Fisheries and Oceans   Pêches et Océans

Land Development Guidelines for the Protection of Aquatic Habitat

These guidelines were produced by the Habitat Management Division of the Department of Fisheries and Oceans and the Integrated Management Branch of the Ministry of Environment, Lands and Parks.

The authors gratefully acknowledge all those people who contributed to the composition of these guidelines.

Complied and edited by Barry Chilibeck, Department of Fisheries and Oceans,
and Geoff Chislett and Gary Norris, Ministry of Environment, Lands and Parks.

First Printing:	May 1992
Second Printing:	September 1993

TABLE OF CONTENTS

TABLE OF CONTENTS 3

LIST OF FIGURES 5

SECTION 1
INTRODUCTION 9

SECTION 2
LEAVE STRIPS 15

SECTION 3
EROSION AND SEDIMENT CONTROL AND SITE DEVELOPMENT PRACTICES 23

SECTION 4
STORMWATER MANAGEMENT 45

SECTION 5
INSTREAM WORK 63

SECTION 6
FISH PASSAGE AND CULVERTS 69

SECTION 7
IMPLEMENTING THE LAND DEVELOPMENT GUIDELINES 81

SECTION 8
LAND DEVELOPMENT EXAMPLE 89

APPENDIX I
REGULATIONS 109

APPENDIX II
SALMONID HABITAT 117

APPENDIX III
OPERATING WINDOWS FOR FISHERIES SENSITIVE ZONES 123

REFERENCES 127

LIST OF FIGURES

Figure 2.1
Riparian and Fisheries Sensitive Zones........15

Figure 2.2
Riparian Zone Benefits to Aquatic Habitat........16

Figure 2.3
Minimum Leave Strip for a Well-defined High Water Mark
in a Residential/Low Density Area........18

Figure 2.4
Minimum Leave Strip Width for a Poorly-defined High Water Mark
in a Residential/Low Density Area........19

Figure 2.5
Minimum Leave Strip for a Ravine or Steep-sloped Banks
in a Residential/Low Density Area........20

Figure 2.6
Plan View of Riparian Leave Strips........21

Figure 3.1
Surface and Slope Erosion and Sediment Control Applications........27

Figure 3.2
Typical Interceptor Ditch Construction and Application........31

Figure 3.3
Typical Silt Fence Construction and Applications........33

Figure 3.4
Sediment Control Pond Plan and Sections........39

Figure 3.5
Sediment Control Pond Riser Details and Baffle Layouts........40

Figure 3.6
Single Lot Development Erosion and Sediment Control Features........44

Figure 4.1
Dry Detention Pond Plan and Sections........51

Figure 4.2
Wet Detention Pond Plan and Sections........53

Figure 4.3
Detention Pond Control Structure Typical Details........54

Figure 4.4
Infiltration System Design and Typical Application........58

Figure 4.5
Coalescing Plate Oil-Water Separator........59

Figure 6.1
Culvert Installation Limiting Fish Access........72

Figure 6.2
Culvert Providing Upstream Fish Passage........73

Figure 6.3
Culvert Installation for a Small Creek with Provision for Fry Passage....................................75

Figure 6.4
Diagram and Photo of a Rock Outlet Pool and Tailwater Control Structure............................78

Figure 6.5
Diagram and Photo of Typical Culvert Baffle Layout and Installation.....................................80

Figure 7.1
Land Development Guidelines Screening and Application Chart...84

Figure 8.1
Predevelopment Map...91

Figure 8.2
Erosion and Sediment Control Map..94

Figure 8.3
Developed Site Map..96

Figure 8.4
Stream Information Summary (SIS) Report Data for Land Development Example................97

Figure 8.5
Land Development Example Site IDF Curves..103

Figure 8.6
Calculation of Predevelopment and Post-development Peak Flows for Land Development Example..106

Figure 8.7
Calculation Spreadsheet and Simplified Hydrograph for Detention Volume Requirements.....107

Figure A2.1
Anadromous Salmonid Life Cycle..119

Figure A3.1
Fisheries Sensitive Zone Areas of British Columbia...126

LIST OF TABLES

Table 1.1 - Partial List of Agency Approvals for Land Development Projects........................12
Table 3.1 - Required Surface Area and Overflow Rates for Discrete Particle Settling...............35
Table 4.1 - Advantages and Disadvantages of Various Detention Technologies.......................47
Table 6.1 - Fisheries and Design Considerations for Stream Crossing Structures.....................70
Table 6.2 - Sustained, Prolonged and Burst Swimming Speeds For Various Fish.......................75
Table 8.1 - Example Development Construction Schedule..91
Table 8.2 - Land Cover Factors used for Rational Formula..98
Table 8.3 - Land Cover Factors used in Overland Flow Tc Calculation....................................99
Table 8.4 - Recurrence Intervals and Catchment Areas..100
Table 8.5 - Land Development Example IDF Data...101
Table A3.1 - Fisheries Sensitive Zone Species Timing Windows..126

SECTION 1
INTRODUCTION

Purpose and Scope

The purpose of these guidelines is to protect fish populations and their habitat from the damaging effects of land development activities. The information contained in these guidelines pertains to the preservation of Pacific salmon populations, a federally-managed resource (DFO), and steelhead, trout, char and other freshwater species, which are managed by the provincial Ministry of Environment, Lands and Parks (MOELP). These guidelines apply primarily to salmon, trout and char, collectively termed salmonids, but are applicable to all fish species. Understandably, the recommendations contained in these guidelines are generalized and, as such, are applicable to a wide range of situations. Although the federal and provincial agencies work in close association, it is important that both be contacted whenever a problem arises regarding fisheries resources that cannot be resolved through reference to the land development guidelines. In some instances and locations, it may be necessary for personnel of the federal and provincial habitat management agencies to modify recommendations presented in these guidelines to reflect site specific conditions and in order to protect salmonid habitat.

Fish Habitat, Land Development and Fisheries Sensitive Zones

DFO is responsible, under the *Fisheries Act* (R.S.C., 1985, c. F-14), to protect fish and fish habitat in "waters frequented by fish" (Appendix I provides a brief regulatory synopsis for land development purposes). This includes protection from any work in or near these waters. The provincial government (MOELP) is responsible for management of steelhead, trout, char and other non-salmonid freshwater species under the *Fisheries Act*. The definitions of fish and fish habitat under the *Fisheries Act* are as follows:

- *Fish* — all fish, shellfish, crustaceans and marine animals, and the eggs, spawn, spat and juvenile stages of fish, shellfish, crustaceans and marine animals.
- *Fish Habitat* — the spawning grounds, nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes.

All developments in or adjacent to waters containing fish or fish habitat, whether marine or freshwater, require the approval of DFO and MOELP. In order to better define the requirements for protection of aquatic habitat, Fisheries Sensitive Zones (FSZ) were developed. They are defined as the instream aquatic habitats, as well as the out-of-stream habitat features such as side channels, wetlands and riparian areas. Land developments have the potential to seriously degrade and destroy fish habitat and impact fish populations. Accordingly, DFO and MOELP carefully control work in and around the Fisheries Sensitive Zone.

Land Development Guideline Objectives

The primary goal of these guidelines is to ensure that the quantity and quality of fish habitat are preserved and maintained at the productive level that existed prior to land development activities. The *Fisheries Act* provides the legislative basis for DFO's *Policy for the Management of Fish Habitat* (DFO 1986) and the principle of no net loss of the productive capacity (i.e. the maximum natural capacity) of fish habitat. Each land development project, therefore, is subject to the following guideline objectives.

- Provision and protection of leave strips adjacent to watercourses.
- Control of soil erosion and sediment in runoff water.
- Control of rates of water runoff to minimize impacts on watercourses.
- Control of instream work, construction and diversions on watercourses.
- Maintenance of fish passage in watercourses for all salmonid life stages.
- Prevention of the discharge of deleterious substances to watercourses.

The second goal of these guidelines is to encourage the provision of environmental assessment/impact information to DFO and MOELP thereby improving the efficiency and effectiveness of the regulatory referral and approval process. These guidelines are intended to assist land developers to identify problems prior to development and present feasible solutions or measures to prevent potential negative effects on fish and fish habitat. Their use will also avoid potentially costly mitigation, restoration and compensation requirements. An overall awareness of environmental concerns regarding land development, fish and fish habitat is essential if the national goal of sustainable development is to be achieved.

Referral and Approval Process

Land development projects are referred by individuals, companies and other agencies to both DFO and MOELP. In most cases, the proponent of the project is responsible for providing the required assessment information to the agencies involved. This information is summarized in an impact assessment document, described later in the guidelines, that outlines the development proposal and describes how the features of these guidelines will be incorporated. Generally, the potential impacts on fish and fish habitat will be determined by DFO and MOELP staff based on habitat function, productivity, uniqueness and sensitivity. The productive capacity is then rated and used to evaluate the impact of the proposed development. If a potential impact exists, alternate siting, mitigation or compensation options are examined to determine if no net loss can be achieved. If no net loss can be achieved, the project will be approved under the *Fisheries Act*. In some cases, additional information will be requested from the proponent to substantiate the impact assessment. If impacts are unacceptable and alternative siting, mitigation or compensation are not possible, or the required information has not been provided, the project will not be approved. Generally, early consultation with DFO and MOELP, and application of these guidelines, will facilitate generation of a suitable land development plan. Proponents should provide as much accurate information as possible so as to improve the efficiency of the process for all parties concerned.

Federal Environmental Assessment and Review Process (EARP)

The EARP process requires the lead federal agency (the agency with the primary decision-making responsibility) on a project to carry out an initial environmental assessment screening. If there are no impacts or the impacts can be mitigated with known technology, the project will be allowed to proceed. If the screening indicates significant adverse impacts will result, the project will be referred to the Minister of the Environment for public review by the Federal Environmental Assessment Review Office (FEARO).

Regulation of Land Development - Other Jurisdictions

While satisfying the requirements of the *Fisheries Act* is one step in the approval process, there are a number of other possible requirements. Other federal, provincial, municipal or local acts or by-laws may require applications, approvals and permits. These guidelines do not take precedence over statutory and other requirements imposed by other agencies. Approval by DFO in no way constitutes regional or local authority approval of the development of the project. On the other hand, no approval given or implicit, by any regional or local authority, relieves the proponent of responsibilities for the protection of the aquatic habitat as required by federal and provincial statutes. Where fish habitat is damaged or lost, the powers of the *Fisheries Act*, through the court system, may be used to order the proponent to restore or compensate for that habitat and pay the associated expenses. Where other limits or conditions are specified by acts or by-laws, the more stringent or limiting requirement shall take precedence. A list of some federal, provincial and municipal statutes, approvals and permits is included in Table 1.1.

Table 1.1 - Partial List of Agency Approvals for Land Development Projects

Agency	Legislation	Description
Federal:		
Department of Fisheries and Oceans	Fisheries Act	Approval for activities that impact fish and fish habitat including discharges of deleterious substances. Requirements for the provision of fishways, canals, fishscreens or guards and the flow of water.
Transport Canada: Canadian Coast Guard	Navigable Waters Protection Act	Permit for activities in, around, under and over navigable waters for commerce, transportation or recreation.
Department of Indian and Northern Affairs	Indian act	Approval for activities on lands under jurisdiction
Department of Energy, Mines and Resources: Explosives Branch	Explosives Act	Use and transport of explosives.
Federal Environmental Assessment Review Office (FEARO)	Environmental Assessment and Review Process Guidelines Order	Requirement for impact assessment, environmental protection, EARP screening, assessment and review. Administration of public review panel.
Environment Canada:		
Environment Protection	Environmental Protection Act	Environment and human health, toxic substances, water/air quality standards.
Canadian Wildlife Service	Canadian Wildlife Act	Permission for activities affecting wildlife and wildlife habitat in wildlife areas.
	Migratory Bird Conventions Act	Approval for activities affecting migratory birds and their habitat.
Inland Waters	International River Improvements Act	Approval of work affecting water quality and environment of rivers flowing outside Canada.

Table 1.1 - Partial List of Agency Approvals for Land Development Projects

Agency	Legislation	Description
Provincial:		
Ministry of Environment, Lands and Parks:		
Regional Operations	Fisheries Act	Approval for activities that impact fish and fish habitat.
Water Management Branch	Water Act	Approval for short term use, storage and diversion of water. Approval of alterations and work in and about a stream (Section 7).
Environmental Protection Division	Waste Management Act	Permit the discharge or emission of effluent, waste or contaminants into air, land or water. Restrictions regarding solid and toxic wastes.
Crown Lands Branch	Land Act	Regulation of the sale, lease and license of occupation, rights-of-way, special use permits, easements, map reserves and permission to construct on crown lands.
Environmental Assessment Branch	Environment Management Act	Requirements for impact assessment and environmental protection as ordered.
Ministry of Agriculture, Fisheries and Food:	Soil Conservation Act	Permit for the removal of soil from an ALR. Regulations to prevent and control soil erosion.
Agricultural Land Commission	Agricultural Land Commission Act	Approval to use land in the ALR for other than farm use.
Ministry of Health: Provincial Health Officer	Health Act	Approval of construction camps. Regulations for potable water supply, sewage disposal, sanitation and food supply operations.
Ministry of Attorney General: Fire Commissioner	Fire Services Act	Approval for more than 22.5 liters of fuel storage onsite and onsite fuel dispensing.
Ministry of Municipal Affairs, Recreation and Housing: Archaeology Branch	Heritage Conservation Act	Approval to excavate or alter sites of archaeological or historical significance.
Regional/Municipal:		
Regional/Municipal Governments	Municipal Act Regional and Municipal By-laws	Permits for construction. Approval of zoning or re-zoning. Regulation of set backs, development densities (FSR), local land use and building codes. Permits for clearing and burning.

