Fisheries and Oceans Canada
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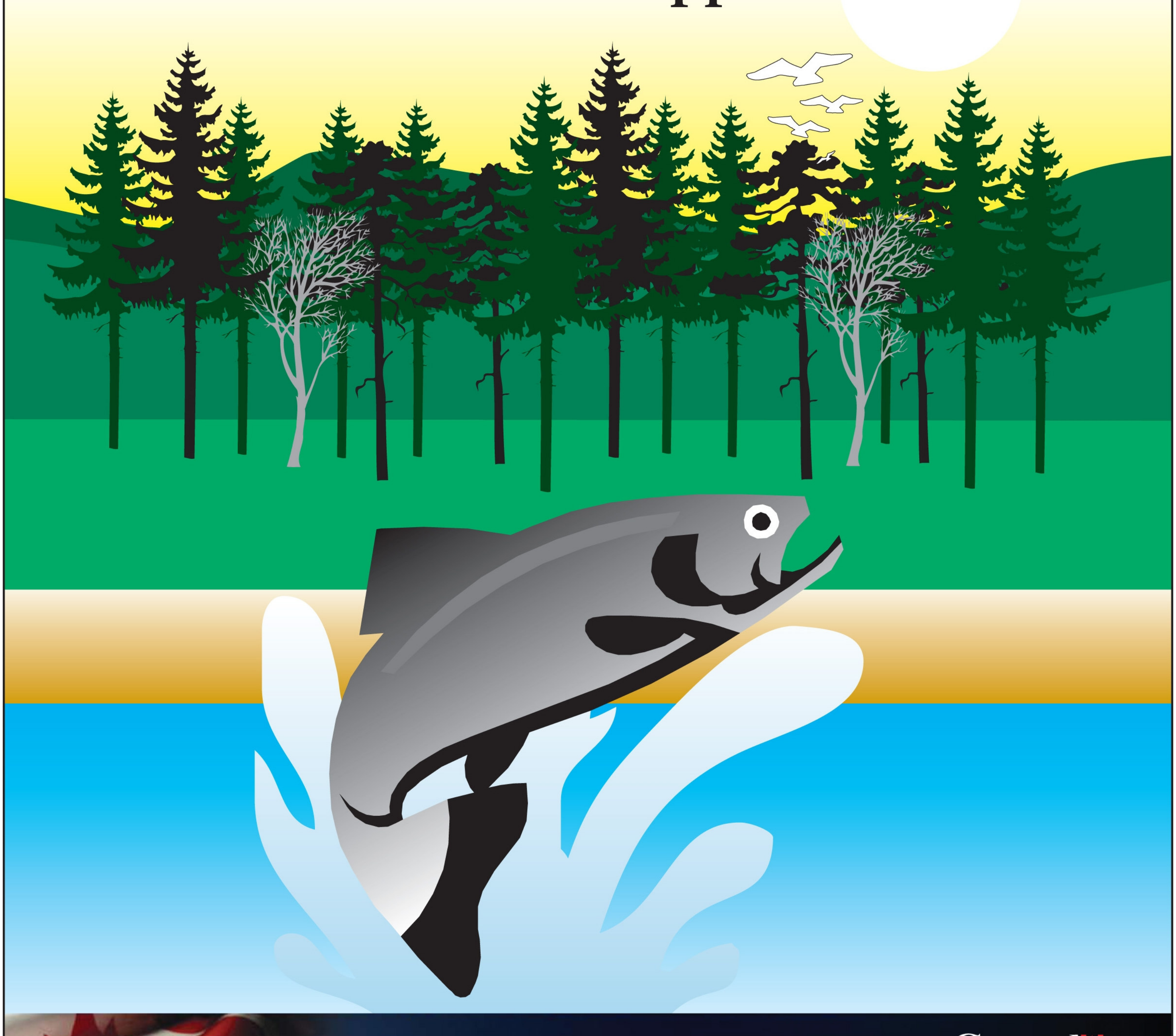
Ecological Restoration of Degraded Aquatic Habitats: A Watershed Approach



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PREFACE

Over the last few years, there grew a need for a manual that would encompass watershed management and fish habitat conservation, protection and enhancement. While DFO (Gulf region) had already produced “A Guide for Fish Habitat Improvement in New Brunswick” in the early 1990’s, it was clear that communities needed to know more than just how to improve fish habitat. Today’s citizens are more aware of environmental issues and they need clear directions on how to mitigate impacts in their watersheds. This, in turn, provides them with the opportunity to bring about positive changes to the environment and eventually, fish habitat.

This manual will help educate citizens on various aspects related to watershed management:

- stewardship and changing attitudes
- watershed processes
- human impacts & how to reduce them
- how streams function
- what is fish habitat
- laws, regulations, & permits
- watershed and stream assessments
- habitat needs of various fish species
- fact sheets on various fish habitat restoration techniques

DFO (Gulf region) staff is proud of this manual and hopes it will be useful in helping communities achieve a sustainable management of their watershed.

ACKNOWLEGEMENTS

The present document is the result of dedicated work by a team of DFO Gulf Region staff and Thaumas Environmental Consultants Ltd.

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1.1 INTRODUCTION

1.1.1 Background

Since the implementation of DFO's Policy for the Management of Fish Habitat (1986), there has been increasing involvement of community based groups in fish habitat restoration activities. Fish habitat restoration (sometimes called rehabilitation, enhancement or creation) projects have been carried out in an effort to regain lost fish habitat productivity, and restore ecological functions in damaged ecosystems. The goal of restoration projects is to ensure that the dynamic processes of natural ecosystems (i.e. structure and function) are re-established.

Over the years, there have been many changes on the environmental front. The focus has shifted from managing single species (e.g. enhancing salmon populations) to the management of living natural resources at the watershed and ecosystem level. The emphasis is on moving from a top-down management approach to a more community-based, decision-making process. This more holistic approach aims at conserving, protecting or enhancing aquatic species and their habitats in an ecosystem unit or a geographical unit (within a watershed). It also considers the entire spectrum of social, economic, and environmental factors that contribute to deteriorating conditions that were often overlooked in past restoration activities.

Aquatic habitat conservation issues are often rooted in complex combinations of economic development and land-use activities, which are not easy to resolve. The watershed approach to restoration seeks to correct the underlying causes of habitat degradation rather than just treating site-specific symptoms. Such an approach is strongly supported by DFO's Policy for the Management of Fish Habitat (1986), through its focus on integrated resource planning and management.

Over the years, millions of dollars have been invested nationally in aquatic habitat rehabilitation, yet questions remain as to whether true gains have been obtained in habitat productivity. In Ontario, a review of over 90 habitat improvement/restoration projects concluded that few could document actual biological success (Smokorowski *et al.*, 1998). In another study, Frissel and Nawa (1992) evaluated the success rate of artificial instream structures installed in the western United States. The authors suggested that commonly prescribed instream structural modifications are often inappropriate and counterproductive, and noted that this work commonly failed and caused problems ranging from simply not creating the habitats to outright failure that contributed to increased damage in the watershed. Complex multi-scale interactions between watershed conditions, fluvial processes and structure design interact to determine the physical success or failure of individual structures and projects. The authors concluded that changing structure designs or materials was unlikely to overcome the problem of high damage rates. Rather, Frissel and Nawa (1992) recommended addressing the more critical watershed impacts caused by poor road construction practices, and by the removal of natural riparian vegetation caused by logging, grazing, floods, or building practices.

The decreasing ability of watersheds to maintain healthy fish populations has meant increased commitment of monies to stream and watershed restoration. With this increasing financial commitment, however, have come expectations that ecosystems be restored. To date, however, relatively few documented examples of effective projects exist. The American Fisheries Society even concluded that the lack of strategic planning and reliance on tactical, site-specific projects in the past has resulted in low biologic return on at least some, if not most, of the money being spent on restoration in fresh water stream ecosystems (Roper, 1997).

The lack of success in such projects can be attributable to the fact that too much emphasis is placed on instream habitat restoration at a small-scale, site-specific level. For a project to succeed there is a need to approach habitat improvement from the broader watershed and land-use perspectives. To do this, stream restoration projects must be expanded beyond site-specific instream work. This should include addressing the physical and chemical habitat variables which are limiting productivity throughout the watershed. These factors may have an effect on the life cycle of several fish species. The other expansion of restoration projects must address upslope and riparian conditions that cause fish habitats to decline.

In the Maritimes, aquatic habitat restoration projects have been more successful than studies would suggest. Throughout the region, many groups have undertaken aquatic habitat restoration projects, and most will tell you of the visual difference it has made to the numbers of fish, birds, and wildlife in their area. Studies on Brierly Brook, Antigonish, Nova Scotia (Rutherford, 1994) have confirmed that by mitigating the land use effects through the use of best management practices and instream habitat restoration, there have been increases in spawning and juvenile production of salmonids that are 8 to 10 times the pre-restoration levels, and this level of productivity has been maintained for over ten years (Rutherford, personal communication, 2004).

In many jurisdictions, the high incidence of physical failure and damage and the lack of demonstrated biological success of surviving structures can be linked to a lack of proper planning. To be successful, you have to identify the ongoing impacts and address them before implementing restoration work on the damaged habitats. It is also very important that this instream work be properly designed and properly located in the watercourse so that it assists nature in restoring habitat diversity and productivity.

The first step is to address land use problems by using best management practices. The second step is to design instream structures that work with the natural processes to speed the ecological recovery while addressing the needs of all life stages of the indicator species. Where these two steps have been taken and applied on a watershed basis, there has been a high degree of success. This approach has been used successfully in many streams in the Maritimes with significant increases in stream invertebrates, fish, and riparian wildlife.

To avoid ineffective projects and the potential that the work be viewed as a poor investment within agencies responsible for fish habitat management, this manual takes a watershed approach to restoration planning, starting on the land first then moving into the water. The key to success is to identify factors limiting the productivity of the aquatic habitat and effectively addressing the root causes. Ecological restoration is an investment in our common environmental wealth.

1.1.2 Stewardship: A Lifetime Commitment

In this modern age, most people have some knowledge of the environment and recognize the need for protecting it from irreversible harm caused by human activities. Many become involved in community groups and participate in their projects intended to restore and protect the environment. Increasingly, the term stewardship is being applied to these initiatives. The concept of stewardship is not a new vision, but one which is now gaining in strength. Stewardship integrates human activities with natural ecosystems, and focuses on human intervention to address factors limiting the productivity of natural habitats. The ultimate goal of stewardship is to encourage activities that create a healthier, and more environmentally, socially, and economically sustainable community.

- A steward is a caretaker or a guardian (Adopt-a-Stream).
- Stewardship is an important concept if we are to make our environment a healthier place to live (Adopt-a-Stream).
- Environmental stewardship means looking after our planet, our country, our province, our own backyard, so that it stays healthy and productive for future generations to enjoy.
- Stewardship means thinking globally and acting locally.
- Stewardship means managing our natural living resources in such a way that they are self-sustaining and continue to contribute to the social and economic benefit of Canadians for current and future generations.
- Aquatic stewardship is taking personal responsibility to sustain and enhance freshwater and marine resources, while accepting the obligation to the environment and future users (Recreational Boating and Fishing Foundation).
- The act of entrusting the careful and responsible management of the environment and natural resources to one's care for the benefit of the general community (Environment Canada).

One way to become an environmental steward is to get involved with a local watershed group. Such groups foster a sense of teamwork, empowerment, and responsibility because they involve stakeholders (e.g. landowners, businesses, government agencies, schools, etc.), and they actually do make a difference. One of the goals of watershed groups is to gather together all interested parties and to work with those conducting activities in the watershed to do the work in the most environmentally sound way. All groups should be working toward a watershed management plan, but some focus more on education and awareness of the landowners and the use of best management practices while others may undertake action-oriented projects to help restore ecosystems. Whatever the reasons are for forming a group, they all have two common objectives: to find compromise among stakeholders and their conflicting activities and to plan for future generations. These are initiatives that contribute a great deal to “sustainable development” in the watershed, which is, essentially, balancing environmental, economic, and social values in a way that does not compromise the needs of future generations. Figure 1 shows the current situation in our watersheds where the sustainability balance is only achieved a small portion of the time. The ultimate goal is to attain overall sustainability, which means the three circles would be perfectly overlaid to become one.

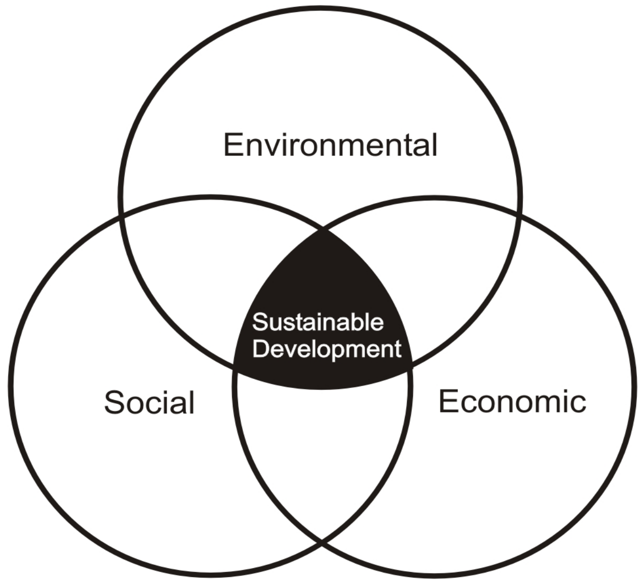

Figure 1. The interconnectedness of the three main components of sustainable development.

1.1.3 A Strengthened Approach

In the late 1980's, DFO (Gulf Region) produced a document entitled "*A Guide for Fish Habitat Improvement in New Brunswick*". The former guide reflected the interests of the angling groups and the past approach of promoting the enhancement of salmon and trout habitat. This was a narrow focus that didn't take into consideration the needs of other aquatic and riparian species or the requirements of the *Species at Risk Act* (2003). Over the years, the angling groups have joined with other groups of interests in the watersheds to form multi-stakeholder watershed associations. These associations take the broader ecosystem approach to stewardship. This is a very positive development and it is one that DFO would like to encourage. To assist in this developing approach at the community level, there is a need to refocus the restoration manual and to start to address the need for increased education and assistance at the watershed level.

For these reasons, the present document will be focusing on educating the readers on the importance of watershed planning, watershed processes, assessing a watershed, taking action to protect aquatic and riparian resources within a watershed, and techniques for aquatic habitat restoration.

1.2 ECOLOGICAL PERSPECTIVE

The goal of this chapter is to promote sustainable, efficient watershed management activities and to rehabilitate aquatic habitat. Restoration activities that re-establish ecosystem processes and reconnect habitat fragments have the best chance of producing habitats that can support viable fish communities in the long term.

The objective should be to restore watershed processes rather than relying exclusively on in-stream restoration. Restoration must address abiotic and biotic processes within the basin to be successful, and it should not be solely based on the needs of a single fish species or life stage. Wherever possible, the intent is to restore the natural productivity and diversity rather than undertake projects that enable one or two species to bypass a weak habitat through artificial means. Monitoring the effectiveness of specific watershed restoration projects and approaches must become an integral part of the overall watershed restoration strategy. An adaptive management approach must be taken so that the new problems that arise can be quickly addressed and effective projects and initiatives can be built upon.

1.2.1 Ecological Functions of Riparian Systems

1.2.1.1 Freshwater and Marine

Freshwater

Since the first European settlement in the 1600's, our region's riparian zones and watercourses have been extensively altered. The resulting decreases in diversity and function of riparian and aquatic ecosystems have weakened their integrity and productivity. This tops the list of ecosystem concerns, since these habitats are among our most productive and contain critical habitats for fish and most wildlife. They are also our most threatened natural ecosystems.

Degradation of riparian zones and aquatic ecosystems diminishes their capacity to provide critical ecosystem functions, including the cycling and chemical transformation of nutrients, purification of water, attenuation of floods, maintenance of stream flows and stream temperatures, recharging of groundwater and establishment and maintenance of habitats for fish and wildlife. The most important factor contributing to the decline of aquatic biodiversity is the loss or degradation of habitats (Miller *et al.*, 1989).

Riparian areas are three-dimensional zones of biological, physical, and chemical interactions between terrestrial and aquatic ecosystems. Hence, ecological restoration of riparian zones requires a holistic approach whereby activities and conditions across an entire watershed should be considered. Problems affecting fish habitats will not be solved by ignoring deleterious land management practices, either historic or current, that occur at the watershed level.

It may take decades or centuries for watersheds to recover from serious soil erosion. Such recovery begins only after sediment yield from the watershed is reduced back to natural levels. Our watersheds continue to suffer impacts from increased flows, failing and eroding roads and ditches, high erosion rates from some forestry operations and farm fields, subdivision and industrial construction and operation, removal of vegetation from stream banks, instream grazing and unstable slopes.

The current condition of fish habitat in the Maritimes is symptomatic of a complex of ecological problems driven by changes in riparian forests, river channelization, instream works, and local and watershed-scale erosion and sedimentation. Large-scale flood events, due to watershed land use changes and global climate change, are becoming more common, and these reshape channel morphology and fish habitat throughout the length of the watershed.

A watershed assessment is the first step in understanding watershed processes and identifying restoration needs within a river basin and its estuary.

Coastal (Marine)

What streams and rivers carry to the sea is deposited in coastal estuaries. Fresh water flows out across the surface of the estuary entraining salt water as it moves out to sea. This enlarged flow of water out on the surface draws nutrient-rich waters to the surface. Nutrients and sunlight combine with green plants to produce high primary productivity. The estuarine pump, tidal circulation, and a wide variety of depths and substrates make estuaries one of the most productive areas in the sea.

To learn more about coastal ecotypes in the Maritimes you should read "By the Sea" available on the web, or by contacting your local DFO area office for a CD copy. See Section 3.4 (Permits) for contact information.

Web site: http://www.glf.dfo-mpo.gc.ca/sci-sci/bysea-enmer/estuaries-estuaires-e.html

The impact of poor watershed management on coastal ecosystems can be devastating. A description of the impacts can be found in the "National Programme of Action for the Protection of the Marine Environment from Land-based Activities", Atlantic chapter (http://www.npa-pan.ca/docs/chapter7.pdf). These impacts from land-based activities include sewage (human and livestock), excessive nutrients, pesticides, sedimentation, pharmaceuticals, persistent organic chemicals, heavy metals and oil to name just the major areas of concern.

The health of the coastal waters is directly tied to the watershed practices since 80% and, in some cases, 100% of the harmful impacts in the Maritimes originate on the land.

As with freshwater systems restoration, activities in coastal marine habitats need to be planned starting at a broad scale. Actions need to be taken on current impacts from land use, and direct uses. When these impacts are mitigated, you can begin to work with nature to restore the natural processes and functions as quickly as possible.

1.2.1.2 What is Ecological Restoration?

Ecological restoration refers to the process of re-establishing the health and integrity of an ecosystem that has been negatively impacted. Taking a holistic approach means that all species and trophic levels found in the ecosystem are included and are treated equally. This allows for the return of the natural balance and function found in healthy ecosystems.

The re-establishment of natural ecosystem regulation of nutrient cycles and the hydrological cycle are key aspects of ecological restoration. By doing so, the capacity of the ecosystem to self-organize increases and this directly improves the resilience of the ecosystem. Therefore, ecological restoration efforts bolster the natural defences of an ecosystem.

To gauge the success of ecological restoration efforts, indicator species are chosen and closely monitored. These umbrella species are usually species at risk or those sensitive to changes in habitat quality. It is important to remember that while success may be tied to the progress of one indicator species, the goal of ecological restoration is the improvement of the complete ecosystem. Ecological restoration efforts try to work with nature to achieve an optimal situation for productivity, species composition and diversity within the natural physical and chemical constraints. Unlike some other restoration methods, ecological restoration does not attempt to adjust/direct nature to produce more of one desired species or fight nature to produce a desired outcome.

1.3 STRATEGIC PLANNING

The first question to ask is whether or not the aquatic habitat in your watershed, including the estuary and coastal areas, is degraded or not. If you are not sure about the quality of aquatic habitat, then select the process for assessing the degraded habitat.

If you live in one of the few non-impacted areas in the Maritimes, it is very important that you organize to protect the ecosystem by maintaining natural ecological processes and preventing impacts from human activities. Monitoring the health of the ecosystem is a good idea to ensure things continue to function well.

To design a monitoring program, you first consider the aspects of the ecosystem that are the most at risk from activities in the watershed or along the coast. Focus on monitoring the changes that would be caused by these activities. For each variable monitored you should determine the range of natural variation and set target limits that the variable should stay within. For example, if you are monitoring water temperature on the river in the summer, the water temperature will fluctuate as the air temperature changes. This is natural variability. If a healthy summer temperature is under 20^{o}C and your data shows it is getting warmer each year or exceeding 20^{o}C, then you need to take action to solve the problem. The 20^{o}C would be a trigger value that would initiate an action plan. The action plan should be developed at the start of the monitoring program and include all the partners and government agencies who will need to be involved in the solution. Their respective roles should be defined at the outset.

If you are not sure what monitoring to do or there are no imminent threats, then a general health-monitoring program should be initiated. If predetermined variables are within normal ranges, there is little need to worry. However, if a variable starts to change or reaches levels for concern, you should investigate potential causes.

For freshwater systems, you should monitor for temperature, pH, conductivity, dissolved oxygen, nutrients, metals, hydrocarbons (if you suspect problems from gas, oil, cleaning chemicals, or additives), turbidity (with a secchi disc or visual assessment), and an annual walk to assess changes in bank erosion and adjacent land use. More detailed monitoring can include programs to monitor invertebrate populations and fish populations. Protocols have been developed to monitor these populations.

For estuaries, you should monitor salinity, temperature, nutrients, turbidity (with a secchi disc or visual assessment), and an annual walk to assess changes in bank erosion and adjacent land use. If eutrophication is suspected, a chlorophyll *a* test and a macrophytes survey may help confirm whether it is happening or not.

Once it is determined that you have degraded habitats, you need to first address the cause of the problems. You cannot make progress in restoring habitats if the activities that destroyed them are continuing. In cases where the problem is bigger than the local watershed (e.g. acid rain), then it is reasonable to undertake mitigation efforts before the overall problem is solved and cleans itself up. In either case, you should work through the process below to help set out the order in which issues are tackled and to help ensure all the problems are covered.

Figure 2 outlines a planning process, not a linear process, where you have to complete the steps in the order presented. You should assess the current situation, set your goals and priorities, take action, monitor successes, and then repeat the process until you have restored the productivity of the habitat. You may find that land use in the watershed is so poor that it has to be mitigated before any other action is taken. This is often the case and that is why it is the first thing we look at. However, there is little sense in working hard on land use issues if the pH of the water is so low (due to acid rain) that it prevents sustainable fish production. You may also find that land use is a chronic problem that needs to be addressed in the lower reaches of the watershed, that habitat is fragmented by hanging culverts, and that there are long stream reaches without pools. Your first priority would be to get the migrating fish up to the good habitat. Each watershed has different needs and priorities and there isn't a step-by-step cookbook approach that fits all situations.

Fragmentation of Habitats

A common problem in rivers and coastal areas is the fragmentation of habitats and the partial or total blockage of migration routes. These include culverts, dams, fishing gear set illegally, causeways, debris, and long reaches without adequate depth or resting pools.

Land Use Erosion and Runoff Problems

Sources of pollution are easily identified as muddy runoff from farms and forestry operations, decoloured water from pipe outfalls, and the large percentage of a watershed area covered by hard impermeable surfaces draining into storm sewers. Many of these activities or structures are controlled by regulations. However, not all erosion and runoff cases are covered by permits or regulatory controls during the normal operations. No regulation or law applies for livestock in streams, sheet erosion from farm fields, erosion from skidder trails, etc. These have to be dealt with by contacting the landowner and encouraging them to use best management practices.

Water Quality

Water quality for fish and wildlife is a major problem in the Maritimes. In Nova Scotia, large areas are suffering from the impacts of acid rain that has lowered the pH and resulted in a lower habitat productivity. Connected with this are increased levels of dissolved metals leached from the soil by the acid. Another common problem is sand and silt originating from small, but common poor land use activities and bank erosion. For example, a pile of earth on a front lawn, a newly seeded lawn, new gardens, or dirt washed off vehicles and equipment can all get into storm sewers of ditches and into the streams. Thirdly, there are nutrients and chemicals from common activities such as fertilizing the lawn, washing the car, pesticides and cleaners, and poorly constructed or poorly maintained septic systems. The rain is capable of washing these chemicals and nutrients into ditches, storm sewers, and watercourses. The cumulative effects from these numerous, small sources may result in serious impacts to fish habitat.

Riparian Quality and Processes

Adjacent to all water bodies is a strip of vegetation that creates productive and unique wildlife habitats and contributes to the stability, form, and productivity of the aquatic habitats. The width of the area varies depending on the lay of the land and the flood patterns. Experienced foresters and biologists can see the change in the vegetation and define the edge of the riparian zone. For regulatory and guideline purposes, distances have been set to define the riparian zone for stream protection. This is not usually adequate for wildlife and care must be used when working with these distances if they are intended to be buffers to prevent damage to streams. Riparian zones have considerable capacity to buffer impacts by removing sand, silt, excess nutrients, chemicals, and regulating groundwater input to streams. However, look closely at these buffer areas to be sure the pollutants are just not channelling through the area or overwhelming the mitigating capacity. Adequate riparian zones (greenbelts) should be left between water and all land use activities.

Physical Habitat Quality and Processes

Changing flood and flow patterns, past use of the river, ice scour, man-made control points which restart meander patterns, and the lack of slow but regular input of large organic debris all contribute to degraded physical habitats. The fact sheets at the end of this manual focus on instream techniques to restore the natural functions of the stream ecosystem.

If you do not have a degraded habitat or have been successful in your restoration efforts, the most important thing is to enjoy the healthy environment you are living in.

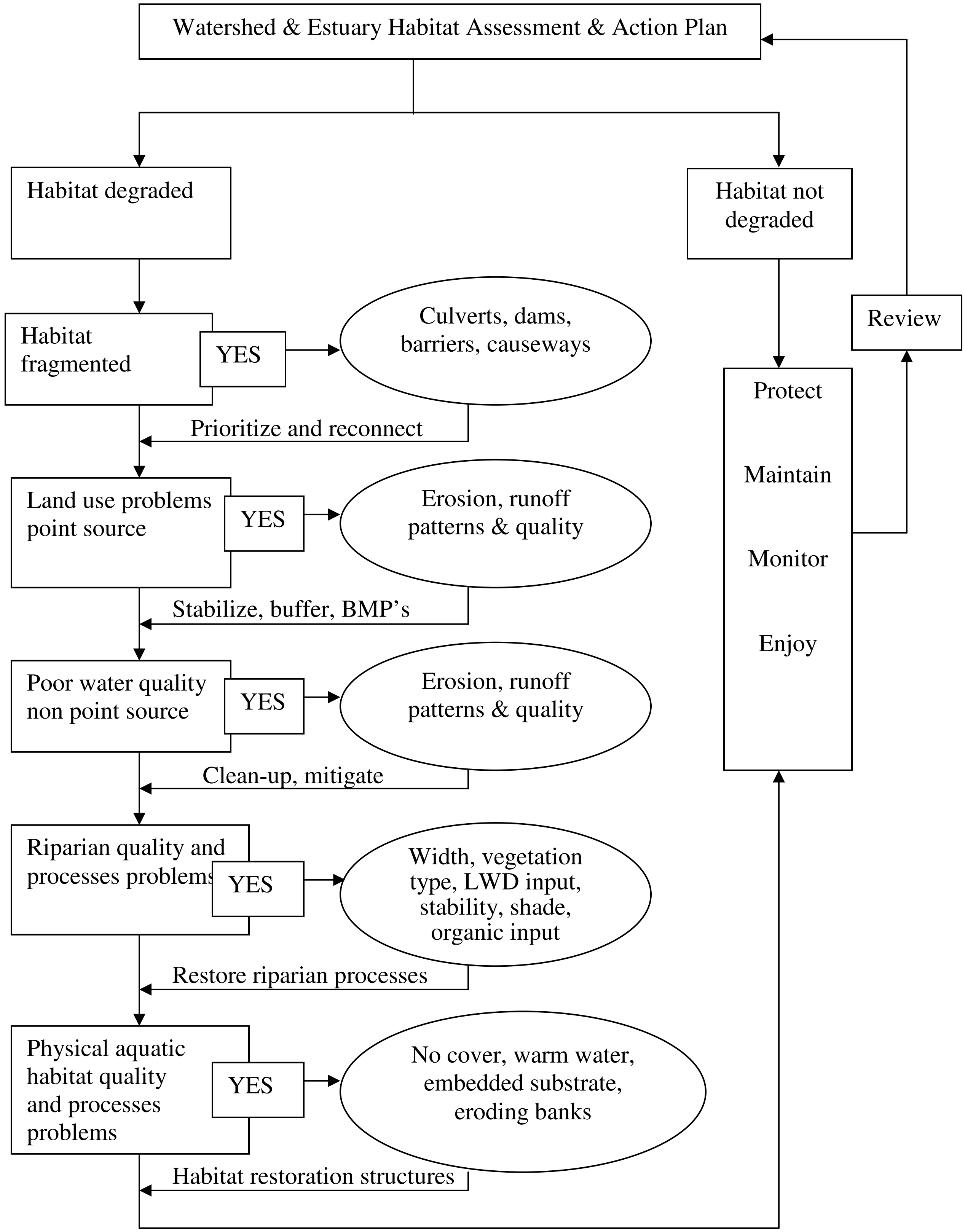

Figure 2. Hierarchical decision making tree for watershed assessment and action planning (modified from Roni *et al.*, 2002).

2.0 WATERSHED PROCESSES, HUMAN IMPACTS, AND MITIGATION OF IMPACTS

2.1 INTRODUCTION

This part of the manual will focus on what happens within a drainage basin (or watershed). It will include general information on natural processes, how humans alter them, and what is normally done to address disturbances. The last chapter will discuss the merits of using fish habitat restoration to accelerate nature's recovery process.

2.2 WATERSHED PROCESSES

A watershed is a geographic concept designating a natural depression or area draining into a single expanse of water. Rainwater, runoff, snowmelt, and groundwater are all elements of this hydrologic entity. Other factors such as climate, land features, vegetation, and land use all affect the quality and quantity of water within the watershed.

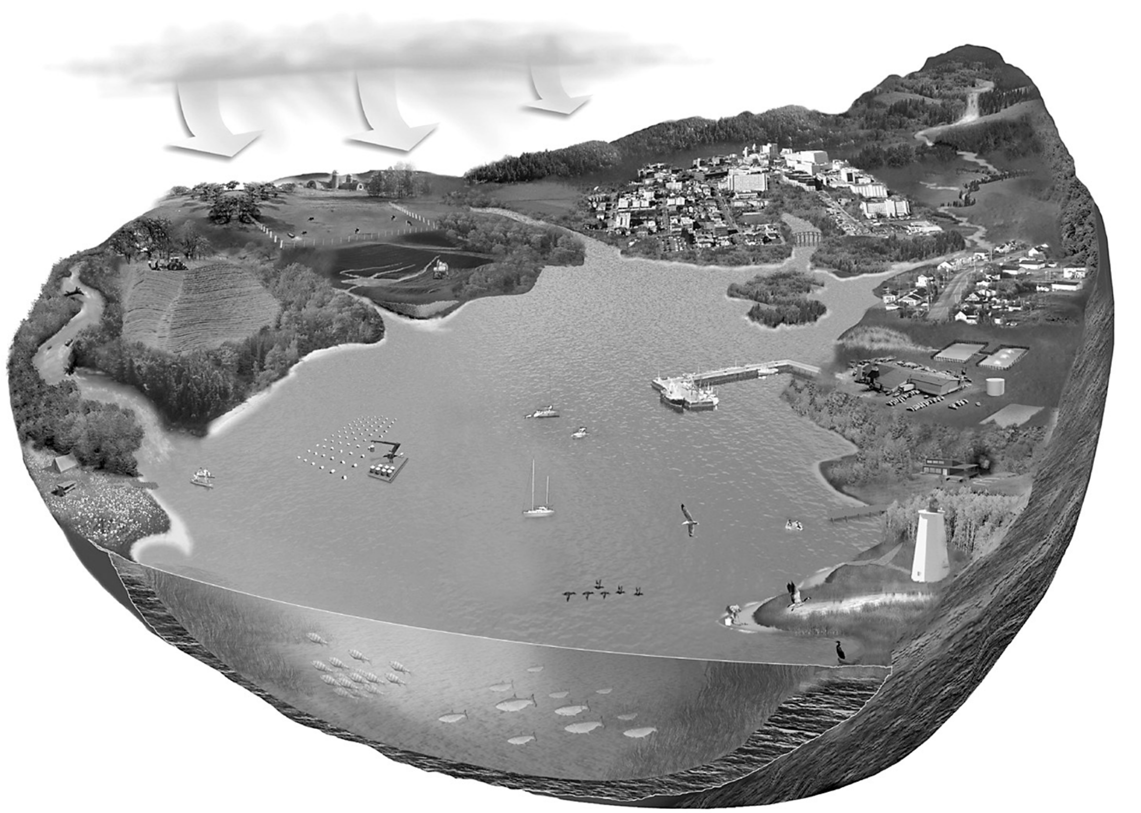

Figure 3. A watershed model (Integrated Management of Our Watershed, Fisheries and Oceans Canada, 2001).

2.2.1 Land Formations

During the last glaciation (12,000-15,000 ya), eastern Canada was mostly covered by glaciers. The receding glaciers defined the watersheds. Over time, as these glaciers melted and receded, they deposited distinct geological features like *drumlins*, which are smooth, oval hills (Columbia Electronic Encyclopedia, 2003). Sediments from glaciers were also transported by freshwater streams that carved tunnels in the ice and transported large amounts of sand and gravel the glaciers had eroded from the bed rock. When the ice melted, these deposits remained as ridges called *eskers*. Sand and gravel carried beyond the edge of the ice formed outwash plains, which are extensive flat areas with many lakes (The Last Billion Years, 2001). During the melting of glaciers, materials such as glacio-marine *lag* (sand, gravel, and pockets of fine sediments) and *till* (unsorted rock, gravel, and sand mix) were also deposited. Such features are typical of geology in the Maritime Provinces (The Atlas of Canada, Natural Resources Canada, 2004).

2.2.2 Climate, Vegetation and the Hydrologic Cycle

Climate is a major factor in determining the amount of precipitation that falls and the type of vegetation that grows in a certain area.

When precipitation falls, it "washes" the air bringing with it particles and dissolved gases. As it reaches the ground, the impact of the falling raindrops is partially minimized by vegetation. A portion of the water is retained by the vegetation and falls to the ground later, a portion is absorbed by the vegetation itself, and another portion is evaporated back into the air. If the ground is not covered by vegetation, the pressure from the falling raindrops breaks down soil structure by dislodging small particles. When the raindrops hit rock, they partially contribute to its weathering. Under normal weather conditions, adequate vegetation encourages good soil structure and stability. Hence, vegetated soils absorb water at a faster rate than bare soils. The soils are also uneven, so they hold pockets of water, giving it a longer period of time to soak into the ground. This recharges groundwater reserves that maintain the flows in streams and provides water for the plants during dry weather. When the rate at which the soil can absorb water is exceeded, the excess water becomes runoff. The runoff "washes" the surface of the ground, carrying with it some of the exposed soils and any contaminants, as it flows quickly to watercourses. The vegetation will also slowly release a quantity of this groundwater back into the air by means of transpiration and some will evaporate back from the surface of water bodies. The total amount of water released into the atmosphere is called *evapotranspiration*. The exchange of water between the land and the atmosphere is defined as the hydrologic cycle (Figure 4).

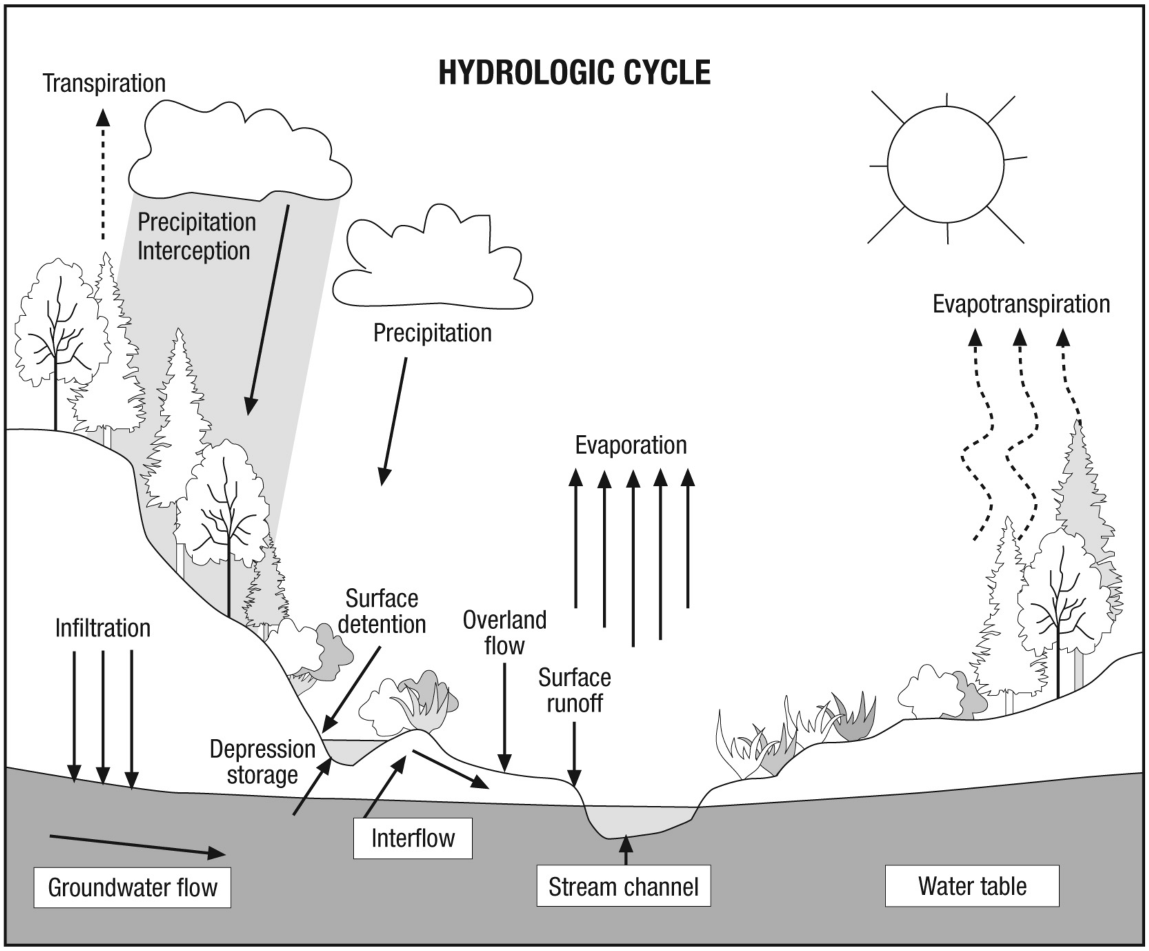

Figure 4. The hydrologic cycle (Ontario Ministry of Natural Resources and Watershed Science Center, 2002).

2.2.3 The Formation of Rivers and Fish Habitat

The Watercourse

There are many physical processes within a watershed that are responsible for giving a watercourse its shape. A watercourse originates in the upper reaches of a watershed where the land is at a higher elevation. These small streams are fed by cold water springs, runoff during rain events, or spring snow melt (intermittent or ephemeral streams). The force of gravity pulls the water downhill toward the lowest elevation. The flowing water erodes the topsoil, sediments, cobble, and gravel and it starts to form a *channel*. The flowing water is slowed by resistance from the substrate on the bottom, instream woody debris, and the banks of the channel. Water also loses speed as it begins to slosh from side to side. For example, as water sloshes to the left side, it's level is higher on the left side of the stream than on the right. The water on the high side falls under the flow and digs a pool on the left side of the stream. It then sorts cobble, gravel, sands, and silts, forms a point bar on the right, and builds the crest of the riffle downstream of the pool. The water then flows down the riffle/run, sloshes up on the opposite side, and digs a pool on the right side. The water's digging action places a pool at approximately 5 to 7 channel widths on alternate sides and forms what is known as the meander pattern (Figure 5). The flow that forms the channel is the annual maximum daily flow that occurs 66% of the time in a flood frequency analysis. This is known as the 1:2 year flood. Many people prefer to use the instantaneous flow to define the size of the fish habitat channel and the return periods range from 1:1.5 to 1:1.85 in Maritime streams (Bob Rutherford, personal communication). Either way, there is a direct relationship between the flows, the channel width, and the meander length.

While flowing down a valley, water will encounter resistance from geological formations (bedrock or constrained valleys), vegetation, as well as structures like culverts, bridges, and dams thus forcing it to readjust the meander pattern. Furthermore, as water erodes substrate in one section of the channel, it deposits it in another section. This action gives a channel a more or less serpentine or sinuous shape.

Vegetation also plays a role in channel development. Grasses and shrubs grow along the edges of the channel in areas that are dry during most of the summer months. The roots of the plants help bind the soils and the tops lie down during high flows to prevent erosion. Fall and spring high flows are slowed as they pass through the vegetation and drop silt, sand and gravels they are carrying. This helps build and maintain the banks. These higher stable banks contain the 1:2 year daily peak flood flows and allow the water to create deeper pools, clean the bottom of sands and silts, and provide more diversity of stream habitats.

Branches, roots and trees (Large Woody Debris, LWD) that grow or fall into the river in random locations, also play an important part in building the structure of the stream and its habitats. In gravel and cobble bed rivers, the LWD is moved by flows. This helps clean and sort the bed materials as the logs are moved and the logs embed where the bottom currents are slow at the head of the pools and in the pools. Logs embedded at the head of the pools establish the toe of the riffle/run areas, allowing them to build stable slopes without the gravel being washed into the pools. The small branches lying in the pools provide habitat diversity and cover for all aquatic species. Roots hold soils on the banks and permit undercuts, important for cover in medium to large rivers, to form. Roots also form low dams in small streams, which help maintain water depth and habitat structure.

Streams exist in many forms and they can exhibit different flow patterns. Rosgen (1994) developed a stream classification system which is widely used today and which helps explain the varying characteristics of watercourses (Figure 6). Various stream types can be observed in a single watershed (i.e. A-type in the headwaters, to C-type in the mid reaches, and to E-type in bogs or meadows). Generally, as a river flows downstream, it progresses from highly eroding streams with coarse substrate (>2 % slope) to gently sloping streams and rivers (< 2%) with finer cobble-gravel substrate and low gradient rivers (< 0.2%) with fine gravels sands and silt substrates.

In the Maritimes, it is suspected that many streams are C-type, because they are sinuous, moderately entrenched, and gently sloping (< 2%). However, B, D, E, and F-type stream reaches may also be found.

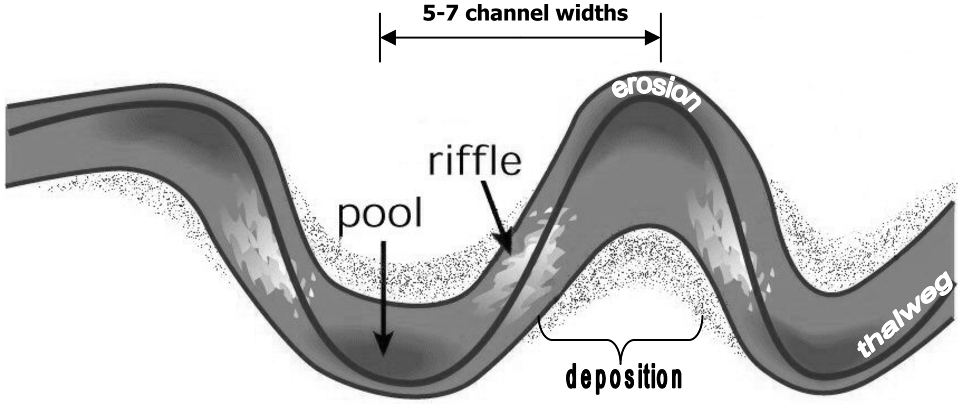

Figure 5. Pool-riffle sequence and erosional and depositional features in meandering streams (modified from FISRWG, 1999).

