Draft Methodology Report: *For the Clear and Foster Creek Fish Passage Assessment and Prioritization Project*

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[Note these three pictures will be replaced with Clackamas photos for final report]

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Executive Summary

The purpose of this report is to describe the methods that will be used for the Clear and Foster Creek fish passage assessment and prioritization project. The reason for explicitly describing the actual methods used this early in the project is to allow the Clackamas River Basin Council (CRBC), Technical Advisory Committee (TAC), and other concerned parties to comment on the methods before the project gets too far along. This report is divided into the following components:

- Key Start-up activities: These include the creation of a base map with potential crossings and creating the framework for databases and coverage for geographic information systems (GIS) to input data from field surveys and other sources into. From this base map there are a total of 147 crossings of which approximately 35-40 have previously been surveyed by the county or other sources. It also includes a framework for asking for landowner permission to get site access and information. Also included is a summary of other fish passage data in the Clear and Foster Creek basins from county, private and federal sources and how this data will be incorporated into the assessment.

- Field protocol: This section reviews field protocols then creates a draft of the methods used to measure fish passage and other characteristics in and around stream crossings. The field protocol used here is more involved than those used in similar assessments because the objectives include creating correction strategies and costs for each dysfunctional crossings along with simply determining its fish passage status. There are also methods given for two protocols. The more streamlined protocol may be used for low priority culverts or for county culverts that have already had several key measurements already taken.

- Barrier determination – hydraulic analysis: This section gives methods/criteria used for determining if a crossing is a barrier based on field collected data in and around the culvert. The overall stream flow capacity of the existing culvert will also be determined and compared to peak flows expected and along with other factors will help determine failure risk.

- Conceptual designs and cost analysis: Based on the information given from field measurements the most desirable replacement strategy will be determined from criteria given in this section. The decision criteria takes into account the feasibility of the proposed structure in relation to the local channel and road conditions at the crossing. The listing of feasible replacement corrections include:

- Long span steel and pre-stressed concrete bridges: This option is usually for larger streams greater than 15-20 feet in width. This is most expensive option, but can work on all stream types.
- Short span concrete slab bridges and open box culverts with concrete T footings: This option for high gradient stream reaches with or without bedrock in profile. Spans can reach to 20 feet so this precludes their use on wider streams.
- Open arch metal culverts with footings: This option is useful for streams with bedrock at or near the streambed surface. They are usually used for higher gradient narrower streams reaches.
- Closed bottom metal culverts using streambed simulation: This option works well for 0-8% gradient streams where the crossing has adequate headroom and adequate valley fill to sink the culvert into stream.

If several options are feasible at a crossing the estimated lowest cost strategy will be chosen. The components for several conceptual designs are given in this section along with estimates of cost for replacement/correction for existing structures. Costs are estimated using a variety of sources including overall material and labor cost guides as well as cost information from actual case studies. More weight will be given to actual case studies because the general cost guides do not always account for the difficulties encountered in working in and around fish bearing streams and in providing materials that can bear significant loads in difficult placement. More information is being sought regarding various options and costs at this time so this section is likely to be refined significantly between now and the final product.

- Prioritization: This section outlines the method used for prioritization of replacement crossings for the Clear and Foster Creek basin. A review of other prioritization schemes will be given, but a case is made for a custom prioritization strictly formed around the objectives of key stakeholders and characteristics of the basin in question. The prioritization method used for this project takes into consideration the fish passage status of a crossing, the length and quality of habitat available upstream of a crossing, the connectivity of the crossing with the Clackamas river mainstem, and the cost of the correction, as well as other factors. This custom prioritization for Clear and Foster should be expected to work well in the greater Clackamas basin because the objectives and fish species present are similar.

- Timeline for completion: This section will outline key milestones and dates and timing of tasks and products for this project.

Finally, it must be stressed that these methods will not be finalized until the actual tasks are preformed during the process of the assessment/prioritization activity. If changes are sought in these methods the timeline can be examined to see if there is time to change and modifications can be made. We also expect that some of the finer points regarding conceptual designs and costs along with specific weighting of factors in prioritization will be modified as the process continues.

Introduction

Stream channel crossings by roads have been the cause of serious losses of fish habitat due to improperly designed culverts. Beechie et al.,)1994) estimated the loss in fish habitat from culverts on forest roads as high as 13% of the total decrease in coho salmon summer rearing habitat in a large river basin in Washington state. This percent decrease in summer habitat was considered greater than the sum total effects of all other forest management activities combined. Conroy (1997) reported that as many as 75% of culverts in given forested drainages are either outright blockages or impediments to fish passage based on field surveys done in Washington state (). Surveys of culverts for county and state roads have found hundreds of culverts that at least partially block fish passage (Al Mirati, Oregon Department of Fish and Wildlife (ODFW), Personal Communication 3/99).

Because blockage of fish passage is associated with a loss in habitat for spawning and rearing adult and juvenile fish, fish passage issues can be a focal point of watershed restoration. Assessment and prioritization are critical in locating and then deciding which of the numerous fish passage issues should be worked on first with limited watershed restoration resources. There are numerous approaches to assessing and prioritizing culverts. Assessment methods range from crude (basic ODFW method in Robison et al. 1999) to more quantitative methods (Washington Department of Fish and Wildlife (WDFW), 2000; Robison et al. 2000; or Taylor and Love, 2001). Each of these field methods differ in the types of measurements because the objectives for and uses of these measurements are different.

Likewise there are several methods emerging for prioritizing culverts. Some methods are largely qualitative (Robison et al. 1999). Some methods sum a number of factors (e.g. Clackamas, county method; Clackamas County Fish Passage Technical Team, 2001). Others methods multiply factors (WDFW, 2000). Some use a combination of methods (Taylor and Love, 2001). In the early stages of this art there is room for improvement for determining how to weight factors or if a factor should be additive or multiplicative. Because different stakeholders will have different priorities and different basins will have different target fish species, each major stream basin would probably be best served by a unique prioritization fitted to the priorities and conditions of the basin.

Because the Clackamas basin in general and the Clear and Foster basins in particular have a unique mix of species and priorities, this Draft Methodology Report (DMR) will take elements from several different methods for fish passage assessment and proirtizations and combine them to meet these needs. In specific after consultation with several basin stakeholders the overriding objectives for this project seems to be:

- Create an assessment and priority scheme for correction of stream road crossings that gives adequate information to justify the acquisition of grant or other funding efforts to take corrective actions on the most pressing needs. This system should take both local and watershed wide issues into account in developing priority and cost information.

This DMR outlines the elements of this overall objective and then develops assessment and prioritization methods around this objective custom fit to the unique characteristics of the Clear and Foster Creek basin. In particular the DMR outlines methods for:

- determining fish bearing streams and road crossings for this project;
- developing a landowner permission process to gain access to sites and develop understanding, acceptance, and support among this key stakeholder group;
- developing a field assessment protocol and fish passage analysis methods tailor made to fit into design cost analysis and prioritization methods;
- developing conceptual designs of likely replacement or corrective actions for culverts not providing fish passage; and
- creating a prioritization scheme that takes into account local and watershed factors as well as design and cost information.

In addition there is a detailed time-line to provide information on to when each task will be done.

Key start-up Activities

The two key start-up tasks that are being worked on concurrently with the development of the DMR is the upgrade to the map coverage to better determine fish use extent and the development of a landowner permission process scheme. The latter is extremely important as previous comprehensive assessment efforts have been damaged by lack of permission to assess fish passage status for key crossings in the assessed basin (David Evans and Associates, 2001).

Upgrade Map Stream Coverage and get updated list of potential crossings

With a major change to the Forest Practices Act in 1994 came a mandate to determine the fish presence/absence of all forested streams on state and private forestlands. Fish use is being determined by a fish presence/absence protocol that requires careful fish sampling during appropriate seasons of maximal fish use extent (ODF and ODFW, 1995). Before this mandate fish bearing status and protections ended at the upstream boundary of what were called “class one” streams. These streams had known significant fish use, however it was well known that there was often fish use upstream of the boundary. In order to better understand fish use on streams, Oregon Department of Forestry (ODF) conducted surveys on several townships in Western and Eastern Oregon in 1992-93 (ODF, 2001). From these surveys several criteria were developed that approximate the end of fish use for small forested streams (Table 1). Since Clear and Foster Creek belong to the “interior georegion,” upper extent of fish use is approximated by streams with 100 acres watershed area or by map or GIS determined slopes of 20% or more. Currently, these fish use transitions are being upgraded on the Clear and Foster Creek stream GIS coverage for streams that do not have the confirmed end of fish use. In addition, the “physical survey” field criteria in Table 1 and actual fish presence observations will be recorded to further upgrade the coverage throughout the field season.

Once the fish use extent is upgraded then a listing of all potential stream road crossings will be developed along with a map with a unique number for each crossing (Appendix A).

Table 1: Summary of interim process for determining approximate upstream extent of fish use (from ODF, 2001).

Type of Barrier		**Physical Survey**		**Map Analysis**
Falls & Chutes		Salmon & Steelhead	Resident Trout	Any waterfall marked on a map.
		8'+	4'+	
		2'+ require a jump pool 1.25 times the fall or chute height.		
Channel Steepness	With Pools	30' or more @ 20%+	20' or more @ 20%+	20%+
	W/O Pools	30' or more @ 12%+	20' or more @ 12%+	
Lack of Livable Space		No pools approximately 12" or more in depth during spring spawning.		60 Acres or Less (Coast 80 Acres or Less (South Coast) 100 Acres or Less (Interior) 300 Acres or Less (Siskiyou) 350 Acres or Less (Blue Mountain and East Cascade)

Landowner Participation and permission process

The Clear and Foster Creek fish passage assessment is a unique endeavor in that it will attempt to assess the total population of potential fish passage barriers within both basins. This includes potential barriers that are on private land. Most fish passage assessments are conducted by an agency or individual company that, through a commitment to common goals and objectives, has achieved internal agreement about the process and potential results. Though a convenient and logical approach based on organizational hierarchies, this method ignores the natural boundaries of watersheds and therefore, leaves the basin-wide challenge of achieving fish passage unresolved.

Public landowners in the Clear and Foster Creek basins are already involved, to varying degrees, with the proposed basin-wide fish passage assessment process. Individuals representing most public landowners in the basins have helped formulate project goals and have had an opportunity to express their desired outcomes for the project. The coordination challenge for this particular assessment, because of its watershed boundary focus, will be gaining the understanding, acceptance, and support of private landowners so that they participate in the process.

"Private land" encompasses a wide range of ownership types, management objectives and owner perceptions. In the Clear and Foster Creek basins, these include private timber companies, small woodland owners, nurseries, Christmas tree farmers, large agricultural farmers, hobby farmers, private homeowners, and development owners. To gain cooperation and earn acceptance for the fish passage assessment, each of these private interests must be approached in a manner that addresses its unique concerns.

Though most landowners will share the same concerns, some will weigh the potential for regulatory action more heavily than others, while others will regard the potential for financial costs as their primary issue. Others may simply resent the intrusion of a public process on their land holdings. For each instance there should be a public outreach tool that will provide the information they require to engage in the process.

The goals for reaching out to private landowners are:

- Gaining trust
- Education
- Involvement

Trust is an important part of a productive, long-term relationship. The consulting team recognizes that by actively implementing the fish passage methodology within the Clear and Foster Creek basins, we will be representing the CRBC in person. Trust that has been built through hard work and time by the CRBC must be maintained, and additional degrees of trust fostered through clear and honest communication and display of actions. Communication methods that will foster trust are discussed below.