Review and Updating of the Land Development Guidelines

These guidelines will be reviewed and updated every two years to account for changes in technologies, standards or requirements regarding land development and its associated impacts on the aquatic environment. Comments and input into these guidelines are welcomed and should be forwarded to:

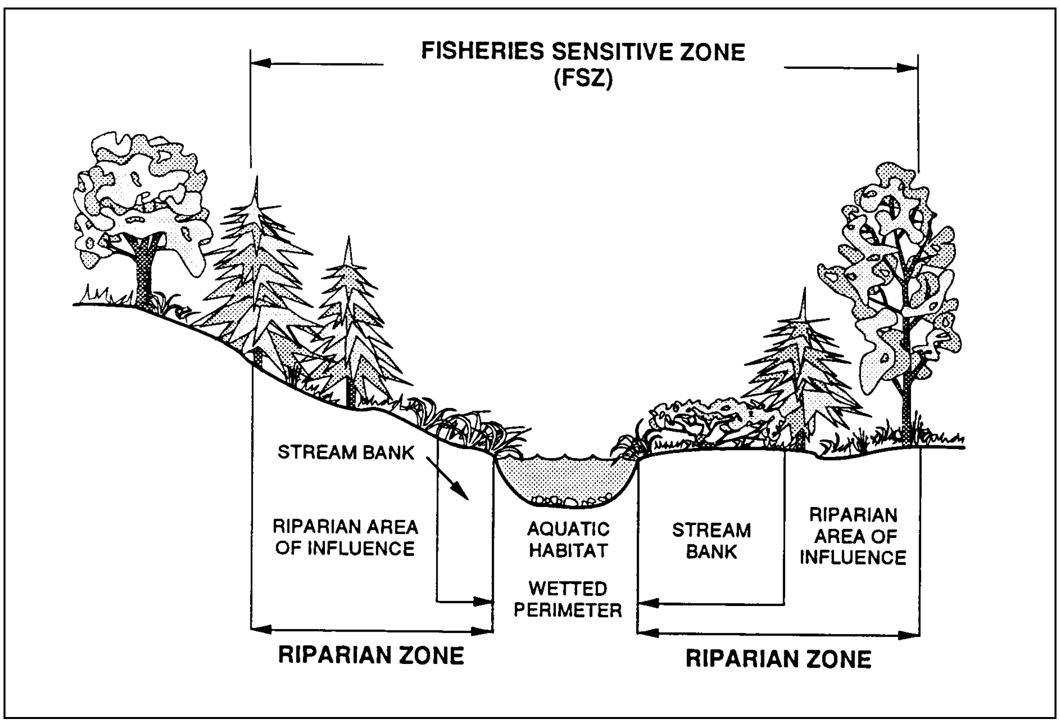
Department of Fisheries and Oceans Canada
Habitat Management Division
Station 327 - 555 W. Hastings Street
Vancouver, BC V6B 5G3
phone: 666-6566
fax: 666-7907.

SECTION 2
LEAVE STRIPS

Objective

The primary objective of leave strips is to protect the riparian zone, which is critical to the maintenance of a healthy aquatic environment. Riparian zones, located next to streams, rivers, lakes and wetlands, have direct influence on aquatic habitat values. They can broadly be described as the area of the streambank, including any side channels and associated banks, and the area of influence, which contains upland areas not normally inundated during high water conditions. Riparian zones and the instream aquatic habitat are both part of the Fisheries Sensitive Zone (FSZ). Leave strips are the areas of land and vegetation adjacent to watercourses that are to remain in an undisturbed state, throughout and after the development process. The extent of the leave strip will be determined by the presence and proximity of a watercourse on or adjacent to the development site, and by the nature of the watercourse and surrounding land use. **Leave strips should be provided on all watercourses that flow into or contain fish or fish habitat. This may include wetlands, ponds, swampy areas or other intermittently wetted areas, small streams, side channels and ditches which may not flow throughout the entire year (ephemeral).** The leave strip also helps to protect private property from flooding and potential loss of land due to stream erosion and instability.

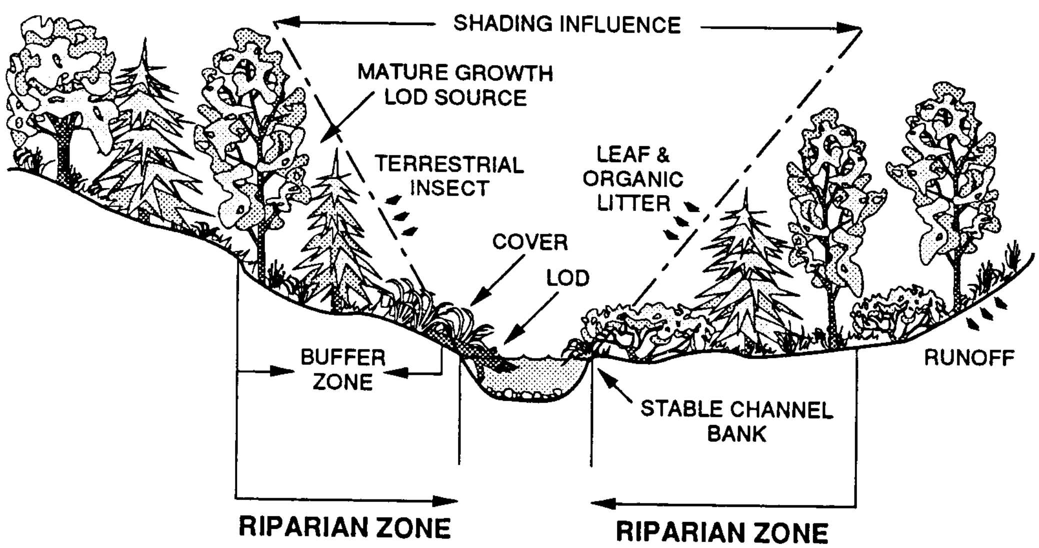
Figure 2.1 Riparian and Fisheries Sensitive Zones



Impact of Riparian Zones on Aquatic Fish Habitat

The riparian zone has characteristics that protect and nurture quality aquatic fish habitat. Disturbance or destruction of the riparian zone can have serious impacts to both the short and long-term viability and productivity of fish and fish habitat.

Figure 2.2 Riparian Zone Benefits to Aquatic Habitat



Food Source

The largest supply of food items and material supporting the aquatic food chain originates from outside the stream's waters. Riparian zones provide food directly by providing habitat for terrestrial insects that fall into the water becoming food items for fish. The organic matter, leaves and needles provide a food source for many aquatic insects which in turn become food items for fish.

Large Organic Debris (LOD) Source

The large mature deciduous and coniferous trees along a streambank provide a future source of large organic debris in the aquatic environment and should be preserved. Fallen dead trees and snags, eroded root structures and logs are the large organic debris that provides stream bed stability, cover and habitat for young fish. LOD should not be removed from the stream FSZ.

Water Temperature Regulation

The density and height of the streamside vegetation influence the amount of light reaching the water surface, hence water temperatures and dissolved oxygen saturation levels of streams. A developed canopy provides a stable shading influence which helps regulate water temperature ranges and rates of fluctuation. This ultimately reduces stress on fish populations and improves habitat quality.

Stream Buffer Zone

Streamside vegetation and ground cover intercept runoff and act as an effective filter for sediment and pollutants that would normally be deposited into the water column and would impact fish and fish habitat.

Stream Cover

Streamside vegetation plays an important role by providing cover and shelter which reduces stress and losses from predation for both juvenile and adult salmonids.

Streambank Stability

The living network of roots and vegetation provide "living rip rap", limiting bank erosion and stream degradation. Channel stability enhances aquatic habitat values in productive stream reaches.

Permanent Protection of Leave Strips

The leave strip should be permanently protected under one of the following methods: dedication as park, by return of the land to the Crown in the name of the local government, re-zoned as a protected area or reserve status, or secured with restrictive covenants. The development of trails for public access and use may be considered, however they should not be designed or constructed so that they adversely affect the stream's aquatic habitat and should be included in the overall development plans for DFO/MOELP review.

Leave Strip Boundaries

Once the extent of the leave strip has been determined, the boundary must be defined by legal survey and depicted on the appropriate development project drawings as "Leave Strip". Leave strip boundaries should be clearly defined in the field (e.g. by the installation of snow type fencing) prior to the commencement of any site work. The fencing should be securely fastened on posts to prevent movement and have signs notifying the leave strip boundary. Such boundary definition should remain in place and be maintained in good order until completion of construction of buildings on the site. It can be removed as part of final inspection on completion of the site work. To prevent incursions into the leave strip after construction or to protect sensitive areas, permanent fencing should be installed.

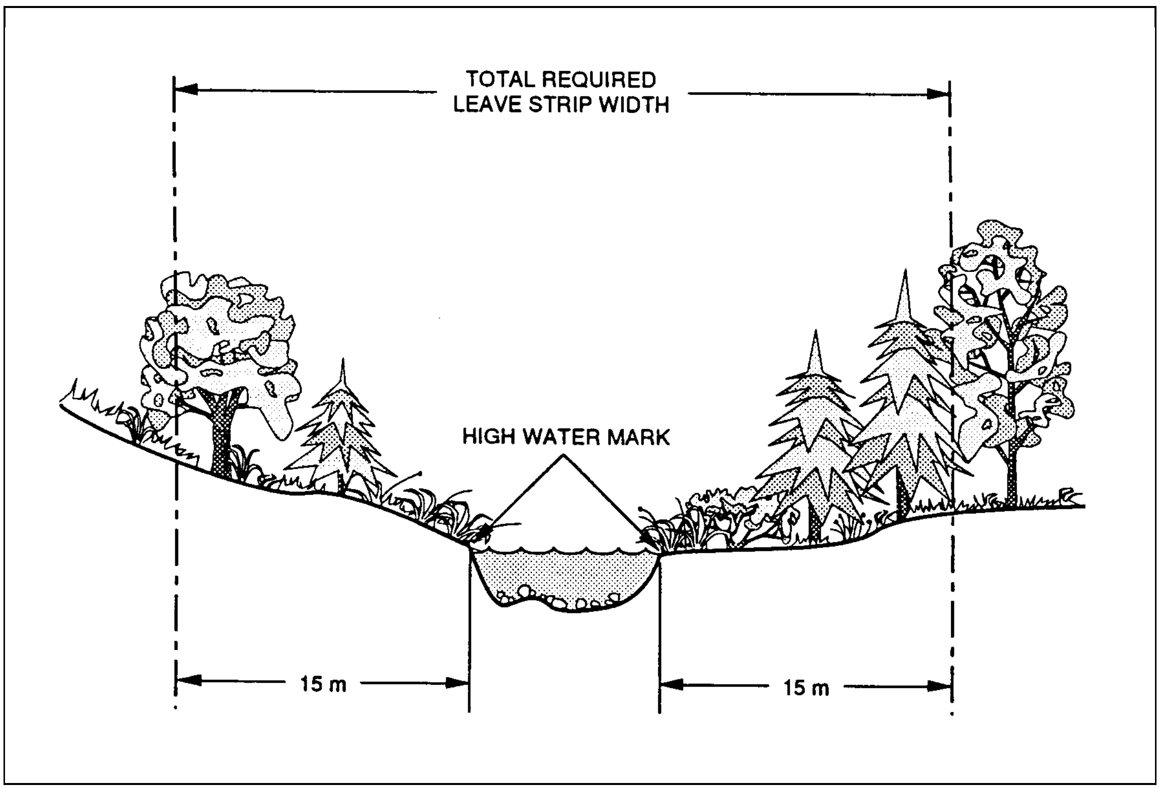
Leave Strip Widths

Minimum leave strip widths for riparian zone protection can be established with these guidelines. The stream high water mark must first be determined, usually the water level reached during the mean annual flood event or top of the stream bank, and the widths specified are then measured from that high water mark. They are measured perpendicular to and away from the stream bank, for the distance specified, on both sides of the stream.**These are suggested minimum widths and may be altered by DFO/MOELP staff to suit onsite conditions** . **DFO or MOELP should be contacted if there is any difficulty in determining the existing high water mark, or required leave strip width for a certain watercourse or development** . In many cases, the leave strip may have to be widened to protect critical fish habitat within the FSZ. Many regional and municipal authorities have specific zoning and set-back requirements for flood protection, parks, community planning, etc. They will take precedence if they exceed the minimum requirements of these guidelines.

Watercourse with well defined high water mark in a Residential/Low Density Area

The minimum leave strip width on each side of the watercourse should be 15 meters from the high water mark.