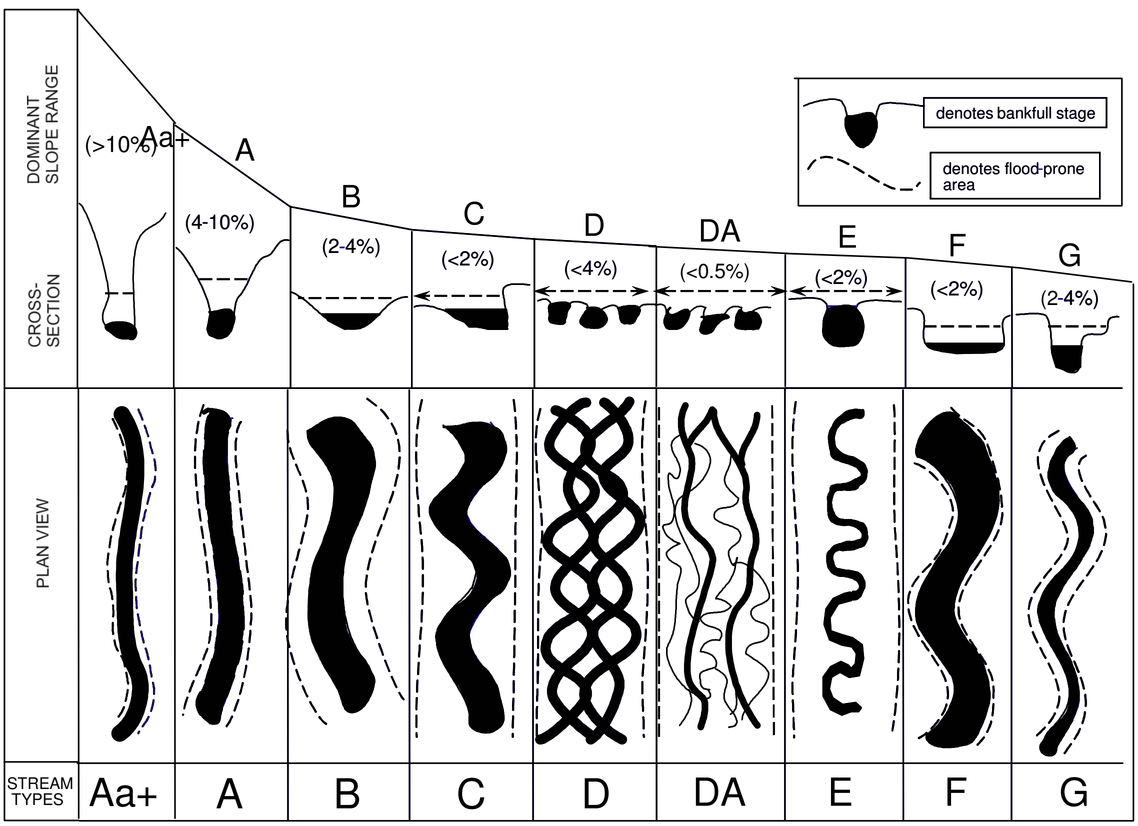

Figure 6. A stream classification system based on morphological features (Rosgen, 1994).

The Floodplain

The channels that we observe today have been shaped by floodwaters that occurred frequently (i.e. floods recurring every year-and-a-half). The riparian flood plain valley that contains a watercourse is, in turn, shaped by rare, extreme events like a 1:100 year flood (see Figure 7 for different flood levels). The larger river valley is shaped by geological forces, glaciers, historic rivers, or the slow erosion by the meandering of the river over millions of years. Over time, sediment is mobilised and redeposited elsewhere as the river migrates laterally within the valley. This creates distinct river features such as chutes, oxbows, oxbow lakes, and meander scrolls (remnants of old channels) adjacent to the present watercourse. How such features are created is dependant on local geology, stream flow variations and vegetative cover patterns.

Historically, floodplains have been known as fertile lands, because periodic flooding carries nutrient and mineral rich silt which is deposited on the land. Hence, floodplains contain rich soil that is home to a wide array of plants and animals. The *riparian zone*, the frequently flooded part of the floodplain adjacent to the stream, is often one the most productive areas on land and has a high biodiversity (FISRWG, 1999). In fact, Beschta (1991) concluded that riparian zones provide the following benefits to a stream:

- Protection against temperature extremes;
- Bank stabilisation;
- A source of allochtonous materials (leaves, needles, woody debris, etc.);
- Protection against sedimentation;
- Recycling of nutrients.

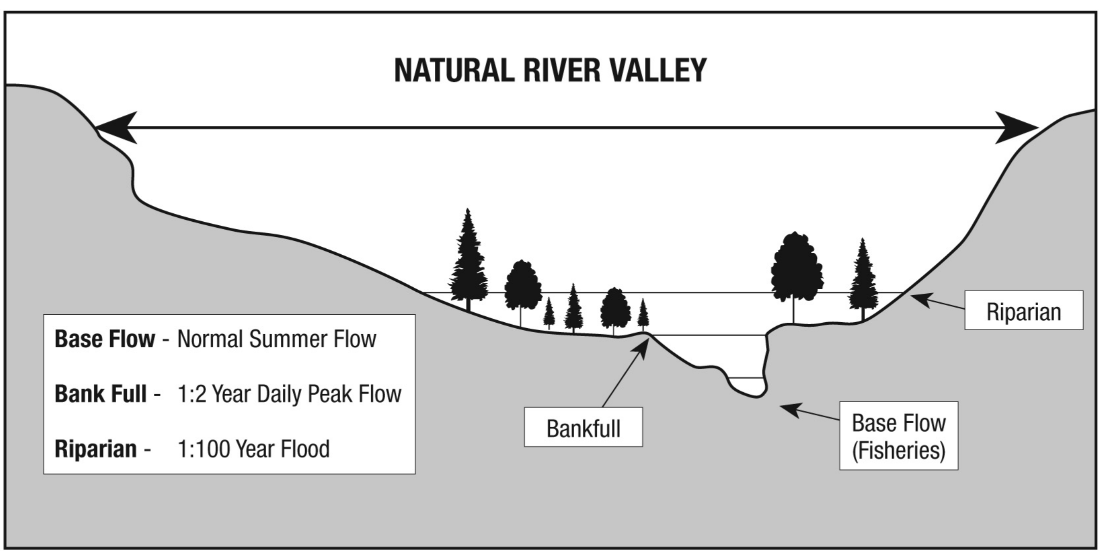

Figure 7. The relationship between water levels and precipitation events (modified from Ontario Ministry of Natural Resources and Watershed Science Center, 2002).

Fish Habitat

When a stream achieves a balance in the erosion and deposition of sediment, and retains its physical characteristics (i.e. slope, width/depth ratio, substrate composition, etc.), it is said to be in “dynamic stability”. Key factors to keeping this “dynamic stability” are rainfall intensity and frequency, and riparian vegetation.

A stream with healthy riparian vegetation normally receives a regular and slow input of large woody debris (LWD) from the riparian zone. LWD is moved and broken up by the flows, but assists in keeping the channel stable by being incorporated into the bottom and banks of streams. It also assists in creating a diversity of fish habitat by forming instream cover and small eddies (pockets of slow-moving water within the channel). As LWD decompose, they also provide food to microbes which are in turn eaten by scraper type invertebrates (e.g. caddisfly larvae). Some invertebrates live in the holes and crevices on LWD. Such features provide ideal rearing and feeding areas for some species of fish and make LWD an essential part of the stream habitat.

Other important habitat components include spawning areas located at the edge of pools where there are springs and seeps, or the head of riffles where water seeps through the gravel and out onto the riffle. These habitats rely on a delicate balance of the erosional-depositional processes.

When hydrologically balanced and in presence of ample riparian vegetation, a stream is host to a multitude of organisms, from microscopic bacteria and fungi, to phytoplankton and zooplankton, to larger aquatic invertebrates, and predatory fish.

Pool-Riffle Habitats

These watercourses have an overall gradient (slope) of less than 2 % (i.e. a two meter drop over a distance of one hundred meters). These are the streams that the habitat restoration techniques are designed for. For this reason, care must be taken when applying the same techniques on streams with steeper gradients. These streams meander to the right and left, scouring pools on the outside bends (each 5 to 7 channel widths). The channel design width, or fish habitat channel, is directly related to the size of the 1:2 flood flow calculated based on the daily peak flow. If you use instantaneous peak flows you will find the channel size is related to the 1:1.5 to 1:1.8 return period. Care has to be taken when designing based on the bankfull width between the perennial vegetation on the opposite banks. Most streams that have lost the pool-riffle structure, and have become primarily run, are wider than the pool-riffle streams and have a flat bottom cross-section. Using this width, your structures will be approximately 20 % too far apart. When using bankfull width, it is important to find a stream reach that is stable and representative of the stream in a natural condition.

The most habitat diversity and the highest productivity are attained when streams are in “dynamic balance” with the pools migrating at a rate measured in millimetres to a couple of centimetres per year and bed load movement a minimum and comprised mainly of very low levels of silt and sand. The most productive riffles are on 1.2 % to 0.8 % slopes and are made up of gravels and cobble with less than 10 % sands and silts (Amiro, 1993). These riffles are essential for invertebrate production (food for fish and small birds) and habitats for juvenile salmon. Without them, fish productivity is seriously limited. The riffles must have a well-developed thalweg (the deepest portion in a cross section) and the crest should be oriented at 30° from straight across the stream and toward the next pool downstream. Diagonal bars with short steep riffles are non-productive, do not provide the proper hydraulics for salmonid spawning, and can be partial barriers to fish migration.

The pools are of best quality when they are deeper than 45 cm in low flow and have plenty of clean gravel and cobble on the bottom, undercut banks, overhanging vegetation, and large organic debris. The pools provide cover and refuge for all fish species and life stages in summer and winter low flows, and migration resting and spawning holding pools for adults. The slope on the tail of the pools is best if it is 1.8 to 2.4 % for spawning. Deeper pools are required for adult salmon holding pools.

At higher gradients (over 2 %), there is a lot of riffle and very little run or pools. This habitat is best suited to the younger age classes of salmon and can be very productive if baseflows are good and the small percentage of pools are well developed and suitable for spawning. As the gradient drops, there is a shift towards more pools and less riffles. Salmon habitat is best at 75 % riffle run and 25 % pool (0.75 % gradient) but the best trout habitat is 50 % pool and 50 % riffle run (0.5 % gradient), and in the higher gradient step pool formations. Lower gradient reaches have more pool and are well suited to migrating adults, brown trout and suckers.

Step-Pool Habitats

The step-pool habitats become evident in watercourses with gradients above 2 % and become dominant when the gradient surpasses 4 %. Lower gradient rivers still have the same frequency of pools (5 to 7 channel widths) but the drop between them is taken up in short steps over rocks or rapids with long runs and short pools. As the gradient increases the watercourse runs disappear and there is a series of drops over large organic debris, or rocks into pools. The pool frequency becomes as short as one per channel width in small streams and three channel widths in larger rivers. These higher gradient watercourses are habitat for trout with densities dependant on the percent pool and quality. Restoration has been done on these watercourses but it is still experimental and there is no clear understanding of how well it is working. The techniques used for these types of streams are not described in this manual, but the work can be done by those familiar with these streams.

2.2.4 Physical, Chemical, and Biological Components of a River Ecosystem

Although it is not the intention of this manual to attempt to describe the complexity of stream systems, it is nonetheless important to present general concepts. Over the years, researchers have tried to describe how streams are structured and how they function. Biologists have described what organisms live in a stream, while hydrologists and geo-morphologists have described how flows act on a stream to give its physical character.

One method of characterising streams was presented by Strahler (1957). He proposed identifying streams with numbers, starting with small tributaries as first order and increasing in level as streams join together and as a river flows toward the sea. Although Strahler's system was simple to comprehend and apply, it did not explain physical, chemical and biological features. In contrast, a widely-accepted model for describing the dynamic character of streams was developed by Vannote *et al.* (1980) called the River Continuum Concept. Under this concept, it is proposed that consistent changes in biota and the ecosystem can be observed from the headwaters to the estuary (Figure 8).

2.2.4.1 River Continuum Concept

Headwaters

Trees normally shade small headwater streams, so instream primary production (the growth of green plants) is low due to the lack of direct sunlight. This means that instream production of oxygen is low, perhaps lower than the oxygen required by living organisms. Hence the oxygen production/respiration ratio is less than one ($P/R < 1$). For energy needs, these streams rely on terrestrial inputs of organic materials (leaves, coniferous needles, twigs, etc.). In order to transform this organic material into a useable form of energy, small streams have a community of bacteria and shredder-type insects to break down these materials and a smaller population of collector or gatherer-type insects to feed on drifting algae and the smaller, broken down materials (called Coarse Particulate Organic Matter or CPOM).

Mid-sized Streams

As the forest canopy opens for wider streams, there is a shift to instream primary production produced instream by green plants that are fed by nutrients and the increased amounts of sunlight. Changes become apparent in these streams as aquatic vegetation and algae proliferate. This boosts the production of oxygen to the point where it surpasses respiration by animals ($P/R > 1$). Most of the organic matter is CPOM, so collector or gatherer-type invertebrates are most abundant, followed by grazers who feed on microbial film on the surface of decaying organic matter.

Large Rivers

In larger river systems, primary production is reduced ($P/R < 1$) because of increased water depth (less light penetration) and increased turbidity. The main source of food is no longer from riparian vegetation, and less from aquatic vegetation. At this point, much of the CPOM is broken down, but there is still an abundance of Fine Particulate Organic Matter (FPOM) that becomes available food to collector or gatherer-type invertebrates.

As a river progressively flows to the sea, water becomes warmer. Hence, cold-water fish (e.g. salmonids, sculpins) tend to be found in smaller streams, whereas warm-water fish (e.g. bass, pickerel) are found in larger streams.

In the Maritimes, rivers are primarily the small- and mid-class streams in the continuum. In many areas, low phosphorous levels are also a limiting factor on instream production of plant materials. This makes the input of organic material from the riparian zone, and the stream's ability to retain it to feed instream insects, very important to the overall productivity of the aquatic habitats.

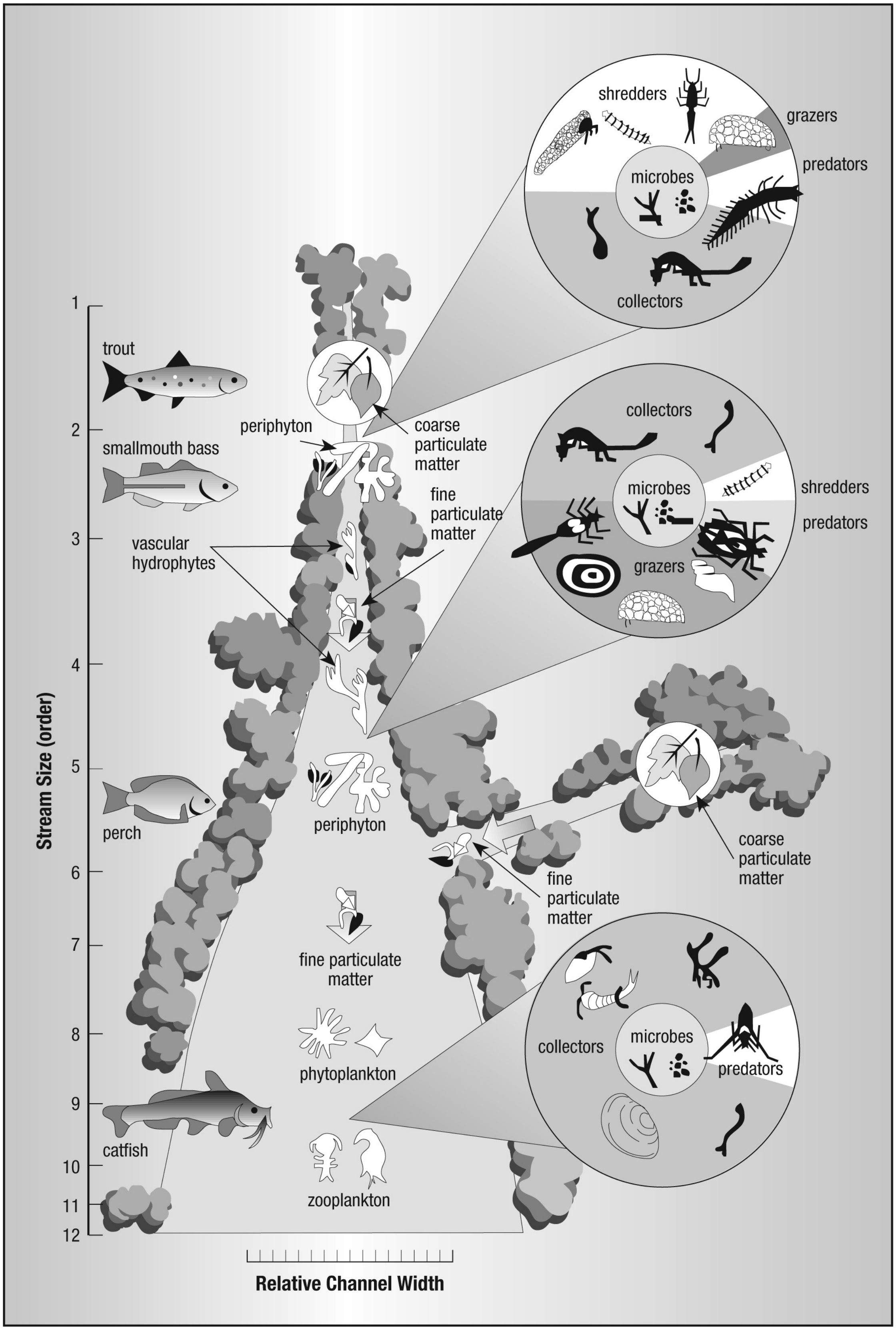

Figure 8. The River Continuum Concept (Vannote *et al.*, 1980).

2.2.5 <u>How Fish Habitat is Defined by Law & Policy</u>

In Canada, the federal Minister of Fisheries and Oceans Canada (DFO) is responsible for conserving and protecting all fish habitat. These powers are assigned to the Minister in the *Fisheries Act*.

Under Section 34 of the *Fisheries Act*, fish habitat is defined as:

"spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly to carry out their life processes."

Fish are defined in the Act (Section 2) as:

"(a) parts of fish,

(b) shellfish, crustaceans, marine animals, and any parts of shellfish, crustaceans or marine animals, and

(c) the eggs, spawn, larvae, spat and juvenile stages of fish, shellfish, crustaceans and marine animals."

Section 35 in the Act also states that:

35. (1) No person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat.

35. (2) No person contravenes subsection (1) by causing the alteration, disruption or destruction of fish habitat by any means or under any conditions authorized by the Minister or under regulations made by the Governor in Council under this Act.

DFO's "Policy for the Management of Fish Habitat" (1986) has a main objective of achieving a "net gain in the productive capacity of fish habitats for the social and economic benefit of Canadians". There are three goals in the Policy: conservation, restoration and development of fish habitat. The guiding principle for the conservation goal is "No Net Loss of productive capacity".

The Department of Fisheries and Oceans Policy for the Management of Fish Habitat (Presented to Parliament by the Minister of Fisheries and Oceans October 7, 1986) is available at http://www.dfo-mpo.gc.ca/canwaters-eauxcan/infocentre/legislation-lois/policies/fhm-policy/index_e.asp

2.3 HUMAN IMPACTS ON WATERSHEDS AND OPTIONS FOR MITIGATION

Humans have always been fascinated by water. Whether a river is used as a source of drinking water, transportation, recreation, or for the dilution of wastes, such uses often conflict and usually inflict serious harm on the aquatic habitats.

This chapter will explore the cumulative impacts associated with urbanisation and land use within watersheds in the Maritime Provinces. The problems are common and abound, yet the solutions are difficult to implement. Practical and feasible options for mitigation and remediation will be explored and offered within a watershed planning framework.

2.3.1 Storm Water Management

Increased storm water flows to streams and rivers, resulting from changes in land use, are a major cause of damage to fish habitats. The increased flows change the channel geometry, the width, and in turn the pool-riffle pattern. Higher flows can wash out road crossings designed for lower flows and cause major stream bank erosion. Poor land use also lowers groundwater levels by reducing infiltration so that low flows in summer and winter become critically low. The resulting silt and direct disruption reduces aquatic habitat productivity and it may take decades to recover.

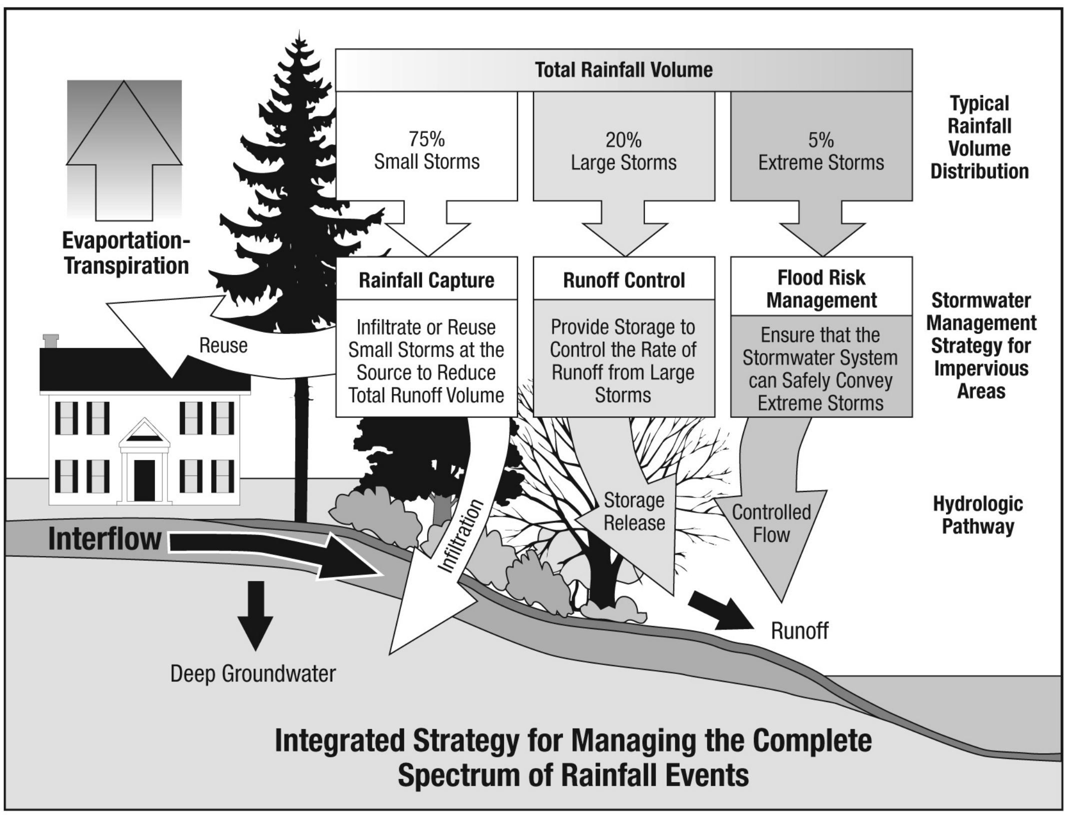

Figure 9. Integrated strategy for managing the complete spectrum of rainfall events. (Centre for Watershed Protection, 2004 - http://www.cwp.org/).

Once a watershed develops to the point of having over 10% impervious surfaces, it should be considered fully developed if the watercourses are to be protected. It is well documented that the more a watershed becomes hardened (i.e. impervious), more surface runoff is created. The objective is to control storm water runoff, allowing for as much infiltration into the ground as possible. Land development should plan for the rainfall capture up to the Mean Annual Flow levels, which is equal to or a bit higher than the 1:2 year storm. Larger storm runoff should be stored and let out into the streams at a controlled rate. The extreme storm peaks will be lowered by the other techniques and care has to be taken to ensure the flows do not damage property (normally the 1:100 year storm) and that this flood plain is vegetated and stable.

Solutions:

There are best management practices for the control of runoff that can be implemented in the planning and operational phases of any development.

These can be found in:

- "A Guide to Land Use Planning in the Coastal Zone in the Maritime Provinces" (Stewart *et al.* 2003).
- For urban and residential development, a good guide is "BC Storm Water Planning" (Kim A. Stephens, May 2002).
- For agricultural land use, consult your local Department of Agriculture.
- "On the Living Edge: Your Handbook to Waterfront Living" (Living-by-Water Project - http://www.livingbywater.ca).

2.3.2 Fish Migration Barriers

In any developed watershed, there are instances when fish migration is either impeded (e.g. due to low flows during the summer or a lack of suitable holding and resting pools, poorly designed fish passage at dams or improperly set culverts.) or completely blocked (e.g. by dams or perched culverts).

Dams

Many of today's dams are relics of the past and since many of them are no longer of any economic use, they have been neglected and are in a state of disrepair. In addition to being a serious environmental or public liability (should the dam breach), older dams may not have DFO approved fish ladders to allow migration (a requirement of Section 20(1) of the *Fisheries Act*). Impeding fish migration seriously affects the life cycle and productivity of several diadromous fish species like salmon, sea-run trout, eel, and gaspereau. Other impacts may include the disruption of sediment transport processes within a river, leading to an eventual build-up of sediment on the upstream side of the dam. If there is significant industrial activity upstream, most often those sediments become contaminated with toxic chemicals. In light of those challenges, dam owners eventually have to consider either upgrading their dam and installing a fish ladder or decommissioning the dam altogether.

Solutions:

1. Decommission the dam to restore the natural flow and ecological function of the river. This will require the expertise of engineers and hydrologists, and if the dam is large, removal could be

costly. Nonetheless, an increasing number of owners and communities are choosing to decommission dams because of the social and economic benefits of having a free flowing river.

2. Install a DFO approved fish ladder. This requires engineering expertise, but it will usually be more economical and will maintain the dam for other uses.

Culverts

Today's culverts are installed under stricter conditions than in the past. Hence, it is not surprising that most of the impacts originate with culverts installed 20 or more years ago or those not installed according to current standards. Problems with culverts occur because they are either misaligned with the watercourse or installed on an improper slope on the streambed. In such cases, a culvert may erode the stream banks or bed downstream and this leads to the deposition of sediments further downstream. A hydraulic imbalance may be felt for a certain distance downstream as the watercourse re-adjusts its erosional-depositional processes to achieve a balance. With time, if problems are not corrected with a wrongly installed culvert, it may become perched (set high off the stream bed at the downstream end), thus totally blocking fish migration.

<u>Solutions</u>:

1. Install culvert according to DFO Guidelines for the Installation of Bridges and Culverts and provincial guidelines that are available from local DFO habitat offices or provincial environment departments.

2. Report any perched culvert to the local DFO office or the provincial environment department so that corrective action can be taken.

Low flows

If they are going to migrate upstream, fish need water that is at least as deep as their bodies. Secondly, they need pools with low velocities that provide cover from predators and an area to rest in. Degraded watercourses can lose their pool-riffle pattern and thalweg due to excessive siltation and many other direct impacts. In low flow situations, there may not be enough water depth for migration, and in higher flows, there may be faster velocities and nowhere to rest. Watercourses with no apparent barriers can still stop migration if good habitat structure is not present. Low flows also compound problems at culverts that are set too high or have wide flat bottoms and no water depth. These flows can also make many debris jams, dams and other structures impassable.

<u>Solution</u>:

There are several techniques that can be used in gravel, cobble and small boulder streams to restore the pool-riffle and thalweg structure. These are detailed later in the manual. Culverts and other obstructions can be modified to increase water depth and provide proper passage. Generally, if culverts are designed to current standards and installed properly, they should work effectively. Consult the current design guidelines.

2.3.3 Sources of Siltation

The impacts of silt on water quality and fish habitat are well documented (Waters, 1995; Anderson *et al.*, 1996). Effects include increased turbidity in the water column, loss of benthic invertebrate productivity, smothering of fish eggs, destruction of spawning areas, and fish gill abrasion. In addition, many fish are sight feeders, so increased siltation can impede their sight and their chances of catching food.

Erosion normally occurs when soil is not protected by vegetation. Although serious, the source of siltation is not always obvious. Sediments can come from several sources; however, they usually originate from erosion accelerated by human activities. Construction sites, dirt roads and ditches, gullies in agricultural fields including pastures, stream bank erosion due to poorly constructed bridges or culverts, and extreme runoff events all have the potential to worsen erosion and siltation.

Much can be done to reduce the incidence of siltation from erosion. For example, DFO and provincial environment departments have activity review processes where any activity within a fixed distance of a watercourse is subject to a review (30 m in N.B. and P.E.I, 10 m plus additional width depending on slope and soil type in N.S.). If a permit is issued, it normally requires measures for preventing siltation.

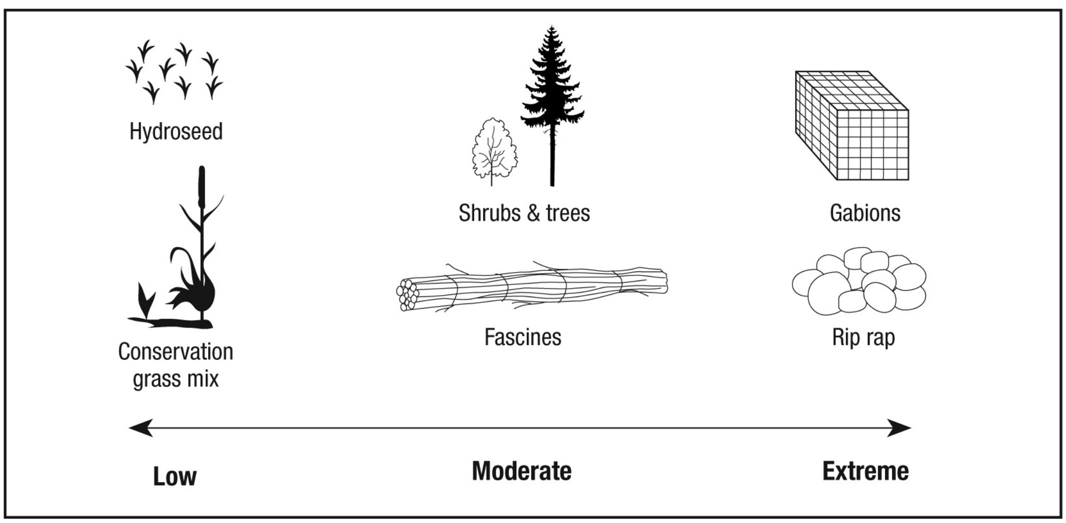

Figure 10. Methods for stabilising soils according to imminent erosion.

Solutions:

For any activity that may result in the removal of vegetation or the exposure of soil, measures must be immediately taken to stabilize the site in which the activity took place. A minor disturbance may only require the installation of a silt-capturing fence or hay mulch, but a more serious one may require grading of the site to divert runoff from exposed soils and bioengineering techniques (i.e. fascines, a rope-shaped bundle of live cuttings, lashed together with twine and brush mats) and re-vegetation (hydro-seed, shrubs and trees). Figure 10 explains how methods of stabilization should be chosen according to the potential seriousness of erosion.

2.3.4 Nutrient Over-Loading

Nutrient over-loading is a problem in many Maritimes lakes, estuaries and sometimes streams. Naturally occurring or man-made chemicals include nitrogen (in the form of ammonia, nitrites, and nitrates) and phosphorus. Nutrient sources can include wastewater treatment plants, runoff from farmlands, home and commercial fertilizers, home and commercial cleaning products, septic systems, decomposition of organic matter, and in some cases, leaching from soil and rocks (phosphorus). The problem with nutrients is that it only takes small concentrations to promote the prolific growth of aquatic plants and algae. One thing is certain: as nutrient levels increase there are changes in the biological community.

In the Maritimes, freshwater systems are naturally poor in phosphorous. This is due to the low supply available from rocks and soils of the region and also because healthy forest vegetation retains and recycles available phosphorous. The removal of riparian vegetation can disrupt the natural recycling of phosphorous and human activities can add phosphorus to the watershed. This, in turn, can change an oligotrophic (nutrient poor) ecosystem with clear, cool, and well-oxygenated water to a mesotrophic (nutrient abundant) or a eutrophic (nutrient rich) ecosystem with plant and algae overgrowth that absorbs heat from the sun and loses oxygen to abundant decaying plants.

In small maritime streams, sunlight, nutrients, and instream plants and algae account for only a small percentage of the aquatic productivity. The greater part comes from leaf falls and other organic material from the banks and the riparian vegetation. The organic material falls to the stream bottom, where it lies in interstitial spaces in the gravel or cobble and in pools. It is then digested by bacteria and shredder insects. As nutrient levels rise, there is an increase in algae and plant growth, a change to predominantly grazing and filter-feeding type insects, and a buildup of decaying organic matter on the stream substrate. The decaying action requires oxygen; hence, dissolved oxygen levels can be drastically reduced in eutrophic ecosystems. When increased algae growth happens in lakes, water becomes opaque and it absorbs more heat from the sun. This can cause surface water temperatures to rise to above healthy levels for cold-water fish (e.g. trout) and shift fish populations to warmer water species (e.g. dace).

In coastal and marine systems, nitrogen is usually limiting. Although there is normally adequate mixing of the water, light often becomes the limiting factor on plant production. Coastal areas are on the receiving end for nutrients and organic wastes from land use and human activities in the entire watershed. In estuaries dominated by river flow and low-energy estuaries with small tides, nutrients are captured by the estuarine pump action and held in the estuary (i.e. nutrients cannot be flushed away, so they remain in the estuary). In such cases, there is abundant plant growth near the source of the nutrients and in shallow, low-energy areas along the shore. Thick mats of algae form on plants and on intertidal flats, and decaying vegetation lowers oxygen levels. In extreme cases, decaying organic matter may consume all the available oxygen. When this happens, it decays anaerobically and releases hydrogen sulphide (rotten egg smell). Abundant algae growth can smother existing vegetation, degrade clam flats and oyster beds, and reduce habitat quality for valued fish species including migrating anadromous species. Estuaries with a deep basin and sill along their boundary can also lose oxygen in the bottom waters of the basin in the same way as lakes. In these deeper waters, living organisms may die and deep water over-wintering areas are reduced. Fish kills can also occur when the surface waters are pushed out by winds and the bottom oxygen-poor waters well up along the shores. New evidence is showing that nutrient-rich estuaries may maintain and even promote the proliferation of fecal coliform bacteria, thus reducing the quality of habitat for the production of marketable shellfish and recreational uses of the estuary. Nature, in its own special way, can assimilate and recycle organic wastes with its biological, biophysical and biochemical processes. If the impact from human activities is small, then natural processes can be used to mitigate biodegradable wastes. These natural functions are not well understood by urban planners, industrial users, and land owners in the watershed.

Nutrient sinks can be found throughout the watershed, starting with wetlands, riparian zones, and low areas that contain water only during heavy weather events. Riparian zones are also part of the flood plains where water runoff is slowed by vegetation and organic debris on the forest floor. This provides the capacity to remove and bind nutrients and reduce the risk of eutrophication downstream.

Eutrophication: a process by which a body of water becomes enriched in dissolved nutrients that stimulate the growth of aquatic plant life, usually resulting in the depletion of dissolved oxygen (Merriam-Webster Online Dictionary). Eutrophication is often the result of human activities within the watershed. The activities often involve importation or creation of nutrients or waste products, physical manipulations of the watershed that remove its assimilative capacity by infilling or draining wetlands, and increasing opportunities for non-point source pollution. These actions are often justified on the basis of economic considerations and convenience for the people and governments.

Many of these activities can upset the balance within the watershed and can often be attributed to ignorance on the part of planners, regulators, and other interests within the community. Many decisions are not reversible and nature has not had the time to assimilate the impacts or create a new balance. It is time the community recognized these oversights and attempt the resolve some of them. A problem developed over many years is not expected to resolve itself overnight.

Solutions:

1. Reduce point sources of pollution (i.e. at the effluent or point of entry into a watercourse). This means that effluent standards need to be improved so that both fecal bacteria and nutrients are reduced to levels which can be assimilated by the ecosystem without community shifts or eliminated through better waste treatment (tertiary), livestock is removed from streams, manure is properly stored and disposed of, fertilizer use is reduced and used properly, septic systems are properly built and maintained, and everyone uses environmentally-friendly cleaning chemicals.

2. Although difficult to detect, non-point sources are suspected as a major source of nutrients. Controlling direct runoff to watercourses, stabilizing eroding gullies on pastures, improving manure storage practices, increasing the riparian zone width, and protecting and enhancing wetlands—all help reduce this type of pollution.

2.3.5 Nutrient Management Plan

The elements of a watershed nutrient management plan should include the following:

- A clear and simple education program for all the point and non-point source contributors in the watershed. Providing a simple and understandable explanation of the possible impacts and how to reduce them could create positive results in the short to medium term.
- When attempting to address an issue, clarify the role of the community group and build a relationship of trust in the private and public sectors within the watershed.
- Set realistic goals and standards on which a nutrient management plan can be based. Understand the complexity of the issue and promote participation from respective interests within the community.
- Establish a monitoring and documentation program to determine if the goals are being achieved. Be careful to develop a monitoring program that is capable of protecting sensitive data while maintaining the trust of respective interests within the community.
- Establish indicators that can be understood by the public. This will allow everyone to see and appreciate the collective value of the many elements of the proposed plan.
- Promote nutrient management values across the watershed (rural and urban) and, through education, ensure that home owners, land owners, lawn care business owners, and high energy users such as manufacturers and fuel distributors are included in the partnership. It is important to also include retailers of fertilizers as well as researchers and advisors on the impacts of these products.
- Identify information gaps in the data and promote research in that area. This is very important to maintain and refine the many components of a nutrient management plan.
- Get involved in public consultations. Ensure that nutrient management plans are developed by qualified agrologists.

In summary, the larger the tributary, the greater the need to manage nutrient inputs to coastal areas. The success of the program will depend on the contribution of everyone in meeting the goals set by the nutrient management plan.

2.3.6 Destruction of Riparian Vegetation and Wetlands

Riparian Vegetation - When a watershed is developed, many predictable changes happen. As roads, buildings and infrastructure are constructed, the removal of vegetation is inevitable. The area lost to urbanisation also translates into an area where water will no longer be absorbed or retained by the soil. Additionally, the area becomes impervious. According to Schreier (2004), when more than 10% of a watershed's surface becomes hard and impervious, there will be predictable losses in the productivity and biodiversity of aquatic species. Other changes also happen in the hydrological regime of watercourses, as peak storm flows increase and baseflows diminish (Zandbergen, 1998). This means that the stability of the instream habitats will be compromised, losing their pool-riffle form and diversity as the streams widen to carry the additional flows, and low flows will not provide enough cool water for fish to survive.

Pollution also increases because of urbanization, as untreated wastes, petroleum products, road salts, silt, and cleaning chemicals directly make their way to a watercourse via ditches, pipes or storm sewers (see Section 2.3.7).

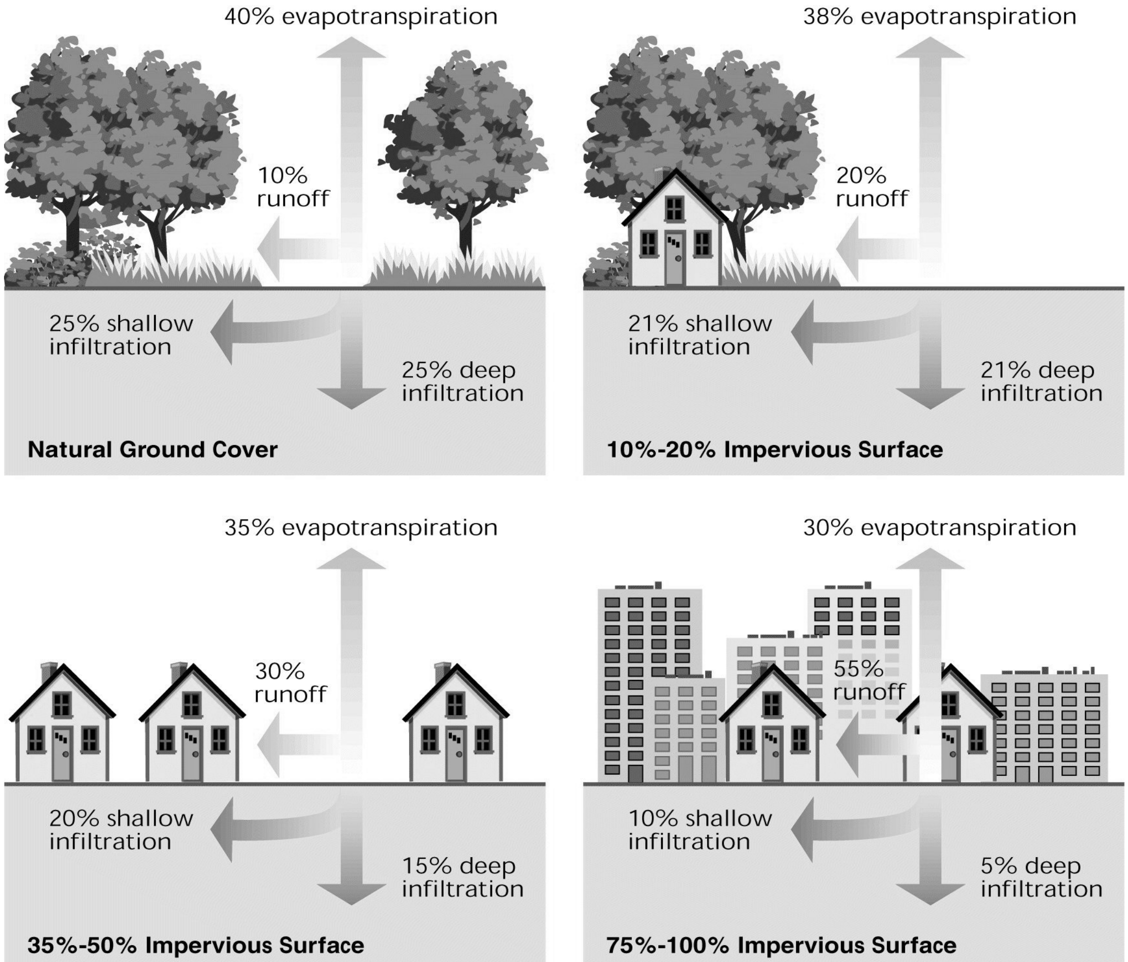

Figure 11. Relationship between impervious cover and surface runoff (FISRWG, 1999).

Solutions:

1. The impacts of urbanisation can be mitigated by taking steps to minimize impervious surfaces, protecting exposed soils, and the use of more environmentally friendly products and methods for gardening, cleaning and winter maintenance.

2. Individual landowners can choose to leave trees and vegetation in place when building a dwelling. Secondly, they can choose a gravel or stone driveway instead of a paved one. Runoff from roofs and paved areas can be directed to French drains where the water will infiltrate into the ground. Storm flows can be captured in holding areas to remove suspended wastes and rebalance the stream flow pattern.

3. Improved road networks: municipal and provincial governments need to improve planning so that fewer roads are needed to service an area, and runoff is diverted onto the surrounding land as often as possible rather that flowing in ditches to the watercourse. Fewer roads also translate into savings.

