typically need to be run continuously through project completion. This requires 24 hour monitoring for refueling and pump maintenance. Pump failure is also common and requires backup pumps ready on site to replace the failed pump.

Bypass pump

Water quality BMPs

- Establish a site-specific spill prevention and erosion control plan prior to beginning work. Such a plan may include:
  - a site plan with a description of the methods of erosion/sediment control;
  - methods for confining, removing and disposing of excess construction materials;
  - measures for washing and maintaining equipment;
  - a spill containment plan;
  - measures to reduce and recycle hazardous and non-hazardous wastes; and
  - measures to disconnect road surface and ditch water from all typed waters (see BMPs in Board Manual Section 3 Guidelines for Forest Roads).
- Do not use wood that has been treated with creosote or pentachlorophenol for any part of the structure, including pilings, beams, structural supports, and decking. These components must remain free of these toxic substances for the duration of their functional lives. Detailed information about preservative options can be found on the Western Wood Preservative Institute web site at http://wwpinstitute.org/.
- Ensure that no chemicals or any other toxic or harmful materials are allowed to enter or leach into the stream.
- Minimize sediment delivery to typed water.

- Dispose of all project waste material such as construction debris, silt, excess dirt or overburden material above the limits of floodwater in an approved upland disposal site.
- Stop work if high flow conditions that may cause siltation are encountered during the project or if the coffer dams are compromised. Do not re-start work until the flow subsides.
- Do not allow uncured concrete or concrete by-products to enter the stream at any time during construction. Completely seal all forms used for concrete to prevent uncured concrete from getting into the stream.
- Ensure that all materials and equipment used for construction, monitoring, and fish salvage are free of aquatic invasive species. Decontaminate all materials and equipment so that no viable invasive species are transported to or from the job site.

Equipment operation BMPs

- Where practical, based on project scale and site conditions, accomplish the work by hand or with hand-held tools.
- Where possible, operate equipment from the road, road shoulder, bridge, top of the bank, dry gravel bar, work platform, or similar out-of-water location. Work within a dewatered channel or a channel with diverted flow is acceptable with the use of BMPs. In-water equipment operation should be avoided, but where necessary it should be identified and addressed in the spill prevention and erosion control plan.
- Check equipment daily for leaks and make any necessary repairs prior to commencing work activities along the stream. Ensure equipment is free of external petroleum-based products while working around the stream. Remove accumulations of soil or debris from the drive mechanisms (wheels, tires, tracks, etc.) and undercarriage of equipment prior to working near or in the stream.
- Equipment crossings of the stream are discouraged and should be proposed only when and where necessary to complete a project or access a project site.
- Operate equipment in the stream channel only if the drive mechanisms do not enter the channel or when the work area is dry or within an area where the stream flow is bypassed.
- Limit equipment use near the stream to specific access and work corridors to minimize disturbance to stream banks and vegetation. Service, refuel, and maintain equipment in an upland area to prevent contamination of surface waters. When practical, this service site should be located at least 200 feet from any receiving waters. Fueling areas should be equipped with sufficient spill containment supplies to prevent a spill from reaching typed waters.

Site restoration BMPs

Alteration or disturbance of the bank and vegetation should be limited to that necessary to construct the project. Trimming and cutting riparian vegetation is preferred to stump removal. Affected bed and bank areas should be restored to pre-project condition. This includes regrading and restoring banks and channel beds back to natural contours, removing unnecessary fill, controlling the potential for invasive species, revegetating disturbed areas with native vegetation, and restoring wood loading in the channel consistent with the rest of the stream.

- Place any trees cut during the project, that otherwise would be required to be left by forest practices RMZ rules, on the bank or in the stream to provide fish habitat and restore natural stream processes.

- Do not return in-stream flows to the project area until all in-channel work is completed and the banks are adequately stabilized to minimize sediment delivery to the stream or stream channel.
- Remove all structures, materials or equipment from the site and dispose of all excess spoils and/or waste materials properly upon completion of the project.
- Restore the channel bed, bank, and shoreline areas similar to their pre-project natural condition.
- When preparing a revegetation plan for the site, consider the precipitation zone, species native to the site, and the likelihood of natural revegetation.
- Site restoration includes replacing woody vegetation generally representative of the species and densities of adjacent undisturbed riparian vegetation. Plant a native erosion control grass seed mix immediately after construction to prevent future erosion, stem the invasion of noxious weeds, and stabilize the soil on any disturbed areas (see Board Manual Section 3 Guidelines for Forest Roads, Part 4.5 Vegetation BMPs). Spreading hay over the seed can help anchor the seed to the soil and reduce erosion.
- To the extent necessary to replace woody vegetation removed during construction, plant site-appropriate conifer or hardwood seedlings and/or transplant local shrubs no later than the fall or spring dormant periods following project completion. Generally, the replanting of woody vegetation should take place between October 31 and March 30.
- Where planting is needed, overplant, monitor, and maintain the plantings to assure that woody plant density is in compliance with the revegetation plan.

4.4 Mitigating for unavoidable impacts for Type S and F water crossings

- Possible impacts should be considered on site and may include:
  - Channel simplification resulting in loss of spawning and/or pool habitat.
  - Significant riparian stand removal or modification.
- Potential mitigation measures:
  - Installation of logs with root wads in the channel downstream of the new crossing is preferred. The intent is to install the largest functional pieces possible that would have otherwise contributed riparian function from a mature riparian stand. Conifer species such as Douglas fir or cedar provide habitat forming function in the stream for longer periods than hardwood species. Based upon stream size and existing riparian condition, strategies could include the following:
    - Installed wood should be a minimum of 12 inches diameter and 6 feet in length in streams under 4 feet channel bed width.
    - In streams over 4 feet channel bed width, installed wood should be a minimum of 12 inches in diameter and 1.5 times the channel bed width of the stream in length.
    - Wood should be placed so as to interact with stream flow.
    - Wood should be placed so as not to create fish passage barriers.
    - The total number of installed pieces should be determined on a case by case basis, and should be proportionate to the size of the affected stream.
  - In-channel work to restore channel geometry and substrate typical of undisturbed reaches.
  - Riparian replanting of disturbed areas with appropriate species.

4.5 Culvert Design

Culverts installed in Type S and F Waters must be large enough to transport water, sediment, and wood likely to be encountered during all flows, up to and including *100-year flood* events. DNR and WDFW can help the landowner choose which culvert option is appropriate for the site.

4.5.1 Culvert installation

In this manual "culvert installation" includes culvert replacement projects.

If culverts are not installed and maintained properly, they have the potential to:

- Create fish passage barriers due to excessive stream velocities, headcuts upstream, or scouring downstream.
- Reduce downstream transport of sediment, LWD, and organic material resulting in decreased habitat complexity and food web productivity in downstream reaches.
- Alter natural channel forming processes.
- Disconnect floodplains and off-channel habitat.
- Damage the road and disrupt access.

4.5.2 Culvert design options

4.5.2.1 No-slope design

The no-slope culvert method is expected to pass fish when sized appropriately and installed on a flat gradient. It allows for the natural movement of bedload and a stable channel bed inside the culvert.

A no-slope culvert is designed to have the following characteristics:

- The culvert width is equal to or greater than the active channel width at the dimension where the culvert meets the streambed.
- The culvert is set at a flat zero slope gradient.
- The outlet invert (bottom of the culvert at the outlet or downstream end) is countersunk below the channel bed by a minimum of 20 percent of the culvert diameter or height.
- The inlet invert (bottom of the culvert at the inlet or upstream end) is countersunk by a maximum of 40 percent of the culvert diameter or height.
- The culvert has adequate capacity to accommodate the *100-year flood* flow and associated debris likely to be encountered.

The no-slope design option is usually applicable in the following situations:

- Small channels generally less than 10 feet channel bed width.
- New and replacement culvert installations in simple channel conditions.
- Low to moderate natural channel gradient (generally less than 3 percent slope but may be acceptable for higher stream gradients with appropriate countersink requirements and based on site specific conditions). The "generally less than 3 percent" recommendation gives the designer the option to use the no-slope method in a variety of rise and length combinations. Steeper slope channels generally require a deeper fill and a sloped culvert, i.e., stream simulation. Low energy stable streams that are over 3 percent may be appropriate for no-slope culverts. Pre-application consultation with DNR and WDFW is recommended for no slope culvert designs in channel segments exceeding 3 percent gradient.

- Stream gradients up to 5 percent may be considered based on site-specific situations where the natural gradient of the stream can be maintained upstream and downstream of the installation of a culvert set at zero grade. No-slope culverts are not appropriate for high gradient channels. This is because an improperly installed culvert set at a slope less than the gradient of the stream can over steepen the upstream channel, often leading to a headcut that can degrade fish habitat, destabilize the channel, and release sediment that can bury the culvert. It can also deposit large quantities of sediment downstream resulting in channel impacts, bank erosion, and flooding.
- Streams with little evidence of instability (mass wasting, high sediment transport).
- Where site conditions permit a culvert width of at least 1.25 times the natural channel width upstream of the structure.
- Where the likelihood of upstream head cutting can be avoided.

The no-slope culvert option is appropriate where the channel gradient (percent slope) multiplied by the culvert length do not exceed 20 percent of the culvert height. In other words, the steeper the stream gradient, the larger and/or the shorter the culvert must be to fit within a no-slope design. This can be applied with a certain degree of flexibility around these limits, provided the necessary hydraulic engineering expertise is available to account for the implications of constricting the upstream end of the culvert with the accreted bed or by installing a larger culvert. Figure 10 illustrates the elements of a no-slope culvert design.

For more information on the no-slope culvert design, please see the guidelines in the WDFW publication, *Design of Road Culverts for Fish Passage* (Bates et al. 2003), which can be found at http://wdfw.wa.gov/publications/00049/.

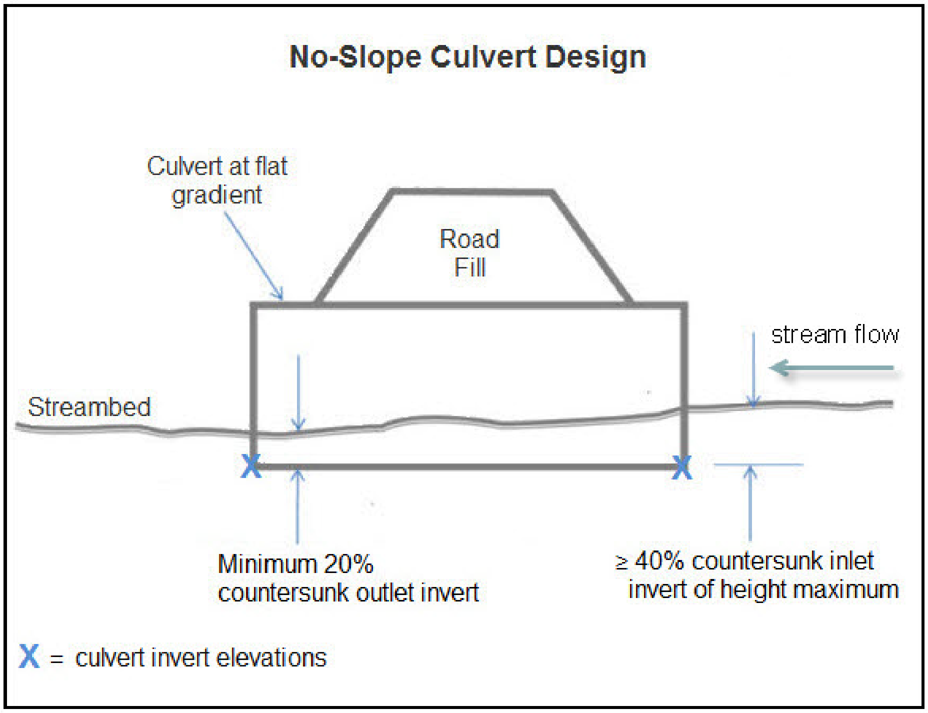


Figure 10 Design elements of a no-slope culvert

The culvert outlet invert must be countersunk a minimum of 20 percent of the culvert height (round culvert diameter or vertical measure of an arch, box or elliptical structure). Adequate culvert countersink is vital for proper performance and fish passage. When the stream gradient is low, it is recommended that the culvert be countersunk more so long as the inlet is not countersunk more than 40 percent. Inlet countersink designs greater than 40 percent may be appropriate under certain situations such as wetlands or wetland channels, where head cut is likely to occur that will flatten the stream gradient. The culvert outlet invert must be installed at the correct elevation relative to the downstream channel bed and overall channel profile. Since this outlet elevation is critical for any successful culvert design, it must be established and clearly benchmarked for post-project review prior to commencing any excavation for the project. While a full channel profile is not always necessary for new no-slope installations, it is critical for culvert replacements where the channel will adjust upon removal of the previous grade controlling structure. In all cases, the outlet invert must be accurately identified and surveyed prior to construction in order to establish a benchmark that relates to reference points outside of the project. This benchmark will confirm proper invert elevation and serve as post-project reference.

