Fish Passage – Culvert Inspection Procedures

by

M.A. Parker

Ministry of Environment, Lands and Parks,
400–640 Borland Street, Williams Lake, British Columbia, Canada V2G 4T1

Watershed Restoration Technical Circular No. 11

2000

Canadian Cataloguing in Publication Data
Parker, M. A. (Michael Alan)

Fish passage : culvert inspection procedures

(Watershed Restoration technical circular ; no.11)

ISBN 0-7726-4290-7

1. Fishways – British Columbia. 2. Fishes – Migration – British Columbia. 3. Fish habitat improvement - British Columbia. 4. Culverts – British Columbia - Maintenance and repair.
I. Watershed Restoration Program (B.C.) II. Title

SH157.85.F56P37 2000 639.9'77 C00-960231-3

Acknowledgements

The author sincerely thanks all of the Ministry of Environment Fisheries staff in the Cariboo Region for inspiring the creation of this guide, and ensuring that the issue of fish access at road crossings remains a priority part of the Watershed Restoration Program. Thanks to the Watershed Restoration Program headquarters staff at the University of British Columbia for supporting the development of this new WRP technical circular and ensuring its distribution. Many individuals and organizations provided input into the critical review of the first three drafts of this guide, in particular Paul MacMahon, Andrew Wilson, Oliver Baker, Gerry Naito, Vince Poulin, Darrin Sollitt, Wendell Koning, Darren Hebert, Dave Donald, Troy Larden, Cris Guppy, Jeff Lough, Chris Picard, Rob Baldwin, Dave Heller, Bruce McFarlane, Pat Slaney, Daiva Zaldokas, Chris Nowotny, Carmanah Research Ltd., and Bioterra Consulting. Many others have provided input as well after field testing in various regions of the province, but not having anticipated the strong response to this guide I never kept a comprehensive list. However, all comments were reviewed and incorporated as much as possible into this final version. To the many who have shown interest, the author offers thanks. Funding for the development, field-testing and production of this technical circular was provided by Forest Renewal BC.

Contents

Introduction

The connectivity of a diversity of fish habitats is integral to supporting the abundance of fish species and their life stages found in British Columbia's fresh water habitats. Tributary streams, lakes, off-channels, back channels, ponds, and sloughs all provide critical habitat. Ensuring that these components remain connected for the free migration of spawning adults and rearing juvenile fish is a critical piece of the equation in maintaining healthy populations. A variety of natural and man made barriers limit connectivity of habitat and greatly reduces the fish production in some systems. The Fish Passage - Culvert Inspection Procedures (FPCI) assesses fish passage at culverts and evaluates the findings in conjunction with other known barriers to identify priority barrier crossings that are eligible for improvement under Forest Renewal British Columbia's (FRBC) Watershed Restoration Program (WRP). In order to prioritize access issues, all crossings within a watershed are typically evaluated, such that the relative importance of addressing those that are eligible for funding through FRBC programs is within a watershed context.

The FPCI procedures have been developed to assess fish access at culvert bearing road crossings installed before the implementation of the Forest Practices Code. Although an informal evaluation of this type is completed during a WRP Fish Habitat Assessment Procedure (FHAP) - Level 1 Field Assessment (Johnston and Slaney 1996), this is only done if the road crossing happens to be within the portion of stream reach from which data is being collected. Therefore, a culvert above or below the site may not be assessed, and certainly a comprehensive assessment of watershed culverts is not completed. Similarly, the WRP Sediment Source Surveys (SSS) (Moore, G. 1994) funded by FRBC may evaluate every culvert crossing in a watershed for sediment delivery, but it does not assess fish passage. Therefore, the FPCI procedure has been developed to evaluate one of the most easily addressed fish habitat constraints. Access to existing habitats.

The FPCI is easily incorporated into the Watershed Restoration Program toolbox with other assessments and activities. It should be considered as a potential add on component to be included as part of a Fish Habitat Assessment Procedure, as it addresses one of the high priority objectives of FRBC; fish access. In many watersheds an FHAP may have already been completed, in which case the FPCI can be carried out as a stand-alone assessment that draws on habitat value information collected during the FHAP. Interior Watershed Assessment Procedures (IWAP) and Coastal Watershed Assessment Procedures (CWAP) may provide a reasonable selection tool in determining which watersheds should undergo an FPCI as these procedures identify the number of road crossings per kilometer of stream. The higher the number of crossings the greater the likelihood that stream connectivity issues associated with crossings could exist.

The FPCI is a watershed approach to determining connectivity of fish habitats, and relative priorities of FRBC eligible crossings in the stream network, in order to address fish access issues associated with road crossings. The priorities identified by the FPCI are then incorporated into the overall restoration planning for a watershed, adding a critical component to the rehabilitation of fish and fish habitat. Even though this assessment has been developed for use in the Watershed Restoration Program and the eligible funding criteria established by Forest Renewal British Columbia, it is easily applied to other non-forestry locations and programs without modification.

The data collected herein provides support for determination of fish passage, as well as serving as a quality assurance tool to be used for expert evaluation in determining if additional assessment is required. If a fish passage issue is identified and prioritized to be addressed, a prescription will need to be completed to re-establish fish access at the crossing. All prescriptions leading to installation of new FRBC eligible crossing structures will need to meet Forest Practices Code standards.

The FPCI is best completed by a qualified fisheries biologist because of the need to carry out fish sampling and identification at crossings where fish inventories have not been previously completed, and a subjective evaluation of the value of fish habitat to be gained by restoring access.

FPCI Deliverables

The FPCI should produce the following products:

- A 1:50 000 scale Terrain Resources Information Management (TRIM) based watershed map numerically identifying all field sites visited, all culvert-bearing crossings assessed, the status of fish passage at those crossings, known fish bearing stream reaches, potential fish-bearing (based on gradient and connectivity to a fish-bearing reach), streams not assessed, known natural and anthropogenic barriers to fish passage, all waterways, the road network, and the watershed boundary. Optionally, the maps could identify roads scheduled for or undergoing deactivation, and fish distribution information (distinguishing between Fisheries Information Summary System [FISS], project sampling, or other documented source).
- A final report including a prioritized fish access restoration plan, identifying which FRBC eligible crossings should be replaced/modified based on degree of barrier, number of metres of access to be gained, value of the gained habitat, percent of habitat that is inaccessible, and the status of fish species present. This plan also identifies which sites need further assessment due to unconfirmed access or fish presence.
- One culvert inspection form (Form A – Appendix 1) and series of pictures for each culvert crossing fully assessed in the watershed. These are to be organized in the final report such that the Form A and four photos for each culvert site assessed are presented together.
- Completed “FPCI Summary Table” (Form B – Appendix 1) outlining a prioritized list of culvert crossings that present some degree of barrier to fish passage and their eligibility for funding under FRBC.
- Completed “Other Priority Culvert Crossings Summary Table” (Form C – Appendix 1) outlining non-barrier crossings of importance based on observations made during the field visit.
- Completed “Sites not Assessed Table” (Form D – Appendix 1) that describes the reason for not completing a full assessment on a site visited in the field. The reason for not completing a full assessment may include a bridge, ford, or deactivated site being found upon a site visit.

If the FPCI is completed in conjunction with a FHAP Level 1, the FPCI mapping information is added to the map produced for the FHAP or as a mylar overlay. These maps should be produced both digitally as an ARC

Plot file and in hard copy. Digital specifications and symbols should be consistent with those discussed in Appendix 2.

The results of the FPCI should be part of a complete watershed restoration effort. The inspection of culverts should be coordinated with other field assessments, and if possible implementation of prescriptions should be coordinated with other on-the-ground efforts. However, in a watershed where a fish species is threatened or endangered, establishment of passage will likely be a priority to be remedied immediately.

Planning Field Work

A four step process constitutes the planning for assessment of crossings in a watershed. The first two steps are office based, while the latter two are field based. The steps outlined take us from a maximum number of candidate sites for assessment to only those that will receive the full FPCI procedure.

Step 1. Identify all potential culverted stream crossings within the project watershed.
This step provides a starting point by quantifying the *maximum* number of sites that may need to undergo a full assessment. The recommended approach for this step is to select all crossings on 1^{st}, 2^{nd}, or 3^{rd} order streams on a 1:50,000 map of the project watershed. Generally, this approach covers all streams that are of a size that culverts were the crossing structure employed. In very high or low rainfall areas it may be necessary to either drop or add one stream order respectively, to encapsulate all culvert crossings.

Step 2. Identify all crossings on fish bearing or potential fish bearing streams within the project watershed.
Using the group of crossings identified in Step 1, select which crossings are on fish bearing or potential fish bearing streams, and eliminate all others. If there has been a Forest Practices Code (FPC) Stream Classification carried out on the watershed, crossings on those streams classified as S5–S6 need not be evaluated. If a formal stream classification has not been conducted, all culverts on known fish-bearing streams and tributaries of known fish-bearing streams not limited by a known permanent fish barrier (e.g., falls, chutes, dams) or a gradient of >20% (>25% in areas that may hold bull trout) must be field visited.

These first two steps conclude the office preparation and give a list and map of all sites that must be visited in the field. However, not all of these sites will undergo a full FPCI assessment. In order for a full assessment to be required the crossing must also meet the criteria outlined in the two steps below. From a planning perspective, experience within the Cariboo Region of British Columbia has shown that only 35-50% of the crossings identified at the end of Step 2 will undergo a full assessment, however this may vary by geographic location.

The next two steps are undertaken in the field to determine whether a full assessment including all data collection is to be carried out.

Step 3. Identify that the crossing is a culvert crossing.
Often when the sites identified in the first two steps are visited in the field a culvert may not exist to evaluate. The crossing may be a bridge, ford, or have been deactivated, and therefore not require a FPCI. These sites are not in need of a full assessment, but are recorded on Form D – Appendix 1.