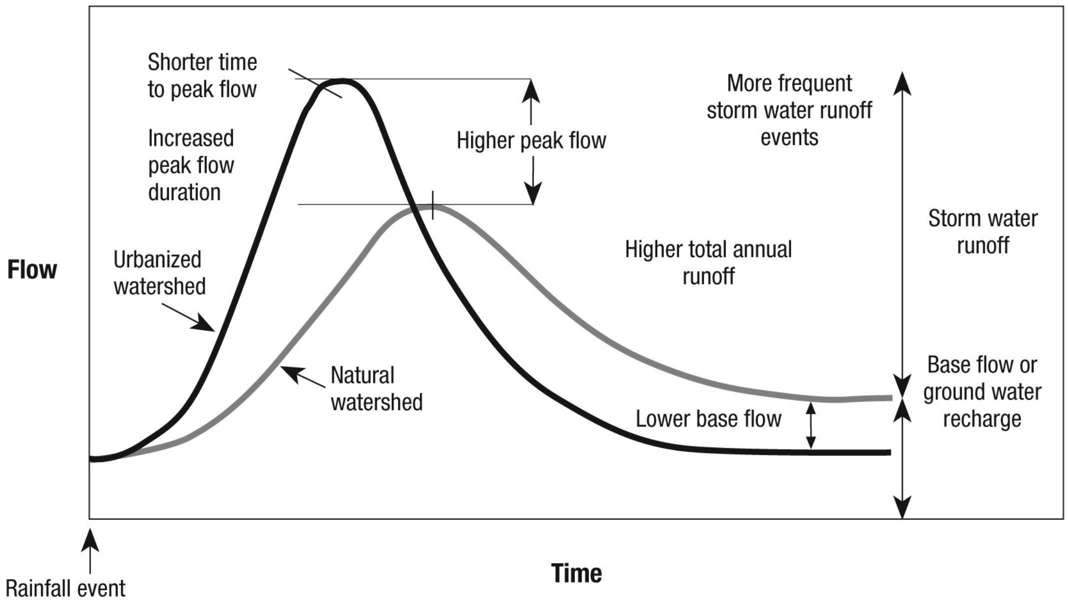

Figure 12. Generic changes to storm runoff hydrograph in urban watersheds (Zandbergen, 1998).

Wetlands - Wetlands are also the victim of development as an increasing number of people wish to build their dwellings near water. Although some provincial regulations or policies prohibit the infilling or destruction of wetlands, over the years, more than 70% of wetlands have been destroyed in Canada and as much as 90% lost in certain areas of the Maritimes (Ducks Unlimited Canada). In addition to losing biodiversity, the destruction of wetlands can increase the likelihood of flooding in riparian zones, areas where riparian landowners have built their homes or cottages. Other impacts may be the lowering of the water table and increased erosion.

Ducks Unlimited Canada have published the following “ten facts” about wetlands:

- Wetlands are found all over the world
- Wetlands keep our water clean
- Wetlands are valuable wildlife habitat
- Wetlands can help to reduce flooding
- Wetlands are great places to have fun
- Wetlands can help treat waste water
- Wetlands make great outdoor classrooms
- Wetlands help to replenish groundwater
- Wetlands help to guard against erosion
- Canada’s wetlands continue to disappear

Solutions:

Urban planners should receive formal training on environmental sensitivity of certain habitats. After such training, planners should strive to include sensitive habitats in urban development plans, and goals should be set to exceed provincial guidelines (e.g. leaving more than 30 m buffer zones and to strictly limit activities in or near wetlands).

2.3.7 Air and Water Pollution

Chemical pollution of the environment has been a persistent problem since the beginning of the industrialized era (early 1900's). Granted, society has made many strides in improving efficiency standards, reducing energy use, and cutting wastes and residual pollution. Despite those improvements, contamination of air, water and soil continues today. Governments have enacted legislation and regulations to "control" pollution with moderate success.

Sources of environmental pollution are numerous, but the most common in the Maritimes are:

Airborne

- Smog – nitrous oxides (NO_x) and volatile organic compounds (VOC) react under sunlight to form ozone at ground level. When ground level ozone and airborne particles mix, this creates smog, the leading trigger of respiratory and cardiac illnesses in cities.
- Nitrous oxides (NO_x) – gases originating from the combustion of fossil fuels. These are Greenhouse gases and contributors to acid rain.
- Sulphur dioxide (SO_2) – gas originating from the combustion of fossil fuels, especially coal. Forms sulphuric acid when combined with moisture in air and leads to acid rain. A portion of the acid rain in Maritimes originates in U.S. cities along the eastern seaboard, the mid-western US, and central Canada, but we are also contributing substantial amounts to the problem.
- Methane (CH_4) - gas originating from the decomposition of organic wastes. Intense livestock production can also contribute to significant amounts of methane. This is a Greenhouse gas.
- Carbon dioxide (CO_2) – gas originating from the respiration of animals and combustion of fossil fuels. Greenhouse gas.
- Carbon monoxide (CO) – gas originating from incomplete combustion of fossil fuels.

These gases are increasing in the atmosphere and they are contributing to global warming. Those gases also dissolve in precipitation and, in the case of the oxides (NO_x, SO_2, and CO_2), they form acids which are altering vegetation, soils, and water quality in the Maritimes.

It must also be understood that contributions to the watershed may be originating from great distances away. "Atmospheric deposition" is an issue that not well understood or included as a contributing source. The concept of an airshed needs to be considered and its potential impact on watersheds and coastal areas. It must be recognized that any significant change in these deposits will require multi-lateral agreements between National Governments regarding industrial emissions. It must be recognized that everyone can reduce atmospheric deposition by reducing fossil fuel consumption. This means reducing fuel consumption by turning equipment and cars off when not in use and heating only areas needed in our homes. Although the contributions may be small, cumulatively, they will make a difference. The airshed of lighter pollutants is considered to be 600 to 800 km in distance.

Waterborne

- Organic chemicals – found in the effluent of industries transforming wood products. Some chemical compounds found in pulp and paper effluents act as "endocrine disruptors", i.e. they mimic female estrogens. Such chemicals may adversely affect the reproductive capacity of fish (Fairchild, 1999). Because of their potent toxicity, many of those chemicals are regulated under the Canadian Environmental Protection Act regulations (CEPA). For more information, go to http://www.ec.gc.ca/eds/fact/broch_e.htm.
- Petroleum products (gas, oils, solvents, etc.) – their pathway into the environment are from roads, washing vehicles, and from leaks and spills.
- Metals – in watersheds with historical mining activity, concentrations of metals may be elevated. Wood preservatives and other industries also present a significant risk of pollution. However, in some cases, concentrations of certain metals may be naturally elevated. For instance, levels of aluminium, manganese and iron tend to be high in some Maritime streams due to natural leaching of rocks and soils. This is accelerated by acid precipitation.
- Nutrients (dissolved nitrates/nitrites, ammonia, and phosphorus) – naturally occurring compounds, but their presence is exacerbated by human activities. Sources include fertilizers, municipal sewage, septic systems, and heavy cleaning compounds with phosphates. Nutrients encourage plant and algae growth in waterways. The presence of strong concentrations of nutrients in water often leads to eutrophication (see Section 2.3.4).
- Fecal coliform bacteria and aquatic pathogens – originating mainly from the wastes of warm-blooded animals. Sources may include municipal lagoon effluents, faulty septic systems, and agriculture farm runoff. Recent research suggests that the presence of nutrients may also encourage the proliferation of such pathogens.
- Pesticides – used in agriculture, forest plantations, on lawns, and around homes for the control of weeds and pests.
- Household and commercial cleaning products – such chemicals end up in either municipal treatment systems or in storm sewers. In most cases, municipalities are not equipped to treat or remove such chemicals before they are discharged into nature. In the past, many cleaning products contained phosphates, nutrients that encouraged algae growth.
- Siltation - occurs when water runoff erodes soil and transports sediments into a watercourse. Silt can severely impact fish habitat.
- Road salts – they dissolve in water runoff from roads and enter watercourses via ditches. Strong inputs of salt can change the salinity of water and negatively affect living organisms. In fact, salt has recently been listed as a potentially toxic chemical under the *Canadian Environmental Protection Act (CEPA).*
- Naturally occurring pathogens – *Escherichia coli* (a bacterium) and *Cryptosporidium sp.* (a single-celled organism) are but two examples of pathogens introduced into water systems from the feces of wild fauna. Other organisms like *Pseudo nitzchia,* microscopic algae, are harmless in themselves, but in great numbers they produce neurotoxins that are harmful and potentially deadly to humans (Bates, 2004).

2.3.8 <u>Invasive Species</u>

Water has long been the route of choice for transporting goods. Unfortunately, high traffic at sea has led to the inadvertent introduction of exotic species in our coastal waters. Once introduced, exotic species can compete with local species for food and habitat. In some cases, this has lead to the collapse of commercially viable species or created difficulty for fishers and aquaculturists. Recently, three invaders have made headlines in the Maritimes (excerpts from DFO Web site - http://www.glf.dfo-mpo.gc.ca/sci-sci/inva-enva/index-e.html):

- Oyster thief (*Codium fragile tomentosoides*) – This green alga is a native of Japan and was detected in 1996, in Caribou, N.S. The Oyster thief smothers mussels and oysters, preventing them from opening their shells to filter feed. Starved and weakened shellfish are easy targets for predators. Gas bubbles trapped under dense mats of oyster thieves can lift shellfish off their beds and float away with them. Fouling caused by the alga results in increased labour costs in shellfish harvesting. The Oyster thief also displaces native kelp, a preferred habitat used by many species, including sea urchins and lobster.

- Clubbed tunicate (*Styela clava*) – The clubbed tunicate, a native from the western Pacific, was reported in the Brudenell River, P.E.I., in January 1998. Clubbed tunicates grow in dense clumps of up to 1000 individuals per square metre. Adult tunicates can reach a length of 16 to 18 cm. Infestation of docks, buoys, and other hard surfaces has occurred from the low tide mark to depths of four to five metres. Clubbed tunicates interfere with the settlement of oyster and mussel larvae and compete for space and food with young oysters and mussels. They are serious pests for aquaculture.
- Green crab (*Carcinus maenas*) – The European green crab was observed in St. Georges Bay, N.S., in 1995. Green crabs are a dominant predator eating a variety of species, especially shellfish such as clams and mussels. Green crabs are smaller and more aggressive than the native rock crab. Green crab populations have spread more than 100 km in a few years. Green crabs probably contributed to the collapse of the soft-shell clam industry in Maine during the 1950s.

There are also examples of intentional introduction of exotic species or the escape of species from aquaculture operations. The importation of fish species is strictly regulated and permits have to be obtained to move species of fish into the Maritime Provinces, between provinces, or between watersheds. In the past, approvals were obtained for the introduction of Rainbow trout, and aquaculture escapes have introduced Coho salmon and strains of Atlantic salmon that are not native to the Maritimes. Past practices have allowed the stocking of fish between watersheds with different genetic strains of Atlantic salmon and have introduced species such as the Brown trout, Smallmouth bass, and pickerel into our watersheds. Illegal stocking of fish continues and is seriously degrading our aquatic habitats.

Solutions:

1. Before trailering a boat, it should be washed, as well as the anchor, trailer and other equipment with fresh water and/or spray with undiluted vinegar. Remove any plants or animals. Water should be drained from the boat motor, bilge, and wells. Equipment should dry completely, if possible.
2. For larger vessels, use anti-fouling paint to reduce settlement of organisms on the hull. Don't take on or release ballast water in ports, or near aquaculture facilities.
3. Never release live bait, aquarium fish, crayfish, or plants into the water.

4. Clean clams or other shellfish in the water where they were collected. Move them with a minimum amount of water.
5. Learn to identify invasive species in your area and report any sightings to DFO and the provincial fisheries department.
6. Don't move species from one watershed to another unless you obtain an *Introduction and Transfer Permit* from DFO to ensure these organisms will not escape and harm the natural ecosystem.

2.4 WATERSHED PLANNING FOR AQUATIC ECOSYSTEM HEALTH - ADDRESSING THE LIMITING FACTORS

Community and watershed planning is a complex and involved process. Education and appreciation of the extent of the problem must be understood at the watershed level before real improvements can be enjoyed. Education provides the greatest opportunity and allows the community to set realistic goals for their initiatives. Goals must be modest and medium to long term. This will be necessary in order to retain the interest of the community and effect real change.

In addition to educating and setting realistic goals, there is a need to target areas where it will be the most cost-effective to reduce inputs. The process could be long and difficult; however, choosing that approach is likely to produce the best results for the money. The community typically prefers this approach.

Watershed planning for aquatic ecosystems begins in the headwater streams and marshes, continues down through all of the streams, brooks, rivers, lakes, bogs and marshes all the way to the estuary's flats, salt marshes, grass beds and sub-tidal waters out to the sea.

The process of watershed planning takes into consideration the specific features of a watershed and the unique combination of topography, soils, and land use. In the Maritimes, watersheds are largely forests and agricultural lands, but there are growing areas of residential development (urban and rural) and industrial sites. All of these types of land uses can contribute significant amounts of waste to watercourses. This can result in the storage of large quantities of nutrients such as nitrogen and phosphorus in sediments. In estuaries, if large inputs of nutrients happen over time, the bottom sediments may trap some of the nutrients and they may be re-suspended during storm events, thus worsening the effect of eutrophication. Another common limiting factor is high water temperature. In fact, some studies have found water temperature to be the most limiting factor for several trout species (Stoneman and Jones, 2000).

Many land-use activities have contributed to the deterioration of water quality and aquatic habitat within watersheds. The following steps will help communities in outlining a plan to address some of the limiting factors.

<u>First Step</u>: Mapping Current Land Use and Practices.

Map the current land uses and assess them against best management practices, which can be found in many guidelines published by federal and provincial agencies responsible for the various use sectors and the environment departments. Land use information can often be obtained from the province in the form of the Geographical Information System (GIS). Two good reference publications are:

- REMEDIAL OPTIONS GUIDEBOOK prepared by The Canada/New Brunswick Water Economy Agreement and Atlantic Coastal Action Program (ACAP) ACAP-Saint John, N.B. (http://www.atl.ec.gc.ca/community/acap/pdf/remedialguidebook_e.pdf); and
- MASSACHUSETTS EROSION AND SEDIMENT CONTROL GUIDELINES FOR URBAN AND SUBURBAN AREAS – A Guide for Planners, Designers and Municipal Officials. Original Print: March 1997; *Reprint: May 2003* (http://www.mass.gov/dep/brp/stormwtr/files/essec1.pdf).

There is little point in starting to restore aquatic habitats if land-use practices continue to damage the ecosystem. However, in the Maritimes, many of the habitat damaging activities have ceased. In the past, a lot more land was used for farming. Many of these farms were abandoned by the 1930's and now have maturing forests on them. Most of the forest cover in the Maritimes has been cut over more than once. Log driving was common in streams and rivers up to the 1960's, and gravel removal for construction was common practice in the recent past. Streams were realigned into straight channels for rail and road construction, along property lines, or to make fields more useable.

Many watersheds have no current impacts and many others have only minor impacts. If this is the case in a particular watershed, one can proceed to the second step.

Second step: Identifying Limiting Factors

- Look for the factors that are currently limiting the production of aquatic species. For example, these may be high summer temperatures, very shallow flows in summer and mid-winter (with no deep water for fish to move to), low pH, or oxygen levels. Many of the factors which limit productivity can be mitigated and there are techniques that can be used to work with nature to speed up the recovery of these habitats. Streams in the Maritimes have a long history of use and recovery; however, the habitat can take decades even centuries to recover if they are not assisted by providing the right conditions.

- Identify indicator species that are valued in the watershed and make a special note of any species at risk. It is preferable to do this for more than one level in the food web (i.e. insects, fish, birds, amphibians).

- Provide habitat needs by lists of variables for selected species. Some can be evaluated year round (i.e. silt in the substrate, eroding banks, perennial vegetation, LWD in stream, pools, and instream cover). Some need to be evaluated in the right season (i.e. high water temperatures, or oxygen loss in deep cold water in lakes, low pH, and low flow).

- Several ways to assess these – Ecological Monitoring& Assessment Network (EMAN) protocols cover many species (e.g. invertebrates, frog watch, etc.). There are also EMAN Draft protocols for coastal and marine habitats. See the EMAN Web site for protocols: http://www.eman-rese.ca/eman/ecotools/protocols/

Third step: Protection

- Few land use problems or damaged habitat - habitat must be preserved.
- Land use problems are fixed and restoration is underway or completed.
- River watch type program so to report any problems to authorities.

2.5 SPEEDING UP THE RECOVERY PROCESS THROUGH HABITAT RESTORATION

In a watershed, if impacts were to stop and the runoff was clean, nature would eventually bring most of the watercourse back into a dynamic balance with a stable pool-riffle pattern and natural levels of productivity. However, it is not reasonable to expect all activities to stop. For this reason, development and climate change are going to continue to alter the hydrology of watersheds and reduce the productive capacity of native species. To reverse this trend, all the activities in the watershed need to operate with best management practices in order to limit their impact on the environment. Only then can one work with nature to help it move as quickly as possible toward recovery.

The restoration techniques and the sizing and layout in the river are intended to work with the flows and vegetation to speed up natural recovery processes. The structures themselves may provide some habitat, but the main intent is to help develop a diversity of habitats needed for a sustainable productivity. The structures should allow nature to make the changes to the stream structure and function over a three to five-year period. It is these changes that will show the most results. Structures will require some minor maintenance during this time but positive changes should be seen in the river habitats and between the structures if they are functioning properly. If improvements are not seen or maintenance is high, someone should reassess the design and layout. Log structures will last in excess of 25 years and may have to be replaced if the management of the riparian zone is not supplying a slow but regular input of large organic debris.

Habitat restoration structures are intended to work with nature. The flows, riparian vegetation, large woody debris (LWD) and rocks imitate what nature does over much longer periods of time. Unfortunately, restoration techniques have not yet been developed for all habitat types. The ones that have demonstrated excellent results are suitable for small to medium size and low gradient watercourses with predominantly cobble and gravel bottoms. Large rivers with boulder substrate and high gradient watercourses with step-pool structures require different approaches not described in this manual. Design work for step-pool and large substrate watercourses requires the consideration of experts.

3.0 PLANNING A PROJECT

3.1 ASSESSMENTS

To ascertain whether an area is appropriate for restoration and which techniques would be useful, a thorough assessment of the area in consideration must be conducted. The assessment should be broken into the following four assessment levels. While the levels start with a broad look at the region in question and become more specific, it is important to remember that each level is very important and should be given equal consideration. It is important that any assessment be conducted in a way that can be interpreted by someone other than the assessor, and that it can be used to recommend appropriate restoration needs and approaches.

3.1.1 First Level Assessment – Land Use History of the Watershed

It is very important that a clear picture of historical land use in the watershed is drawn before focusing on current or site-specific assessments. Historical evidence can help explain underlying causes of problems found in the watershed. While in no way exclusive, the following are examples of common historical impacts found in Maritime watersheds.

Forestry Impacts: If the region has a history of forestry activity, any information concerning the specifics of that activity is useful. Patterns of clearcutting, road construction, airborne application of pesticides, and other common forestry practices can have long-term detrimental effects on the local watershed. If there is a history of log driving in the watershed, it is important to know where flow control dams and mills were located, as sections of the river or stream may have been straightened.

Agriculture: The extent and type of farming located previously in the watershed may help explain some current problems. If large sections of the watershed were once fields, it would explain some impacts on local hydrology. Farmers often realigned streams along field and property lines to improve access and workability of the fields. Livestock using the stream may have caused extensive bank erosion and siltation of the stream bottom. Any historic use of fertilizers or pesticides and herbicides should also be noted.

Urban Development: Urban development can directly impact watersheds in many ways, including changes to hydrology, channel realignment, and contamination of many varieties (including silts and sand, nutrients, pesticides and herbicides, salt and chemicals of all kinds) that make their way to storm sewers and then to streams.

Other Industry: Any past industrial activity in the watershed may have had long-lasting, deleterious impacts on the local area. From the damming of rivers/streams, to channel realignment, water diversions, and removal of streambed gravel, any physical alteration to a watercourse is very damaging. Chemical contamination of the soils and stream sediments is common at these sites. Industrial dump sites can contain virtually hundreds of chemicals.

Ice Jams and Flooding: Past activities that have over-widened a watercourse may have created a situation where the shallow winter flows freeze to the bottom of the river and the thin layer of water flowing over the top builds up the ice. In some cases this has reached a point where the channel is bankfull with ice and the water flows through the riparian zone, displacing over-wintering animals and freezing and damaging the vegetation. In the spring, surface ice from upstream jams up in these areas, causing flooding, or blocks of ice may scour stream bottom habitat (redds and over-wintering juveniles), level out the pools and riffles, and scrape vegetation off the banks. In the Maritimes, this process is common, because of the freeze-thaw winter cycles. Watercourses that are damaged by ice have difficulty recovering naturally and need restoration to stop the yearly damage to habitats.

It is important to remember that if physical changes happened long ago, they may have become over-grown with vegetation and be hard to spot. Any possible contamination from former industrial sites or historical pollution of any waterways should also be noted.

3.1.2 Second Level Assessment – Current Impacts

Forestry Harvesting Patterns: If any forestry activities are being conducted in the watershed, it is important to know the scale of the work, its location and who is conducting it (i.e. large crown, large private, small private). If possible, information must be acquired on whether they are using selective or clearcutting harvest methods and what guidelines or Best Management Practices (BMP) they are following. All crown and most large private forestry operations have management plans. These should be obtained wherever possible. Most of the Maritimes is privately owned and individuals and small companies do not prepare management plans for their lands. The age of any cuts already present in the watershed and the number of road crossings should be noted. Due to the land ownership patterns in the Maritimes, most areas have far more roads than permissible in other jurisdictions in Canada.

Agriculture Patterns and Types: If any agricultural activities are being conducted in the watershed, it is important to know the scale, type and location. If there is pasture land within the watershed, factors such as direct access of livestock to waterways, the storage and disposal of manure, and possible fecal contamination of watercourses and coastal habitats must be considered. The specific type of agriculture present (row crops, orchards, etc.) must be known because each has variable effects on erosion, possible contamination of groundwater/surface water, etc. The chemicals used in each operation and the guidelines and BMPs used by the operator should also be noted.

Urban Development: If there is urban development within the watershed, the lot sizes, the density of lots, and the level of development on the lots must be known. Note whether septic systems or a central sewage system are in use, along with wastewater treatment efficiency (whether it is working properly or not). Proper controls for runoff of storm water must be addressed for any urban development. Not only can uncontrolled storm water quickly carry contaminants from developed areas into waterways, but the sudden flow increases related to storm water having direct access to streams or rivers without proper buffer zones can also cause morphological damage to the streambed. This is directly linked to the percentage of hard surfaces found in the developed area (see Imperviousness). As more area is covered with surfaces that do not retain precipitation, this increases amounts of storm water flow into waterways over shorter periods of time and causes habitat destruction in the waterway.

Transportation Development: Assessment of this section should focus on road and track construction with a close proximity to, or crossing a waterway. If a culvert is present and is not properly installed, it may create a barrier to fish passage. It should be noted whether the culvert is perched above the water level or whether it is positioned correctly. Culvert length and diameter can also be a barrier to fish passage, so the length and diameter of each culvert in the watershed should be obtained. If road/track construction has taken place in close proximity to a waterway, incidents of channel realignments must be noted. It is important to remember that channel realignments may have occurred many years in the past, and the present stream may appear at first to be undisturbed. Any ditching near a waterway must also be noted, specifically with regard to the possibly of contaminating the waterway (silt, salt, oil, etc.).

3.1.3 Third Level Assessment – Aquatic and Riparian Habitat Assessment

Stream Habitat Features:

When assessing a stream for habitat features, it is important to assess the following aspects:

1) Water Quality – general tests for water quality (pH, temperature, conductivity, dissolved oxygen, nutrients, metals, and fecal coliform bacteria) are important and can help point out possible problems in a watershed.
2) Pools – deep sections of a stream or river. Properly developed pools provide cover, help regulate water temperature, aid in fish passage, and are refuges for juvenile fish during low flow periods. A lack of pools is a clear indicator that something is wrong in the watershed.
3) Thalweg – the deepest part in a cross-section of the main channel of a waterway, provides passage, maintains a minimal water depth during low flow periods to keep the water cool and provides habitat for juvenile fish and insects.
4) Cover – the availability of cover present in the waterway. This can include small to large instream boulders not set in sand or silt, instream vegetation, large organic debris, sections of deep water, water of dark colouration, overhanging vegetation and undercut banks.
5) Embeddedness – The spaces between rocks and boulders in a streambed are essential habitat for aquatic invertebrates and they form the base of many key food chains and cover for small fish. Therefore, it is important that cobble, rocks, and boulders are minimally embedded (i.e. set in sand and silt).
6) Bank Stability – Bank erosion is a major input of silt that can lead to high embeddedness in a stream, and it usually means the watercourse is unstable and realigning itself to adjust to changes in flow volumes or other disturbances. Its presence is a clear indicator that something is wrong in the watershed.
7) Bank Vegetation – Bank vegetation is important for cover, nutrient input, bank stability etc. Percent cover and predominant vegetation types should be noted.

Lake Habitat Features:

When assessing a lake for habitat features, it is important to assess the following aspects:

1) Dissolved Oxygen Concentration Regime – Essential to any species living in a lake, the dissolved oxygen concentration (DO) is a key aspect of habitat. DO is usually not uniform throughout a lake; the following habitat features will have an effect on the DO regime present.

2) Temperature Regime – During warmer seasons, lakes can provide sanctuary for species that cannot remain in the warm, shallow water found in streams. Water temperature directly impacts DO, as warm water decreases DO and cooler water increases DO. However, the lack of circulation and decaying vegetation can reduce the DO levels in the cool water, leaving the cold-water fish without habitat.
3) Nutrient Load – The amount of nutrients available in lake water directly impact the level of algae and other aquatic plants and microscopic organisms in a lake. Phosphorous is normally the nutrient that controls plant growth in fresh water. If there is a high level of this nutrient present, it can cause excessive plant growth.
4) Lake Depth – An important feature as depth can affect both DO and the temperature regime in a lake. In most moderately deep or deep lakes, a thermocline develops that separates two distinct water temperature zones, the warmer, upper layer (the epilimnion) and the cooler, bottom layer (the hypolimnion). If proper mixing (annual turn-over) or external sources of DO (spring water) do not exist, the bottom layer may become anoxic (without oxygen). If this occurs, it limits the use of the lake as a refuge for species trying to find cooler water during warm periods.

3.1.4 Fourth Level Assessment – Aquatic Habitat Rehabilitation Plan

Finding Habitat Limiting Variables

Habitat assessment is a process of determining the limiting factors and is a critical pre-requisite to determining the productive capacity of the habitat and the restoration requirements. Despite some intensive surveys on some rivers, such information is not available for Maritime watercourses. If it was available, it would make the design of a restoration project much easier. Unfortunately, it is not easy to identify all of the limiting factors, and each watercourse can have its own unique combination of factors that interact to limit the productivity throughout the year. Bisson (1992) summarized a number of potential barriers to identifying important limiting factors which are still valid today.

These include:

1. *Excessive reliance on professional judgment in the absence of site-specific data*. Limited budgets, insufficient time, personal biases, single day assessments and short reach assessments all contribute to excessive reliance on professional judgment. Additionally, reliance on inappropriate models incorporating incomplete or inconclusive data and single species models may lead to misidentification of the limiting factors. Local community monitoring and assessment of the watercourse (all life stages of chosen species, all seasons, and for several years) is the only effective way of identifying the limits.

2. *Extrapolation in space and time*. Bisson (1992) cautions investigators about extrapolating and provides several examples indicating high variation in stream fish population size which may be related to a succession of limiting factors within a single stream. Again, knowing your stream and how it functions over time is the only way to ensure you have found the limiting factors.

3. *Oversimplification of complex ecological situations*. There is an assumption that often underlies habitat enhancement programs, namely that fish populations are linearly related to the

amount of rearing habitat. This is not always the case because due to territoriality, larger fish require larger habitats. Habitat quality also has a major effect on productivity. Other factors affecting habitat productivity include the fluctuation of available food, the presence of competitors and predators, and off-site problems such as pollution events, fish barriers, and over fishing. All of these factors increase the difficulty of relating rearing area to population density.

4. *Focusing exclusively on one aspect of life history*. Even if a limiting factor is identified at a particular life history stage, addressing it may not solve the overall productivity problem. A common management intervention is to bypass poor quality or inaccessible spawning habitat that is limiting to productivity by using hatchery rearing and stocking, only to find that another habitat, such as pre-smolt winter habitat, is controlling production. Again, it is necessary to consider multiple limiting factors that could potentially affect different life stages and the entire life cycle of the fish species of interest.

5. *Failure to consider critically important factors*. Bisson (1992) identifies several areas where the understanding of stream life history information is poor, including such factors as predation, nocturnal habitat preference, use of winter refuges, etc. Furthermore, the fact that fish are migratory and capable of both short- and long-term movements at all life stages is another complexity to consider.

Limiting factors should be thought of as bottlenecks through which all the fish and wildlife have to pass. If the bottleneck habitat will only allow a few individuals to survive, then that habitat controls or limits the productivity. The diagram below is a depiction of how a limiting habitat can effect the population of Atlantic salmon.

3.1.5 Habitat Assessment Methods and Protocols

There are numerous survey forms and approaches used to assess fish habitat. Generally you can find a form for each jurisdiction and, in some cases, extensive manuals on how to fill them out and computer programs to help analyse the data. Many have been developed to provide information to fisheries stock managers or to provide information for single species fish habitat models. The biggest challenge with any of the forms is how to interpret the data once it is collected. How do you find the variables that are limiting the productivity of the habitat?

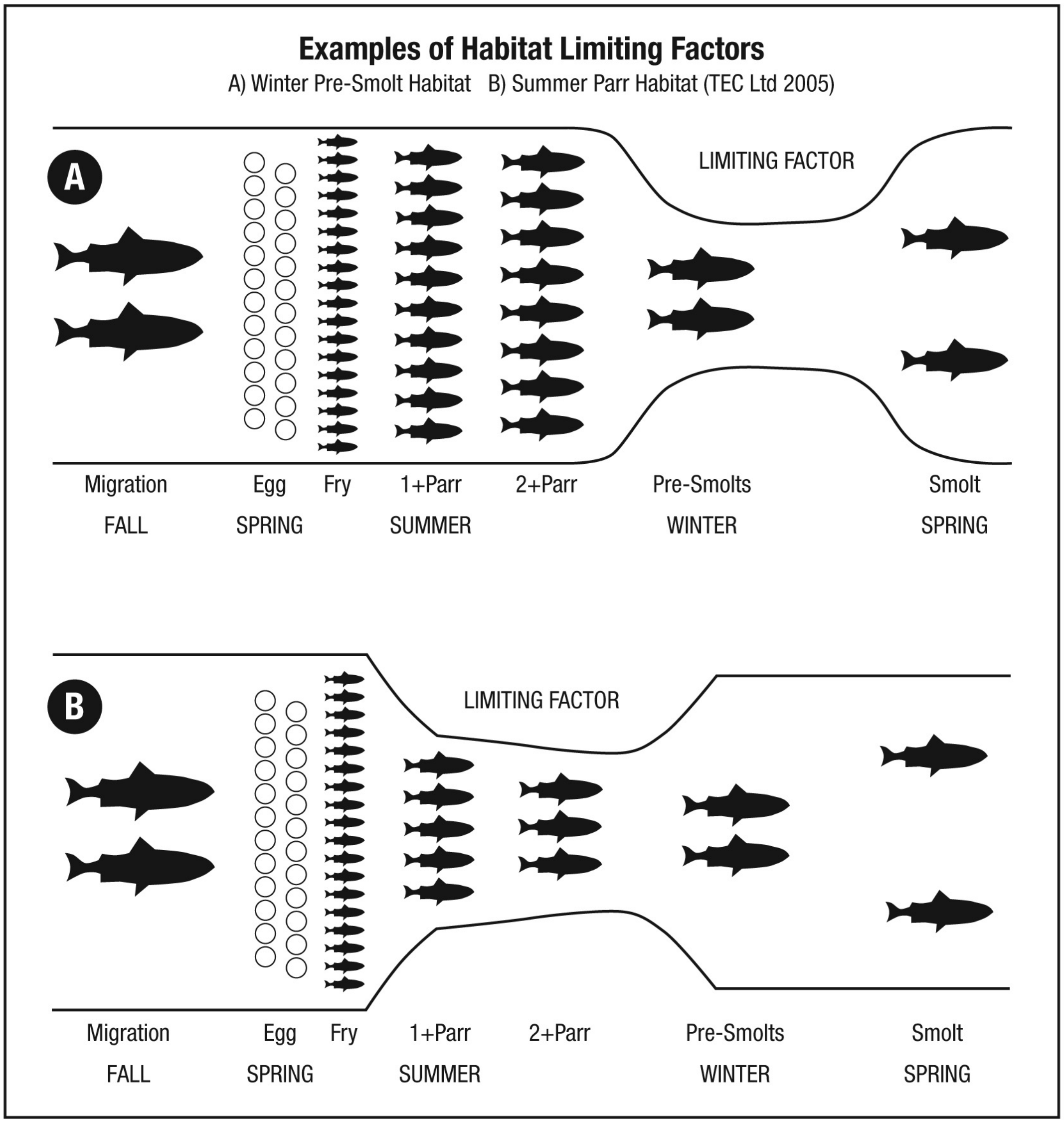

Figure 13. Example of habitat limiting factors for Atlantic Salmon: a) winter pre-smolt habitat and b) summer parr habitat (Thaumas Environmental Consultants Ltd., 2005).

Is it necessary to do detailed assessments if one or two of the variables are obviously weak? What protocol is followed to ensure the data is comparable between assessors, years, other rivers and the habitat models? What techniques are used to work with the natural processes to rehabilitate the habitat?

The best approach for a community group is to "think like a fish". To do this select common species in the watershed and starting with the spawning migration, think through the needs of species in each life stage and season. What do they need to be healthy and grow in the estuary and river? To answer these questions the tables on the next few pages list the variables, which individually or in combination, commonly limit fish habitat productivity in Maritime watercourses. In the adjacent columns are the ranges for the variables that are considered to be excellent, good and not sustainable for a selection of common sport fish and indicator fish species. These values are intended for use in identifying limiting habitat variables. They are not considered to be levels at which the ecosystem falters and the population collapses but indicative of where to focus the restoration work. For values used in violations or environmental impact assessments, contact your local DFO biologist.

The following section includes a brief description of the sampling protocols for each variable so that the data will be consistent throughout the assessment, for monitoring from year to year, and comparable to other assessments in the region.

With respect to the restoration of the habitats, the objective is to work with nature to move the limiting variables into the good or excellent range. Furthermore, links between the variable that needs to be improved and the appropriate restoration techniques are found in the fact sheet section. Many of the techniques used to restore the physical habitat solve problems with many of the limiting variables.

The actual layout of instream structures is not explained in detail, because this requires someone trained in the hydrology of watercourses and the design and layout of restoration techniques to complete the plan for the project. This part is very important, because if the structures are not sited properly, they may not create the improved habitat; they may become buried, washed out, or, in rare cases, create their own limiting factor. A poor design is the most common reason for the failure of restoration projects. To avoid wasting all your efforts, get a trained person to spend a couple of days doing a proper layout.

The spacing between instream structures is normally 6 channel widths. The size of the structures becomes clear after surveying the sites and from reading the information provided in the restoration fact sheets. You can usually develop a good estimate of the extent of the work required and estimate costs and the logistics of getting the work done.

Following the tables is a list of monitoring protocols used for other aquatic species by the Ecological Monitoring and Assessment Network (EMAN) and other local organizations. These will be useful in broadening the restoration and monitoring work beyond fish to be more ecosystem-based in your watershed management.

Select the species that frequent your stream or should be present. Then think about each life history stage and consider all of the variables that are listed below for each of the species you have selected. Based on existing data or local and traditional knowledge, select those variables that have the potential to be limiting in your watershed and provide an explanation of why you think the other variables are not limiting. For example, if you know the pH in your river and in all its tributaries stays in the Excellent or Good range for salmonids all year long, then it can be eliminated from the survey. However, if the summer temperatures rise into the mid 20’s in the lower reaches or any of the tributaries, then it is important to measure temperature throughout the watershed during the warmest part of the year to find the viable habitats and identify reaches that can be rehabilitated. Basically, during your data collection, you need to assess and monitor the limiting variables for the community of species which are or should be inhabiting the watercourse if it were healthy.

It is almost impossible to do a complete assessment in one pass along the stream. Some experienced assessors can see the problems which will exist at other times of the year, but this expert opinion is often wrong because each watershed has its own characteristics. So be prepared to get to know your stream in all four seasons, particularly during the critical low flow periods in summer and winter and the spring and fall spawning periods.

3.1.5.1 Basic Data Collection

It is important that all samples and data related to a site are accurately recorded:

- The GPS location, topographic map grid references, permanent markers such as site numbers painted on trees or boulders, or accurately described (i.e. Nine Mile Brook at the outlet of the culvert on Highway 14, in N.S.). Mark the location on the most detailed map or aerial photo available. 1:50,000 maps are good but 1:10,000 are better.
- The time and date the sample or measurement was taken.
- The equipment used to take the measurement or sample.
- The name of the person taking the sample or measurement and the recorder.
- The weather during sampling.
- Photograph the area, recording the photo number and the direction you are facing.
- All right – left directions in the fact sheets and plans are given as if you were facing downstream.

Measurements are normally taken on a reach-by-reach basis. The length of a reach can be set at a standard length (i.e. each 50m) or each habitat unit, which is six times the channel width. This last method will give a new reach length at the junction of each tributary. For initial surveys of a watershed, assessments may be taken just at the junction of tributaries. Reaches would be assessed on the main stem above and below the tributary and one in the tributary. This will provide an overview of the habitats' health and help identify where efforts should be focused.

3.1.5.2 Various Fish Species and Habitats

A) Salmonids (Atlantic salmon, Brook trout, Brown trout)

1 - Water Depth and Velocities During Migration and Spawning

Estuary

When salmonids migrate upstream (from the estuary), they spend time in depressions at the bottom, at the head of tide. They remain in this salt/brackish water for various lengths of time and if conditions for river migration are not good, they return to nearby coastal areas to feed. They return some weeks later to reattempt the upstream migration if and when the conditions are right. If holding areas are impacted by development or if they have changed due to sedimentation, then the number of fish they can hold is reduced. This limits the number of fish that can migrate on a freshet and the total number that migrates up the river to spawn.

Table 1. River water depth (cm) and velocities (cm/sec) during migration and spawning.

Species	Min depth	Preferred velocity	Maximum velocity	Notes
Brown trout	> 18	60	250	
Atlantic salmon	> 18	75	250	
Brook trout	4 to 18	20 to 45	120	Fish size dependant

Notes

- Adults require these depths and velocities only during their migration to spawning areas. Values less than these will commonly be found in summer and fall low-flow periods and will halt migration at these times.
- Adults will swim against the preferred velocity or as close to it as they can find: mid-water in shallow flows and secchi disc depth in deeper waters. Secchi disc depth is the depth to which you can see a white object lowered into the water.
- Using burst speeds, fish can get past short sections with higher velocities. They can swim against velocities up to 10-body lengths per second and for up to 10 seconds. If water velocities do not impede fish from travelling the required distance while swimming against the flow, then the section is passable. However, the flow should be considered a partial barrier if the velocity exceeds the maximum velocity listed in the Table 1.
- To fully utilize habitat, spawning fish should be able to go as far up the stream as possible to get the optimum distribution of fry. Even the larger salmon and trout will use first and second order streams if access and holding pools are good.

Sampling protocol

Walk up the river during migration season and follow the route the fish would take based on depths, velocities (table above), pool quality, and frequency (tables below). Note the areas of river the fish would have trouble passing through. These may include wide, shallow sections without pools, or culverts, dams and debris jams.

Equipment

Meter sticks, floats, stop watch and camera.

2 - Pool Area and Quality During Migration and Spawning

Table 2. Percent pools (area) during migration and spawning.

Species	Excellent	Good	Poor	Notes
Brown trout	50 to 90	15 to 25	< 15	
Atlantic salmon	20 to 25	10 to 30	< 5	
Brook trout	35 to 65	12 to 90	< 5	
Salmonids				

Notes

Assessments should be done at migration flows. If this is not possible, the depth of the water at the crest of the riffle below the pool should be measured and then estimates should be taken on how much pool there would be if the flow were at normal fall flows.

Sampling protocol

Pools are all areas in the watercourse that are deeper than the average depth of the watercourse. This percentage is measured or estimated on a reach-by-reach basis.

Equipment

Measuring tape, meter stick, survey rod, and calculator.

Table 3. Pool class rating during migration and spawning.

Species	Excellent	Good	Poor	Notes
Brown trout	> 30% of the area is composed of 1st class pools.	> 10% but < 30% of the area is 1st class pools or > 50% is 2nd class pools.	< 10% of the area is 1st class pools and < 50% is 2nd class pools	See pool class descriptions below
Atlantic salmon	20% of the area is composed of 1st class pools	> 10% but < 20% of the area is 1st class pools or > 30% < 50% is 2nd class pools.	< 10% of the area is 1st class pools and < 30% is 2nd class pools	
Brook trout	> 30% of the area is composed of 1st class pools	> 10% but < 30% 1st class pools or > 50% 2nd class pools	< 10% 1st class pools and < 50% 2nd class pools	

Notes

This classification of pools should be done in conjunction with the percent pool and pool frequency assessment.

Salmonids need to hold in the stream near the spawning areas and they all seek good water depth, low velocities, and cover. The holding capacity of the pools can regulate the number of spawning fish in well-stocked streams.

Sampling protocol

Rate all pools according to the following classification scheme:

First-class pool: Large and deep. Pool depth and size are sufficient to provide a low velocity resting area. More than 30% of the pool bottom is obscured due to depth, surface turbulence, or the presence of structures such as logs, debris piles, boulders, or overhanging banks and vegetation. Or, the greatest pool depth is > 1.5 m in streams < 5 m wide or > 2 m deep in streams > 5 m wide.

Second-class pool: Moderate size and depth > 45cm at low flow. Pool depth and size are sufficient to provide a low velocity (> 0.5m/sec) resting area. From 5% to 30% of the bottom is obscured due to surface turbulence, depth, or the presence of structures. Typical second-class pools are large eddies behind boulders and low velocity; moderately deep areas beneath overhanging banks and vegetation.

Third-class pool: Small or shallow or both < 45cm at low flow. Pool depth and size are sufficient to provide a low velocity resting area. Cover, if present, is in the form of shade, surface turbulence, or very limited structures. Typical third-class pools are wide, shallow, reduced velocity areas of streams or small eddies behind boulders. Virtually the entire bottom area of the pool is discernible.

Fourth class pool: shallow sections of stream with low gradient and size and depth are sufficient to provide resting areas for parr. Cover is limited to spaces under the substrate. The entire bottom is discernable.

Equipment

Meter stick or survey rod to measure depths.

3 - Frequency of Holding and Resting Pools for Migration

Pools are very important to fish during spawning migration. A fish's ability to swim against the current is related to its species, its physical condition, and its length. Periodically, fish need areas with low velocities to rest in before moving to the next section of river. Pools must provide cover, low velocities, and enough space to accommodate all the fish that need to rest. For migrating fish, it is important to consider the frequency of first and second-class pools.

Table 4. The frequency of holding and resting pools for different salmonid species.

Species	Excellent	Good	Poor	Notes
Brown trout	6 channel widths	12 channel widths	> 24 channel widths	
Atlantic salmon	6 channel widths	12 channel widths	> 24 channel widths	
Brook trout	6 channel widths or more in step pool streams	12 channel widths	> 24 channel widths	

Sampling protocol

Channel widths are measured in stable sections of stream straight across between the base of the perennial terrestrial vegetation on each side. Watercourses in the Maritimes tend to be over widened by 20% due to ice activities and past uses. This is particularly true in sections where the pools are poorly developed. If this is the case at the sampling site, reduce the width measurement by 20% and use this number in assessing pool frequency.

