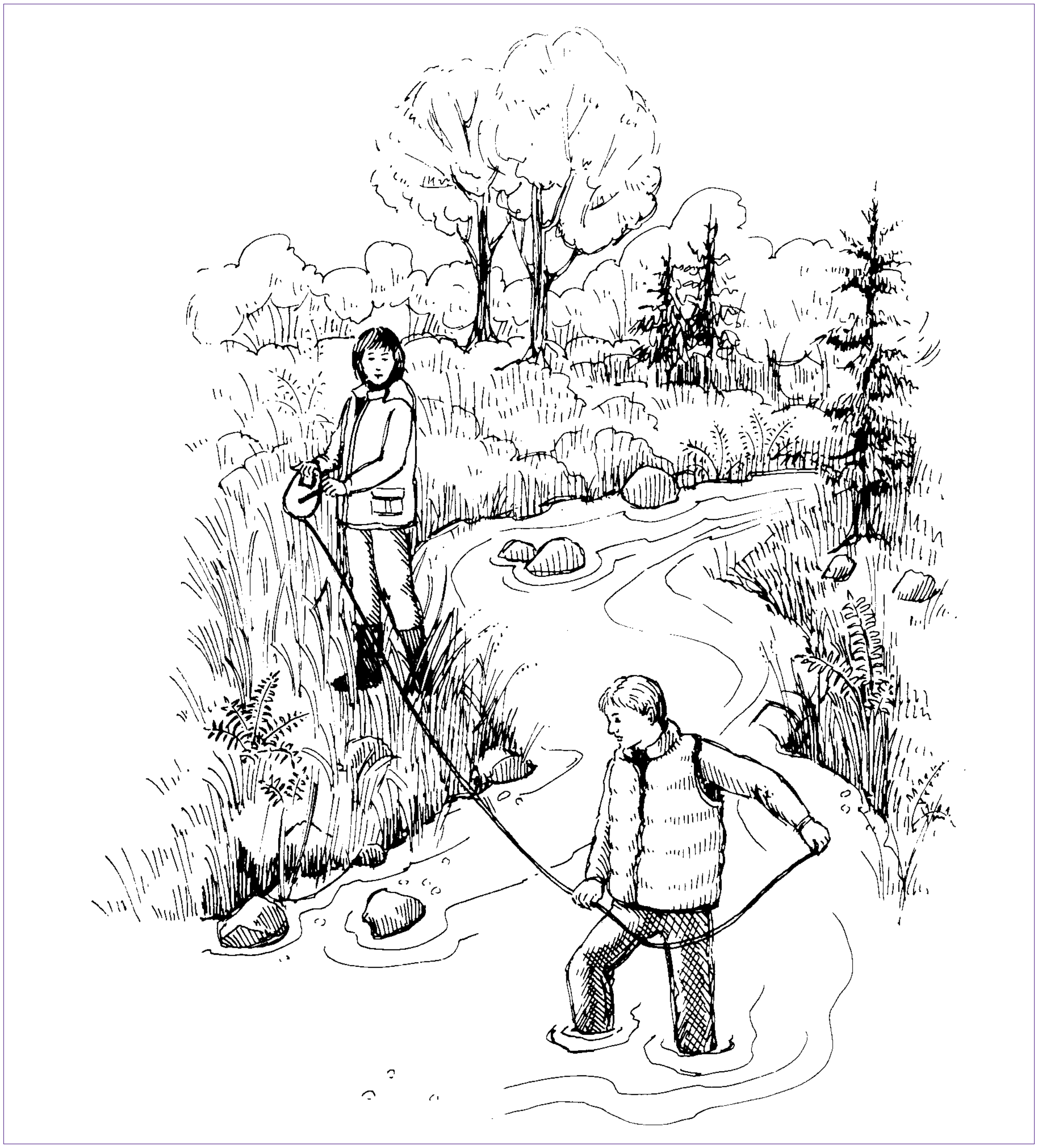
The **Stewardship** Series

The Streamkeepers Handbook



A Practical Guide To Stream And Wetland Care

Canada

Province of British Columbia

STREAMKEEPERS

Module 14
An Introductory Handbook for Instream Habitat Restoration Projects

Project Approval Required	Training	Time Commitment (per year)	Number of People	Time of Year
yes	recommended	1 week to ongoing	2 or more	Mostly summer low flow

Fisheries and Oceans   Pêches et Océans

Canada

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MODULE 14
An Introductory Handbook for Instream Habitat Restoration Projects

Welcome to the Streamkeepers Program! The Department of Fisheries and Oceans Community Involvement Program provides these Streamkeepers training modules. These modules encourage "hands on" environmental activities in watersheds in British Columbia. Volunteer groups, schools, and individuals are using this material to monitor and restore local waterways. Your local Fisheries and Oceans Community Advisor can provide more information.

Introduction

Earlier Streamkeepers training modules provided information on assessing watershed and stream health and on restoring stream banks through planting and fencing. Module 14 is a handbook designed to prepare you for the next level of restoration work, resolving problems within the stream itself. This module does not provide step-by-step instructions because most projects need to be designed specifically for a site. Instead, it introduces you to the complexities of stream behaviour, describes the steps in planning a habitat restoration project, and outlines several publications that do provide detailed instructions. Professional biologists and engineers usually do the work of restoring degraded stream channels. Since these projects have significant impact on stream habitat, they require government approval. Volunteer groups also can undertake restoration projects, but they need to be well prepared for the work and should seek advice from professionals.

Repairing stream damage caused by human disturbance can be a difficult task. A stream is a complex system that strives to stay in equilibrium. Some attempts to repair damage can lead to even greater damage if the project and its results are not well thought out. The structure may wash out, cause property damage or rapid erosion, or alter the stream channel. Instream work must be done at a time of year least likely to harm fish and other aquatic organisms. Groups that undertake a restoration project can be liable for damage caused to adjacent properties if various government agencies have not reviewed and approved the project.

As with any problem, you will develop a better long-term solution by considering the underlying cause of the problem rather than by treating an isolated symptom. This handbook is designed to help you identify and resolve problems resulting from human disturbance in the watershed. You will not attempt to improve on nature. Any disturbance of watershed land affects the stream. In some parts of the province, logging, mining, or agriculture have a great impact on the land base and stream health. Although urbanization affects less of the land base in the province, it causes a great deal of damage in concentrated areas. Channelization and altered flow patterns have affected most urban streams.

A major focus of this handbook is predicting whether a restoration project is likely to succeed at a particular location. This helps you avoid wasting time, money, and effort on a project that could get washed out or cause further damage. In some cases, it is better to do no work within the channel because of an unstable stream or surrounding terrain.

This handbook introduces you to stream hydraulics, which helps you understand the forces at work in a stream and predict the outcome of restoration work. It shows you how to bring together the information you collected in earlier modules and assess the severity of habitat problems (Steps 1 and 2). There are several criteria to help you evaluate the site, the potential project, and the probable outcome. After considering these criteria, you will be able to decide whether or not to proceed. The handbook then helps you choose a suitable project for your stream (Step 3), develop a proposal (Step 4), implement the project (Step 5), and evaluate and maintain the site (Step 6). You can take some steps on your own. For example, you can assess the condition of the stream, identify problem areas, and decide whether your site is suitable for a restoration project. However, you should seek expert advice in designing the project, obtaining approvals, and constructing the project.

In many parts of the province, your DFO Community Advisor (CA) will be your first contact. Depending on resources in your community, you may get help from the provincial Ministry of Water, Land and Air Protection (WLAP) or federal fisheries biologists and engineers, or from staff in the recently developed WLAP Urban Salmon Habitat and Watershed Restoration Programs. Staff or graduate students at local colleges and universities also are useful resources. You may want to call on these people to help you develop your project. They are used to dealing with technical matters and the approvals process. Their level of involvement with the project will vary, depending on the experience and resources in your group.

Modules 1 and 2 describe reconnaissance and habitat assessment procedures. Complete these activities for your stream or stream segment before you consider any habitat improvement projects. You also should do Modules 3, 4, 11 and 12, the biological and water quality assessments.