Step 4. Identify that the channel at the crossing is viable fish habitat.
When the candidate site is visited in the field a culvert may be in place at the crossing, but there is no defined stream channel associated with the crossing. If the crossing is only a low draw or swale that has no defined stream bank and is vegetated throughout, a full assessment is not required. If the channel is dry at the time of the site visit and there is no indication of lake or wetland habitats above the crossing a full assessment is not required. If there is no viable fish habitat an explanation is recorded on Form D – Appendix 1, and the site mapped as visited but not assessed.

All crossings that pass the criteria outlined in the above four steps are to undergo a full FPCI assessment. The following section on FPCI Form A Completion will explain the step by step process of data collection in the field.

FPCI Form A Completion

The following text describes the assumptions and interpretations that one will need in order to complete the FPCI form in a manner consistent with its design. Procedures used to collect a measure shall be consistent with those outlined in the *Fish Habitat Assessment Procedures,* WRP Technical Circular No. 8, April 1996 (Johnston and Slaney 1996) unless otherwise specified in the following text. If more than one culvert exists at a single site, Form A should be completed for each culvert. One set of photos for such a site is adequate if all culverts can be seen within the photo.

Note: All categories on Form A are to be completed. If data are not measurable, record “NM.” If it is not an applicable or available record, record “NA.”

Stream Name: Record the gazetteer name for the stream that passes through the culvert. If there is a local name which is used more frequently or is the primary name used locally, this should follow the gazetteer name or “unnamed.”

Road Name/ID#: The road name should be that by which the road is best known whether it be a proper name or a British Columbia Ministry of Transportation and Highways number. The ID# is the forestry call number assigned to the road, and should include the road kilometre to the nearest 0.1 km.

Road Location (MoF District): Road location is the Ministry of Forests district within which the specific site is found. If the road access begins in a second forest district, that district name should follow the name in which the site is found.

Example: Horsefly/Quesnel – This indicates the site is in the Horsefly Forest District, but that the only access is from the Quesnel Forest District.

UTM/GPS Location (differentially corrected to an accuracy of ± 10 m)**:** The coordinates of the culvert should be recorded. Whenever possible these should be taken with a GPS. If GPS reception is not available, determine the coordinates from a map. The coordinates are important in relocating the correct site for work at a later date, particularly if there is no road access to the site because of deactivation in part of the system.

1:20 000 Map Number: Indicate the 1:20 000 British Columbia Geographic Series map sheet number on which the site can be found.

Watershed Code: Record the hierarchical watershed code for the stream. This is obtained from the Ministry of Environment, Lands and Parks (MELP) Watershed Dictionary. If standard watershed codes have not been assigned to the stream, follow the guidelines in the *User's Guide to the British Columbia Watershed/Waterbody Identifier System* available on the web at: http://www.elp.gov.bc.ca/fsh/IS/products/w_atlas/standards/watershed.htm# User's_Guide (Province of British Columbia 1998a) to assign an interim location point (ILP) to the stream mouth. The watershed code should correspond to those used during Overview and Level 1 FHAP (Johnston and Slaney 1996) if they have been conducted on the stream.

Watershed codes can be found on the BC Environment web site at <http://www.env.gov.bc.ca/gis>.

Site Number: Site number will be a number in a chronological sequence given to the culvert site inspected. The number is then used to represent the site on the 1:50 000 TRIM watershed map to be produced as a project deliverable. The numbering does not need to follow any particular order, although it should proceed either upstream or along a roadway for ease of locating them on the map (Fig. 1). If more than one culvert exists at a site they should be labelled with a single site number followed by a letter in brackets (e.g., 4(A)) with the letters being sequential for the culverts from left to right facing downstream.

Recorder's Name(s): Record the name of the individual(s) who completed the FPCI, and the name of the organization for which they were working. This information makes it easier to clarify any points or recording problems.

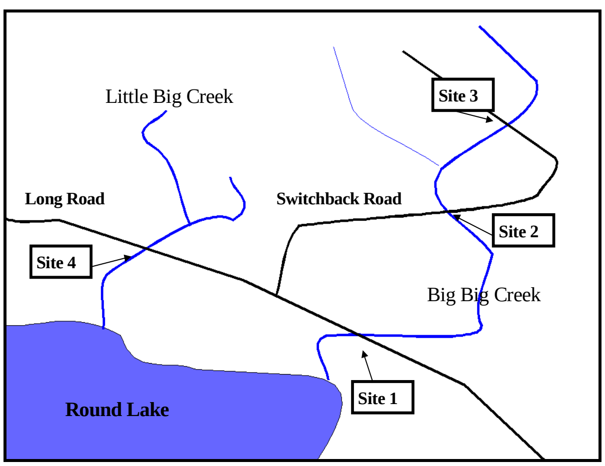


Figure 1. Example of numbering for culvert sites.

Culvert Characteristics

The following are characteristics particular to the culvert itself. They include measurements to determine if the installation is a barrier either through water velocity, incline, length, or drop. The information collected in this section also allows for calculations that may help indicate if passage is a problem at other times of the year when flows may be significantly different than on the day the site was assessed. General comments on culvert characteristics can be recorded in the space adjacent to the title, or in the comments section at the bottom of Form A.

Culvert Diameter (accuracy ± 50 mm)**:** Culvert diameter should be the diameter of a round culvert, the widest portion of an oval culvert, or the width of a box culvert. Measurements should be recorded in millimetres. To allow for fish passage, no culvert should be less than 400 mm in diameter east of the Cascade Mountains and 600 mm west of the Cascade Mountains or less than the mean bankfull width, whichever is greater. Similarly, the minimum opening recommended by the Forest Practices Code for log culverts is 0.5 m in depth and 1.5 m (1500 mm) in width (Province of British Columbia 1995b).

Culvert Length (accuracy ± 0.1 m)**:** The length of a culvert can, by itself, prove to be a barrier to fish. Fish may be able to swim faster than the velocity of water in culverts over short distances, but not as long as it takes for them to pass through a long culvert. Length of the culvert should be the distance, measured in metres to one decimal position, from one end of the culvert to the other. In the case where the ends of a culvert are tapered, the length of the end serving as the stream bed should be measured. If a float (e.g., a hockey ball) is attached to the measuring tape, it can be floated through the culvert for those too small to climb through.

For adult salmon migration, average water velocity should not exceed 1.2 m•s^{-1} and 0.9 m•s^{-1} for culverts less than and greater than 24.4 m in length, respectively (Adams and Whyte 1990). Therefore, the measure collected here should be used in conjunction with culvert water velocity collected below, and Table 1 in order to evaluate fish passage.

Culvert Material: The material of the culvert should be noted, differentiating between steel and wood, smooth and corrugated, and indicating if there are baffles installed in the culvert. Smooth culverts offer less resistance to water and create little turbulence, and are therefore more difficult for fish to pass through.

Culvert Water Velocity (m•s^{-1})**:** The velocity of water passing through the culvert should be measured in metres per second (m•s^{-1}).

Historically, culverts were installed with a diameter about one-third the natural width of the stream that passes through them. This was possible because culverts are so “efficient” at passing water that they do not need to be as wide as the stream in order to pass the same volume of water. This is in large part because the culvert is smooth, meaning there is little turbulence to slow the water. Since the culvert is one-third the width of the stream, the velocity of water in the culvert increases to three times that of the stream. It is the energy associated with velocity increases that often limits fish passage, and the energy in the above example increases nine times with the three-fold velocity increase. If velocity alone appears to be the barrier to fish passage, it may be slowed by installing baffles or by backflooding the culvert. Re-installing a culvert at a lower gradient may also slow the water.

A water velocity meter should be used for this measurement, and the reading taken at 0.4 times the depth of water at the deepest point in the culvert. Due to the linear uniformity of most culverts, one or two measurements should suffice. If more than one measure is taken, record the average velocity in the shaded block on Form A. To verify that the water velocity meter is working correctly, record the time for a orange to float over a measured distance in the culvert with the first measures of the day, or after a long bumpy ride between points with the velocity measurement. This may also be the only alternative when the water depth in a culvert is very shallow, preventing the operation of a meter. The water velocity should be recorded in $m \bullet s^{-1}$. Also keep in mind that even though the culvert diameter might equal or exceed the channel width, the wetted width of the culvert is likely to be less than the wetted width of the stream, and therefore water velocity will be higher in the culvert.

With the exception of streams that might harbour steelhead, water velocity in excess of 7 $m \bullet s^{-1}$ should be considered a barrier to all fish passage. Given that juvenile passage is critical in most systems 0.5 $m \bullet s^{-1}$ will be the upper limits of passage for many species. Table 1 lists the swimming speeds of various species of fish. The fish must be able to swim faster than the culvert water velocity for a period of time long enough to pass through the culvert. For velocity to be considered a barrier, it must exceed the swimming abilities of the target species and life stage at the time the fish are expected to be migrating. As the time of culvert assessment may not be the same as migration, the velocity measure taken here is only an indicator of potential velocity barrier. The one exception would be if the measure is taken during base flow and the velocity still exceeds the swimming abilities of the target species. Velocities that limit juvenile passage, but likely permit adult passage would be considered partial barriers.

For example: If a juvenile sockeye has a burst swimming speed of 0.6 m•s^{-1} and the culvert water velocity is 0.5 m•s^{-1}, the sockeye swims through at a gain of 0.1 m•s^{-1}. If the culvert is 20 m in length, it would take the fish at least 200 seconds to pass through the culvert. A juvenile is highly unlikely to swim at burst speed for 200 seconds, and therefore it is probable that the culvert water velocity is a barrier to the fish.

Table 1. Swimming capabilities of some salmonids. (Adapted from Katopodis and Gervais 1991; cited in Chilibeck et al. 1993).