Direct interaction with private landowners either through personal meetings on their property and/or discussion of methods, findings, results, and solutions is an excellent opportunity for education about fish passage and habitat issues. The consulting team actively embraces sharing our technical knowledge with basin stakeholders whenever it is solicited. We also hope to gain the local and site-specific knowledge from the landowners that they have acquired through long-term experience, observation, and training. We will encourage this exchange wherever possible. The CRBC stands to gain from continued personal interactions in the basin as well and the consultants will make every effort to formally transfer information contributed by landowners to the Council.

Through project involvement, the consultants hope that a greater interest in the objectives, actions, and goals of the CRBC will be fostered with private landowners and that this interest will continue beyond the scope of this particular project. Watershed councils are made up of concerned, interested local volunteers. Any positive contributions that the consulting team can make to increasing landowner participation within the Council will be encouraged.

To meet the fish passage assessment outreach goals, the outreach objectives related to the assessment are to:

- Establish contact and introduce the project
- Educate and exchange information
- Gain permission to examine potential fish passage barriers on the ownership
- Communicate results

Contact and Introduction

The first step will be to let landowners who have potential fish barriers on their property know that the fish passage assessment is occurring, who will be conducting it, why it is being conducted, how it will be conducted, where it will be conducted, when the consulting team would like to conduct it, and what the potential outcomes of the process will be.

Using the GIS data layers already assembled for the Clear and Foster Creek Basin Watershed Assessment, we will query private properties that contain potential fish passage barriers (accomplished by overlaying stream and road layers with tax lot information). Using the list of landowners generated by this process, we will send out a postcard (under development) to each, describing, in a concise format, the information above. Included in this postcard will be contact information for the CRBC, including the CRBC website address. Because GIS-based queries are only as good as the information they query and rarely is all information perfect, these postcards will also be taken into the field to leave with landowners who were missed but may own land with potential fish barriers.

A few days after the postcards have been received, Jenny will begin to personally contact landowners by phone based on their basin location and the sampling prioritization of the potential fish barrier on their property. The purpose of this phone call will be to answer questions and to gain permission to access their land. If necessary, Jenny will continue the contact and introduction phase by visiting the landowner. Though possibly not necessary from an information exchange or introduction perspective, personal visits can generate a high degree of trust which facilitates the permission process.

Jenny will engage in other general forms of introduction by contacting local agency outreach experts including those from the Soil and Water Conservation District, Oregon Department of Fish and Wildlife, Farm Bureau, Oregon State University Extension, and Oregon Department of Forestry to coordinate communication and project goals. She will work with the CRBC to create a press release to send to local Clackamas newspapers announcing the project and informing landowners of the ongoing field work. She will also contact grange hall organizers and hang flyers in grange halls and local grocery stores or other community gathering places.

Education and Information Exchange

This phase is a continuation of the Contact and Information phase. Through personal contact and the CRBC website, Jenny and George will provide background information on the goals and objectives of the fish passage project, the need for the project, and the expected outcomes of the project. Personal contact, either over the phone or in person on-site, will offer excellent opportunities to learn from the landowner in terms of what they have observed in local fish populations, how they have managed for fish passage, local flooding history, and what their concerns and goals are related to fish passage and road maintenance. This landowner information will be recorded and, depending on its relevance, communicated directly to the CRBC, shared with the WPN watershed assessment team, and/or included in the fish passage final report.

In coordination with the CRBC, Jenny will provide information to the CRBC website to create a 24/7 fish passage project information resource. Website pages will provide more detailed information on the importance of fish passage for fish habitat and long-term basin survival, what constitutes barriers to successful fish passage, how fish passage barriers can be remedied, what the basin hopes to accomplish in terms of fish passage, the relationship of this project to the Oregon Plan, contact information, and eventually results. While the consulting team is actually out in the field, there will be weekly or more frequent updates of where the consulting team is in the field and where they expect to travel next. After field work is completed, Jenny will post the timeline for the expected final report along with any evolving information related to Phase 2 of the project.

Access Permission

Gaining access to private land is critical to the success of this fish passage project. Via initial contact made through postcards and phone calls and with the assistance of local basin experts from various agencies, the consulting team hopes to receive landowner permission to 100% of the potential fish passage barriers on private land. A critical aspect of this phase will be clear communication of what the results of the survey will be used for. The consulting team will strongly emphasize the non-regulatory nature of this survey and the economic benefits that a thorough survey can offer in terms of selecting the lowest cost option necessary to successfully achieve long-term fish passage.

As needed, we will also focus on the community nature of this project in that no landowner or type of ownership is being singled out. Rather, all basin residents are contributing to its outcome and success. We will also appeal to the landowners' sense of place and pride in their basin by discussing the importance of fish passage for healthy fish populations throughout the basin, the understood historical reach of fish within the basin, and the unique opportunity this effort is offering to the Clear and Foster Creek watersheds to serve as a role model for similar Oregon Plan efforts.

While on site, the consulting team will remain highly aware that we represent the CRBC. As such, we will arrive as scheduled (if arrangements have been made), communicate clearly and honestly with the landowner if the opportunity arises, complete our work as quickly as possible taking only the information necessary to complete the survey, and leave no evidence of our efforts except those communicated to the landowner. We will provide business cards and other requested contact information if the landowner desires.

Results Communication

In terms of public outreach, the final tasks of a project such as this one are as important as the initial contact phases. Interested landowners will want to know what became of the information collected on their land. Providing clear and open communication of results is a critical element of fostering long-term trust and participation in the process. In addition, landowner feedback solicited at presentation meetings will be critical to improving the methodology and process for the larger basin-wide fish passage assessment. This point will be emphasized in the course of the Clear and Foster Creek basins presentations.

The website will be extremely useful for communicating results and posting notices of public meetings to discuss results. If possible, meetings should be scheduled to coordinate with similar meetings being held for the presentation of the watershed assessment process. In addition, Jenny will work with the CRBC to create a press release to send to local newspapers announcing the project results and the public meetings. If necessary, postcards may also be sent out at the close of the project to thank landowners for their cooperation and to inform them of where they can obtain the results.

Field Protocol

The field protocol will be divided into two levels of measurements:

- Detailed protocol: for most culverts gives enough information to do detailed cost and design analysis; (Many of the elements of this protocol are adapted from Dent, 1999) and

- Fast Protocol: for some lower priority culverts if the number of culverts field surveyed becomes greater than the time allotted on contract. The cutoff point is about 125-150 culverts. Low priority status will be for culverts that have minimal upstream habitat and are not well connected downstream (i.e. have blocking culverts downstream or are at a great distance from the mainstem). The current estimate there are 147 culverts in the Clear and Foster Creek basin on fish bearing streams with 35-40 culverts being on county ownership and previously surveyed. This estimate may change as field verification is conducted on these crossings. Based on the current estimate, the fast protocol will not be used on lower priority culverts because there are few enough culverts to do the detailed method on every one. This fast survey will also be done for previously surveyed county culverts. The fast protocol for these culverts will fill in essential missing information not taken in previous survey.

Detailed protocol

The detailed protocol consists of the following measurements. The form and abbreviated code sheet are given in Appendix B.

Crew Name – Name of crew member(s) taking measurements

Crossing Number – A unique number for each crossing surveyed taken from developed base map.

Stream Name – Taken from maps. If no-name creek then state what creek it is tributary to (such as "Trib. to Bear Cr.")

Road Name/ID - The road name should be the name by which the road is best known. This can be a proper name or number. If the name is unkown it can be named after a landmark (perhaps after a nearby stream, harvest unit, or ranch).

UTM/GPS – The coordinates of the culvert will be recorded using a recreational grade global positioning system (GPS). The GPS reading can be compared to those developed by GIS to check accuracy and if at right location.

Photo documentation: #1 looking upstream with potential outlet drop in photo, #2 inside the barrel looking upstream, and #3 looking downstream at inlet. These photos can be invaluable when unsure of recorded data for one reason or another.

Structure Information Measures

Crossing Type (code):

	RC	Round Culvert (Closed bottom structure, CBS)
	PA	Pipe Arch (CBS)
	OA	Open-Arch (Open bottom structure, OBS)
	BR	Bridge
	FD	Ford
	OB	Open Box (OBS)
	LG	Log Culvert (OBS)
	BX	Box or rectangular (CBS)
	OT	Other

See Table 2 for descriptions regarding these types.

Culvert Measurements CBS and OBS

Structure size - Diameter (in) and length (ft) for round culvert,
- Rise and span and length (in, in & ft) for arches,
- Span (ft) for bridge or ford.

***Culvert Elevations**:* Measured with a transit level. Crew will record the elevations at the (a) road surface at mid road, b) inlet invert, (c) outlet invert, (d) low point of a downstream pool and (d) the crest of a downstream riffle or weir (Figure 1). By dividing elevation difference between inlet and outlet by culvert length the culvert slope can be determined as a check of the quality of the measures. The riffle or weir/riffle crest should be within 2-4 channel widths of the culvert outlet in distance. For a description of culvert characteristics see Figure 2.

The amount of outlet drop is the difference in elevation between the downstream weir crest and the invert elevation at the outlet. Backwater and culvert depth calculations can be done with these elevations as well. Where the culvert inlet is beveled, care must be taken to ensure that the measured culvert length corresponds to the length over which the transit level measurements were observed. All elevations should be relative to a base elevation given at the road surface. The difference between the road surface elevation and the average elevation of the culvert inlet and outlet represents the fill height. All these parameters can be calculated on a spreadsheet.

Culvert condition: will be described as:

GD good,
MD mechanical damage,
RS rusted, bottom out,
CL collapsed or
OT other (specify).

***Footing condition*:** for open-bottom structures **(OBS)** will be described as

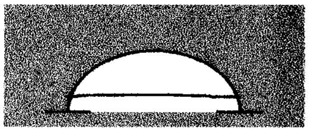
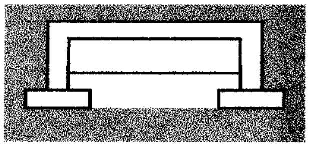
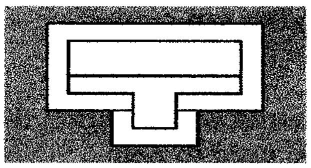
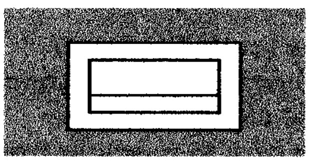
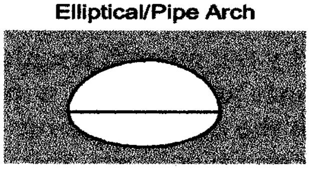
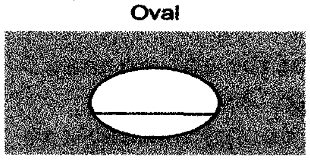
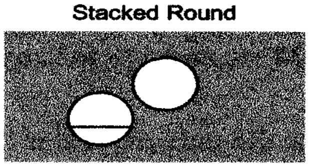
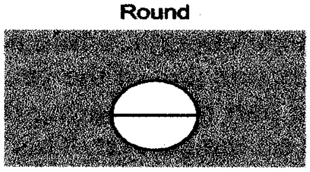
ST Stable (no scour near edges)
ER Eroding (scour near edges but OBS not cantering or deforming)
FL Failing (scour plus deformation)

Downstream Weirs

Downstream weir type	GW	Gabion weirs
	RW	Rock weirs
	WD	Woody debris
	WR	Wood and rock
	NO	None
	OT	Other, explain

Note: Mitigation structures are installed downstream of culverts to back water into the culverts or to retain sediment. If there is water backing at least into the outlet of the weir a channel cross-section should be taken of the downstream riffle or weir similar to that done for bridges below. In fact the length and depth measurements for bridges form can be used for this with proper notation for what it is for in making comments on the form.