Equipment

Measuring tape.

4 - Spawning Area

Salmon and Brown trout spawn where the water is drawn down through the gravel. These areas are typically located at the tail of a pool where there is a head difference between the water level in the pool and the downstream riffle or run. The head difference causes the water to seep through from the tail of the pool, under the crest of the riffle, and emerge on the riffle. A water seepage rate of 100 cm/hr is excellent to bring oxygen to the eggs and remove wastes but this flow is hard to find and measure. Other good sites with similar hydrology include the areas above digger logs and small debris jams and the edges of pools where the seepage goes under the flood plain before returning to the stream. If fish are to use a particular site, water flow under the gravel must run parallel to the surface flow. Short, steep riffles which cross the river at more than 30 degrees have seepage and surface flows which are not parallel and the fish are seldom able to build successful redds. When searching for spawning habitat, one must look for head differences (between the tail of the pool and the riffle downstream), whether the riffles are aligned closely with the flow, and the presence of clean bottom gravels with little silt.

Brook trout use essentially the same habitats as salmon but they prefer areas where the water is upwelling (i.e. seeping from the gravel). Such areas can be found along the edge of lakes and streams where the groundwater level is at least 30 cm higher than the watercourse water level or where water is returning to the stream after seeping under the flood plain. These areas can be detected by temperature differences in seep water and stream water. Normally, seep water is colder in the summer and warmer in the winter.

Table 5. Spawning area depth and velocity during spawning.

Species	Depth cm	Excellent Velocity over redd cm/s	Velocity over redd cm/s Good	Notes
Brown trout adult	> 24	40 to 70	30 to 80	
Atlantic salmon	> 25	60 to 80	35 to 90	
Brook trout	> 15	N/a	N/a	Spawn primarily in springs and seeps with excellent springs having > 40 cm head

Sampling protocol

Must be sampled in the late fall (October, November or December) during moderate freshets. Measure the velocity over the tail of the pool.

Equipment

Meter stick or survey rod for the depths and a float (an orange is good) and a stopwatch.

5 - Spawning Substrate

Table 6. Spawning substrate preference of salmonid species.

Species	Excellent	Good	Poor	Notes
Brown trout	< 3 % fine sand < 15 % sand 40 –50 % gravel 40-50 % cobble	Degrades with increasing sand and silt content	> 20 % fine sand &silts	
Atlantic salmon	< 3 % fine sand < 15 % sand 40 –50 % gravel 40-50 % cobble	Degrades with increasing sand and silt content	> 20 % fine sand &silts	
Brook trout	< 3 % fine sand < 15 % sand the rest gravel	Degrades with increasing sand and silt content	> 20 % fine sand & silts	

Notes from Peterson (1978):

- Fine sand (0.06-0.50 mm);
- coarse sand (0.5-2.2 mm);
- gravel (2.2-22 mm);
- cobble (22-256 mm).

Sampling protocol

This is best done by measuring off an area 50 cm x 50 cm at the tail of a pool and visually estimating the percentage of each size class. Other methods are available see Hamilton (1984).

Equipment

Meter stick.

6 - Percentage Area With Spawning Gravel

Table 7. Percentage of total study area consisting of spawning gravel size.

Species	Excellent	Good	Poor	Notes
Brown trout A	5	2	1	Measure gravel sizes of 0.3 to 10 cm in areas > 0.5 m^2 and at depths > 15 cm only Class A = 1 to 7 cm
B		5	2.5	Class B = 0.3 to < 1 and > 7-10 cm
Atlantic salmon	5	2	1	
Brook trout	5	2	1	

Sampling protocol

This should be estimated for each reach.

7 - Egg Habitat

The eggs remain buried in the gravels over winter and need a flow or seepage of water to bring them oxygen and remove wastes. It is also important that the stream is stable and the redds are not washed out or scoured by ice.

Table 8. The average minimum daily dissolved oxygen level (mg/L) during embryo development.

Species	Excellent	Good	Poor	Notes
Brown trout < 10 ^{o}C	> 10	> 7	< 6	
> 10 ^{o}C	> 13	> 10	< 9	
Atlantic salmon	> 13	> 10	< 9	
Brook trout < 15 ^{o}C	> 6.5	4.5	< 4	
> 15 ^{o}C	> 8.5	6.5	< 6	

Notes

Oxygen saturation is preferable for all water temperatures.

Table 9. The average maximum daily water temperature (^{o}C) during embryo development.

Species	Excellent	Good	Poor	Notes
Brown trout	7 to 13	4 to 14	< 3 or > 14	
Atlantic salmon	3 to 7	1 to 8	< 0.5 & > 9	
Brook trout	4 to 11	2 to 15	< 1 to > 17	

8 - Alevins

When the eggs hatch in the early spring the alevins move between the spaces in the gravel. At this point, there are large losses of young fish if there is sand and silt filling the spaces as the alevins cannot get out of the shell or straighten out and move freely. When the alevins absorb the yolk sac and become fry, they swim up through the gravel to live in shallow low velocity areas in the stream. Again, the sand and silt content of the gravel has to be very low to allow them to swim up and to provide them cover from predators. The process of digging a redd cleans the sand and silt out of the redd area, but if the sand and silt content is high in the substrate it works back into the redd gravels over the winter.

9 - Fry Habitat

Emergent fry move out of the redd area up to 100 m. They progress mainly downstream as they seek suitable habitat. If the densities are too high for the available habitat, the excess fry die within a few days. It is important that low velocity, shallow areas with clean gravel and abundant cover be readily available for these young fish.

Table 10. Substrate in shallow low current water.

Species	Excellent	Good	Poor	Notes
Brown trout fry	Gravel	Cobble	Embedded gravel, cobble or sand	
Atlantic salmon fry	Gravel	Cobble	Embedded gravel, cobble or sand	
Brook trout fry	Gravel	Cobble	Embedded gravel, cobble or sand	
Salmonid fry	Gravel	Cobble	Embedded gravel, cobble or sand	

10 - Parr Habitats (Summer and Over-winter)

The primary limiting factor on parr is water temperature, which is directly related to reduced oxygen and the lack of suitable instream cover.

Table 11. Summer water temperature ranges (^oC) for salmonids.

Species	Excellent	Good	Poor	Notes
Brown trout	11 to 19	8 to 21	< 6 or > 24	
Fry	7 to 15	7 to 19	< 6 or > 20	

Atlantic salmon	11 to 19	9 to 21	< 6 or > 24	
Brook trout	10 to 16	5 to 20	< 3 to > 22	
Salmonid	10 to 16	8 to 20	< 6 or > 22	Mixed population

Notes

- This is a very simple variable to monitor and a very common limiting factor.
- Temperature has to be combined with oxygen to find suitable habitats.
- For salmonids in streams or crowded conditions, oxygen > 6 mg/L. In ponds or lakes where there is no current, oxygen > 3 mg/L. Levels below 6 mg/L must not last more than two weeks.

Sampling protocol

Average maximum daily water temperatures have a greater effect on trout growth and survival than minimum temperatures. The temperature that supports the greatest growth and survival is the “excellent” temperature range above.

Restoration techniques

- Thalweg and pool development
- Add riparian zone vegetation to provide more shade

Table 12. Percent pools during the late growing season, low-water period.

Species	Excellent	Good	Poor	Notes
Brown trout	50 to 90	15 to 25	< 15	
Atlantic salmon	20 to 25	10 to 30	< 5	
Brook trout	35 to 65	12 to 90	< 5	

Notes

Assessments should be done at low summer flows; if this is not possible, the depth of the water should be measured at the crest of the riffle below the pool and then estimates should be taken on how much pool there would be if the flow were lowered by this depth.

Sampling protocol

Pools are all areas in the watercourse that are deeper than the average depth of the watercourse. This is measured or estimated on a reach-by-reach basis.

Equipment

Measuring tape and meter stick or survey rod.

Table 13. Pool class rating during the late growing season, low-flow period.

Species	Excellent	Good	Poor	Notes
Brown trout	> 30 % of the area is composed of 1st class pools.	> 10 % but < 30 % of the area is 1st class pools or > 50 % is 2nd class pools.	< 10 % of the area is 1st class pools and < 50 % is 2nd class pools	See pool class descriptions below
Atlantic salmon	20 % of the area is composed of 1st class pools	> 10 % but < 20 % of the area is 1st class pools or > 30 % < 50 % is 2nd class pools.	< 10% of the area is 1st class pools and < 30 % is 2nd class pools	Pools are critical for parr in low flow conditions and over-wintering pre-smolt
Brook trout	> 30 % of the area is composed of 1st class pools	> 10 % but < 30 % 1st class pools or > 50 % 2nd class pools	< 10 % 1st class pools and < 50 % 2nd class pools	

Notes

This classification of pools should be done in conjunction with the pool assessment percentage.

Sampling protocol

Rate all pools according to the following classification scheme.

First-class pool: Large and deep. Pool depth and size are sufficient to provide a low velocity resting area. More than 30 % of the pool bottom is obscured due to depth, surface turbulence, or the presence of structures such as logs, debris piles, boulders, or overhanging banks and vegetation. Or, the greatest pool depth is > 1.5 m in streams < 5 m wide or > 2 m deep in streams > 5 m wide.

Second-class pool: Moderate size and depth > 45 cm at low flow. Pool depth and size are sufficient to provide a low velocity (> 0.5 m/s) resting area. From 5 % to 30 % of the bottom is obscured due to surface turbulence, depth, or the presence of structures. Typical second-class pools are large eddies behind boulders and low velocity, moderately deep areas beneath overhanging banks and vegetation.

Third-class pool: Small or shallow or both < 45 cm at low flow. Pool depth and size are sufficient to provide a low velocity resting area. Cover, if present, is in the form of shade, surface turbulence, or very limited structures. Typical third-class pools are wide, shallow, reduced velocity areas of streams or small eddies behind boulders. Virtually the entire bottom area of the pool is discernible.

Fourth-class pool: shallow sections of stream with low gradient and size and depth are sufficient to provide resting areas for parr. Cover is limited to spaces under the substrate. The entire bottom is discernable.

Equipment

Meter stick or survey rod to measure depths.

Table 14. Substrate used for escape cover and overwinter habitat for small juveniles.

Species	Excellent	Good	Poor	Notes
Brown trout	Cobble	Gravel	Sand	Non embedded
Atlantic salmon	Cobble	Cobble	Sand	Non embedded
Brook trout	See note	Cobble	Sand	Undercut banks, and Large organic debris provide cover in pools. Small fish use instream non embedded cobble for cover

Note

Trout can use streams with sand or silt bottoms if they have sufficient cover for all life stages.

Sampling protocol

Measure 50 cm x 50 cm plots on the stream bottom and estimate the percentage of each bottom type suitable for cover in riffle, run, and pool areas.

Equipment

Measuring tape.

Table 15. Percent cover during the late growing season and overwinter habitats.

Species	Excellent	Good	Poor	Notes
Brown trout	> 30	20	15	low-water period at depths > 15 cm and near bottom velocities < 15 cm/s
Juvenile	> 15	10	5	
Atlantic salmon	> 40	20	10	Un-embedded cobble is excellent Un-embedded gravel is good
Brook trout	> 25	15	5	Substrate as for salmon or vegetation, Large organic debris, or under cut banks

Sampling protocol

Visual estimate of the percentage cover in a reach.

11 - Pre-Smolt Habitat

Atlantic salmon pre-smolts spend the last winter in the river in pools feeding actively. The best habitat is in first- or second-class pools with ice cover. This provides a diversity of cover, large enough for the pre-smolts, and the ice cover helps regulate the water temperature. However, these pools are often lacking and they can limit the population by restricting survival during this last stream stage.

When salmonids move downstream, they face into the current. They move within the stream to find velocities of 45 to 60 cm/s to carry them down. In ponds and lakes, where velocities fall below 15 cm/s, they turn and swim with the current or following the bank, seeking the outlet. Swimming depth is mid-water where you can see the bottom and secchi disc depth in deeper and coloured water. Obstructions include debris jams and especially dams because they have unnatural outlets. Dams often force the fish to go deeper in the water to find bottom outlets or rise to the near surface without the guidance of a sloping bottom to find surface outlets. To assess these obstructions, it must be determined if the fish will find the outlet at their preferred swimming depth and velocity.

12 - General water quality

Table 16. Range of tolerated pH values. Use the highest and lowest measurement.

Species	Excellent	Good	Poor	Notes
Brown trout	6.8 to 7.8	6 to 8.4	< 5.5 & > 8.6	
Organic acid		5.5 +	< 5.0	
Atlantic salmon	> 6	> 5.5	< 5.0	
Organic acid		5.0 to 5.4	< 4.7	
Brook trout	6.5 to 8	5.5 to 8.5	< 5 & > 9	
Organic acid			< 4.2	Need pH 5.5 to 8 in springs or seeps for spawning

Note

If the water is colourless use the values on the same line as the species name. If the water is tea coloured, it contains organic acids; therefore, use the Organic acid levels following the species. Organic acids are produced in marshes and bogs and are less toxic than acid rain acidity and in fact mitigate many of the effects of acid rain by binding the heavy metals.

For lacustrine habitats, measure pH in the zone with the best combination of dissolved oxygen and temperature.

Sampling protocol

During low flow periods, the majority of the water in a stream is groundwater, and this flow will have the highest pH that can expected to be found during the year. Low pH is found during high flow periods especially with the spring snowmelt. Rain events from west and southwest are very acid because they come from highly industrialized areas. Regular sampling assessments or continuous monitoring is best, although time consuming. To find limiting factors, sample during the period when the pH is expected to be at its lowest value.

Table 17. The average minimum daily dissolved oxygen level (mg/L) during embryo development and the late growing season.

Species	Excellent	Good	Poor	Notes
Brown trout $< 10\ ^oC$	> 10	> 7	< 6	
$> 10\ ^oC$	> 13	> 10	< 9	
Atlantic salmon $< 15\ ^oC$	> 6.5	4.5	< 4	
$>15\ ^oC$	> 8.5	6.5	< 6	
Brook trout $< 15\ ^oC$	> 6.5	4.5	< 4	
$> 15\ ^oC$	> 8.5	6.5	< 6	

Notes

Oxygen saturation is preferred for all water temperatures.

Sampling protocol

This is an important variable but very difficult to sample during the winter. This sampling should be carried out if it is expected that a high biological or chemical oxygen demand is created by land use activities in the watershed. This is not a common limiting factor.

13 - General Stream Structure and Stability

Sedimentation & Suspended Soils

A large volume of suspended sediment will reduce light penetration and photosynthetic activity of phytoplankton, algae, and rooted aquatic plants, especially those farther from the surface. Overall, suspended sediments lead to fewer photosynthetic plants available to serve as food sources for insects and in turn a lower food supply for fish.

When sediments are introduced into surface waters, they are either deposited on the bed of the stream or lake or suspended in the water column (suspended load). Bed load is large sediment particles that move by bouncing and rolling along the bottom. Generally, the suspended load in flowing water consists of grains less than 0.5 mm in diameter. Lake suspended loads usually consist of the smallest sediment fractions, such as silt and clays.

The water current transports particles in both the bed load and the suspended load. Because the particles in the bed load move by rolling or bouncing along the bottom, bed load transportation occurs in flowing waters. These bed load particles fall into the spaces between the gravel and cobble in the stream bottom and reduce invertebrate habitat, juvenile fish escape and overwinter cover, and infill spawning beds. The volume of sediment transported and whether or not it is suspended or bed load is dependant on the particle size and the flow velocity. A high flow velocity can transport a greater number of larger particles than a slower current. Any sediment transported by water is subject to deposition as flow velocity decreases.

The amount of sediment deposited on a rocky substrate can be quantitatively defined by an estimation of the percent embeddedness. The percent embeddedness is the degree to which fine sediments such as sand, silt, and clay fill the interstitial spaces between rocks in a substrate.

A 70 % embedded substrate will cause changes to occur in the structure of macro-invertebrate fauna and most fry and small parr will leave an area or die when embeddedness levels reach 50-60 %.

<u>Optimal Ranges</u>

0 to 10 % embeddedness	Excellent Conditions
< 25 % embeddedness	Good Conditions
25 – 50 % embeddedness	Fair Conditions
50 – 75 % embeddedness	Poor Conditions
> 75 % embeddedness	Poor Conditions

Note that trout can thrive in streams with high embeddedness if the springs and seeps used for spawning are clean and there is abundant instream cover in the form of undercut banks and large organic debris.

A guide to percent embeddedness (Hamilton 1984):

- *0 % embeddedness* = No fine sediments on substrate.
- *25 % embeddedness* = Rocks are half surrounded by sediment and are not covered by sediment.
- *50 % embeddedness* = Rocks are completely surrounded by sediment but are not covered by sediment.
- *75 % embeddedness* = Rocks are completely surrounded by sediment and half covered by sediment.
- *100 % embeddedness* = Rocks are completely surrounded by sediment and completely covered by sediment.

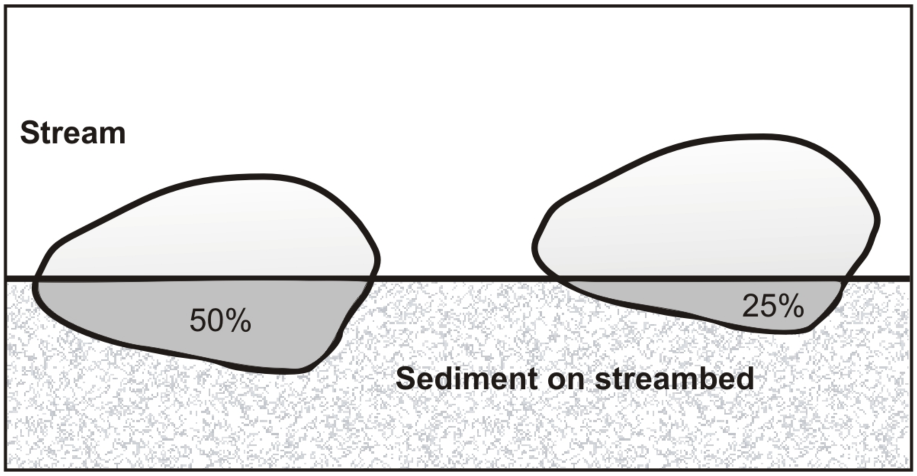

Figure 14. An example of substrate embeddedness.

Suspended solids should be kept to a minimum. USA and European guidelines for salmonid streams set an upper limit of 25 mg/L as the long-term average and 80 mg/L in a grab sample. Canadian (CCME) guidelines for aquatic life set a limit of 10 mg/L above background levels for watercourses with background less than 100 mg/L. As the levels of suspended solids rise above 25 mg/L, salmonids lose the ability to see the drifting food and insects become detached from the substrate and drift. The growth and condition of the fish is reduced the longer the suspended solids are > 25 mg/L during the growing season.

Bed loads in Maritime streams are primarily sand and silt from erosion caused by poor land use and poorly designed instream structures such as culverts and bridges etc. As this bed load infills the gravel/ cobble/boulder substrates, it prevents the river from sorting these heavier substrates by "cementing'' them into the bed. The result is a river that has a shallower cross section with poor thalweg and pool development and is approximately 20 % over widened.

<u>Options for Restoration</u>

Digger logs, rock sills, deflectors.

Table 18. Percentage of stream area shaded between 10:00 and 14:00 (for streams < 50 m wide).

Species	Excellent	Good	Poor	Notes
Brown trout	50 to 75	> 25	< 10	Do not use for cold < 18^0C, summer maximum
Atlantic salmon	50 to 75	> 25	< 10	
Brook trout	50 to 75	> 25	<10	Do not use for cold < 18^0C, summer maximum

Sampling protocol

Estimate the percentage of the reach shaded on a sunny day. There are hand held convex mirrors with grids marked on then for the estimation of forest crown cover that are useful but not necessary.

Table 19. Dominant substrate type in riffle-run areas & food production.

Species	Excellent	Good	Poor	Notes
Brown trout	A	B	C	See below
Atlantic salmon	A	B	C	See below
Brook trout	A	B	C	See below

For all salmonids the dominant substrate (> 50 % of the area):

A) Rubble or small boulders, or aquatic vegetation in spring areas, dominate; limited amounts of gravel, large boulders, or bedrock.

B) Rubble, gravel, boulders, and fines occur in approximately equal amounts or rubble-large gravel mixtures are dominant. Aquatic vegetation may or may not be present.

C) Fines, bedrock, small gravel, or large boulders are dominant. Rubble and small boulders are insignificant < 25 %.

Table 20. Percent fines (< 3 mm) in riffles and runs.

Species	Excellent	Good	Poor	Notes
Brown trout	< 10	10 to 25	> 35	
Atlantic salmon	< 10	10 to 25	> 35	
Brook trout	< 15	15 to 35	> 45	

Sampling protocol

Combine the estimate of the two variables above. Measure 50 cm x 50 cm plots on the riffle areas and estimate the substrate types.

Table 21. Vegetation Index (trees, shrubs, and grasses) along the stream bank during the summer for allochthonous (leaf litter) input. Vegetation Index is 2 (% shrubs) + 1.5 (% grasses) + 1(% trees) + 0 (% bare ground) = the score below.

Species	Excellent	Good	Poor	Notes
Brown trout	> 120	60 to 120	< 40	
Atlantic salmon	> 120	60 to 120	< 40	
Brook trout	> 120	90	< 60	

Table 22. Average percent rooted vegetation and stable rocky ground cover along the stream bank during the summer.

Species	Excellent	Good	Poor	Notes
Brown trout	> 75	40 to 75	< 30	
Atlantic salmon				
Brook trout	75	40 to 75	< 25	

Sampling protocol

Visual estimates of the vegetation types and percent rooted vegetation on both banks by taking sections of 10 m (5 m to your right and 5 m to your left) as you face the bank. Sum up the totals for the reach.

Table 23. Average annual baseflow regime during the late summer or winter low-flow period as a percentage of the average annual daily flow (cubic feet per second - cfs).

Species	Excellent	Good	Poor	Notes
Salmonids	50	30	20	

Average annual peak flow as a multiple of the average annual daily flow. For embryo and fry habitat suitability, use the average and highest flows that occur from time of egg deposition until two weeks after fry emergence.

Table 24. Average annual peak flow as a multiple of the average annual daily flow.

Species	Excellent	Good	Poor	Notes
Salmonids	2 to 3	> 1 and < 4.5	1 and > 5	

Sampling protocol

These are difficult variables to monitor if the stream does not have a gauging station or a staff gauge with flow duration curves. However a problem can be seen by observing the flows and estimating which of the above categories the stream is in. Generally forested watersheds with permeable soils fall into the excellent category. Developed watersheds with hard impermeable surfaces fall into the poorer categories.

Options for Restoration

Runoff control and ensure groundwater areas are recharged.

14 - Lake Habitat

The same water quality, cover, and physical habitat variables apply to lakes. Lakes are often holding areas for adult salmon during the summer and may have a small population of parr when the population in the watershed is high or during times when the stream habitats are unsuitable and the young fish fall back into lakes. Shallow lakes are warm throughout the water column and usually have water temperatures that are too high for good habitat during the mid-summer. Deeper lakes stratify with the warm water on the surface and cool water on the bottom, and they are suitable for the fish 3 to 6 m down. The fish seek the preferred water temperature. If the organic loading in the lake is low, then the decaying material in the cool waters will not reduce the oxygen level below 6 mg/L and the salmon will stay and trout will grow well. If organic loading or nutrient loading is high, the oxygen will be depleted and these cool water refuge areas are lost. Temperature and oxygen profiles during the late summer define this limiting factor.

B) Alewife (Alosa pseudoharengus) and Blueback Herring (Alosa aestivalis)

<u>Estuary</u>

The juveniles, who migrate to the estuary in the late summer, stay in the estuary until the main population returns from its marine feeding areas the next spring. Adult Alewives and Blueback herring have a high tolerance for salinity changes and can move quickly from one to the other. Both species stage near the head of tide waiting for the right water temperatures in the river.

<u>Water Temperature</u>

Alewives begin to migrate into fresh water in the spring when the temperature rises above 11 ^{o}C. The migration rate varies directly with the rate of water temperature rise. Typically the best migration is on warm sunny days when the water temperature rises quickly and slows in the night as the temperature begins to drop. This has often been mistaken for the need for light but alewives will migrate late into the evening if the water temperatures continue to rise. Optimum migration and spawning temperatures are 16 to 20 ^{o}C. So the run begins in April in the south and is as late as the end of June in northern areas of the Maritimes.

Blueback herring begin to migrate at 14 ^{o}C and typically peak two to three weeks later than the alewives although the runs overlap. Optimum migration temperatures are 17 to 26 ^{o}C.

<u>Velocities</u>

Both species prefer to migrate against currents of 30 to 50 cm/s moving into slower water to hold and rest. Suitable resting areas must be available in the river at least every other habitat segment or each twelve channel widths.

<u>Water Depths During Freshwater Migration</u>

The water must be deeper than their body. Typically they swim with their dorsal fin at mid-water where you can see the bottom or at the secchi disc depth in deeper water. This means they move up and down in the water column with changing light levels. Both species are schooling fish and migrate in horizontal V shape schools of four to five fish forming the V. If the lead fish follows the preferred velocity and depth, higher velocities and shallower depths may stop the others. This is why pool and weir type fishways work best because the school can move up together over the weir.

Turbulence

These fish are laterally compressed and do not tolerate turbulence from the side.

Feeding

Both species are zooplankton feeders and will also eat fish eggs. They do feed during migration but food of a suitable size is seldom available.

Spawning Substrates and Depth

Alewives spawn in pools, still waters, and lakes, wherever the current is sluggish and the water depth is between 15 cm and 3 m. Cover is considered an important variable and while this may be vegetation, it is normally water colour in the maritime rivers.

Blue-back herring spawn where the water currents are faster in deep stretches of river or in flooded margin areas. Both species are dispersal spawners. Their eggs initially stick to bottom materials, but they lose their adhesive property after several hours in the water.

Juvenile Rearing

The eggs hatch in three to four days at 20 ^{o}C and remain in the warm shallow waters feeding on zooplankton. Survival is most closely related to food supply with the optimum being 100 zooplankton/L. Juveniles are concentrated in the littoral zone of the lakes and still waters.

Downstream Migration

Adults return to sea after spawning and repeat spawning rates are as high as 60 %. Juveniles moved downstream in the late summer in response to cooling water temperatures. They also swim at mid-water where you can see the bottom and at the secchi disc depth in deeper waters or at night. There has to be downstream passage at these depths for them to find the flow. This can be a problem at dams with deep or shallow surface outlets.

General Stream Structure

Alewives use rivers with lakes and still waters which warm the water quickly during warm spring days. They will migrate all the way to the headwater lakes. A well-developed stream channel with pools and a good thalweg provides good migration habitat. Long runs, hanging culverts and dams fragment the habitat.

Blue-back herring do not migrate very far up the river and are found in the lower reaches in deep runs and backwaters.

C) Rainbow Smelt (Osmerus mordax)

Spawning Migration

Smelt spawn at night and most of them return to the tide at night. If streams are close together, then fish may spawn in several streams in the same year. Migration begins early in the spring and, in many cases, occurs under the ice.

Water Temperature

Rainbow smelt spawn at temperatures between 4 and 9 ^{o}C; however, they have been known to spawn in water between 10 and 15 ^{o}C in northern New Brunswick. Hatching time is temperature related: 25 days at 7 ^{o}C and 8 days at 16 ^{o}C.

Water Depth

Water depth varies between 0.1 m and 1.3 m.

Substrate Type

Substrate type is typically gravel with water velocities 0.6 to 0.8 m/s. Survival rates are very low, in the order of 1 to 2 %.

General Stream Structure

Good stream pools, thalweg structure, and un-embedded gravel in the lower reaches of the river provide the best migration and larval survival.

D) American Eel (Anguilla rostrata)

Spawning

Based on larval counts, spawning appears to take place in the Sargasso Sea south of Bermuda, from February to April. Adults die after spawning. The larvae are carried by ocean currents and spend up to 2 years at sea. The larvae metamorphosize to glass eels after one year and then again as they enter the coastal areas to become yellow eels or elvers. They move into fresh water in the early spring. Once in fresh water, they actively swim against moderate velocities upstream and rest in low velocity areas. Eels continue to move upstream as they become older.

Substrate Type

Substrate type varies but they require excellent cover in the substrate or in organic debris. They feed on anything that lives in the same habitat.

For additional references see http://www.nwrc.usgs.gov/wdb/pub/hsi/hsiintro.htm for habitat suitability indexes and species profiles.

3.2 WATERSHED ASSESSMENT AND STREAM SURVEY SHEETS

Each jurisdiction and even departments within the jurisdictions have developed their own habitat stream survey methodology and forms. The data collected is useful in determining the basic needs for a restoration plan and to compare to data collected using the same methodology several years later to document changes. There is a methodology that has been used in New Brunswick for many years, and these forms and directions on how to collect the data can be obtained from the provincial district biologist and local fish habitat biologists. In Nova Scotia, the Nova Scotia

Adopt-a–Stream Manual has forms to use in collecting data on the history of activities in the watershed, current land use problems, and instream habitat assessment. DFO has also used a modified habitat suitability index approach based on Brook trout habitat models. This last approach is similar as the process outlined above for several species.

In P.E.I., there have been several techniques used and the local habitat biologists can be consulted.

Before beginning a survey you should contact your local habitat biologist to find out if the river has been surveyed before and what advantages there would be to repeating the same survey methodology. The key thing to ask is will there be someone with the skills to interpret the survey in a way which will be useful in meeting project goals.

The forms below are in summary form, which can be used to organize the conclusions drawn from "thinking like a fish" and using the Watershed & Estuary Habitat Assessment & Action Plan chart. Remember this is a process which involves learning about the watershed and the impacts of activities. It is an ongoing process that includes assessment, action, monitoring and review in a continual cycle. Through this approach the productivity of the aquatic habitats in the watershed can be restored and maintained.

3.2.1 Watershed Assessment and Planning Guide Instructions

On the next page, there is a form that should be filled out with the following information:

- The date the assessment was completed.
- The location of the river reach or sub-watershed and how it was defined. For example the form may be completed for each 50m of stream or for the section that flows through a landowner's property or within a town's limits. The important thing is to do the survey for the whole watershed and accurately note the location of the reach with GPS or map grid coordinates.
- Assessors: the names of those involved in the assessment.
- Category: these may be subdivided to assist in the assessment by addressing common problems in the watershed.
- List each land use problem found.
- Location: note the GPS or grid reference for each problem site.
- Action required: make suggestions as to the type of action that needs to be taken. For example: invite landowners to adopt best management practices, or add riprap to a bank, etc.
- Priority: on a scale of one to ten, with one being the most important, rate the need to do this work to meet goals.

Watershed Assessment and Planning Guide

Date: ___________________ Watershed / reach: _______________________

UTM Coordinates (start and finish): ___________________E, _______________________N

Assessors: ____

Category	Nature of problems	Location	Actions required	Priority
Habitat fragmentation				
Land use problems				
Water quality				
Riparian quality& processes				
Physical habitat quality				

Stream Survey

This form is designed to be filled out on a reach-by-reach basis or for a sub-watershed as you "think like a fish" for the salmonids. A similar approach can be taken for the other species. The quality assessment as good, poor, or unsustainable will focus the restoration work that needs to be done.

Stream Survey Summary Form

River	Date	Assessor
Reach number	Start GPS	Finish GPS
Weather	Air temp	Water temp
Life stage	Variable	Quality
Migration	Avg. water depth	
	Water velocity (m/s)	
	% Pool	
	Pool class	
	Frequency of pools	
Spawning	Water depth	
	Water velocity	
	Substrate quality	
	Availability of gravels	
	Cover	
Egg	Winter dissolved O_2	
	Max daily temperature	
Alevin	Embeddedness	
Fry	Substrate quality	
	Shallow areas	
Parr	Summer water temp	
	% pool fall and over winter	
	Pool class	
	Substrate cover	
	Over winter cover	
Pre-smolt	Pools with ice cover	
Downstream migration	Velocities	
	Barriers	
Water quality	pH	
	Dissolved O_2	
	Clarity	
General stability	Embeddedness	
	Shade	
	Vegetation index	
	Vegetation vs. bare	
	Low flow as % of annual	
	Peak flow	

3.3 PROJECT COSTS

Project costs vary depending on the skill levels of those hired to do the work and the availability of volunteer labour. Most groups have found that undertaking a watershed project takes a lot of time to complete the planning, write the funding proposal, talk to land owners, apply for permits and then actually doing the on-the-ground work. If funding can be found for a project coordinator, then the projects move faster and are better coordinated than if all the planning and organization work is dependant on volunteers. However, volunteers have completed some of the best projects completed to date, and in some cases an individual has taken on all the planning and has been successful.

Project costs can vary greatly from one organization to another and from site to site. Plan to keep the costs down by using on-site materials wherever possible and as much in-kind donations and volunteer time as possible. Involving local businesses, landowners, and volunteers helps build a feeling of ownership for the work and the health of the aquatic habitats, which translates into stewardship for this resource.

3.4 PERMITS

3.4.1 Federal Permits and Approvals

3.4.1.1 DFO Authorization

The Canada *Fisheries Act* (Section 35) makes it illegal to harmfully alter, disrupt, or destroy fish habitat without an authorization from the Minister of Fisheries & Oceans.

Project proponents are responsible for assessing the impact of their activities on the productive capacity of the aquatic habitats to produce fish, which contributes to an aboriginal, commercial, or recreational fishery. If the project is going to harmfully alter, disrupt, or destroy fish habitat a letter of authorization may be obtained from the local area DFO office.

Habitat restoration, when done properly, does not harmfully alter the habitat. To be sure the project is planned properly, consultations need to be done with the local DFO Area Office and a letter of approval should be obtained. DFO is linked to the other federal and provincial permitting systems through a network of referrals. By contacting the local DFO office, useful advice can be given on the preparation of the other permit applications for restoration.

Fisheries and Oceans Canada
Oceans and Habitat Division
Moncton, New Brunswick
Telephone: (506) 851-7768

Fisheries and Oceans Canada
Oceans and Habitat Division
Tracadie-Sheila, New Brunswick
Telephone: (506) 395-7722

Fisheries and Oceans Canada
Oceans and Habitat Division
Antigonish, Nova Scotia
Telephone: (902) 863-5670

Fisheries and Oceans Canada
Oceans and Habitat Division
Charlottetown, Prince Edward Island
Telephone: (902) 566-7839

3.4.1.2 Canadian Environmental Assessment Act

If the proposed work is going to harm fish habitat in some way, an authorization will need to be issued by DFO. This authorization triggers the Canadian Environmental Assessment Act. At this time, restoration work done by hand is exempt from a CEAA review. However, if machinery is going to be used in a watercourse, the activity may trigger an environmental review. Some of the structures used in restoration are being approved through a class screening process, so if works are going to be carried out according to the approved methods, a formal environmental impact statement may not have to be prepared.

3.4.1.3 Species at Risk Act

This Act makes it illegal to disrupt the habitats of endangered or threatened species listed in the regulations. Information on the current list and the designation of critical habitats can be found at http://www.sararegistry.gc.ca/default_e.cfm. An application for restoration work will be reviewed for impacts on these species; however, it is good to check before undertaking detailed planning. The watershed restoration plan should include the protection and restoration of habitats of listed species. All of the techniques in this manual are aimed at restoring the natural productivity of the watercourse, but this may at times conflict with one or more of these species.

3.4.1.4 Navigable Waters Protection Act

A navigable water is any body of water capable of being navigated by floating vessels of any description for the purpose of transportation, commerce or recreation. This includes both inland and coastal waters. The final authority to determine the navigability of a waterway rests with the Minister of Transport Canada or his/her designated representative. A permit is required for any work including:

- any bridge, boom, dam, wharf, dock, pier, tunnel or pipe and the approaches or other necessary or associated works,
- any dumping of fill or excavation of materials from the bed of a navigable water,
- any telegraph or power cable or wire, or
- any structure, device or thing, whether similar in character to anything referred to in this definition or not, that may interfere with navigation.

NWPA **Review Process**

Before beginning a project, contact:
Transport Canada
P.O. Box 1000
Dartmouth, Nova Scotia
B2Y 3Z8
Phone: (902) 426-2726
Fax: (902) 426-7585

A Navigable Waters Protection (NWP) Officer will assist in determining what information and documentation is required for preparing and submitting an application under the *NWPA*.

Once the project design has been finalized, the application needs to be submitted to the nearest NWPA office in the area, including details regarding the applicant, the nature of the work, other permits obtained, property ownership and drawings and plans of proposed work. It is extremely important that plans be drawn accurately. Freehand sketches may not be acceptable and could delay approvals.

An "approval" issued under the *NWPA* authorizes the work only in terms of its effect on navigation. It remains the owner's responsibility to obtain any other permits (i.e. federal, provincial or municipal), which may be required. Therefore, early in the planning stages it is encouraged to contact the local, provincial Departments of Natural Resources /Environment / Fisheries and municipal offices to discuss their specific requirements.

For more information see; http://www.tc.gc.ca/marinesafety/Ships-and-operations-standards/nwp/guide.htm

3.4.2 Provincial Permits

3.4.2.1 New Brunswick

Watercourse and Wetland Alterations

Background:

In an effort to help protect New Brunswick's surface water resource from the effects of activities such as: constructing poorly planned buildings, uncontrolled landscaping and forestry activities, and the installation of dams or other such water obstructions, the Department of the Environment and Local Government administers the Watercourse and Wetland Alteration Regulation Permit program. Although this program has been in place for 20 years, not everyone has a clear understanding of when a watercourse or wetland alteration permit is necessary.

Wetlands throughout the province (including coastal marshes) are considered watercourses and any person working within 30 m of a wetland is required to obtain a Watercourse and Wetland Alteration permit.

Simply put, the program applies to all open channels, natural or artificial, that hold or carry water for any part of the year. Lakes, ponds, rivers, streams, brooks and wetlands are clearly watercourses; as are reservoirs, canals, and ditches.

It is important to inquire about the need for a Watercourse and Wetland Alteration Permit before doing any vegetation clearing, soil excavation, construction or landscaping activities within 30 metres of a watercourse or a wetland.

When is a Permit Required?

Activities for which a Watercourse and Wetland Alteration Permit is required are as follows:

- Construction of structures on or in the watercourse or wetland, such as retaining walls, breakwaters, bridges, culverts or wharves.
- Installing or modifying a dam or other water level control structure, or installing or modifying a pipeline crossing.
- Carrying out repairs to existing structures on or adjacent to a watercourse or wetland that result in a change in the size, shape, materials or alignment of the structure, or involve construction or excavation. This includes building or maintaining a drainage ditch or roadway within 30 m of a watercourse or a wetland.
- Driving or operating any machinery in a wetland or on the bed of a watercourse, or operating heavy machinery within 30 m of a wetland or the banks of a watercourse.
- Disturbing ground within 30 m of a wetland or the banks of a watercourse.
- Removing vegetation from a wetland or the bank or bed of a watercourse, or the harvesting of trees within 30 m of a wetland or the banks of a watercourse.
- Depositing or removing any material such as fill, sand, mud, gravel, rocks, debris, etc. from a watercourse or wetland or land located within 30 m of a watercourse or wetland.
- Draining, pumping, or otherwise taking water from a watercourse or wetland.
- Creating or altering a pond connected to a watercourse or wetland or that is within 30 m of a watercourse or a wetland.

Types of Permits:

The Department of the Environment and Local Government issues two types of Watercourse and Wetland Alteration Permits: the "Standard Permit" and the "Provisional Permit".

The *Standard Permit* applies to projects large enough to involve the design or investigation by a professional engineer. Examples of such projects would include bridges, dams or large culvert installations.

The *Provisional Permit* applies to smaller projects such as landscaping or vegetation removal.

How to Apply For a Permit:

When applying for a permit, it is necessary to describe the project. The description should include the project plan, location and how the work will be undertaken. Department staff will review the information and advise the applicant of the most appropriate manner for completion of the work ensuring minimal effect on the watercourse or wetland.

The permit application forms are available from any office of the Department of the Environment and Local Government and at all Service New Brunswick centres.

Assistance with completion of the application form is available from staff of the Department of the Environment and Local Government. In most cases it will be necessary to attach to the application form a map of the area and a sketch of the proposed work plan.

When Will The Permit Be Issued?

While a small job is likely to get prompt approval, more ambitious projects can take as long as two months. Some larger projects require consultation with other Departments such as the Department of Fisheries and Oceans, or the NB Department of Natural Resources.

How Is The Regulation Enforced?

The Department of the Environment and Local Government carries out periodic inspections of watercourse and wetland alteration work sites to ensure that only the work described in the Watercourse and Wetland Alteration Permit is being carried out, and that it is done in accordance with the conditions specified.

If the terms of the permit are not followed or if work is being done without a permit, the Minister of the Environment and Local Government may issue a stop work order and/or an order to remove or repair the work that has been done.

Finally, legal proceedings may be undertaken against anyone who violates the Act, the Regulation, or Ministerial orders. If convicted of an offence under this Regulation, an individual may be fined up to $50,000 where as the fine for corporations may be as high as $1,000,000.

Further Information:

Additional information or assistance can be obtained by contacting NBDELG Watercourse and Wetland Alteration Staff:

FREDERICTON
Phone: (506) 457-4850
Fax: (506) 453-6862

Civic Address:	Watercourse and Wetland Alteration Program 20 McGloin St. Fredericton, N.B. E3A 5T8
Postal Address:	P. O. Box 6000 Fredericton, N.B. E3B 5H1

http://www.gnb.ca/0009/0373/0001/0004-e.asp

3.4.2.2 Nova Scotia

Water Approval: Watercourse Alteration

Who Needs This Approval?

Any persons or persons who wish to use or alter a watercourse or a water resource or any natural body of water by:

a. Constructing or maintaining a culvert;
b. Constructing or maintaining a bridge which is in the watercourse, or using equipment closer than 3 m from the watercourse;
c. Constructing or maintaining a causeway, wharf, weir, fish way or other instream structure;
d. Removing material from a surface watercourse;
e. Diverting a water course from its natural channel;
f. Installing or maintaining fishing equipment, fishway, counting fence, fish habitat improvement structure, aquaculture cage or any similar structure in a watercourse;
g. Dredging or any other modification of a surface watercourse;
h. Installing or maintaining a pipeline, cable or other equipment in a surface watercourse;
i. Placing rock or other erosion protection material in a surface watercourse;
j. Any other alteration of a surface watercourse or the flow of the water.

An approval is not required for:

a. use of seawater;
b. use of brackish water from an intertidal zone of a river estuary;
c. maintenance of lands and structures incorporated by marsh bodies under the *Marshland Reclamation Act.*

Issuing Department / Agency: Nova Scotia Environment and Labour

Where can you get this approval and/or further information? Any Regional or District Office of Environment and Labour or at http://www.gov.ns.ca/enla/offloc.htm

OR

Head Office
Nova Scotia Environment and Labour
Phone: (902) 424-5300
Fax: (902) 424-0503
e-mail: ecs@gov.ns.ca

Office Location:
Terminal Road Building
5151 Terminal Road
5th Floor
Halifax, N.S.

Mailing Address:
P.O. Box 697
Halifax, N.S. B3J 2T8

Application Forms & Process:

You can get an application form for this Approval from any Regional or District Office of the Department. After it has been completed, it is submitted to the Department.

When the Department receives an application, staff reviews it to see if all the required information is on the form, and if the required supporting information has been provided. If not, the application package is returned with an explanation as to what is missing.

Once an application has been accepted by the Department as complete, the application form and supporting documentation undergo a technical review and evaluation. This is to decide if the activity being proposed meets the minimum standards, policies, guidelines, procedures and regulations that are administered by the Department.