		Maximum swimming speed (m•s^{-1})		
Species	**Life stage**	**Sustained***	**Prolonged****	**Burst*****
Coho and chinook	Adults	0.0-2.7	2.7-3.2	3.2-6.6
	Juveniles (120 mm)		0.4-0.6	
	Juveniles (50 mm)		0.2-0.4	
	Adults	0.0-1.0	1.0-3.1	3.1-6.3
Sockeye	Juveniles (130 mm)	0.0-0.5	0.5-0.7	
	Juveniles (50 mm)	0.0-0.2	0.2-0.4	0.4-0.6
Cutthroat and rainbow	Adults	0.0-0.9	0.9-1.8	1.8-4.3
	Juveniles (125 mm)	0.0-0.4	0.4-0.7	0.7-1.1
	Juveniles (50 mm)	0.0-0.1	0.1-0.3	0.3-0.4
Steelhead	Adults	0.0-1.4	1.4-4.2	4.2-8.1
Chum/Pink	Adults	0.0-1.0	1.0-2.3	2.3-4.6
Whitefish	Adults	0.0-0.4	0.4-1.3	1.3-2.7
Arctic grayling	Adults	0.0-0.8	0.8-2.1	2.1-4.3

* Sustained swimming speeds are the swimming velocities that can be maintained indefinitely.
** Prolonged speeds are the swimming velocities that can be maintained for up to 200 minutes through difficult areas.
*** Burst speeds are the swimming velocities for escape and feeding up to 165 seconds.

Culvert Shape: Select the appropriate culvert shape from those illustrated in Figure 2 and record the name in this block. If the culvert shape does not reasonably resemble one of those illustrated, write “N/A” in the block and describe its shape under the comments sections of the FPCI Form. Furthermore, if the culvert has an open bottom, or the bottom has been covered by natural substrates, this should be noted in the comments section. Figure 3 shows stacked round culverts.

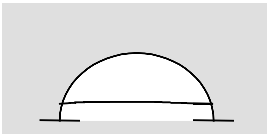
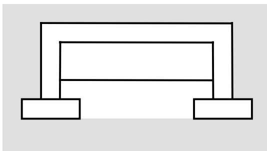
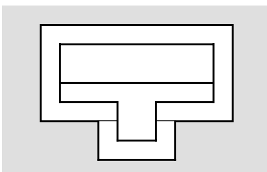
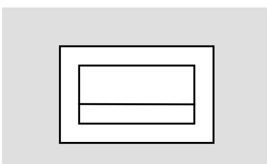
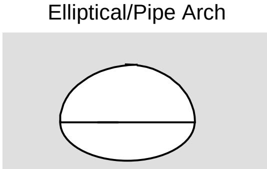
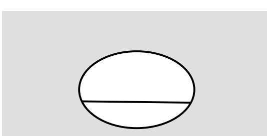
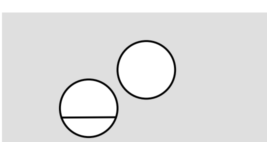
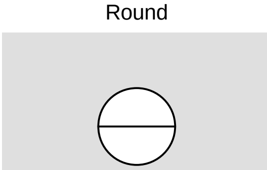
Type of culvert	Fisheries considerations	Hydraulic considerations
Open Bottom Arch 	• If properly designed and installed it does not limit fish passage. • Retains natural stream substrate. • Water velocity not significantly changed.	• Wide bottom enables passage of high flows while minimizing increases 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 2. Culvert shapes (cited in Adams and Whyte 1990).

Figure 3. Stacked culverts in the Bradley Creek watershed. The smaller top culvert handles flows at extreme high flow periods.

Culvert Wetted Width (cm)**:** Record the current wetted width within the culvert in centimetres. If needed, this can later be used to help calculate water volumes, or verify velocities within the culvert.

Culvert Slope (accuracy ± 0.5%)**:** Using a surveyors level, field staff should determine the slope, in percent, of the culvert. Using an Abney hand level or surveyors level measure the relative elevation of the upper and lower ends of the culvert bottom (take care to measure from the bottom of the culvert, and not the stream itself). These raw data are recorded on Form A, and the difference divided by the culvert length to determine the slope in %. On some large culverts and culverts with high fill slopes, it may be easiest to view through the culvert, but on smaller diameters and any internally damaged or angle culverts, this technique will not work.

If water velocity is a barrier, reducing the slope of the culvert may adequately reduce water velocity to allow passage. As well, the reduction in water velocity means a reduction in energy available to scour the downstream area below the culvert. Culvert slope should not exceed 0.5% for a culvert without baffles and greater than 24 m long, 1.0% for a culvert without baffles and less than 24 m, and 5% for any culvert with baffles (Adams and Whyte 1990).

High Water Mark (cm)**:** When the field crew assess the culvert, water volume may appear to be a problem with little flow present to allow passage. Similarly, flows may appear to be adequate enough, while not producing a velocity barrier. However, this is only one day of the year. Is it representative of flows at critical times? One part to answering this question may be to measure the high water mark on the culvert. This often appears as a rust stain (Fig. 4) on the inside of older steel culverts, but may be less visible on newer culverts and those of different material. Taking this measure will allow, with the other measures collected, a rough calculation of flow volumes and velocities at this higher water level. This, for example, may then help us understand why spring spawners are not getting above the culvert, as a velocity barrier is created at the higher flow. Similarly, it may help explain why a stream with observed critically low flow through a culvert has a good distribution of fish both above and below the site, as a higher flow found at other times of the year adequately allows passage. Keep in mind that juvenile fish migration is more greatly affected by the velocity changes associated with such volume changes. Finally, this measure may simply allow for a recommendation to assess the culvert again at the higher flow level to determine its impact.

Figure 4. Rust stains on these dual culverts in the Swift River watershed show a high water mark.

Record the high water mark in cm, or write “N/A” in the box if there is no visible indication of what the high level flow may be.

The information presented here is not intended to preclude other reasonable methods for determining stream discharge. Professional Engineers, who will be required to design bridge or major culvert placements under the Forest Practices Code, are ultimately responsible for establishing the design discharge for that structure. Any calculations carried out here are only meant to serve as a guideline to determine if an existing structure appears to be ineffective for the level of flows, and for preliminary budget planning for replacement.

Current Culvert Water Depth (cm)**:** Using a metre stick, record the depth of water currently flowing through the culvert at the deepest point. In order not to impair adult fish passage it has been recommended that the depth of water within the culvert should never be less than 15 cm for resident trout and 30 cm for adult anadromous fish (Votapka 1991). Often these minimums are not met at all times of the year. Culverts should be considered partial barriers if adult migration is limited during key spawning periods because these minimum depths are not being met. Baffles and backflooding the culvert are two options to increase water depth in a system where all of the stream flow is passing through the culvert, but at a volume too low to allow passage.

Culvert Outfall Drop (cm)**:** Measure the vertical drop between the bottom of the culvert to the surface of the stream or pool at the outflow (Fig. 5). This measurement will be used with the pool depth at the outfall, and jumping abilities of the target fish species to assess if the drop is a barrier to fish migration (Table 2). When making such an assessment, it must be remembered that the heights in Table 2 are under ideal conditions and quite optimistic. The measures do not take into account that the fish must jump into a culvert, as opposed to anywhere within the stream width, to get over the obstacle. As this part of the evaluation is conducted, field crews must be sensitive to whether the drop might change significantly under other flow conditions. At high flow there may be little vertical drop at the outflow, whereas under low flow conditions the drop may increase significantly and the plunge pool may become critically shallow.

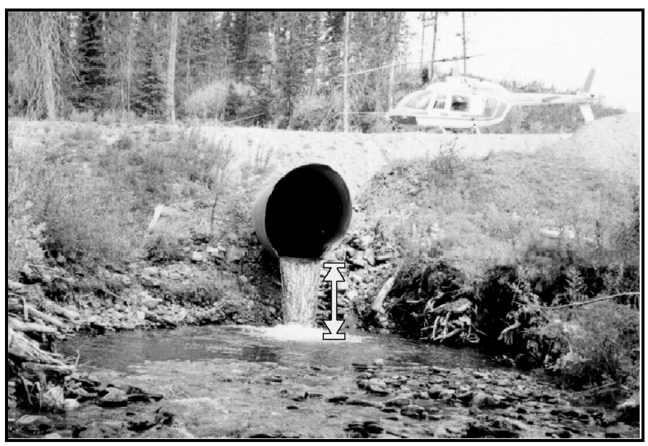


Figure 5. The culvert outfall drop is measured from the lip of the culvert to the water surface below. Photo at Foster Creek, Swift River watershed.

Table 2. Jumping abilities of target fish species (adapted from citation in Whyte et al. 1997).

Species	Life stage	Max. jump height (m)	Min. pool depth required (m)
Coho and chinook	Adults	2.4	3.00
	Juveniles (120mm)	0.5	0.63
	Juveniles (50mm)	0.3	0.38
Sockeye	Adults	2.1	2.63
	Juveniles (130mm)	–	–
	Juveniles (50mm)	–	–
Cutthroat and rainbow	Adults	1.5	1.88
	Juveniles (125mm)	0.6	0.75
	Juveniles (50mm)	0.3	0.38
Steelhead	Adults	3.4	4.25
Chum/Pink	Adults	1.5	1.88
Whitefish	Adults	1.0	1.25
Arctic grayling	Adults	1.0	1.25

Culvert Maintenance: If the culvert being assessed is in a state that requires maintenance, this box should be marked. A subjective evaluation of the severity of the maintenance problem is reflected by circling High, Moderate, or Low. If there are no maintenance issues with the site circle “No.” Maintenance may include, for example, replacing armouring at the inlet or outlet; replacing bent, collapsed, or severely rusted culverts; or removal of debris accumulation.

Fill Slope Depth (accuracy ± 0.5 m)**:** The amount of fill slope may determine what future type of structure is installed, or whether the costs associated with a solution are currently justified based on the anticipated habitat gain. Therefore, if the fill slope from the top of the culvert is greater than 2 m, the depth of the fill slope should be recorded to the nearest 0.5 m using a measure tape. This measure is an estimate, and does not take into account the angle of the fill slope.