Principles

The following material is adapted from Trout Unlimited's Saving a Stream. It summarizes the principles that apply in developing any habitat restoration project.

"Cardinal Rules" of Stream Restoration

adapted from Saving a Stream (Trout Unlimited)

Look at the big picture. Focus on the riparian zone and watershed too, not just the stream.

Learn from nature. Try to duplicate conditions in healthy, productive sections of a stream when designing a project.

Focus on the limiting factors at work in your stream. Address the most important factors. Focus on the causes, not just the symptoms.

Each stream is like an individual - treat it that way! Consider the physical, hydraulic, and biological characteristics specific to your stream.

Work with, not against, the natural capacity of streams and watersheds to restore their own health. Changing land use practices in the watershed may be enough to improve stream conditions.

Involve a wide variety of experts, including professionals and local landowners familiar with the watershed.

Strive for natural appearance.

Stream Hydrology

The information in this section is provided to help you understand the forces that create and maintain streams. It will help you distinguish between natural processes in a stream and problems caused by human interference. It also will help you understand why some locations are better for a restoration project than others. Streams contain and channel much energy. Any materials or structures you place in a stream are liable to be eroded, moved, and deposited downstream.

Human activities have affected most streams in B.C. to some extent. This discussion begins with the concept of undisturbed streams and moves on to those affected by humans.

The Dynamic Forces of a Stream

Flowing water is a powerful force. It carves out a channel, moves materials downstream, and sometimes changes course unexpectedly. The stream system is in equilibrium. If one part is altered, the stream will work to regain equilibrium by altering another part.

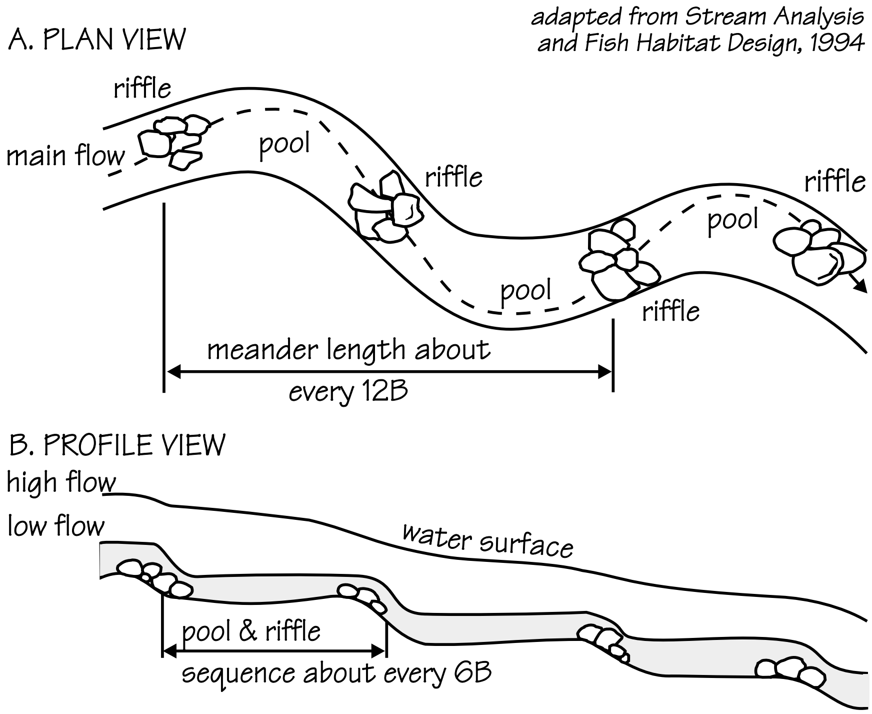
Several complex factors shape the stream channel. The most important factors are **hydraulic force** (flowing water) and debris load (e.g., rocks, wood, ice carried in the water). Flowing water moves in a three-dimensional wave pattern. It makes the current snake horizontally from one side of the flood plain to the other and, simultaneously, undulate vertically from the top of the water column to the bottom. The sinuous meander pattern is repeated regularly, on average every twelve times the channel width (Figure 1a). Also, the vertical wave pattern creates a sequence of pools and riffles (Figure 1b), repeated about every six times the channel width. Human intervention, such as channelization, or natural features, such as bedrock outcroppings and large woody debris, can disrupt the three-dimensional flow pattern.

This flow pattern causes scouring of both the stream bed and the banks. Consequently, the stream moves a great deal of material downstream. The lighter, smaller sediment moves downstream faster than larger, heavier material. Material carried by a stream is called alluvium. Stream channels formed in this way are called **alluvial**.

Over time, the stream moves back and forth across the flood plain. Although the boundaries change, features such as depth, width, and general shape of the channel remain constant. This holds true even in different parts of the world, among rivers with similar size and climate.

The hydraulic force of a stream is controlled by the size of the watershed and climatic conditions. These characteristics establish the volume of runoff flowing into a stream during flood peaks, which in turn determine stream width and depth. The peak floods that shape the stream channel are called **bank- full** floods and occur, on average, every two out of three years.

Figure 1
Average Meander, Pool and Riffle Spacing Expressed in Bankfull Channel Widths (B)



The debris load of an alluvial stream comes from the surrounding land. The size of particles moved along by the stream depends on underlying geology of the area, the volume of water, and gradient of the stream bed. With material moving downstream continuously, only the larger materials tend to remain at a given point. The stream bed usually consists of large boulders and cobbles in the steep upper reaches, cobbles and gravel in the moderately-sloping middle sections, and gravel, sand, and silt in the low-gradient lower reaches.

Most British Columbia streams, particularly those along the coast, are alluvial. Their beds, banks, and flood plains shift and their boundaries change readily. Since water deposited the material, water can move it again.

Tractive Force

The stability or mobility of stream bed materials is controlled by stream gradient (slope) and water discharge. Water flowing over the stream bed exerts a tractive force, measured in kilograms per square metre (kg/m2) of stream bed. The tractive force calculation incorporates both slope and water discharge and is useful for estimating stability of the bottom substrate.

CALCULATING TRACTIVE FORCE:

tractive force = 1000 X water depth X slope

where:

tractive force	= force of water over the stream bed area(kg/m2)
1000	= specific weight of water (1000 kg/m3)
depth	= water depth (m) (step 2, Module 2)
slope	= stream slope (no units) (step 4.1, Module 2)

EXAMPLE

average bankfull channel depth	= 0.6 m (water depth during flood)
slope	= 0.03 or 3% (3 m elevation drop over 100 m stream length)

Field studies have shown that, at a given flow, the tractive force (in kg/m2) exerted on the stream bed has the same numerical value as the smallest diameter of stable material (in cm). Smaller materials are mobile at that flow. This relationship works for loose rock greater than one centimetre in diameter. However, more force (greater water depth and/or greater gradient) is required to move packed and silted gravel.

As shown in the example above, you can use the tractive force calculation, along with stream bed composition data, to assess stream bed stability during flood conditions. Measuring the bankfull channel depth (Module 2, pages 8 and 9) during low flows helps you estimate water depth during a large flood.

At this site, stream bed substrates greater than 18 cm in diameter are stable during bankfull flood and those less than 18 cm are mobile. You can estimate stream bed stability during flood flows by comparing this number to the stream bed composition data, also collected during the Module 2 survey. For example, if only 30% of the stream bed particles are larger than 18 cm, then 70% move during flood flows.

Thus, since most of the stream bed moves during bankfull floods, you probably will run into problems maintaining an instream structure at this location.

You also can use the tractive force calculation to choose the appropriate size of materials for a restoration project involving gravel or boulder placement (example on page 23). In practice, engineers often incorporate a safety factor when designing projects. They may suggest using materials 1.5 times greater than the calculated value. In the above example, only material greater than 18 cm in diameter will be stable during a bankfull flood. Although you could place boulder clusters at this site, you could not place spawning gravel here and expect it to last for long. You might consider adding a weir to retain the gravel. However, it is easier to find a more suitable location, where the channel is flatter, shallower, and has lower tractive force. For example, you could add spawning gravel in an area where the bankfull depth is 0.4 m and the slope is 1%. Here, the tractive force is 4 kg/m2 and the minimum diameter of stable substrate is 4 cm.