Table 2. Culvert types (taken without modification from Parker, 2000)

Type of culvert	Fisheries considerations	Hydraulic considerations
Open Bottom Arch 	• If properly designed and installed it does not limit fish passage. • Retains natural stream substrate. • Water velocity not significantly changed.	• Wide bottom enables passage of high flows while minimizing increases in flow depth. • Large waterway opening for low clearance installations.
Open Bottom Box 	• If properly designed and installed it does not limit fish passage. • Retains natural stream substrate. • Water velocity not significantly changed.	• Can be designed to maintain normal width of the stream channel.
Trough Box 	• Can be designed to provide fish passage. • Trough concentrates water maintaining fish passage even at low flows. • Baffles can easily be installed.	• Can be designed to maintain normal width of the stream channel. • Trough can fill with bed load material and create a maintenance problem.
Box 	• Acceptable for use with approved design in stream channel. • Limits fish passage during low flow due to decreased flow depths. • Baffles can easily be installed.	• Can be designed to maintain normal width of fish-bearing streams.
Elliptical/Pipe Arch 	• Acceptable for use with approved design in fish-bearing streams. • Can be designed to retain some stream substrate. • Wide flat profile makes it possible to improve fish passage by backwatering the structure.	• Wide bottom of culvert enables passage of high flows while minimizing increases in flow depth. • Large waterway opening for a low clearance installation.
Oval 	• Avoid use in fish-bearing streams or incorporate appropriate design modifications. • Represents a compromise between pipe arch and round. • Stream substrate not easily retained in culvert.	• Squat profile useful in low fill situations. • Shape results in deeper water depth than pipe arch, but does not offer as broad a bottom area.
Stacked Round 	• Allows for fish passage during a wider range of flows than a single culvert.	• Same hydraulic properties as type of single culvert used (e.g., round, box).
Round 	• Avoid use where fish passage is important. • Incorporate approved design modifications to permit fish passage. • High velocity and other hydraulic properties greatly discourage fish passage. • Baffles are difficult to install.	• Generally constricts stream width and creates high flow velocities with increased chance of scour. • Concentrates water during low flows.

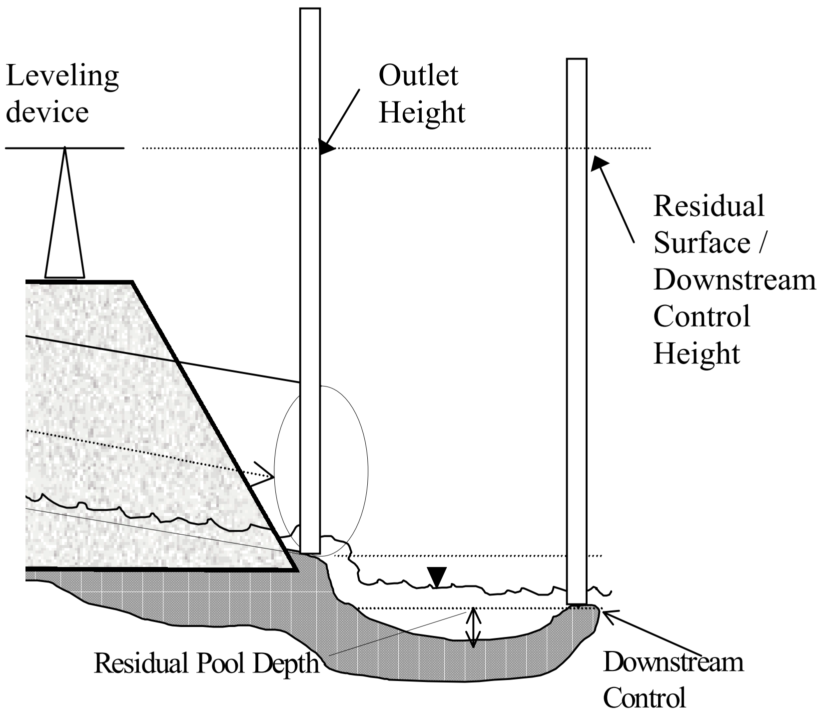


Figure 1. Residual pool schematic using downstream weir height (Robison et al., 2000)

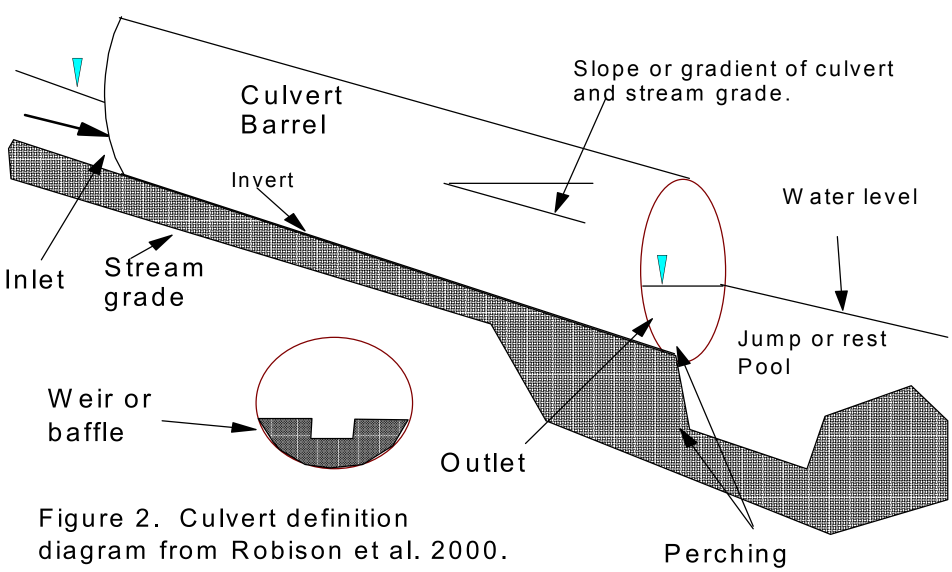


Figure 2. Culvert definition diagram from Robison et al. 2000.

Weir Condition:	ST	Stable
	BE	Bank erosion around structure
	UC	Actively undercutting structure
	SD	Sediment deposition behind structures has filled to elevation of outlet
	OT	Other (explain)

***Weir Dewatering*:** Yes or No (Y/N) is the weir dry on its crest at time of measure.

Backwatering (ft): Length of backwatering within the pipe due to outlet mitigation at the time of measurement. This is used as a check against the relative elevation measures taken above. If you show a relative elevation of a downstream weir as greater than that of the inlet elevation of the culvert and the culvert has no backwatering even when water is flowing, there is something wrong with the elevation measurements.

Weir drop (in): Measured from the residual water surface of the structure to the residual water surface below the structure. If more than one structure (multiple weirs) there will be a measure between each structure.

Distance between outlet mitigation and crossing (ft): Measured from the outlet to the mitigation structure. If there are multiple structures crew will document average distance between them and their number.

Embedded or Streambed Simulation Designs

Sediment pattern (code): For natural-bed or countersunk structure designs give a qualitative description of how material is arranged in the structure. Use NA for structures that are not designed to collect sediment (baffled culvert, bridge).

SS	Simulated streambed (channel type forms such as bars and sinuosity, material contiguous bed material)
CR	Contiguous rock fill (rock contiguous throughout the structure)
IN	Contiguous rock fill in culvert except within 1-3 meters of the inlet which is bare or has sparse rock cover.
SR	Sparse rock fill (rock in culvert but not contiguous)
NM	No material in culvert
NA	Not applicable

Bed material in Structure (code): For embedded or streambed simulation designs document the predominant size of material (listed in Table 2) for the length of the crossing. There may be more than one but no more than three. Use NA for structures that are not designed to collect sediment (baffled culvert or culvert placed flat) and NO if there is no material in the culvert.

Depth of embedding at outlet (in): Measure the difference in elevation between the average surface of the embedded streambed and the invert within the first 0-10 feet from the culvert outlet. When the culvert is deeply embedded you can measure/determine diameter or rise of culvert and then measure opening height and subtract to get the embedding depth.

Depth of embedding culvert barrel (in): Measure the difference in elevation between the average surface of the embedded streambed and the invert of the culvert in the interior of the culvert beyond the inlet area and outlet area.

Depth of embedding culvert inlet (in): Measure the average difference in elevation between the average surface of the embedded streambed and the invert of the culvert within the first 0-3 meters distance of the culvert inlet.

Table 3. Codes used for size classification of material used in road fill armor, road surface armor, stream crossing structures, and channel substrate (Kaufmann and Robison, 1998).

Code	Material	Size description
BD	Bedrock	Bigger than a car/continuous layer (>12 ft)
BL	Boulders	Basketball to car-sized (1 foot – 12 feet)
CB	Cobble	Tennis ball to basketball (3 inches – 12 inches)
GR	Gravel	Ladybug to tennis ball (0.1 inches – 3 inches)
FN	Fines	Silt/clay muck to visible particle; gritty - sand
NO	---	None
NA	---	Not applicable

Inlet Measures

Inlet opening (%)**:** As compared to design opening area. Estimate the percent opening left as compared to an undamaged inlet.

Inlet design (code)**:**

- NM Not mitered.
- MI Mitered
- OT Other

Inlet Drop (Yes/No): Note if there is an inlet drop. An inlet drop is when the bed of the stream upstream of the culvert is at greater elevation than the invert or simulated bed/embedded bed of the culvert.

Baffled/embedded culverts:

Baffle design:

WB	Weir baffles
OF	Offset weir
PW	Porior design notch weir (Notch weir angled 45^{o} downstream.)
NW	Notch Weir
SR	Sediment Rack
OW	1 Outlet Weir only
MW	Multiple weirs (downstream from culvert outlet)
OT	Other
NO	None

If none is the answer the next measures/estimates can be skipped.

Distance between baffles/weirs (ft)**:** Average for multiple weirs.

Distance between last baffle and outlet (ft): Measured from the base of the last baffle to the outer edge of the culvert.

Height of Baffle (in): Measured at the highest point of the baffle above the invert of the culvert.

Depth of Baffle Notch (in): Measured from top of baffle to base of notch.

Road Fill Measures

Road Fill Armor (code)**:** Using the codes in Table 3 classify the size of material used for armoring the road fill on the upstream and downstream side of the crossing.

Bridges:

Please note bridges will not be measured unless serious visual indicators of abnormally narrow span as compared to stream width is encountered causing a potential fish passage problem.

Bridge Type:

LS	Log stringer
RR	Railroad Car
MI	Metal I-beam
CC	Concrete
OT	Other Describe in comments

Bridge Span (ft)**:** Measured from one side of the stream to the other (Figure 3).