Stream Characteristics

The following characteristics of the stream are recorded in order to determine how the system may be impaired by the culvert. In particular, this section determines whether or not there is biological evidence of a barrier, and how the morphology of the stream may have adapted to the culvert. Methods used to collect data in this section should be the same as those methods outlined for the same measurements under the *Fish Habitat Assessment Procedures,* Watershed Restoration Technical Circular No. 8 (Johnston and Slaney 1996) unless otherwise specified below. General comments on stream characteristics can be recorded in the space adjacent to the title, or in the comments section at the bottom of Form A.

Stream Reach: If the stream has been divided into reaches as part of another WRP assessment, indicate the reach number designation consistent with the other assessments. Otherwise record “N/A.”

Sediment Source/Degree: This category is an observational record. The individual completing the FPCI form should circle either “yes” or “no” if they consider there is presence/absence of a sediment source directly related to the culvert/road crossing (Fig. 6). They must then evaluate the degree of impact they feel this sediment source is having on the stream habitat. Higher impact would come with a high rating for connectedness, to the stream, for fine material (versus coarse) being released, size of sediment source, likeliness of continued erosion, and visible deposition of fines in substrate below source. Based on this subjective evaluation, the recorder circles “High,” “Moderate,” or “Low” to indicate the degree of sediment and records the nature of the sediment source in the adjacent box. If necessary, the comments section can be used to explain the evaluation of the sediment source further.

Pool Depth at Outfall (cm)**:** Using a metre stick, measure the depth of the pool immediately downstream of where the culvert water plunges into the stream at the outlet. If there is not a discernible drop between the culvert and the stream, measure the depth of the pool/stream at the point where the velocity of the water leaving the culvert visibly dissipates. The depth of the pool below an elevated culvert is extremely important in determining fish passage. For optimal jumping, the pool must be a minimum of 1.25 times the culvert outfall drop recorded above (Fig. 7). Only if there is a plunge pool meeting this specification is it likely that the target fish species will be able to use the hydraulic jump and approach the maximum jump heights recorded in Table 2. If water drops onto rocks and does not plunge cleanly into the pool, maximum jump heights will be greatly reduced regardless of pool depth.

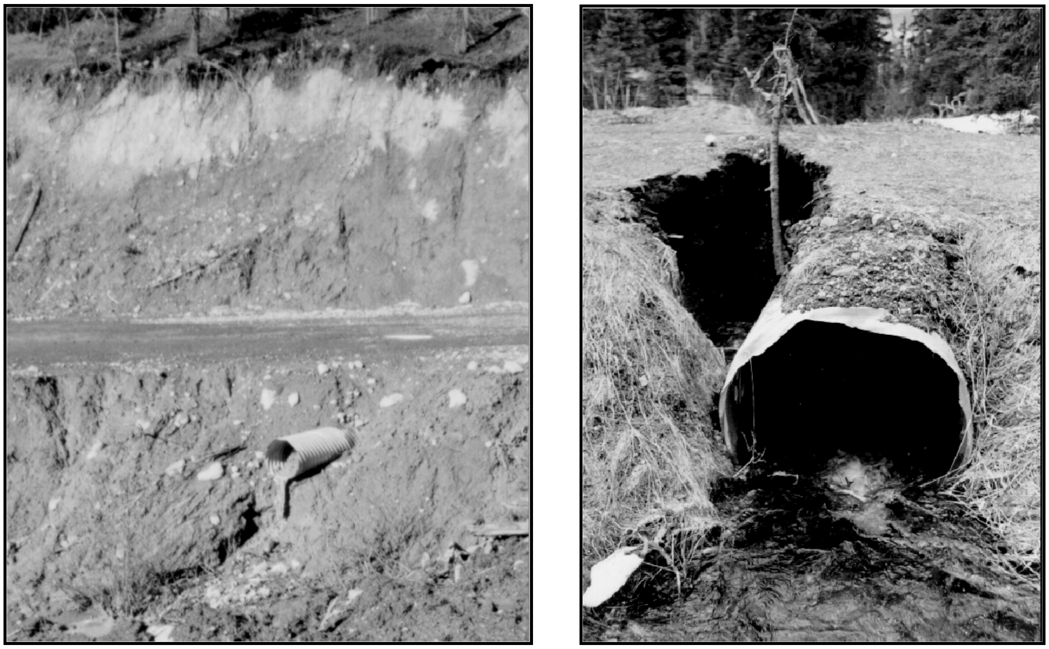


Figure 6. Improper installation or undersized culverts such as the one on a tributary to the Anahim Lake (left) or Horsefly drainage (right) can be significant sediment sources to fish bearing waters.

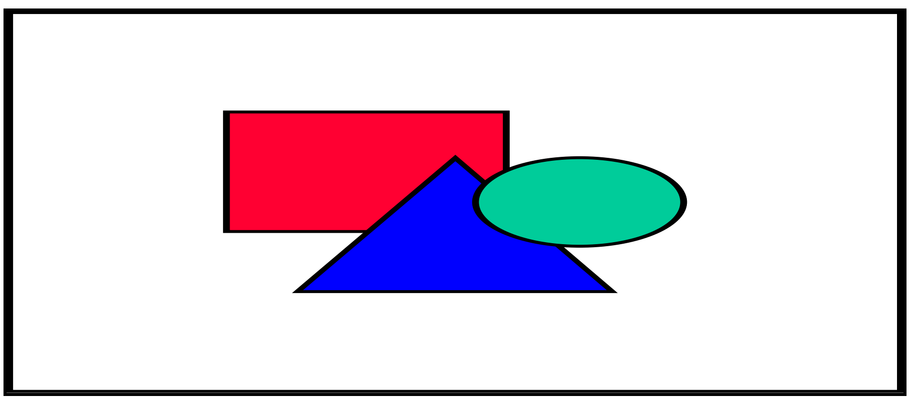


Figure 7. Optimal stream drop characteristics to allow fish passage (cited in Adams and Whyte 1990).

Stream Classification: If a stream reach has been classified according to the guidelines outlined in the Forest Practices Code *Riparian Management Area Guidebook* (Province of British Columbia 1995a) (Table 3), that designation should be recorded.

If a formal stream classification according to the Forest Practices Code has not been completed, use a "P" in front of the classification to indicate preliminary (i.e., PS2). This is very important, as stream classification has significant implications for forest management. On Form A, circle the appropriate stream class and "P" if preliminary.

Table 3. Stream classifications guidelines (from Province of British Columbia 1995a).

Stream classification	Channel width	Stream classification	Channel width
S1	>20 m	S4	<1.5 m
S2	>5 ≤20 m	S5[a]	>3 m
S3	1.5 ≤5 m	S6 [a]	<3 m

[a] S5–S6 streams are without fish and are not community watershed streams.

Blue Listed/Significant: Indicate the species that were present, either above or below the culvert, which are either "Blue listed" or "otherwise significant species." Use the abbreviations from Table 4. If the species is identified as significant, the recorder should explain this under the comments section. If, during sampling, a provincially blue- or red-listed species is identified, the British Columbia Conservation Data Centre form, Appendix 3, should be completed and mailed to the Resources Inventory Branch.

According to the British Columbia Conservation Data Centre, red-listed species include any indigenous species or subspecies (taxa) considered to be extirpated, endangered, or threatened in British Columbia. Extirpated taxa no longer exist in the wild in British Columbia, but do occur elsewhere. Endangered taxa are facing imminent extirpation or extinction. Threatened taxa are likely to become endangered if limiting factors are not reversed. Red-listed taxa include those that have been, or are being, evaluated for these designations.

Blue-listed species include any indigenous species or subspecies (taxa) considered to be "vulnerable" in British Columbia. Vulnerable taxa are of special concern because of characteristics that make them particularly sensitive to human activities or natural events. Blue-listed taxa are at risk, but are not extirpated, endangered or threatened. More information can be found by contacting the Conservation Data Centre internet site at <http://www.elp.gov.bc.ca/rib/wis/cdc> or by phoning (250) 356-0928. Provincially red- and blue-listed (2000) freshwater fish species are shown in Appendix 3.

Table 4. Standard fish species codes.

SP	Species present but not identified	**PK**	Pink salmon	**DV**	Dolly Varden
		CO	Coho salmon	**RB**	Rainbow trout
NF	No fish	**SK**	Sockeye salmon	**ST**	Steelhead
GB	Brown trout	**CT**	Cutthroat trout	**LT**	Lake trout
CM	Chum salmon	**BT**	Bull trout	**EB**	Brook trout
CH	Chinook salmon				

Wetted Width (m)**:** This is the wetted stream width on the day of the FPCI, and is measured in metres to one decimal place. The width should be measured at a minimum of two places above the culvert and two places below the culvert, and the total of all measures averaged. These measures should be taken a minimum of 25 m above and below the culvert, so as to avoid influence of the culvert on channel width. If the FPCI Form is completed along with a Fish Habitat Assessment, measurements from the latter assessment for the reach, which includes the culvert may, be used.

Bankfull Width (m)**:** This measure is the bankfull stream width and is recorded in metres to one decimal place. It is the width to where perennial vegetation is well established on the banks. The width should be measured at a minimum of two places above the culvert and two places below the culvert, and the total of all measures averaged. These measures should be taken a minimum of 25 m above and below the culvert, so as to avoid influence of the culvert on channel width. If the FPCI Form is completed along with a Fish Habitat Assessment, measurements from the latter assessment for the reach, which includes the culvert, may be used.

Water Depth (cm)**:** This is the average stream depth on the day the FPCI Form is completed, and is measured in centimetres. The depth should be measured at a minimum of two sites above the culvert and two sites below the culvert, and at ¼, ½, and ¾ of the distance across the stream perpendicular to the flow. The total of all measures are then averaged. These measures should be taken a minimum of 25 m above and below the culvert, so as to avoid influence of the culvert on channel depth. If the FPCI Form is completed along with a Fish Habitat Assessment, measurements from the latter assessment for the reach, which includes the culvert, may be used.