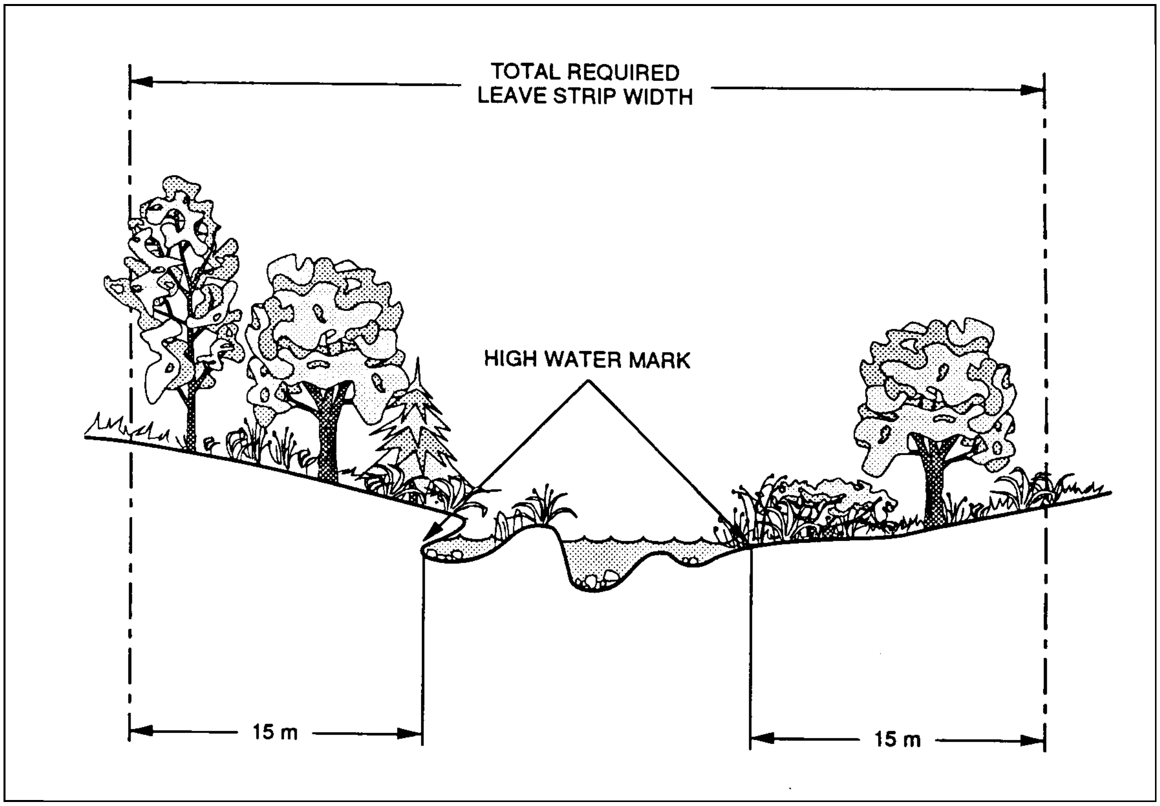
Figure 2.3 Minimum Leave Strip for a Well-defined High Water Mark in a Residential/Low Density Area



Watercourse with poorly-defined high water mark in a Residential/Low Density Area

Careful consideration must be given to establishing the existing high water mark in wide flood plain or multi-channel areas, and features such as floating vegetation mats, undercut banks and seasonally dry areas, must be taken into account. These areas usually have high salmonid habitat values and require protection because they are difficult to restore or compensate for if damaged or destroyed. The minimum leave strip width on each side of the watercourse should be 15 meters from the high water mark.

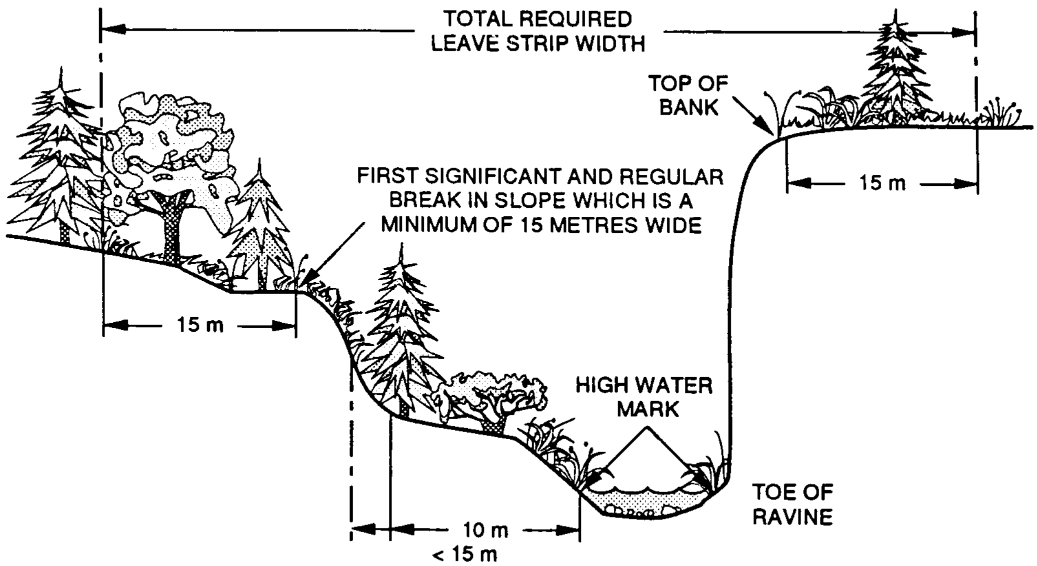
Figure 2.4 Minimum Leave Strip Width for a Poorly-defined High Water Mark in a Residential/Low Density Area



Watercourse with steeply sloped topography in a Residential/Low Density Area

Steep slopes adjacent to watercourses have the potential for major adverse effects on aquatic habitat. Major problems are generally due to erosion, gully formation, loss of riparian vegetation and bank instability associated with surface runoff down steep slopes. Additional stream channel instability can cause channel and bank erosion resulting in large-scale mass wasting and sediment inputs to the aquatic habitat. Leave strips at the top of slopes provide an effective buffer for the entire ravine area and protect the sensitive crest areas. Accordingly, leave strip widths should maintained at the top of the ravine or steep sloped areas. If the distance from the high water mark to the toe of the slope is less than 15 meters, then the leave strip should be located at the first significant and regular break in slope which is a minimum of 15 meters wide.

Figure 2.5 Minimum Leave Strip for a Ravine or Steep-sloped Banks in a Residential/Low Density Area



Watercourse with well defined high water mark in a Commercial/High Density Area

Because of higher utilization of land and development of impervious areas within commercial, industrial and multi-family/multi-dwelling developments, the potential for increased impacts on watercourses can be great. Accordingly, protective leave strips should be widened to provide additional protection. The minimum leave strip width on each side of the watercourse should be 30 meters from the high water mark

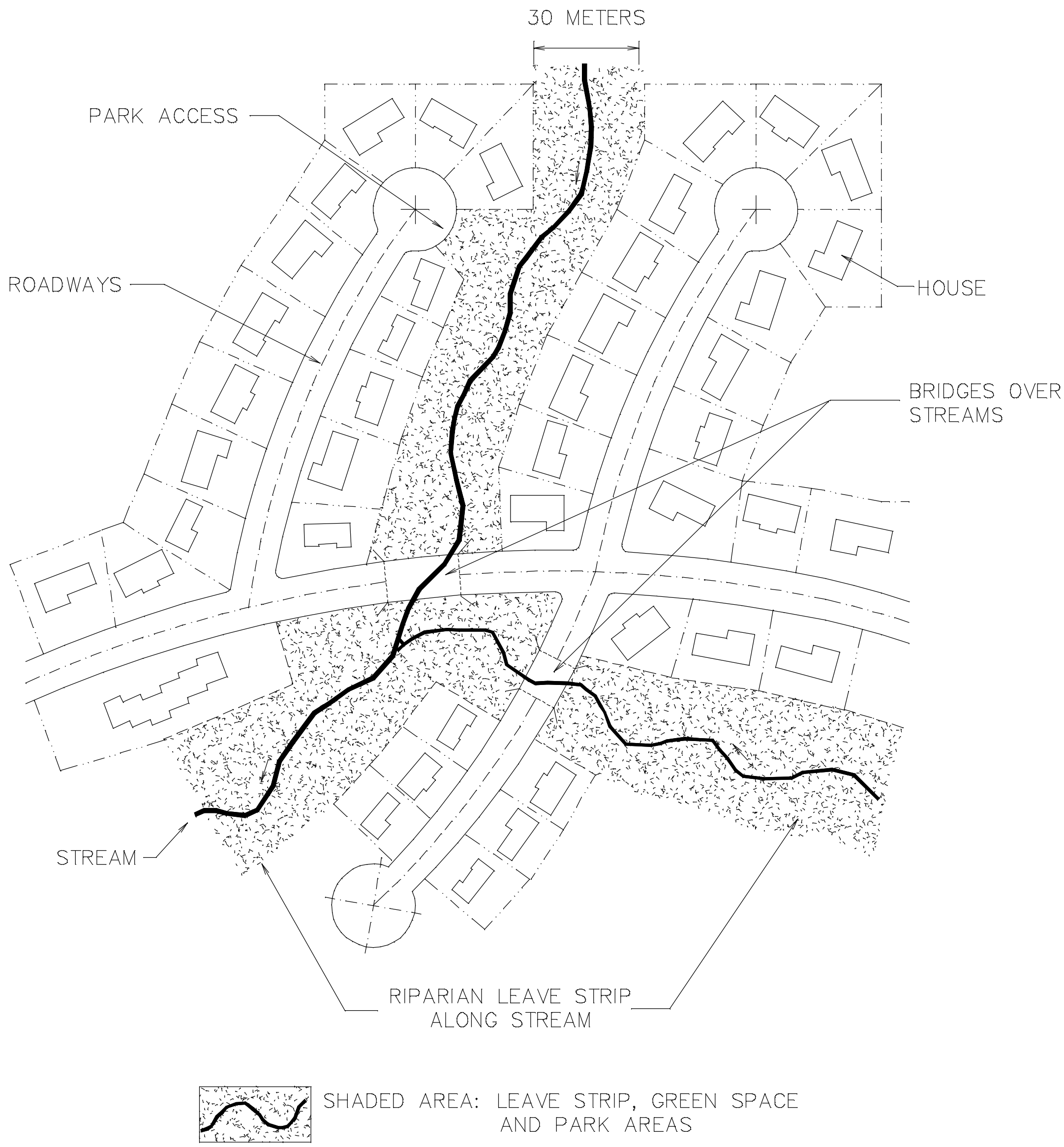
Watercourse with poorly-defined high water mark in a Commercial/High Density Area

Similar to a residential/low density area, but with an increased minimum width to allow for higher land utilization. Where the watercourse is ill-defined, the minimum leave strip width on each side of the watercourse should be 30 meters from the high water mark.

Watercourse with steeply sloped topography in a Commercial/High Density Area

Similar to a residential/low density area, but with increased minimum width to allow for higher land utilization. If the distance from the high water mark to the toe of the slope is less than 30 meters, then the leave strip should be located at the first significant and regular break in slope which is a minimum of 30 meters wide.

Figure 2.6 Plan View of Riparian Leave Strips



Guidelines for Construction Practices within the Fisheries Sensitve Zone

The following provisions are steps intended to protect leave strips and maintain a healthy functional riparian zone. For additional information regarding work within the FSZ, see **Instream Work** and **Appendix III**.

Planning and Minimizing Impacted Area

- Streambank characteristics and vegetation should be taken into account when planning development activities in and around rivers and streams.
- During development of the land, there should be no unauthorized work or disturbance into the FSZ.
- Where encroachment into a leave strip is required, specific plans must be prepared and approved by DFO/MOELP in advance.
- Requests for permission to encroach will only be considered for major vehicle or footbridge crossings, utility crossings, and stormwater discharge outfalls.
- The plans for such encroachments should include details including the extent of work areas; plans for the control of water discharged from the work area; the timing of work; and the details for restoration after construction.
- Carefully select access points to streambank through the riparian zone, minimize the size and duration of disturbance, and preserve streamside vegetation and undergrowth wherever possible.
- Limit machinery and equipment access and direct disturbance to streambank areas.

Stabilizing Impacted Area

- Physical stabilization of eroding or eroded banks may be required to promote bank stability and regeneration of riparian vegetation.
- Design and construction of stabilization works should prevent their subsequent erosion.
- Remove disturbed, unstable debris from the riparian zone to prevent it from being swept away during high water.
- Retain stable large organic debris (LOD) which does not impede flows and fish migration, or promote bank erosion.

Revegetating Impacted Area

- Revegetate disturbed areas immediately following completion of work in riparian zones.
- Establish ground cover to prevent surface erosion and deeper rooted plants and shrubs to prevent streambank erosion.
- Cedar, vine maple, alder, cottonwood, willow, salmonberry and red osier dogwood are common native plants used to augment brush and large plant formation.
- Large tree species will provide long-term sources of LOD.

SECTION 3
EROSION AND SEDIMENT CONTROL AND SITE DEVELOPMENT PRACTICES

Objective

Land development activities, such as clearing land, grading slopes, road building, and excavation and stockpiling of materials, can lead to the erosion of soils into nearby watercourses. These watercourses may contain fish and fish habitat, or flow into other streams that do. Increased surface runoff as a result of the development, due to lack of vegetation, infiltration and ponding, and the loose condition of disturbed soils leads to increased downslope transport of soils by the runoff. Even after the replacement and compaction of slopes and surfaces, soil erosion, gully and channel formation can occur. Sediments are composed of undissolved organic and inorganic materials ranging in size from microscopic particles to boulders, transported by flowing water. The finer material is carried suspended in the volume of water and is known as suspended sediment or suspended load. Larger material, generally consisting of coarse sand, gravels, and boulders, is carried along the channel bottom by the flow of water and is known as bed load. Understandably, on and offsite runoff management is a key factor in erosion and sediment control. Additionally, by preparing and covering disturbed soils, revegetating slopes and lining runoff channels, the amount of soil available to be eroded can be reduced. The objective of these erosion and sediment control guidelines is to minimize sediment inputs into fish habitat by reducing the potential for erosion, by stabilizing disturbed soils and intercepting sediment-laden runoff. Erosion and sediment control is extremely important because sediment can have severe negative impacts on all life stages of fish and their habitat. The following are examples of key fish and fish habitat impacts.

- Suspended sediment can settle on spawning areas, infill the intragravel voids and smother the eggs and alevins in the gravel.
- Bed load and settled sediments can infill pools and riffles, reducing the availability and quality of rearing habitat for fish.
- Suspended sediment can clog and abrade fish gills, causing suffocation or injury to fish.
- Suspended sediments can reduce water clarity and visibility in the stream, impairing the ability of juvenile fish to find food items.
- Settled sediments can smother and displace aquatic organisms (benthic invertebrates), reducing the amount of food items available to fish.
- Increased levels of sediment can displace fish out of prime habitat into less suitable areas.