Review by the Department of Fisheries and Oceans (Canada), Transport Canada, local authorities and community organizations may form part of the review process.

If an applicant fails to meet these criteria, staff will tell them which specific criteria have not been met to the satisfaction of the Department.

If an applicant meets all the criteria, the approval will be sent to the applicant by mail. This approval will list any terms and conditions that the applicant must satisfy.

Waiting Period: a maximum of 60 days, provided that all the items that must accompany the application have been received.

Expiry & Renewal:

This approval is valid until the expiry date included on the approval. It can be renewed. Note: it is the responsibility of the Approval holder to contact the Department before it expires; NO NOTICE of renewal will be sent out by the Department.

Price: $100. Although plans are underway to exempt restoration projects planned through recognized programs with trained staff.

Related Requirements:

Terms and conditions will be issued for each specific proposal and activity.

Other permits approvals that may be required:

a. *Navigable Waters Protection Act*, 1985, Transport Canada;
b. Use of Crown Lands; See http://www.gov.ns.ca/snsmr/paal/dnr/paal066.asp

Additional Information:

1) "Watercourse" means any creek, brook, stream, river, lake, pond, spring, lagoon or any other natural body of water, and includes all the water in it, and also the bed and the shore (whether there is actually any water in it or not). It also includes all groundwater.

2) "Water resource" means all fresh and salt (marine) waters, including all surface water, groundwater and coastal water.

Legislative Authority: Environment Act, Statutes of Nova Scotia, 1994-95, Chapter 1, http://www.gov.ns.ca/legislature/legc/statutes/envromnt.htm.

Nova Scotia government web site 2005 http://www.gov.ns.ca/snsmr/paal/enviro/paal181.asp

3.4.2.3 Prince Edward Island

Watercourse Alteration Permit

How do I obtain a permit for my Watercourse /Wetland Alteration Project?

All proponents must submit applications in time to complete the approval process prior to the initiation of the work. Applications for major projects scheduled for the instream work season should be submitted prior to June1rst. The applicant should allow a minimum of six weeks for a response either approving or rejecting the application; if the application is complete and sufficient detail has been provided no additional information is required.

The most common cause for delay is the lack of detailed information on the application in regard to the proposed alteration. The map showing the area of the proposed alteration can be a good quality photocopy. These can be obtained from your nearest Forestry or Access PEI site. You may also want to view and print an aerial photograph of the area. Enter the parcel identification number (PID) in the Address Locator and click on Show Address Details.

It is important that the exact location of the watercourse/wetland as well as the access route are accurately and clearly marked on this map as representatives from the Watercourse Alteration Advisory Committee may visit the site. A 1:50,000 topographic map is ideal for this purpose.

How much does it cost?

There is no charge to obtain a Watercourse/Wetland Alteration Permit with the exception of water withdrawal for irrigation purposes.

Forms

Applications for Watercourse Alteration Permits are available at all Access PEI locations.

Application for Watercourse or Wetland Alteration Permit:

http://www.gov.pe.ca/forms/pdf/548.pdf

http://www.gov.pe.ca/infopei/onelisting.php3?number=20117

3.5 SAFETY

Common safety precautions:

- Let a responsible person know where you are going and when you will be back.
- Advise the same person upon return.
- Carry a cell phone in a waterproof case and have emergency numbers and contacts both stored on the phone and in a waterproof book.
- Wear appropriate footwear and clothing for the terrain and weather. This is the Maritimes, so carry a change of clothes and extra clothing to stay dry and warm.
- Wear hunter orange clothing in all hunting seasons.
- If crossing private land, speak to the landowner and advise them of the works to be carried out and ask if there are any potential hazards.
- Power equipment (e.g. chain saws, electrofishers) must only be operated by trained people.
- For small power tools, read manufacturer's safety instructions.
- Take all necessary precautions with tools. Keep the surrounding area clear and the tools in good working order.
- Keep a first aid kit nearby and have at least two people trained in first aid on the work site.
- When traveling in the woods, carry a survival kit that will keep you warm, dry, and fed in case of getting lost or injured.
- Carry a map of the area and a compass and know how to use them. Even by following a river, but it is still easy to get disoriented. Travelling cross-country may be necessary to get out on time or in an emergency.
- Someone has to be in charge of the work site. It is that person's responsibility to ensure everyone knows what work is being done and the safety rules that apply. It is also their responsibility to ensure that the rules are followed.
- Each person on the project must know where the safety equipment is and how to get help.
- Doing instream work by machine can be dangerous and it often attracts onlookers. Go over the safety rules with a qualified machine operator and be sure everyone on site is aware of the safety procedures.
- Awareness and education. Take the time to meet with all the workers and discuss safety issues that they may have seen. Come to an agreement on the solutions.

4.0 INSTREAM TECHNIQUES FOR HABITAT RESTORATION

4.1 INSTREAM COVER

A) Half Logs / Instream Log Cover
B) Artificial Undercut Banks (Lunkers)
C) Rock or Boulder Groupings
D) Root Wads

4.1.1 DFO Fish Habitat Restoration Fact Sheet: Half Logs / Instream Log Cover

Purpose:

To provide instream cover for juvenile and adult fish.

Conditions Where Applicable:

- Use in streams where instream cover for juvenile and adult fish is limiting.
- Can be used in streams that are not prone to severe flooding and ice damage.
- Most suitable for medium to large streams (≥ 8 m or ≥ 25 ft).
- Avoid streams with a shifting sand bottom.
- Used in streams with solid substrate.

Habitats created:

- Cover for juveniles.
- Adult cover.
- Critical adult spawning cover.

Advantages:

- Can be installed as a permanent or temporary structure.
- Inexpensive and easy to install.
- Can be placed along side the bank or in open water.
- Can be constructed and dismantled very quickly.
- Can be adjusted with little effort for optimum success.

Disadvantages:

- If not set in correct stream conditions or location, usefulness is reduced.
- Not suitable in streams with wide fluctuations in flow.
- If not installed properly will catch debris.
- The structure may be damaged by ice.

Design Criteria:

- Must remain submerged to be effective.
- If to be used as permanent structure, then build and set in place during mid-summer to early fall.
- If built as temporary installation (i.e., to provide cover for spawning fish) can be assembled, dismantled, and stored on site.
- Materials include:
    - Temporary log/concrete block style - 30 cm (12 in) concrete blocks, galvanized fencing wire (any gauge from 12-16) and green logs to 15 cm (6 in) in diameter.

    - Half log wooden block style - log approximately 30 cm diameter, one to two meters long, cut in half lengthwise, wooden blocks approximately 30 cm diameter.
- Length of logs used is variable depending on availability and size of shelter to be built.
- In permanent sites set in place at the edge of the main current but angled (30°) to the main current flow. If this does not prove effective adjust angle or location as required.
- In temporary locations (e.g. for spawning fish) logs can be placed along stream bank or in mid-stream and installed parallel to main current.

Implementation steps:

1. Obtain logs. Strip off all bark after removing branches.
2. Evenly space three concrete blocks and lay four logs on top.
3. Allow the logs to overlap the edge of block.
4. Situate smallest logs to outside edge, and use configurations the same as the half log cover structures.
5. Use galvanized wire to lash logs in a crossover fashion to concrete blocks.
6. Staple the crossover points.
7. Move unit to desired position.
8. Pack rocks in a sloped fashion at the head of the uppermost block and at the rear of the lower block. This is done to stabilize and anchor unit.
9. Place several large, flattened rocks on the top to hold logs down until they lose their buoyancy.
10. If shifting is a problem, move unit or secure using T-bar fence posts driven between logs and into substrate.
11. For temporary installation the stone piling may not be necessary. When adult fish have left spawning area these units can be taken out of the water and stored until the next spawning season.

References**:**

Bastien-Daigle, S., A. Vromans, and M. MacLean. 1991. A Guide for Fish Habitat Improvement in New Brunswick. Fisheries and Oceans Canada. Canadian Technical Report of Fisheries and Aquatic Sciences. 1786E : iv + 109 p.

Ontario Ministry of Natural Resources. Community Fisheries Involvement Program: Field Manual.

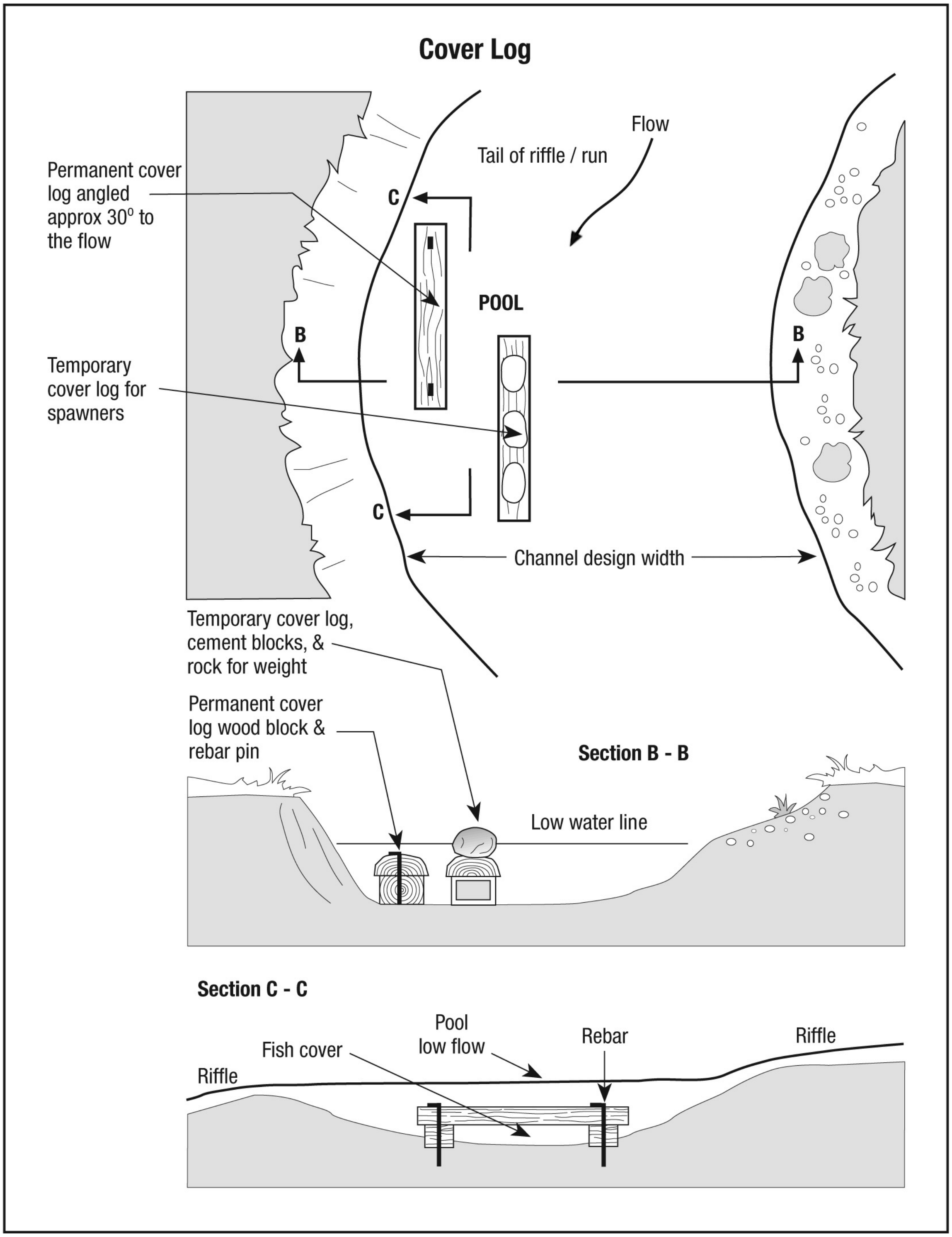

Figure 15. Conceptual drawings of temporary and permanent cover logs (Thaumas Environmental Consultants Ltd.).

4.1.2 DFO Fish Habitat Restoration Fact Sheet: Artificial Undercut Banks (or Lunkers)

Purpose:

- To provide hiding and escape cover for both juvenile and adult fish.

Conditions Where Applicable:

- In streams where cover may be limited for juvenile and adult fish.
- In streams of width greater than 10 m.
- In streams exhibiting low to moderate flooding.
- In streams where ice damage is not severe.

Habitats created:

- Juvenile and adult cover and overwinter areas.
- Adult cover during spawning.

Advantages:

- Provides an abundance of hiding places for fish.
- Can protect stream banks from further scour or erosion.
- Provides a good use for dead wood and stumps, if these are available nearby.

Disadvantages:

- Can catch debris and ice if not placed properly.
- May constrict flow and cause damage downstream.
- If not constructed properly may have a damming effect.
- May require annual maintenance.

Design Criteria:

- Build during the summer low flow period.
- The structure can be built along an eroding bank either on the outside of a bend or along a straight stretch where water depth is 0.3 m - 1.2 m (1- 4 ft).
- It can also be built out from a natural "dead water" bay along the shore.
    - The structure width can extend out to the edge of the current/eddy interface, but it should never extend into the main current more than ¼ of the way across the stream.
    - The structure should protrude no more than 30 cm (1 ft) above the water surface at the front, but slope up gradually to meet the bank behind.
    - No material should protrude out beyond the outer surface edge of the structure. This will help to maximize the fish-ability of the jam.
    - Both ends of the structure should taper into the stream bank to reduce collection of debris. Depending on the amount of flooding and erosion, both ends may require stabilization with riprap.

- Length of structure is variable depending on local conditions i.e., size of stream, flooding, availability of wood. Log jam structures of one hundred metres in length have been built.
- All dead wood logs and stumps must be readily available near the work site.
- A slight modification to this technique can be used to provide bank stabilization.
- In the absence of wooden logs and stumps, concrete slabs may be used for building the platform. The local DFO Area Office should be consulted before undertaking such work.

Implementation steps:

- Determine location. As mentioned above, the structure can be built along an eroding bank either on the outside bend, along a straight stretch of deep water, or built to fill in a backwater area (NOTE: the term eroding bank simply refers to the bank opposite to the silt depositing side and not necessarily to an active erosion site).
- If an existing natural debris jam is to be enhanced, then the following approach should be used:
  1. Add or remove material to obtain desired shape which conforms to design criteria.
  2. Spike green logs along outside edge of structure. Spikes are 20 - 25 cm (8 -10 in). Use larger dock spikes if they are necessary. Logs are placed slightly under the water surface, if possible.
  3. Logs must run parallel to the main current; then the structure is tapered at both ends and keyed into the stream bank.
  4. Remaining material on jam is spiked together forming a complete unit.
  5. In addition, posts can be dug into the substrate and spiked to the outer perimeter of logs for added stabilization and anchoring.
  6. If work is beginning at a location where there is not an existing debris collection area, then the following approach should be followed:
     a. Determine location conforming to design criteria.
     b. Outline area with stakes.
     c. Construct outer shell using green logs.
     d. Add stumps and logs as required and secure.
     e. If additional bank stabilization is required, more material is used along the bank to form a dense barrier to the current flow within the structure.

References:

Federal Interagency Stream Restoration Working Group (FISRWG). 1998. Stream corridor restoration: principles, processes and practices.

Ministry of Natural Resources of Ontario. Community fisheries involvement program: field manual.

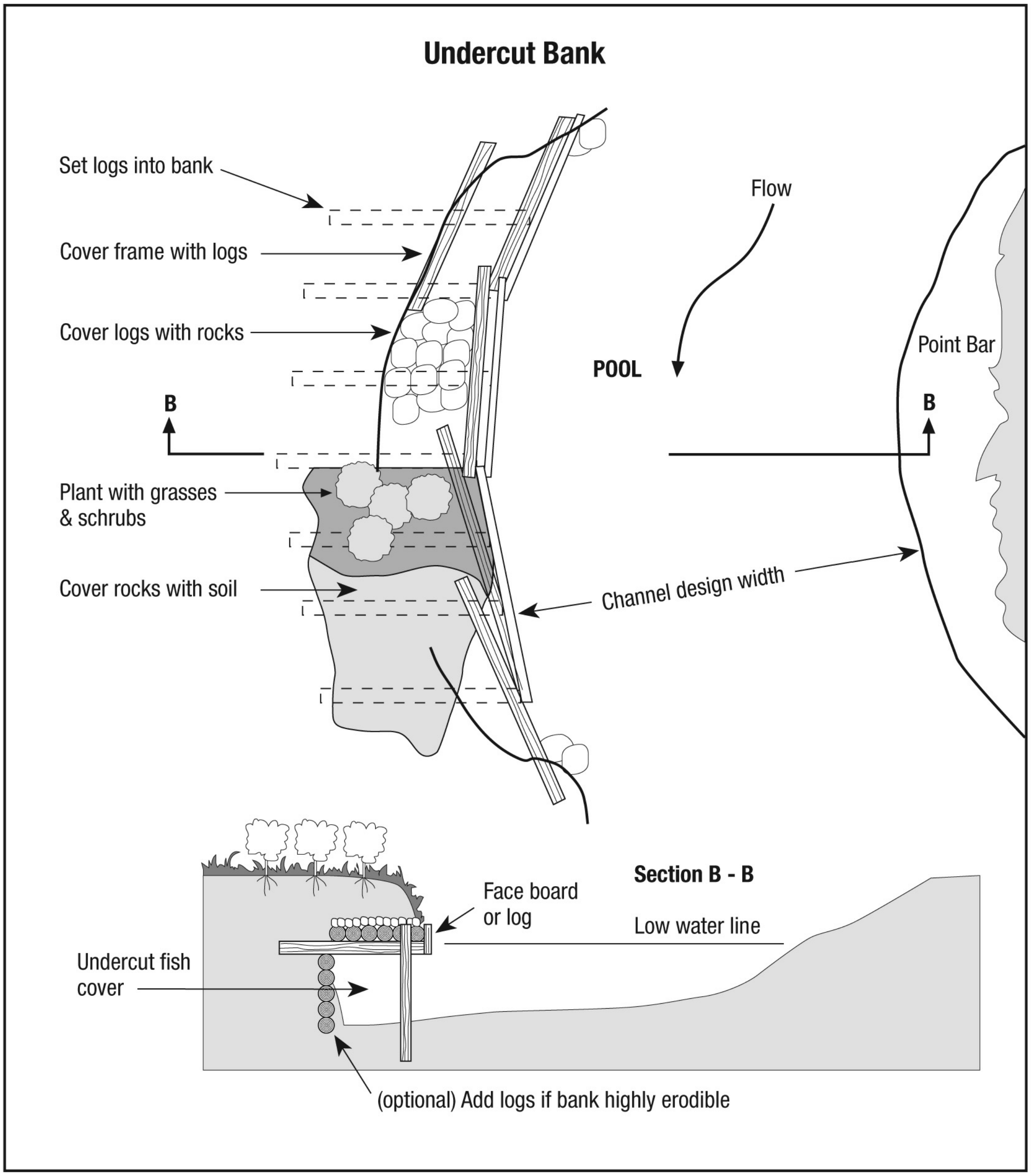

Figure 16. Conceptual drawing of an artificial undercut bank (Thaumas Environmental Consultants Ltd.).

4.1.3 DFO Fish Habitat Restoration Fact Sheet: Rock or Boulder Groupings

Purpose:

- To provide overhead and lateral cover.
- To break up uniform currents to help break up and dislodge sands and silts.
- To provide resting areas for feeding salmonids.
- To increase the scour in pools.

Conditions where applicable:

- This technique is for streams with low to moderate gradients and where pools and riffles are relatively equal.
- In riffle areas, small boulders can be placed on cobble gravel riffles which lack suitable resting areas for salmon parr.
- In deep runs, boulders can be placed to create resting areas for salmon and trout.
- In pools, larger boulders can be placed to aid in scouring sediments and to provide cover.
- Boulders can be placed along the bank to create quiet areas for fry.

Habitats created:

- Fry and juvenile cover.
- Adult holding sites.
- Removes silt and sand from substrates and improves insect habitats.
- Digs pools for summer and winter low flow refuges.

Advantages:

- They look natural.
- Increase available cover habitat for fish.
- Scour sediments sorting out the fines and improving insect and juvenile habitats.

Disadvantages:

- High costs if boulders need to be transported.
- Placement is labour intensive.
- Large boulders require machinery.
- Boulders placed near banks can cause scouring. Placement of the boulders is very important.
- Rocks are often oversized and can cause the change in the natural pool riffle pattern by placing a pool out of sequence.
- Boulders may become buried over time.

Design criteria:

- Assess the habitat and the need for the structures. This should be done by experienced biologists.
- Map out the section to be improved, detailing the depths and main current.
- Boulders are generally placed in or near the thalweg if they are used for parr and adult cover.
- Do not obstruct more than 20 % of the stream at any point.
- Boulder size depends on the size of the stream and application. Typical sizes range from 30 cm to 90 cm.
- Angular boulders are preferred.
- In pools, a cluster of three or four boulders works well.
- Works should be carried out during mid-summer low flows.
- Avoid using boulders in streams prone to ice scour and severe flooding.

Implementation steps:

- Obtain landowner permission before collecting field stone or crossing their land with the rock.
- Have the boulders transported to the project site and stockpiled near the river.
- Finalize patterns and locations for rock placement.
- Begin placing the boulders at the downstream end of the project and work upstream.
- Larger boulders can be carried on a rock stretcher.
- Place boulders on a substrate relatively free of larger rock and set them securely into the stream bed.

Riffle areas:

- This technique is seldom used in Maritime streams because the riffles normally armour themselves with suitable size cobble and small boulders to act as cover for salmon parr.
- Boulders should be 25 to 35 cm in diameter.
- Boulders are placed in the thalweg in a staggered fashion approximately 1 m apart.

Deep runs and pools:

- Boulders up to 90 cm in diameter.
- In a deep run, they are sized so that the top of the boulder is at the surface of the water in low flow and set in the thalweg approximately 2 m apart.
- In pools, boulders up to 2 m in diameter can be set in clusters of three or four in the thalweg.

Fry habitat:

- The intent is to create pockets of dead water along the outside edge of pools.
- This technique should only be used in rivers with 50 % or greater pools or on still waters.
- Place a large boulder (up to 60 cm) along the outer edge of the flow so that it is just breaking the water surface in low flow. Boulders are placed one boulder diameter apart.

References:

Ministry of Natural Resources of Ontario. Community fisheries involvement program: field manual.

Bastien-Daigle, S., A. Vromans, and M. MacLean. 1991. A guide for fish habitat improvement in New Brunswick. Fisheries and Oceans Canada. Canadian technical report of Fisheries and Aquatic Sciences. 1786E: iv + 109 p.

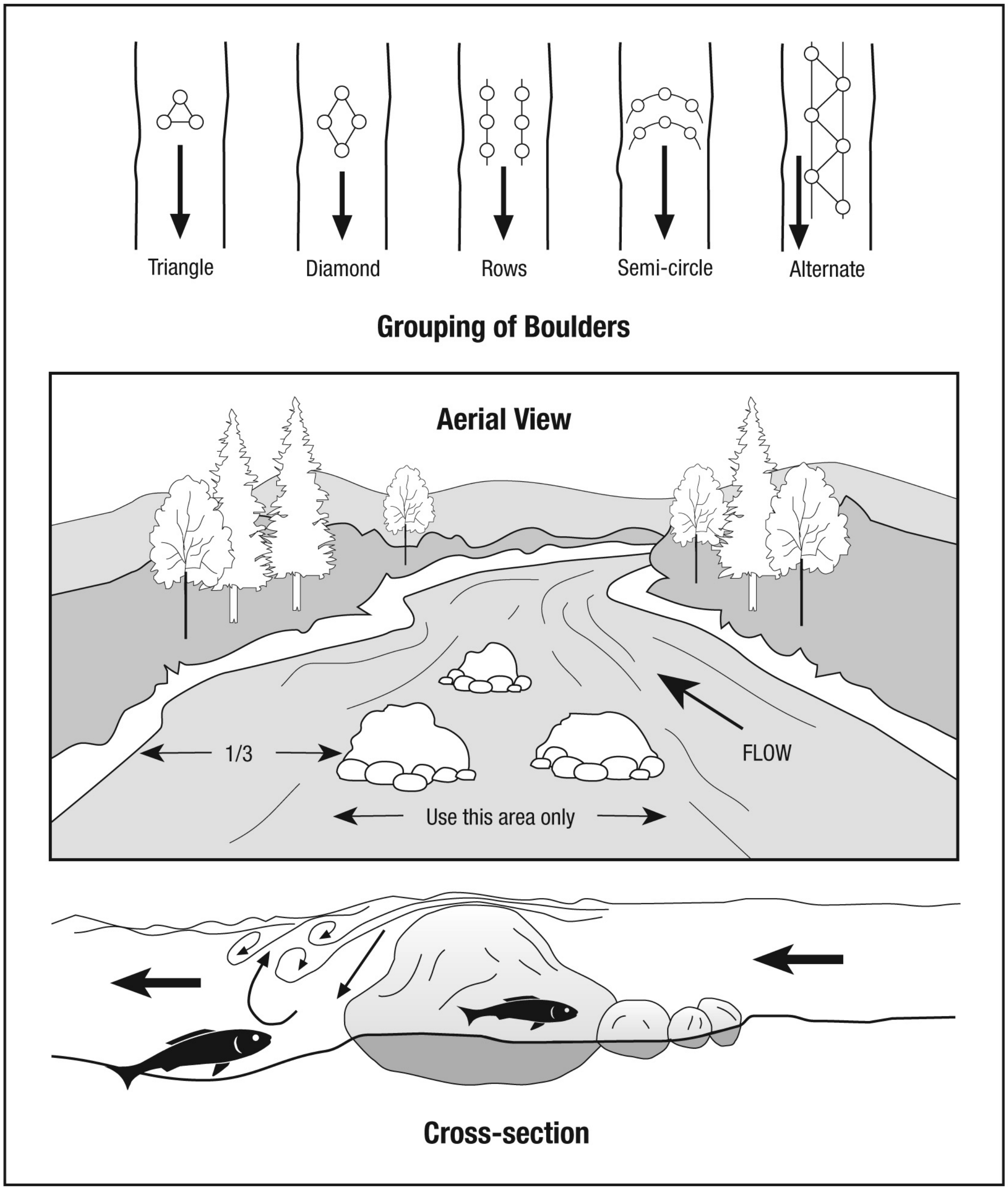

Figure 17. Conceptual drawings of boulder clusters (DFO, 1991).

4.1.4 <u>DFO Fish Habitat Restoration Fact Sheet: Root Wads</u>

Purpose:

- To stabilize eroding banks and provide instream cover.

Conditions were applicable:

- On the outside of pools where there is a high eroding bank.
- Pools lacking cover.

Habitats created:

- Instream cover.
- Bank stabilization and reduced siltation.

Advantages:

- Will tolerate high water velocities if the root wads are well anchored.
- Use of native materials can sequester sediment and woody debris, restore stream banks in high velocity streams, and improve fish rearing and spawning habitat.
- Some species, such as willow, often sprout and accelerate colonization.

Disadvantages:

- Structure may have limited life, depending on gravel movement and ice scour.
- Structure might need eventual replacement if vegetation does not grow or soil bioengineering systems are not used.
- Site must be accessible to heavy equipment.
- Materials might not be readily available at some locations.
- Can create local scour and erosion.
- Can be expensive.

Design criteria:

- Have the work designed by a habitat restoration biologist.
- Where appropriate, root wads should be used with soil bioengineering systems and vegetative plantings to stabilize the upper bank and ensure a regenerative source of stream bank vegetation.
- Trees with root wads should be sized according to the stream and bank height.
- Success depends on anchoring the trees well at both ends and causing a minimum of damage to the banks.

Implementation steps:

- A typical site would use trees with 2 m diameter root wads, trees 6 to 9 m long.

- The tree is buried in the bank or driven into the bank so that the base of the root wad faces the current.
- Space the logs so that the root wad touches the trunk of the log upstream from it.
- Anchor the logs using cable and a dead man's log or a drivable anchor.

References:

British Columbia Ministry of Environment, Lands, and Parks and Ministry of Forestry. Fish habitat rehabilitation procedures, watershed restoration Technical Bulletin No. 9, 1997.

Federal Interagency Stream Restoration Working Group (FISRWG). 1998. Stream Corridor Restoration: Principles, Processes and Practices for Details on Root Wads.

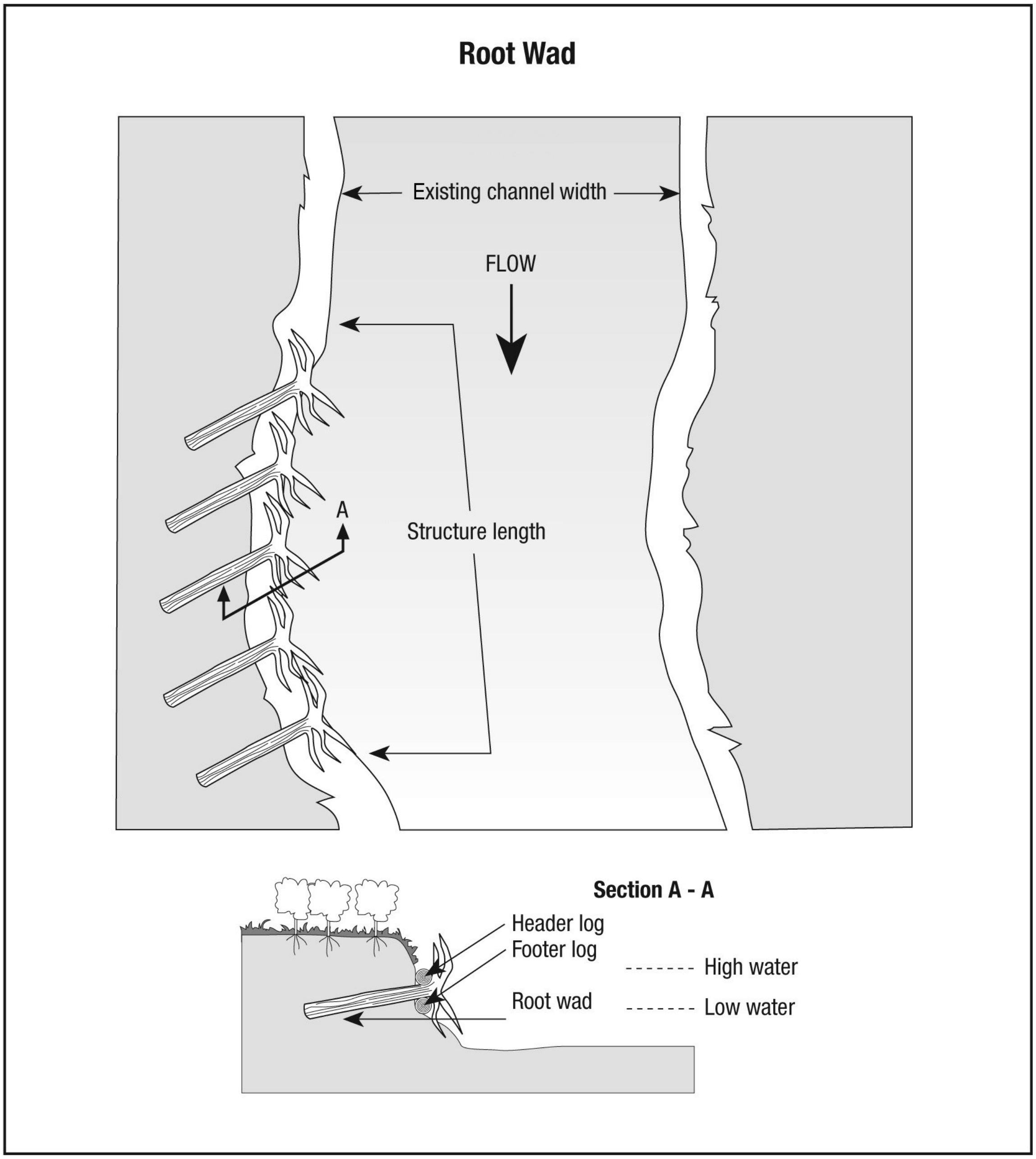

Figure 18. Conceptual drawing of root wads (Thaumas Environmental Consultants Ltd.).

4.2 BANK STABILIZATION

A) Rock Riprap
B) Kickers
C) Log Riprap
D) Combination of Riprap and Vegetation
E) Planting of Streamside Vegetation
F) Tree Revetments
G) Brush Mats (Sediment Traps)
H) Brush Bundles (Fascines or Wattles) and Brush Mattresses
I) Fence Posts

4.2.1 DFO Fish Habitat Restoration Fact Sheet: Rock Riprap

Purpose:

- To provide stream bank erosion control in serious to extreme conditions.
- To provide additional fish habitat.

Conditions Where Applicable:

- Where high water, ice, or groundwater seepage has caused excessive erosion damage to stream banks and stream bends. Angular rocks of a selected size range are placed in a "knitted" fashion or fitted snugly on the bank to achieve maximum strength and durability.
- This technique is useful in areas where water velocities do not exceed 4 m/s (12.4 ft/s) at flood stage and/or where submergence lasts continuously for more than a few days.

Habitats created:

- Reduced siltation of habitats.

Advantages:

- Rock tolerates some lateral seepage.
- The rock's rough surface tends to reduce water velocities thus dissipating the stream's erosion energy force and minimizing the erosion problem.
- The riprap barrier is flexible and adjusts to minor shifts and movement of the bank.
- Immediate protection is provided.
- It improves instream cover habitat for juvenile and adult fish.
- In the long term it acquires a natural appearance, especially after being planted or colonized with vegetation.
- Easy to apply and repairs are generally made quickly but seldom required.

Disadvantages:

- Access to site for heavy machinery may be difficult.
- Installation costs can be high for large-scale projects. Installation usually requires a backhoe or excavator for grading and placing of larger material.
- If the rocked bank is not long enough and is not "placed" in properly at the upstream and downstream ends or the toe of the bank, the erosion problem can be shifted upstream or downstream. If not properly "placed" into the streambed, the structure can be undermined and failure expected.
- In the short term riprap often looks unnatural until colonized by plants.
- Provides a “hardened” bank and limits growth of vegetation.
- It may interfere with the natural, lateral movement of the stream.

Design Criteria:

- Rock should be placed on a well-graded slope no steeper than 2:1. The grade of the slope is determined by the site's soil conditions.
- The type of rock used depends on local availability (quarried stone including shot rock, field stone, rubble, glacial till). Angular material is preferred over round, washed, glacial till. Avoid shales and other "soft" rocks as they can break up with the ice.
- The rock size is a function of several variables including stream flow velocity. Rock size is determined by an engineer or other qualified person during the design stage. Water velocities greater than 3.5 m/s (10.9 ft/s) require a more extensive design.
- Riprap is generally applied at a thickness of at least 1.5 times the maximum stone size and not less than 30 cm (12 in) thick.
- Failure of the structure can result from improper grading, rock size, length of structure, installation methods, and failing to "tie" the structure into the bank at a critical location. Critical locations include the bank toe and upstream and downstream ends of the structure. An experienced backhoe operator is a great asset in combating these problems.
- Extend riprap to the top of the bank or at least 0.6 m (1.9 ft) above the high flow level. This is variable depending on the river.
- The largest rocks are fitted (keyed) into the bank toe and upstream and downstream ends. The ends of the project must taper into the bank. Fitting the rock into the bank toe will require the use of a backhoe to either push the rock into a soft substrate or dig into a hard substrate to fit rock beneath the stream bed.
- Any displaced rock should be repaired immediately.
- Design for peak flow period.
- Construct during low flow period.
- The ability of riprap to withstand the erosive forces depends on the inter-relation of a number of variables. As conditions vary considerably from watershed to watershed and site to site, this technique should not be attempted without the prior approval and assistance from a professional engineer or other qualified person.
- In addition, rock can be used as a stream channel narrowing technique. In this case the only grading required is to remove the crown (overhang) from the bank. Enough rock is placed on the bank to achieve the necessary grade. If a stream bed has been damaged by cattle trampling, instream machine work, ice or debris jamming or similar events, with the result that the channel has widened by two or three times its natural width, rock can be added to both sides of the stream to create a new mini floodplain and narrower stream channel.

Implementation Steps:

- These are only suggested steps and may be modified.
- Prepare the site.
- Clear area of debris.
- Grade banks to the recommended slope.
- Dig out the toe trench.
- Install any seepage drains required.
- Place the riprap.

- Riprap can be placed by hand or by machine. Riprap should be placed to its full thickness in one operation.
- If rock is placed under water the riprap thickness should be increased 50 % over that above water.
- Blend or "feather" the ends of the riprap section into the upstream and downstream banks.
- A vegetative cover should be established on any areas that were graded but not covered with riprap.

References:

DFO Gulf Region Culvert Guidelines.

Ministry of Natural Resources of Ontario entitled the “Community Fisheries Involvement Program: Field Manual”.

Federal Interagency Stream Restoration Working Group (FISRWG). 1998. Stream Corridor Restoration: Principles, Processes and Practices.

4.2.2 DFO Fish Habitat Restoration Fact Sheet: Kickers

Purpose:

- To stabilize eroding stream banks.
- To protect property or to prevent damage.
- To create cover for fish.

Conditions Where Applicable:

- In low to moderate gradient stream reaches (up to 2%).
- In larger streams or rivers (> 8 m wide).
- In streams where flooding is light or moderate.
- In streams where ice damage is not a potential hazard.
- Avoid streams that exhibit a shifting substrate or hard rock rubble substrate.
- Should be used in combination with bank riprap.

Habitats Created:

- Fish cover immediately downstream of the boulders.

Advantages:

- It improves instream cover habitat for juvenile and adult fish.
- Reduces the potential for bank erosion, for part of the water is redirected into the thalweg.
- Little maintenance is required.

Disadvantages:

- Access to site for heavy machinery may be difficult, as the installation usually requires a backhoe or excavator for grading and placing of larger material.
- Provides a "hardened" bank and limits growth of vegetation.
- It may interfere with the natural, lateral movement of the stream.

Design Criteria:

- The type of rock used depends on local availability (quarried stone including shot rock, field stone, rubble, glacial till). Angular material is preferred over round washed glacial till. Avoid shales and other "soft" rocks as they can break up with the ice.
- The rock size is a function of several variables including stream flow velocity. Rock size is determined by an engineer or other qualified person during the design stage. Water velocities greater than 3.5 m/s (10.9 ft/s) require a more extensive design.
- Failure of the structure can result from improper grading, rock size, length of structure, installation methods, and failing to "tie" the structure into the riprap on the bank at a critical location. Critical locations include the bank toe, and upstream and downstream

ends of the structure. An experienced backhoe operator is a great asset in combating these problems.

- Extend riprap to the top of the bank or at least 0.6 m (1.9 ft) above the high flow level. This is variable depending on the river.
- Fitting the rock into the stream bed will require the use of a backhoe to either push the rock into a soft substrate or dig into a hard substrate to fit rock beneath the stream bed.
- Any displaced rock should be repaired immediately.
- Design for peak flow period.
- Construct during low flow period.
- The ability of riprap to withstand the erosive forces depends on the inter-relation of a number of variables. As conditions vary considerably from watershed to watershed and site to site, this technique should not be attempted without the prior approval and assistance from a professional engineer or other qualified person.

Implementation Steps:

- These are only suggested steps and may be modified.
- Prepare the site.
- Clear area of debris.
- Grade banks to the recommended slope.
- Dig out the toe trench.
- Place the riprap.
- Riprap can be placed by hand or by machine. Riprap should be placed to its full thickness in one operation.
- If rock is placed under water the riprap thickness should be increased 50 % over that above water.
- Blend or "feather" the ends of the kicker into the upstream and downstream banks.
- A vegetative cover should be established on any areas that were graded but not covered with riprap.

References:

Charles MacInnis and Danielle Goff, DFO Antigonish area office. Personal communication.

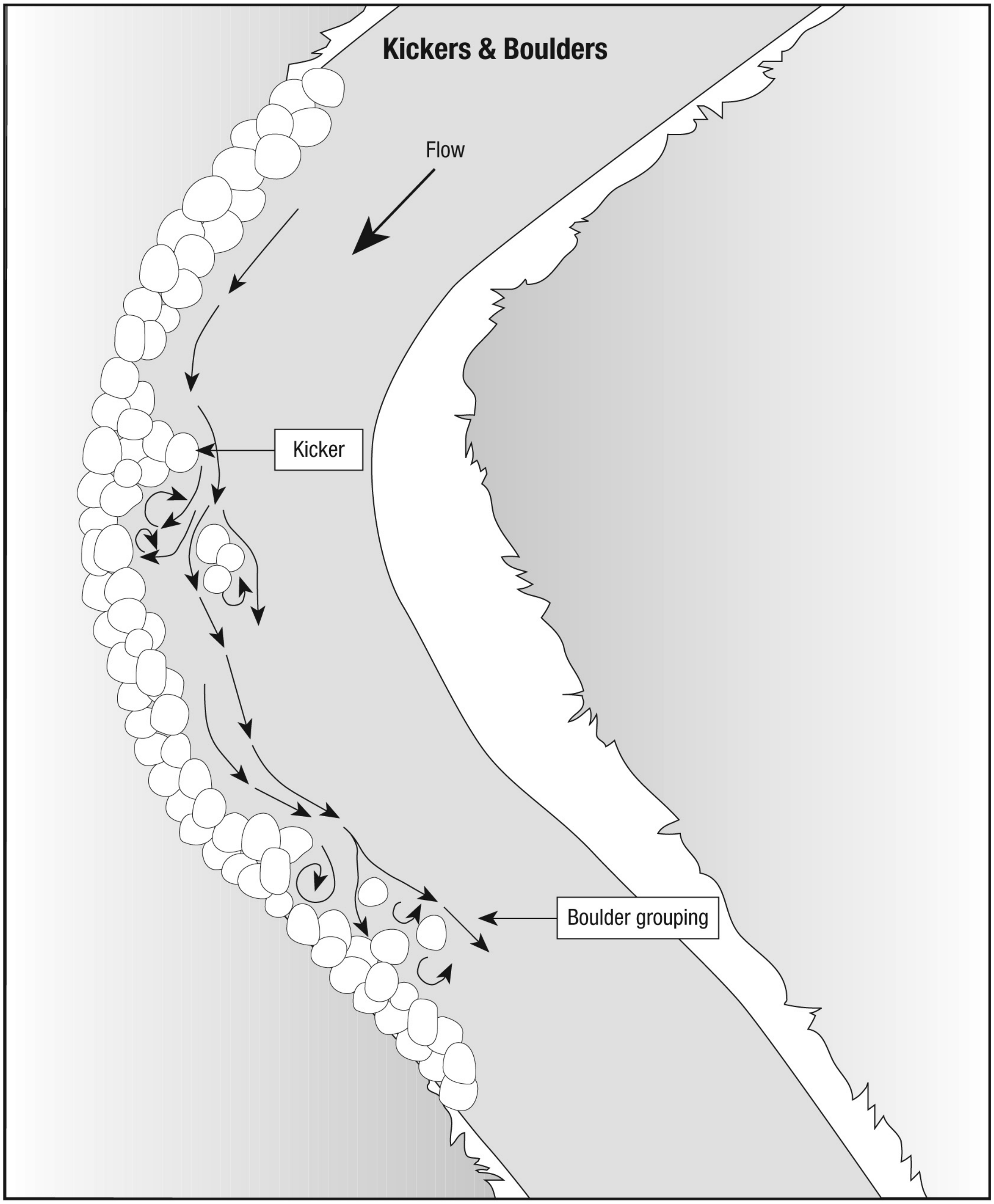

Figure 19. Conceptual drawing of kickers and boulders used to create instream cover and to reduce bank erosion (DFO, 2005).

4.2.3 DFO Fish Habitat Restoration Fact Sheet: Log Riprap

Purpose:

- To stabilize eroding stream banks.
- To narrow stream width.
- To create additional fish habitat.