The width of the stream bed inside the culvert, based on the designed outlet countersink elevation, will be as wide as the average channel bed width of the streambed. The formula for the minimum culvert width to channel bed width is:

Minimum culvert diameter = 1.25 x channel bed width; conversely
Width at 20% countersink = 0.8 x culvert diameter

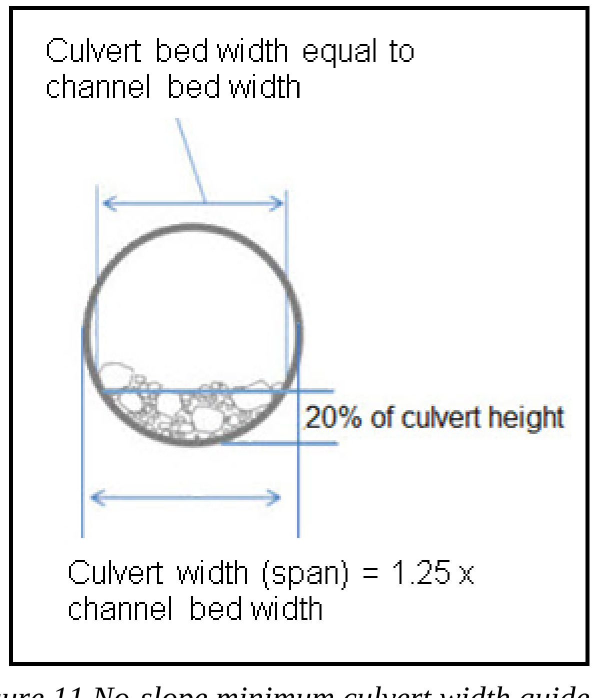


Figure 11 No-slope minimum culvert width guideline

The area at the inlet remaining open (above countersinking) must provide enough opening to pass the 100-year flood level with consideration for debris likely to be encountered (Figure 12). *Mitering* the culvert *inlet* may aid in peak flow and debris transport.

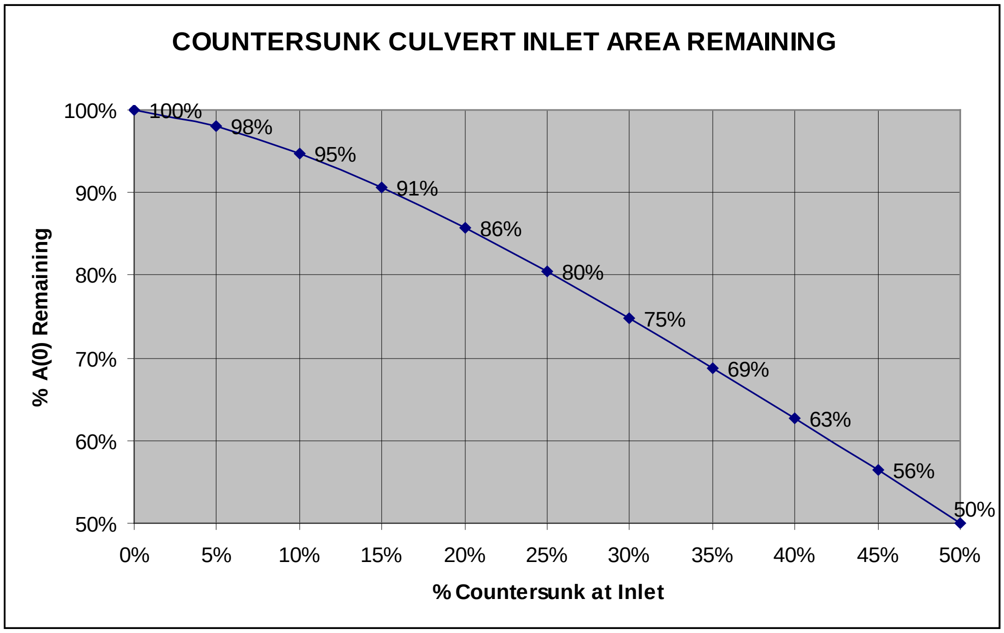


Figure 12 Culvert inlet area remaining versus percent of countersink

No-slope culverts countersunk deeper than 20 percent of the culvert height have the greatest possibility of providing for fish passage over the long term. Consider designing from the top-down (i.e., start at 40 percent/50 percent countersink at inlet, so the outlet countersink is maximized >20 percent). For no-slope culvert design with a countersink at or near 20 percent, or in high energy systems, there is a high likelihood of failure. The designer may want to consider a larger structure. Pre-application consultation is encouraged.

Culverts are filled with well-graded material consistent with the surrounding channel characteristics when natural processes are not expected to fill the culvert within two years (and there is no significant wedge of material upstream of crossing). No filling is required in wetland situations because the culvert will naturally backwater when set at proper elevations, which will provide pool habitat for fish species.

Pipe arches, also known as squashed pipes, need to be sized and designed to meet the above guidelines using the *Handbook of Steel Drainage & Highway Construction Products* from the American Iron and Steel Institute, 1994 edition, for geometry, sizing, and flow calculations.

4.5.2.2 Stream-simulation design

The stream-simulation method is intended to mimic a stream channel, allowing for minor adjustments in response to changes in upstream and downstream channel dynamics. The structure is placed at or near the natural channel slope and incorporates natural substrate features that mimic the adjacent streambed, provide for fish passage, and allow for the natural transport of sediment, wood, and organic debris.

Generally, the stream-simulation option is an appropriate method in the following circumstances (Bates et al. 2003):

- New and replacement culvert installations.

- Complex settings, including sites with moderate to high natural channel gradient and/or sites requiring long culverts.
- Narrow stream valleys.
- Locations where passage is required for a broad range of aquatic species.
- Systems where passage must be provided for species with poorly understood requirements.
- Ecological connectivity; downstream transport of wood, sediment, and organic material is required.

Culverts designed to simulate streambeds are sized wider than the channel width, and the bed inside the culvert is sloped at a similar or greater gradient than the upstream channel stream reach (no more than 125 percent of the upstream gradient). This type of culvert is filled with substrate material that emulates the natural channel, erodes and deforms similar to the natural channel, and is unlikely to change the channel gradient unless specifically designed to do so.

The most basic stream-simulation culvert is a bottomless culvert placed over a natural streambed. Here, the natural streambed remains in place. More complex designs may involve substrate intermixed with immobile bedform elements (e.g., boulders) to maintain bed conditions within the structure. Typical low gradient and high-gradient stream-simulation schematics are shown in figures 13 and 14.

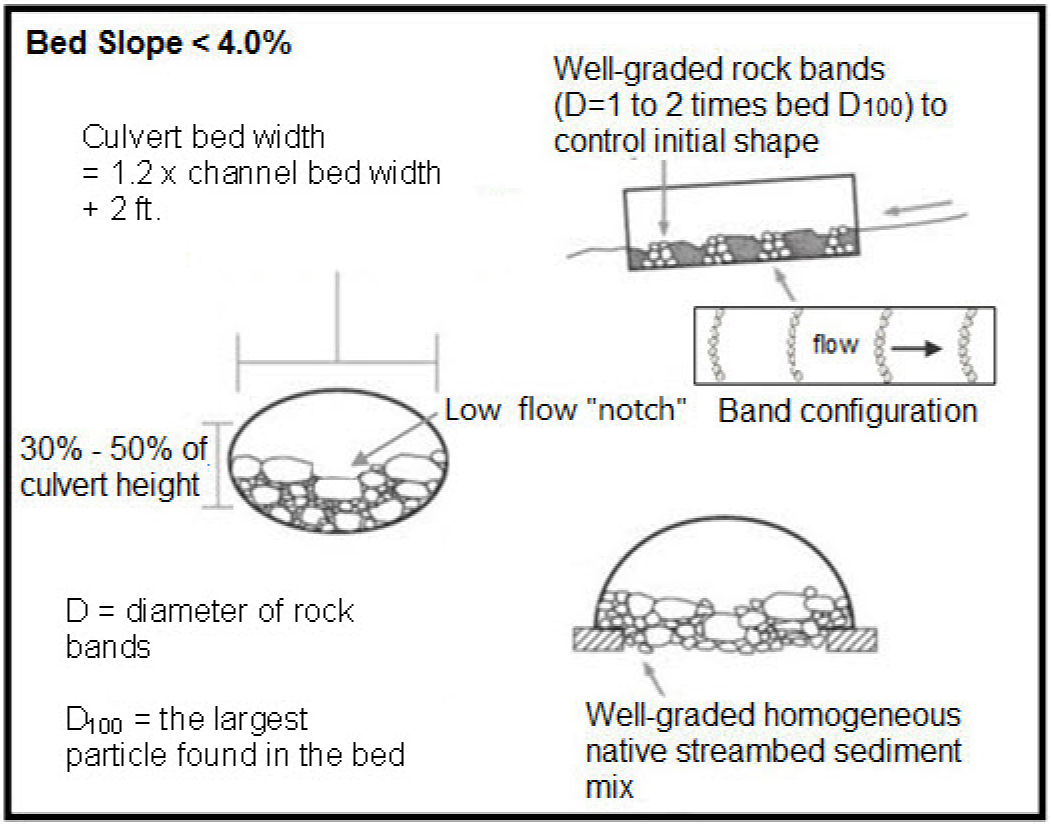


Figure 13 Profile and cross sections for typical stream-simulation culverts for low to moderate gradient settings
(<4 percent slope) Source: Bates et al. 2003

Stream-simulation projects should be surveyed, designed and constructed in a manner consistent with the WDFW publication, *Design of Road Culverts for Fish Passage* (Bates et al. 2003), Chapter 6 - Stream Simulation Design Option. This publication can be found at http://wdfw.wa.gov/publications/00049/wdfw00049.pdf.

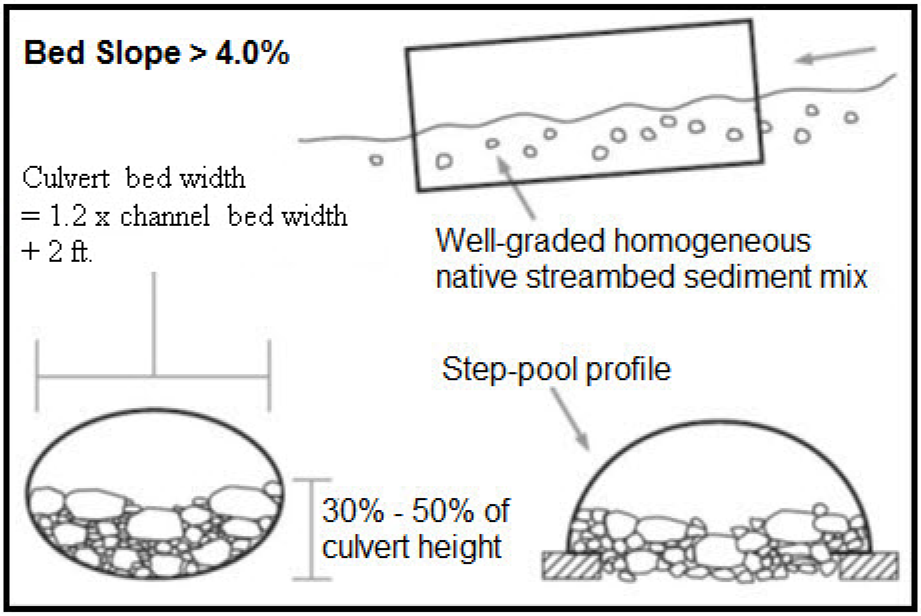


Figure 14 Profile and cross sections for typical stream-simulation culverts for higher gradient settings (>4 percent slope) Source: Bates et al. 2003

Stream simulation is achieved when physical conditions in the culvert look and function similarly to those in the adjacent natural channel. These conditions imply acceptable passage for fish and other aquatic organisms.

Typically, culverts are set along the natural stream gradient, countersunk 30 to 50 percent, filled with a range of streambed gravel sized to match the naturally occurring ambient substrate, resist scour, and are sized to a diameter D = 1.2 times the channel bed width plus 2 feet.

4.5.2.3 Hydraulic Design

This design option requires a high degree of expertise in hydraulic engineering and hydrologic and geomorphic modeling capabilities, a thorough understanding of the swimming performance and biological requirements of the target species, and site-specific survey information.

Historically, this method was a standard approach used to design culverts for fish passage. It has become less favored, however, because of uncertainty related to fish passage performance, a limited range of applicable settings, and a number of ecological limitations. Specifically, the passage requirements of many target species are poorly understood, which contributes to design uncertainty. Even when the passage requirements of target species are adequately addressed, the structure may fail to provide passage for non-target species. This may lead to a range of unforeseen ecological consequences. Considering the above, this design option is unlikely to achieve the objective of the forest practices rules to pass all fish species at all life stages.

Finally, this type of structure may not provide adequate transport of sediment and organic material, contributing to broader effects on ecosystem function, degradation of the adjacent stream channel, and declining performance over time.

Because of these limitations, the hydraulic design option is most commonly used for temporary retrofits of existing barrier culverts in circumstances where replacement or removal is not practical in the immediate future. See WDFW's *Design of Road Culverts for Fish Passage* manual (Bates et al. 2003) for additional guidance on this method.