Bankfull Depth (cm)**:** This is the average bankfull stream depth (to perennial vegetation) and is measured in centimetres. The vertical height from waters edge to the bankfull depth should be measured at a minimum of two sites above the culvert and two sites below the culvert. These four measures are entered on Form A to preserve the raw data. These measures should be taken a minimum of 25 m above and below the culvert, so as to avoid influence of the culvert on channel depth. The average of these measures is then later calculated and added to the Mean Water Depth to determine the Mean Bankfull Depth. This amount is recorded in the right hand column of Form A. If the FPCI Form is completed along with a Fish Habitat Assessment, measurements from the latter assessment for the reach, which includes the culvert, may be used.

Stream Gradient (accuracy ± 0.5%)**:** Stream gradient is defined as the change in vertical height divided by the distance over which that change occurs. It is expressed as a percent. Using an Abney level or equivalent, the gradient is measured over a minimum distance of 50 m, or the longest visible distance if vision is obscured at 50 m. Record the stream gradient both above and below the culvert. These measures should be taken at least 10 m away from the culvert to avoid any influence from the culvert placement. Calculate an average gradient from the two measures and record it on Form A.

Stream Water Velocity ($m \cdot s^{-1}$)**:** In this block record the velocity of the stream a minimum of 25 m above and below the culvert placement. After identifying a transect across the stream perpendicular to the flow, check the velocity at 0.4 times the depth at a series of locations along the transect using a flow meter (Newbury and Gaboury 1993). Measurements should be made more frequently where the flow is more irregular, and should be 30 cm to 3 m apart depending on the size of the stream. Average the measurements to produce a stream water velocity in metres per second. Where the stream channel morphology appears extremely irregular, it is good practice to time a floating chip to see if similar velocities are identified.

Fish Presence: Based on some form of sampling, determine if there is presence of fish above or below the culvert. Species should be identified, so that if necessary, argument might be made for resident fish above a culvert that acts as a barrier to other species found below the culvert. In this section of the form simply circle “yes” or “no” if presence has been determined, and “no survey” if the information was not collected. If electrofishing, a length not less than ten times the channel width to a minimum of 100 m should be covered if no fish are being found. Similarly, minnow traps should be left for a minimum of 12 hours if fish are not being found. Note: This sampling does not *confirm* absence. No sampling above a culvert is required if there has been confirmed fish presence through FISS within a 5 km length of stream above the culvert in which there are no stream crossings and no potential gradient barriers. In such a case indicate “No Survey.” Under “Fish Sampling Method” indicate FISS, and under “Species Present” indicate what species were given by FISS. In all other cases, sampling is to be carried out. Sampling is always to be carried out below a culvert.

With the exception of any methods described above, sampling should be carried out according to the Forest Practices Code *Fish–stream Identification Guidebook* (Province of British Columbia 1998b).

Optional: It should be clarified with the proponent if sampling is to be done according to RIC standards and a point sample card completed for inventory records.

Fish Sampling Method: If it is known, the method of fish sampling should be recorded in this space. If the FPCI crew is to do the sampling, the proper collection permits must be obtained from the British Columbia Ministry of Environment, Lands and Parks, and Canada Department of Fisheries and Oceans prior to initiating any sampling. If the presence or absence is being taken from a previous assessment (i.e., FISS or Stream Information Summary System [SISS] maps), the recorder should indicate this as the sampling method. If the recorder does not have confidence in the sampling, this should be indicated under the comments section of the FPCI Form, and a recommendation of the assessment may be to re-sample.

Sampling Effort: If sampling was conducted by the field crew completing the FPCI Form, indicate the amount of time spent sampling.

For example: If a Gee Trap is used, indicate the number of hours it was in place. If electrofishing, record the length of time of actual shocking. Make sure to record effort above and below the culvert separately, and record the time, with appropriate units in this box.

Species Present: Use the species abbreviations in Table 4 to indicate all species present. If there appears to be a barrier to some species, indicate this in the comments section. Otherwise, simply indicate the total species composition. A complete list of species can be found in *Fish Habitat Assessment Procedures* Watershed Technical Circular No. 8, April 1996, Appendix D. If during sampling, a provincially blue- or red-listed species is identified, the British Columbia Conservation Data Centre form (see Appendix 3) must be completed and mailed to the address on the form.

Beaver Activity/Type: Indicate if there are any current signs of beaver activity within sight of the culvert. If there is activity, record whether it is a dam, house, and/or culvert blockage. In the comments section indicate if the beaver structure itself might create a fish passage barrier (juveniles/adults).

Barrier Evaluation

This final section should provide the reader with a summary of the FPCI Form and its evaluation. It identifies the nature of any access issues and any compounding issues. Although there have been many measures collected to determine the status of a barrier, it is the cumulative effect of the whole spectrum of measurements that may ultimately determine if there is a barrier or not, and evaluating the cumulative effect, by its nature, becomes somewhat subjective.

Barrier: It is important to identify the degree to which the culvert acts as a barrier to fish passage. Typically, there will be either a full barrier or no barrier. However, the form allows the evaluator to suggest a partial barrier in situations where seasonal high/low flows make the site a barrier, or if the culvert is a barrier only to particular life stage or species. If you are unable to determine whether the culvert is a barrier, select "undetermined." Remember that fish presence above and below a culvert does not confirm passage, as a resident population may exist above the culvert, or a partial barrier may exist.

The recorder **must** justify their choice of barrier in the next section.

Barrier Type: Barrier type may be one or a series of things selected from the completed form. The data collected should be used in detail to justify the barrier rating selected in the previous box, and to support the type of prescription suggested in the "prescription" block. It is important to note that if one believes that a barrier outfall drop would be passable at a higher flow, they must consider the potential for a velocity barrier at that higher flow period when assigning "Barrier" and "Barrier Type."

For example: "The full barrier determination was made for the following reasons. There was no measurable culvert outfall drop, however, the 32 m long culvert appears to be a barrier, carrying water velocities of 2.3 $m \cdot s^{-1}$. This is further supported by the lack of fish presence above the culvert, when several species where found in Gee Traps below. A deep pool has been scoured at the outlet. The culvert is approximately 45% the width of the stream and therefore capable of handling the flow, but has a slope of almost 5%."

Comments: There are several issues that must be covered under the comments section.

- First, and possibly most important, if a stream ford has been found, and a culvert or bridge is recommended, it can be recorded by the

FPCI by completing the applicable sections of the form, and indicating the nature of the ford in the comments section. Fords should be a primary concern on fish-bearing streams.

- Second, if the culvert is in poor condition (e.g., through rusting, cracking, bending) such that it is likely to affect the function of the culvert, this should be indicated.
- Third, if there is no vehicle access to the culvert for some reason, such as partial road deactivation, the recorder should explain the access limitation.
- Fourth, it should be noted if there appears to be debris accumulation problems with the culvert that affect flow or are causing erosion.
- Fifth, as mentioned above, this space should be used to elaborate on such issues as sediment source and whether the species above the culvert are fewer than those below.
- Sixth, if there is FISS species information, or some other reliable data source outlining species in the vicinity of the culvert, which adds to site sampling, this should be noted.
- Finally, the comments section is to be used to record any other concerns or comments that the field crew may have regarding the data collected or need for restoration.

Site Photos: A series of four photos should be taken if the culvert is a barrier or suspected barrier. These should be upstream and downstream views both above and below the culvert. If there is no concern of a barrier problem, one photo of the inlet and outlet of the culvert should be taken. Photos are extremely valuable in determining changes at the site over time, and in helping to prescribe works to address barriers. Record the film roll number and frame for which a photo was taken. If additional pictures are taken this should be indicated in the comments section.

The purpose of taking photos is to document such factors as substrate, height of road fill over the culvert, and to visually present the structure for which the measures have been taken. As scale is important, place some object within the photo that will be identifiable by the viewer.

Office Calculations

The following activities are required only for those culverts that have been assessed as either a full or partial barrier. They are not required for all sites. Therefore, these calculations or results are to be completed in the office after returning from the field.

Q_{100} Culvert Diameter Estimate (mm)**:** New culverts must be able to accommodate a 100 year flood frequency (Q_{100}) under the Forest Practices Code. The following formula can be used to *estimate* if a current placement meets Q_{100} based on the data collected during the FPCI. The following is only accurate if the required placement is less than 2000 mm diameter. This formula does not replace that required by the Forest Practices Code.

Step 1.

$$A=((W_w+W_{bf})*D_{bf})/2$$

Where: A= bankfull area at average annual peak
W_w = mean wetted width (m)
W_{bf}= mean bankfull width (m)
D_{bf}= mean bankfull depth (m)

This *assumes* that the bankfull area (A) represents the average annual peak (Q_2), and that W_w is equivalent to the stream bottom width. This latter assumption is likely only true if assessments are done near low flow. W_w, W_{bf}, and D_{bf} are as measured on the FPCI Form.

Step 2.

Use the Area calculated in Step 1 above to estimate the Q_{100} area from the following formula (Province of British Columbia 1997).

$$Q_{100} = 3(A)$$

Step 3.

Use the Q_{100} calculated above in the following formulas to estimate the culvert area (m^2) required to carry the Q_{100} *after* it has been embedded the required 20%.

For round culverts, use:

$$\text{Total culvert area required} = Q_{100} \times 1.16$$

For elliptical culverts, use:

$$\text{Total culvert area required} = Q_{100} \times 1.25$$

Step 4.

Look up the total culvert area required, calculated in Step 3 above, in Table 5 and find the corresponding culvert diameter. This value should be written in millimetres in the Q_{100} Diameter Estimate block of Form A.