Conditions Where Applicable:

- In low to moderate gradient stream reaches (up to 2%).
- In streams less than 15 m. (50 ft) wide.
- In streams where flooding is light or moderate.
- In streams where ice damage is not a potential hazard.
- Avoid streams that exhibit a shifting substrate or hard rock rubble substrate.
- Banks to be stabilized should not be more than 1.0 m (3.1 ft) in height.

Habitats created:

- Reduced siltation of habitats.

Advantages:

- Stabilizes moderately eroding banks.
- Uses natural materials. The cost of materials is low and the structure blends into the natural setting.
- The logs have uneven surfaces that provide hiding cover locations for fish.

Disadvantages:

- Building the structure is labour intensive.
- The structure has general application to streams less than 15 m (50 ft) wide.
- Does not work well in streams that have wide fluctuations in water level.
- Life expectancy of structures is relatively short compared to rock riprap.
- Annual maintenance (spring & fall) may be required.
- Wood might not be readily available at site.

Design Criteria:

- This technique can be used to stabilize an eroding stream bank or to narrow the stream width. In the case of the former, a log wall is built up to the height of the eroding bank. In the case of the latter, the profile of the structure is kept low so that freshets can easily overtop the structure - the structure acts like a deflector.
- Build along an eroding bank where water depth is 0.3 - 1.0 m (1 - 3.1 ft). The eroding bank can be along a straight stretch or an outer bend.

- The structure width should extend out to the edge of the current but not more than 150 cm (60 in) from the toe of the eroding bank. Do not narrow the stream to less than its 1:2 year flood flow or natural width.
- Use logs 15 - 35 cm (6 - 14 in) in diameter if available at the site, preferably wood that would be slow to rot.
- Determine the amount of material suitable for the project. The structure needs enough logs to stretch the entire length of the erosion site and enough to stack up to the original height of the bank. This wall is usually one layer thick.
- Slope backfilled area gradually into stream bank. This will allow water to overtop the cribbing during flood periods. The profile of the structure must be kept low.
- Use heavy duty 3.3 m (7 ft) (minimum length) T-bars or metal posts as main supports (NOTE: if metal posts are used, a hole must be drilled 10 cm (4 in) from top to secure wire).
- Shorter wooden or metal stakes, approximately 40 cm (16 in.), are used on the old bank to help secure the structure.
- Use heavy duty galvanized fencing wire (9-16 gauge) for lashing materials.
- For backfilling structure, brush, stumps, rotten wood, or gravel should be used.
- Wooden bundles can be created using branches and small logs; wired or tied with bailer twine. The bundles should be approximately 1.0-1.5 m (3.3 - 5.0 ft) long and 30 cm (12 in.) in diameter.
- Until experience is gained, work should only be attempted on sections less than 20 m (66 ft) in length.
- The timing of this technique may not be critical since actual instream work is minimal. However, this type of work is ideally suited during mid-summer when stream flows are low.

Implementation Steps:

- Determine location.
- Stake the line of the current with temporary wooden stakes to mark the outside edge of the new bank. The line of the current can be determined visually by standing upstream of the planned devices. It is important that this be located with some accuracy as it is essential that the current, if possible, run swiftly along the edge of the outside logs. Be careful not to narrow the stream to less than the natural bank width. You may need some expert help to determine the placing of the structure.
- Stockpile necessary materials at the site.
- Begin work at the upstream portion of the structure.
- Using a sledge or pile driver, drive a line of metal fence posts into the streambed at 1.0 - 1.5 m (3.3 - 5.0 ft) intervals so that they lean into the current at about a 10-degree angle and lean out slightly. This prevents the buoyancy of the logs lifting the stakes out of the water during the spring runoff. The metal stakes should be located along the line marked by the temporary stakes that can be removed after all the metal posts are in place.
- Use heavy gauge fence wire to lash a line of logs to the metal posts and form a wall. It is important that these be located right on the stream bed, not on silt or mud which should be removed, exposing the underlying gravel before the logs are moved into place. Wire should be placed around the logs and posts in a figure "8" fashion.

- Repeat the above procedure building up successive rows of logs to within 10 cm (4 in.) of the top of the metal posts.
- The structure can be strengthened by driving a second row of stakes on the bank side of the horizontal logs in areas where the spring runoff is fierce   Do not use poplar logs because beavers love to eat them. These should be wired to the outside line of metal posts by pushing the wire through the gaps provided by irregularities in the horizontal logs.
- Backfill the space between the log wall and the old bank to within about 15 cm (6 in.) of the top of the metal posts. This is a good way of getting rid of bank-side debris (brush, stumps, rotten wood, turf, rocks, etc). Compact the mixture by jumping up and down on it, and put the heaviest items of fill on top to keep everything down.
- Drive a series of stakes (wood or metal) in an offset pattern to the main stakes at a distance of 50 - 100 cm (1.8 - 3.1 ft) back from the edge of the old bank at an angle back from the stream. Dig a shallow trench to eventually bury the wire. Wire these to the outside line of metal stakes with double strands of heavy gauge fence wire. A crossover pattern of wire wrapping is suggested. Tighten the whole structure by inserting a stick between the strands of wire and twisting.
- Complete the backfilling with turf and bundles of brush to cover the bracing wire. About 10 cm (4 in.) of the outside metal posts should be left exposed.
- Properly constructed wooden devices such as these can last for years in low gradient streams. Moreover, if strong-rooted wood shrubs (red-osier dogwood, bank willows) are planted immediately behind the streamside logs, the root systems will grow to form a solid mat which, even if the logs should rot, will provide a firm and permanent bank.

References:

Ministry of Natural Resources of Ontario, entitled "Community Fisheries Involvement Program: Field Manual". 1982.

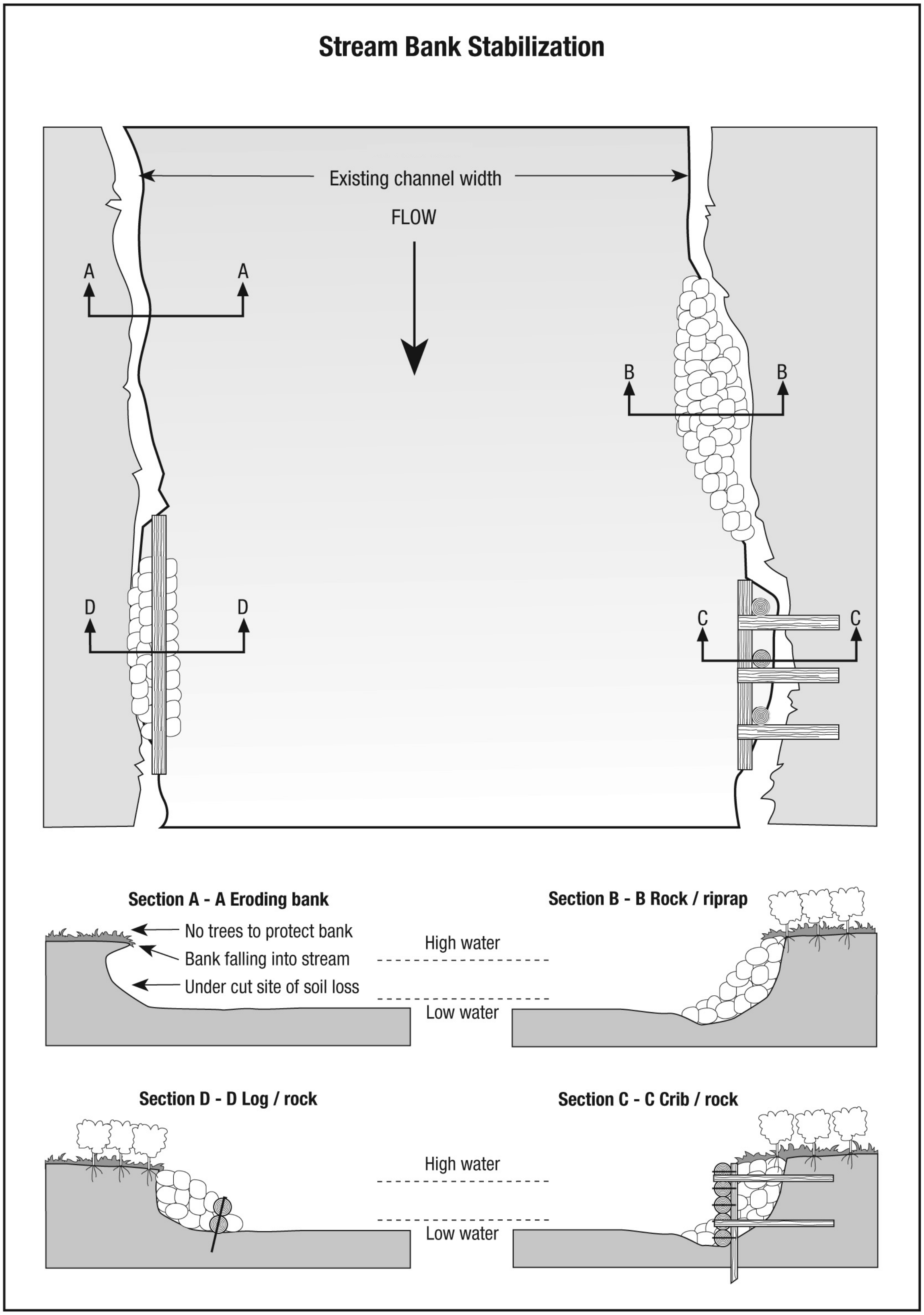

Figure 20. Conceptual drawings of several types of stream bank stabilization techniques.

4.2.4 DFO Fish Habitat Restoration Fact Sheet: Combination of Riprap and Vegetation

Purpose:

- To stabilize banks and further improve habitat by providing shade, cover, and leaf fall.

Conditions where applicable:

- Where erosive forces are too strong for vegetative methods alone.

Advantages:

- Improves bank protection by forming a root mat under the rock.
- Increases deposition of sediments.
- Little maintenance.
- Improved aesthetics.

Disadvantages:

- Cuttings can be damaged by the rock placement.
- Cuttings have to be driven well into the soil.

Design criteria:

- Design the bank as described in the riprap bank stabilization fact sheet.
- Plant live stakes of shrubs in the soil under the rocks so that the stake protrudes between the rocks.
- Planting can be done during or after placing riprap on the banks.
- Fascines can be planted in the rock work as it is being built.
- Care must be taken to avoid damaging the plants when placing the rock.
- The toe of the bank can be covered with riprap up to the ordinary high water level and vegetative methods can be used on the bank above the rock.
- These methods can be adapted for use with any of the constructed bank stabilization methods.

Implementation steps:

- Implement the work as outlined on bank stabilization fact sheet for riprap.
- Construct the toe of the riprap to the low water mark.
- Plant shrubs, stakes, and fascines in the soil and riprap around them.
- If the layer of riprap is not too thick, it is possible to drive the stakes or live posts between the rocks and well into the soil.

References:

Federal Interagency Stream Restoration Working Group (FISRWG). 1998. Stream Corridor Restoration: Principles, Processes and Practices.

British Columbia Ministry of Environment, Lands, and Parks and Ministry of Forestry. 1997. Fish Habitat Rehabilitation Procedures, Watershed Restoration Technical Bulletin No. 9.

Schiechtl, Hugo. 1980. Bioengineering for Land Reclamation and Conservation. University of Alberta Press.

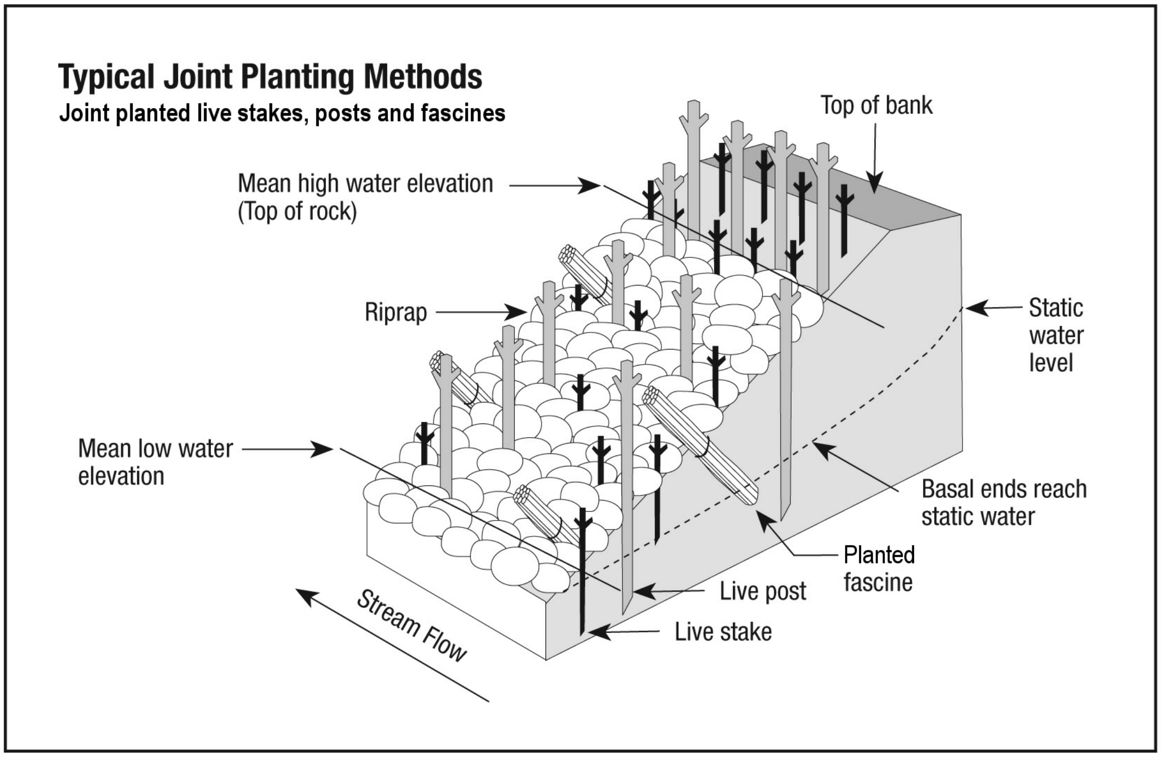

Figure 21. Conceptual drawing of joint plantings to reduce stream bank erosion (B.C. Ministry of Environment, Lands, and Parks and Ministry of Forestry, 1997).

4.2.5 DFO Fish Habitat Restoration Fact Sheet: Planting Streamside Vegetation

Purpose:

- To stabilize stream banks, reducing erosion and resulting sediment deposition.
- To regulate stream flow. For example, in winter, tree cover (forest or buffer strip) reduces the penetration of frost, retains surface snow for a longer period and allows for a slow spring melt. During the summer, in the headwater areas, trees allow for rain water to seep into the ground for storage, and then to be released slowly to maintain a steady summer stream flow.
- To provide stream quality conditions that are favourable to various fish species.
- To provide aesthetically pleasing vegetative cover.
- To provide conditions for attracting certain wildlife and insect species.

Conditions Where Applicable:

- Where streamside vegetation has been removed by human activities (e.g. agriculture, logging, & urbanization).
- Where trampling of stream banks by livestock is severe.
- Where stream water quality is being impaired because of the removal of the streamside vegetation. For example, water temperatures may be too high to support certain fish species; or sediment and contaminants may be entering the watercourse because of the lack of a buffer strip to filter out the eroded soil particles and associated contaminants.
- In some cases, all that is needed is to erect a fence. A fence will protect the bank from being trampled by livestock, vehicles or pedestrian traffic. A protected stream bank will soon allow the natural vegetation in the area to become established.

Habitats Created:

- Provides stable banks to reduce siltation.
- Provides shade.
- Provides leaf litter and food source for instream insects.

Advantages:

- Improve the aesthetics of the streamside.
- Attracts wildlife and insects species that provide food for fish.
- Can control erosion and may reduce flooding.
- One of the most economical and most effective means of soil stabilization.
- A good grass cover can be expected in the first year and will be well established in two or three years.

Disadvantages:

- Restricts other land use possibilities. For example, it may take some land out of agricultural production.

- It may attract certain undesirable weed species.
- Summer and late fall germination of certain seed varieties may be difficult.
- Some maintenance such as mowing and/or occasional removal of woody vegetation (e.g. alders) may be required.

Design Criteria:

- Seed growth is partially dependent on slope and soil conditions of stream banks.
- Streamside vegetation should consist of a mixture of grasses, shrubs and trees. In many instances it may be desirable to have a zone of grass and shrubs close to the stream edge and trees planted further back from the bank.
- In areas where you want to establish ground cover, plant a mixture of grasses and legumes close to the stream edge.
- In areas where you want to establish shade as well as bank cover, plant shrubs and trees.
- Consider native species that thrive under local conditions. It may be necessary to examine the site first to determine what vegetation is present.
- Dense stream bank vegetation is not always desirable. You may want to provide open areas for light penetration so that ground cover becomes established and fish-ability of the stream is improved.
- Consider soil types, drainage conditions, high water levels, and wind and sun direction before selecting the species for planting. Plants require proper conditions to become established and grow. It may be necessary to seek professional advice from a biologist, community advisor, or district forester.
- The best time for planting is generally the early spring after frost. Fall planting can be done successfully only in light, open soils, when planting stock have dropped their leaves.

Soil Preparation and Mulch:

- Plants need soil to grow. This might seem obvious but many restoration projects plant grasses and bushes in mineral soil without adequate drainage, organic content, or nutrients. If the topsoil is gone from the site, you will have to do proper soil conditioning will have to be done if the plantings are to survive.
- It is not likely that the planted grass, shrubs and trees will be watered as they would be in a garden. Hence, it is important to plant during seasons with regular rainfall and mulch around the shrubs and trees to preserve soil moisture. Grasses may need a light mulching with hay or straw to keep the rain from eroding the soil and seeds and to keep soil moisture.

Design steps:

- The stream bank should be at a stable slope; if not, it may be necessary to grade the bank or stabilize it using rock riprap, log riprap or another structure.
- The species to be planted should be chosen carefully.

1. Grasses and Legumes: Plant a mixture of grasses and legumes. Legumes supply nitrogen to the soil and consequently enhance the establishment of the plantings. Legumes to consider are birdsfoot trefoil (*Lotus corniculatus*), or crownvetch (*Coronilla varia*). Both of these species have a long life and are adapted to a wide range of soils and moisture. Crownvetch, however, does best in dry to well-drained areas. Grasses to consider with the legumes are creeping red fescue (*Festuca rubra*) or tall fescue (*Festuca arundinacea*). Soil and moisture conditions may dictate the use of other grasses or legumes. Seed mixtures called "Highway mix" or "Conservation mix" are good combinations to use in the Maritimes. Most seed suppliers can advise on mixtures to use on the soil type of the area to be planted.

2. Shrubs: An ideal shrub is red osier dogwood (*Cornus stolonifera*). This small shrub (approximately 1.8 m; 6 ft. high) is well suited to stream banks as it grows best in moist soils and spreads by producing runners or stolons. Other shrubs to consider are rugosa rose (*Rosa rugosa*), multiflora rose (*Rosa multiflora*), highbush cranberry (*Viburnam trilobum*) and speckled alder (*Alnus rugosa*). Several willow shrub species could also be considered. Most shrub species (especially speckled alder) require cutting back every third or fourth year for maintenance management to improve low and dense growth characteristics. Avoid planting large tree growing species. Large tree species tend to transpire large quantities of water.

On less fertile or sandy soils, plant autumn olive (*Elaeagnus umbellata*). This medium shrub (2.4 - 4.2 m; 8 - 14 ft. in height) is well suited to stream banks as it quickly lays down a protective layer of litter. On steep slopes, plant rugosa roses. This shrub (2 - 3 m; 6 - 10 ft. in height) is a good erosion control plant because of its dense growth, ability to grow on bare soil and thicket-forming abilities. It grows best on protected, south facing slopes. Well back on the stream bank, plant highbush cranberry. Highbush cranberry is a tall shrub (2.4 - 3.6 m; 8 - 12 ft.) and grows best in well-drained fertile soils or in wetter soils if the soil is fertile. Select species that can be found growing locally in similar locations.

3. Trees: Most native tree species can be used. As a general rule plant deciduous (hardwood) species on north slope (south facing) and east slope (west facing) and conifer (softwood) species on the south slope (north facing) and west slope (east facing). It is necessary to plan in advance. Many shrubs and tree species are only available at certain times of the year and need to be ordered in advance, particularly if a large site is being planted. Also, the best time for planting is early spring as soon as the frost is out of the ground. It is also necessary to prepare the site for planting. Site preparation is designed to remove weeds that may compete with the small, newly planted tree or shrub for moisture, nutrients and growing space that it needs to survive. Also, use native species that thrive in specific soil and moisture conditions. Many of these plants can be transplanted to a new site in early spring. If you are not familiar with the techniques of transplanting, request assistance from a biologist, district forester or community advisor. Remember, if working on private lands, get permission prior to any transplanting.

Implementation Steps:

Grasses and Legumes:

1. Although dependent on local conditions, a recommended mixture for planting a grass/legume mixture is 20 - 30 kg/ha (18 - 27 lb/acre) of grass seed and 15 -20 kg/ha (13

- 18 lb/acre) of legume. Without the legume seed, a grass seed at 500 - 150 kg/ha is recommended.
2. Prepare a good seed bed and fertilizer (10-10-10 or 10-20-0 at 300 - 500 kg/ha; 268 - 446 lbs/acre), plant in the spring as legumes do not establish after mid-August, and mulch with straw or wood chips to reduce weed growth.
3. On steeper parts of the bank, it may be necessary to hold the mulch in place with coconut fibre mesh, pegged chicken wire, pig wire, or snow fence. This should be done in combination with cultivation or mulching to reduce weed growth.
4. Hand cyclone or hydro-seeder should be used to apply the seeds and fertilizer.

Shrubs:

1. Plant one or two year old nursery seedlings in a trench. If a trench cannot be made, remove some sod where the shrub is to be planted.
2. Plant in a zigzag row with a one-meter spacing to reduce weed competition (see Figure 22).
3. Mulch laid on the soil aids greatly in keeping soils moist and reducing weed competition.
4. Another method of establishing red-osier dogwood and willows is to plant fresh cuttings from established shrubs. First, cut from the parent shrub shoots of last year's growth, 1/4 inch (0.6 cm) in diameter. Then, stick the cuttings in the water's edge and push the shoot down to the water level. Allow one or two buds to remain exposed. If rooted plants are available, chances of survival will be improved.
5. Spring plantings yield best results.

Trees:

1. Prepare the planting area by ploughing furrows 7.5 – 12.5 cm deep (3 – 5 in.), 1.8 m (6 ft) apart. Plant trees in the furrows. Furrow wetlands in the fall and plant the following spring. Lacking a plough, or where land is rocky or hilly, remove 1 square foot (one-ninth of a square metre) of sod from each planting spot with a shovel and plant the tree in the centre. During planting, carry trees in a pail containing a few centimetres of water. Use damp moss or wet burlap for extra protection of trees in transit. Fence the planted area if grazing or trampling by livestock is a risk. The establishment and development of shrub and tree plantings can take place more rapidly with proper care.
2. Plants lost to animal damage or winter killoff should be replaced.
3. Plants may be fertilized to enhance their growth but this practice should only be done in combination with cultivation or mulching to reduce weed growth.
4. Mulching with sawdust, straw or woodchips is often recommended to keep the soil moist and reduce competition from unwanted plants.

References:

Bastien-Daigle, S., A. Vromans, and M. MacLean. 1991. A guide for fish habitat improvement in New Brunswick. Fisheries and Oceans Canada. Canadian Technical Report of. Fisheries and Aquatic Sciences. 1786E : iv + 109 p.

Ministry of Natural Resources of Ontario titled the “Community Fisheries Involvement Program: Field Manual”. (1982).

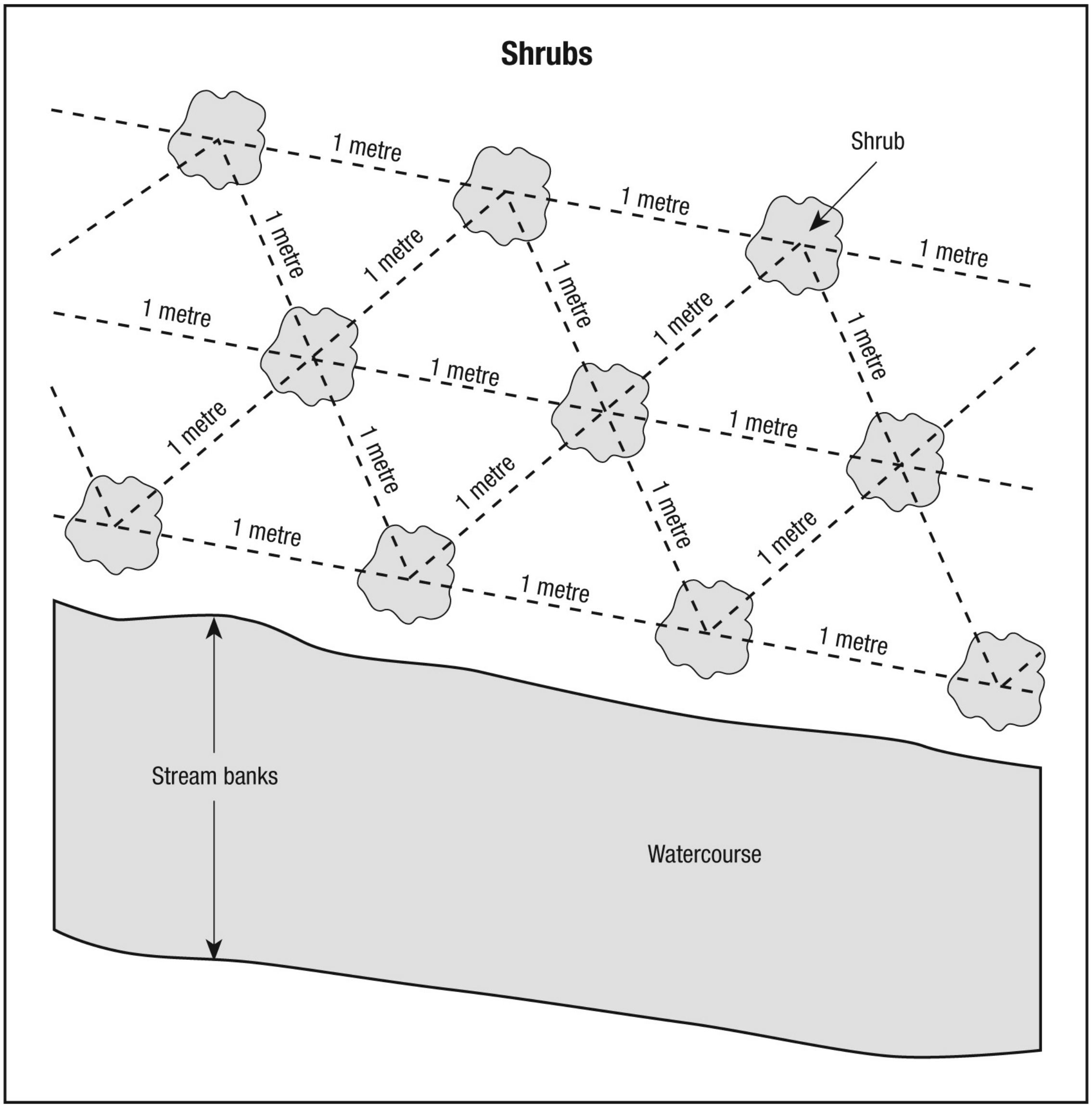

Figure 22. Conceptual drawing of typical shrub plantings (DFO, 1991).

4.2.6 DFO Fish Habitat Restoration Fact Sheet: Tree Revetments

Purpose:

- Protect banks from fluvial scour and toe erosion.

Conditions Where Applicable:

- Low to moderate velocity settings with non-cohesive banks that are prone to toe erosion.

Habitats Created:

- In some cases it provides cover.
- Main purpose is to reduce siltation of habitats.

Advantages:

- Provide good protection from bank erosion and instream cover during high flow periods.
- Work best on streams with stream bank heights under 3.7 m (12 ft) and bankfull velocities under 2 m/s (6.5 ft/s).
- Use inexpensive, readily available materials.
- Capture sediment and enhances conditions for colonization of native species particularly on streams with high bed material loads.
- Species that are resistant to decay are best because they extend the establishment period for planted or volunteer species that succeed them.
- Where appropriate, tree revetments should be used with soil bioengineering systems and vegetative plantings to stabilize the upper bank and ensure a regenerated source of streamside vegetation.

Disadvantages:

- Large trees must be cut down.
- Moving large trees and digging a proper ditch to anchor them in requires heavy machinery.
- If not done properly, digging a trench along a stream bank may cause extensive sedimentation.
- Wire anchoring systems can present safety hazards.
- Limited life and must be replaced periodically.
- Might be severely damaged by ice flows.
- Not appropriate for installing directly upstream of bridges and other channel constrictions because of the potential for downstream damages should the revetment dislodge.
- Should not occupy more than 15 % of a channel's cross sectional area at bankfull level.
- Not recommended if debris jams on downstream bridges might cause subsequent problems.

Design Criteria:

- Discuss the project with a biologist, community advisor, agricultural engineer and/or other experienced person as required.
- It is very important that the individual trees be anchored tightly to a stump with galvanized wire or nylon cable, while inflicting minimal damage to the stream banks.
- Avoid anchoring to live trees if possible.
- Each end of the treated section of stream bank must be well protected.
- For streams less than 5 m wide: A row of interconnected trees attached to the toe of the stream bank or to a deadman log. Protruding roots in the stream bank reduce flow velocities along eroding stream banks, trap sediment, and provide a substrate for plant establishment and erosion control.

Implementation Steps:

- Obtain whole, freshly cut coniferous trees. Otherwise, needles may fall off prematurely and this will reduce the effectiveness of the structure.
- Anchor whole trees to stream banks with the root wad (butt end) typically pointing upstream (downstream-oriented structures have also proven successful).
- At moderate energy sites, stream banks can be treated with an integrated tree-rock-live cutting structure built in an interlocking matrix.
- At sites with cohesive bank material, trenches may be cut to receive each debris unit.
- At sites lacking cohesive bank material, a broad bench should first be cut. This bench should be big enough to receive the largest trunk to be used (generally less than 9 m).
- The easiest way to conduct revetment assembly is by starting at the downstream limit and progressing upstream.
- Footer logs are excavated as deeply as possible relative to the thalweg. Maximum depth of placement will be determined by substrate and flow conditions at the time of installation.
- Root wads are then installed with the root fan overhanging the footer log.
- Header logs, rocks and backfill soil are then added. The backfill soil used should be heavily planted with live plant material.

References:

British Columbia Ministry of Environment, Lands, and Parks and Ministry of Forestry. 1997. Fish Habitat Rehabilitation Procedures, Watershed Restoration Technical Bulletin No. 9.

Federal Interagency Stream Restoration Working Group (FISRWG). 1998. Stream Corridor Restoration: Principles, Processes and Practices.

United States Department of Agriculture, Natural Resource Conservation Service, Watershed Science Institute. 1999. (http://www.wsi.nrcs.usda.gov/products/).

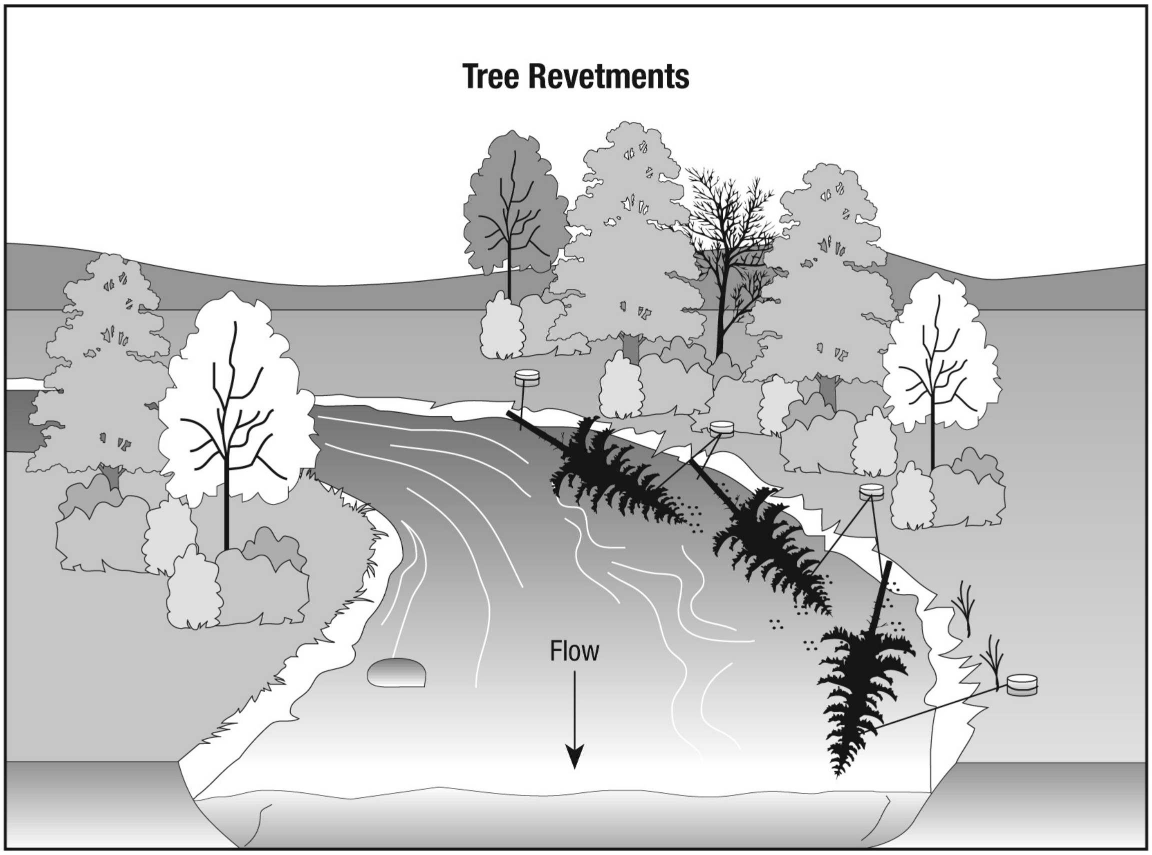

Figure 23. Conceptual drawing of tree revetments to protect stream bank from erosion (USDA, 1999).

4.2.7 DFO Fish Habitat Restoration Fact Sheet: Brush Mats (Sediment Traps)

Purpose:

- To stabilize point bars and tidal mud flats adjacent to river channels.

Conditions where applicable:

- In rivers with a high-silt bed load.
- On intertidal mud flats adjacent to the river channel.

Habitats created:

- Captures silt on point bars reducing siltation.
- Helps develop thalweg and pools.
- Stabilizes channel.

Advantages:

- Cost effective.
- Uses local materials.
- Traps silt and helps build banks and reduce erosion.

Disadvantages:

- Manpower intensive.
- Limited life span if the area does not vegetate.

Design criteria:

- Evergreen branches approximately 2 m long or small trees.
- Stake down and secure in place.
- Place stump end upstream and branch parallel to the flow.

Implementation steps:

- Cover the point bar (inside the meander bend) with the branches working up from the downstream end.
- Overlap the branches like shingles.
- Stake down the stump end and tie down the branch to the one underneath if needed.
- The branches will catch the silt in high flows or high tide and build a stable bar.

References:

Lea Murphy, DFO Charlottetown Area Office. Personal Communication.

T. Dupuis, D. Guignion, R. MacFarlane and R. Redmond. 1994. A Technical Manual for Stream Improvement on Prince Edward Island. Canada/PEI Cooperation Agreement for Sustainable Economic Development. Morell River Management Cooperative Inc.: vii + 176p.

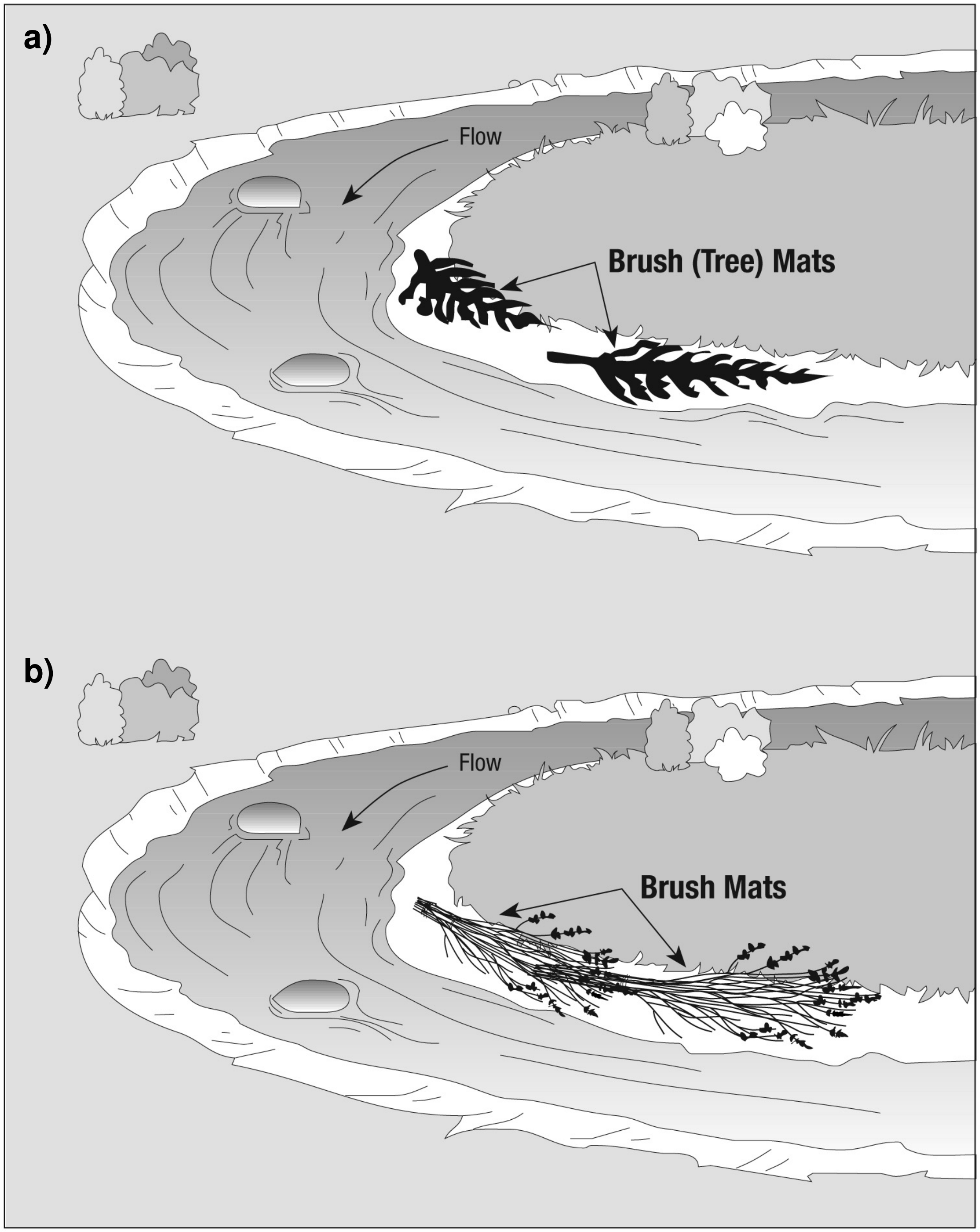

Figure 23 (a) and (b). Conceptual drawings of brush mats used for capturing sediments and reinforcing stream banks (Dupuis *et al.*, 1994).

4.2.8 DFO Fish Habitat Restoration Fact Sheet: Brush Bundles (Fascines or Wattles) and Brush Mattresses

Purpose:

- Primarily to stabilize stream banks.
- Also provides shade and leaf fall for fish habitat.

Conditions where applicable:

- Eroding earth banks.

Advantages:

- Looks natural.
- Self maintaining.
- Provides shade and primary productivity to the stream.

Disadvantages:

- Full stabilization effect takes time to develop.
- Plants may need to be replaced if they do not grow.

Design criteria:

- Select plants suitable for the soils and moisture content.
- Use integrated methods of bank stabilization to ensure stability.

Implementation steps:

1. Fascines:

- Tie live cuttings into bundles.
- Use on slopes at 1:1 slope or less.
- Dig trenches parallel to the stream.
- Typical spacing of trenches 1 m to 1.5 m apart.
- Place bundles in trenches and stake in place.
- Cover with a thin layer of soil.
- This is best done in the spring or fall.

2. Brush Mattresses:

- Place live branches longer than 1.5 m at a density of 20 to 50 branches per metre.
- The butt ends of the branches are buried to facilitate rooting.
- Secure with stakes and tie down with smooth wire or jute rope.
- Cover the entire mattress with a thin layer of soil.

- Use on banks with 2:1 or 3:1 slopes and greater than 2 m high.

References:

British Columbia Ministry of Environment, Lands, and Parks and Ministry of Forestry. 1997. Fish Habitat Rehabilitation Procedures, Watershed Restoration Technical Bulletin No. 9.

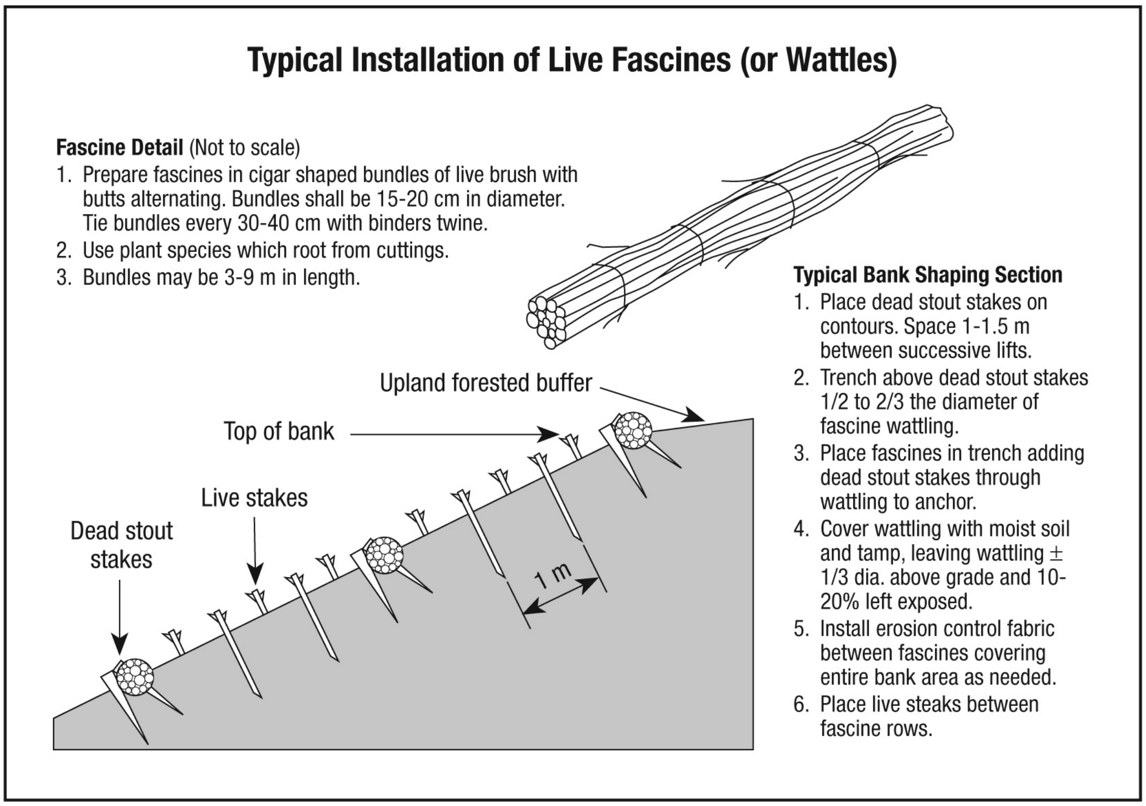

Figure 24. Conceptual drawing of brush bundles (also called fascines or wattles) used to protect stream bank from erosion (B.C. Ministry of Environment, Lands, and Parks and Ministry of Forestry, 1997).