4.5.2.4 Alternative Design Methods

Alternative design methods may be considered if they can be shown to meet or exceed fish protection standards. Alternative methods that haven't been demonstrated for their effectiveness in meeting fish protection standards are likely to require additional review. In addition, projects constructed under an alternative design method must be monitored for effectiveness. If the structure is shown to be ineffective over time, it will need to be replaced with a proven design method.

4.5.3 Culvert Retrofitting

A culvert retrofit is a modification placed in an existing culvert in order to improve fish passage. Retrofits commonly include baffles and/or weirs inside the culvert barrel. However, baffles reduce the hydraulic capacity of culverts. These structures are complicated as they must alter water velocities to allow for fish passage in culverts that do not pass all fish. (See 4.5.2.3 Hydraulic Design above.) Retrofitting a culvert is not a long-term solution, but may be used in some instances until the culvert can be replaced with a fish passable structure such as a bridge or a stream-simulation culvert.

4.6 Bridges

If properly located, sized, and installed, bridges provide the most protection to fish life and unimpeded fish passage, maintain natural channel processes, and provide the least risk of failure. Bridges are far less susceptible to plugging than culverts, and fish passage conditions under bridges are less likely to be affected by changes in streambed elevation. Pre-fabricated bridges are available that eliminate the complexity of engineering and may prove to be more cost effective than a culvert alternative. Bridge installation can be significantly simpler than culvert installation, with less in-water work, excavation, fill, and need for dewatering.

A bridge should be constructed in fish bearing waters where the site assessment indicates that a culvert is not a viable option. This is particularly true for larger streams and steeper channels, or when the movement of large debris or excessive sediment is frequent. See 4.2 Stream Channel Assessment.

The following guidelines apply both to new bridges and to the replacement of existing crossing structures. For the purpose of these guidelines, a bridge is any crossing that has separate structural elements for the superstructure, piers, abutments, and foundations.

Appropriately designed bridges should protect natural geomorphic and fluvial processes. These goals can be achieved by:

- Preventing excessive backwater during floods that could lead to scour of the stream bed within the waterway.
- Preventing deposition of sediment upstream which could increase lateral shifting of the river channel and therefore require future bank armoring.
- Preventing or limiting local scour or coarsening of the stream substrate.
- Allowing free passage of woody debris expected to be encountered in the stream. This reduces maintenance and allows for distribution of wood downstream.
- Allowing natural evolution of the channel longitudinal profile (meander and vertical scour) to the extent compatible with safety of the bridge, its road approaches, and adjacent private property.
- Allowing continued down-valley flow of water onto the floodplain, thereby reducing flood height, providing flood capacity, and permitting side channel development and other riparian processes.
- Reducing the risk of bridge failure from catastrophic floods.

All items in the list above may not apply to every bridge crossing. In many cases, existing site constraints may have already reduced the natural level of the channel and fish habitat productivity as a result of past man-made features.

<u>Bridge design and construction considerations</u>

- Pier placement within the wetted area of channel bed width should be avoided.
- Existing channel spanning bridges that have exhibited no channel effects may be replaced with a similar bridge span.
- For confined channels, the distance between bridge abutments should be at least channel bed width and may need to be placed further apart to pass 100 year flood flows without causing backwater elevations to exceed 0.2 feet. Consultation with DNR and WDFW is advisable. Figure 15 illustrates the relationship between channel bed width and the bridge structure for confined channels. This figure shows a bridge founded on spread footings, and the abutment protection required to protect the bridge footings. Other foundation and abutment protection methods are possible and preferred, but the width required between them remains the same.

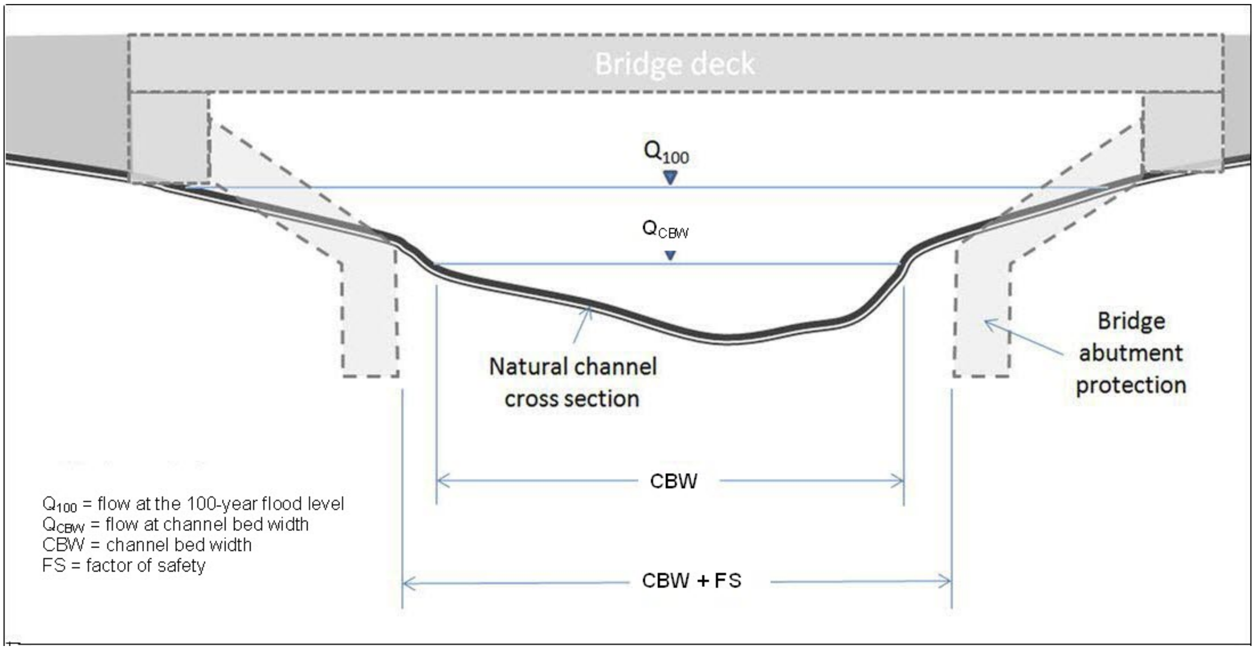


Figure 15 Bridge cross section over a confined channel showing the relationship between the channel bed width and the recommended width between abutment protections. The factor of safety is determined by the designer. The bridge may also be founded on piling or drilled shafts which would eliminate scour risk.

- Bridges should account for lateral channel movement (meandering) that will occur in their design life.
- In general, the bottom of the superstructure (stringers, girders, etc.) should be at least three feet above the 100-year flood level.
- The stream channel created or restored near and beneath the bridge should have a gradient, cross-section, and general configuration similar to the existing channel upstream and downstream of the crossing, provided that the adjacent channel has not been previously channelized.
- Bridge designs constructed in unconfined channels and floodplains can be more complex. Therefore, it is important that pre-application consultation occur with DNR and WDFW when anticipating bridge construction in such areas. Tribes may also be consulted for additional expertise.
- Floodplains adjacent to the channel also provide critical habitat for fish; therefore, impacts must be minimized. Spanning the entire width of the channel plus the floodplain is not usually practical, but preserving natural function of the floodplain is important. Therefore, careful consideration should be given for minimizing the possibility of floodplain areas being blocked or impeded by road approach embankments.

4.7 Fords in Type S and F Waters

Fords are a type of water crossing where vehicles drive through stream channels. They must be constructed and maintained in a manner that will prevent damage to fish life, habitat, and water quality. Fords have a high potential to generate and deliver sediment and may impede fish passage, both of which represent actual damage to public resources and must be avoided. However, under limited circumstances fords may be considered when they provide better public resource protection than other water crossing structures. A well designed and maintained ford creates no channel constriction, passes debris, and poses no hazards associated with road fill.

Fords are only appropriate to use during periods of low or no stream flow (whether dry or frozen) and if sediment delivery is minimized or avoided. If flow conditions change, a ford crossing may no longer be an appropriate stream crossing method. Vehicular traffic should be isolated from flowing water whenever possible.

Fords should be used only in locations where the *protection of fish life*, habitat, and water quality can be assured. Whether a ford is appropriate or not depends on the characteristics of the stream to be crossed, local topography, and management of traffic on the road.

Fords should be the last resort and only used in cases where other crossing methods have been considered and rejected. Fords may be considered for temporary use in watercourses where:

- Stream banks are naturally low and channel depths shallow;
- There is gentle topography with low bank height and low gradient approaches;
- The stream has low flow or no flow during the anticipated season of use;
- The stream is associated with a spur road rather than a mainline, and where there is minimal traffic; and/or
- The stream is subject to mass wasting events, debris transport, or extreme seasonal peak flows.

In order to avoid resource impacts and minimize delays, it is strongly recommended that pre-application consultation occurs with DNR and WDFW when anticipating ford construction. Tribes may also be consulted for additional expertise. Timing restrictions or use conditions may be applied because fords have the potential to generate sediment delivery or harm fish. Therefore, anticipate that a written plan for ford construction and maintenance, and restoration of the stream crossing may be required upon application.

Construction BMPs

- Separate traffic from flowing water by utilizing a vented ford.
- Construct fords at right angles to the stream.
- Construct fords outside of all known or suspected spawning areas such as pool tailouts.
- Inspect and maintain fords to provide for fish passage and maintain water quality, and notify DNR if fish passage is impeded or water quality is impacted.
- If the streambed does not have a firm rock or gravel base, install clean, washed rock or gravel to reduce sedimentation. Concrete, pavement or other debris should not be used to construct hardened fords. Placement of material should be limited to the approaches and crossing.
- Restoration of a ford after it is used should include restoring the slope and revegetating/stabilizing the banks of the stream, as well as removing any non-native material that may alter stream flow.
- To complete restoration, block vehicular access to the crossing location.

Maintenance BMPs

Streambeds are part of a dynamic system where storm events frequently change the stream bed and banks. Fords should not require maintenance after every such event. Re-evaluate the use of a ford if frequent or extensive maintenance is required.

Maintain fords to:

- Keep road approach ditch-outs and water bars functioning.
- Minimize road surface runoff and control stream bank erosion. See Board Manual Section 3 Guidelines for Forest Roads, Part 4.3 Erosion Control.
- Prevent multiple approaches.
- Provide for unimpeded fish passage.

Construction and maintenance BMPs for fords in Type N Waters can be found in Part 5.3.

PART 5. WATER CROSSING STRUCTURES IN TYPE N WATERS

5.1 Culvert Design

Before designing a water crossing, you should verify the water type with DNR. Please refer to the water type definition in WAC 222-16-031. If unsure about how to determine *bankfull width*, see Board Manual Section 2 Standard Methods for Identifying Bankfull Channel Features and Channel Migration Zone. Contact DNR if you have questions.

This section includes three common methods to determine culvert sizing based on the *100-year flood level*, any one of which can be used. See Table 2. Alternative methods may be considered. To facilitate the application review process, you are encouraged to explain how you determined the appropriate culvert size if your proposed water crossing structure is less than bankfull width.

Method A (Sizing Table Method) uses field-verified bankfull width and average bankfull depth and Table 3 to determine the diameter of the culvert. You may need a larger size to accommodate debris if the culvert diameter is less than bankfull width.

Method B (*Bankfull Width* Method) uses field-verified bankfull width at the stream crossing to determine the diameter of the culvert.

Method C (Hydraulic Design Method) is a hydraulic-based crossing design method that uses estimated stream flows. The size of the culvert is based on the local 100-year flood level calculations and the nomograph in Figure16. Use local knowledge of wood loading to appropriately size culverts for the passage of woody debris.

Table 2. Three methods to size Type N Water culverts

	Method A **Sizing Table**	**Method B** **Bankfull width**	**Method C** **Hydraulic Design**
Summary	Enter bankfull width and average bankfull depth into the culvert sizing table (Table 3).	Choose culvert diameter equal to or greater than bankfull width.	Calculate 100-year flow, determine culvert size using nomograph (Figure 16), and account for debris.
Complexity	Medium/Low	Low	High
Data Required	Measured bankfull width and average bankfull depth.	Measured bankfull width only.	100-yr flow (various methods and data requirements).
Analysis Required	Table 3	None	Peak flow calculation, use of nomograph (Figure 16).
Does Method provide for passage of debris?	No – needs additional consideration.	Yes	No– needs additional consideration.
Where to use	Where bankfull width and depth is easily determined. Where basin area and/or hydrology are uncertain.	When simplicity is required. Where bankfull width is clear, but depth uncertain. Where abundant mobile debris is present at the site.	Where hydraulic expertise is available. Where site-specific design and/or a non-round culvert are desired. Where bankfull width and depth is difficult to determine.