Comparing the value calculated in this procedure with that actually measured in the field will provide an estimate of whether the existing structure is capable of handling a 100 year flood event. The methodology outlined here *should not* be used to determine Forest Practices Code requirements, only to estimate if standards are likely being met. If you calculated that one 2000 mm culvert is required and two 1000 mm culverts are in place, the Q_{100} requirements are **not** being met. The two smaller culverts will not carry the same volume of water as the one bigger one, even though the cumulative diameters are the same. This can be seen by comparing the total area of the one 2000 mm culvert in Table 5 with the total area of two 1000 mm culverts.

Road Responsibility: Road responsibility should identify the federal, provincial, licensee name, or private land holder responsible for the road, if this is known. This may be determined after the field visit through investigation and need only be provided for crossings where a barrier has been identified or some other impact noted. If it can not be determined who is responsible for the maintenance of the roadway, record “NSR,” meaning non-status road. If there is a best guess about the responsibility, record “NSR” followed by the suspected party. Road responsibility is important so that, prior to addressing a culvert issue, it can be determined if the responsible party wishes the proponent to work, if removal may be an option because the road is scheduled for deactivation, and what type of coordination might be necessary to minimize disruption for those using the roadway.

Stream Length Above Barrier (m)**:** Stream length above barrier is the map wheel distance to the next known barrier, or the end of the fish-bearing length as determined by inventory or gradient. This length should be recorded in metres. It is not the sum of all tributaries above this crossing, but only the mainstem length. Lakes and ponds are included in the linear measurement. This measure is used in the FPCI scoring matrix, Table 6. Note that it is important to estimate this distance accurately because the benefits of correcting the barrier are determined by how much fish habitat is restored.

Table 5. Effective culvert area/diameter relationship[a] (adapted from Province of British Columbia 1997).

Round culverts		Elliptical/Pipe arch culverts	
Diameter of culvert (mm)	**Total culvert area required (m^2)**	**Diameter of culvert (mm)**	**Total culvert area required (m^2)**
500	0.19	560 × 420	0.19
600	0.27	680 × 500	0.27
700	0.37	800 × 580	0.37
800	0.48	910 × 660	0.48
900	0.61	1030 × 740	0.61
1000	0.74	1150 × 820	0.74
1200	1.06	1350 × 870	1.06
1400	1.44	1630 × 1120	1.44
1600	1.87	1880 × 1260	1.87
1800	2.36	2130 × 1400	2.36
1810	2.58	2060 × 1520	2.49
1970	3.04	2249 × 1630	2.90
2120	3.54	2440 × 1750	3.36
2280	4.07	2590 × 1880	3.87
2430	4.65	2690 × 2080	4.49
2590	5.26	3100 × 1980	4.83
2740	5.91	3400 × 2010	5.28
3050	7.32	3730 × 2290	6.61
3360	8.89	3890 × 2690	8.29
2000	3.14		
2200	3.80		
2400	4.52		
2700	5.73		

[a] Shading indicates a multi-plate culvert.

Percent Stream Barred (%)**:** This calculation is simply the total map wheel distance of *fish-bearing length* of the main channel on which the assessed culvert lies, divided by the “Stream Length Above Barrier” as calculated above.

This measurement is important in setting priorities, because in mountainous areas where tributaries often become non-fish bearing due to gradient after a very short length, the relative importance of this short but limited habitat may not be adequately reflected by simply examining stream length above the barrier as recorded in the previous section.

Prioritization of Assessed Culverts

At this point, all culverts have been assessed, and Form A field data, and office calculations completed for each. The next step is the prioritization of assessed sites for restoration of fish passage, and the completion of the Culvert Inspection Summary Table in Appendix 1 Form B.

Prioritization should be based on gaining fish access to habitat segregated by a barrier culvert. The following considerations are the basis for prioritization, but could be modified by a contract monitor. Therefore, confirmation of prioritization should be made with a contract monitor at this point. The priorities here intentionally do not take into consideration severity of sediment source or strictly maintenance issues. These are important, but do not achieve the objective of regaining habitat access. Any assessed sites that fall within these parameters and are not prioritized for work as a barrier should be listed as an "Other" priority as in Appendix 1, Form C.

Table 6 is used to score assessed sites and assign a priority class for restoring fish passage. This table is completed on Form A such that it can be easily referenced with the collected data. At this point, all sites evaluated in the matrix have been assessed as either full, partial, or undetermined barriers. Fish species are classed as "Multiple" – multiple target species will benefit *or* regionally significant (as signed off under the Forest Practices Code by the Ministry of Forests District Manager), red- or blue-listed species will benefit. "Single" – a single target species will benefit, or "Other" – species generally considered coarse fish will be the only to benefit. If the species mix could be placed in more than one scoring box, choose the highest score of the two. "Habitat Value" is a subjective score by the contractor based on the value of the stream habitat to be gained and is based on complexity and limiting habitats. "Barrier" comes from the appropriate section of the FPCI Form A. "Length of New Habitat" is the map wheel distance to the next known barrier. "% Stream Barred" as taken from Form A is the length of new habitat divided by the total fish-bearing length. "Limiting to Upstream Barrier" should be scored "Yes" if there is another culvert upstream of the site being scored that has also been assessed as a full, partial or undetermined barrier. In all other cases, this category is scored "No." The relative numerical scores associated with each category are then summed.

Once summed, an assessed site is given its final "Priority Rank" based on the scoring classes listed below. The ranking of high, moderate or low is then recorded with the score in the FPCI Summary Table (Appendix 1, Form B).

Table 6. FPCI scoring matrix.

Fish species		Habitat value		Barrier		Length of new habitat		Stream barred (%)		Limiting to upstream barrier	
Multiple or significant	10	H	10	Full	10	≥1 km	10	>70%	10	Yes	5
Single	6	M	6	Partial	6	<1 km ≥500 m	6	51–70%	6	No	0
Other	3	L	3	Undeter	3	<500 m	3	<50%	3		

Priority Classes:

Highest ranking scores	55–39
Moderate ranking scores	38–26
Low ranking scores	25–15

The FPCI Summary Table can then be used to prioritize work based on FRBC eligibility, funding available, field season available, or other considerations. Regardless of rank or score, sites that were an "undetermined" barrier require further field assessment to confirm the barrier or lack thereof prior to any further prescriptive or on-the-ground work. It should be stressed that all sites, even those of low priority, should be addressed as they are a barrier to fish passage.

FPCI Report Format

A few general guidelines to provide consistent reports are suggested, but final deliverables need to be confirmed with a contract monitor. There are three primary sections that must be included in the report. They are as follows:

- Section 1 should consist of all barrier culvert information and the FPCI Summary Table from Appendix 1, Form B. Each site should be represented individually by the Appendix 1, Form A and the four mandatory photos of that site. These should be grouped in high, moderate, and low priority ranking. The Summary Table with a discussion completes this section.
- Section 2 should consist of all non-barrier culvert sites of significance. This includes all culvert sites on the Other Priority Culvert Crossings Summary Table from Appendix 1, Form C. Form A and the four mandatory photos for each site are presented in similar format, followed by the summary table and discussion.
- Section 3 is two Appendices. The first is of all remaining Form A sites and photos that did not fall into one of the two prior groupings. This should be any passable culvert sites. The second is of "Form D- Sites not Assessed" as found in Appendix 1 of this manual

Moving to Prescriptions

The FPCI procedures has been written to provide an assessment of the current capability of a culvert to allow fish passage. A full prescription is not part of completing the FPCI. There are several issues that need to be addressed before determining the level of detail required for the prescription.

- The MELP Designated Environment Official (DEO) and Department of Fisheries and Oceans for the area in question should be contacted in order to determine if there are limits on the type of new structures that may be installed.
- There needs to be proper confirmation of the status of road responsibility so that an appropriate funding source to carry out any prescriptions can be identified.
- There needs to be confirmation of all road deactivation plans within the area, so that money is not spent on a site that may soon be deactivated.

When these items are addressed, each site should be visited to determine a preliminary prescription. The preliminary prescription should determine if the structure needs to be replaced, or if some modification to the existing structure is possible. If the outlet channel is moderately confined, and the culvert sized to Q_{100} or greater, some form of downstream weir or riffle that backfloods or otherwise creates access may be possible. Undersized structures, or local topography may necessitate that some replacement structure be considered. Once the preliminary options are determined, a cost benefit analysis should be performed by answering several questions. They include: What is the cost of the structure options? What is the value of the habitat to be gained? How critical is this habitat to the target species? What is the expected use of the road crossing the stream? What is the expected life of the road crossing the stream? Are there any plans for future deactivation of the crossing? Answering these questions will help determine the type of expenditure and structure that is justified.

Depending on the prescription it may be necessary to have a road engineer design any new installations. The design will need to be approved by the DEO. Approvals may be needed in various instances from the Department of Fisheries and Oceans, MELP Water Management Branch, Ministry of Forests regional road engineer, and MELP Fisheries Branch. If the crossing is to be restored for fish passage under the Watershed Restoration Program, the MELP Regional WRP Fisheries Specialist should be able to provide guidance on what approvals need to be sought.

Any new structures eligible to be placed under the Watershed Restoration Program to restore fish access must meet the current Forest Practices Code Standards and approvals. Two publications are currently the basis for the installation of stream crossings in British Columbia: *Forest Road Engineering Guidebook* (Province of British Columbia 1995b); and *Stream Crossing Guidebook for Fish Streams* – a working draft for 1997/1998 (Province of British Columbia 1997). The latter guidebook is expected to be updated sometime in the year 2000.

References

Adams, M.A., and I.W. Whyte. 1990. Fish habitat enhancement: A manual for freshwater, estuarine, and marine habitats. Department of Fisheries and Oceans Canada. DFO 4474. 330 p.

Chilibeck, B.G., G.R. Chislett, and G. Norris [eds.]. 1993. Land development guidelines for the protection of aquatic habitat. British Columbia Ministry of Environment, Lands and Parks, Victoria, B.C.