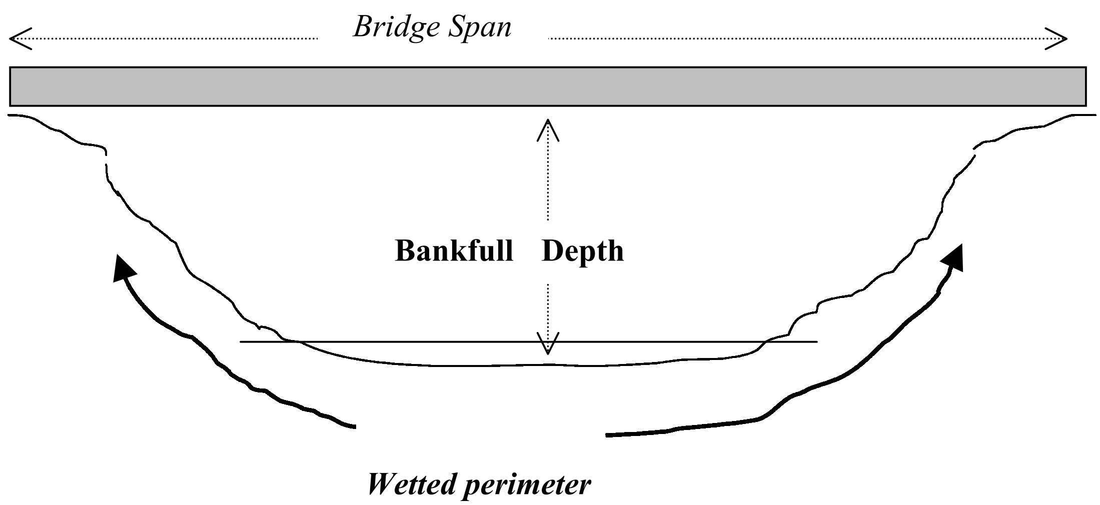


Figure 3. Schematic of measurements needed for calculating flow capacity of bridge design (from Dent, 1999)

Opening depth **(ft):** Measured from channel bed to the bottom of the bridge (this measure will be used to calculate wetted perimeter and cross-sectional area) every 15 cm on streams with a wetted width less than 3 m and every 30 cm on streams 3 m and greater.

Increment (in): Record the increment used to measure depth. This will be in equal distances from the left bank. Use increment of 15 cm or 30 cm based on stream width as outlined above.

Bridge Footing condition**:** Described as:

ST	Stable (no scour near edges)
ER	Eroding (scour near edges but OBS not cantering or deforming)
FL	Failing (scour plus deformation)

Ford/Dam Measures

Fords will only be measured if they are hardened and creating a noticeable drop of high velocity stretch along their length. Generally speaking these should be rare measurements. Likewise, dam measurements should be rare but are important because of their potential to disrupt fish passage.

Jump (in): Measured from top of hardened ford or diversion dam to residual water surface.

Residual Pool Depth (in): Measured at the deepest point in the pool downstream of the for or dam when present to the residual water surface (See Figure 1).

Material Size used for the ford <u>upstream</u>, <u>at the crossing</u> and <u>downstream</u> of the ford or dam (code)**:** Characterize the size of material in each location as described in Table 3. There can be more than one but no more than three.

Road surface condition**:** Describe the section of road draining into the stream crossing as:

GD	Good
RU	Rutted
GU	Gullied
FL	Failing

Channel and Valley Measures

Elevation Profile: (Check off on form and put measures in comments or separate sheet) This measure represents the elevation of the streambed taken generally 100 feet upstream and downstream of a culvert. Depending on channel conditions the length of this measurement can be expanded or contracted. If it appears that the inlet is backing up sediment due to bar formation or other evidence of accelerated deposition, the profile will have to be extended up to 500 feet or more upstream of the culvert. If the downstream section shows evidence of culvert induced incision the profile may need to be extended as well. To get a profile use a transit level to measure a section upstream from the culvert by taking elevation differences over a channel length. A way of doing this is to establish a "relative base elevation" perhaps on the crown of the road surface and take all other measurements of elevation relative to this. The measurements of elevation should at a minimum be taken at every significant bed high and low elevation such as the crest of a riffle or the bottom of a pool. The distance between measures should seldom be over 6-10 feet. The measurements should be set-up to be plotted on an x-y graph using a spreadsheet and in format look something like this:

Length	Elevation (ft)	Comment
0	100.00	Inlet invert of the culvert
-0.1	100.20	Upstream of inlet on channel bed
-3.0	100.45	Riffle Crest
-4.5	100.25	Bottom of Pool
"	"	" Series of measures"
-50	104.25	Upstream end of measures
20	99.00	Outlet Invert
21	98.1	Bottom of Downstream pool
23	98.9	Riffle Crest elevation
"	"	"Series of Measures"
70	96.80	Downstream end of measures

The measures can be taken in comments or on separate sheet. The final profile would look something like what is in Figure 4. The ideal elevation of the invert of the culvert can be determined by looking at the minimum bed elevations and plotting a line as done in Figure 4.

In taking elevational measurements it will be important to get the elevation of the inlet and outlet along with the elevation of the downstream and upstream side of the road surface to estimate fill height. Another important measurement for some crossings will be to take a measurement of the road centerline elevation at the culvert crossing and take a measurement 30-40 feet in each direction along the road centerline profile to get an indication of the curvature of the road into the crossing. This will indicate if the road can be lowered at all or can be raised up to provide more headroom if needed. These measurements should be taken along with streambed profile measurements described above.

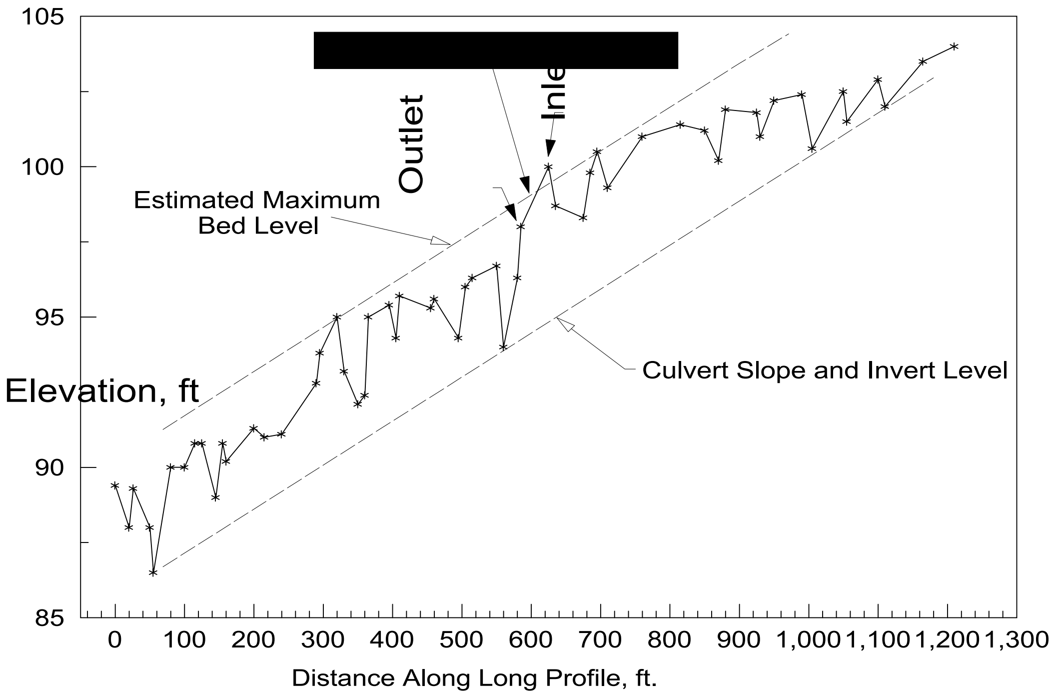


Figure 4. Culvert elevation profile (from Reba, 2002)

Channel Substrate: Upstream of the influence of the culvert inlet, characterize the size of the channel substrate using the codes described in Table 3. Put down the most predominate size followed by other sizes.

***Bankfull flow width (ft)*:** Measured at the average annual high water mark upstream from the influence of the culvert inlet. See lectures on how to measure this. This is measured at 10 points along the stream at distance of one channel width apart.

Stream/valley fill (code)**:** This refers to the layers of unconsolidated gravel, sand cobble, and other sediment that lie over the top of the bedrock. It is measured from the parent material or bedrock to the top of the deposit.

NF	No fill: (mostly bedrock channel, possibly point bar deposits and terrace-like sediment deposits < 5 feet high, may be valley- wall constrained)
SF	Shallow fill: (limited bedrock plus cobble/gravel/sand channel with narrow floodplain and terraces 5-10 feet high)
DF	Deep Fill: (no bedrock showing in channel, broad, well-developed floodplain)

Valley type (code):

NV	Less than 3 x channel width or < 100 feet (on a side)
WV	Wide valley: greater than 3 x channel width or >100 feet (on a side)

Overflow Dip Measures

Overflow dip*:* May be used on roads built on wide flood plains or in other situations (Figure 5) (use NA if not present). Using a transit level the crew will measure the elevation of the structure, the lowest elevation of the dip, and the elevation of the lowest point controlling the capacity of the overflow dip. The width of the overflow dip is measured from the height of the lowest point controlling the overflow dip capacity to the opposite side of the dip.

Overflow dip road surface armor (code): Using the codes in Table 3, classify the size of material used to armor the road surface of the dip (may be more than one, but no more than three).

Overflow dip road fill armor size: Using the codes in Table 3, classify the size of material used to armor the road fill associated with the dip (may be more than one but no more than three codes). This is recorded separately for the downstream and upstream sides of the crossing.

Overflow dip road surface condition**:**

ST	Stable
ER	Eroding
FL	Failing

Overflow dip road fill condition**:**

ST	Stable
ER	Eroding
FL	Failing

Dip width (ft)**:** Measured from the height of the lowest point controlling the overflow dip capacity to the opposite side of the dip.

Distance from dip to structure (ft): Measured from the center of the crossing structure to the lowest point in the dip.

Dip low point (ft): Lowest point elevation in the overflow dip relative to the crossing structure as measured with the level.

Dip control point (ft): Lowest point elevation of the two upper boundaries of the overflow dip controlling the capacity of the overflow dip.

Overflow maximum depth (ft): The difference between the height of the culvert bottom and the height of the bottom of the overflow dip.

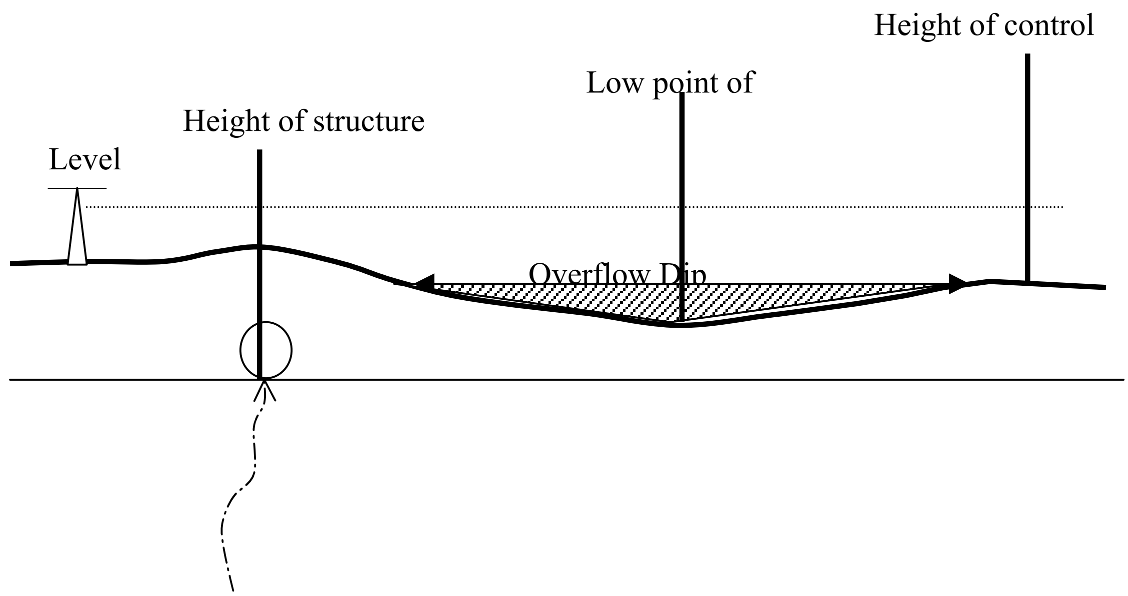


Figure 5 – Over flow dip schematic (adapted from Dent, 1999)

Fast Protocol Field Methods

General information taken for each Culvert Crossing

Crew Name – Name of crew member(s) taking measurements

Crossing Number – A unique number for each crossing surveyed taken from developed base map.