Table 3. Method A, culvert sizing table for Type N Waters

Bankfull width (BFW) in Feet	**Average Bankfull Depth in Inches**											
	3	6	9	12	15	18	21	24	27	30	33	36
1	*15	*18	24	30	--	--	--	--	--	--	--	
2	24	30	30	36	42	42	48	48	--	--	--	B
3	30	36	42	48	48	48	54	54	54	60	60	60
4	30	42	48	54	54	54	60	60	66	66	72	72
5	36	48	54	54	60	60	66	66	72	72	78	78
6	36	48	54	60	66	66	72	72	78	78	84	84
7	42	54	60	66	72	72	78	78	84	84	90	90
8	42	60	66	72	78	78	84	84	84	90	90	90
9	48	60	66	78	78	84	84	90	90	90	96	96
10	54	66	72	78	84	84	90	90	96	96	96	--
11	60	66	72	84	84	90	90	96	96	--	--	--
12	66	72	78	84	90	90	96	96	--	--	--	--
13	66	78	78	90	90	96	--	--	--	--	--	--
14	72	78	84	90	96	96	--	--	--	--	--	--
15	78	84	90	96	96	--	--	--	--	--	--	--
16	78	84	90	96	--	--	--	--	--	--	--	--
17	84	90	96	--	--	--	--	--	--	--	--	--
18	84	90	96	--	--	--	--	--	--	--	--	--
19	90	96	--	--	--	--	--	--	--	--	--	--
20	96	96	--	--	--	--	--	--	--	--	--	--

* See WAC 222-24-042(2) for details relating to size restrictions when installing culverts.

<u>Method A (Sizing Table Method)</u>

Step 1: Verify the stream is a Type N Water and then determine the bankfull width and average bankfull depth using methods shown in Board Manual Section 2 Standard Methods for Identifying Bankfull Channel Features and Channel Migration Zones.

Step 2: See the culvert sizing table (Table 3) to determine the diameter of the culvert. Consult with DNR for culvert diameters larger than 96 inches. For culvert sizes in the shaded areas of chart, it is recommended to use bridges, pipe arches, or open bottom culverts.

<u>Method B (Bankfull Width Method)</u>

Step 1: Verify the stream is a Type N Water. Measure the bankfull width in the field using the methods shown in Board Manual Section 2 Standard Methods for Identifying Bankfull Channel Features and Channel Migration Zones.

Step 2: Size the culvert diameter no smaller than bankfull width. *Note*: *This method may not be possible in areas that are difficult to accurately measure bankfull width.*

Method C (Hydraulic Design Method)

Method C is a hydraulic-based crossing design method that uses an estimate of stream flow for a 100-year flood level to size culverts based on a nomograph. Figure 16 is a nomograph for calculating sizes for round corrugated metal culvert pipes on Type N Waters.

Limitations to the use of Method C:

- Hydraulic design method assumes there is culvert inlet control. This is a condition where the hydraulic capacity of the culvert is limited by the inlet configuration. This generally occurs in culverts steeper than 2 percent with unrestricted outflow.
- Flow measurements of past 100-year flood level may be unavailable.
- Estimated 100-year flow volumes may be hard to predict because of rain-on-snow events and inaccurate calculations of basin size.

Step 1: Verify the stream is Type N Water. Then determine the flow volume of the 100-year flood event (q value on the nomograph in Figure 16) by:

- Using stream flow records from gauged streams.
- Estimating the 100-year flood level. Table 4 lists three methods to estimate stream flows for the 100-year flood level.

Step 2: Use the nomograph in Figure 16 to determine the culvert diameter:

- Select culvert entrance type (armored headwall, mitered to slope, projecting).
- Select maximum headwater to culvert diameter ratio (HW/D). Do not exceed 0.9 when using native soils for the fill. This will ensure performance without reliance on hydraulic pressure to pass storm events.
- Project a line from the Entrance Type bar through the Water Discharge bar (q) to arrive at a point on the Culvert Diameter bar (D).
- Round up to the nearest culvert diameter listed.
- Consider adding additional size to the culvert if debris is present in the stream.

Table 4. Three ways to estimate the 100-year flood level to be used with Method C Hydraulic Design.

	COMMENTS
Regression Equations Method Follow instructions at http://wa.water.usgs.gov/pubs/wrir/flood_freq/ Further information may be found at http://water.usgs.gov/osw/streamstats	Easy to use web-based method. Uses a prediction equation with a standard error of 37 to 77 percent. Best used for basins greater than 50 acres. Developed using lower elevation stream flow gauge stations that measured larger basin areas typical in forest culvert design.
Flow Transference Method Follow instructions at http://wa.water.usgs.gov/pubs/wrir/flood_freq/	Useful method when water-crossing structure is in or near a gauged basin. Transfers in-stream gauge station information to an un-gauged drainage area.
Rational Method Follow instructions in chapter 2.5 of the Washington State Department of Transportation's Hydraulics Manual at http://www.wsdot.wa.gov/Publications/Manuals/M23-03.htm	Uses rainfall intensity charts and equations to calculate flow for small basins less than 300 acres. Maps may be difficult to obtain for forested basins.

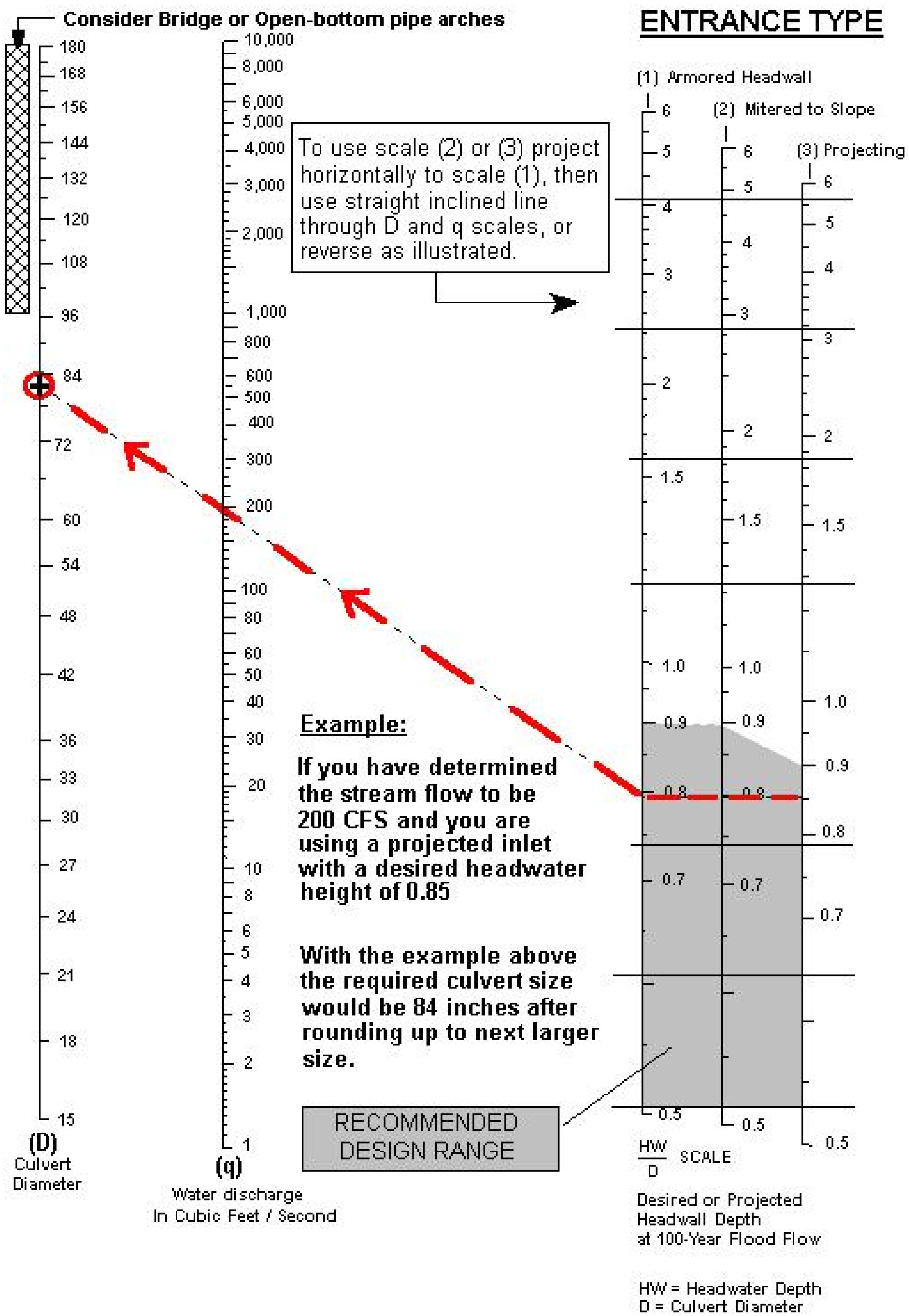


Figure 16 Nomograph for calculating sizes for round corrugated metal culvert pipe on Type N waters.

5.2 Construction BMPs for Culverts and Bridges

Minimizing the number of water crossings in the following locations will reduce road costs and risks to water quality and other public resources:

- In areas requiring steep road approaches.
- Across braided stream channels.

- On flat stream gradients immediately downstream of steep stream gradients. (These areas are susceptible to high sediment deposition.)
- In areas requiring deep fills.
- Immediately downstream of unstable slopes or landforms (see Board Manual Section 16 Guidelines for Evaluating Potentially Unstable Slopes and Landforms).

Figure 17 provides guidance for culvert design and installation that will reduce potential catastrophic failures due to debris (wood and sediment) blockages.

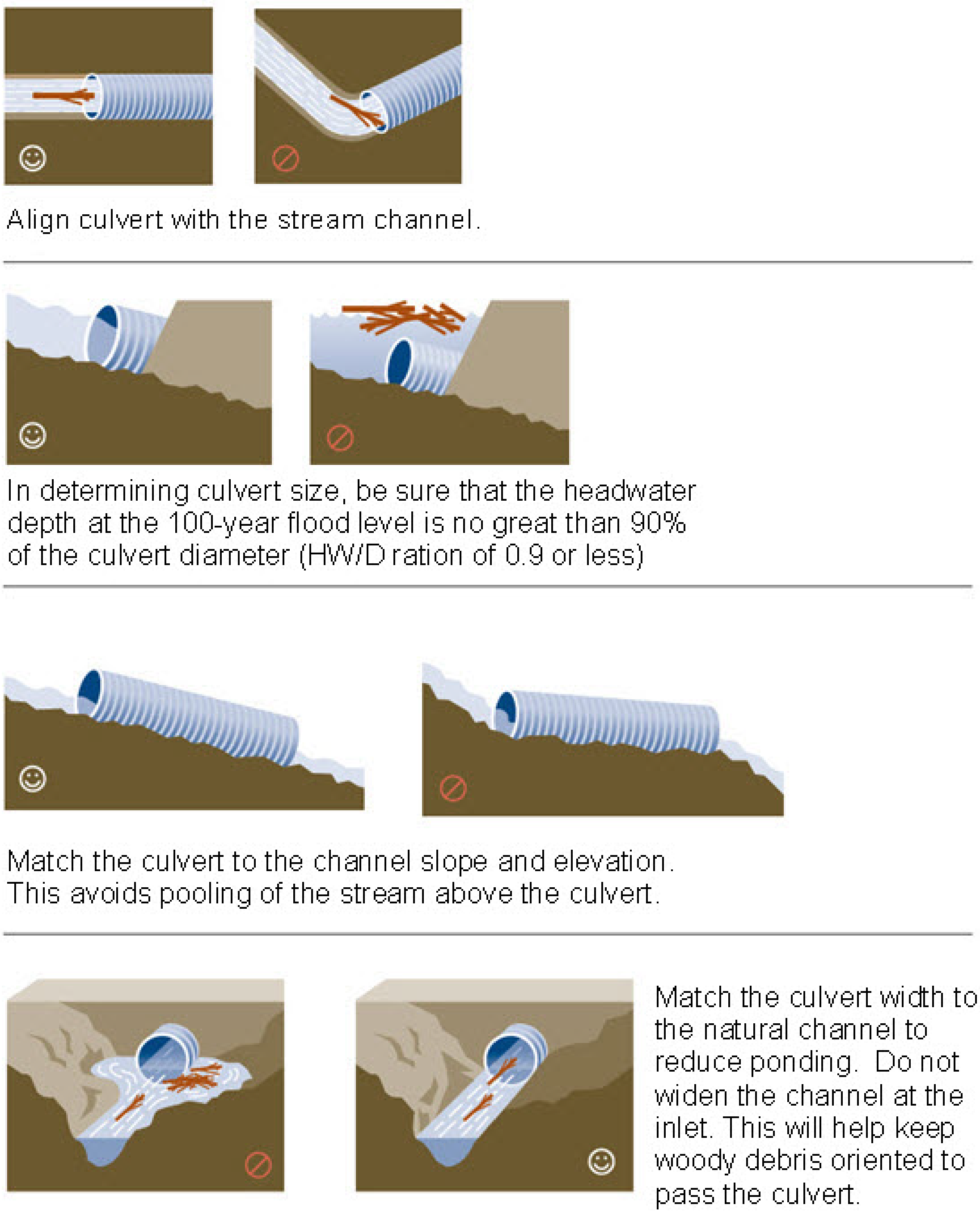


Figure 17 Design to prevent culvert plugging hazard

Deeper fills and streams with greater debris transport potential BMPs

Steeper gradient streams often require deeper fills over the crossing structure, increasing the amount of sediment that would be delivered if the fill fails. Steeper gradient streams also have the potential to transport more woody debris, increasing the risk of a plugged culvert. In these situations, where water is more likely to come over the road and cause fill failure, select the BMPs or other measures from the following list that best fit the local conditions:

- Construct an armored dip on the fill over the stream crossing structure. This reduces fill erosion potential and improves resistance to road failures resulting from high water flows and debris. Use coarse material, compact the fill, and armor with large rock.
- Dip the road grade and armor the fill to direct water onto stable vegetated ground within the natural drainage (see figures 19a and 19b).
- Outslope the road at the crossing.
- Construct an armored spillway at the intersection of the stream's gorge wall and the water-crossing fill.
- Place large riprap on the upstream fill slope and at the dip on the downstream fill slope.
- Install oversized culverts or *miter* the culvert inlet to improve flow characteristics and to help orient debris.
- Consider installing trash racks or debris deflectors above the inlet in channels with high debris transport.