Clay, C.H. 1961. Design of fishways and other fish facilities. Department of Fisheries of Canada . Queens Printer (Ottawa) 301p.

Griffiths, C., T. Cheong, and S. Hawthorn. 1997. Standards for fish and fish habitat mapping. British Columbia Ministry of Environment, Lands and Parks, Resources Inventory Branch, Victoria, B.C. 72 p.

Johnston, N.T., and P.A. Slaney. 1996. Fish habitat assessment procedures. British Columbia Ministry of Environment, Lands and Parks, and British Columbia Ministry of Forests, Victoria, B.C. Watershed Restoration Technical Circular No. 8. 97 p.

Katopodis, C., and R. Gervais. 1991. Ichthyomechanics. Freshwater Institute. Central and Arctic Region. Department of Fisheries and Oceans Canada.

Moore, G.D. 1994. Resource road rehabilitation handbook: Planning and implementation guidelines (interim methods). British Columbia Ministry of Environment, Lands and Parks, and British Columbia Ministry of Forests, Victoria, B.C. Watershed Restoration Technical Circular No. 3. 121 p.

Newbury, R.W., and M.N. Gaboury. 1993. Stream analysis and fish habitat design: A field manual. Newbury Hydraulics Ltd. Gibsons, B.C. 262 p.

Province of British Columbia. 1995a. Riparian management area guidebook. British Columbia Ministry of Forests and British Columbia Ministry of Environment, Lands and Parks, Victoria, B.C. 75 p.

Province of British Columbia. 1995b. Forest road engineering guidebook. British Columbia Ministry of Forests and British Columbia Ministry of Environment, Lands and Parks, Victoria, B.C. 153 p.

Province of British Columbia. 1997. Stream crossing guidebook for fish streams: A working draft for 1997/1998. British Columbia Ministry of Environment, Lands and Parks, and British Columbia Ministry of Forests, Victoria, B.C. 81 p.

Province of British Columbia. 1998a. User's guide to the British Columbia watershed/waterbody identifier system. British Columbia Ministry of Fisheries, Victoria, B.C. 15 p.

Province of British Columbia. 1998b. Fish–stream identification guidebook. British Columbia Ministry of Forests and British Columbia Ministry of Environment, Lands and Parks, Victoria, B.C.

Votapka, F.E. 1991. Considerations for fish passage through culverts. National Research Council. Transportation Research Board. Washington, D.C. Research Record #1291. Vol. 1.

Whyte, I.W., S. Babakaiff, M.A. Adams, and P.A. Giroux. 1997. Restoring fish access and rehabilitation of spawning sites. Chapter 5 *in* P.A. Slaney and D. Zaldokas [eds.]. Fish habitat rehabilitation procedures. British Columbia Ministry of Environment, Lands and Parks, and British Columbia Ministry of Forests. Watershed Restoration Technical Circular No. 9. 341 p.

Appendix 1. Culvert assessment forms

The following forms are a mandatory component to completing the culvert assessment. The first form, Form A, is the field data form that records all of the relevant measures of the stream habitat, current culvert installation, and impact of the structure. It also serves as the basis for required calculations of Q_{100} flows and estimated Q_{100}culvert size. Lastly, Form A collects repeatable measurements for later expert evaluation to determine if additional asssessment is required, thereby serving as a Quality Assurance / Quality Control tool.

Form B and C are for the presentation of the analysis of Form A. They are not necessarily mutually exclusive as the culverts that show up on Form B "FPCI Summary Table" may also show up on Form C "Other Priority Culvert Crossing Summary." These two forms separate what activities may be eligible under current FRBC funding criteria for fish passage and what problems are maintenance issues or sediment issues that do not directly affect fish passage but need to be addressed through another avenue.

Finally, Form D is the documentation of why a visited site did not require an FPCI Form A to be completed. The reasons will vary, but generally will fall from Step 3 or Step 4 in the section titled "Planning Field Work".

Form A – Fish Passage – Culvert Inspection – Side 1

Date (mm/dd/yy)	/ /	Stream Name	
Road Name/ID#		Road Location (MoF district)	
UTM/GPS Location		Watershed Code	
1:20 000 Map Sheet		Recorders Name	
Site Number			

Culvert Characteristics: ______________________________

____

Culvert Diameter (mm)	mm				Culvert Slope (%)	Us	Ds	%
Culvert Length (m)	m				High Water Mark (cm)	cm		
Culvert Material					Culvert Water Depth (cm)	cm		
Culvert Water Velocity (m•sec-1)					Culvert Outfall Drop (cm)	cm		
Culvert Shape					Culvert Maintenance	Hi / Mod / L / No		
Culvert Wetted Width (cm)	cm				Fill Slope Depth (m)	m		

Stream Characteristics: ______________________________

____

Stream Reach		Stream Classification	S1 S2 S3 S4 S5 S6 P
Pool Depth at Outfall (cm)	cm	Blue Listed/Significant	
Sediment Source/Degree	Yes / No – Hi / Mod / L		

Measure	Measurement(s) Below Culvert			Measurement(s) Above Culvert			Average Measurement
Wetted Width (m)							m
Bankfull Width (m)							m
Water Depth (cm)							cm
Bankfull Depth (cm)							cm
Stream Water Velocity (m•sec-1)							m•s-1
Stream Gradient (%)							%
Fish Presence	Yes / No / No survey			Yes / No / No survey			NA
Fish Sampling Method							NA
Sampling Effort (time)							NA
Species Present							NA
Beaver Activity/Type							NA

Barrier Evaluation:

Barrier	Full	Partial	None	Undetermined
Barrier Type	______________________________ ______________________________ ______________________________			

Site Photos:

Roll # ______________________________

Inlet upstream photo # ______________________________ Inlet downstream photo # ______________________________

Outlet upstream photo # ______________________________ Outlet downstream photo # ______________________________

Form A – Fish Passage – Culvert Inspection – Side 2

Comments: ____

____

____

____

____

____

____

____

____

____

Office Calculations: (*to be completed for full and partial barriers only)

Q100 Diameter Estimate (mm)	mm	**Stream Length Above Barrier**	m
Road Responsibility		**% Stream Barred**	%

Prioritization Calculations – FPCI Scoring Matrix:

Fish species		**Habitat value**		**Barrier**		**Length of new habitat**		**Stream barred (%)**		**Limiting to upstream barrier**	
Multiple or significant		H		Full		≥1 km		>70%		Yes	
Single		M		Partial		<1 km ≥500 m		51–70%		No	
Other		L		Undeter		<500 m		<50%			

Total Score:______

Form B – FPCI Summary Table

Fish Passage - Culvert Inspection Summary Table

Priority Rank	Score	Site Number	Barrier	Stream Length Gained (m)	% Stream Barred	X - Reference Site Number(s)	FRBC Eligible

Priority Rank: A high/moderate/low ranking based on Table 6 Scoring Matrix.

Score: Numeric score based on the sum of all Table 6 scoring classes.

Site Number: Culvert assessment site number from Form A "Site Number."

Barrier: Degree of culvert barrier from Form A "Barrier."

Stream Length Gained: The number of metres of stream length to be gained by replacing the barrier culvert as measured with a map wheel.

% Stream Barred: The stream length gained (as above) divided by the total fish bearing mainstem length of system on which culvert exists. From Form A "% Stream Barred."

X-Reference Site Number: The culvert assessment site number from Form A of any site that impacts the same immediate stream system, that must be addressed in conjunction with this site. For example any upstream or downstream culverts that need to be replaced in coordination with this site.

FRBC Eligible: Indicate if the crossing is eligible for FRBC funding under current eligibility guidelines.

Form C – Other Priority Culvert Crossings Summary

Other Priority Culvert Crossings Summary Table

Priority Rating	Site Number	Maintenance Issues	Sediment Source	Notes

Assumptions: None of the sites identified in the above table are identified in the FPCI Summary Table, and none of the sites identified in the above table is a full or partial barrier to fish passage. However, these sites have been deemed to have significant maintenance (structural) or sediment delivery concern to warrant further consideration.

Priority Rating: A high/moderate/low rating subjectively based on the contractor's observations and the fisheries value of the stream.

Site Number: Culvert assessment site number from Form A.

Maintenance Issue: Indicate "Y" if there is a structural maintenance issue with the culvert crossing.

Sediment Source: Indicate "Y" if there is a sediment delivery issue at the culvert crossing.

Notes: Indicate the structural issue that requires maintenance of the culvert crossing and/or explain the sediment issue of the culvert crossing.

Form D – Sites not Assessed Summary Table

Site Number	Assessment	Notes

Site Number: Unique identifier number for site visited but not assessed under FPCI Form A.

Assessment: Indicate assessment result that justified not completing assessment. Choices include but are not limited to bridge, deactivated, ford, no channel, and dry channel. The reasons will vary, but generally will fall from Step 3 or Step 4 in the section titled "Planning Field Work".

Notes: Describe any additional information observed or considered in the decision not to complete an assessment.

Appendix 2. Digital requirement (optional)

This material is an optional requirement in completing the culvert assessment. It is the responsibility of the contract monitor to identify whether this step needs to be completed. The appendix provides one means of completing a ARCplot digital mapping product as part of the assessment.

Mapping should be produced digitally and delivered as both a hard copy map and a digital ARCinfo ARCplot file unless otherwise specified.

1. Hardcopy maps should be produced on a watershed or sub-basin scale such that the entire watershed, or sub-basin fits on one mapsheet at a 1:20 000–1:70 000 scale.
2. Base maps using TRIM coverage for known stream barriers, roads and waterways should be dated in the legend to indicate the year of the TRIM base. Any updating of roads from other sources (e.g., airphotos, satellite imagery) should also be dated in the legend. Forest companies may have more up to date digital coverages that could be used to produce the base map.
3. Streams should be mapped as one of three types:
    - **Known Fish Bearing** as red line, and supported by FISS data or other reliable data, and source dated in the Legend.
    - **Fish Bearing by Gradient** as dashed red line which is all stream reaches from the confluence with a known fish-bearing stream up to the first gradient break >20% (>25% if bull trout present, consult with regional MELP fisheries staff if bull trout are thought to be present) or known permanent barrier. This category would also pertain to streams above such a gradient break or barrier where there is a lake or other body of water in which it is likely a resident population of fish may exist.
    - **Unknown Stream Status** in blue line should be used for all other waterways unless they have been proven non-fish bearing as per current Forest Practices Code *Fish–stream Identification Guidebook* (Province of British Columbia 1995a).