The Effect of Human Disturbance on Stream Dynamics

Gradual bank erosion is a natural process that benefits stream life. It creates habitat diversity by creating pools, undercut banks, back eddies, and sloughs. It exposes tree roots and provides new sources of gravel. These features give character to the stream and provide complex habitat for the various stages in the life cycles of fish and other stream organisms.

However, human activities in the watershed often accelerate the erosion process by affecting the two basic processes that form the stream channel: hydraulic force and debris load. Many habitat problems you will discover in your stream surveys result from poorly planned activities. Removing natural vegetation, channelizing streams, impounding water, or paving and building up areas change the pattern of water flow in the watershed. They also change the rate of erosion on the surrounding land. Streams in urban areas often suffer severe habitat degradation because the land base is highly developed and streams have been modified and channelized to protect private property.

When sediment input or water flow changes, a stream adjusts its shape to compensate. Several kinds of human activities create similar symptoms in the stream channel. Adding a habitat restoration structure is an attempt to treat these symptoms. However, an effective long-term solution must address the cause of the problem.

Increased discharge results from any land use that reduces the amount of natural vegetation, especially paving of urban areas and logging. Increased discharge leads to increased water depth and velocity, creating increased energy that dissipates by eroding stream beds and banks. This increases the debris load of the stream. The channel adjusts by becoming wider and sometimes deeper. Gravels wash away, leaving only cobbles and boulders in steeper sections and fine sediment in lower gradient sections near the mouth of the stream.

Decreased discharge comes from diverting tributaries and other sources of runoff, or from withdrawing water for irrigation, industrial, and domestic uses. The shallower water depth and slower velocity mean the stream has less energy available to erode the banks and move stream bed materials. The stream may become narrower and shallower. Usually, fine materials accumulate and compact the stream bed.

Increased debris load comes from activities that accelerate soil erosion, such as agriculture, logging, and urban development. The stream has enough energy to carry a certain amount of sediment. When that amount is exceeded, the extra is deposited on the bottom. This sediment fills pools, silts the gravel, changes the gradient, and usually raises the level of the stream bed. The stream tries to maintain its original channel size, so it erodes the stream banks to make a wider channel.

Decreased debris load comes from damming, dredging, culverting, and channelizing streams. These activities diminish the sources of new material available to replenish what the stream has washed downstream. The stream channel often deepens and narrows. Gravel bars may disappear and only larger material or bedrock remains as the gravel migrates downstream.

Channelization affects the shape of the stream directly, and often has the same effect as increased discharge. Straightening a stream and eliminating its meanders creates a higher gradient over a much shorter distance. Often such activities include protecting the banks with rip-rap or concrete, which can create a narrower channel and lead to deeper water during floods. Higher water velocities result from such activities.

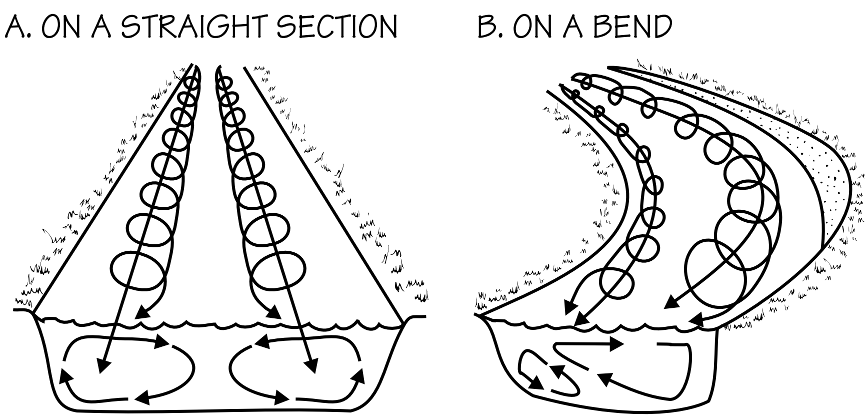
Hydraulic Impacts of Habitat Restoration Projects

Most habitat restoration projects involve placing a structure in the stream to create either pool habitat (by scouring) or gravel bar riffle habitat (by depositing). Many of these structures cause both scour and deposition. Predicting the impact of adding a structure to a stream is an imprecise science, developed more through observation than theoretical application. With experience, the results are becoming more predictable.

Unobstructed water moves in a double spiral pattern, as shown in Figure 2a. The water moves clockwise on one side of the channel and counterclockwise on the other side. In a straight section, the two spirals are equal in size, and the main flow (thalweg) follows the middle of the stream.

Figure 2
Screw-like Spiral Pattern of Stream Flow

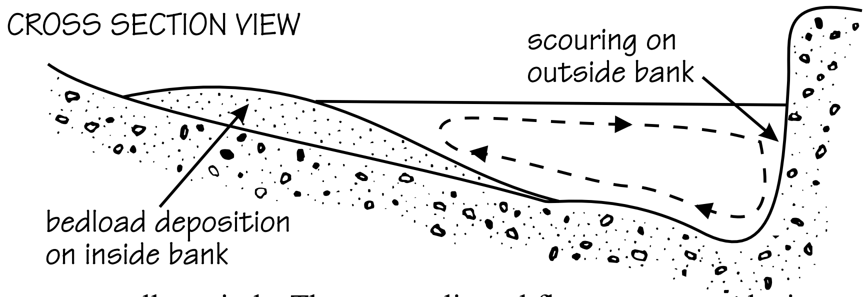
adapted from A Training in Stream Rehabilitation, 1988



A bend in the stream disrupts the equilibrium between these two spirals and alters the direction of rotation. The spiral at the outside of the curve becomes bigger and the one on the inside becomes smaller (Figure 2b). The thalweg follows the predominant spiral, so it shifts to the outside of the curve. Continual scouring produces deeper water on the outside of the bend and continual deposition forms a point bar on the inside of the bend (Figure 3).

Natural obstructions and restoration structures disrupt the pattern of spiral flow. The effect of this disruption is relatively easy to predict when a simple habitat structure is placed at an ideal stream location. When more than one structure is added, or where the location is less than ideal (Table 1, page 22), the spiral flow pattern is broken into

Figure 3
Scour and Deposition Patterns on a Stream Bend



many smaller spirals. These complicated flow patterns make it more difficult to predict the amount and location of scour and deposition.

Three situations can cause scouring:

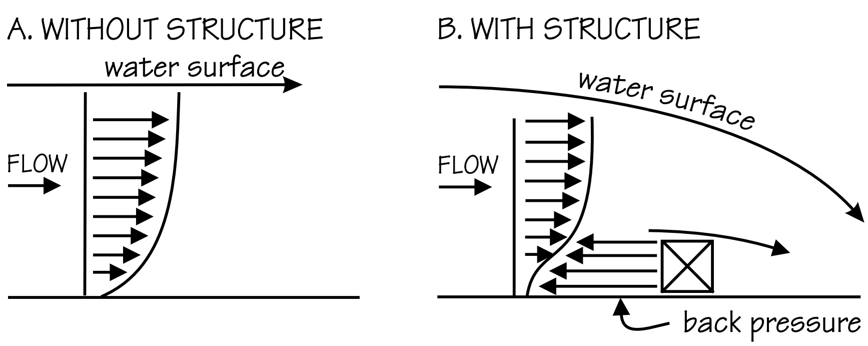
- on the outside bend of a meander
- where water falls over a structure
- where water velocity increases (e.g., at a constriction or where the gradient becomes steeper)

Some habitat structures create all three types of scour, whereas others create mainly one type.

Similarly, three situations can cause deposition of material:

- on the inside bend of a meander
- in a quiet area created by back-pressure upstream of an instream structure (Figure 4)
- where water velocity slows (e.g., eddies, wider areas of the channel, lower gradient sections)

Figure 4
Velocity Profile in a Stream
A. Without a Structure and B. With a Structure



adapted from A Training in Stream Rehabilitation, 1988

The following general hydraulic principles apply when you design a structure to create scour and deposition areas.