Erosion and Sediment Control Methods

The key factors in erosion and sediment control are to intercept and manage off and onsite runoff. This limits the potential for soils to be eroded and form sediments in surface runoff. Runoff and surface erosion control is more effective and less expensive than sediment control with sediment control ponds only. Sediment control ponds have a limited capacity to remove sediments and are a last line of defense against sediment entering watercourses. Sound and sensitive development and construction practices are far more effective in complying with the objectives of these guidelines. Described below are the general principles of erosion and sediment control (ESC) and their application to land development activities (from Goldman, 1986).

Plan the development to the existing terrain and site conditions.

- Design and plan the development of roads, utilities and building sites with as little soil excavation and disturbance as possible.
- Design and plan development for the particular soil conditions and topography of the site.
- Confine construction to least critical areas and minimize impervious areas.
- Consider non-development of land in areas with extremely sensitive fish habitat values.

Schedule development to minimize risk of potential erosion.

- Where possible, plan construction activities during dry months of the year to avoid potential rain events and delays.
- Stage development to allow "green-up" or re-establishment of vegetation and minimize erosive areas.
- Halt construction during periods of heavy precipitation and runoff to minimize soil disturbance.
- Restrict vehicular and equipment access or provide working surfaces/pads.

Retain existing vegetation where possible.

- Minimize clearing rights-of-way and stripping of building sites.
- Avoid clearing and grubbing areas with sensitive soils.
- Consider aesthetics and retention of vegetation, including undergrowth.
- Physically mark clearing boundaries on the construction site.

Re-vegetate/protect denuded areas and bare soils.

- Seed or re-vegetate cut and fill slopes, and disturbed natural slopes.
- Cover temporary fills or stockpiles with polyethylene sheeting or tarps.
- Use mulches and other organic stabilizers to minimize erosion until vegetation is established on sensitive soils.
- Plan seeding and planting to allow establishment before end of growing season

Divert runoff away from denuded areas.

- Minimize flow over bare areas by diverting overland flows away from development areas.
- Isolate cleared areas and building sites with swales to re-direct runoff.
- Avoid steep slopes below rills and gullies.
- Retain natural drainage patterns wherever possible.

Minimize the length and steepness of slopes where possible.

- Erosion and soil loss is greater the longer and steeper the slope. Minimize both length and steepness of all slopes at engineering/planning stage.

Minimize runoff velocities and erosive energy.

- Maximize the length of flow paths for precipitation runoff to minimize energy of flow.
- Construct interceptor ditches and channels with low gradients to minimize secondary erosion and transport.
- Line unavoidably steep interceptor or conveyance ditches with filter fabric, rock or polyethylene lining to prevent channel erosion.

Design development for increased runoff.

- Design and engineer ditches and channels for post development flows.
- Construct stable, non-erodible ditches, inlet and outlet structures.

Retain eroded sediments onsite with erosion and sediment control structures.

- Utilize sediment traps and silt fences.
- Provide bed load clean-outs at culverts and ditches.
- Construct and operate sediment control ponds.

Plan, inspect, and maintain erosion and sediment control structures.

- Develop and follow a maintenance and inspection schedule as part of the development plan.
- Stockpile the required erosion/sediment control materials: filter cloth, rock, seed, drain rock, culverts, staking, matting, polyethylene, used tires, etc.

Slope Protection

The following techniques should be employed to prevent the initiation of surface soil erosion and movement of sediments from slopes. The surface preparation applied to slopes can be determined by the type of material and grade of the slope. The measures used for erosion and sediment control on slopes are as follows.

- Application of surface protection.
- Application of silt fences.
- Design and installation of interceptor ditches.
- Application of other land development erosion control features or approved erosion control measures.

Conditions of implementation of these erosion and sediment control measures for slopes should be as follows.

- In dry conditions, all cut/fill and cleared natural slopes and surfaces should have erosion controls implemented within 14 days.
- In wet conditions, erosion control should be implemented immediately on completion of the grading operations of the worked area.
- Slopes exceeding 3.0 meters in height and steeper than 2H:1V should be reviewed by a Professional Engineer to assess slope stability, erosion, and drainage control requirements.

The photographs in Figure 3.1 illustrate some prominent features of both slope and surface erosion control structures.

Temporary Slopes

Protection for a duration up to 6 months. Temporary slope preparations are determined by subgrade type (below) and slope/erodibility.

- **Bed Rock/Hard Glacial Till Subgrade:**
  Slopes may be left exposed.
- **Silt, Sand, Mixed Sand/Gravel Subgrade:**
  Temporary surface protection.
- **Organic or Top Soil Subgrade:**
  Temporary surface protection.
- **Coarse Gravel/Cobble Subgrade:**
  Slopes may be left exposed. No surface protection unless erosion develops.

Figure 3.1 Surface and Slope Erosion and Sediment Control Applications

Long Term or Permanent Slopes

Protection for a duration exceeding 6 months. Permanent slope preparations are determined by subgrade type (below) and slope/erodibility.

- **Bed Rock/Hard Glacial Till Subgrade:**
  Slopes may be left exposed.
- **All Other Subgrade Types:**
  Permanent surface protection.

Soil Excavation Stockpiles

All soil which is stockpiled for more than 7 days and less than 2 months should be covered with polyethylene or totally contained by a silt fence as a temporary measure to prevent erosion. Longer term stockpiles should be shaped to have side slopes no steeper than 1.5H:1V and remain covered with polyethylene, or have temporary surface protection applied.

Graded Areas

Temporary graded areas, such as housing lots, should be protected from erosion through the use of straw mulch and/or polyethylene tarps in non-traffic areas and a gravel cap in zones of construction traffic. Final graded or landscaped areas should have the appropriate permanent surface protection or landscaping in place as soon as possible.

Surface Protection

The purpose of these techniques is to absorb raindrop impact, reduce runoff velocity, improve infiltration, bind soil particles with roots, and protect the soil from the wind. The rapid establishment of a vegetation cover is generally recognized as the most cost effective form of surface erosion control. Protection of the soil surface with mulches or other materials will provide immediate erosion control until vegetation is established. When time is limited or vegetation establishment is not a goal, or weather conditions are unsuitable, the use of polyethylene sheeting or tarps is recommended.

Temporary Surface Protection

Surfaces and slopes less than 2H:1V use Seeding with Straw Mulch:

- Soil surfaces to be treated should be rough. Scarify to a maximum depth of 2.5 cm if necessary. Broadcast 100% fall rye seed at a rate of 50 kg/ha. Include 19-23-14 fertilizer at a minimum rate of 200 kg/ha.
- Cover the seeded area with at least 5 cm of straw, preferably applied with a blower. The straw should be held in place with a hydroseeder application of wood fiber mulch at 500 kg/ha and a tackifier at 40 kg/ha, or with netting.

Surfaces and Slopes up to 1H:1V use Seeding and Hydromulching:

- Soil surfaces to be treated should be rough. Scarify to a maximum depth of 2.5 cm if necessary. Broadcast 100% fall rye seed at a rate of 50 kg/ha. Include 19-23-14 fertilizer at a minimum rate of 200 kg/ha.
- Apply wood fiber mulch (designed for hydroseeding) at a rate of 2500 kg/ha together with tackifier at a rate of 60 kg/ha (or at the manufacture's recommended rate) with a hydroseeder to form a continuous blotter-like cover.

Highly Erodible Surfaces and Slopes use Seeding and Erosion Control Revegetation Matting (ECRM):

- Soil surfaces to be treated should be rough. Scarify to a maximum depth of 2.5 cm if necessary. Broadcast 100% fall rye seed at a rate of 50 kg/ha. Include 19-23-14 fertilizer at a minimum rate of 200 kg/ha.
- Roll the ECRM, a biodegradable pre-seeded erosion control mat, upon the soil surface and anchor it at the top. It needs to be adequately stapled to ensure it remains in place and in direct contact with the soil.

Highly Erodible Surfaces and Slopes use Polyethylene Cover

When immediate protection is needed or other protective techniques are not feasible, polyethylene sheeting or tarps can be used. It should be well anchored to resist wind (old tires are ideal) and prevent major leakage. Breaks in the cover should be repaired immediately. Polyethylene sheeting is not recommended for use on sites to be left idle for more than 2 months, unless weather conditions preclude the establishment of vegetation.

Permanent Surface Protection

Protection within 14 days for a duration exceeding 6 months. Options are identical to those described for temporary surface protection except for the following changes:

- The broadcast seed application should consist of fall rye at a rate of 20 kg/ha, plus the following mix (all percent by weight) at a rate of 60 kg/ha.

25% creeping red fescue	15% hard fescue
5% redtop	15% orchard grass
20% perennial ryegrass	10% alsike clover
10% white clover	

- The fertilizer should consist of standard commercial materials, with at least 60% of the nitrogen in the form of slow release urea. The rate of application should be based on laboratory soil analysis, with a minimum of 400 kg/ha of 19-20-12.
- All permanent surfaces and areas that are in final form and are to be vegetated as per the landscape plan, should be done as soon as practically possible (delays greater than 14 days, temporary slope and surface protection should be applied).

Interceptor Ditches

Interceptor ditches are structures designed to intercept and carry clean surface runoff away from erodible areas and slopes, reducing the potential surface erosion and limiting the amount of runoff requiring treatment. Alternatively, they can collect sediment contaminated runoff from slopes and carry it, without further erosion, to treatment areas or sediment ponds. Figure 3.2 shows typical installations of interceptor ditch structures as well as ditch lining types.

Design of Interceptor-Conveyance Ditches

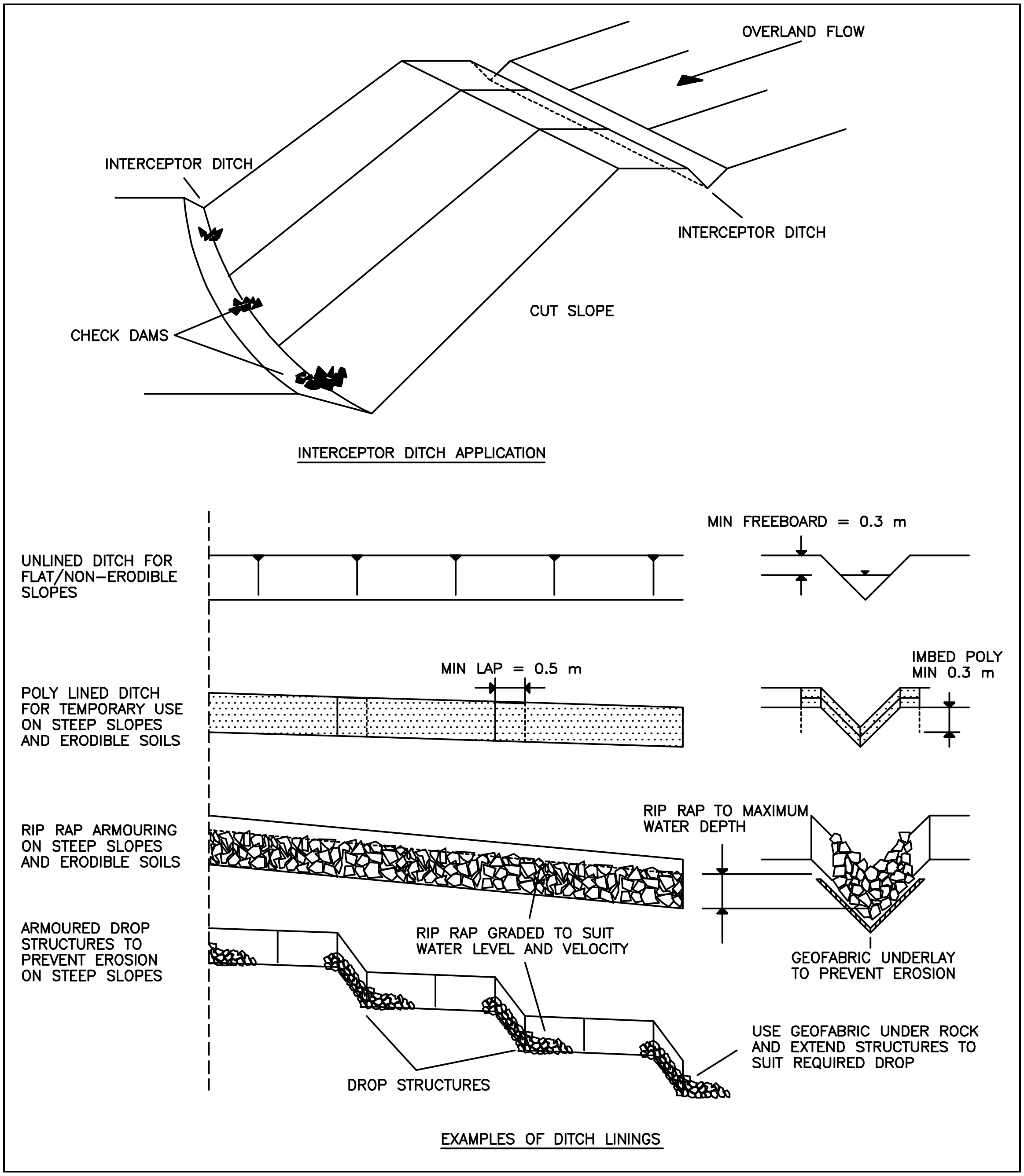
- The location and access to interceptor ditches should be determined following analysis of the topography, the existing or planned drainage pattern and subgrade conditions. They should be laid out, following contours if possible, and constructed during initial clearing.
- Interceptor ditches should be located along the uphill boundaries of development sites, the uphill sides of major cut and fill slopes, to intercept and convey overland runoff.
- Interceptor-conveyance ditches should be designed to take a 2 year (1:2) storm runoff flow with 0.3 meters freeboard. Sideslopes should be no steeper than 1H:1V.