In addition, it may be necessary to indicate ephemeral streams as a dashed line of appropriate colour. This should be confirmed with a contract monitor prior to completing mapping.

- All culverts assessed should be indicated on the FPCI map by the culvert symbol (code PI30005000) of the RIC *Standards for Fish and Fish Habitat Mapping* (Griffiths et al. 1997), and accompanied by an unique identifying reference number. The FPCI pen colour of this symbol should indicate the degree of barrier where red – full barrier, black – partial barrier, blue – no barrier, and green – undetermined, as shown in Figure 2-1. The basic culvert symbol and guidebook can be obtained from the web at:

<http://www.env.gov.bc.ca/gis/arcsymbols.html> and
<http://www.env.gov.bc.ca/fsh/ids/gis> respectively.

- All sites visited, but not assessed because they turned out to be non-culvert crossings, should be indicated by a dark grey circle as in Figure 2-1, and accompanied by an unique identifying reference number.

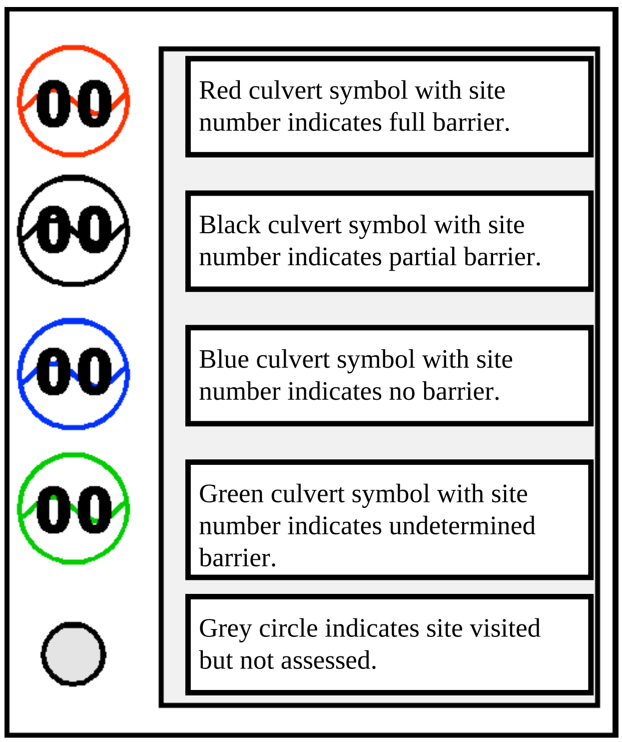


Figure 2-1. Mapping symbols.

Fish Species Distribution

1. Delineate points on the TRIM streams indicating locations of:
    - Upper (and lower if applicable) limits of distribution by fish species, and where appropriate by life stage (adult or juvenile).
    - A single point is used where more than one species or life stage have the same upper or lower limits.

- Map and legend different distribution sources such that they can be distinguished (ie. FISS, current study, etc.).

Obstructions

1. Delineate the location of non-culvert obstructions as points on the hard copy TRIM map. Identify each point with the appropriate RIC Standard symbol.

Digital File

- All digital data will be available in ARC/INFO version 7.0 export format with no compression and exist in North American Datum 1983 and Albers projection. The plot files are to be delivered on a compact disc medium to the contract monitor. The Contract Monitor should be contacted to verify the Ministry Plotter model and ensure that the delivered files are compatible.

Appendix 3. British Columbia Conservation Data Centre form

This appendix identifies fish species identified by the British Columbia Conservation Data Centre as either red- or blue-listed. Such species, when found during a culvert assessment, need to be specifically noted on Form A, and the form found in this appendix completed and sent to the BC Conservation Data Centre. Digital forms, a year 2000 species list, and additional information are downloadable from the CDC web site at www.elp.gov.bc.ca/rib/wis/cdc/index.htm.

B.C. Conservation Data Centre

FIELD OBSERVATION FORM (ANIMALS)

Complete only for species on CDC tracking list. Information is not required for all fields, but please fill out at least the fields in bold face.

Species

____

Name of recorder/reporter

____

Address & phone #

____

____

Location (be as precise as possible, preferably to within 100 m; however, even very general information will be used)

____

____

____

UTM grid reference (from blue grid on 1:50 000 NTS map): MAP GRID: ________________

ZONE (e.g., 10U) ____ ___ EASTING ___ ___ ___ ___ NORTHING ______ ___ ___ ___

Date			**Numbers**					**Notes**	
			Adult		**Immature**				
year	**month**	**day**	**Male**	**Female**	**Male**	**Female**	**Unkn.**		

Evidence of Breeding

____

____

Habitat (incl. dominant plants if possible; a general description of area)

____

____

Elevation___________ metres feet (circle one) Slope_________ Aspect__________

Comments/Remarks (any additional information you can provide will be useful; for example, access, habitat disturbance or other threats, health or behaviour of animals)

____

____

____

____

____

____

Our primary need is for location to be as precise as possible. A photocopy of a 1:50 000 topographic map, showing exact or approximate location would be appreciated, although not necessary. You can indicate precision of location with the letters: S = within 100 m radius; M = within 1 km; G = within about 10 km.

Please return forms to:

Conservation Data Centre
Resources Inventory Branch
Ministry of Environment
P.O. Box 9344
Victoria, B.C. V8W 9M1

B.C. Conservation Data Centre - 2000

RARE FRESHWATER FISH TRACKING LIST

(sorted phylogenetically within each taxonomic group)

SCIENTIFIC NAME	COMMON NAME	GLOBAL RANK	PROV. RANK	PROV. LIST
***FRESHWATER FISH				
Cottus bairdi	Mottled Sculpin	G5	S3	BLUE
Cottus confusus	Shorthead Sculpin	G5	S2S3	BLUE
Cottus sp 2	Cultus Lake Sculpin	G1	S1	RED
Acipenser transmontanus pop 1	White Sturgeon (Kootenay River pop)	G4T1Q	S1	RED
Acipenser transmontanus pop 2	White Sturgeon (Columbia River pop)	G4T?Q	S1	RED
Acipenser transmontanus pop 3	White Sturgeon (Nechako River pop)	G4T1Q	S1	RED
Acipenser transmontanus pop 4	White Sturgeon (Fraser River pop.)	G4T2Q	S2	RED
Coregonus artedi	Cisco	G5	S1	RED
Coregonus nasus	Broad Whitefish	G5	S2	RED
Coregonus sardinella	Least Cisco	G5	S2	RED
Coregonus sp 1	Dragon Lake Whitefish	GX	SX	EXTINCT
Salmo clarki lewisi	Westslope Cutthroat Trout	G4T3	S3SE	BLUE
Oncorhynchus clarki clarki	Coastal Cutthroat Trout	G4T4	S3S4SE	BLUE
Salvelinus malma	Dolly Varden	G5	S3S4	BLUE
Salvelinus confluentus	Bull Trout	G3	S3	BLUE
Thymallus arcticus pop 1	Arctic Grayling, Williston watershed population	G5T1Q	S1	RED
Spirinchus sp 1	Pygmy Longfin Smelt	G1Q	S1	RED
Thaleichthys pacificus	Eulachon	G5	S2S3	BLUE
Acrocheilus alutaceus	Chiselmouth	G5	S3	BLUE
Hybognathus hankinsoni	Brassy Minnow	G5	S3	BLUE
Notropis atherinoides	Emerald Shiner	G5	S1	RED
Notropis hudsonius	Spottail Shiner	G5	S2	RED
Phoxinus eos x phoxinus neogaeus	Northern Redbelly Dace X Finescale Dace	HYB	S1	RED
Rhinichthys osculus	Speckled Dace	G5	S2	RED
Rhinichthys sp 4	Nooksack Dace	G3	S1	RED
Rhinichthys umatilla	Umatilla Dace	G4	S2	RED
Margariscus margarita	Pearl Dace	G5	S3	BLUE
Catostomus platyrhynchus	Mountain Sucker	G5	S3	BLUE
Catostomus sp 4	Salish Sucker	G1	S1	RED
Lota lota population 1	Burbot, lower Kootenay population	G5T1	S1	RED
Lota lota population 2	Burbot, lower Columbia population	G5T1	S1	RED
Gasterosteus sp 1	Giant Black Stickleback	G1	S1	RED
Gasterosteus sp 2	Enos Lake Limnetic Stickleback	G1	S1	RED
Gasterosteus sp 3	Enos Lake Benthic Stickleback	G1	S1	RED
Gasterosteus sp 4	Paxton Lake Limnetic Stickleback	G1	S1	RED
Gasterosteus sp 5	Paxton Lake Benthic Stickleback	G1	S1	RED
Gasterosteus sp 12	Hadley Lake Limnetic Stickleback	GX	SX	Extinct
Gasterosteus sp 13	Hadley Lake Benthic Stickleback	GX	SX	Extinct
Gasterosteus sp 14	Vananda Lake Benthic Stickleback	G1	S1	RED
Gasterosteus sp 15	Vananda Lake Limnetic Stickleback	G1	S1	RED
Pungitius pungitius	Ninespine Stickleback	G5	S1	RED
Cottus bairdi hubbsi	Mottled Sculpin, ss hubbsi	G5T?	S3	BLUE
Cottus bairdi punctulatus	Mottled Sculpin, ss punctulatus	G5T?	S2	RED