Stream Name – Taken from maps if no-name creek then state what creek it is tributary to (such as "Trib. to Bear Cr.")

Road Name/ID - The road name should be the name by which the road is best known. This can be a proper name or number. If the name is unkown it can be named after a landmark (perhaps after a nearby stream, harvest unit, or ranch).

UTM/GPS – The coordinates of the culvert will be recorded using a recreational grade global positioning system (GPS). The GPS reading can be compared to those developed by GIS to check accuracy and if at right location.

Photo documentation: #1 looking upstream with potential outlet drop in photo, #2 inside the barrel looking upstream, and #3 looking downstream at inlet. These photos can be invaluable when unsure of recorded data for one reason or another

Crossing Type (code):

RC	Round Culvert (Closed bottom structure, CBS)
PA	Pipe Arch (CBS)
OA	Open-Arch (Open bottom structure, OBS)
BR	Bridge
FD	Ford
OB	Open Box (OBS)
LG	Log Culvert (OBS)
BX	Box or rectangular (CBS)
OT	Other

See Table 2 for descriptions regarding these types.

If the culvert is a CBS or OBS then take the following measurements at the outlet side:

Outlet Drop (in)**:** This is estimated using a ruler or meter stick from the invert of the culvert to the residual water surface. See Figure 2 for information on residual pool concepts. This measurement is for CBS only.

Culvert Gradient (%)**:** Looking upstream in the culvert with an abney level or clinometer measure the slope of the culvert by sighting on a common spot in the culvert such as bolt line or the top of the culvert upstream.

Culvert Dimenisions**:** For round Diameter (in) measure with tape or meter stick and length (ft) visually estimate. For other shapes span (in), rise (in) measured and then culvert length visually estimated.

Culvert Condition**:**
New – Bright galvanized steel
Aged – Brightness worn away
Old – Rusting and thinning of culvert
Det – Holes in culvert severe rusting

If the culvert is CBS and drop is greater than 2 feet or the culvert slope is greater than 3% with no substrate embedding the culvert **then cease measurements** – The culvert will not likely pass adult fish and will not pass juvenile fish. This will probably constitute the majority of CBS culverts installed previous to 1994. If a culvert has 3% gradient and significant backwatering into it from a downstream weir (i.e., all the way to near the inlet) then continue measurements. If the backwatering is just into the outlet then cease.

If the culvert is OBS then the following should be taken:

Footing condition**:** For open-bottom structures **(OBS)** will be described as

ST	Stable (no scour near edges)
ER	Eroding (scour near edges but OBS not cantering or deforming)
FL	Failing (scour plus deformation)

For both OBS and CBS take the following:

Outlet mitigation structure type	GW	Gabion weirs
	RW	Rock weirs
	WD	Woody debris
	WR	Wood and rock
	NO	None
	OT	Other, explain (i.e. a riffle backing water into pipe)

If there is a weir downstream or a riffle backing water into the culvert take the following measurements.

Backwatering (ft): Estimated length of backwatering within the pipe from the outlet due to a downstream weir at the time of measurement. If the backwatering spans the entire culvert then put the estimated length of the culvert as the degree of backwatering.

Outlet mitigation drop (in): Estimated from the residual water surface of the structure to the residual water surface below the structure. If more than one structure (multiple weirs) there will be a measure between each structure.

Distance between outlet mitigation and crossing (ft): Measured from the outlet to the mitigation structure, if there are multiple structures crew will document average distance between them and their number.

Bankfull width**:** Estimated on the outlet side

Step 2 – Barrel Measurements Inside Culverts

Embedded Culverts:
Sediment pattern (code): For natural-bed or embedded structure designs give a qualitative description of how material is arranged in the structure. Use NA for structures that are not designed to collect sediment (baffled culvert, bridge).

SS	Simulated streambed (channel type forms such as bars and sinuosity, material contiguous bed material)
CR	Contiguous rock fill (rock contiguous throughout the structure)
IN	Contiguous rock fill in culvert except within 1-3 meters of the inlet which is bare or has sparse rock cover.
SR	Sparse rock fill (rock in culvert but not contiguous)
NM	No material in culvert
NA	Not applicable

Sediment size inside culvert (code): From codes in Table 3. Can circle up to three. Double circle the predominant type.

Baffled/embedded culverts:

Baffle design:

WB	Weir baffles
OF	Offset weir
PW	Porior design notch weir
NW	Notch Weir
SR	Sediment Rack
OW	1 Outlet Weir only
MW	Multiple weirs downstream from culvert
OT	Other
NO	None

If none is the answer the next estimates can be skipped.

Distance between baffles (ft)**:** Average for multiple weirs.

Distance between last baffle and outlet (ft): Measured from the base of the last baffle to the outer edge of the culvert.

Height of Baffle (in): Measured at the highest point of the baffle above the invert of the culvert.

Depth of Baffle Notch (in): Measured from top of baffle to base of notch.

Step 3 Inlet Measurements on upstream side of culvert

Inlet Drop (Yes/No): Note if there is an inlet drop. An inlet drop is when the bed of the stream upstream of the culvert is at greater elevation than the invert or simulated bed/embedded bed of the culvert. Take for CBS culverts only.

Bankfull width: Estimated on the inlet side use tape and take a couple of measures.

Measures for Bridges and Fords with Fast Protocol

Bridges:

Bridge Type:

LS	Log stringer
RR	Railroad Car
MI	Metal I-beam
CC	Concrete
OT	Other Describe in comments

Bridge Span (ft)**:** Measured from one side of the stream to the other (Figure 2).

Bridge Abutment condition**:** described as

ST	Stable (no scour near edges)
ER	Eroding (scour near edges but OBS not cantering or deforming)
FL	Failing (scour plus deformation)

Bankfull width (ft): See advanced on how to measure take in at least three spots and average.

Ford/Dam Measures

Fords will only be measured if hardened and there is obvious indication of a drop or a section of high velocity water across the ford.

Jump (in): Measured from outlet to residual water surface.

Residual Flow Depth (in): Measured at the deepest point in the ford to the residual water surface. This represents the depth of tailwater over the ford or dam top or weir will often be zero.

Residual Pool Depth (in)**:** Measured at the deepest part of the pool downstream of the crossing when present to the residual water surface.

Material Type: **Rock, Other (explain)**

Material Size used for the ford upstream, at the crossing and downstream of the crossing (code)**:** Characterize the size of material in each location as described in Table 2. There can be more than one but no more than three.

Ford or dam top surface condition**:** Describe the section of road draining into the stream crossing or dam as:

GD	Good
RU	Rutted
GU	Gullied
FL	Failing

Preliminary sampling plan

It is anticipated that the detailed method will be used on approximately 100crossings giving adequate information to determine fish passage status and to pick a design alternative and do a preliminary cost estimate on that alternative. The fast protocol (or elements of it) will be conducted on previously surveyed culverts to fill in essential information for prioritizations and design and cost analysis.

Barrier Determination: Hydraulic Analysis

For each crossing, the field data will be analyzed as to whether it is a full, partial or non-barrier to fish passage. Barriers will be defined by using thresholds from the field measurement data as outlined below.

Partial Fish Passage Blockage

For this project "partial fish passage blockage" is defined as: stream crossings, because of their design, maintenance, or condition, are not allowing for juvenile salmonid fish passage. Juvenile salmon, for the most part, require two feet per second or less velocity, outlet perching less than 6 inches, and little to no inlet constriction or drop according to the ODFW guidelines (ODFW, 1997). In addition, the culvert should be free from debris that may concentrate flow and increase velocities. Flow depths should be 12 inches or more in the culvert or the culvert should have a simulated natural streambed similar to channel conditions in the natural channel.

In terms of measured crossing dimensions, partial fish passage blockage would occur if the following conditions are not met. Much of these conditions are taken and adapted from Robison et al. 1999.

For bare (non embedded) culverts:

1. Unless backwatered properly the slope should not exceed 0.5%. Even if at 0.5% slope or less the culvert inlet invert should be placed six inches lower in elevation than the height of the downstream riffle or weir height. Backwatering properly for culverts of greater than 0.5% slope will be determined using an estimated tailwater elevation and then input this value along with other key measured values into FishXing software (USFS, 1999) to evaluate if the backwatering is adequate. Generally, there will have to be a tailwater elevation of at least one 1.5 feet greater than the invert of the inlet to have adequate backwater on culverts greater than 1% slope that are 50 feet or more in length. However, the exact degree of backwater must be calculated because of all the possible combinations of slope, culvert length, and tailwater depth. For this analysis, the fish passage design flow will be determined via accepted methods in ODFW (1997).

2. The outlet drop or any associated weir drop should be no more than 0.5 feet from the culvert outlet lip to the residual pool water elevation. If there is any outlet drop, the residual pool for the downstream jump pool should be 1.5 times deeper than the jump. For culverts that do not use streambed simulation designs, in order to get required water depth, adequate backwatering from the outlet end is needed.

3. To control constricting of flow at the inlet, the culvert diameter or span should be at least 0.5 times the width of the natural bankfull channel. The culvert should be free of large debris blockages or cave in areas that constrict flow and make for high velocity areas. There should be little or no inlet drop such that the flow drop as water enters the inlet is less than a few inches. The culvert inlet invert should be about level with the channel bed immediately upstream.

4. The culvert should be less than 100 feet long.

For embedded culverts:

1. The culvert should have a variety of material embedding it forming a simulated natural channel inside the culvert. The material should in most places be a foot or more deep. It is not enough just to have placed material in the culvert, but there should be evidence of deposition and reworking of smaller material. If material is lacking, we will use the assumptions for the non-embedded culvert above.

2. There should be no outlet drop.

3. The inlet should have sediment in it and there should be no sudden drop in bed elevation at the inlet. The culvert width should also at least 90% of the average bankfull channel width to prevent channel constriction, channel scour, and drops from occurring at the inlet. Even if greater than 90% but less than 100% inlet constriction will be carefully reviewed by evaluating inlet photos and measurements.

For baffled culverts:

1. Generally speaking, the baffles/weirs should be 0.1-0.15 times the total height of the culvert. The spacing varies with streamflow and culvert gradient should be set up such that one baffle/weir at least at low flow, backwaters slow water to the base of the next weir at a minimum depth of eight inches when the pool is at residual conditions. If evaluating baffled culverts, it is important to take culvert gradient, weir height, and weir spacing to use in calculations to determine adequacy. The exact calculations will be determined as needed and developed from techniques and references from (Robison and Pyles, In review)

2. There should be little or no outlet drop (no more than six inches). If the weir is put on the edge of the outlet that drop should be calculated from the residual pool water level to the top

of the weir. If there is a small drop the residual pool for the jump pool should be at least 1.5 times as deep as the drop distance.

3. There should be little or no inlet drop and the top weir should backwater into the upstream natural channel.

For Bridges and Open Bottom Structures:

1. Generally speaking a bridge or open bottom structure (OBS) pose no fish passage problems. An exception is when a bridge/OBS is undersized and flowing on bedrock. In these instances the bridge or arch may constrict flow and blow out boulders and cobbles leaving a bedrock chute. For calculation purposes, if the bridge/OBS can pass a fifty-year flood flow without over topping this should not be a problem. Only if there are visual indications of fish passage issues will measurements and calculations be done for bridges and OBS.