Construction of Interceptor Ditches

The construction and protection of the ditch should be based on the expected design flows, subgrade soil conditions, gradient and design life.

- **Bed Rock/Hard Glacial Till Subgrade:**
  Ditches can remain unlined.
- **Silt, Sand, Mixed Sand/Gravel, or Organic Subgrade:**
  Ditches should be lined with 0.6 mm polyethylene if it is overlapped 0.5 meters, bedded on non-angular material, and the top edges are anchored in small (0.30 meter deep) trenches along the top of the ditch. The subgrade should be free of any angular material.
- **Coarse Gravel/Cobble Subgrade:**
  Shallow gradient ditches may remain unlined. Steep gradient ditches should be armoured or lined with polyethylene as above.
- **Steep Gradient and/or Large Volume Ditches:**
  Steep gradient and/or ditches carrying a large volume of water will require full rock armouring to design water levels to prevent scour and bank erosion.
- Interceptor ditches may require energy dissipators at changes in grade and elevation, as well as armouring at changes in direction. Energy dissipators may be weirs built of broken rock, gabions, concrete or timber. The location and design of energy dissipators should be done by a Professional Engineer.

Figure 3.2 Typical Interceptor Ditch Construction and Application



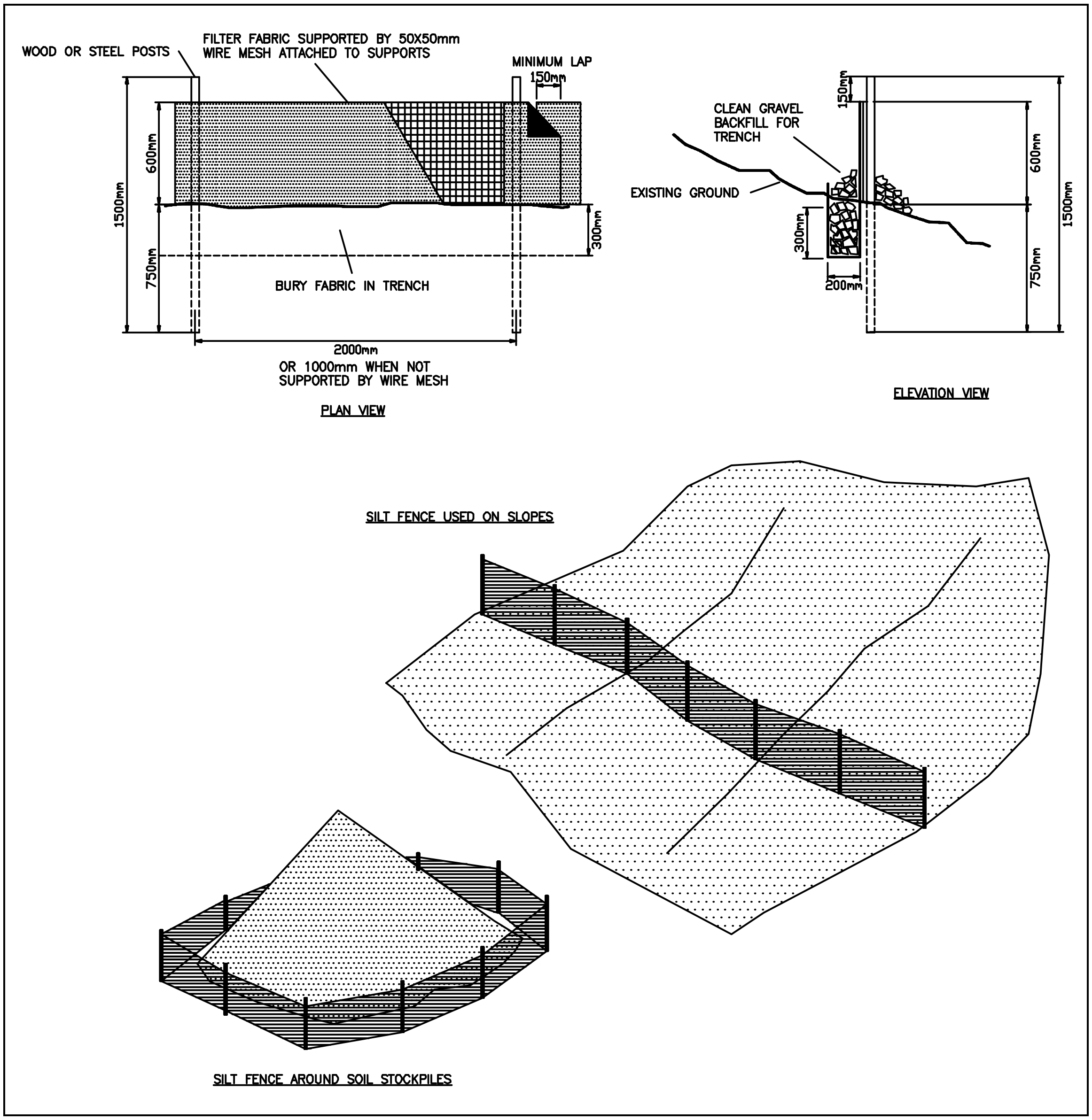
- Excavated bed load traps or pools formed by gravel berms can be constructed to collect eroded material. They should be located downstream of points of sudden reduction in gradient. They should be cleaned out after heavy rainfall or during periods of sustained precipitation.
- Sideslopes should be seeded to reduce erosion and subsequent maintenance, and also to improve appearance, especially for permanent works. Temporary ditches should be filled and the area reclaimed when they are no longer required.
- A regular, permanent maintenance program is necessary to keep ditches in good working order. Silt has to be removed from silt traps, weirs may have to be adjusted or repaired, additional rip-rapping may be necessary. All ditches and structures should be inspected after heavy rainfall or during periods of sustained precipitation.

Silt Fences

Silt fences and related structures provide an effective filter for sediment-laden runoff from eroded slopes and surfaces. The fine openings do not allow the passage of sediment coarser than about 0.02 mm. Silt fences are effective boundary control devices, trapping the sediment close to the erosion source and preventing mobilization into runoff, but have a limited sediment retention capacity. Figure 3.3 illustrates some typical applications using silt fences for erosion control, and design parameters.

- Silt or filter fences should be installed on the lower perimeter of slopes (lower 1/3 to 1/2 of site) and areas where the erodibility is high and/or it is desirable to contain waterborne movement of eroded soils. Such areas include the bottom of cut or fill slopes, material stockpiles and disturbed natural areas.
- Filter fabric or geotextile may be a pervious sheet of slit film woven polypropylene, nylon, polyester, or ethylene yarn, having the following properties.
    - Minimum Filtering Efficiency 90%.
    - Minimum Flow Rate 0.012 m^3/m^2/minute.
    - Minimum grab tensile strength 700 N.
    - Minimum equivalent opening size 0.15 mm (median 0.21 mm).
- If standard strength filter fabric is used it must be backed by a wire fence supported on posts not over 2.0 meters apart. Extra strength filter fabric may be used without wire fence backing if posts are not over 1.0 meters apart. Fabric joints should be lapped at least 0.15 meters and stapled. The bottom edge should be anchored in a 0.30 meter deep trench, or some equivalent manner, to prevent flow under the fence.
- If the filter fabric decomposes or becomes ineffective, it must be replaced and the fence repaired.

Figure 3.3 Typical Silt Fence Construction and Applications



Other Erosion Control Measures

The following sediment and erosion control structures are used to varying degrees to mitigate onsite erosion and control runoff.

Sediment Traps

Sediment traps should be installed at the lowest point on each lot prior to excavation and construction on the site. Swales or ditching should convey surface runoff to these traps prior to pumping or discharge from the site. Sediment traps operate like small sediment control ponds by controlling the discharge of sediment offsite.

Swales

Swales are effective at re-directing surface runoff away from erodible sites and reducing the amount of sediment laden runoff generated onsite. They should be constructed of clean, non-erodible granular material in 0.3 meters high ridge with a low gradient to prevent scouring and further sedimentation.

Gravel Berms, Small Silt Fences, Check Dams and Bale Structures

These should be installed in overland flow paths, swales and other possible locations of concentrated flow to arrest migration of erodible soils. Their number and spacing will depend on the nature of the construction operations. They are effective at controlling sediment close to its source.

Culverts

Groundwater seepage and other small flows can be contained and flumed away from sensitive slopes and cut banks to prevent erosion of toe areas and maintain slope stability. They are also effective for conveying flows down steep slopes where it would be impossible to convey through an open channel.

New Drainage Systems

Storm sewer and drainage systems should have their inlets blocked, or should have sediment traps installed at inlets until all work is complete. During curb construction, roadside drainage should be temporarily controlled in swales and directed into the storm sewer system at suitable locations provided with sediment traps. Systems can be utilized for conveying flows to sediment control ponds.

Sediment Control Ponds

Design of Sediment Control Ponds

Sediment control ponds are the last line of defense before runoff is discharged from the development site. There is a practical limitation on the minimum size of particles that can be settled because of particle size, settling characteristics, residence time and land area available for sediment ponds. This minimum size has been set at 0.02 millimeters (mm) which equals a settling velocity (v_s) of 0.02 cm/s @ 0°C. Even at design flows, many particles smaller than 0.02 mm will pass through the sediment control pond and can be deleterious to fish and fish habitat. This emphasizes the importance of minimizing the amount of site soils eroded and allowed to enter the sediment control ponds. The table below illustrates the increasing pond area (m^2) required per unit flow (m^3) to provide discrete particle settling using the following equation and assuming a specific gravity of solids = 2.65:

$$A = \frac{1.2Q}{v_s}$$ Erosion and Sediment Control, USEPA, 1976.

Table 3.1 - Required Surface Area and Overflow Rates for Discrete Particle Settling (m2 pond area per m3 of flow)

particle classification	particle diameter (microns)	Water Temperature				
		0°C	5°C	10°C	15°C	20°C
coarse sand	1000	3	3	3	3	3
medium sand	500	8	7	6	5	5
fine sand	250	40	33	28	23	19
coarse silt	62	621	528	455	396	464
medium silt	31	2486	2111	1819	1583	1389
fine silt	16	9332	7924	6829	5943	5213
very fine silt	8	37327	31697	27318	23773	20853
coarse clay	4	149310	126788	109271	95091	83413
medium clay	2	597239	507153	437085	380364	333653
fine clays	1	2388956	2028611	1748342	1521458	1334612

The proper design and operation of settling facilities in no way removes the responsibility of the proponent from achieving the site runoff water quality objectives . Where the use of gravity settling will not provide the required effluent quality, or where lack of space does not permit provision of such facilities, the proponent may wish to consider the use of mechanical settling devices or chemical agents. The design requirements of such facilities are beyond the scope of these guidelines and would require detailed plans prepared by a Professional Engineer. Such an installation would also require approval from MOELP - Environmental Protection Division for operation, maintenance, discharge and disposal of the residue.

Site Runoff Water Quality Requirements

Runoff water from the development site should contain less than 25 mg/liter of suspended solids (or non-filterable residue, NFR) above the back-ground suspended solids levels of the receiving waters during normal dry weather operation and less than 75 mg/liter of suspended solids above background levels during design storm events. However, where spawning areas are situated in the receiving waters, the storm runoff water discharged should not, at any time, increase suspended solids levels above background suspended solids levels in the receiving waters. Background suspended solids levels are the natural instream suspended solids or NFR levels measured upstream of the point of discharge in the watercourse. **If there is any question regarding the normal dry weather or design storm background level, DFO or MOELP staff should be contacted**.

Location and Number of Sediment Control Ponds

- Sediment control ponds should be located at the lowest practical point in the catchment area.
- The location, number, and size of ponds will reflect the area being developed at any one time, but a minimum of two (2) should be constructed.

Design Parameters for Sediment Control Ponds

• Design particle size	0.02 mm.
• Design pond area	developed site 5 year (1:5) storm to calculate design area based on runoff flow and design particle or minimum of 1% of the total erodible area.
• Design horizontal velocity	horizontal velocity which will not cause suspension or erosion of deposited material.
• Design hydraulic retention time	minimum of 40 minutes.
• Design drawdown time	48 hours with no incoming flow or loss of accumulated solids.
• Overflow spill capacity	developed site 1:10 year (1:10) storm event.
• Emergency spillway capacity	developed site 1:100 year (1:100) storm event.

Dimensions and Capacities of Sediment Control Ponds

- Minimum effective flow path 5 times the effective pond width.
- Minimum freeboard 0.6 meters.
- Minimum free settling depth 0.5 meters above the top-of-sediment elevation.
- Minimum sediment storage depth 0.5 meters.
- Maximum interior sideslopes 2H:1V.
- Maximum exterior sideslopes 3H:1V.

Inlet and Outlet Structures of Sediment Control Ponds

- The inlet should distribute incoming flow across the width of the pond.
- Bypass piping or multiple ponds should be installed to allow pond servicing.
- A pre-treatment sump to remove coarse sediments is required.
- Only clarified surface water should be allowed to leave the pond.
- The dewatering drawdown holes should be protected with a granular filter to prevent formation of high velocity currents which could resuspend settled sediment.
- Discharge and conveyance of discharged pond flows should not cause erosion of natural drainage systems. Plastic culvert piping should replace ditching for temporary pond applications to limit disturbance in the FSZ.