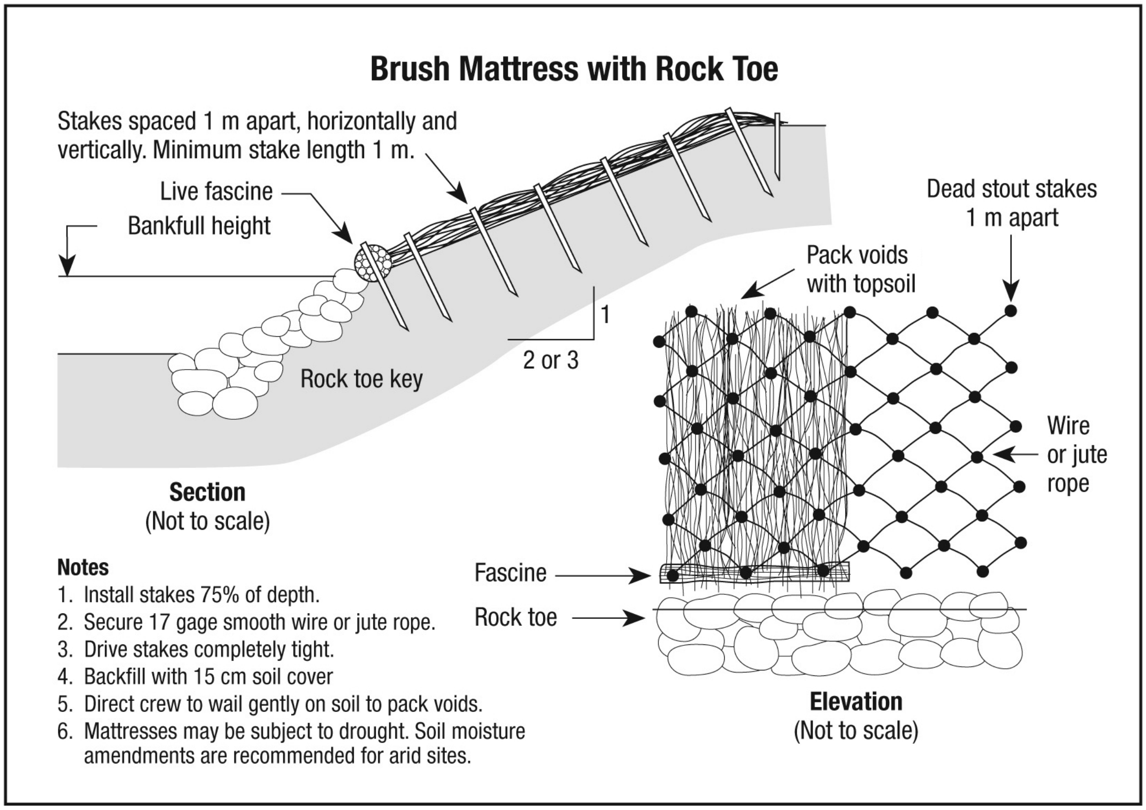

Figure 25. Conceptual drawing of brush mattresses used to protect stream bank from erosion (B.C. Ministry of Environment, Lands, and Parks and Ministry of Forestry, 1997).

4.2.9 DFO Fish Habitat Restoration Fact Sheet: Fence Posts

Purpose:

- To re-establish an eroding bank.
- To narrow an over-widened section of stream.

Conditions where applicable:

- Where the stream has been over widened by erosion or other activities and you need to re-establish the natural stream width.

Habitats created:

- Stabilizes bank and reduces siltation of habitats.
- Narrows the channel improving thalweg and pool development.

Advantages:

- Inexpensive if materials are on site.
- Easy to install.
- Excellent bank stabilization.
- Blends into surroundings.

Disadvantages:

- Labour intensive.
- Will not tolerate wide fluctuations in water levels.
- Limited life span. Requires regular maintenance.
- Design criteria.
- Use on streams less than 15 m wide.
- Does not provide cover.
- May undermine if the stream bed is erodible.

Design criteria:

- Build the wall up to the height of the normal high water or the flood plain height on the adjacent bank, whichever is lowest.
- Determine the natural stream width and lay out the posts to blend into the banks at both ends.
- Use woods that are resistant to rot such as cedar or hemlock.
- Do not stack logs above the original bank height.
- Backfill should be sloped into the existing bank.

Implementation Steps:

- Drive fence posts or metal t-bar stakes in a double row the width of your logs.
- Drive stakes along the top of the bank at least 3 m into the bank to act as bracing.
- Wire the outside line of stakes to the bracing stakes in a zigzag fashion using heavy gauge wire.
- Place a windlass in each wire to tighten the structure after the logs have been placed.
- The wire on the bracing stakes should be buried in a shallow trench.
- Stack the logs between the outer rows of posts, tie each layer of logs to the posts, and overlap the ends of the logs as you each layer is stacked.
- Backfill the area behind the log wall to just above the bracing wires, with brush, and earth as available.
- Top the bank with soil and plant with grasses and shrubs.

References:

Bastien-Daigle, S., A. Vromans, and M. MacLean. 1991. A Guide for Fish Habitat Improvement in New Brunswick. Fisheries and Oceans Canada. Canadian Technical Report of Fisheries and Aquatic Sciences. 1786E : iv + 109 p.

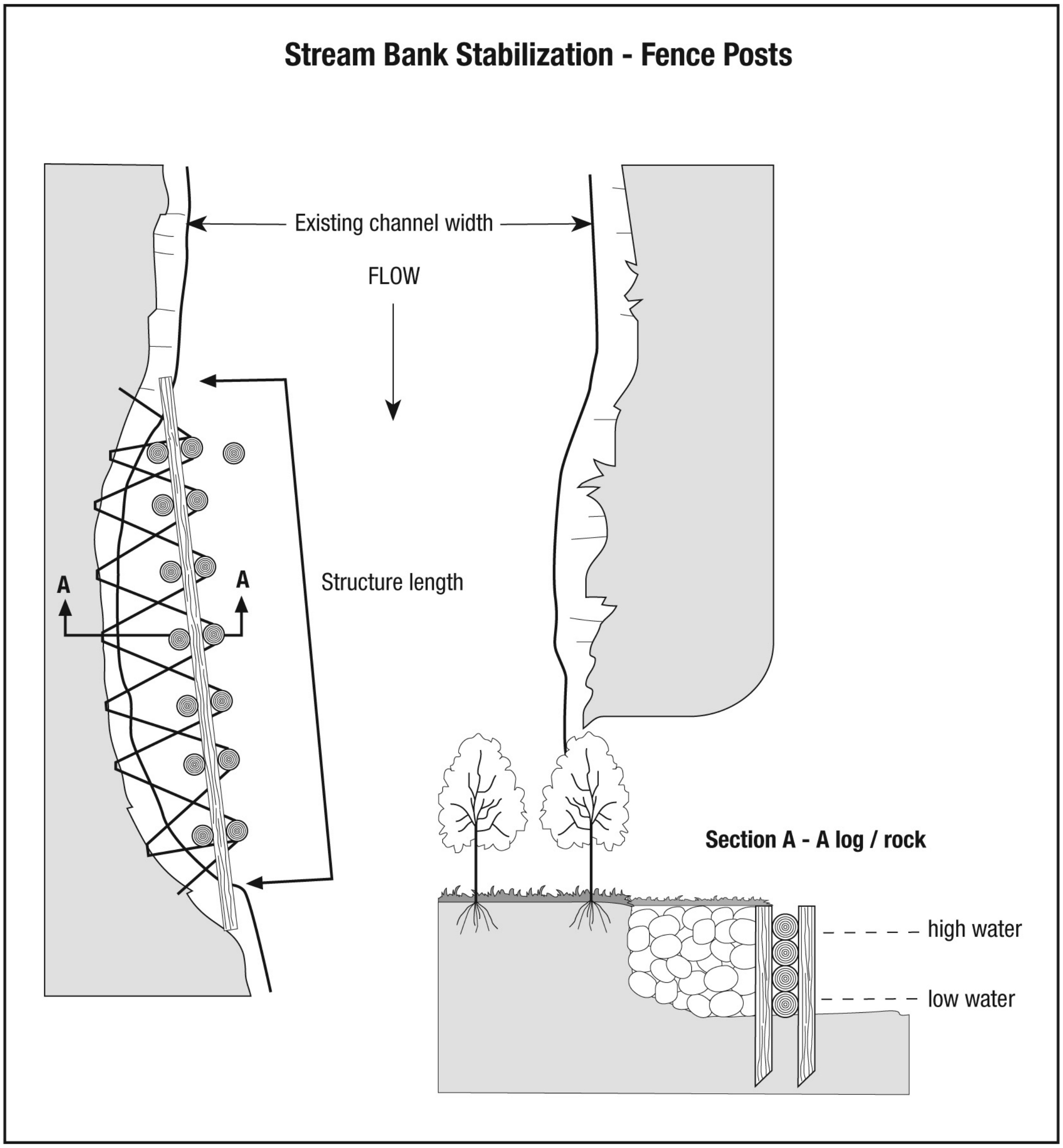

Figure 27. Conceptual drawing of fence posts used to protect stream bank from erosion (Thaumas Environmental Consultants Ltd.).

4.3 POOL-RIFFLE CREATION AND CHANNEL NARROWING

A) Digger Logs
B) Deflectors
C) Rock Sills
D) Low Head Barriers and Weirs

4.3.1 DFO Fish Habitat Restoration Fact Sheet: Digger Logs

Purpose:

- To support a section of riffle upstream and create a pool downstream to enhance trout and salmon habitats and develop habitat diversity.

Conditions Where Applicable:

- In a stream with low to moderate grade (up to 2 %), with gravel or small cobble substrate, and where natural flows and currents can be allowed to shape the streambed.
- The log acts as a gradient control holding the riffle/run substrate from falling into the pool. They are not intended to create a significant head difference and plunge pool.

Habitats Created:

- Pool habitats > 45 cm deep in low flow.
- Instream cover under undercut log.
- Sort substrates removing sands and silt to point bars and flood plain.
- Sorted substrate and pools capture leaf litter and organics, supports larger insect populations, provides better spawning and juvenile escape cover, and over-wintering habitats.
- Encourages the development of the thalweg between pools.
- Imitates natural digger log processes in streams.

Advantages:

- If positioned correctly, a digger log will create a pool that will not fill in.
- Creates overhead instream cover and helps develop a proper riffle/pool ratio and sorted gravels in disturbed streams.
- Can be built with on-site materials in remote or poorly accessible forested areas.

Disadvantages:

- If not positioned/anchored correctly, digger logs will wash away, do nothing or further disturb habitat.
- Can be labour intensive to install.
- If not placed properly, may disrupt navigation in the waterway for small craft such as canoes.
- Structure must be checked regularly to make sure it is still functioning correctly.

Design Criteria:

- For best results, the digger log should be placed at the head of a natural pool. These are every six channel widths based on the width of a 1:2 year flood flow channel (or bankfull width) and on alternating sides of the stream.

- Proper placement is critical to their success in creating habitat diversity.
- Logs are most effective in streams under 6 m (20 ft) wide.
- Log diameter should be approximately 10 cm (4 in.) to 15 cm (6 in.) with a minimum of taper from one end to the other.
- The digger log must be firmly anchored to the substrate.
- It should be rotated to a 30^o angle from straight across the stream and, when looking downstream, turned toward the side the pool is on.
- The upstream end of the log should be set lower than the rest of the log to concentrate low flows on the pool side of the stream.
- The ends of the log must fit tightly to the banks and be well rocked in place to prevent erosion of the banks. Some fact sheets call for the ends of the log to be set up to 1 m into the bank. This is not necessary in most Maritime streams unless the log is in a gravel bar or other soft bank material.
- A rock ramp should be built, sloping the streambed up to the log on a 20:1 ratio. Typically, this means a 1 - 3 m (3 - 10 ft) long ramp on the upstream side.
- Cobble and large rocks armouring the surface should be removed from the pool area to assist the scour by the flows.
- The thalweg location for digger logs is the low end of the log. This location in over-widened channels can be set at the bank that will maximize the meander length and lower the gradient or the logs can be aligned and use deflectors to narrow the channel maintaining the gradient as needed.
- Logs work with the stream flows to sort gravel and shape pools and riffle thalweg. This typically takes two to three years to fully form.
- Logs and ramps need periodic maintenance until the stream has achieved its new form and vegetation has stabilized the new banks.
- The logs work with the flows to create the habitats. The substrate that is scoured from the pool area is needed to build the point bar and shape the channel.
- When the pool has formed, the cobble and large rocks that were removed initially may be replaced to provide juvenile instream cover as needed.

Digger Log with Deflector:

- The deflector is installed on the downstream end of the digger log.
- Its tip is at the edge of the channel design and all dimensions, angles and form are the same as described in the deflector fact sheets.
- The deflector will help dig a longer pool and speed the narrowing of the over-widened stream.
- This combination gives the benefits of both structures.

Implementation Steps:

- Discuss project with the area fish habitat biologist, community advisor or other qualified person prior to implementation.
- Preferably use hardwood logs of appropriate size because they withstand scour with fine gravels better than softwoods.
- Survey stream to locate proper position for digger log.

- Place digger log into stream, firmly anchoring it to the substrate with re-bar.
- Build a good rock ramp on the upstream side. Remember that the log will undercut so the rock against the log must be large enough not to fall through. If large rock is not available, use wire mesh, plastic snow fence, or geotextile to attach to the log and lay under the ramp to hold up the smaller rock and prevent it from falling into the undercut. A more environmentally friendly way to provide for the undercut is to lay a second log against the digger log making the structure two logs wide and then build the ramp using the smaller rocks.

Application Requirements:

- Some application processes require detailed drawings of each structure. This is particularly true of NWPA approval processes on navigable watercourses. If required, provide the following information:
- Select the drawing of the right or left pool as required.
- For each digger log provide a copy of the plan provided below with the following measurements filled in.
- Existing stream width (ESW). This is measured bank to bank between the bases of perennial vegetation (in metres).
- The channel design width (CDW) is the width (in metres) of the fish habitat channel the restoration is trying to develop. Typically this is the width of the 1:2 year flood channel based on the daily peak flow (or bankfull width).
- Structure length (SL). This is the length in metres, along the structure from the existing banks. Bank rocking around the ends of the log should be enough to prevent erosion but not intrude into the channel any significant distance.
- If any other measurements already on the drawing will be changed, note the changes on the drawing.
- In the lower left corner fill in the name of the group and the date.
- In the lower right corner fill in the location, a GPS reading if available, and site number linking the drawing to information in the permit application.

References:

DFO fact sheets (1994).

Thaumas Environmental Consultants Ltd. 2005. Personal Communication.

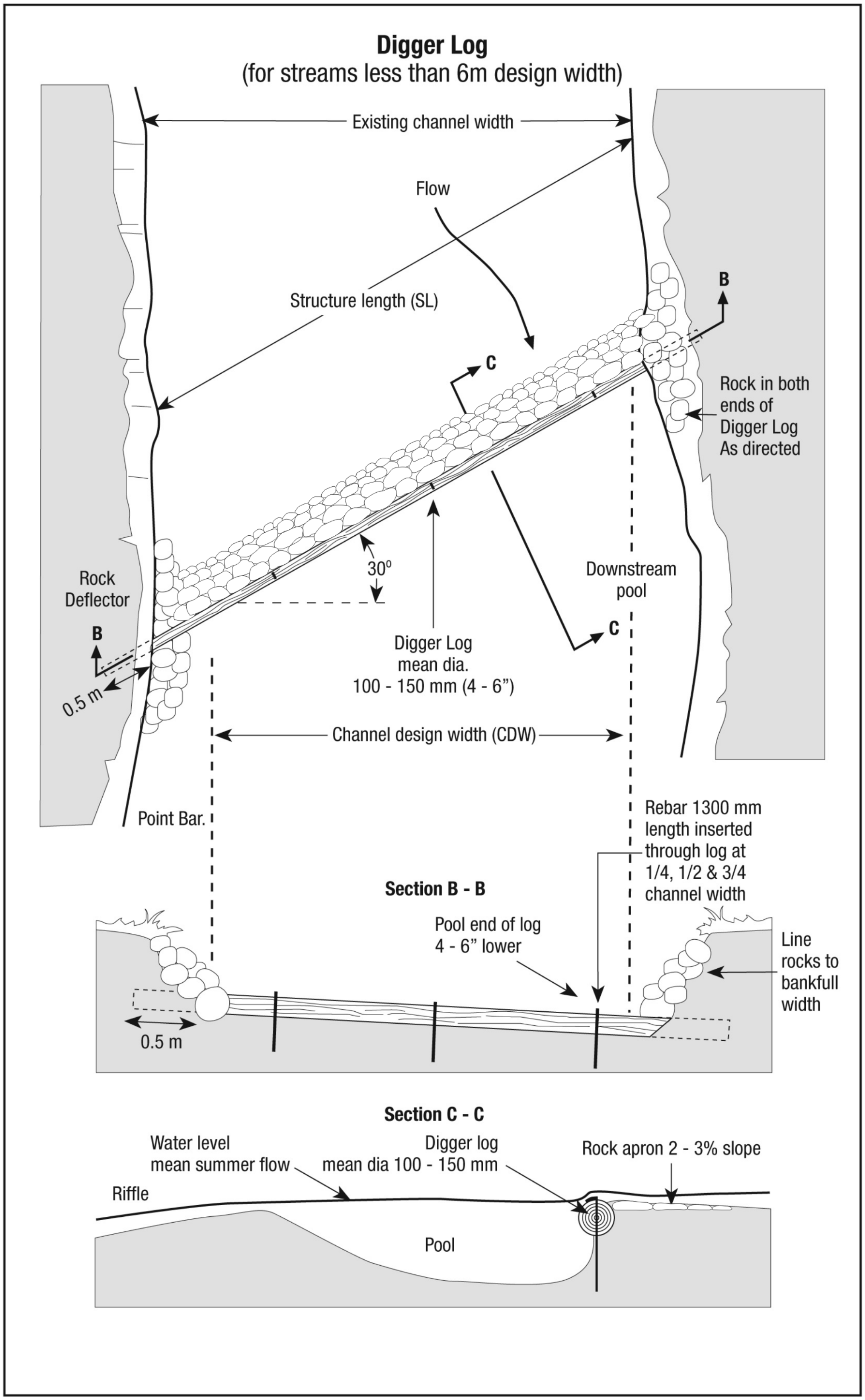

Figure 28. Conceptual drawing of a digger log (Thaumas Environmental Consultants Ltd.).

4.3.2 DFO Fish Habitat Restoration Fact Sheet: Deflectors

Purpose:

- To provide rearing habitat for juvenile and adult trout by developing a narrower, deeper channel and/or a pool area.
- To flush silt from a stream reach.
- To create a point bar and allow silts to redeposit alongside the bank.

Conditions Where Applicable:

- Deflectors are typically used in low gradient (up to 2 %), wide, sluggish sections of streams. In these areas, silt tends to become trapped, thus reducing the quality of the salmonid habitat. Deflectors should not be used where there is an unstable flood plain or other unstable reaches of the stream without additional stabilization works.
- Deflectors can be installed as single structures or twin units. As single structures they are installed in a staggered fashion on alternate banks. Twin deflectors can be installed as a single unit or several may be required especially along long, straight stretches of sluggish water.

Single Deflectors:

- Used to concentrate flow, narrow and deepen the channel.
- The use of several of these structures in an alternating fashion encourages meandering of the stream by deflecting the main current (thalweg) toward the centre of the stream or opposite bank.
- Single deflectors are placed 6 stream widths apart based on the fish habitat channel or 1:2 year daily peak flow channel width (or bankfull width).
- Pool/run length should not exceed five channel widths.
- In many cases a single deflector can be combined with submerged bank cover on the opposite bank.

Twin Deflectors:

- Pinching devices that tend to concentrate flow.
- It may be necessary to construct several of these channel-pinching devices in particularly long sections of a stream to restore salmonid habitat.

Habitats Created:

- Used primarily to develop the thalweg.
- Will develop pools on the opposite side of the stream and just downstream of the deflector.
- Normally create the upstream end of a point bar.
- Twinned deflectors narrow and center the fish habitat channel in over-widened sections.
- Enhance fish habitat for juvenile and adult fish.

Advantages:

- Aid in stabilizing stream banks and consequently controlling erosion.
- Accentuate the stream flow, keeping downstream reaches of the stream clean of sediment deposits.
- Tree deflectors are easy to build by hand.

Disadvantages:

- Those constructed with boulders or log cribs may require heavy equipment to install and consequently require more extensive regulatory review and additional work to prevent any adverse effects caused by the construction equipment.
- If heavy machinery is required, costs may be high.
- Deflectors can cause erosion problems and add to bank and watercourse instability if they are not properly located.
- Deflectors may require some bank stabilization work downstream on the opposite bank.
- Deflectors require considerable experience to determine their proper location.
- If trees are used, they need to be freshly-cut. Otherwise, needles may fall off and the structure will not work as intended.

Design Criteria:

- Since deflectors are used to concentrate and redirect the stream flow, the existing pattern of stream flow needs to be determined before attempting any work.
- Deflectors should be placed upstream and on the opposite side of a natural pool.
- Use materials that will withstand flood conditions (e.g. trees or log riprap in low flood-prone areas, rock in moderate flood prone areas, and riprap mixtures with large median size and cribbing in severe flood prone areas).
- Preferred locations include long sluggish stretches of water. To determine appropriate location sites for single and twin deflectors, in most cases it will be necessary to obtain professional advice from a fisheries biologist, community advisor, or other qualified person.
- A series of single deflectors alternating from bank to bank will assist in maintaining a natural meander pattern.
- Deflectors should not restrict more than one-third of the stream width (if the stream is over-widened).
- The tips of the deflector(s) must not narrow the stream to a width less than the natural 1:2 year flood channel width (or bankfull width).
- Deflectors guide the water rather than dam it.
- They should have no protrusions on which drifting debris can accumulate.
- Rock and log crib deflectors should be triangular in shape (i.e. 30^o on the bank at the upstream tip, 90^o at the tip out in the stream and 60^o at the downstream bank. The 30^o angle guides the current toward the center of the stream rather than the opposite bank and therefore is less apt to cause erosion downstream. If downstream erosion does result from your work then some bank protection work may be necessary.

- The downstream edge of the deflector should be at an angle of 90° to the upstream edge. This will allow floodwaters that overtop the deflector to leave at an angle away from the bank.
- It is also important to place some protective material, such as boulders, on the bank where the wing deflector meets the bank.
- If using a single deflector and the opposite bank is eroding, it should be stabilized by rocking or another suitable method.
- Re-vegetate any exposed soil as soon as possible after work is completed.

Implementation Steps:

Deflectors can be constructed using four different materials: trees, rock riprap, log riprap, and log crib and rock.

Tree Deflector:

- Tree deflectors should be built in areas subject to low to moderate levels of flooding.
- Use thick, freshly cut coniferous trees like balsam fir or various spruce species.
- Determine suitable locations so that the downstream end of the tree (i.e. the tip of the tree) is just above the upstream end of a pool.
- The height of the deflector should be set so that at peak flows, logs, ice and other debris can pass unimpeded; otherwise severe bank erosion could result. Therefore it is important to know flooding characteristics of the stream before the onset of the project.
- Anchor the tree stump to the top of the stream bank with rebar and secure to a nearby tree with rope or galvanized wire. Also, anchor the tip of the tree onto the stream bed with reebar.
- Protection is required where the stream bank and deflector meet. Use smaller riprap to secure bank at least one metre (3 ft) back from low waterline.

Rock Deflector:

- Rock deflectors should be built in areas subject to low to moderate levels of flooding.
- Rock deflectors should be built at sites where rock is plentiful or can be delivered to the site.
- Determine suitable locations so that the downstream end is just above the upstream end of a pool.
- Excavate streambed (if necessary) to firm bottom to prevent undermining.
- If building structure adjacent to eroded bank it may be necessary to grade bank to a natural slope. If bank is not of porous material then place gravel to a depth of 30 cm (6 in) on the slope before laying any stone.
- Determine size (area to be covered) of the deflector. The help of an experienced person will be an asset.
- At base of the structure, use large rocks 36 - 38 cm (14 - 15 in) to construct outside edge or rocks 1.5 times the size of the largest rock in the river. The largest rocks should be placed on the upstream side and near the bottom. Fit the largest rock at the apex of the deflector. Use double rows of rocks in the upstream side of deflector. First row of rocks

should be fitted into streambed. When fitting, lay rocks masonry style (i.e. with joints staggered).

- Slope deflector up to the bank from the tip to the top of the bank forming a shape like the corner of a pyramid. Fill in center of deflector with smaller stone. If the bank is high, the deflector should be sloped up to a height that exceeds the 1:20 year storm flow or the height of the flood plain on the opposite bank if it is lower.
- Height of deflector should be set so that at peak flows, logs, ice and other debris can pass unimpeded; otherwise severe bank erosion could result. Therefore it is important to know flooding characteristics of the stream before the onset of the project.
- To prevent rock from rolling or moving, use angular rock and chink in smaller rock in open spaces along upstream face.
- Protection is required where the stream bank and deflector meet. Use smaller riprap to secure bank at least one metre (3.1 ft) back from low waterline.
- Upstream and downstream ends of the deflector should be protected with rock to prevent the river from washing around ends.
- Anchoring the structure by vegetating top of structure with grasses or shrubs may be desirable. Flooding characteristics will determine which plant type is most suitable.
- The bank opposite the deflector should be stable or may have to be protected to prevent erosion.

<u>Log Riprap Deflector</u>:

- Log riprap deflector should only be built in areas subject to low levels of flooding and ice damage.
- Build on sites where quality wood is available or can be delivered.
- Determine suitable location for this technique.
- Obtain necessary materials: No.9 gauge galvanized wire, 20-30 cm (8-12 in) angular rock, 2.1 m (7.0 ft) T-bars, 3.0-6.1 m (10-20 ft) logs and prepared brush bundles. Materials and methods for construction are similar to those used in the Log Riprap bank stabilization technique.
- Stake outer edge of structure with T-bars.
- Set in T-bars at spacing of 1.5 m (4.9 ft). Angle T-bars upstream. Flat side of T-bar should face stream bank.
- T-bars should be hammered into the streambed to within 10 cm (4 in) of the low water mark.
- Cut and place first log along upstream side then along downstream side. Continue placing logs on top. Top log should be at water level or slightly higher.
- T-bars should extend no more than 10 cm (4 in) above top of uppermost log.
- Fill in center of deflector with brush bundles, rock, etc. When top of deflector is reached place large logs over top and wire down.
- Drive a series of stakes (wood or metal) in an offset pattern to the main stakes at a distance of 50 - 100 cm (1.8- 3.1 ft) back from the edge of the old bank at an angle back from the stream. Dig a shallow trench to eventually bury the wire. Wire these to the outside line of metal stakes with double strands of heavy gauge fence wire. A crossover pattern of wire wrapping is suggested. Tighten the whole structure by inserting a stick between the strands of wire and twisting.

- Hit T-bars with sledgehammer to tighten wire slightly.
- Key in upstream and downstream of structure. Place in angular rock at the base of the deflector.
- When silt bar develops downstream, stabilize by planting.

Log Crib Deflector:

- Log crib deflector can be built on sites that are subject to moderate to high levels of flooding.
- Build at sites where rock and logs are plentiful or can be delivered.
- Determine suitable location for this technique.
- Estimate and obtain the required materials. Materials and methods used in this technique are similar to those in the Log Crib Structure technique.
- Prepare a trench in the stream bank to the desired depth and length to accommodate the upstream deflector log. Particular care must be taken to orientate the angle of this log so as not to aggravate or create additional problems downstream (such as erosion).
- Prepare a trench in the stream bank for the downstream log of the crib frame.
- The proportion of the total log to be anchored into the bank is dependent on the following: the amount of log protruding into the main stream, amount of ice movement, volume of water and the type and amount of debris, including logs and limbs which may impact the structure as they are transported downstream. Logs are typically embedded 1.2 - 2.4 m (4 - 6 ft) into the bank.
- The downstream log of the crib frame must not protrude beyond the upstream lag at the apex of the deflector.
- Excavate streambed to a firm bottom. Secure logs to streambed by drilling through logs and driving in reinforcing rods through logs into streambed. Further anchoring may be obtained by driving T-bars (possibly cut in half) into the streambed adjacent to and on the inside of the deflector. Secure T-bars to log with galvanized wire. T-bars should extend only to top of log.
- NOTE: A frame is generally only required when the materials used (rocks, gravel, rubble) are not of sufficient size to withstand stream flows or depth of water. If all wood components can be submerged the life expectancy will be increased. If logs are exposed to air they should be peeled.
- If the structure must be greater than one log high, secure logs together with dock spikes. Before using dock spikes, pre-drill holes 7.6 - 12.7 cm (3 - 5 in) less than the length of the dock spike. Drive the dock spike across the grain of wood where possible.
  - Cross brace logs can be added to increase strength of the structure.
  - Rocks and rock rubble are placed within the frame.
  - Where violent and frequent flows are not expected to overtop the deflector, soil may be used to cover the rocks and then seeded with grass. In cases where only soil is used to fill the frame, shrubs may also be planted. Both grass and shrubs will add shade, cover and improve aesthetics.

Application Requirements:

- Some application processes may require detailed drawings of each structure. This information may be required by the NWPA approval processes on navigable watercourses. If required, provide the following information:
    - Indicate the type of deflector to be used.
    - For each deflector site provide a copy of the plan provided below with the following measurements filled in.
    - Existing stream width (ESW). This is measured bank to bank between the bases of perennial vegetation in meters.
    - The channel design width (CDW). This is the width (in metres) of the fish habitat channel to be developed. This corresponds to the width of the 1:2 year flood channel based on the daily peak flow.
    - Record the distance that the structure extends into the existing channel.
    - Record the location (GPS reading if available) and assign a site number to link the drawing to information in the permit application.
    - If any other measurements already on the drawing will be changed, note the changes on the drawing.

References:

T. Melanson T., S. LeBlanc, M. Goguen, and N. LeBlanc. 1999. Enhancement of Regional Sport Fisheries Through River Restoration: Case Studies for Shediac, Cocagne, Bouctouche, and Kouchibouguacis Watersheds. Southeastern Anglers Association 1996-1998 Progress Report. 78 p.

Ministry of Natural Resources of Ontario "Community Fisheries Involvement Program: Field Manual". 1982.

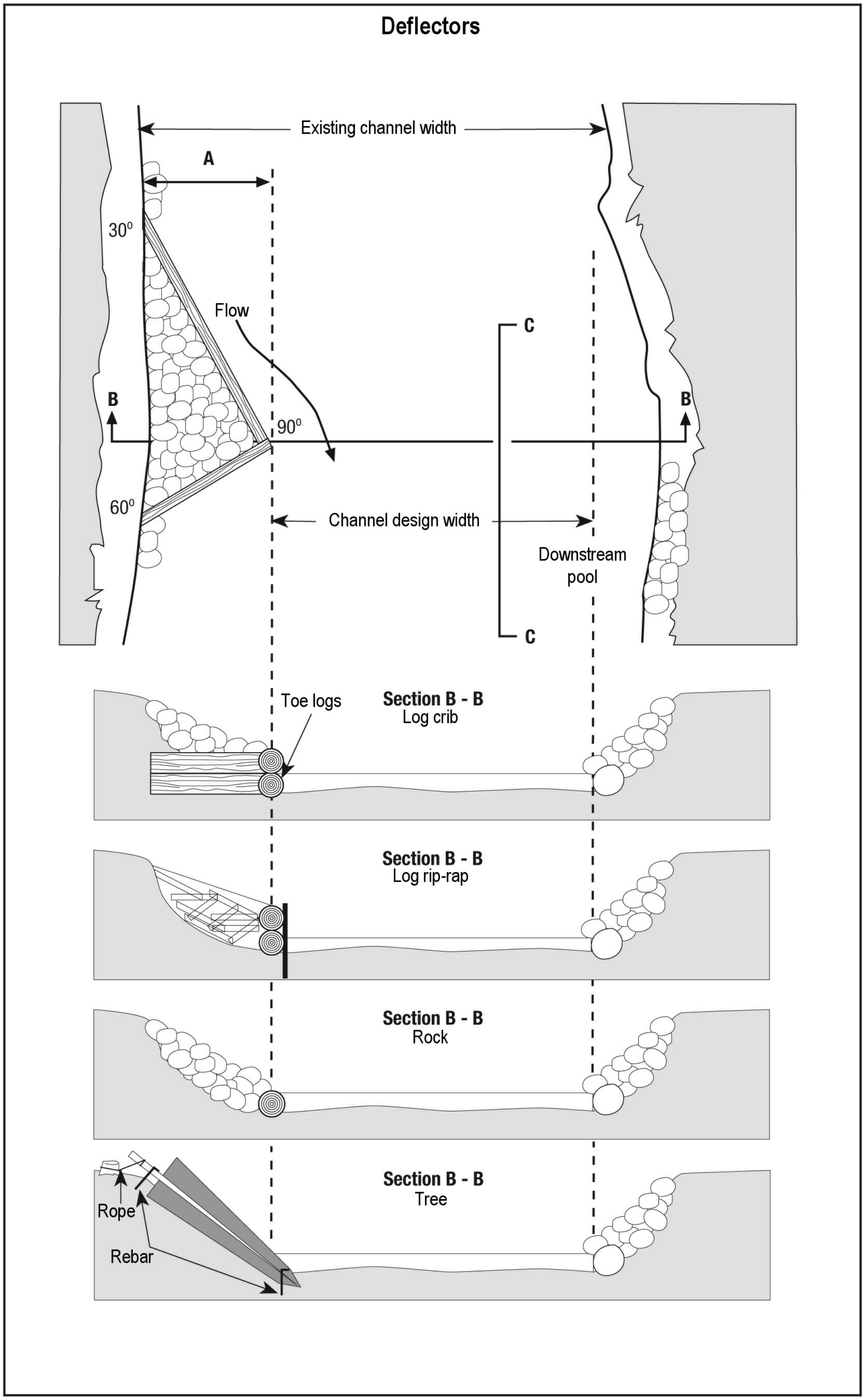

Figure 29. Conceptual drawings of a deflector and several types of deflectors (Thaumas Environmental Consultants Ltd. and DFO).

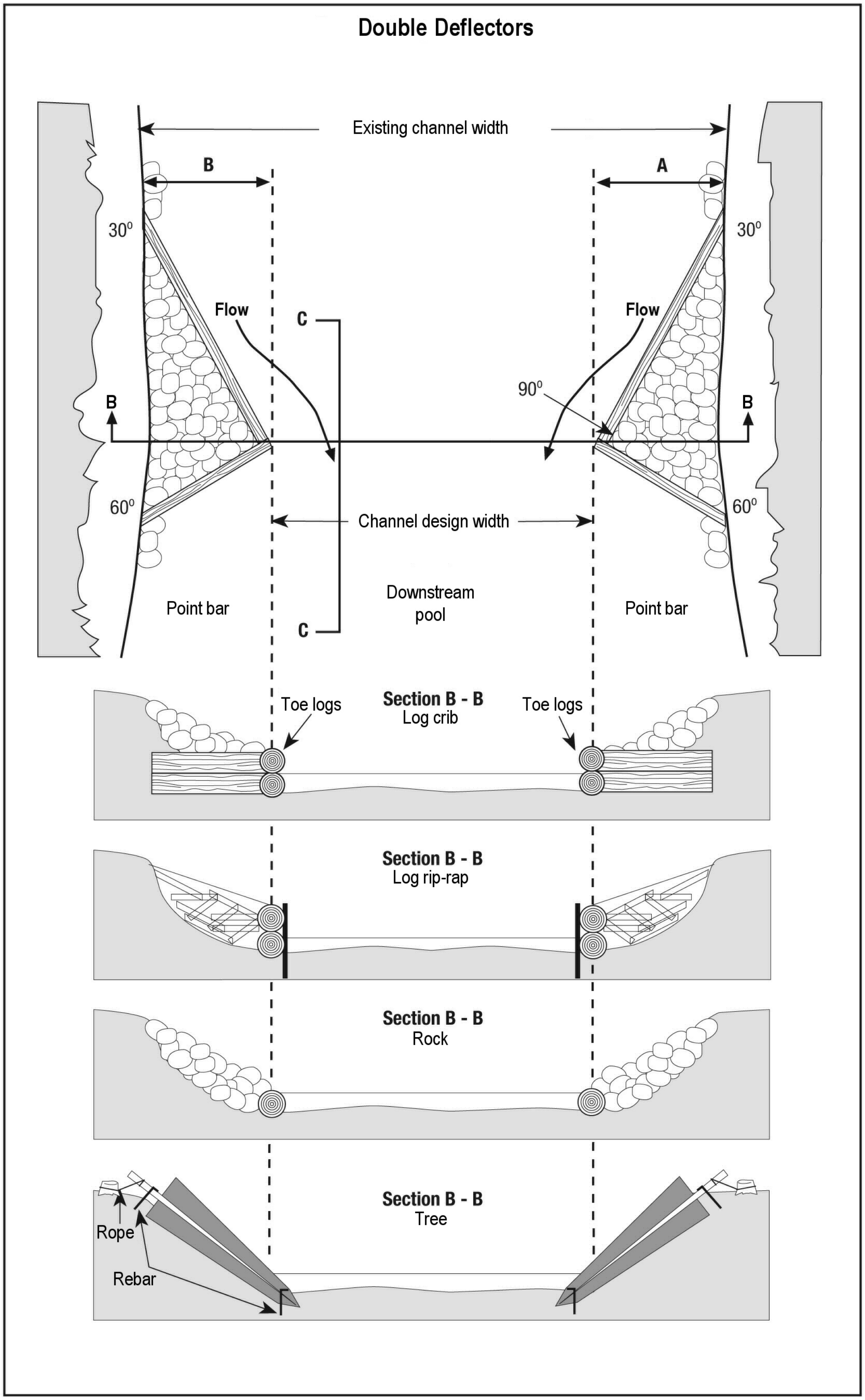

Figure 30. Conceptual drawings of double deflectors and several types of double deflectors (Thaumas Environmental Consultants Ltd. and DFO).

4.3.3 DFO Fish Habitat Restoration Fact Sheet: Rock Sills

Purpose:

- To support a section of riffle upstream and create a pool downstream to enhance trout and salmon habitats and develop habitat diversity.
- Used to create stable deepwater habitat in a stream.

Conditions Where Applicable:

- In a stream with low to moderate grade (up to 2 %), with gravel or small cobble substrate, and where natural flows and currents can be allowed to shape the streambed.
- The rock sill as a gradient control holding the riffle/run substrate from falling into the pool. They are not intended to create a significant head difference and plunge pool.
- The sills serve the same function as the digger logs and can be found in natural streams. They can be scaled up for larger streams and rivers where you can't find suitable sized logs.

Habitats Created:

- Pool habitats > 45 cm deep in low flow.
- Sorted substrate, with sands and silt redistributed to point bars and the flood plain.
- Sorted substrate and pools capture leaf litter and organics, supports larger insect populations, provides better spawning and juvenile escape cover, and overwintering habitats.
- Encourages the development of the thalweg between pools.
- Creates deepwater habitat, which is as essential for many fish species as cover to maintain temperature stability etc.

Advantages:

- Uses natural processes to develop deep pools; the continuing scour will prevent pools from filling in.
- If positioned correctly, a rock sill will create a pool that will not fill in.
- Helps develop a proper riffle/pool ratio and sorted gravels in disturbed streams.
- Can be built with on-site materials where there is an availability of rock larger than needed for stability in a stream of the size being restored.

Disadvantages:

- If not positioned, sized and anchored correctly, rock sills will breach or wash away, do nothing, or further disturb habitat.
- If placed too high, may disrupt navigation in the waterway for small craft such as canoes.
- Requires machinery on larger steams and on rivers to move rocks into position.
- Can be done by hand on smaller streams but requires extensive manual labour.
- Disruption of substrate will cause turbidity and possible sedimentation of fine materials downstream.

- Does not provide the undercut cover that digger logs do. This means additional work would need to be done to provide cover for rearing and for sea trout and salmon spawning areas. The bottom will slough into the pool on the upper side and generally you do not get as great a pool depth or the same diversity of habitats.
- Structure must be checked regularly to make sure it is still functioning correctly.
- Maintenance can be higher than properly built digger logs in small streams.
- Access for materials and equipment can be difficult.

Design Criteria:

- For best results, the sill should be placed at the head of a natural pool. These are every six channel widths based on the width of a 1:2 year daily peak flow flood channel (bankfull width) and on alternating sides of the stream.
- Can be sized for all watercourse widths. Select rock sized at least four times the diameter of the largest armouring rock in the watercourse. Rocks this size may be on site where the geology provides small boulders.
- The use of these instream structures in the main stem of streams or stream sections with gradients in excess of 2 % is not recommended.
- The structure should be located at the head of the natural pool or at the bottom end of the riffle/run. These are both the same place in the stream.
- The spacing should be every six channel widths based on the natural width of the channel for a 1:2 year flood flow.
- The sills are rotated to a 30^{o} angle from straight across the stream and when looking downstream, turned toward the side the pool is on.
- The sill should be at streambed level at the thalweg and rise on a 3 % (34:1) slope to the width of the design channel then 10 % (10:1) to the banks of the existing channel.
- The thalweg and channel design width section of the rock sill can be moved from side to side in an over-widened channel to increase meander length, lower gradient and help dig deeper pools. Alternately, they can be aligned to maintain the existing gradient depending on needs.
- The thalweg location may be left flush with the channel bottom for 10% of the channel width before it starts to rise and should be located one-third of the design channel width from the poolside.
- The channel at the site of construction should be a single, main channel with cobble/gravel substrates and stable vegetated banks. Additional bank stabilization may be needed.
- A rock ramp should be built on the upstream side, sloping the stream bed up to the sill on a 20:1 ratio.
- Cobble and large rocks armouring the surface should be removed from the pool area to assist the scour by the flows.
- When the pool has formed, the cobble and large rocks, removed initially, may be replaced to provide juvenile instream cover as needed.
- Sills work with the stream flows to sort gravel and shape pools and riffle thalweg. This typically takes two to three years to fully form.
- Sills and ramps need periodic maintenance until the stream has achieved its new form and vegetation has stabilized the new banks.

- The sills work with the flowing water to create fish habitat. You are not digging a pool. The material that is scoured from the pool area is needed to build the point bar and shape the channel.

Implementation Steps:

- Discuss project with a habitat restoration biologist, community advisor or other qualified person prior to implementation.
- There are two approaches to selecting rock.
  - Use a standard riprap rock mix with the median rock diameter at least 10 % larger than the cobble armour on the stream bottom. A R500 riprap mix is commonly used on gravel cobble bed streams.

  or
  - Use large boulders. If doing the work by hand on small streams, use rock up to 60 cm (24 ft) so they can be moved. On larger rivers, use boulders up to two tons and place by machine.
- Dig a trench across the stream deeper than 10 % of the stream width up to 1.5 m. For a riprap mix, the trench width and depth should be at least 2 times the size of the largest rocks. For small boulders, dig the trench two rocks wide and set the boulders in an alternating pattern like brickwork. For large boulders, use a single-row width.
- Set in as per the design criteria.

Modifications:

- Rock sills can be used in combination with deflectors to narrow the watercourse and aid in developing a longer deeper pool.
  - The deflector is built according to the details in other fact sheets and placed on the downstream end on the side opposite the pool.
  - The sloping up of the rock sill outside the channel design width has the effect of narrowing the watercourse and building point bars so there is not a great a need for deflectors.