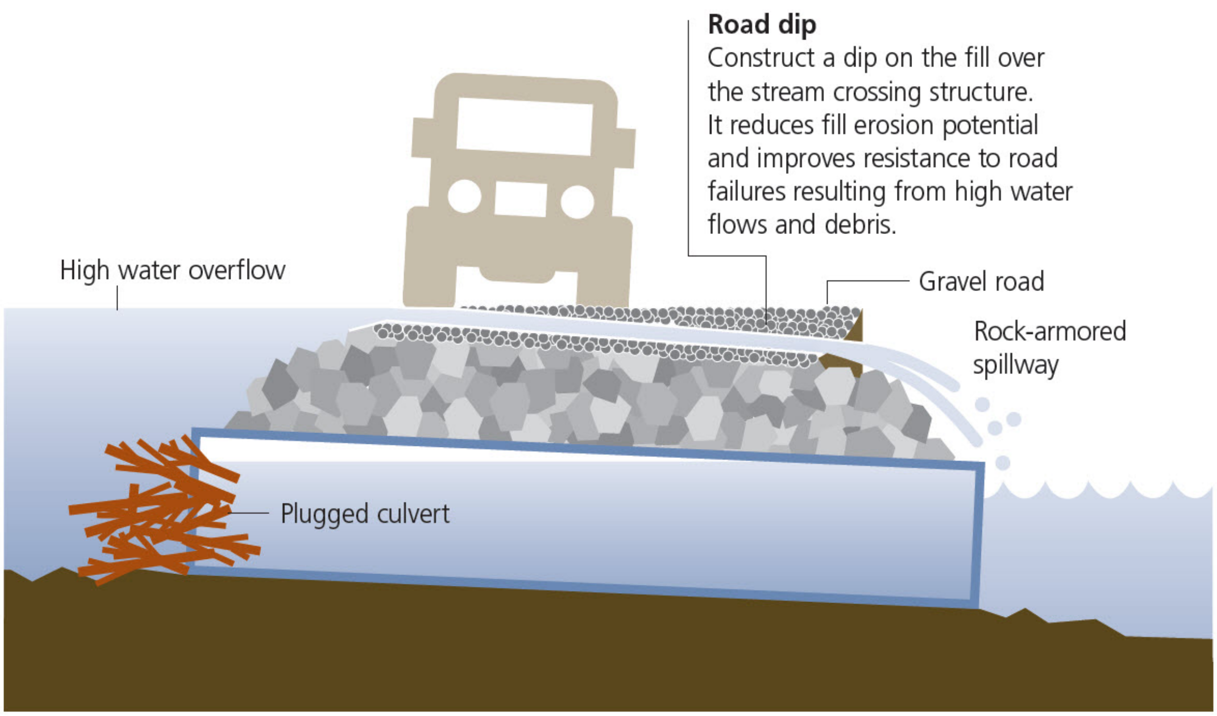


Figure 18a Armored relief dip design

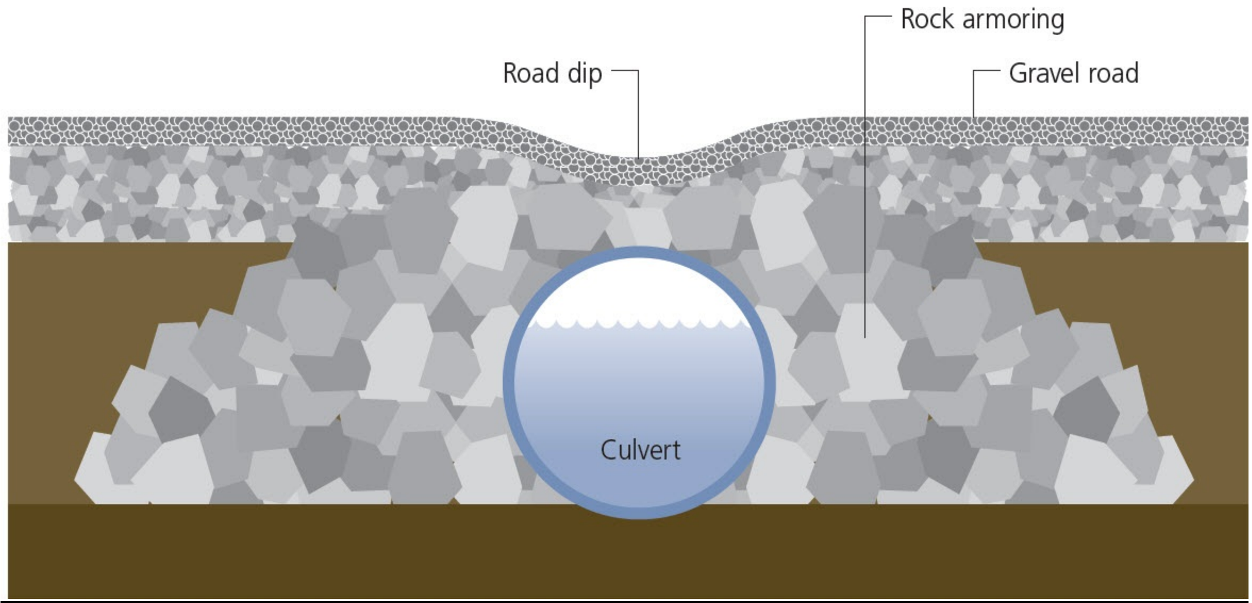


Figure 18b Armored Relief Dip Design.

Consider increasing the size of a crossing structure when**:**

- The crossing is in the rain-on-snow zone.
- The crossing is in a location where ice jams or anchor ice can occur.
- The stream contains large amounts of mobile debris (wood, gravel).
- The crossing is inaccessible during winter.
- The crossing requires deep fills.
- Crossing a flat, broad area with poorly defined channels.
- You are considering installing a new culvert with a diameter equal to or less than bankfull width.

Water crossing construction BMPs

- Cover culverts with adequate fill according to manufacturer specifications. This minimizes damage to culverts during road maintenance. It also distributes the weight of passing vehicles, preventing culverts from being crushed.
- Prevent stream flow erosion by sizing culverts adequately. Placement of riprap around the inlet and/or outlet of a culvert may also prevent erosion.
- Use erosion control measures to armor fills to minimize erosion and sediment delivery. See Board Manual Section 3 Guidelines for Forest Roads, 4.3 Erosion Control.
- For roads with natural surfacing, apply surface rock at culvert approaches.
- In areas where beavers are present, consult DNR and WDFW.
- Place slash and/or debris above the 100-year flood level outside of the riparian management zone or wetland management zone in a stable location except where the material is used to construct sediment filters on road fill slopes.
- When within a quarter of a mile from a fish bearing stream, consult with DNR and WDFW to determine if there is a need for a bypass structure during installation to divert flowing waters and prevent delivery of sediment to the fish bearing water.
- Ensure that the culvert is set and bedded at an even grade without a hump, belly, or curves.

Water crossing maintenance

Inspect all water crossing structures regularly and after storm events to ensure proper function. The following may indicate the need for maintenance or replacement:

- The stream flows regularly over the road.
- The stream flow is diverted from the culvert inlet and into the ditch.
- Severe erosion or scour within the ditch located downhill from the crossing.
- Stream flows diverted from the culvert inlet into another stream channel (basin).
- Streambed material accumulations at the culvert inlet.
- Down-cut channel bottoms and eroded stream banks occur immediately downstream of the culvert (outlet scour/drop).
- Erosion of the fill located above the culvert inlet.
- The culvert inlet is crushed or severely dented.
- The culvert inlet is damaged (inspect entire culvert to ensure it is fully functional).
- Sediment is delivering to typed waters.
- Evidence of head-cutting upstream of the water crossing structure.

5.3 Fords in Type N Waters

Fords are a type of water crossing where vehicles drive directly through streams. They have a high potential to generate and deliver sediment, and are only appropriate to use during periods of no or low stream flow. If flow conditions change, a ford crossing may no longer be an appropriate stream crossing method. Vehicular traffic should be isolated from flowing water whenever possible.

Fords may be suitable in the following circumstances:

- Where there is minimal vehicle traffic.
- In sites where access limits regular maintenance.
- Where variable stream widths exist from frequent landslides, debris flows, or ice flows originating upstream.
- When culverts or bridges are not an option because:
  - The crossing is too difficult to maintain.
  - High debris loading is present in stream channel.

Construction BMPs

- Fit the ford to the conditions on site (e.g., stream substrate and stream bank stability, stream width, depth and flow volume, lateral and vertical channel stability, flood frequency, debris loading).
- Install stabilizing material if the streambed does not have a firm rock or gravel base. Use reinforced concrete planks, crushed rock, riprap or rubber mats.
- Make sure equipment is in good working condition and doesn’t leak oil.
- Install ditch-outs or water bars on each side of the approaches to divert water away from the stream.
- Construct the ford so you can maintain it.
- Construct temporary fords to facilitate abandonment and site rehabilitation.

Maintenance BMPs

Streambeds are part of a dynamic system where storm events frequently change the streambed and stream banks. Fords should not require maintenance after every such event. If frequent or extensive maintenance is required, re-evaluate the use of the ford.

Maintain fords to:

- Keep road approach ditch-outs and water bars functioning.
- Minimize road surface runoff and control stream bank erosion. See Board Manual Section 3 Guidelines for Forest Roads, 4.3 Erosion Control.
- Prevent multiple approaches.

PART 6. WATER CROSSING STRUCTURE MAINTENANCE AND REPAIR

Even when water crossing structures exceed *channel bed width*, they can require maintenance to provide for the transport of water, sediment, and wood, and in Type S and F streams, the free passage of fish. Large storm events can create high stream flows that transport large quantities of sediment and debris that can quickly overwhelm a culvert inlet. Culverts and most bridges are not designed to withstand debris flows, dam break floods, lahars, etc. Typically, properly designed and installed water crossing structures survive these catastrophic events and with proper maintenance their transport functions can be restored. However, chronic maintenance situations are usually a symptom of undersized or poorly performing water crossing structures and replacement should be considered when repeated maintenance responses are required to service the crossing structure. Although bridge piers and abutments can require some maintenance following peak flow events, culvert maintenance is the most common maintenance activity.

Maintenance activities should be accomplished whenever possible during low summer flows to:

- avoid times when fish are spawning;
- reduce impacts to the stream channel and flow; and
- to simplify and expedite the maintenance activity by taking advantage of low stream flows.

In seasonal streams, it is always best to conduct maintenance activities when dry or non-flowing.

Water crossing maintenance activities conducted outside the normal summer operating season should be considered an “emergency situation” requiring an expedited response to protect the structure or the road, or restore fish passage. This action should only occur when the road, the stream, or fish are immediately threatened.

Maintenance and repair BMPs

Lengthening an existing bridge or culvert in a Type S or F Water is considered a new project rather than simple maintenance.

- Limit disturbance to the stream bank, stream bed, and riparian vegetation to that necessary to complete the maintenance or repair project.
- Where practical, accomplish work by hand or with hand-held tools in order to minimize disturbance to the stream.
- Stop work if fish are observed in distress, a fish kill occurs, or water quality problems develop.

- In Type S or F streams, the completed project must provide or maintain fish passage. This includes culvert repair activities.
- If the project is sufficiently large, bypass the stream flow to minimize disturbance to the stream and fish habitat. For additional guidance, see 4.3 Dewatering BMPs, and Part 9 Fish Capture and Exclusion.
- Operate equipment from the road, road shoulder, or bridge deck to reduce stream bank and riparian vegetation impacts.
- Clean equipment of soil, debris, and external petroleum products before working near the water. Also, inspect equipment daily for leaks and immediately repair it when detected. For additional guidance that may apply, see Equipment BMPs in Part 4.3.
- Restrict sediment removal from the culvert crossing to that necessary to restore flow through the structure and do not extend more than 25 linear feet upstream from the inlet or downstream from the outlet.
- Do not conduct sediment removal where fish are spawning or are known to spawn.
- Limit sediment removal to deepening the streambed; do not widen the streambed. Stream banks should not be modified or disturbed.
- Once the project is completed, the stream bed should not contain pits, *sumps* or depressions that can trap fish or create a fish passage barrier when water levels fluctuate.
- Relocate all excavated material to an approved waste site where it will not reenter typed waters unless directed otherwise by DNR.
- Relocate LWD whenever practical downstream from the culvert or bridge structure. See Part 10.3 Large Wood Placement, Removal or Repositioning for additional guidance.
- Remove and reposition debris in a manner that minimizes the release of bedload, logs or debris downstream.
- Repair culverts to restore their original, as-built condition, and provide unimpeded fish passage.
- Culvert repair may include headwall construction. Bridge repair may include replacement or installation of new bank armor. In all cases, limit rip rap installation to that necessary to protect the structure. See Part 10.4 Stream Bank Protection for additional guidance.
- When replacing bridge decking, do not deliver bridge parts to the stream. New decking material should not include creosote or pentachlorophenol.
- When painting a bridge, do not deliver paint chips or overspray new paint to the stream.
- Once the project is completed, protect the disturbed or exposed areas from erosion to ensure that fine sediment does not deliver to the stream.
- Depending on project scope and scale, re-vegetation or other activities may be necessary to restore the site to pre-project conditions. See Site Restoration BMPs in 4.3 for additional guidance.