Operation and Maintenance of Sediment Control Ponds

- Settled sediment should be removed after each storm event or when the sediment capacity has exceeded 33% of design sediment storage volume.
- Periodic inspection and removal of accumulated sediments and the required inspection and maintenance interval should be noted on the design drawings.
- Accumulated sediment removed during pond maintenance must be disposed of in a manner which will prevent its re-entry into the site drainage system, or into any watercourse.
- The tops of slopes or berms around sediment control ponds should be wide enough to provide a safe and stable work area where required for the operation of maintenance equipment and personnel and should be covered with crushed stone and/or turf stone to prevent damage to the structure, and loosening of soil which could wash into the pond.
- Multiple ponds or a single large superpond may be designed for a large development, but a minimum of two should be constructed for pond maintenance requirements.
- Sediment control ponds should be constructed during initial site development and maintained until all building construction and site grading work is completed. Sediment ponds may be retrofitted for use as stormwater detention ponds.

Stability and Public Safety of Sediment Control Ponds

- The stability of sideslopes for all earthen ponds should be confirmed by a Professional Engineer. All interior sideslopes in areas subject to water level fluctuations should be stable against pore water pressure during rapid drawdown. Exterior sideslopes should be structurally stable under all loads and hydraulic conditions.
- Suitable fencing and signage should extend around the perimeter of all ponds.
- Discharge risers greater than 450 mm diameter should have a trash rack to exclude large objects.
- See Figures 3.4 and 3.5 for typical sediment control pond design and details.

Figure 3.4 Sediment Control Pond Plan and Sections

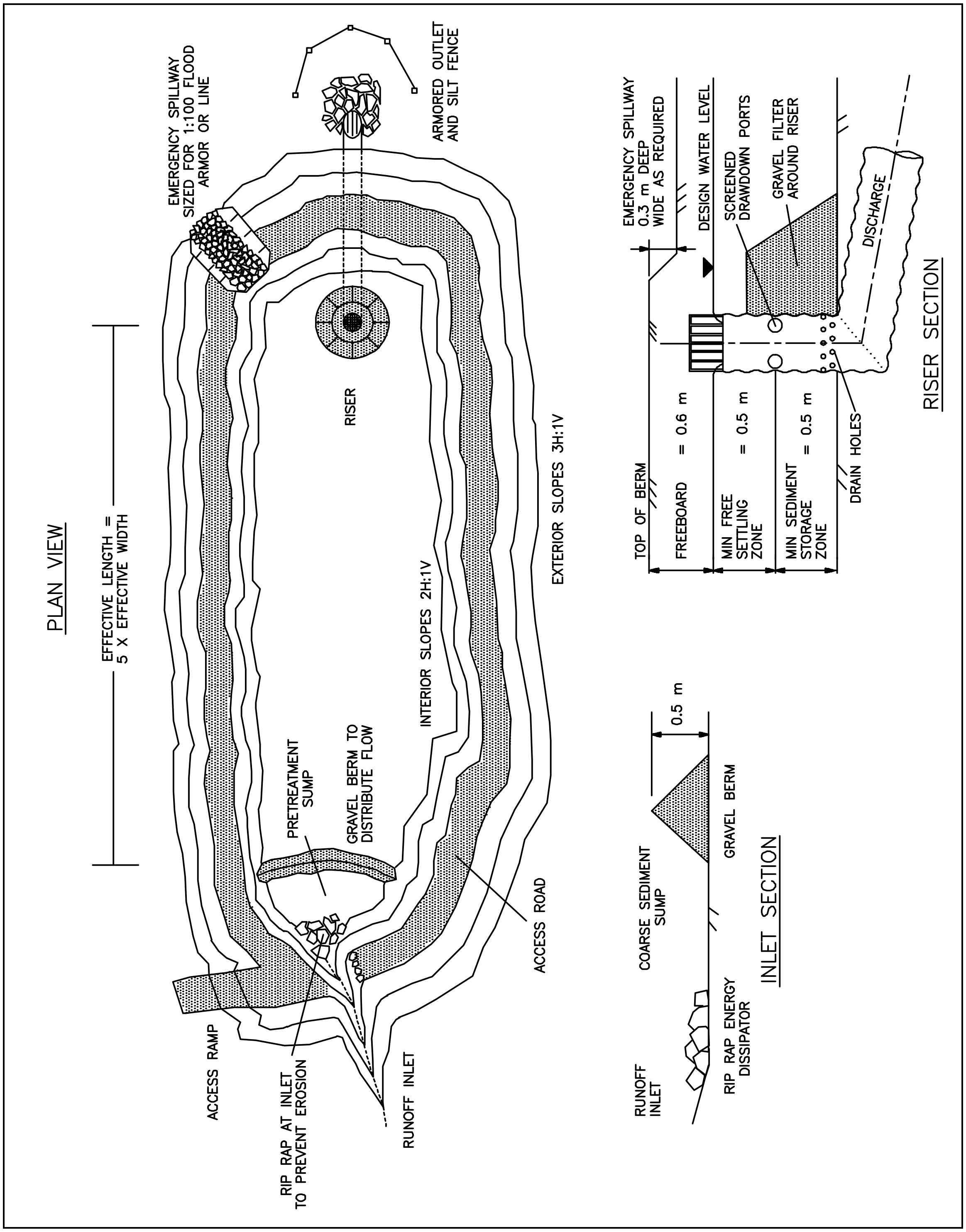
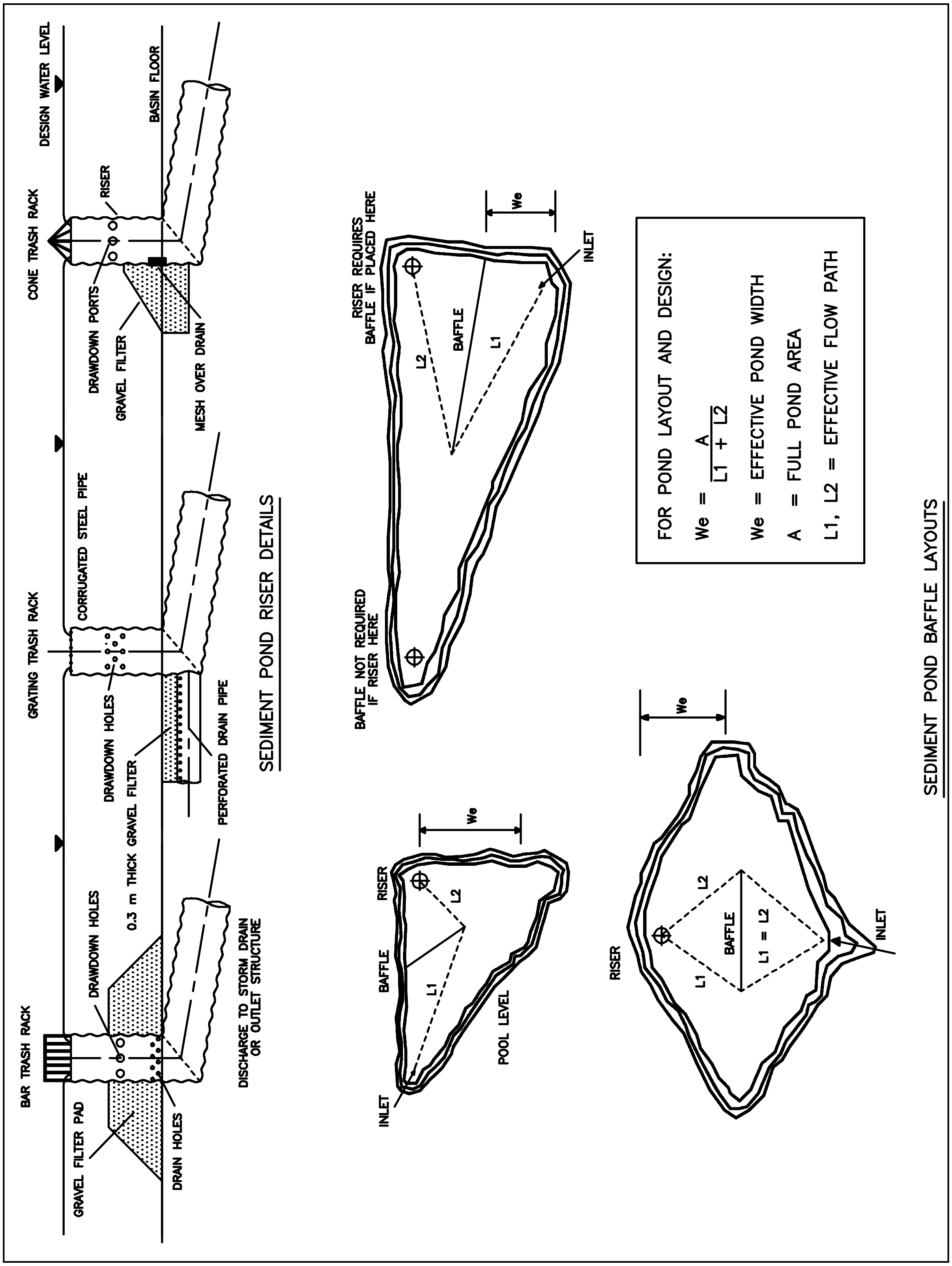


Figure 3.5 Sediment Control Pond Riser Details and Baffle Layouts



Guidelines for Control of Deleterious Substances on the Development Site

Common deleterious substances: sediments, raw and uncured concrete, mortar, glues, paints, lubricants, organic and inorganic contaminants, fuels and oils, can have detrimental or toxic effects on the aquatic environment and fish life (see Appendix I for definitions of "deleterious substances"). In most instances, the control of these substances can be dealt with through an awareness of their detrimental effects, the practice of good housekeeping (i.e. daily site clean-ups, use of disposal bins, etc.) on the development project site, and the proper use, storage and disposal of such substances and their containers. The following control guidelines should be reviewed by the developer and construction contractor to ensure no deleterious substances are released into fish habitat.

- Raw or uncured waste concrete and grouts should be disposed of by removal from the development site or by burial on the site in a location and in a manner that will not impact on a watercourse.
- Wash down waters from exposed aggregate surfaces, cast-in-place concrete and from concrete trucks should be trapped onsite to allow sediment to settle out and reach neutral pH before the clarified water is released to the storm drain system or allowed to percolate into the ground (approximately 48 hours).
- Fuels, lubricants and hydraulic fluids for equipment used on the development site should be carefully handled to avoid spillage, properly secured against unauthorized access or vandalism and provided with spill containment according to codes of practice.
- Fuelling and lubricating of equipment onsite should only be done after the equipment to be serviced is moved to a constructed service pad with a separate drainage collection system, as far as possible from detention or sedimentation facilities and leave strips.
- Any spillage of fuels, lubricants or hydraulic oils should be immediately contained and the contaminated soil removed from the site and properly disposed of in accordance with the federal Department of Environment - Environmental Protection (DOE/EP) and the provincial Ministry of Environment, Lands and Parks - Environmental Protection Division (MOELP/EPD) requirements. Any spills should be reported immediately to DOE/EP (phone: 666-6100) and MOELP/EPD (phone: 1-800-663-3456) for their counsel on appropriate clean up procedures.
- Hydraulic fluids for machinery used for instream work should be biodegradable in case of accidental loss of fluid.
- Waste oils and hydraulic fluids should be collected in leak-proof containers and removed from the site for proper disposal or recycling.

- The rinse and cleaning water or solvents for glues, paints, wood preservatives and other potentially harmful or toxic substances on the development site should be controlled so as to prevent leakage, loss or discharge into the storm drain system.
- Gypsum board wastes must be removed from the project site, preferably to a recycling facilities, or an approved disposal sites (disposal of gypsum board wastes by burying onsite is not permitted).
- Wood wastes, such as hog fuel, sawdust and wood chips, are not acceptable for fill material because of the potential release of toxic leachates from these wood wastes into the aquatic environment.
- Where land is being redeveloped and there is contamination of the site, those contaminants must be removed, disposed of, or otherwise neutralized, as prescribed by DOE/EP and MOELP/EPD, prior to proceeding with redevelopment of the affected lands. Potential mitigation and costs of contaminant removal are the responsibility of the land owner.

Guidelines for Development of Site Access

Significant release of sediments to the drainage systems and receiving waters can be caused by site access development and lack of control during land development and building construction activities. Included in the design of proper site access for minimizing potential impacts are:

- Construction site accesses should be restricted in number and to locations that will serve as permanent access after development.
- Access pads and roads should be constructed prior to site area development, and in a manner that will prevent the loosening of native subsoil.
- Access roads should be constructed or topped with a suitable coarse granular material with a minimum of fines and clays. Non-woven geotextile is recommended as a separation layer over the native subgrade. Organic topsoil should be stripped prior to road construction if possible, and removed offsite or stockpiled.
- Wood wastes, such as hog fuel, sawdust and wood chips, are not acceptable for the construction of access roads and support operations because of the potential release of toxic leachates from these wood wastes into the aquatic environment.
- Runoff from the access roads should be collected via interceptor ditches or swales. These flows should be routed to sediment ponds to allow the settling of sediments before release to the drainage system.
- Sweeping of loose soils from surfaced streets is recommended over water flushing to prevent soil entry into storm drains and the aquatic environment.

- Transport of excavated materials from the site should limit spillage on adjacent road surfaces and dropping of loose soils in the form of dust or mud from wheels, tracks and undercarriages of equipment.

Guidelines for Single Lot Development

The objectives during the development of an individual lot are to minimize erosion and release of sediment offsite by controlling the development and construction activities. Single lot erosion and sediment control measures include: planning the construction access; minimizing clearing and grading activities; control of excavated soil stockpiles; surface and slope preparations; and surface runoff control.

Site layout and Clearing

At the earliest stages, the individual lot development should be designed having regard to the general principles of erosion and sediment control, specifically:

- Design and layout of the building site to minimize impervious areas.
- Retain existing vegetation and ground cover where possible.
- Schedule construction to dry months of the year.
- Restrict vehicle access and provide a surfaced working area.
- Minimize clearing and stripping of set backs and easements.
- Clearly mark building area and clearing boundaries onsite.