Bankfull Depth

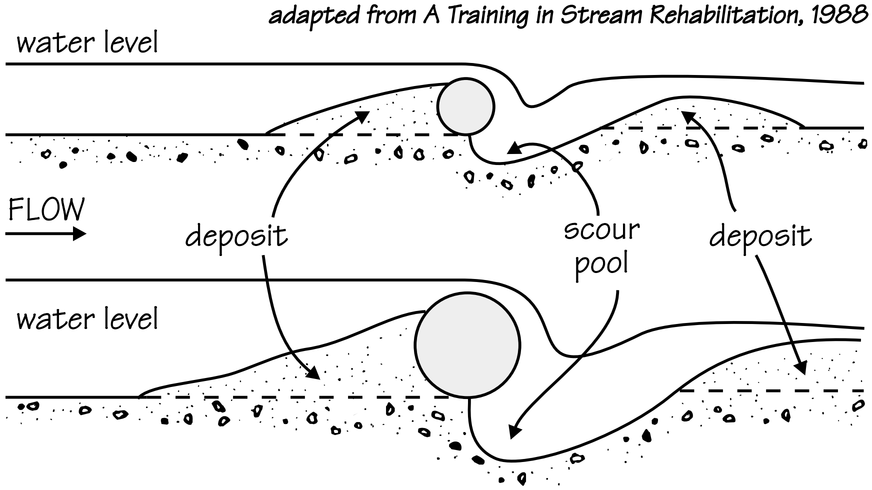
Bankfull channel depth determines water depth, which in turn determines the depth of scour around an obstruction. Experience has shown that the maximum scour depth created around a structure is slightly greater than bankfull depth.

Structure Height

The height of a structure also influences the amount of scour. Generally, higher structures create deeper plunge pools (Figure 5). Observations have shown that the depth of the scour is at least as great as the structure height. Depth of scour is limited by the available stream energy, which depends on bankfull channel depth, as discussed above. Experience also has shown that higher structures deposit more and deeper bedload both upstream and downstream of the structure than do lower structures.

Figure 5
The Effect of Structure Height on Scour and Deposition Zones

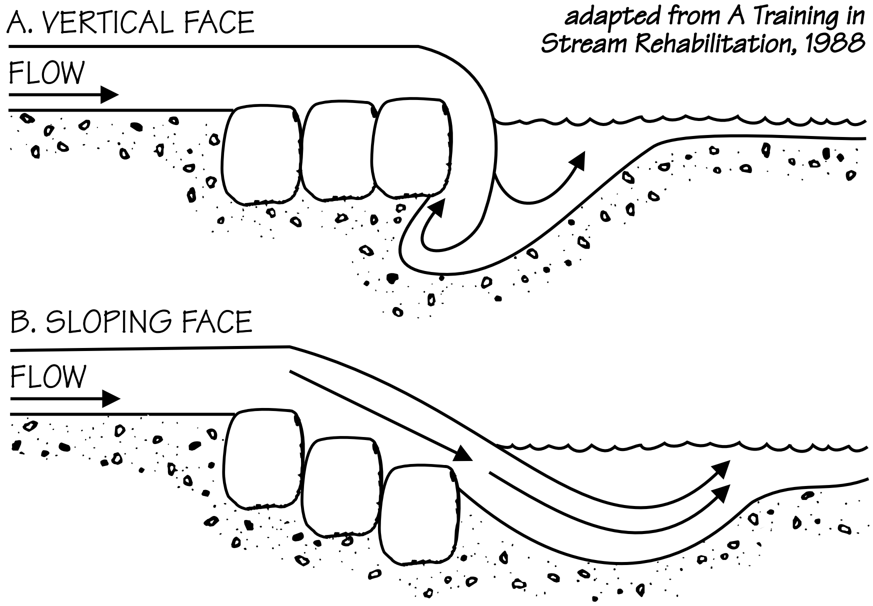
adapted from A Training in Stream Rehabilitation, 1988



Angle of Downstream Face of the Structure

This angle affects the stability of the structure by determining where the force of the stream is directed onto the stream bed. A vertical face creates scour at the base of the structure, undercutting it and ultimately causing it to slip into the newly created scour pool (Figure 6a). A sloped face directs the water away from the base, which causes both scour and deposition further downstream (Figure 6b).

Figure 6
The Effect of A. Vertical Versus B. Sloping Structure Face on Scour Location



Orientation of the Structure

Water passing over a structure moves downstream in a direction perpendicular to the angle of the structure. Figure 7 shows how various instream structures affect stream flow and the patterns of scour and deposition. These patterns were observed following installation of the structures. The size of the spiral pattern in each sketch shows the amount of scour possible.

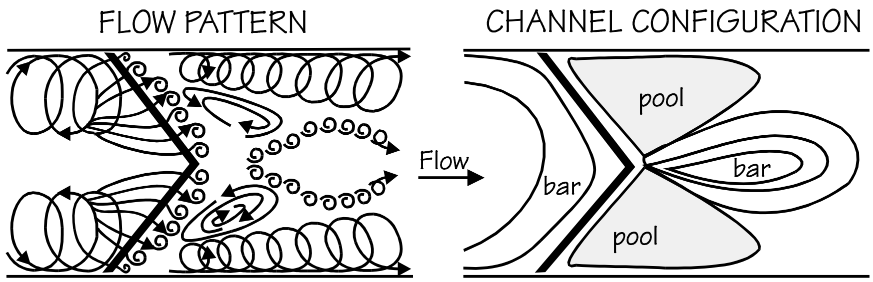
The patterns occur repeatedly, but with considerable variability among structures. For example, a V-shaped weir with its apex pointing downstream directs the flow toward both banks (Figure 7a). Scour pools develop at the banks and material deposits in the quiet midstream area. A V-shaped weir with its apex pointing upstream directs flow toward the centre of the channel, constricting the channel and creating deeper scour there (Figure 7b). However, at high flow some upstream V-weirs may split the flow and direct it towards the banks. Straight structures that span the stream can be oriented to spread out the flow, rather than constrict it. A long structure (two to three times the stream width) placed diagonally in the stream spreads the flow, decreases the water velocity and energy, and deposits material upstream and downstream of the structure (Figure 7c).

Several illustrations show full-spanning structures. However other structures, such as boulder groupings, wing deflectors, and other

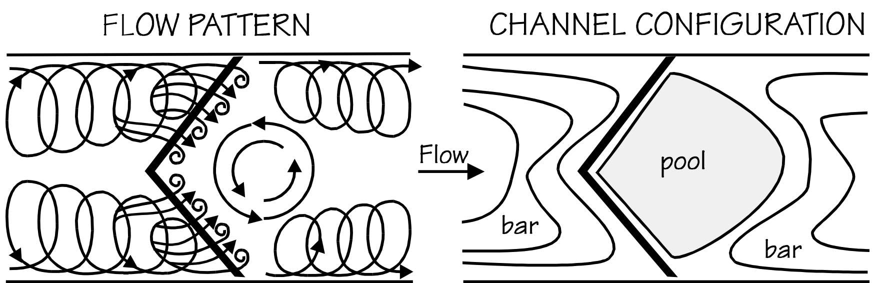
Figure 7
The Effect of Structure Orientation on Flow, Deposition and Scour