PART 7. TEMPORARY CULVERTS

In general, temporary culverts are used for a limited time and when streams are at low flows. In some instances, and depending on the location, temporary culverts may be used for more than one season within the effective period of an FPA to extract timber or provide temporary access. However, temporary culverts left in place September 30 to June 15 need to be designed to pass fish and accommodate the *100-year flood level* and anticipated debris. In these situations, and when designed properly, temporary culverts will have a minimal effect on stream processes and fish habitat.

Temporary culverts should be designed and installed to:
- Minimize the disturbance to the bed and bank of the stream;
- Safely pass the flows and debris expected during the time they will be in place; and
- Provide passage for fish migrating in the stream for the time the culvert will be in place.

Temporary culvert BMPs
- Placement and timing limitations for allowing temporary culverts in Type S and F Waters is determined based on the species of fish present at the proposed crossing location.
- Maintain unimpeded fish passage in all fish bearing streams. The best crossing locations have a low approach elevation and a narrow stream channel.
- Locate the crossing where the stream is relatively straight and minimal riparian vegetation is growing on the bank.
- Place the pipe on top of geotextile fabric and cover it with clean fill to minimize disturbance and easily restore the bed and banks of the stream. Log puncheon can be used alone or in association with a culvert to pass expected flow.
- Maintain the temporary culvert throughout the life of the project.
- Remove the culvert, associated fill, including log puncheon, and geotextile material in a manner that restores the site to pre-project conditions.
- Remove temporary culverts and all road approaches, and block traffic by a predetermined date.

PART 8. WATER CROSSING REMOVAL AND ABANDONMENT

Road abandonment is the complete removal of bridges, culverts, fords, and associated fill, and the elimination or water barring of the connected roadways. For forest practices purposes, road abandonment is defined in WAC 222-24-052(3). Removal means a crossing is taken out with the intention of replacement at a later time. Both operations will re-establish fish passage, although the intended purpose of abandonment is to re-establish the natural drainage with no additional maintenance required.

Water crossing removal or abandonment should re-establish channel connectivity and the passage of fish if the stream is a Type S or F Water.

Generally, a water crossing removal should include:
- Creation of a channel that is similar in size and configuration to channel conditions upstream and downstream;
- A natural transition to the channel upstream and downstream of the crossing;

Properly abandoned road crossing

- Incorporation of large wood pieces, which can help expedite the restoration of the channel and fish habitat conditions. This wood is commonly available from trees removed from the road fill;
- Ensuring stable side slopes that do not exceed 2:1 unless matching the natural stream bank or valley walls; and
- Appropriate erosion control to address sediment delivery from exposed slopes.

Where water crossings are permanently abandoned, restoration of the channel and floodplain should include:

- Complete removal of the culvert or bridge support structures and all imported road fill material;
- Re-sloping of the banks to the original valley width, or at a minimum restoring the flood prone width of the stream to its natural capacity; and
- Re-vegetation and/or replanting of exposed stream banks or valley walls with native trees and shrubs to help expedite development of a functioning riparian condition.
- It is recommended that the road fill be excavated back to the flood prone width or the original valley width. This allows the stream to use its floodplain and re-establish the full riparian zone.
- In cases where the channel occupies a valley formed by glacial or fluvial processes far in excess of those present today (an *underfit channel*), it is recommended that the fill be pulled back to the flood prone width (the horizontal extent at a height of twice the bankfull depth).

Where water crossing removal is temporary and another structure is expected to be installed, the site may not require the same level of fill removal. In this case, water crossing removal should include removal of the culvert or bridge structure and associated fill. Typically, removal of fill should occur to at least *channel bed width* + 2 feet, or channel bed width x 1.2, whichever is greater. It is always preferable to pull fill back to at least the flood prone width (see Figure 19). In totally confined channels where channel bed width equals valley width, the fill removal need not exceed the channel bed width.

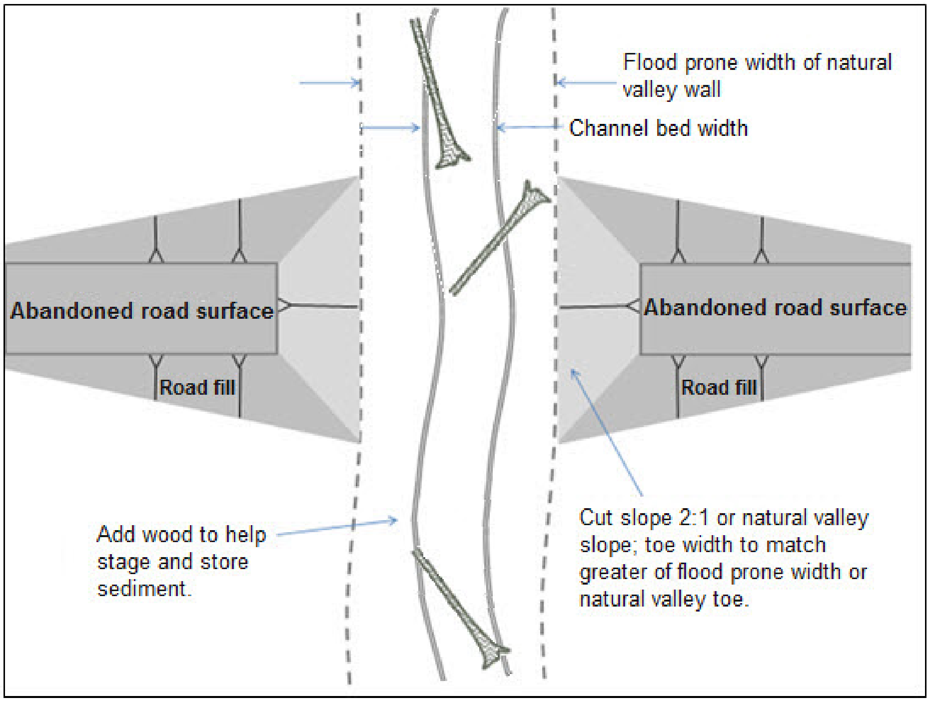


Figure 19 Plan view of road crossing abandonment showing excavation of road fill and placement of large wood when it is available on site and non-merchantable

When planning culvert removal, the overall drop through the culvert should be measured. The overall drop is the outfall height plus the vertical drop through the culvert (slope times length). See Figure 20. When the culvert is removed this overall drop will be expressed as a single vertical face at the inlet end of the excavation. This face will either regrade (downcut) or remain, depending on the height and the vertical face material.

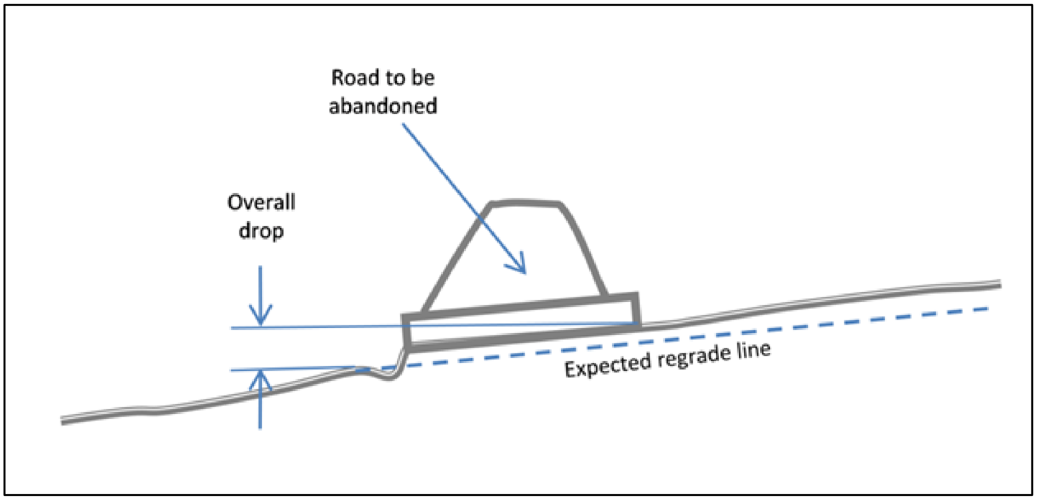


Figure 20 Profile view of road crossing abandonment showing the overall drop in water surface

When the outfall drop is moderate and the bed material mobile, the crossing can be abandoned and the regrade expected to resolve itself over time without repercussions. The concern is if the bed materials or the underlying soil or rock does not readily erode, there will be a distinct drop that can be a barrier to fish passage for a long time.

The following guidelines are recommended:

- If the overall culvert outlet drop is greater than one foot and the channel bed is composed of or underlain by soft or weathered bedrock, cemented glacial till, or hard clay, then the upstream bed should be excavated to form a continuous profile of a similar slope as the adjacent channel. A hard bedrock sill was probably present before the culvert was installed and will be the same challenge to fish passage as it was before. Adding wood and gravel from the fill slope to the excavation will improve channel recovery in this latter instance (shown in the upper profile in Figure 21).
- If the overall drop is less than 2 feet and the bed is gravel, then the culvert can be removed without further work done to the channel.
- If the drop is in excess of 3 feet, then the upstream channel should be regraded to form a continuous profile through the worksite and into the upstream channel (shown in the lower profile in Figure 21).

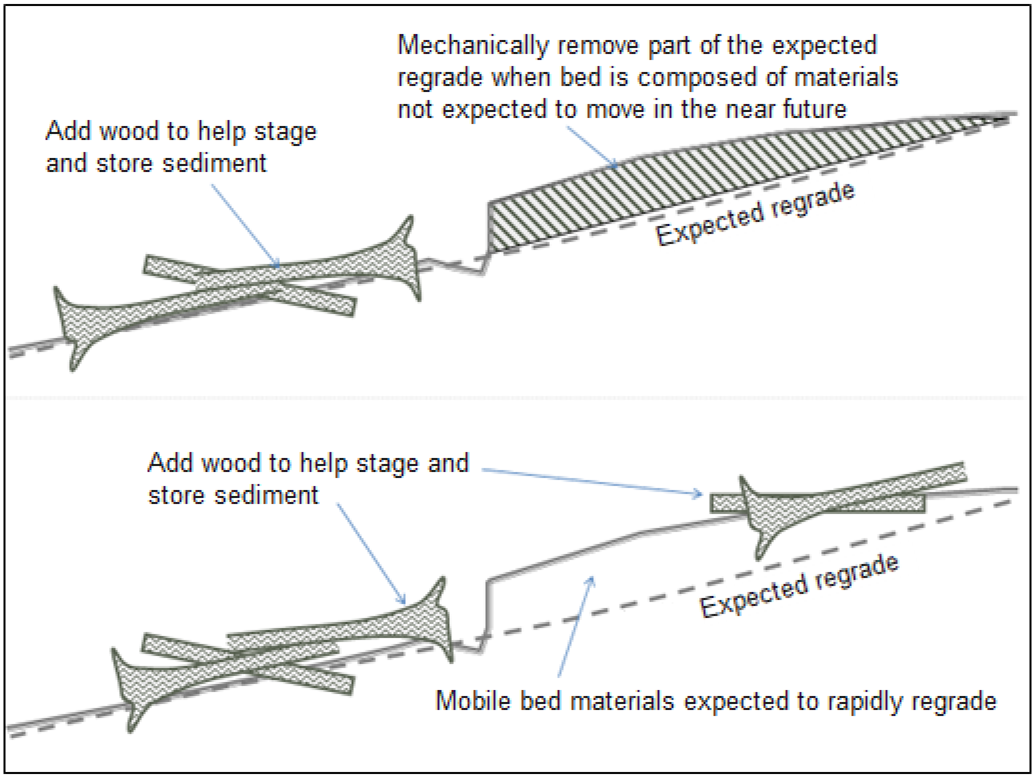


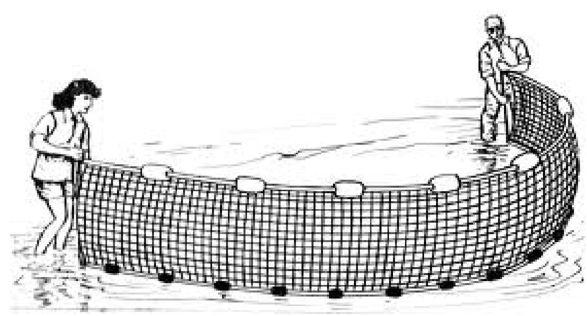
Figure 21 Stream profiles at road crossing abandonment sites showing two regrade treatments.