Soil Erosion Control

Surface soil erosion from individual lots and building sites is generated mainly from soil excavations and graded areas. To minimize erosion onsite the following should apply:

- Cover temporary fills or soil stockpiles with polyethylene or tarps.
- Re-vegetate or final landscape disturbed areas as soon as practically possible.
- Limit machine access and operation to prepared access areas only.

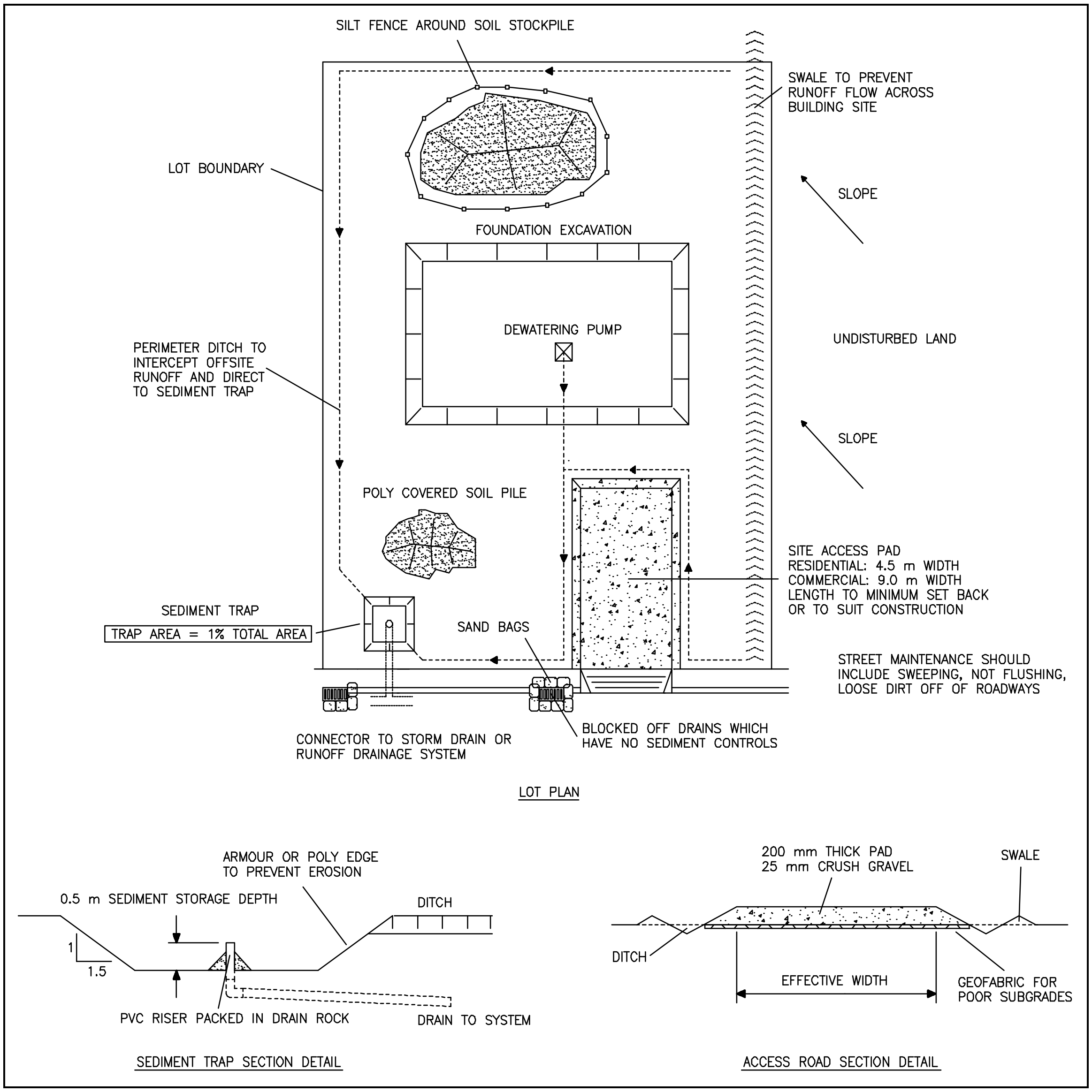
Drainage and Sediment Control

Site drainage features can usually incorporate sediment control features to limit the offsite transport of sediments directly into watercourses or into storm drainage systems that discharge into watercourses:

- Divert runoff away from cleared areas by use of swales or low berms.
- Utilize silt fences around soil stockpiles and sloped areas.
- Collect runoff into site sediment traps prior to discharge offsite.

Figure 3.6 illustrates a typical lot development plan with erosion and sediment control features .

Figure 3.6 Single Lot Development Erosion and Sediment Control Features



SECTION 4
STORMWATER MANAGEMENT

Objective

The primary objectives of the stormwater management guidelines are to limit the post-development 1:2 year storm offsite runoff rate to the predevelopment 1:2 year rate and to maintain, as closely as possible, the natural predevelopment flow pattern and water quality in the receiving watercourse. The clearing, grading and servicing of development sites within a watershed alter the natural hydrology of the watershed. The increase of cleared and developed areas decreases the ponding and transpiration of precipitation that previously provided detention, which delayed runoff thereby reducing peak flows. The increase of impervious areas and routing of stormwater flows decreases retention of precipitation by infiltration, which reduced the surface runoff component thereby reducing total runoff volumes. With reduced detention and retention, runoff can concentrate rapidly into significantly higher peak flows combined with increased runoff volumes (i.e. longer periods of higher flows). This combination of hydrological factors can initiate or accelerate channel and bank instability in receiving watercourses with negative impacts on fish and fish habitat. In addition, due to reduced infiltration and local groundwater recharge, baseflows during low flow conditions can be substantially lower than predevelopment baseflows, reducing the amount and quality of habitat available to fish during these critical periods. These flow-related impacts are often combined with:

- Decreased water quality resulting from pollutants and sediments introduced by the surface runoff.
- Loss of habitat related to channelization and culverting of small streams.
- Destruction of wetlands and related riparian areas through drainage and development.

All these related impacts are typical of a disturbed, urbanized watershed, and result in a reduction of the diversity and productivity of the aquatic habitat. As research, implementation and assessment of stormwater management practices progress, the objectives of these guidelines will be changed to reflect higher levels of downstream protection to protect fish and fish habitat.

Selection of Stormwater Management Technology

At the earliest stage, stormwater management plans should be designed to maintain the predevelopment flow pattern and volumes over the entire water season. Alterations in the stream hydrology are often compounded by the diversion and re-location of flows by use of flow splitters and inter-watershed stormwater connectors. The large-scale diversion and disruption of flows in a watershed, including interception of baseflows and relocation of catchment areas, will not be permitted where impacts to fish and fish habitat may occur.

In a developed environment, detention ponds and other runoff management technologies are required to replace some of the natural processes that existed prior to development. They do not completely replace the natural characteristics of runoff flow retention and detention, or water quality buffering and sediment filtering. They are used primarily to detain flows, thus limiting the peak rates of runoff from the developed site, provide some retention through infiltration and recharge to groundwater flows, and remove some sediment carried by stormwater runoff. The type of facility for a particular project should be based on the size of development, degree of detention required and specific site conditions. Table 4.1 illustrates some of the advantages and disadvantages of various stormwater management technologies. It should be recognized that certain stormwater management technologies provide both water quantity and water quality benefits. These runoff water quality objectives are also contained within these guidelines. Where practical and cost-effective, it is expected that developers will implement technologies that provide benefits to both water quantity and water quality to protect fish and fish habitat.

Stormwater Detention Objective

The stormwater detention objective is to limit the post-development 1:2 year storm offsite runoff rate to the predevelopment 1:2 year rate and to maintain, as closely as possible, the natural predevelopment flow pattern in the receiving watercourse. The 1:2 year detention level has been adopted by DFO and MOELP to account for the increase in impervious areas in developments and understanding that environmental impacts (e.g. stream erosion, sedimentation; loss of riparian habitat, stream channel changes, etc.) are occurring due to the more frequent, smaller storm events. Detention requirements can be estimated by various methods: rational method, SCS (U.S. Soil Conservation Service) unit hydrograph and level pool routing, as examples. The selection of the method of analysis depends on the size of development and type of information available, as well as the intended application of the results. Most analyses should be done or reviewed by a Professional Engineer. Additionally, there are many computer software packages available that aid in the analysis and design of these facilities, especially in the design of larger, complex drainage and community detention systems. Methods for determining the required degree of detention in the worked example are illustrations, not endorsements, of a particular design method. Many regional and municipal authorities have specific runoff and detention requirements. They will take precedence where they exceed the objectives of these guidelines.

Table 4.1 - Advantages and Disadvantages of Various Detention Technologies

Technology	Advantages	Disadvantages
Wet Ponds	- good water quality buffering - excellent sediment removal - good for multiple use areas - good for aesthetics and park values - suitable for large detention volumes - good peak rate control	- high capital and construction costs - formal permanent facility - large land area used - poor runoff volume retention - possible insect control problems
Dry Ponds	- good for multiple use areas - suitable for large detention volumes - good peak rate control - used in conjunction with infiltration	- poor water quality buffering and sediment removal - large land area used - on-line better than off-line - empty ponds have poor aesthetics - high capital and construction costs
Wet Tanks or Vault Detention	- good multiple use if covered/buried - good for building/rooftop runoff - use close to structures/foundations - good for built-up areas	- not suitable for large detention volumes - poor for high sediment inflows - requires maintenance/clean-out - poor water quality buffering
Infiltration Systems	- good water quality buffering - excellent small storm retention - excellent groundwater recharge - good peak rate control with detention - good for isolated developments - good for clean inflows (i.e. rooftops)	- not suitable for sediment inflows - poor in areas of high groundwater - high capital and construction costs - may require surface discharge - not suitable for large detention volumes - not suitable for low permeability soils
Engineered Stormwater Systems	- design into storm drain system - simple retrofit of existing systems and catch basins	- may cause localized flooding - extra capital costs for system sizing and orifice control manholes
Community Detention Facilities	- provide management for a larger area - share costs with municipality or number of owners - good for aesthetics and park values - design into community plan	- possible re-routing of upstream feeder creeks in large community facilities - construction during early stages of development - large infrastructure cost/responsibility - cost sharing may be difficult
Onsite Detention Facilities	- design to suit built-up area - flexible for different requirements	- potentially larger total area used - potentially higher individual costs
Constructed Wetlands	- excellent water quality buffering - excellent sediment removal - good for aesthetics and park values - suitable for large detention volumes - excellent peak rate control - good groundwater recharge	- requires large area - high capital and construction costs - high maintenance costs - possible insect control problems

Stormwater Detention Ponds

There are several types of detention ponds whose functions are the same, but which differ in design and operation. Detention ponds generally provide temporary storage of runoff in the form of a pond. The variation in pond type and operation allows the design to suit the size and type of development. Dry ponds provide temporary detention by filling during storm events, and slowly releasing runoff at a predetermined rate until empty. Because of the temporary nature of the detention of the storm runoff, dry pond technology can be utilized in multi-use areas like playing fields, parking lots, natural depressions, etc. Wet Ponds maintain a minimum level of water at all times and provide detention by storing runoff above this permanent level. They release at a predetermined rate down to the minimum water level. Wet ponds are a permanent structure which can be featured within a developed area. With an on-line pond, all storm runoff passes through the detention pond and the discharge is controlled to a desired predevelopment runoff rate. With an off-line pond, only that portion of the storm runoff which exceeds the allowable discharge, usually the predevelopment runoff rate, is bypassed and detained by the pond. That volume detained is released when the runoff volume decreases below the predevelopment runoff rate. Where the detention structure provides water quality benefits, on-line facilities are preferred due to the fact that all flows are provided some level of treatment.

Design of Dry Detention Ponds

Dry detention ponds are permanent facilities that remain after the development is complete, and must be protected and maintained on a regular basis. The following are guidelines and specifications for the design, construction and operation of dry detention ponds for these guidelines (See Figure 4.1 for dry detention pond details).

Location and Number of Dry Detention Ponds

Dry detention ponds generally require a suitably sized area located at the lowest point in the development area. The number of detention ponds required will be determined by the area available for detention storage and the contributing catchment area.

Design Parameters for Dry Detention Ponds

- Design discharge rate — predevelopment 2 year (1:2) storm runoff rate.
- Overflow spill capacity — post-development 100 year (1:100) storm event.
- Emergency spillway capacity — post-development 100 year (1:100) storm event.

Dimensions and Capacities of Dry Detention Ponds

- Maximum interior sideslopes — 4H:1V.
- Maximum exterior sideslopes — 3H:1V.
- Maximum water depth in pond — 1.0 meters.
- Minimum free board totop of berm — 0.6 meters.

- Ratio of effective length to effective width 5:1.

Inlet and Outlet Structures of Dry Detention Ponds

- A pretreatment sump to remove sediments in the runoff is required.
- Discharge and conveyance of pond flows should not cause erosion of natural drainage systems.
- A spill control-type inlet and outlet structure is recommended as in Figure 4.3.
- Oil absorbent pads should be installed in the inlet and outlet structures.