Rock Sills (to create riffles):

Rock sills are really gradient controls. To dig and develop pools they are used in the same way as digger logs. However, they can be used in other locations in the watercourse to achieve different results.

- When a watercourse has been badly disrupted and plans are to restore the alignment of the watercourse and to build meanders, pools, and riffles, rock sills can be used to stabilize the crest of the riffle. The design of the sill is the same as if it was at the head of a pool with the thalweg on the same side as the pool adjacent to and above it. The rock ramp above it is built on an approximately 2 % slope and the riffle on an approximately 1 % slope in such a way that the sill is flush with the crest of the riffle. Any drop over the sill will scour on the downstream side and if the riffle needs to be on a slope greater than 1 % it will have to be armoured with rock larger than the armour cobble generally found in gravel cobble streams.

- When a river gradient is changed by realignment, channelization, or over-widening of a reach, the stream bottom cuts back or degrades to find a new stable slope and to provide material to rebuild the reach below. In this case, the altered section of stream needs to be rebuilt but sills can also be used at the crests of riffles to stop them from degrading faster or to restore their original height.
- In steep streams with a step-pool pattern, rock sills can be used to step the watercourse down over steep sections.

All of these techniques require detailed design, and since they require heavy machine work, a detailed regulatory review will be required.

References:

British Columbia Watershed Restoration Program. (1997).

MacInnis, Charles and Danielle Goff, DFO Antigonish Area Office. 2005. Personal communication.

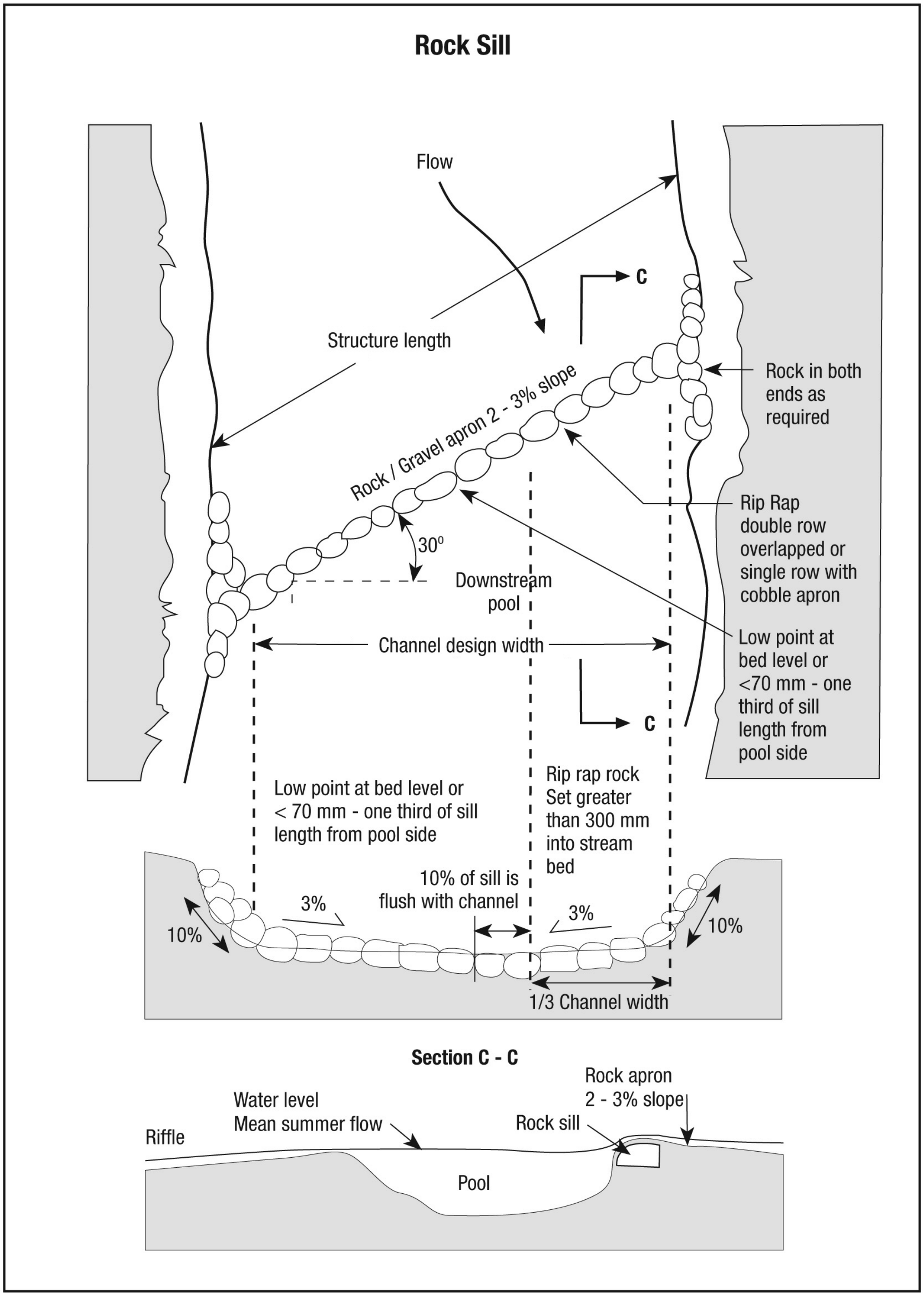

Figure 31. Conceptual drawing of a rock sill (Thaumas Environmental Consultants Ltd.).

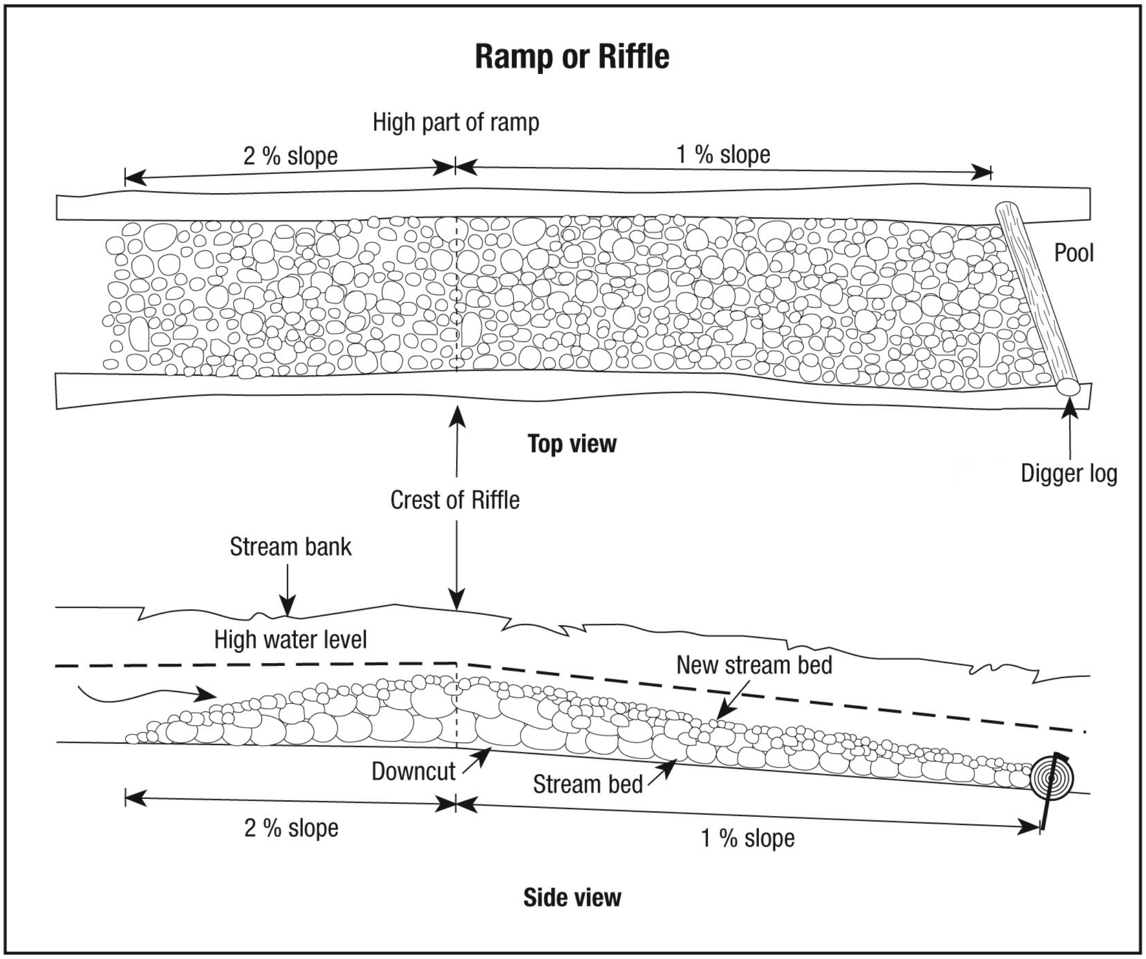

Figure 32. Conceptual drawings of a rock sill used as a gradient control in a riffle.

4.3.4 DFO Fish Habitat Restoration Fact Sheet: Low Head Barriers and Weirs

Purpose:

- To construct a low head weir with fish passage and back up water in order to create a pool.

Conditions where applicable:

- One or more of these weirs may be used to form a series of steps and pools over natural or man-made barriers.

Advantages:

- Can backup water at the lower end of a culvert plunge pool to provide improved passage at barrier culverts.
- Can be made to look natural.

Disadvantages:

- Can create fish passage problems if not designed properly.
- Require maintenance.
- Require detailed plans for permit approval.
- May require machinery.

Design criteria:

- Weirs can be a rock berm, a gabion berm, or a log berm.
- The head drop over the weir must not exceed 30 cm.
- Fish passage must be provided by a notch and apron for the fish to swim through.
- Weirs should be at least 3 m apart and the downstream weir must fit into the natural meander pattern of the stream.
- This is building a step pool section of stream to bring the flow through a steep section.

Implementation steps:

- Select the location for the structures so that the pool elevations are not more than 30 cm difference and the pools are at least 3 m apart.
- If the weir is used to provide passage at a culvert, the water depth in the outlet of the culvert should be 15 cm and the weir at least 2.5 times the diameter of the culvert downstream.
- For rock weirs, select rock large enough so that it will not be moved by the flows and dig a trench across the river in the inverted V-shape. Fill with the large rock, ensuring that the lowest point be in the center. Shape the upstream rock apron on a slope no steeper than 2:1.

- For gabion weirs, set the gabion baskets halfway into the substrate, shape the upstream rock apron on a slope no steeper than 2:1.
- For log weirs, set the brace logs level on the bottom of the stream, nail the cross log to the braces and drive the rebar through the log into the substrate at least 2 m.

References:

Federal Interagency Stream Restoration Working Group (FISRWG). 1998. Stream Corridor Restoration: Principles, Processes and Practices for Low Head Barriers and Weirs.

Bastien-Daigle, S. A. Vromans and M. MacLean. 1991. A Guide for Fish Habitat Improvement in New Brunswick. Fisheries and Oceans Canada. Canadian Technical Report of Fisheries and Aquatic Sciences. 1786E : iv + 109 p.

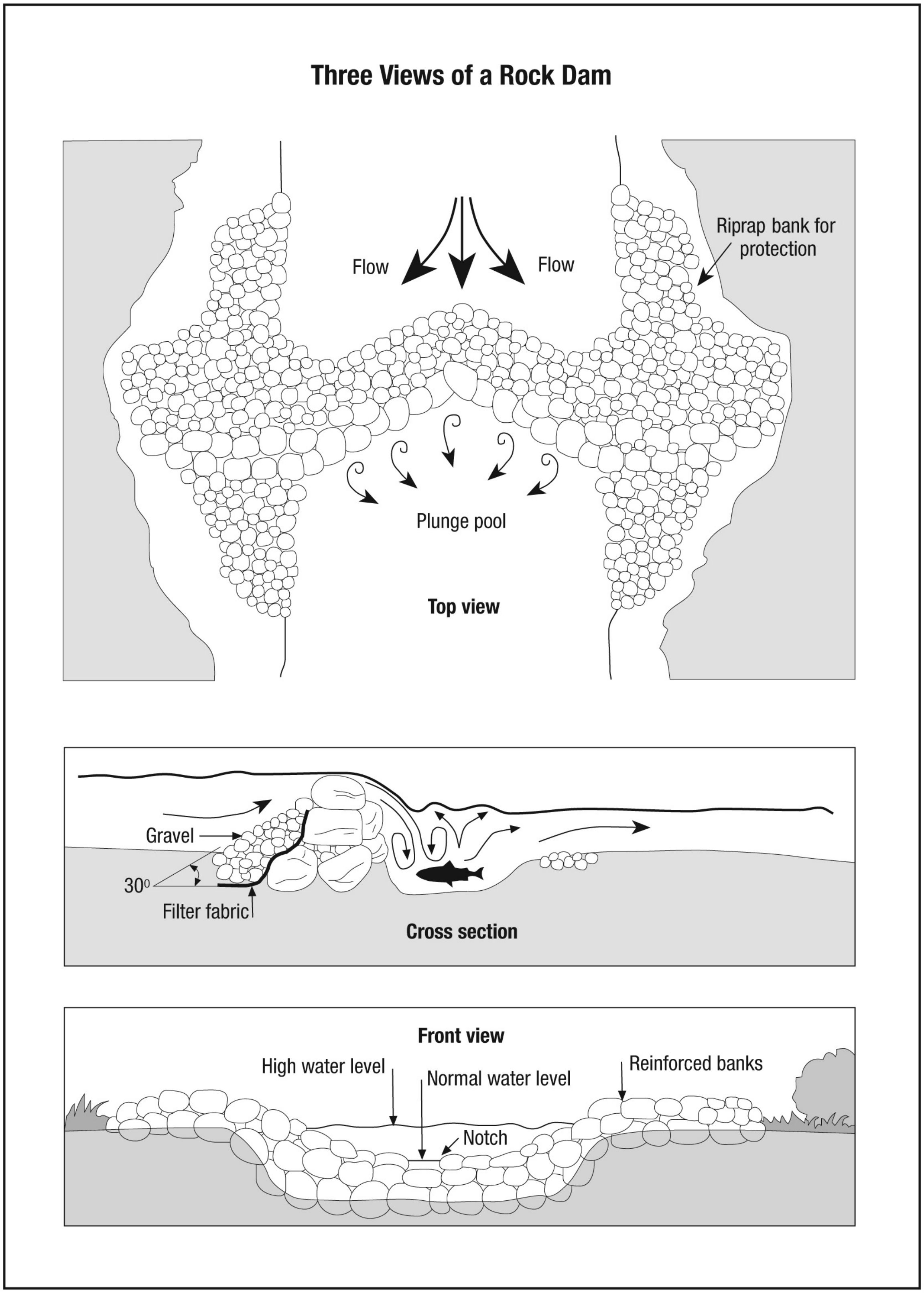

Figure 33. Conceptual drawings of a rock dam (Bastien-Daigle *et al.*, 1991).

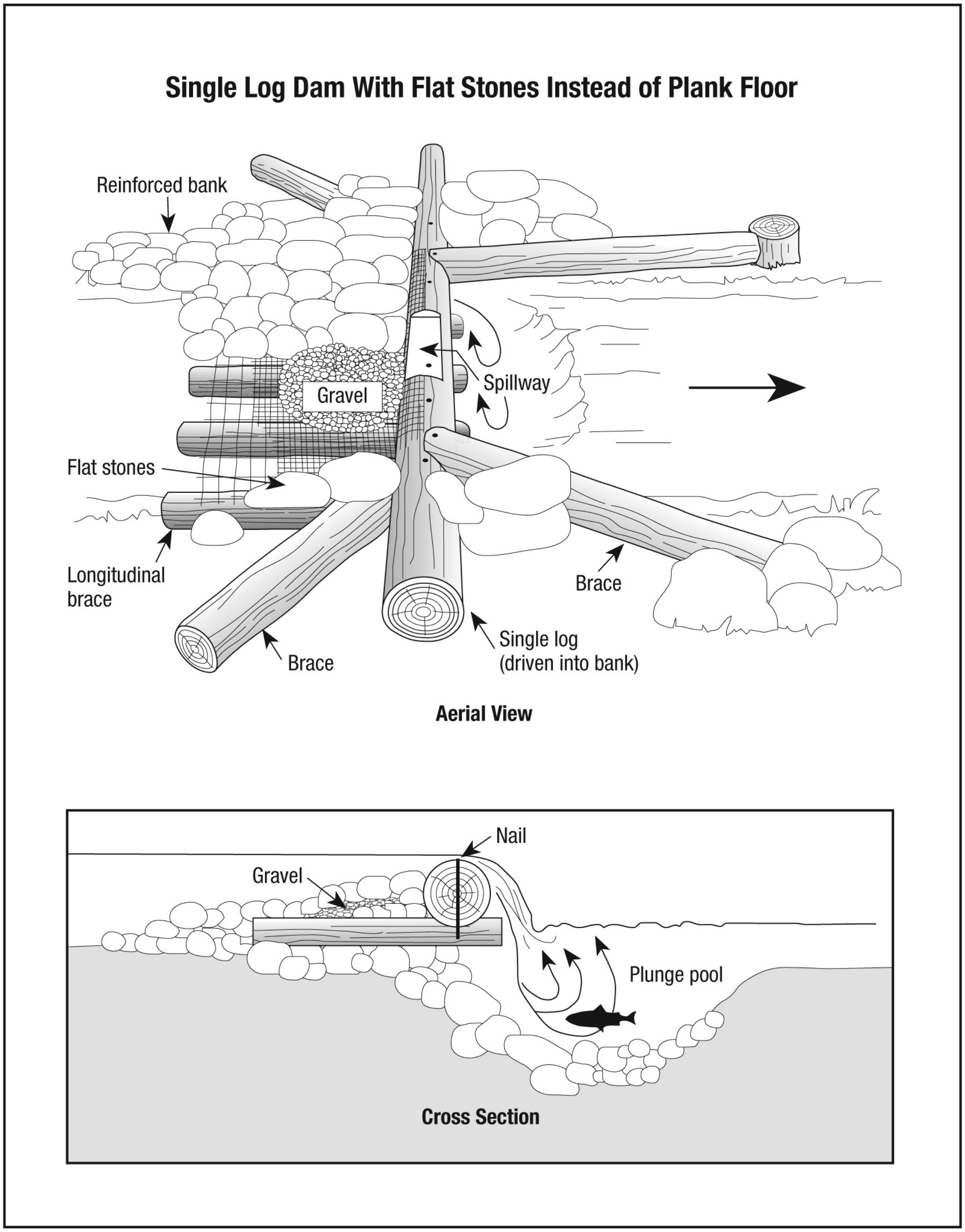

Figure 34. Conceptual drawings of a single log dam with rock ramp (Bastien-Daigle *et al.*, 1991).

4.4 REMOVAL OF OBSTRUCTIONS AND DEBRIS

A) Instream Artificial Debris
B) Woody Debris Jams
C) Beaver Dams (Active and Old)
D) Thinning of Alders

4.4.1 DFO Fish Habitat Restoration Fact Sheet: Artificial Instream Debris

Purpose:

- To remove man-made debris that may contaminate water, hinder fish passage, or alter the stream's hydrology.

Conditions where applicable:

- Debris removal is the removal of material foreign to the normal composition of a watercourse. Examples of debris include car bodies, tires, shopping carts, empty containers, and garbage.
- All human garbage should be removed.

Advantages:

- Aesthetically pleasing.
- Can remove contaminants.
- Can prevent bank erosion.
- Can permit fish passage.

Disadvantages:

- Can remove important cover.

Design criteria:

- Garbage should be removed.
- Precautions must be taken to ensure any contaminants such as oil do not leak out during removal.
- Care must be taken not to damage stream banks when removing heavy objects.
- If the debris has remained in the watercourse for a long period of time, it may have become so deeply embedded that removing it would cause more damage than leaving it in place.

Implementation:

- All garbage should be disposed of according to local, provincial and/or municipal procedures and in approved dumps.
- No heavy equipment (e.g. bulldozers, tractors, or backhoes) are allowed in the watercourse or on the banks to carry out the work.
- Material must be winched out of the streambed by machinery or equipment stationed a minimum of 15 m from the edge of the bank of the watercourse.

References:

N.B. Department of Environment and Local Government. Watercourse alterations technical guidelines.

4.4.2 DFO Fish Habitat Restoration Fact Sheet: Woody Debris Jams

Purpose:

- To remove excess branches, logs, and fallen trees that are hindering fish passage or altering the stream's hydrology.

Conditions where applicable:

- Large woody debris (LWD) plays a role in the development of fish habitat and provides instream cover. Only excessive amounts of LWD should be removed because it may:
  - Become a barrier to fish migration.
  - Lower the water's oxygen content through decay.
  - Trap silt, creating build-ups leading to decreased flow or upstream flooding.
  - Cover and destroy clean gravel substrate.
  - Cause bank erosion.
  - Flood adjacent lands.

Advantages:

- Aesthetically pleasing.
- Can remove contaminants.
- Can prevent bank erosion.
- Can permit fish passage.

Disadvantages:

- Can remove important cover.
- Removal of large woody debris can destabilize the stream and lower the productivity of the fish habitat.

Design criteria:

- Debris jams should be assessed by a habitat biologist for removal advice.
- Generally debris jams, which are not causing bank erosion and backup less than 40 cm of water, should be left.
- If the debris has remained in the watercourse for a long period of time, it may have become so deeply embedded that removing it would cause more damage than leaving it in place. Disturbing firmly embedded logs, branches, or other debris not only releases sediment into the water but may disrupt the fish habitat of which they have become a part.
- Accumulations of sand, silt, or gravel are not considered to be debris, even if they originate from an upstream location in the watercourse or built up due to the debris jam.
- Disturbing firmly embedded logs, branches, or other debris not only releases sediment into the water but may disrupt the fish habitat of which they have become a part.

- Consideration should be given to the consequences of removing uprooted trees, which are securely fastened to the banks of a watercourse. The root systems may be preventing erosion of the bank.

Implementation Steps:

- With the landowner's permission, woody debris may be placed in the riparian zone where it will not be washed back into the stream.
- Badly damaged or dead trees, which could fall into the watercourse, should be removed, but trees containing active nest cavities should be left.
- Trees leaning over the water such that the trunk is at an angle of 30^{o} or less, measured from the water surface, should be removed.
- Branches from overhanging trees which would catch debris floating in the watercourse should be trimmed.

References:

N.B. Department of Environment and Local Government. Watercourse Alterations Technical Guidelines.

4.4.3 DFO Fish Habitat Restoration Fact Sheet: Beaver dam (Active and Old)

Purpose:

- To remove or breach beaver dams in order to provide fish passage and prevent erosion or damage to property or infrastructure.

Conditions were applicable:

- The decision to remove beaver dams should be made in consultation with your local wildlife biologist.
- Beaver dams provide holding pools that are refuge for fish in low flow periods and during winter.
- Not all beaver dams are fish passage problems under normal migration flows.
- Beaver dams are not considered to be debris.

Advantages:

- Opens up passage for migrating fish.
- Drains the pond and restores stream habitats.
- Reduces silt accumulation.

Disadvantages:

- Drains a pond that may be important summer refuge and overwintering habitat for fish.
- Active dams are rebuilt quickly.

Design criteria:

- Carefully follow provincial guidelines, as they could vary among provinces.
- Follow the conditions set out in the Watercourse Alteration PSrmit, if one is needed.
- When carried out manually by a representative of the provincial wildlife department or under provincial guidelines, the removal of beaver dams does not require a permit.
- If removed by mechanical methods, a watercourse alteration permit is required.
- Contact your local provincial wildlife biologist for more information regarding the removal of beaver dams.

Implementation steps:

- Carry out the work according to guidelines, permits, or direction from a provincial wildlife biologist.

References:

NB Department of Environment and Local Government **-** Watercourse Alterations Technical Guidelines.

4.4.4 DFO Fish Habitat Restoration Fact Sheet: Thinning of Alders (Overhead and Instream)

Purpose:

- To thin alder growth and the growth of other small trees, which are obstructing the stream flow.
- To increase sunlight penetration and increase primary productivity of the stream.

Conditions Where Applicable:

- Generally, alders, weeds, or small trees growing on or within the banks of the watercourse should not be removed, as they augment natural fish cover, contribute to food input from terrestrial insects and control erosion.
- In some cases, the growth is obstructing the flow and causing the stream to retain sediments and become shallow and braided. In these cases, the habitat would benefit from alder thinning.
- Occasionally, canopy overgrowth may reduce sunlight penetration and affect the primary productivity of the stream. Thinning the alders should only be attempted if fish habitat productivity is limited and it will not result in significantly increased water temperatures.

Advantages:

- Prevents siltation.
- Returns the flow to a single channel.
- Flushes out accumulated silt.
- Increases primary productivity.

Disadvantages:

- Can reduce important instream cover.

Design criteria:

- Determine the natural stream width.
- Find the main channel through the alders.

Implementation steps:

- Selectively clear the instream alders or small tree branches back to the natural stream width following along the main channel.
- The alders can be thinned out so to allow one person to walk in the thalweg (clear branches over the thalweg to a height of 2 m).
- Maintain the forest canopy.
- All debris that is removed should be disposed of where it will not return to the watercourse.

- Debris can be woven between the alders across braided channels to catch debris and keep the flows in the main channel.

References:

NB Department of Environment and Local Government - Watercourse Alterations Technical Guidelines.

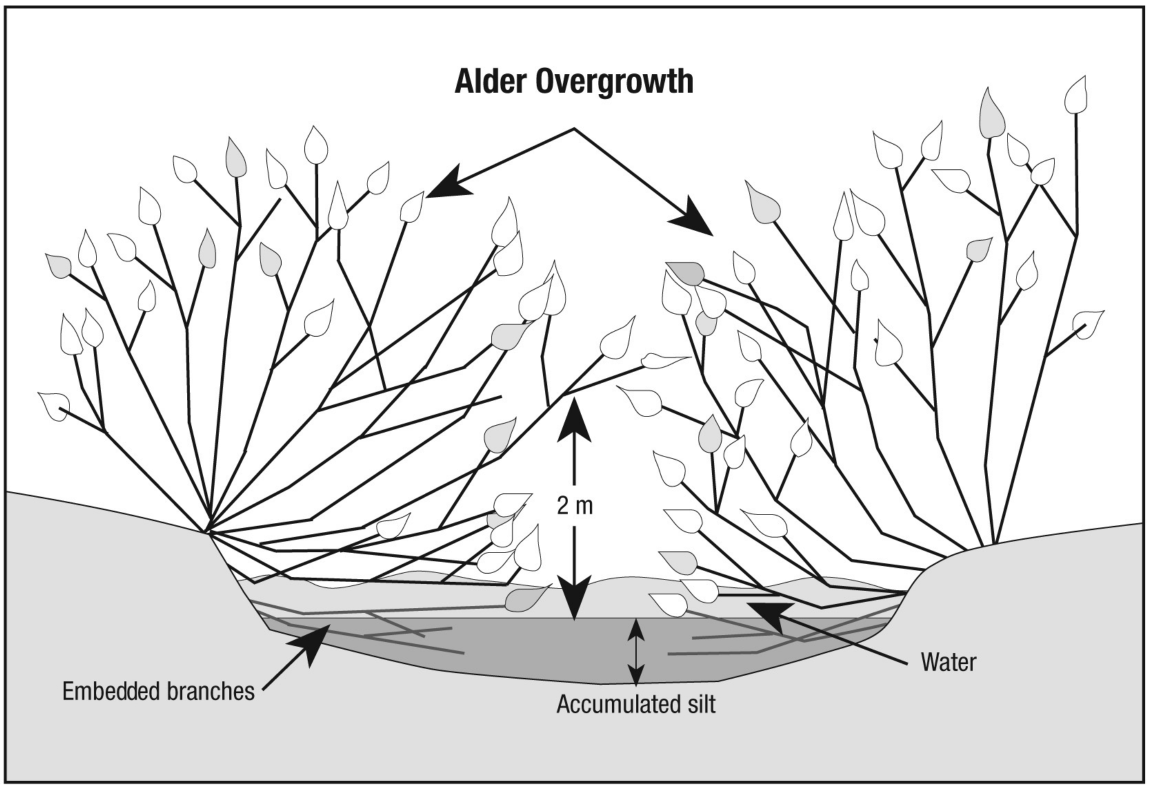

Figure 35. Conceptual drawing on clearing alder overgrowth.

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6.0 GLOSSARY

Abutment A wall or mass supporting the end of a bridge, arch or span, and sustaining the pressure of the abutting earth.

Adult Life stage of fish where they have matured and are able to spawn (reproduce).

Aggradation Progressive rising of a channel bed by accumulation of sediment.

Algae Small microscopic plant life consisting of one-celled to many-celled life forms either free-floating or benthic (on the bottom of lakes and streams). Algae forms the base of many food chains as many algae are involved in photosynthetic activity. Often found attached to substrate material (rocks, logs, etc.) in streams and lakes.

Alevin Also called sac fry. Life stage of development of the salmonid embryo from hatching to absorption of the yolk sac.

Alignment The fixing of points on the ground for the laying out of a culvert, bridge, abutment or pier.

Anadromous Fish that spend a portion of their life cycle in both fresh and salt water. These fish reproduce and spend most/all of their juvenile rearing in freshwater and a portion of their adult life cycle at sea (e.g. Sea-run Atlantic salmon and brook, brown and rainbow trout).

Approach Velocity The speed at which water approaches a culvert, constriction, spillway, weir, or water intake structure.

Apron The protective material laid on the bed of a watercourse to prevent scour.

Aqueduct A conduit, usually of considerable size, used to convey water. The conduit may consist of one or more of the following: canal, pipeline, tunnel, siphon, or so-called “inverted siphon”.

Bankfull Width The distance between the bases of perennial vegetation on opposite banks. This is normally the width of the one-in-two year daily peak flow channel.

Bank Height The vertical distance from the stream edge to the top of the bank adjacent to the stream.

Bank Stability The degree of erosion on the banks of streams as caused by natural forces or by human activity. This can be descriptive or can be determined as a proportion of the stream bank that is stable (i.e. demonstrating no erosion) or, alternatively, unstable.

Barrier Any obstruction that impedes the movement of fish, the stopping of a spawning run, or the blocking of individuals from nursery areas or areas of maturation.

Bedrock All exposed rock with no overburden.

Boulder All rock over 25 cm (10 in) in diameter.

Braided Channel Refers to the stretch of river that is divided into separate channels which successively meet and divide. Often associated with low gradient stretches or river mouths (deltas). Braided stretches often provide good spawning habitat.

Brush Bundle Stems of species such as red osier dogwood and willow, 150 cm to 180 cm in length, tied into a bundle with wire.

Canopy Cover Refers to the cover or shading provided by the foliage and branches of large trees hanging over the stream. Canopy cover is usually expressed as a percentage of the stream that is covered by the foliage and branches of large trees.

Carrying Capacity Also called productive capacity. Refers to the maximum average number or weight of a given organism that a stream or river can maintain through natural processes.

Catadromous Fish that spend a portion of their life cycle in both fresh and salt water. Catadromous fish reproduce in salt water and their young invade freshwater systems and grow to maturity when the adults return to the salt water to reproduce. An example are eels which travel to the Sargasso Sea for spawning and the young swim or drift back to their continental waters and ascend streams.

Channel A long, narrow, sloping trough-like depression where a natural stream flows or may flow.

Channel Pattern Proper channel pattern is a sign of watershed health. A normal stream should follow a riffle-pool pattern, with proper meanders occurring every 6 stream-widths (if a stream is an average of 2m across, meanders will occur ever 12m).

Channel Sinuosity Refers to the degree of meander or bending of a stream channel and can be quantified as the total channel length over a distance in relation to the minimum distance between these two points.

Cobble Rock material between 8 and 25 cm.

Cover An area of shelter in a stream that provides aquatic organisms with protection from predators and/or a place to rest and conserve energy.

Culvert A closed conduit for conveying water through an embankment.

Debris Floating or sunken trash (including car bodies, empty containers, and garbage) and dead or decaying vegetation.

Debris Removal Removal of material from the bed or banks of the watercourse foreign to the normal composition.

Deflector A triangular structure built in a stream to deflect water; it creates a deeper, narrower area and/or pool area, and it flushes sediment.

Deleterious Causing damage; harmful.

Depth Refers to the distance from the stream bottom to the water surface. This can be at a specific point or can be averaged for a cross section, stream section or reach, etc.

Discharge Stream flow. The rate of flow or the volume of water flowing at a location in the stream in cubic metres per second. Discharge can be instantaneous or averaged daily, monthly or annually.

Drainage Basin A concave surface collecting precipitation into one stream.

Ecology The (branch of biology) science dealing with the relation between living organisms and their environment; the relationship between the distribution of human groups relative to resources with consequential social and cultural patterns.

Enhancement Refers to the activities and strategies that are intended to improve the production of fish in a given watershed, section of stream, or in some instances, a region encompassing several rivers. It can include activities such as fry and juvenile stocking and rearing, adult transfers, kelt rejuvenation, stream remedial and obstruction removal, etc.

Environment The sum of all external conditions and influences affecting the existence and development of living organisms.

Erosion — The weathering of streams, rivers and their watersheds by the forces of wind, water, ice, gravity, etc. Also refers to erosion by forces caused by human intervention.

Estuary — A semi-enclosed body of water which has a free connection with the open ocean and within which sea water is measurably diluted with fresh water derived from land drainage.

Fascines — Bundles of live cuttings from shrubs.

Filter Fabric — A granular material or woven fabric used in erosion control.

Fish — Where used as a noun means any species of fish protected by Federal or Provincial regulations.

Fisheries — The commercial, recreational or sustenance harvest or catch of fish in watercourses; the fish stocks.

Fisheries Act — Federal legislation protecting fish and fish habitat.

Flats — Stream habitat that is characterized by water with slight to moderate currents with unbroken surface, with less depth than pool habitat and usually wider than the stream average. Substrate is usually comprised of fine materials.

Flood Plain — The flat region bordering a stream that is subject to frequent, if not annual, flooding during periods of high discharge. Material in this region is usually deposited from sediments transported by the stream high flows.

Freshet (Spate) — A rapid rise in stream discharge and level as a result of heavy rains or, in the winter/spring, as a result of melting snow and ice.

Fry — The life stage of fish, after hatching from the egg, during their first year of life. Newly hatched fish that have not started feeding and are using up their reserves from the yolk sac are referred as *alevins*.

Gabion — Wire baskets filled with coarse gravel or rock used especially to support the bank of a watercourse or abutment.

Gradient (Slope) The general slope or vertical drop of a stream-per-unit of length. Usually measured in metres/kilometres and can be estimated from topographic maps for long stream sections or can be visually estimated or measured, using surveying equipment for shorter stream sections. Gradient has a relationship to velocity, substrate, depth, width, etc. and will often determine the habitat distribution and presence/absence of barriers. Different species prefer various gradients, and each species generally has an average gradient at which a stream is no longer passable. A high gradient will lead to a natural step-pool stream configuration. This will directly affect the restoration techniques that are applicable and should be noted.

Gravel Rock material between 0.2 and 8 cm.

Groundwater Water that is found under the earth's surface usually in porous rock, soil and other cavities.

Habitat The total environment (physical, chemical and biological) required by an organism to complete all of its life processes. For fish this includes the requirements for space, food, shelter, reproduction, rearing and nursery area, water quality, etc.

Habitat Improvement Refers to activities and strategies that are intended to improve the carrying capacity of a stream section for fish production. This can include activities intended to correct problems created as a result of human activity or may be intended to provide habitat features that increase the stream potential under natural conditions.

High Water The level of water which fills only the stream channel and not the flood plain; the normal level of water under typical rain conditions.

Ice Scour This refers to the scouring of the stream bank, most frequently at the high water mark, as a result of periods of high discharge in the late winter/spring. Floating ice moved under high water conditions causes erosion of the stream bank and leaves a discernable mark. Often used to estimate the range in discharge of a stream (reach).

Instream Cover Refers to the cover provided for fish from flows, predators, etc in the wetted reaches of the stream by instream debris (logs, tree roots), undercut banks, large substrate (boulders, rocks, etc), and instream vegetation. Instream cover is often estimated as a percentage of the stream area of the total of the above cover features.

Integrated Management — Planning and managing human activities in a comprehensive way so as to reduce conflicts and to consider all factors necessary for the conservation and sustainable use of aquatic resources and the shared use of aquatic space.

Juvenile — A young fish not yet mature enough to spawn.

Large Organic Debris — Refers to trees, logs, branches, etc. that are present in the stream as a result of wind, erosive forces and, occasionally, human activities (e.g. forestry and harvesting). This material can provide cover but can also cause jams and barriers to fish migration and act as sediment traps. Provides good material for invertebrate production.

Lichen — A plant-like organism consisting of algae and fungus living in symbiosis on a solid surface such as boulders, bedrock, etc. Can be used to determine the maximum water level or flood height of a river (i.e. there will be limited lichen growth below the permanent high-water mark.

Log Crib — A structure made of vertically and horizontally placed logs that stabilizes the bank and provides cover for fish.

Marsh — An area of soft, wet or periodically inundated land generally treeless and usually characterized by grasses and other low growth.

Meandering — Refers to the bend or sinuosity of a stream channel. The process by which a stream winds or snakes its way across the surrounding terrain often changing its course gradually as a result of erosion and transportation/deposition of sediments and other material.

Macrophytes — Large (macroscopic) aquatic plants usually associated with low flow, deep areas in a river (flats and steadies) and shallow ponds.

Migration — The deliberate movement of fish from one habitat to another. Includes both the upstream and downstream movement of young fish from rearing habitats to larger habitats (e.g. lakes and the ocean) and adult fish to spawning habitats for reproduction.

Mud — A soft, saturated mixture mainly of silt and clay.

Mulch — A protective covering, such as straw, spread on the ground to reduce evaporation and erosion, control weeds or improve soil.

Non sustainable — Not able to be sustained over an indefinite period without damage to the environment; (of a resource) that cannot be used at a given level without permanent depletion, non-renewable (Oxford [England]; New York: Oxford University Press, 1992).

Nursery Habitat Refers generally to habitat used by juvenile life stages of fish for feeding, cover, growth, etc.

Obstructions Instream features that reduce or prevent the upstream movement and migration of fish. These obstructions can be falls and rapids, beaver dams, log jams, etc. and can also include improperly placed culverts and bridges. Barriers can also include velocity barriers where the stream velocity is too great for fish to swim against. Determination of whether a barrier is passable to fish will depend upon the stream conditions at the time of migration, the species and size of fish, etc. and is best evaluated by professionals.

Organic Debris Refers to all material in a stream that is of organic origin including algae, aquatic plants, trees, etc. as well as material from these sources. A distinction is often made between organic debris and **large** organic debris (see previous section).

Overhanging Cover Refers to cover provided by vegetation such as grasses, shrubs, alders, and other low story trees adjacent to the stream up to 1.0 metre above the water surface. This is distinguishable from canopy cover (see definition) provided by larger trees. It is most often expressed as a percentage of the stream area that is covered by overhanging vegetation.

Peak Flow The maximum instantaneous stage or discharge of a watercourse in flood.

Pools Habitat associated with water of considerable depth (> 50 cm) in relation to the average for the stream section. Pools generally have slow water and a smooth surface, but can be characterized by swift turbulent water flowing into and out of them. Substrate is often comprised of finer material as a result of the drop in stream velocity in pools.

Pool:Riffle Ratio Refers to the ratio, as percentages, of pool and riffle type habitats in a stream reach or section. Habitat with good diversity is characterized by higher pool to riffle ratios.

Plunge Pool Refers to the pool below a barrier or falls created by the erosive forces of water falling from the barrier. The presence and characteristics of a plunge pool is an important factor in the ability of fish to pass a given barrier.

Rapids Habitat that is characterized by rapid, turbulent, shallow water with broken surface often with “white” water flowing over coarse, large boulder/bedrock substrate. Most often associated with larger rivers and the higher gradient stretches of these systems and is analogous to riffle stretches in small streams.

Redd The gravel nest where salmonid fishes lay their eggs.

Riffles Habitat that is characterized by shallow water (<25 cm) with moderate current with broken surface flow usually over gravel, cobble, rubble, and small boulder substrate. Excellent nursery habitat for juvenile salmonids.

Riprap Cobbles, boulders, broken stone or other hard materials dumped or placed along the bank of a watercourse as protection against erosion by water or the elements.

Riparian Related to or situated on the bank of a river or stream.

River A large, natural freshwater surface stream having a permanent or seasonal flow and moving toward a sea, lake or another river in a definite channel.

Rubble See cobble.

Runs Habitat characterized by rapid current flow in a deep, narrow channel over a variety of substrate types. Flow is less turbulent than in riffle/rapids.

Runoff Refers to the water that drains from the terrestrial confines of the watershed into the stream. Runoff amounts are determined by the amount of precipitation, evapotranspiration, temperature, soil permeability, groundwater sources, vegetation, etc.

Salmonid Refers to a member of the fish family classed as Salmonidae and includes salmon, trout, and char.

Sand Granular soil or detritus coarser than silt and finer than gravel, ranging in diameter from 0.0625 to 2 mm.

Scouring Gradual or rapid erosion of material in the stream channel or flood plain by water and/or ice.

Sedimentation The deposition of material in the stream bed, primarily the finer materials (e.g. clays, silt, sediment, sand, etc.) eroded from stream and its watershed.

Shore The narrow strip of land in immediate contact with the water including the zone between high and low water marks.

Silt An earthy sediment consisting of fine particles of rock that is suspended in and carried by water.

Spawn To produce or deposit eggs or discharge sperm.

Spawning Habitat Habitat used by actively reproducing fish for the deposition and incubation of fertilized eggs. For salmonids, this habitat is primarily in a shallow stream section with moderate to strong water flows over primarily cobbles and gravels of distinct size range. It is often associated with pool and riffle habitats.

Spring A surface where, without the assistance of man, water issues from a rock or soil onto land or onto the body of water, the place of issuance being relatively restricted in size.

Stream A watercourse, which has a flow of water for all or part of the year and has a defined channel showing signs of scouring and washing.

Stream Bank The rising ground bordering a stream channel; right and left banks are determined while facing downstream.

Stream Bed The bottom of the stream, below the usual water surface.

Stream Flow The discharge of water at any particular time period; measurement is in a unit volume per second such as cubic feet or cubic metres per second.

Stream Width The distance between vegetated banks. Stream width is an important indicator of general watershed health. If a stream appears to be wide and shallow, in most cases there is a problem. Proper stream width can be calculated from average water flow (see also Bankfull Width).

Substrate The materials making up the bed of a watercourse.

Substrate Size Substrate size is an extremely important factor when planning restoration. While digger logs and rock sills work well with substrates ranging from sand and gravel to small rocks, they are usually completely useless in smaller streams with substrate consisting of large rocks or boulders. However, as streams, water flows and structures get larger in size, the tolerance for larger substrate does increase. The presence of exposed bedrock should also be noted, as it will not be affected by most restoration techniques.

Thalweg The path of maximum depth in a river or stream; it normally follows a meandering path back and forth across the channel.

Vegetation Woody or non-woody plants; in reference here to plants used to stabilize banks and shores and to retard erosion.

Water Quality A general term denoting a category of properties of water; commonly used in reference to chemical, physical and biological characteristics and temperature of water.

Watershed Divide A convex surface, such as a mountain or hill, which sheds water from one point or ridge into several streams which may form its boundary.

Working With Nature This means returning the ecological processes back to as close as possible to the natural function and productivity that existed before poor practices impacted and alerted the system. Most of this can be achieved without significantly affecting our current lifestyle. It just requires that everyone adopt best management practices and work with nature to heal the past damage.