adapted from A Training in Stream Rehabilitation, 1988

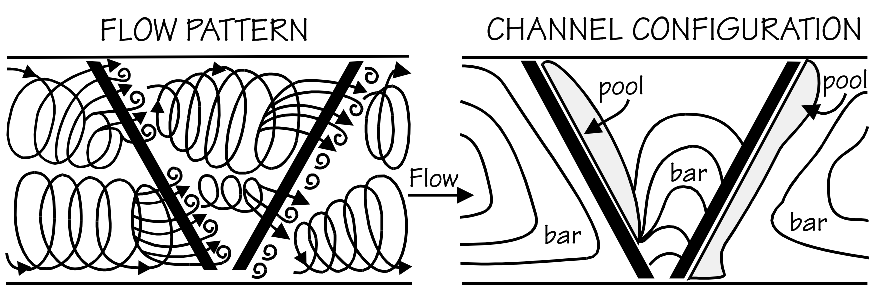
A. DOWNSTREAM V-WEIR



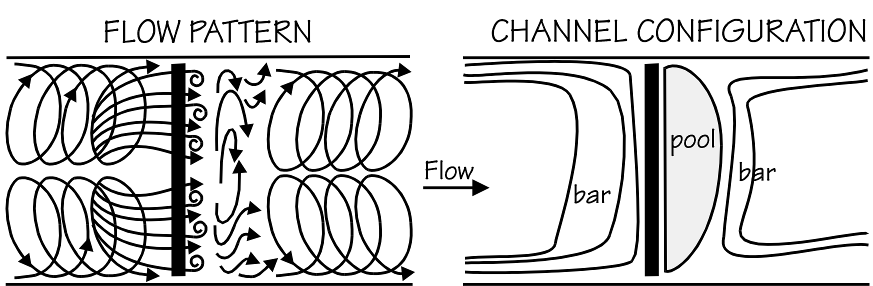
B. UPSTREAM V-WEIR



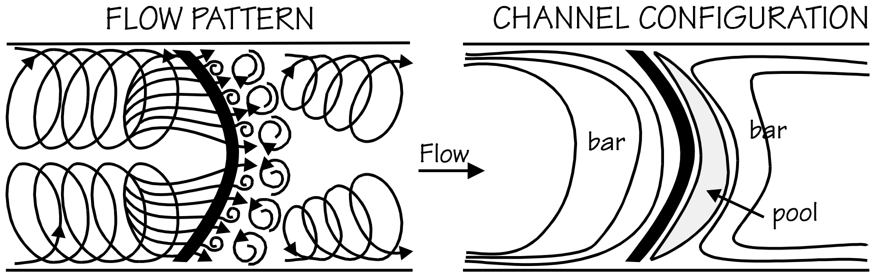
C. DOUBLE DIAGONAL WEIR



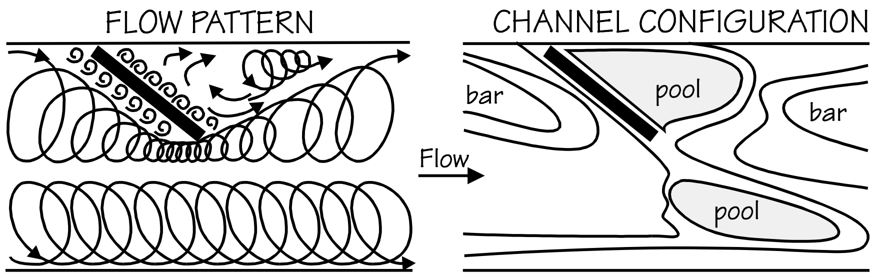
D. PERPENDICULAR WEIR



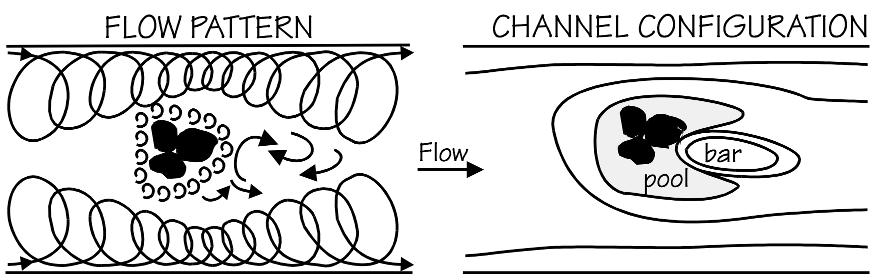
E. U-SHAPED WEIR



F. WING DEFLECTOR



G. BOULDER CLUSTER



Several illustrations show full-spanning structures. However other structures, such as boulder groupings, wing deflectors, and other clusters can provide the same effects but cost less to install and require less maintenance than full- spanning structures.

Safety

All the concerns for personal safety outlined in previous modules are essential when doing stream restoration work. Follow the safety recommendations listed in Modules 1 and 2 when doing watershed and site reconnaissance for a restoration project. Do not attempt to wade fast water or water deeper than your knees. Watch out for slippery stream beds, undercut banks, waterfalls, and fast flowing areas. Be especially careful working around log jams.

In addition, there are special safety concerns to consider when restoring stream habitat. These usually involve construction techniques, so similar safety recommendations apply. Some are outlined in the references for individual techniques or in the Workers Compensation guidelines. Often you will be working right in the stream, around heavy machinery, lifting heavy materials, or using hand tools. There are real dangers involved in this work. Your group may want to buy insurance to cover personal injury.

First Aid

On a project involving more than a few people and heavy machinery, someone at the site should have first aid training. You may want to send a member of the group to Swift Water Rescue Training. Have an evacuation plan in case of a medical emergency. If you will be working right in the water, wear a personal flotation device and proper thermal protection. Send only experienced river swimmers into the water when you work on a large stream. Install a safety line diagonally across the stream downstream of the site, in case someone is swept away. Have a rescue throw bag, first aid kit, survival kit, and cellular telephone at the site. Also, have warm blankets and extra clothes in case someone gets wet or develops hypothermia.

Most instream projects are done during the summer, when the risk of heat exhaustion, heat stroke, or dehydration are greatest. To prevent these conditions, have plenty of fluids available. An active person should drink at least 1.5 litres (50 ounces) of water every eight hours, regardless of air temperature. Plan rest breaks at appropriate intervals.

Safety Around Heavy Equipment and on the Stream

At the start of the day, stress the importance of following all safety guidelines. On a project involving several people, assign someone the job of watching for unsafe practices and correcting them (e.g., tools left lying around, shovels and rakes pointing upward, someone not wearing safety equipment). This is a good job for a less active person.

Although using common sense may seem obvious, it cannot be stressed enough. Wear all the safety equipment recommended for the job (e.g., safety goggles, steel toed boots, waders with felts, hard hats, heavy work gloves, ear plugs).

Stay well back from any heavy equipment. If you cannot see the eyes of the operator, he or she cannot see you. Recognize the limitations and capabilities of each volunteer (for example, some people are more agile than others). Be aware of your surroundings and the possible dangers. Do not use any equipment with which you are unfamiliar.

Step 1: Watershed Reconnaissance

Module 1, Introductory Stream Habitat Survey, tells you how to do an initial reconnaissance of the watershed. When you are done, you will have a map, photographs, and field notes documenting the location and severity of habitat problems along the stream. This information helps you rank habitat problems and select the most important ones to deal with first. For example, without this information you might add spawning gravel and later discover that sediment from an upstream bank failure silts up the gravel. Perhaps spawners cannot pass upstream through a culvert to reach the spawning ground you have created for them.

You also will collect information about land and water use in the surrounding watershed. This information provides clues about the cause of stream channel problems. You may find that resolving a particular land or water use problem in the water- shed provides greater benefits to the stream than does an instream project.

When you select an improvement project, consider why the area does not have desirable habitat now. For example, some stream reaches would benefit from adding large woody debris (LWD). Before you begin, look for reasons why there is little LWD in the stream now. Are there large coniferous trees on the bank that provide a source of LWD? Has urbanization in the watershed resulted in larger floods that wash it out? The best long-term solution where there is little or no stream bank vegetation is to restore that vegetation. Since trees and shrubs take a long time to mature and contribute debris, you also can provide immediate benefits by securing LWD in the stream channel. If there is enough stream bank vegetation, but large floods wash out the LWD, the best long-term solution is to solve the land-use problems that cause the flooding. In this case, you will want to work with your local government to create environmental protection bylaws. For example, some municipalities restrict the total land area that can be covered with impermeable surfaces such as pavement and rooftops. Stormwater detention facilities can be incorporated into new or existing developments to reduce flooding.