PART 9. FISH CAPTURE AND EXCLUSION

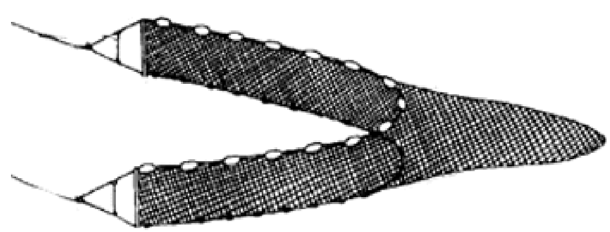
If personnel and resources are available, WDFW and affected tribes may assist with capturing and moving fish from the job site to free-flowing water. DNR can help identify affected tribes in a given area.

- Generally, work below the *channel bed width* should be conducted in isolation from flowing waters.
- In most cases gradual dewatering or bypass should be done in conjunction with exclusion of fish from the work site.
- All individuals participating in fish capture and removal should have training, knowledge, and skills in the safe handling of fish.
- A plan should be designed to consider the channel characteristics and size of the area to be isolated, dewatering methods (diversion with a bypass flume or culvert, sandbags, sheet pile cofferdam, etc.), and the sequence of activities that will provide the best conditions for the safe capture and removal of fish.
- If the stream is small, where seasonal flows are substantially diminished and conditions of elevated temperature or reduced oxygen may be present, fish should not be herded upstream.
- In rare instances fish may have to be relocated a greater distance up or downstream to ensure fish are not concentrated in areas where their habitat needs cannot be met.
- Concentrate fish where they can be easily seined but not where they may be stressed for more than 30 minutes.
- If flows within the work area are gradually reduced over the course of a day or longer, fish may move downstream on their own, preventing the need for capture and relocation. However, if there is sufficient cover such as that provided by a culvert, fish will not likely move, making capture and relocation necessary.

<u>Seining</u>



- If listed fish are present, dip nets and seines must be composed of non-abrasive nylon material.
- Fish capture using a seine net is the preferred method of fish capture.
- For easier capture and to minimize stress, use seines with a bag built into the net.
- Seining during low light conditions such as at dawn and dusk is most effective.



- Snorkeling to help herd fish, in conjunction with the use of a seine net, will improve the success of fish capture.
- Small net mesh sizes usually work best unless water velocities are high.

Baited minnow traps

- Baited minnow traps may be used in conjunction with seining.
- To minimize predation, check traps at least four times per day.
- If water temperatures exceed 15 C, traps should be checked more frequently.

Dip nets

- When gradually dewatering a job site, dip nets are an effective way to capture fish.
- Aquarium nets may work best in very shallow locations for small fish.

Work area isolation using block nets

Use of a block net

- If during the course of in-water work fish may re-enter the work area from downstream, a downstream block net should be installed.
- Select sites that exhibit reduced flow volume or velocity, uniformity of depth and good accessibility.
- Avoid sites with heavy vegetation, large cobble or boulders, undercut banks, deep pools, etc., due to the difficulty of securing and/or maintaining nets.
- Once the first block net is secured at the upstream end, a second block net should be used to herd fish downstream and out of the project area.
- Block nets will need to be composed of 9.5 millimeter stretched nylon mesh and installed at an angle to the direction of flow (not perpendicular to the flow) to avoid impinging fish in the net.
- To anchor block nets, bags filled with clean gravel should be placed along the bottom of the nets.
- Block nets must be secured along both banks and the channel bottom to prevent failure as a result of debris accumulation, high flows, and/or flanking.
- In order to keep fish out of the work site, block nets should be left in place until the work is complete and conditions are suitable for fish.
- Block nets require frequent inspection and debris removal and should be checked three times a day.

Using electrofishing equipment to capture fish

Electrofishing to capture fish

- Electrofishing should not be used unless other methods of removing fish are unsuccessful. Attempts to seine or net fish should always precede the use of electrofishing equipment.
- Electrofishing methods and equipment must comply with National Marine Fisheries guidelines: *National Marine Fisheries Service. 2000. Guidelines for electrofishing water containing salmonids listed under the Endangered Species Act*, http://swr.nmfs.noaa.gov/sr/Electrofishing_Guidelines.pdf.
- A biologist with at least 100 hours of electrofishing experience should be on-site to conduct or direct all electrofishing activity.
- Visual observation techniques such as snorkeling or surveying with polarized glasses may be used to assess effectiveness of fish removal from the site.
- In order to minimize the risks to both personnel and fish, use the minimum voltage, pulse width, and rate setting necessary to create the desired response (galvonotaxis).
- Use only straight DC or pulsed DC current; never use AC current.
- Use low setting for larger fish because they are more susceptible to electrofishing injury than smaller fish.
- Electrofishing should not be used where spawning adults or redds may be exposed to electrical current.
- Electrofishing should not be conducted under conditions of poor water visibility.
- In order to provide a higher likelihood of detecting fish and to reduce injury to fish, a second person with a dip net should be positioned to catch stunned fish before they become impinged in block nets or are lost downstream.
- Immediately remove captured fish from nets and electrical field, and either relocate them downstream or hold in appropriate containers.
- Keep water in holding containers cool and well oxygenated.
- Do not hold ESA listed fish listed in containers for more than 10 minutes, unless containers are dark-colored, lidded and fitted with a portable aerator.
- If dark bands are observed on fish, or signs of stress or injury are noticed, immediately reduce electrofisher settings.

Fish handling, holding, and release

- Plan and conduct fish capture and removal to minimize the amount and duration of handling.
- Ensure that those handling fish have clean hands free of lotion, sunscreen, insect repellent, and other harmful substances.
- Ensure that capture buckets, coolers or holding tanks are maintained with clean, cold, well-oxygenated water.

- Captured fish should be held in containers that are large enough to avoid over-crowding of fish.
- Report any ESA listed fish accidentally killed as a result of fish capture and removal operations.

Reintroduction of flow and fish into isolated work area

- Reintroduce flows gradually into the isolated work area to prevent channel bed or bank instability, excessive scour, turbidity, or sedimentation.
- Make sure each fish is capable of remaining upright and actively swimming prior to release.
- Consider fish habitat characteristics such as flow, temperature, and cover when selecting locations to release fish.

PART 10. OTHER COMMON HYDRAULIC PROJECTS

10.1 Beaver Dam Removal

Beavers play an important ecological role in creating and maintaining ponds and wetlands for fish and wildlife habitat, as well as improving water quality through stormwater and sediment retention. Where beaver activity occurs in narrow bands of riparian habitat, it is often compatible with the management of forested uplands. However, beaver activity can negatively impact water crossing structures. Beaver impacts are often controlled through trapping to keep populations from reaching nuisance proportions. Beaver dam removal is an FPHP. For information or authorization related to beaver removal through trapping, go to http://wdfw.wa.gov/licensing/trapping.

When beavers build dams at bridges or culvert inlets, the pond created by the dam can result in a collapsed or compromised water crossing structure or a flooded stream-adjacent haul road. When the dam impounds a Type N Water, its removal can simply be accomplished in a manner that prevents a sudden release of scour-force flows and/or sediment or debris. When dam removal impacts a Type F or S Water, additional impacts must be considered. Beaver dams that do not pose an imminent threat to roads are to be left undisturbed.

Beaver dams should be removed or modified only when:

- The continued existence of the beaver dam poses an imminent danger as defined in to RCW 77.55.011(12) to the integrity of bridge piers, culverts, or roads; and
- The beaver dam has been in existence for one year or less. Older dams will be considered on a site-specific basis.

Beaver dam removal BMPs

- Avoid dam removal when fish are spawning or when spawning habitat is within 300 feet of the dam. Consult with WDFW for the appropriate work window.
- Leave large wood (>12 inches diameter and ≥6 feet length) in place or move it downstream of the crossing.
- Leave LWD imbedded in the stream bed or banks undisturbed.
- Remove and dispose of smaller limbs and bark debris where they will not re-enter the stream or be available for further beaver activity.
- Streambed or bank excavation, or channel realignment, are not authorized.
- Do not use explosives.

- Remove the dam by hand or with hand tools. Chain saws or vehicle winches may be used to dislodge some of the debris, provided siltation to the downstream areas can be held to a minimum and impacts to *fish life* avoided.
- Station large equipment needed to remove the dam on the bank. However, if equipment is used, it should be operated from the roadway, the road shoulder, or the crossing structure to minimize disturbance to the stream banks and riparian vegetation.
- Remove the dam and debris in a manner that results in a controlled, slow release of impounded water. Down-ramping of the water should not result in stranding fish, or cause damage or erosion to the stream bed or banks.
- Ensure that equipment is free of external petroleum-based products while working near the water.
- Take extreme care to ensure that no petroleum products, hydraulic fluid, sediment-laden water, chemicals, or any other toxic or harmful materials are allowed to enter or leach into the stream.
- Inspect dewatered areas to ensure fish are not stranded. If fish are stranded, capture and move them to the nearest free-flowing water.
- Minimize damage to stream-adjacent vegetation. Re-vegetate disturbed areas and protect against erosion.
- An alternative to removing a beaver dam may be to install a structure like a beaver deceiver which will allow stream flow through the landowner's structure without eradicating the animal. For more information on preventing beavers from plugging culverts, see http://www.wdfw.wa.gov/living/beavers.html.

Mitigating for unavoidable impacts for beaver dam removal or modification

- Possible impacts should be considered on site and may include:
  - Loss of pool habitat.
  - Removal of habitat forming wood from the channel.
  - Possible scour of downstream channel if difficulty implementing BMPs is encountered, resulting in uncontrolled, rapid releases of impounded water.
- Potential mitigation measures:
  - Repositioning or installation of large wood downstream of the beaver-influenced infrastructure.
    - Installed or repositioned wood should be a minimum of 12 inches in diameter and 6 feet in length.
    - Wood should be placed so as to interact with stream flow.
    - Wood should be placed so as not to create fish passage barriers.
    - The total number of installed pieces should be determined on a case by case basis, and should be proportionate to the size of the stream.
  - Planting of appropriate species within the riparian zone formerly inundated by beaver activity.

10.2 Logging Cable Suspension Activities

In the simplest case, this activity category refers to the suspension of logging cables across fish bearing waters to establish tailholds in locations that facilitate "lift" or deflection for tower logging activities. Increased lift results in less soil disturbance during upland logging activities, as well as improved logging safety. A more complex case includes the suspension of payloads (cable yarding) across fish bearing waters. This facilitates landowner access to properties on both sides of a stream where terrain, ownership boundaries, or timber type lines preclude environmentally sensitive road access alternatives.

General BMPs applicable to all cable crossings across streams
- Fully suspend logs transported across Type S or F Waters so no portion enters the stream or damages the bed and banks.
- When changing tailholds over Type S or F Waters, move the lines over or around leave trees and riparian vegetation prior to re-tightening. Suspend cables at a height that minimizes damage to riparian vegetation during yarding activities.
- Do not fell tees into or across Type S or F Waters. However, if this does occur, leave the tree where it entered the water. Do not disturb large woody material in place prior to logging.
- With each cable road change, remove and dispose of limbs and other small debris that enter the stream during logging activities where they will not re-enter the stream.
- Stop cable logging activities if sedimentation occurs in Type S or F streams until the proper erosion control measures are put in place.

BMP applicable to cable suspension only (i.e., not involving timber yarding)
- Work across Type S or F Waters is allowed year-round and limited to the placement, suspension, repositioning, and removal of cables over the stream.

BMPs applicable to yarding timber over streams
- Year-round yarding across Type S or F Waters is allowed when the logs are fully suspended over the trees within the RMZ and the stream.
- Use yarding corridors if full suspension over the trees within the RMZ is not achievable.
- Yarding across Type S or F Waters is generally appropriate from June 1 through September 30 when fish are not spawning. However, consult WDFW for specific spawning timing.
- To maintain the integrity of the riparian zone, yarding corridors must be no wider or more numerous than necessary to accommodate safe and efficient transport of logs. Use natural openings where practical.
- Use the equipment and methods that minimize the number of corridors and RMZ impacts such as skyline yarders with drop-line carriages or other lateral yarding capabilities. For DNR to assess RMZ impacts, provide yarding profiles and the number and locations of proposed corridors in the FPA.
- Use directional felling techniques to fall corridor trees away from the stream channel unless directed by DNR. Leave riparian trees on site.

Mitigating for unavoidable impacts associated with cable suspension through Type F riparian buffers with removal of riparian trees
- Possible impacts should be considered on site and may include:
  - Loss of riparian function.
- Potential mitigation measure:
  - Felling of timber into riparian buffer or across stream (if appropriate) for possible recruitment by stream.