2. Open bottom designs should be free of large debris that may constrict flow and cause high velocity areas inside the arch.

Complete fish passage blockage

AComplete fish passage blockage,@ for this project, refers to instances in which the design, maintenance, or condition of the stream crossing is such that even most (if not all) adult salmonids cannot move upstream through the crossing structure. Blockage would result in conditions that exceed most adult anadromous salmonid fish swimming capabilities. These can be: culvert water velocities for fish passage design flows in excess of 10 feet per second, outlet drops over 4 feet or over 1 foot without adequate jump pools, and extreme inlet drops or material in the culvert that cause severe barriers would cause a blockage.

Flow depths should be 8 inches or more in the culvert at higher flows or the culvert should have a simulated natural streambed similar to channel conditions in the natural channel. In terms of measured crossing dimensions, crossing that have passage blockages would also have measurements outside of the following conditions. These guidelines are not intended for use as guidelines for adult fish passage. They are only used here to make a distinction in severity of blockage. The reason for the distinction of partial vs. complete is a culvert that blocks both adult and juvenile upstream fish passage is more serious than one that only blocks juvenile upstream fish passage. This distinction is an important factor in prioritization.

For bare (non embedded) culverts:

1. Culvert slope should not exceed 4% unless there is backwatering or unless the culvert is less than 50 feet long. For short culverts (less than 50 feet) gradients greater than 4% (up to 6%) can be tolerated if not combined with an outlet jump. For backwatering, if downstream

control is at an elevation that is equivalent to a point in the pipe with less than 50 feet distance to the inlet, the gradient can be up to 6%.

2. The outlet drop should be no more than 4 feet from the culvert outlet lip to the residual pool water elevation. The residual pool is defined as the pool that would be left over if there was no flowing water created by the damning effect of the downstream control point. If there is outlet drop over 6 inches, the residual pool for the downstream jump pool should be at least 1.5 times the height of the drop or 2 feet deep (whichever is less).

3. The inlet should not radically constrict the stream (i.e., 50% or greater than the average channel width) and no evidence of a drop in the streambed between the upstream streambed and the invert of the inlet. The culvert can be deemed a fish passage blockage if the constriction is 50%-90% and there is evidence of a radical drop in the streambed at the inlet of more than 1 foot then unless the culvert is less than 30 feet. The reason for this is the fish will be exhausted and will have difficulty moving through this extremely high velocity water.

4. The culvert should be less than 200 feet long.

For embedded culverts:

1. The culvert should have a variety of material embedding it forming a simulated natural channel inside the culvert. The material should in most places be a foot or more deep. It is not enough just to have placed material in the culvert. There should also be evidence of deposition and reworking of smaller material. If material is lacking, use the assumptions for the non-embedded culvert above.

2. There should be minimal outlet drop of less than 1 foot.

3. The inlet should have tapering stream width coming from upstream not a sudden drop at the inlet. The culvert width should also be at least 1/2 the bankfull channel width to prevent radical channel constriction and drops from occurring at the inlet even if the rest of the culvert has bed material present. If there is a radical inlet jump see assumptions for bare culvert above.

For baffled culverts:

1. Generally speaking, the baffles/weirs should be 0.1-0.15 times the total height of the culvert. The spacing varies with streamflow and culvert gradient but should be set up so that one baffle/weir backwaters slow water to the base of the next upstream weir. When evaluating baffled culverts, it is important to take culvert gradient, weir height, and weir spacing to use in calculations to determine adequacy. More information on calculating weir spacing is in (Robison et al 1999 or Robison and Pyles, In Review). In addition, the baffles should be free from debris and sediment in order to function properly. Sometimes even

when weirs are not spaced at optimum the culvert can still probably at least pass adult fish. However, if the culvert baffle(s) are ripped out or improperly functioning, this may pose a blockage problem. Once again as with the juvenile provisions, methods for calculating velocities, depths and energy dissipation will be developed from information in (Robison and Pyles, In Review) on an as needed basis.

2. The outlet drop should be no more than 4 feet. If the weir is put on the edge of the outlet the drop should be measured from the residual pool water level to the top of the weir or weir notch level. If there is a drop the residual pool for the jump pool should be at least 1.5 times as deep as the drop distance or two feet deep (whichever is less).

3. There should be little or no inlet drop and the top weir should backwater into the upstream natural channel.

For Bridges and Open Arch Culverts:

1. Generally speaking a bridge or open arch pose no fish passage problems. An exception is when a bridge/arch is undersized and flowing on bedrock. In these instances the bridge or arch may constrict flow and blow out boulders and cobbles leaving a bedrock chute. For calculation purposes if the bridge/arch can pass a fifty-year flood flow or more it should not be a problem.

2. Open arches should be free of large debris that may constrict flow and cause high velocity areas inside the arch. However to be a total blockage the problem must be severe causing velocities over 15-20 feet per second or more.

Determining risk of catastrophic fill failure

For each crossing, the projected 100 year peak flow will be calculated from accepted methods depending on the landuse and lay of the land. For small forested basins, the ODF map method will be used and compared to the Campbell method. For agricultural and semi-urban landuse on very small watersheds the rational equation will be used. For larger basins on mixed landuse the USGS equations will be employed or flows compared to nearby gages. Pipe capacity will be determined using methods developed in Robison et al. (1999) for culverts with gradients of more than 2%. For culverts less than 2% other methods (i.e., Norman et al. 1985) will be employed to evaluate possible outlet control.

Conceptual Designs and Cost Analysis

Overview

The following designs will constitute the bulk of designs used for this project. Because of issues of maintenance and juvenile fish passage issues the use of baffles as a possible design for replacement culverts will not be considered. However, there may be some situations in which a retrofit of an existing culvert with excess capacity would have low cost and a modest probability of success and may be proposed. Designs that also rely on zero slope or backwatering from downstream will not be used for replacement designs. However, there may be an existing culvert with excess capacity that could be improved with downstream backwatering as a retrofit that may be proposed.

The following are the most frequently used replacement options:

- **Long span steel or pre-stressed concrete bridges:** This option is usually for larger streams greater than 15-20 feet in width. This is most expensive option, but can otherwise work on all stream types. Railcar bridges are a much less expensive long span option have often been used on private roads but are narrow and until recently have not been load rated.

- **Short span concrete slab bridges and open box culverts with concrete T footings:** This option for high gradient stream reaches with or without bedrock in profile. Spans can reach up to 20 feet so this precludes their use on wider streams. Some have modified the footing and used road barriers in an effort to reduce costs over the T footings.

- **Open arch metal culverts with footings:** This option is useful for streams with bedrock at or near the streambed surface. They are usually used for higher gradient narrower stream reaches. For this project, they will only be proposed for streams flowing at or near bedrock. For streams on deep fill when a closed bottom design will not work the concrete slab bridge or open box culvert is a better accepted lower risk and cost option because the T footings can be placed at depth to be more resistant to possible scour from channel downcutting. Open metal arches on unconsolidated fill tend to be more expensive (if footings are done correctly) or are more apt to fail (if footings not established well below fill level) than the slab/box design. When using any open bottom design where the footing is in the vicinity of the active stream bed, a stream profile like those advocated for closed bottom designs (Robison and Pyles, In Review) should be done to locate the base of the footings below the potential scour zone to guard against possible stream downcutting.

- **Closed bottom metal culverts using streambed simulation:** This option works well for 0-8% gradient streams where the crossing has adequate headroom and adequate valley fill to sink the culvert into stream. For various reasons, including juvenile fish passage requirements this option will be the only closed bottom design option used for this project. For very low gradient streams the culvert will be embedded as well as placed flat as per WDFW (1999) guidelines. For all designs the use of a streambed profile to locate the vertical level of the invert of the culvert will be used to insure that the stream will not down cut and leave the culvert exposed to an outlet jump.

There are many other design types in use including log-stringer bridges, log-culverts, vented fords, various baffle, weir and rock catching culvert designs and many variations of open arches using metal, plastic and fiberglass as material. Open arches also can be designed for spans up to 50 feet as can multi-plate closed bottom culverts. However, some of these design types tend to be experimental while others have relatively short design life. The four options listed above are common, cost effective and have the potential to successful because of experience in installation and design. Between now and the final report full design specifications typical of each of these four primary designs will be given in an Appendix.

Deciding between design options

Based on guidance in Robison et al. (1999); WDFW, (1999); and Ministry of Forests (MOF) et al. (2002) closed bottom designs using streambed simulation are recommended for streams with slopes of zero to eight percent (note: WDFW and MOF advise or prescribe use up to 6% but may allow at greater slopes if justification given). Depending on which guidance the maximum size of stream that these designs are allowed or advised on range in size from 9 to 15 feet in width. Both Robison et al. and the MOF guidance specify also that the stream should have deep unconsolidated fill. Open arches will be confined to areas of well confined bedrock. Open box or short span bridges will be the preferred option on high gradient streams between 0-15 feet perhaps up to 20 feet in width. For bankfull stream widths greater than 15-20 feet, the long-span-bridge becomes the preferred option. These design choice issues creates a decision flow-chart (Figure 6) that will be used for choosing between replacement options.

Situations that involve demolishing or retrofitting a dam or ford will be handled on a case-by-case basis.

In addition, when a stream is at a favorable stream size, gradient and valley fill depth to place in an streambed simulation culvert, but there is a lack of overhead cover, a short concrete slab bridge may be employed to get adequate flow capacity through the crossing. The use of a multiple battery of culverts will be discouraged for low headroom situations due to maintenance issues and the difficulty in getting fish passage through them.

Cost estimates for design alternatives

Cost estimates for each of the design alternatives will be developed based on the use of cost estimate guidebooks such as the Means guide (Means firm, 2002) to heavy construction costs as well as estimated costs from actual case studies and examples. The emphasis will probably be placed more on actual examples because the general estimating guides do not estimate well some of the variables of working in streams with fish protection measures employed. Furthermore, many of the components are not reflected in the general guidebooks. Clackamas County has allowed the use of their cost estimator for county designs. This cost estimator that gives cost for fill and equipment and labor that will be useful for accurately costing out county culverts. For private land culverts a different cost estimation will be employed using provided cost analysis examples from private companies. In addition, a study done by the Forest Engineering Research Institute of Canada (Kosicki and Bennett, 2001) provides several useful cost estimates for several types of open bottom designs in British Columbia that can be used for comparisons.

The cost of actual materials for pipes and open arches will be adapted from Tables from culvert companies on a cost per foot basis for the pipe and various sizes, shapes, fittings and treatments needed. The most common pipe shapes used will be round and pipe arch. In addition, the costs of excavation and installation labor will be developed using the Clackamas county cost estimator and other sources.

The cost for short span bridges will include the slab cost, the footing costs and the installation and design costs. These costs will vary with span over stream and width of road. If the slab will have cover placed over it there will be additional costs for excavation and cover that can be handled using the county cost estimator and other tools.

The cost for long-span bridges will be based on a base cost plus a cost per span length along with the targeted width of the road. Several case study examples are being gathered to estimate these costs for both steel and reinforced concrete bridges.

Information on costs is currently being obtained from several sources and examples over the next few weeks so the information on costs will continue to improve and evolve between now and July when cost data will be developed for each design.