Step 2: Site Assessment

Module 2, Advanced Stream Habitat Survey, helps you assess stream conditions at your proposed project site. You rate the quality of nine important physical characteristics of the stream environment. Completing Module 2 is very important for several reasons. The observations you make during this survey allow you to:

- assess habitat quality, identify physical problems, and determine the extent of damage at a particular site,
- assess stream bed stability and decide whether the site is suitable for an instream project, and
- calculate the size of material needed at the site to withstand flood flows.

You should complete Modules 3, 4, 11 and 12, the water quality and biological surveys. These data provide a good picture of stream health and will help you assess the severity of the habitat problems. You also can use these data to evaluate improvements after you finish the project.

Once you have narrowed down your list of habitat problems, you need to consider the suitability of the site(s) for stream channel modification. The technical resource people can be very helpful at this stage. Table 1 lists twelve important criteria you should use to evaluate your site. The most important criterion relate to the potential erosive force of the stream at your proposed site and the resulting stability of the stream bed. The tractive force calculation described on page 10 provides this information. Besides helping you assess stream bed stability and hydraulic force, the calculation helps you select the appropriate size of gravel or boulders needed for the project.

A paradox of instream restoration work is that the sections of the stream that could benefit most from structural enhance- ment are so steeply sloped and unstable that structures often get washed out. Low gradient areas are well suited to such work, but often they do not need these improvements.

TABLE 1. Site Assessment Criteria	
1.	Evaluate the potential of the project to jeopardize public safety or damage private property.
2.	Evaluate the potential impacts of the project on other wildlife species in and around the stream. Some species, like the Nooksack dace and Pacific giant salamander, have a limited distribution range, are rare, and may be threatened with extinction.
3.	Check that there are no other problems, such as poor water quality or quantity, that could offset the benefits of structural enhancement. You should have discovered these problems in earlier stream surveys.
4.	Calculate tractive force at bankfull flood. This provides information on the stream forces at work during flood conditions, stream bed stability under these conditions, and the size of gravel or boulders neededfor an instream project.
5.	Consider access to the site and availability of local materials. These are important considerations if you need to bring in equipment or move logs, stumps, or boulders to the site.
6.	Locate the project where the stream slope is less than 3%. High gradient areas have high tractive force, so many projects wash out.
7.	Choose an area where stream banks are relatively low and the channel is at least the average width. During floods, the increased stream energy will dissipate on adjacent flood plains rather than within the stream channel.
8.	Locate the structure where stream banks are stable and have well-developed vegetation.
9.	Where possible, place structures in a straight section of stream rather than on a bend. Bank stabilization is an exception, since erosion often occurs on a bend. Avoid highly braided channels that are shifting actively across the valley floor.
10.	In high energy stream segments, select a site with room for a few structures. Upstream structures provide velocity breaks for adjacent downstream structures, and add to the effectiveness of the work. This is not as important in low energy segments, such as below a lake outlet.
11.	Consider the effect of nearby large natural or artificial structures on stream flow and current patterns. They may affect or be affected by your structure. Also, consider where the structure would come to rest should it be washed out. For example, it might lodge in a culvert and cause flooding.
12.	Study the existing stable natural channel features. These features have endured through time and provide clues about successful designs and materials you can copy in your project.

EXAMPLE:
Assessing a Site for Spawning Gravel Enhancement

After completing steps 1 and 2, you may decide that the stream would benefit from adding spawning gravel. You should consider the following questions first.

Does the amount of spawning habitat limit fish production?

Factors other than spawning habitat may limit fish production. For example, coho, trout, and char seldom are limited by spawning area. Before you conclude that increasing the amount of gravel will increase the number of fish, check for other factors. These include rearing habitat, holding pools, over-wintering habitat, water quality or quantity problems, and predators.

Is this a suitable spawning area for the species concerned?

Find out where fish spawn now and the size and depth of spawning gravel in those areas. Check with DFO, WLAP, and the Streamkeepers Database to see if data have been collected on the number, species, and preferred location of returning spawners. Unfortunately, there is little or no information available for many small streams. Usually, it is easier to replace or add gravel to existing spawning areas than to create spawning areas where fish have not spawned in the past. Spawning preferences differ among species and populations of sal- monids. For example, some coho and steelhead spawn as far upstream as possible, whereas some chum spawn very close to the estuary. The physical characteristics that affect the quality of spawning areas are location within the watershed, gradient, substrate stability, gravel depth, size and quality, water depth, and water velocity. Water quality, instream cover, and stream bank vegetation also are important.

Why does the site lack good spawning habitat?

The most common causes of insufficient spawning gravel in urban streams are channelization and increased flood flows. Perhaps stream flow is too fast in this area to allow gravel to settle. If the stream has too little energy, gravel may not migrate downstream to this location and any gravel placed here will become covered in fine sediment. There may be no source of gravel upstream if the banks have been engineered to prevent erosion. A lake or dam may form a barrier to downstream migration of gravel.

Will added gravel stay in the stream?

Some parts of your stream are more suitable than others. Consider gradient when choosing a location. It should be steep enough to prevent siltation, but not so steep that the gravel would wash out. The tractive force calculation allows you to estimate the size of stable substrate for a given location. Gravel catchment devices such as rock weirs can be used to help retain spawning gravel, especially in higher gradient sections.

The example of adding spawning gravel to the stream (page 23) shows you how to apply steps 1 and 2 to planning a restoration project. You may discover a need for additional spawning gravel in the stream but wonder if you have chosen a good location to place new gravel.

Step 3: Project Selection

Table 2 correlates typical habitat problems found during watershed surveys with the appropriate restoration techniques. It is cross-linked to Table 3, which lists the references that describe the techniques in detail. The reference section at the end of the module provides an annotated bibliography to these references.

Appendix 1 provides a brief description of these techniques, where to use them, and their advantages and disadvantages. It does not include detailed instructions since the techniques must be adapted specifically to the site. Your technical resource people can help you select an appropriate project.

Figure 8 shows a sample site plan that includes several stream restoration structures used in series.