10.3 Large Wood Placement, Removal, and Repositioning

Large wood is an essential component of the stream system both in terms of biological diversity and structural complexity. It maintains channel stability and provides shelter for fish from high flows and predators. Large wood traps sediment that can create spawning habitat and provides a medium for aquatic insect production. In forests, wood is typically placed or repositioned as part of an FPHP, either for mitigation purposes or simply to complete the project. It is often necessary to remove or reposition large wood from the channel that is threatening an existing structure such as a bridge pier or a culvert. In these cases it is always best to retain the wood in the stream system if possible. This can be accomplished by relocating the wood downstream from the structure, but not if it could jeopardize downstream structures.

Large wood placement, repositioning or removal BMPs

- Only remove large wood from a stream where necessary to address safety or infrastructure concerns.
- Relocate large wood removed for maintenance or to reduce infrastructure risk downstream whenever possible so as not to reduce the large wood loading in the stream.
- Incorporate relocated large wood into the channel to provide stable, functional fish habitat. This may include placing channel-spanning logs, creating log jams, or introducing a single large log or rootwad to the channel.
- Lift and elevate above the stream when removing and placing large wood to minimize disturbance to the stream bed or banks.
- Leave large wood embedded in the bank or bed undisturbed and intact unless authorized for removal or repositioning.
- Activities should not occur where fish are spawning, or where spawning beds (redds) are visible or documented. Consult with WDFW for spawning and incubation location and timing.
- Remove unattached limbs, bark, and other small woody debris from the stream and place in a location where it will not reenter the stream.
- Large wood repositioning should not result in the release of stream substrate, logs, or debris downstream from the project that could impact the channel, impair fish habitat, or threaten other infrastructure.
- Large wood repositioning should be conducted to avoid or minimize damage or disturbance to the bed, banks, or riparian vegetation.
- Level depressions in gravel bars resulting from the wood repositioning that could strand fish.
- Operate equipment used for repositioning from the road, bridge surface, or road shoulder whenever feasible to reduce disturbance to the stream bank or sensitive riparian vegetation.
- For mitigation purposes or large wood enhancement projects, use the largest wood available, preferably cedar or Douglas fir, with attached roots and a length that will exceed the channel width. If the large wood is without attached roots, the wood length will need to exceed the channel width in order to remain stable in the stream.

10.4 Stream Bank Protection

A bank protection structure is constructed to protect a stream bank from anticipated erosion or to stabilize an eroding stream bank. For forest practices purposes, this activity is typically associated with forest road or water crossing structure protection.

Water crossing bank protection is commonly applied under bridges to stabilize banks and protect abutments and soils around culvert inlets as headwalls to guard against scour and/or stabilize road fill material. Stream bank protection is typically restricted to the water crossing structure site and is relatively simple.

Protection of forest roads is more complicated and involves careful planning and design. It requires a clear understanding of why the erosion is occurring based on some knowledge of stream channel dynamics (for example, the channel migration, channel configuration, and stream energy). This understanding will influence the bank protection design or the decision to simply move the road away from the stream.

It is highly recommended that landowners review WDFW's guidelines regarding channel processes, site assessment, and bank protection solutions in the *Integrated Streambank Protection Guidelines* (Cramer et al. 2003) at http://wdfw.wa.gov/publications/00046/wdfw00046.pdf . Landowners are also encouraged to consult with DNR and WDFW prior to submitting an FPA for bank protection projects that involve stream-adjacent road protection.

Guiding principles for stream bank protection along stream adjacent parallel roads

- Natural erosion processes and rates are essential for ecological health of the aquatic system.
- Human-caused erosion that exceeds natural rates is usually detrimental to ecological functions.
- Natural processes of erosion are expected to occur throughout the channel migration zone (CMZ). Project considerations should include the CMZ and potential upstream and downstream effects.
- Preservation of natural channel processes will sustain opportunities for continued habitat formation and maintenance.

Stream bank stabilization will alter the bed and banks and the physical processes that form and maintain fish habitat. Direct impacts to habitat may include loss of hiding cover, spawning beds, large woody material, riparian function, and channel alteration that decreases complexity and diversity of fish habitat. Therefore, it is usually best to relocate the road or other structure away from the eroding bank to allow natural channel functions to continue. If relocation is not possible and bank protection is necessary, then it should be designed and installed in the least impacting way.

Bank protection methods are either hard approaches utilizing rip rap, concrete, or timber, or soft approaches that incorporate biotechnical methods and materials such as live plantings, root wads, and LWD to mimic natural stream processes. Biotechnical approaches are preferable to hard approaches and should be considered first. Additional mitigation may be necessary if a hard approach is selected. Such mitigation may include the addition or incorporation of root wads, LWD, or other biotechnical elements such as plantings and soil lifts into the bank protection structure.

Stream bank protection BMPs

- Conduct a site and stream assessment to help understand the failure mechanism(s): toe erosion, scour, mass failure, avulsion, etc.
- Determine the level of risk to both the stream and the stream-adjacent road associated with the options:
    - No action; move the road
    - Soft armor

  - Hard armor
- Attempt to utilize soft protection methods. Consider riparian plantings in combination with LWD placement or log jam installation, soil lifts, etc.
- Restrict the bank protection project to the work necessary to protect the eroding banks.
- Restrict the bank protection footprint within the channel to the minimum necessary to protect the toe of the bank, or for the installation of mitigation features approved by DNR.
- Do not disturb or remove LWD that is embedded in the channel or banks except where unavoidable and/or where DNR authorizes removal.
- Design and install the toe of the structure to protect the integrity of the bank protection materials. In other words, use sufficiently sized rock or logs keyed for stability, and bury them below the scour elevation to serve as a foundation to hold the entire structure in place.
- Slope and configure the bank to a stable configuration; rock slopes should not exceed 1.5:1; soft armor should not exceed 2:1 (expressed in run over rise).
- If rip rap is utilized for bank protection material:
  - Conduct the project so spoils and overburden material are retained on the bank face and do not enter the stream channel. Use angular rock to maximize integrity and install to withstand 100-year flows.
  - Do not use rounded material or river rock as it does not provide a stable configuration.
  - Operate equipment from the top of the bank whenever possible to minimize impacts to the stream or channel.
  - Do not end dump rip rap but rather individually place the rock to interlock the material into a stable structure.
  - Protect from erosion all exposed or disturbed areas with the potential to deliver sediment using wheat straw blankets, fabric, wood chips, etc.

<u>Mitigating for unavoidable impacts associated with stream bank protection</u>

- Possible impacts should be considered on site and may include:
  - Disconnecting the stream from its floodplain and/or CMZ (when present) resulting in accelerated velocities during flood flows.
  - Hardening of banks or simplification of bank texture, resulting in reduced energy dissipation, accelerated velocities, and potential scour of the channel and adjacent banks.
  - Channel simplification resulting in loss of spawning and/or pool habitat.
  - Removing habitat forming wood in the channel or banks to install bank protection.
- Potential mitigation measures:
  - Repositioning or installing large wood downstream of or adjacent to treated sections of bank.
    - The total number and size of installed pieces should be determined on a case by case basis and should be proportionate to the size of the stream. For guidance on appropriate placement piece diameters, please see Board Manual Section 26 Guidelines for Large Woody Debris Placement Strategies.
    - Wood should be placed so as to interact with stream flow.
    - Wood should be placed so as not to create fish passage barriers.
  - Planting appropriate vegetation species on disturbed areas within the project limits.

10.5 Other Hydraulic Projects

Hydraulic projects covered in this Board manual commonly occur on forest land in association with other forest practices activities and are regulated by DNR. Occasionally, hydraulic projects may occur on forest land that fall under WDFW's jurisdiction and are regulated under the Hydraulic Code rules (chapter 220-110 WAC). Forest landowners should contact WDFW and DNR for guidance on best management practices and permitting processes for these hydraulic projects, including but not limited to:

- channel change and realignment
- dredging in fresh water areas
- outfall structures
- tide gates
- bulk heads
- salt water bank protection
- conduit crossings

GLOSSARY

“Aggradation” means the geologic process by which a streambed is raised in elevation by the deposition of additional material transported from upstream.

"Bankfull width" means:

(a) For streams - The measurement of the lateral extent of the water surface elevation perpendicular to the channel at bankfull depth. In cases where multiple channels exist, bankfull width is the sum of the individual channel widths along the cross-section (see board manual section 2).
(b) For lakes, ponds, and impoundments - Line of mean high water.
(c) For tidal water - Line of mean high tide.
(d) For periodically inundated areas of associated wetlands - Line of periodic inundation, which will be found by examining the edge of inundation to ascertain where the presence and action of waters are so common and usual, and so long continued in all ordinary years, as to mark upon the soil a character distinct from that of the abutting upland.

“Channel bed width”, for the purposes of the guidelines in this board manual, is defined in the text box in Part 4.2.

“Fish life” means all fish species including but not limited to food fish, shellfish, game fish, and other non-classified fish species and all stages of development of those species.

“**Forest practices hydraulic project**” (FPHP) means a forest practices activity that includes the construction or performance of work that will use, divert, obstruct, or change the natural flow or bed of any Type S, F, or N Water. Stand-alone proposals involving channel change and realignment, dredging in fresh water areas, and constructing outfall structures are not forest practices hydraulic projects and remain governed by chapter 77.55 RCW and chapter 220-110 WAC.

“Invert” means the bottom of the culvert.

“Mitered culvert” means a culvert that has the inlet or outlet cut to fit the angle of the fill slope.

“Nick point” means an abrupt change in gradient in the stream profile such as a waterfall, typically due to a change in rate of erosion.

“No-net-loss” means:

(a) Avoidance or mitigation of adverse impacts to fish life; or
(b) Avoidance or mitigation of net loss of habitat functions necessary to sustain fish life; or
(c) Avoidance or mitigation of loss of area by habitat type.

“Protection of fish life” means the prevention of loss or injury to fish or shellfish, and the protection of the habitat that supports fish and shellfish populations.

“Sump” means a low or recessed area created for collecting water or sediment. Sumps are created to capture water when pumping or acting as filtration.

“Unconfined stream” means a stream with a 100-year floodplain width greater than two times the channel width. Typically, channel confinement is a description of how much a channel can move within its valley before it is stopped by a hill slope or terrace (Rosgen 1996). Unconfined channels can display visible changes in channel characteristics when flow, sediment supply, or the supplies of roughness elements such as LWD are altered. These areas are commonly referred to as response reaches, and usually possess an active floodplain.

“Underfit channel” means a stream that appears to be too small to have eroded the valley in which it flows; a stream whose volume is greatly reduced or whose meanders show a pronounced shrinkage in radius. It is a common result of drainage changes affected by capture, glaciers, or climatic variations.

“Vented ford” means a crossing structure where relatively frequent overtopping is expected, but where the driving surface is elevated some distance above the streambed. Culverts (vents) allow low flows to pass beneath the roadbed.

“100-year flood level” has the same meaning as “flood level – 100 year” in WAC 222-16-010:
"Flood level - 100 year" means a calculated flood event flow based on an engineering computation of flood magnitude that has a 1 percent chance of occurring in any given year. For purposes of field interpretation, landowners may use the following methods:
(a) Flow information from gauging stations;
(b) Field estimate of water level based on guidance for "Determining the 100-Year Flood Level" in the forest practices board manual section 2.
The 100-year flood level shall not include those lands that can reasonably be expected to be protected from flood waters by flood control devices maintained by or under license from the federal government, the state, or a political subdivision of the state

RESOURCES

American Iron and Steel Institute. 1994. *Handbook of Steel Drainage & Highway Construction Products*.

Bates, K. M. et al. 2003. *Design of Road Culverts for Fish Passage*. Washington Dept. of Fish and Wildlife. http://wdfw.wa.gov/publications/00049/wdfw00049.pdf

Cramer, Michelle et al. 2003. *Integrated Streambank Protection Guidelines. Washington Department of Fish and Wildlife*. http://wdfw.wa.gov/publications/00046/wdfw00046.pdf

National Marine Fisheries Service. 2000. *Guidelines for electrofishing water containing salmonids listed under the Endangered Species Act.* http://www.westcoast.fisheries.noaa.gov/publications/reference_documents/esa_refs/section4d/electro2000.pdf

Rosgen, D., Ed. (1996). Applied River Morphology. Pagosa Springs, CO, Wildland Hydrology.

Sali-Caromile, Kay et al. 2012. *Stream Habitat Restoration Guidelines. Washington Department of Fish and Wildlife*. http://wdfw.wa.gov/publications/01374/

Washington Department of Ecology. 2012. Stormwater Management Manual for Western Washington. http://www.ecy.wa.gov/programs/wq/stormwater/manual.html

Washington Department of Ecology. 2004. Stormwater Management Manual for Eastern Washington. http://www.ecy.wa.gov/programs/wq/stormwater/easternmanual/manual.html (Eastern Washington)

West Virginia Department of Environmental Protection. 2013. Pebble Count. http://www.dep.wv.gov/WWE/getinvolved/sos/Pages/SOPpebble.aspx

Western Wood Preservative Institute. 2012. http://www.wwpinstitute.org/aquatics.html

Wolman, M. G. 1954. A method for sampling coarse riverbed material. Transactions of the American Geophysical Union. 35(6): 951-956.