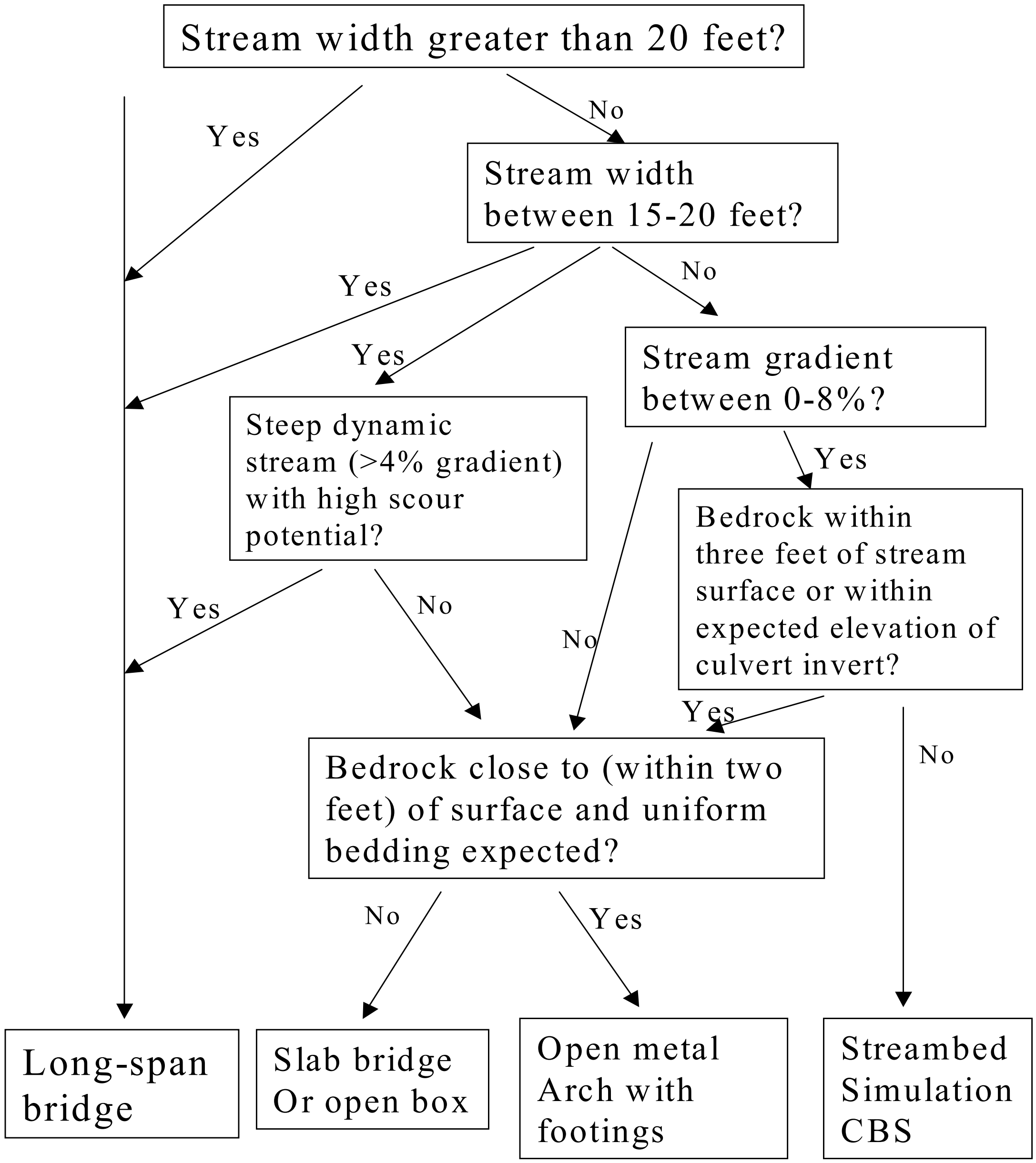


Figure 6. Design alternative decision diagram for the Clear and Foster Creek assessment/prioritization project.

Prioritization

There are two basic methods used to prioritize culverts. One system assigns a numerical value (scores) to the culvert (i.e. WDFW, 2000; Clackamas County, 2001) while the other system does not assign a value but rather places it into broad priority categories based on quantitative and qualitative characteristics (Robison et al. 1999). Some systems can use a combination of classification and scoring (David Evans Assoc., 2001). Within systems that score culverts numerically, the values assigned for different characteristics are added together (Clackamas County, 2001) or multiplied together WDFW 2001 or there can be a combination of adding and multiplying. To more heavily weight a factor in an additive system the numbers should have a greater spread in values between favorable and unfavorable conditions. For instance in the Clackamas County system the overall weighting is a sum of:

Priority Score = (Upstream length recovered) + (Upstream Habitat Quality) + (Upstream Watershed Area) + (Barriers to Fish Passage Downstream) + (Species Known) + (Maintenance: Life expectancy of structure) + (Maintenance is the structure on 5 year paving plan) + (Cost).

Where: The crossing if prioritized is pre-assumed to block fish.
Each factor above is given a score on a range from 0-5 up to 0-30 for other factors.

In this system the two maintenance factors are more heavily swayed by giving them a range in values between 0-30 for scoring as opposed to an ecological factor like upstream length recovered that is given a range of 0-5.

In a system that multiplies factors, the key to weighting is to have a greater spread in multipliers used as a factor. In general a multiplicative factor will have the potential for more weight than an additive one. For instance the WDFW uses the formula (WDFW, 2000):

Priority Index = sum for all species of quadratic (4^{th}) root of [(BPH) x (MDC)]

Where:
B = proportion of passage improvement (passability after vs. before project)
H = habitat gain in m^2
M = Mobility modifier (2 = anadromous, 1 = resident, 0 = exotic)
D = Species condition modifier (3 = critical, 2 = depressed, 1 = other)
C = Cost modifier (3 = <-100,000, 2 = 100,000-500,000, 1 = >500,000)
Note: the summation of all species is the factors are evaluated for each species affected by the crossing and then added together.

In this case the factor M – Mobility factor is weighted from 0-2 based on type of species affected by the blockage. If the species is anadromous (migrates to sea), the overall index value will double over the other values. If the species being blocked is only an exotic fish, the index value will be zero. Because some factors tend to be all important such as the question "does this structure pass fish?" there is a strong argument to use a combination of both additive and multiplicative factors if doing a numerical system for priority. However, the use and weighting of each factor should be carefully thought out. Because each major stream basin has a different mix of species present and land ownership patterns a strong case can be made that a custom prioritization should be done on a basin-by-basin basis.

The preliminary system proposed for the Clear and Foster Creek basin is a combination of an additive and multiplicative numerical system that takes into account the species present and the key ecological factors. For this analysis, the ecological and maintenance aspects will be kept separated to better diagnose crossings based on strictly ecological needs. A separate scoring system will be developed for maintenance issues.

The proposed ecological priority system:

Replacement Index Score Ecological [RISE] = {B * S * [(H*Q) + C)]} / Cost

Where:

B = Degree of barrier with 1.0 = complete barrier, 0.5 = juvenile barrier, and 0 = not a barrier (see previous section for more information on partial vs. complete barrier.)
S = Species downstream of crossing: 1.0 = steelhead or coho; 0.6 = resident fish only; 0 = exotics only
H = Habitat available upstream (ft)
Q = Habitat Quality index as defined by the proportion of different habitat types upstream of culvert. This parameter will be better defined after field work and information regarding the distribution of habitat types upstream of culverts is obtained. It will probably be represented as a qualitative scale from 1-5 and will be used to better quantify the overall habitat upstream of the crossing.
C = Connectivity will be a qualitative class from 1-10 that will be based on the number of miles the structure is from the Clackamas River mainstem along with the number of natural or artificial barriers involved. This will be better defined after the field measurements are taken.
Cost = The cost of the replacement in dollars based on estimated cost of replacement design see previous section for more information on cost estimates and conceptual design choices.

The proposed maintenance priority scoring system:

Replacement Index Score Maintenance [RISM] = (L + F) * O / Cost

Where:

L = Life of the culvert: 0-5 years = 40; 5-10 years = 30; 10-20 years = 20 and 20+ years = 0. The life of the culvert will be estimated from the condition descriptions on the field forms.
F = Fill height: 0 = Low fill 0-5 feet; 10 = Medium fill 5-15 feet; 30 = High fill 15 feet+
O = Immanence of overtopping: 1 = passes the 100 year flow; 2 = passes 50% of the 100 year flow; 3 = passes 10% of the 100 year flow and is frequently observed overtopping.
Cost = Cost of replacement in dollars

All these factors are open to modification at this time. Most of them will be changed as field data is obtained to examine the range in values.

Timeline for Completion

The following list of tasks and due dates represents a timeline of the key milestones of this project:

1. Draft methodology report due **(May 13th)** (Note:All dates 2002)
2. Informal training day for county survey crews regarding field methodology **(May 13th)**
3. Draft report review by TAC **(May 13th–16th)**
4. Meeting to present and receive comments on draft methodologies to TAC **(May 16th)**
5. Information for grant applications to do assessments in greater Clackamas basin **(May 17th)**
6. Organize landowner query results, print out postcards and mail to landowners. **(mid-end of May)**.
7. Create database with unique number for each crossing to store digital photos and data. **(End May)**
8. Field survey of culverts using field protocol modified from Draft methodology report as per TAC comments **(Late May – June)**
9. Provide assistance to CRBC webmaster to create a website or a link to a website to keep basin partners informed about progress on the fish passage assessment project. The website will also incorporate final report and presentation as well. **(May - October)**
10. Complete data entry of field data into data base **(Early July)**
11. Link fish passage status for every crossing in database to GIS coverage. **(August 1st)**
12. Within this database, create potential cost summaries for each crossing. **(August 1st)**
13. Create a hydraulic design calculation sheet for each crossing referenced to the database by the unique numeric identifier also tagged to the GIS. **(August 1st)**
14. Provide hardcopy summaries of the hydraulic calculations and other analyses used to determine the cost estimates and best replacement options. **(Complete August 1st Include as Appendix to final report – September Draft)**

15. Add the preferred design alternative for all barriers and cost estimates as a field in the database that will be linked to GIS for crossings in the Clear and Foster Creek basins. **(August)**
16. Meet with the TAC regarding initial prioritization findings **(August 15th)**
17. Provide a prioritized list of barrier projects, including the quantitative criteria used in ranking and the priority index number for each barrier project. Create a "barrier profile summary sheet" of each priority listed barrier **(Late August)**
18. Present a draft of the final report to TAC (5 copies) for comments **(September 19th)**
19. Receive comments back from draft final report **(October 4th)**
20. Mail out final postcards to thank landowners and advertise public meeting opportunities **(optional – October)**.
21. Give a Power Point presentation including graphics, photos and text that will be shown twice. **(October 18th and one other October date)**
22. Final report due **(End October)** Includes: 5 copies plus 2 copies of all barrier maps and a CD-ROM digital copy of report and maps.
23. Coordinate public meetings with Clear and Foster Creek Watershed Assessment presentations to present fish passage assessment results **(October – November)**.

References

Beechie et.al. 1994. Estimating coho salmon rearing habitat and smolt production losses in a large river basin, and implications for habitat restoration. North American Journal of Fisheries Management 14:797-811.

Clackamas County Fish Passage Technical Team. 2001. A guide to prioritizing culvert maintenance projects for fish passage in Clackamas County, Oregon. Clackamas County Water Environment Services. 6 p.

Conroy, S.C. 1997. Habitat lost and found. Washington Trout Report. Vol. 7:1

David Evans and Associates. 2001. A comprehensive assessment of fish passage barriers in the Scappoose Bay watershed. Prepared for the Scappoose Bay Watershed Council. 33126 SW Callahan Road, Scappoose, OR 97056.