Figure 8
Example of a Series of Restoration Structures

adapted from A Training in Stream Rehabilitation, 1988

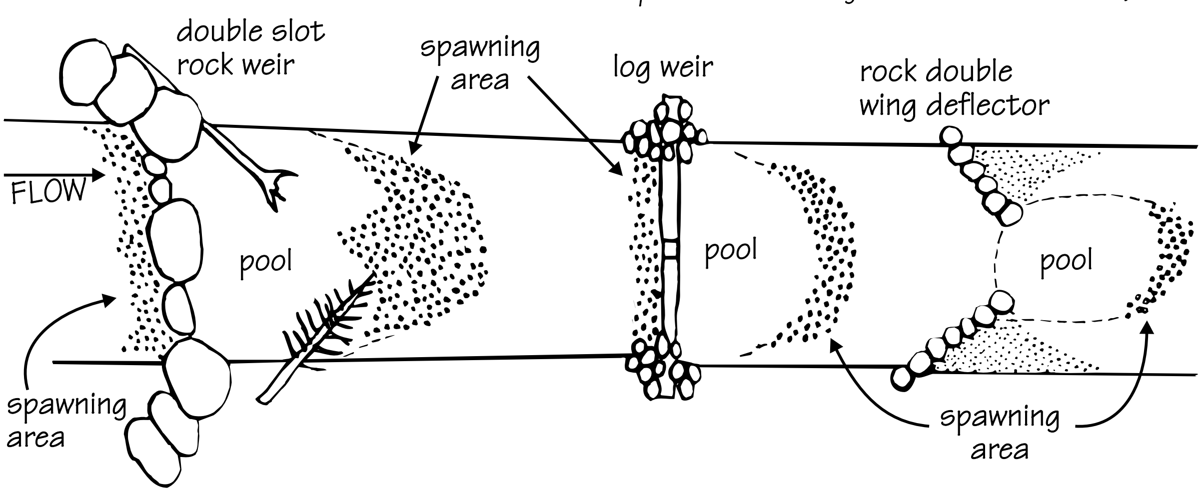


Table 2
Habitat Restoration Techniques

Problem \ Action	Streamside Planting	Streamside Fencing	Rock Rip-Rap	Spiles and Wattles	Tree Revetment	Log Crib/ Log Bank Cover	Culvert Passage	Fishway	Beaver Dam Management	Log Jam Management	Fish Screens	Water Quality Assessment	Stream Invertebrate Survey	Rock/Log Weir	Wing Deflector	Boulder Placement	Gravel Catchment/ Placement	Large Woody Debris Placement	Off-channel Habitat Development	Flow Augmentation	Storm Drain Marking	Community Awareness	Observe, Record and Report	Stormwater Detention
Lack of Riparian Vegetation	◆	◆	◆	◆	◆																			
Livestock Access	◆	◆																						
Streambank Erosion	◆	◆	◆	◆	◆	◆									◆									
Impassable Culvert							◆																	
Impassable Dam/Falls								◆																
Impassable Beaver Dam									◆															
Impassable Log/Debris Jam										◆														
Unscreened Water Intake/Diversion											◆													
Stormwater/ Discharge Pipes												◆	◆								◆	◆	◆	◆
Poor Streambed Material	◆	◆												◆	◆	◆	◆		◆					
Lack of Instream Cover	◆	◆	◆	◆	◆	◆								◆	◆	◆		◆	◆					
Inadequate Stream Flow Seasonally	◆	◆							◆			◆	◆						◆	◆				
Lack of Pool Habitat	◆	◆													◆				◆					
Lack of Off-Channel Habitat																			◆					
Illegal Activity Observed																							◆	

Table 3
Habitat Restoration Publications

Restoration Method / References	Fish Habitat Enhancement: A Manual for Freshwater, Estuarine, and Marine Habitats	The Streamkeepers Handbook: A Practical Guide to Stream and Wetland Care	A Training in Stream Rehabilitation, Emphasizing Project Design, Construction and Evaluation	Stream Analysis and Fish Habitat Design: A Field Manual	Guidelines for Bank Stabilization Projects in the Riverine Environments of King County	Freshwater Intake End-of-Pipe Fish Screen Guideline	A Guide to Selection & Propagation of Some Native Woody Species for Land Rehabilitation in B.C.	Culvert Guidelines: Recommendations for the Design and Installation of Culverts in B.C.	Fish Habitat Rehabilitation Interim Procedures for the Watershed Restoration Program	Urban Runoff Quality Control Guidelines for B.C.	Land Development Guidelines for the Protection of Aquatic Habitat	Design for Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetlands
Streamside Planting	◆	◆			◆		◆		◆			
Streamside Fencing	◆	◆										
Rock Rip-Rap	◆		◆		◆				◆			
Spiles and Wattles	◆				◆				◆			
Tree Revetment			◆		◆				◆			
Log Crib / Log Bank Cover	◆		◆		◆				◆			
Culvert Passage	◆							◆			◆	
Fishway	◆		◆						◆			
Beaver Dam Management	◆								◆			
Log Jam Management	◆								◆			
Fish Screens	◆					◆						
Rock / Log Weirs	◆		◆	◆					◆			
Wing Deflectors	◆		◆		◆				◆			
Boulder Placement	◆		◆	◆	◆				◆			
Gravel Catchment / Placement	◆		◆	◆					◆			
Large Woody Debris Placement	◆		◆	◆	◆				◆			
Off-channel Habitat Development	◆		◆						◆			
Flow Augmentation	◆			◆					◆			
Storm Drain Marking		◆										
Stormwater Detention										◆	◆	◆

Step 4: Project Planning and Approvals

You will work closely with the technical resource people on the planning and approvals process. They can help you assemble the necessary information and cut through the red tape. This step may take much longer than the instream work, so you should start planning well in advance (e.g., in the autumn for a project the next summer).

With few exceptions, instream work must be done within the **"fisheries window",** to reduce the impact of the work on the stream and its inhabitants. This period varies a little around the province, depending on climatic conditions and species of fish in the stream, but generally is between July 15 and September 15. Check with the local DFO or WLAP office for the timing of the fisheries window in your region.

You need project approval from relevant government agencies and written permission from property owners before you start any instream work. Consult with property owners in the initial planning stage. The Water Management Branch of WLAP issues the permits for instream work. A form entitled Environmental Review: Notification for Proposed Works and Changes In and About a Stream under the Section 7 Regulation of the Water Act must be completed and submitted to WLAP. Appendix 2 contains a copy of this form. WLAP will send you the form and a Section 7 User's Guide on request. The agency circulates the application to other interested government offices through the "referral system." Staff at DFO, and the provincial Fish and Wildlife Branch comment on the application and influence WLAP in their decision to approve or reject the application.

It is important to submit all the requested information in the permit application. A well-prepared application contributes greatly to a successful project and increases your chances of quick approval. The information you prepare for the application also can be used when applying for project funding. The following information will form important elements of your proposal:

- location of work (name of stream, specific location of work, street address and legal description of property)
- complete description of proposed work (the specific project, dimensions of the work, and methods to be used)
- site plan, area map, engineering drawings (should be easy to interpret and show clearly the details of the project)
- tenure of land (name of registered owner or lessee, letter of permission from the owner; if on Crown land, include the tenure document)

Consider access for heavy equipment and delivery of material. Plan to use as much local material (boulders, large woody debris, etc.) as possible, but consider carefully the impact of moving or removing material. Arrange as many free sources of materials, equipment, skilled operators, and professional assistance as possible. Ask local businesses to donate, or sell at a discount, materials for the project. Get several quotes.

Step 5: Project Implementation

Now you are ready for the field work! Your technical advisor may supervise the instream work. There are several ways your group can keep the work day running smoothly. A well run and enjoyable day will encourage the volunteers to return for future projects.

Check that all approvals, materials, tools, and equipment are ready. Arrange for duplicates of essential equipment in case of breakdowns. Arrange first aid, a first aid attendant, refreshments, and sanitary facilities. Recruit volunteer labour, especially people with specific skills. Although you want to have more than the minimum number needed, you do not want too many people. Work can be frustrating when too many people mill around with nothing to do or get in each other's way. Make sure the volunteers know what to bring (e.g., work gloves, work boots, waders, personal safety gear, lunch, a change of clothes in case they get wet).

Start the day with a brief orientation, including safety information and assigned tasks. Provide refreshments, a shady rest area and, perhaps, lunch. Take lots of photographs before, during and after construction. A close up of each person at work makes a great thank-you card. End the day with a thorough site cleanup.

Step 6: Evaluation and Maintenance

Most of the projects listed in Appendix 1 require some ongoing maintenance. Usually, the need for maintenance increases with the complexity of the structure. Make sure that everyone involved in the project agrees on who is responsible for maintenance.

You should monitor a variety of stream conditions before and after the project, using Modules 2 (Advanced Stream Habitat Survey), 3 (Water Quality Survey), 4 (Stream Invertebrate Survey), 11 (Juvenile Fish Trapping and Identification) and 12 (Spawner Survey). These data will help you evaluate the success of the project, the health of the stream and subsequent problems in the watershed. Documenting the improvements in stream conditions will help you gain public support for these types of projects. Also, if you conclude that your project is not as successful as you had hoped, you have a chance to make improvements.

Arrange for recognition of the project itself and the efforts of the volunteers. You have made a major commitment of volunteer time and funds. Depending on the size of the project, consider sending letters of appreciation to volunteers and contributors, arranging a barbecue, writing a report for your group, or arranging media coverage.

You and your group will be well aware of the benefits of your project but you need the support of your community for enhancement projects to succeed. Talk about your project with others whenever and wherever you can, including at school and public meetings. Placing an information sign at the enhancement project is especially appropriate. Module 10 contains specific information about increasing community awareness and working with the media.

References Listed in Table 2

This annotated bibliography contains brief comments on the references commonly used in British Columbia for habitat restoration projects. However, it is not a complete list of resource materials. Your Community Advisor can help you locate these references.

Fish Habitat Enhancement: A Manual for Freshwater, Estuarine, and Marine Habitats
Adams, M.A. and I.W. Whyte. 1990. Department of Fisheries and Oceans, DFO/4474. 330 pp.
to get a copy, telephone (604) 666-6614
This manual describes many techniques used to restore stream habitat in B.C. There is a very brief introduction to ecosystem functions, life histories of some aquatic species, and project planning. For each technique it provides background information, advice on appropriate stream conditions, design and installation guidelines, photographs, drawings, maintenance requirements, factors influencing cost, advantages, disadvantages, and examples of successful projects.

A Training in Stream Rehabilitation, Emphasizing Project Design, Construction and Evaluation
House, R., J. Anderson, P. Boehne and J. Suther (eds.). 1988. Oregon Chapter American Fisheries Society, Bend, Oregon.
out of print, contact your Community Advisor
This manual presents course materials used by the Oregon Chapter of the American Fisheries Society for a stream rehabilitation course. The 16 sections cover topics ranging from the theoretical to the practical. Topics include stream hydrology, the usefulness of hydraulic principles in predicting the outcome of habitat improvement projects, and design details for several projects. The manual also discusses watershed analysis, limiting factor analysis, project evaluation, and case studies of past failures and successes in both coastal and interior Oregon streams.

Stream Analysis and Fish Habitat Design: A Field Manual
Newbury, R.W. and M.N. Gaboury. 1994. 256 pp.
to get a copy, write Newbury Hydraulics, Box 1173, Gibsons, B.C. V0N 1V0,
or telephone (604) 886-4625
This manual describes in detail the design of full-spanning cobble and boulder weirs. These weirs control gradient and create a natural and stable series of pool and riffle habitats in a stream. The first three chapters present the steps in project design and describe stream analysis and design procedures. The fourth chapter focuses on site design and construction steps and provides case studies of five Manitoba streams. The text describes, in easily understood language, hydraulic principles from the watershed level down to the streambed microhabitat level. It also shows how to calculate total annual flow yields, used for planning water storage projects to augment stream flow.

Guidelines for Bank Stabilization Projects in the Riverine Environments of King County
Johnson, A.W. and J.M. Stypula (eds.). 1993. King County Department of Public Works, Surface Water Management Division, Seattle, Wash.
to get a copy, telephone (206) 296-1951
This practical guide describes how to assess bank erosion problems on large streams, evaluate alternative solutions, design and construct bank stabilization projects. It provides design specifications for several techniques, emphasizing materials that match the natural surroundings. It also discusses planning, on-site construction supervision, and maintenance. The manual applies to many B.C. streams, even though it focuses on stream geology, ecology, erosion, and bank failure processes in Western Washington.

Freshwater Intake End-of-Pipe Fish Screen Guideline
Anonymous. 1995. Department of Fisheries and Oceans, DFO/5080. 27 pp.
to get a copy, telephone (604) 666-6614
This well-illustrated booklet provides information on the size and design of fixed screens. The screens often are placed over intake pipes used to extract water at up to 125 litres per second. The booklet discusses fish screens for permanent and temporary pipes used for irrigation, construction, and small scale municipal and private water supplies.

A Guide to Selection and Propagation of Some Native Woody Species for Land Rehabilitation in British Columbia
Marchant, C. and J. Sherlock. 1984. B.C. Ministry of Forests Research Report RR84007-HQ, Victoria, B.C. 117 pp.
out of print, contact your Community Advisor
This is a good guide for people ready for more advanced streamside planting techniques than those discussed in Module 7 of the Streamkeepers Handbook. The publication provides details on biology, identification, and propagation of 26 coastal and interior B.C. native woody plant species, excluding large conifers. It describes ecological and physical aspects of disturbed land. It also includes criteria used to select species best suited to various soils and climates.

Culvert Guidelines: Recommendations for the Design and Installation of Culverts in British Columbia to Avoid Conflict with Anadromous Fish
Dane, B.G. 1978. Department of Fisheries and Oceans, Technical Report Number 811. 57 pp.
to get a copy, telephone (604) 666-6614
This report provides culvert installation guidelines that allow fish passage with a minimum of stress. It discusses hydraulic criteria and provides examples of culvert designs and auxiliary fish passage structures such as culvert baffles and tailwater control facilities.

Fish Habitat Rehabilitation Interim Procedures for the Watershed Restoration Program
Slaney, P.A. and D. Zaldokas (eds.). (in prep.). B.C. Ministry of Environment, Lands and Parks, Ministry of Forestry, and Department of Fisheries and Oceans.
to get a copy, telephone (604) 222-6761
This guide for the B.C. Watershed Restoration Program describes many techniques used to restore stream habitat in B.C. There are several chapters on design specifications, along with drawings and photos for specific techniques. The manual discusses principles of stream restoration, the approval process in B.C., procedures to assess stream channels and limiting factors, and life histories and habitat requirements of several species of fish. It also provides criteria for evaluating the potential environmental, social and economic benefits of a project.

Urban Runoff Quality Control Guidelines for the Province of British Columbia
Anonymous. 1992. B.C. Ministry of Environment, Lands and Parks, Environmental Protection Division, Victoria, B.C. 132 pp.
to get a copy, telephone (250) 387-9985
This report is for people working with their municipalities to improve the quality of storm water runoff. There are two main sections. Part I introduces the types and concentrations of contaminants typical in urban runoff. It summarizes information on treatment technologies, characteristics and sources of contaminants, operation requirements, maintenance, ecological impacts of treatment systems, and possible future developments. Part II describes in detail the methods municipalities can use to develop a comprehensive program to control urban runoff quality in a watershed.

Land Development Guidelines for the Protection of Aquatic Habitat
Chilibeck, B., G. Chislett and G. Norris. 1992. Department of Fisheries and Oceans and B.C. Ministry of Environment, Lands and Parks. 128 pp.
to get a copy, telephone (604) 666-6614
This book describes the guidelines designed to protect fish populations and their habitat from the damaging effects of land development activities. It describes techniques and materials you should use to reduce negative impacts when working in or around a stream. It also lists appropriate periods for instream work, both generally and for specific regions of B.C.

Design for Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetlands in the Mid-Atlantic Region
Schueler, T.R. 1992. Metropolitan Washington Council of Governments, publication #92710, 134 pp.
to get a copy, telephone (202) 962-3256
The report presents detailed design guidelines for stormwater wetlands. Diagrams, design criteria, and effectiveness in removing pollutants are described for four basic approaches: the shallow marsh, the pond/wetland, the extended detention wetland, and the pocket wetland. The report also discusses the differences in hydrology, morphology, and ecology between stormwater wetlands and undisturbed natural wetlands.

Other Useful References

Saving a Stream, a Practical Guide to Coldwater Habitat Projects
Trout Unlimited (1996). Washington DC. 42 pp.
to get a copy, telephone (703) 284-9424
This recent publication covers much of the information covered in Module 14. It was written for Trout Unlimited volunteers in the United States. Except for regulatory and approval requirements, most of the information can be used in B.C. It describes six major steps in planning and conducting a habitat restoration program: defining the purpose of the program, recruiting partners and resource people, assessing current stream and watershed conditions, planning the project, organizing and conducting the project, and monitoring and maintaining the results.

Videos

Constructing Pools and Riffles (7 min. video)
to get a copy, write Newbury Hydraulics, Box 1173, Gibsons, BC, V0N 1V0,
or telephone (604) 886-4625
This is a good instructional video for those interested in constructing pool and riffle habitat to stop erosion and improve habitat diversity. The video demonstrates how to select appropriate locations for riffle construction and the steps to follow during a site survey. The viewer is taken step by step through the construction phase and the footage clearly illustrates the application of five main design specifications.

Running Water I: Rivers, Erosion and Deposition (30 min. video)
Earth Revealed Series - Program #19, Magic Lantern Communications Ltd., Oakville, Ontario,
to get a copy, telephone (905) 827-1155.
This introductory video discusses erosion, transport and deposition processes in streams and the factors that influence these processes. It discusses ideas such as stream discharge, velocity, bedload transport, suspended loads, energy budgets, formation of cutbanks and gravel bars, meander patterns, and flood plain formation and function. It also discusses the impact of human activities such as damming and dredging on river dynamics.