Dent, L. 1999. Oregon Department of Forestry's stream crossing monitoring protocol: fish passage and streamflow design. Version 2.2. Oregon Department of Forestry, 2600 State Street, Salem Oregon, 97310. 15 p.

Kosicki, K. and D.M. Bennett. 2001. A summary of alternatives to conventional culvert pipe for forest roads in B.C. Draft report for Contract RTE 041/01 for the Ministry of Forests Resource Tenures and Engineering Branch – Engineering Section. Forest Engineering Research Institute of Canada, Western Division.

Means firm. 2002. Heavy construction cost data 2002. Robert S. Means Co. 475 p.

Normann, M.N. and others. 1985. Hydraulic design of highway culverts. Report FHWA-IP-85-15. Federal Highway Administration.

Oregon Department of Fish and Wildlife and Oregon Department of Forestry. 1995. Fish Presence Surveys. Available from ODF or ODFW local offices.

Oregon Department of Fish and Wildlife. 1997. Guidelines and Criteria for Stream-Road Crossings. October 23, 1997. 7p.

Oregon Department of Forestry. 2001. Stream classification guidance for fish bearing status. In: Forest Practice Rule Guidance. Available from Oregon Department of Forestry, Forest Practices Section, Salem Oregon, 97310.

Parker, M.A. 2000. Fish Passage – culvert inspection procedures. Ministry of Environment, Land and Parks, 400-640 Borland Street, Williams Lake, British Columbia, Canada VGT 4T1. Watershed Restoration Technical Circular No. 11. 47 p.

Reba, M. 2002. Fish passage monitoring of three culverts in Eastern Oregon. M.S. Thesis. Forest Engineering Department, Oregon State Univeristy. Corvallis OR. 97331.

Robison, E.G., A. Mirati, and M. Allen. 1999. Oregon Road/Stream Crossing Restoration Guide. Available from the Oregon Department of Forestry. 2600 State Street, Salem Oregon or http://www.4sos.org/wssupport/ws_rest/OregonRestGuide/index.html. 86 p.

Robison, E. G. and M. Pyles. In Review. Fish passage at road stream crossings: design guide. Forest Engineering Department, Oregon State University, Corvallis, Oregon 97331.

Taylor, R.N. and M.A. Love. 2001. Draft California salmonid stream habitat restoration manual: Part X – fish passage evaluation at road crossings. California Department of Fish and Game.

Washington Department of Fish and Wildlife. 1999. Fish Passage Design at road culverts: a design manual for fish passage at road crossings. Habitat and Lands Program WDFW, March 3, 1999. 49 p. + Appendixes. [Note this can be downloaded at the following internet site: http//www.wa.gov/wdfw/hab/engineer/cm/toc/htm].

Washington Department of Fish and Wildlife (WDFW). 2000. Fish passage basrrier assessment and prioritization manual. Salmonid Screening, Habitat enhancement, and restoration (SSHEAR) Division, WDFW. Olympia, WA.

Appendix A

Basin maps with road coverage and updated stream and fish presence coverage (currently under development). Should be available for review at Thursday meetings.

Appendix B: Field Forms

Detailed measurements field form

Crew Name ________________________ Date_____________Crossing Number ___________________

Stream Name____________________________________Road Name ____________________________

UTM/GPS_________________________________Photos Outlet__ Barrel__ Inlet__

Crossing Type (Circle) RC PA OA BR FD OB LG BX OT ______________________________

Structure Size Dia. (in)_______ Span (in)______ Rise (in)_______ Length (ft) ________ Road width (ft)_____

Culvert Elev. a – Road (ft)_____ b – Inlet (ft)______ c – Outlet (ft) _____ d – Pool (ft) ____ e – Weir ______

Culvert Condition (Circle) GD MD RS CL OT ____

Footing Condition for OBS (Circle) ST ER FL OT ____

Downstream Weir type (circle): GW RW WD WR NO OT ______________________________

Weir Condition (circle): ST BE UC SD OT _______________________ Weir De-water (circle) Y / N

Backwatering (ft) ___________ Weir Drop (in) __________ Dist Cross-Weir (ft) _________

Embedding in Culvert (circle): SS CR IN SR NM NA

Bed material size in culvert (circle): BD BL CB GR FN NO NA

Embed depth Outlet (in)_________ Barrel (in)________ Inlet (in) ________

Inlet Opening % __________ Inlet Design (circle) NM MI OT____________ Inlet Drop (circle): Y / N

Baffle Design (circle): WB OF PW NW MW SR OW NO OT ___________________________

Dist. between baffles(ft) ______ Dist. last baffle(ft) _______ Baffle Hgt.(in) _______ Notch Dep.(in)______

Road fill armor code (circle): BD BL CB GR FN NO NA

Bridge Type (circle): LS RR MI CC OT_____________________________ Bridge Span (ft) _______

Bridge Open Dep (ft) ____ ____ ____ ____ _____ ____ ____ ____ ____ ____ ____ _____ ____ ____

____ _____ _____ _____ _____ ____ _____ _____ _____ _____ ____ _____ _____ Increment (in) _____

Bridge Footing Condition (circle): ST ER FL

Ford/Dam (F/D) Jump (in)______ Residual Pool Dep. (in) ________ Circle ford or dam

F/D bed mat.(circle):Upstream: BD BL CB GR FN NO NA On F/D: BD BL CB GR FN NO NA

D.S. of F/D: BD BL CB GR FN NO NA F/D Road Surface Condition (circle): GD RU GU

Detailed **Monitoring Protocol Field Form Page 2 Channel and Dip Measures**

Elevation Profile__ (use comments) Bankfull Wid. (ft) ____ (1) ____ (2) ____ (3) ____ (4) ____ (5) ____ (6) ____ (7) ____ (8) ___ (9) ____ (10)

Stream Substrate (circle): BD BL CB GR FN NO NA Stream Valley Fill Code(circle): NF SF DF

Valley Type (circle): NV WV

Overflow Dip(circle): Y / N

Overflow Dip road surface armor size (circle): BD BL CB GR FN NO NA

Overflow Dip road fill armor size downstream side (circle): BD BL CB GR FN NO NA

Overflow Dip road surface condition: ST ER FL

Overflow Dip road fill condition: ST ER FL

Dip Width (ft): _____ Dist. dip to structure (ft):______ Dip low point (ft): ______ Dip control point (ft) ____

Overflow depth (ft) ___________

Comments about Crossing:

Fast Monitoring Protocol Field Form Culvert – Ford/Dam – Bridge Measures

Crew Name ________________________ Date_____________Crossing Number ___________________

Stream Name___________________________________Road Name ____________________________

UTM/GPS_________________________________Photos Outlet__ Barrel__ Inlet__

Crossing Type (Circle): RC PA OA BR FD OB LG BX OT _____________________________

*Outlet Drop (in):*_________ *Culvert Gradient (%)*________*Stream Gradient Outlet Side (%)*_________

Culvert Dimensions:
*Structure Size Dia. (in)*______ *Span (in)*_____ *Rise (in)*______ *Length (ft)* __________

Culvert Condition – Culvert Condition (Circle): New Aged Old Det.

Footing Condition for OBS (Circle) ST ER FL OT ____

Downstream Weir type (circle): GW RW WD WR NO OT ______________________________

Backwatering (ft) ____ Outlet Mitigation Drop (in) _____ Dist Cross-Weir (ft) ______ B.F. Width (ft) _____

Sediment pattern in culvert (circle): SS CR IN SR NM NA

Sediment Size in culvert(circle): BD BL CB GR FN NO NA

Baffle Design (circle): WB OF PW NW MW SR OW NO OT _________________________

Dist. between baffles(ft) ______ Dist. last baffle(ft) _______ Baffle Hgt.(in) _______ Notch Dep.(in)______

Inlet Drop (circle): Y / N Stream bankfull width (ft) ___________*Stream Gradient inlet side (%)*______

Bridge Type (circle): LS RR MI CC OT_______________________ Bridge Span (ft) _______

Bridge Footing Condition (circle): ST ER FL Bankfull Width _______ ________ _______

Ford/Dam Jump (in)______ Residual Pool Dep. (in) ________ (Circle dam or ford)

F/D bed mat.(circle):Upstream: BD BL CB GR FN NO NA On F/D: BD BL CB GR FN NO NA

D.S. of F/D: BD BL CB GR FN NO NA Road Surface into F/D Condition (circle): GD RU GU FL

Comments about Crossing:

Appendix B cont. Code Sheet for Forms:

Crossing Type (circle):

RC Round Culvert (Closed bottom structure, CBS)
PA Pipe Arch (CBS)
OA Open-Arch (Open bottom structure, OBS)
BR Bridge
FD Ford
OB Open Box (OBS)
LG Log Culvert (OBS)
BX Box or rectangular (CBS)
OT Other

Culvert condition:
GD good,
MD mechanical damage,
RS rusted, bottom out,
CL collapsed or
OT other (specify).

***Footing condition*: (OBS Only)**
ST Stable (no scour near edges)
ER Eroding (scour near edges but OBS not cantering or deforming)
FL Failing (scour plus deformation)

Downstream weir type
GW Gabion weirs
RW Rock weirs
WD Woody debris
WR Wood and rock
NO None
OT Other, explain

Weir Condition:

ST Stable
BE Bank erosion around structure
UC Actively undercutting structure
SD Sediment deposition behind structures has filled to elevation of outlet
OT Other (explain)

***Sediment pattern (code):* (Embedding in Culvert)**
SS Simulated streambed (channel type forms such as bars
and sinuosity, material contiguous bed material)
CR Contiguous rock fill (rock contiguous throughout the structure)
IN Contiguous rock fill in culvert except within 1-3 meters
of the inlet which is bare or has sparse rock cover.
SR Sparse rock fill (rock in culvert but not contiguous)
NM No material in culvert
NA Not applicable

Bed Material (Table 2) (Also Road surface, stream substrate)
BD Bedrock; Bigger than a car/continuous layer (>12 ft)
BL Boulders; Basketball to car-sized (1-12 ft)
CB Cobble; Tennis ball to basketball (3 in – 1 foot)
GR Gravel; Ladybug to tennis ball (.1 in – 3 in)
FN Fines; Silt/clay muck to visible particle; gritty - sand
NO ---; None
NA ---; Not applicable

Baffle design:
WB Weir baffles
OF Offset weir
PW Porior design notch weir (Notch weir angled 45° downstream.)
NW Notch Weir
SR Sediment Rack
OW 1 Outlet Weir only
MW Multiple weirs (downstream from culvert outlet)
OT Other
NO None

Bridge Type:
LS Log stringer
RR Railroad Car
MI Metal I-beam
CC Concrete
OT Other Describe in comments

***Bridge Footing condition*:**
ST Stable (no scour near edges)
ER Eroding (scour near edges but OBS not cantering or deforming)
FL Failing (scour plus deformation)

***Road surface condition*:**
GD Good
RU Rutted
GU Gullied
FL Failing

***Stream/valley fill (code)*:**
NF No fill: (mostly bedrock channel, possibly point bar deposits and terrace-like sediment deposits < 5 feet high, may be valley- wall constrained)
SF Shallow fill: (limited bedrock plus cobble/gravel/sand channel with narrow floodplain and terraces 5-10 feet high)
DF Deep Fill: (no bedrock showing in channel, broad, well-developed floodplain)

Valley type (code):
NV Less than 3 x channel width or < 100 feet (on a side)
WV Wide valley: greater than 3 x channel width or >100 feet (on a side)

***Overflow dip road surface condition*:**
ST Stable
ER Eroding
FL Failing