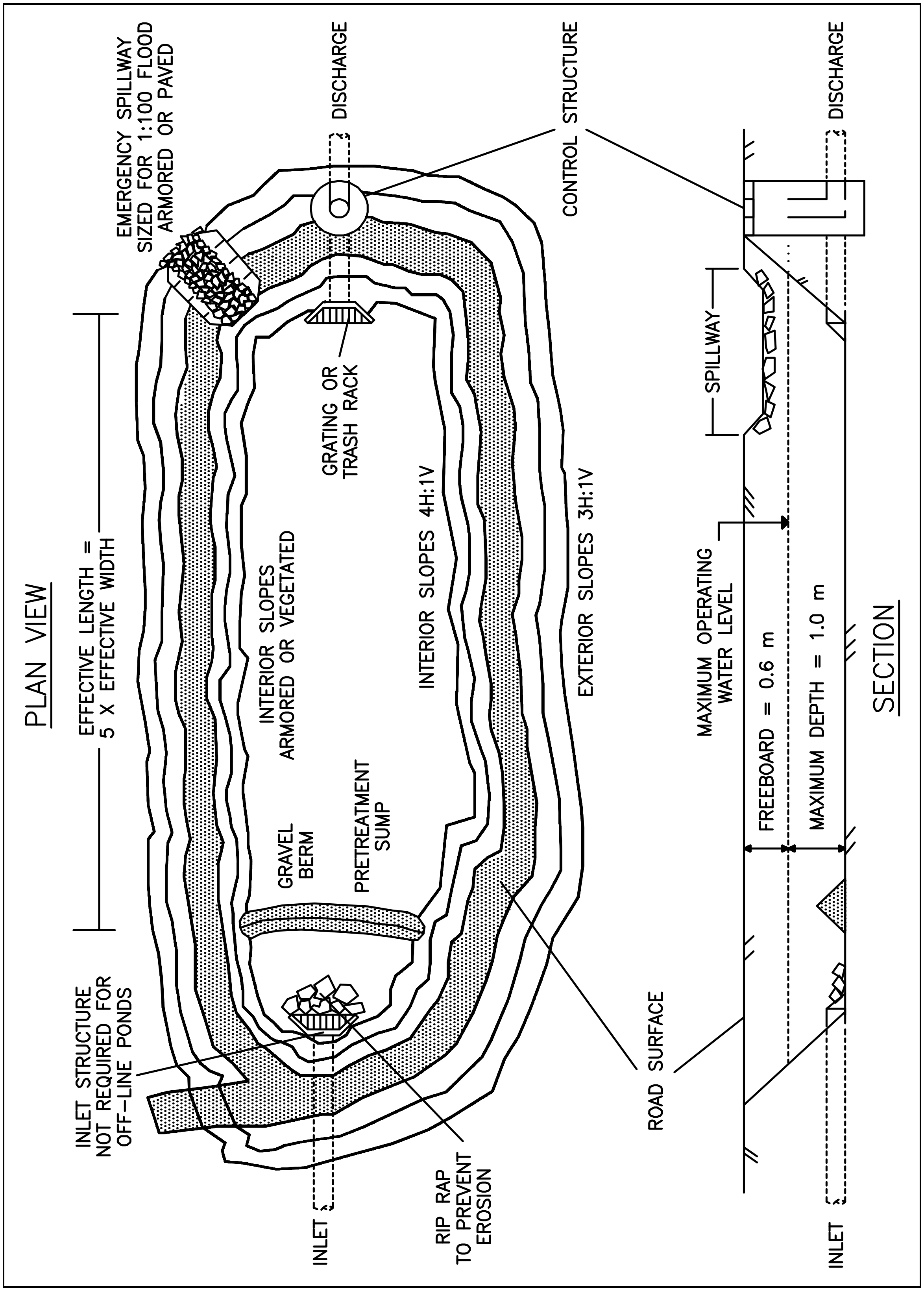
Operation and Maintenance of Dry Detention Ponds

- The top of slopes or berms around sediment control ponds should be wide enough to provide a safe and stable work area where required for the operation of maintenance equipment and personnel.
- All interior surfaces of the pond should be protected from erosion and, where possible, vegetated with suitable plant types to promote the removal of stormwater pollutants.

Stability and Public Safety of Dry Detention Ponds

- The stability of sideslopes for all earthen ponds should be confirmed by a Professional Engineer. All interior sideslopes in areas subject to water level fluctuations should be stable against pore water pressure during rapid drawdown. Exterior sideslopes should be structurally stable under all loads and hydraulic conditions.
- Discharge riser should be designed to exclude debris and large objects.
- The pond perimeter should be fenced, and have signs posted at intervals advising of the maximum water depth and prohibiting water use for human consumption or bathing.

Figure 4.1 Dry Detention Pond Plan and Sections



Design of Wet Detention Ponds

Wet detention ponds are permanent facilities that remain after the development is complete, and must be protected and maintained on a regular basis. The following are guidelines and specifications for the design, construction and operation of wet detention ponds (See Figure 4.2 for wet pond details).

Location and Number of Dry Detention Ponds

Wet detention ponds require a suitably sized area generally located at the lowest point in the development area. The number of detention ponds required will be determined by the area available for detention storage and the contributing catchment area.

Design Parameters for Wet Detention Ponds

- Design discharge rate predevelopment 2 year (1:2) storm runoff rate.
- Overflow spill capacity post-development 100 year (1:100) storm event.
- Emergency spillway capacity post-development 100 year (1:100) storm event.

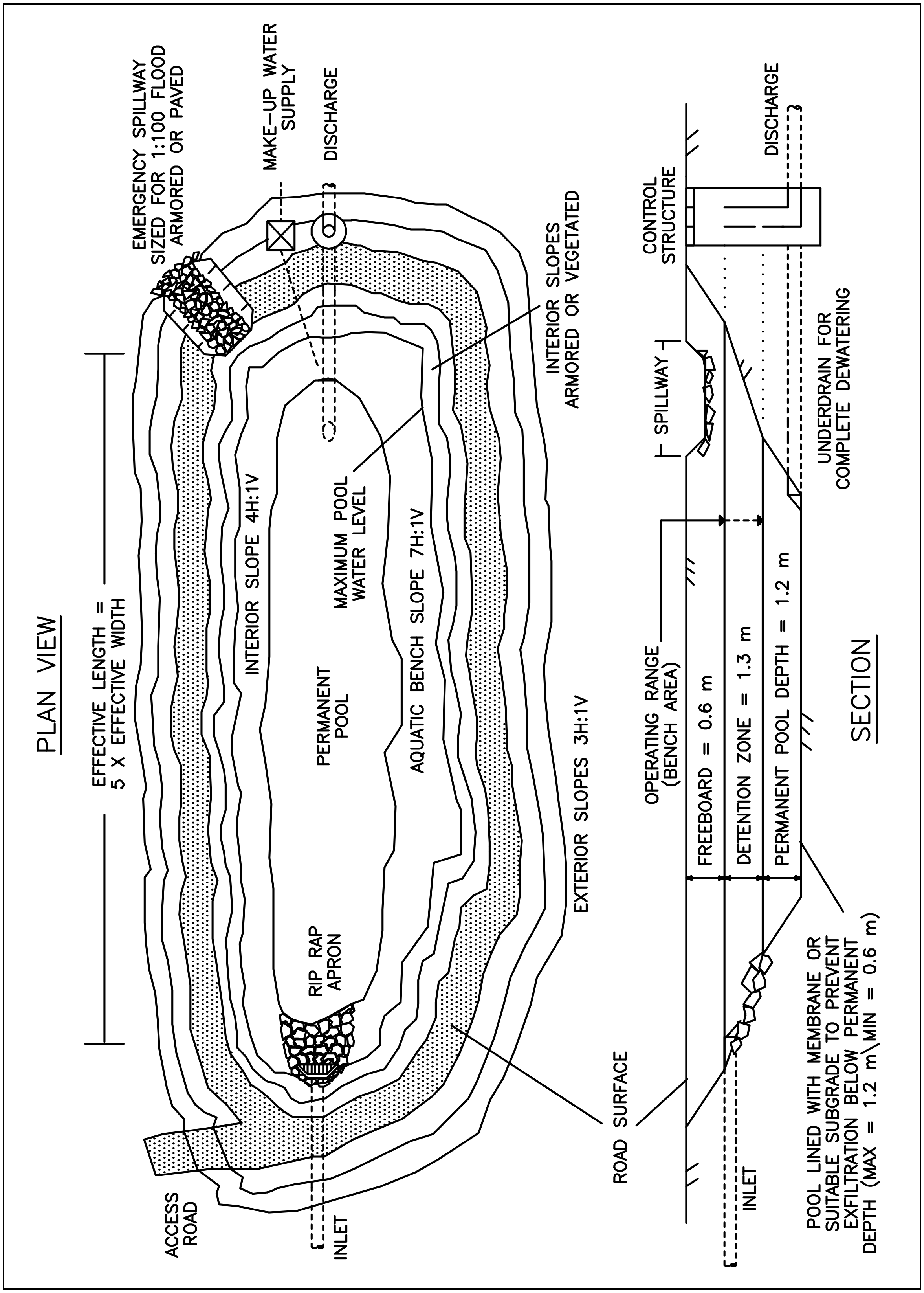
Dimensions and Capacities of Wet Detention Ponds

- Maximum interior sideslopes above active storage 4H:1V.
- Maximum interior sideslopes in active storage zone 7H:1V.
- Maximum interior sideslopes below active storage 4H:1V.
- Maximum exterior sideslopes 3H:1V.
- Maximum water depth 2.5 meters.
- Minimum permanent storage depth 0.6 meters.
- Maximum permanent storage depth 1.2 meters.
- Maximum active detention storage depth 1.3 meters.
- Ratio of effective length to effective width 5:1.

Inlet and Outlet Structures of Wet Detention Ponds

- A pretreatment sump to remove sediments in the runoff is required.
- Wet pond has auxiliary water supply for make-up water to maintain minimum depth.
- Discharge of pond flows should not cause erosion of natural drainage systems.
- A spill control-type inlet and outlet structure is recommended as in Figure 4.3.
- Oil absorbent pads should be installed in the inlet and outlet structures.
- Pond outlet structure will contain provision for complete drainage.

Figure 4.2 Wet Detention Pond Plan and Sections



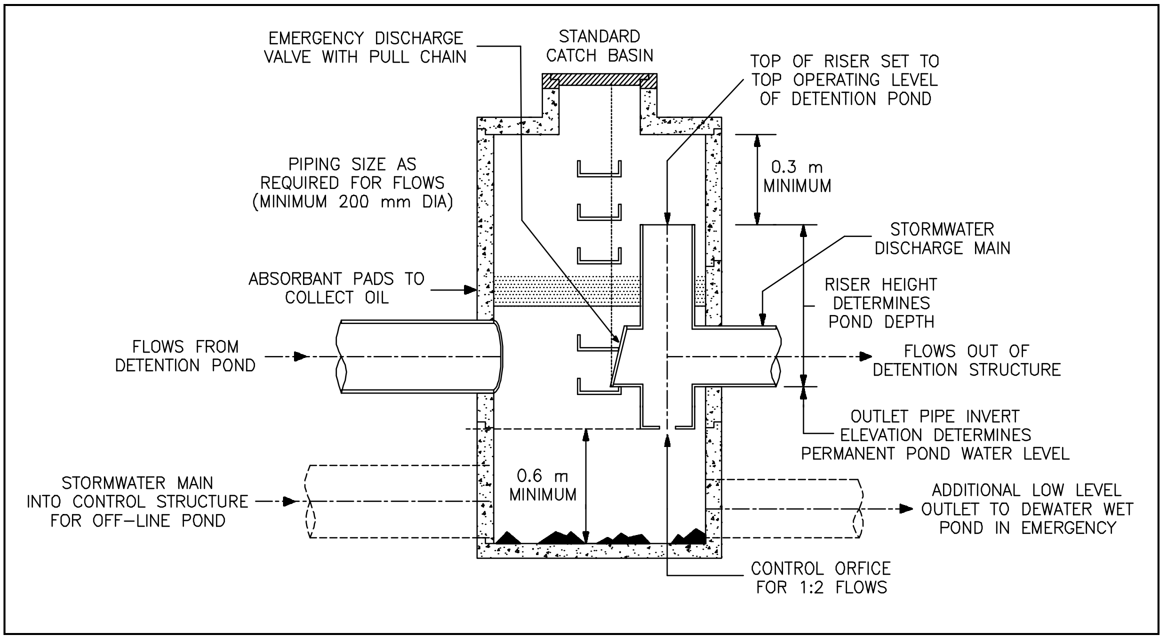
Operation and Maintenance of Wet Detention Ponds

- The top of slopes or berms around sediment control ponds should be wide enough to provide a safe and stable work area where required for the operation of maintenance equipment and personnel.
- All interior surfaces of the pond should be revegetated or protected from erosion.
- Pond outlet should draw deeper, cooler waters from pond to limit thermal effects of pond on water temperatures. Riparian areas should be re-vegetated to provide shading to the permanent pond area using plants of native species
- Pond outlet and outfall design should promote rapid re-aeration of pond discharges to limit the potential for depressed dissolved oxygen content in receiving waters with fish habitat.

Stability and Public Safety of Wet Detention Ponds

- The stability of sideslopes for all earthen ponds should be confirmed by a Professional Engineer. All interior sideslopes in areas subject to water level fluctuations should be stable against pore water pressure during rapid drawdown. Exterior sideslopes should be structurally stable under all loads and hydraulic conditions.
- Discharge riser should be designed to exclude debris and large objects.
- The pond perimeter should be fenced, and have signs posted at intervals advising of the maximum water depth and prohibiting water use for human consumption or bathing.

Figure 4.3 Detention Pond Control Structure Typical Details



Design of Detention Systems for Built-up Areas

Detention of stormwater can be designed to fit into existing developments where space is limited and construction of a conventional pond-type facility is not practical.

Roof Top Detention

- The use of roof top storage should be considered for industrial, commercial and institutional buildings with flat roofs.
- Appropriate building code requirements covering rain loading must be followed (National Building Code, 1990, Part 4, Commentary 1).
- The release rate from the roof top should be controlled by a roof top detention device. Overflow scuppers should be provided at the maximum operating water level.

Parking Lot, Park Area and Work Yard Detention

Parking lots, park areas and work yard areas may be used for temporary water detention to shallow depths. Generally, the flooded area operates like a dry pond where the runoff rate is controlled by a valve or orifice located in an outlet pipe or manhole.

- The allowable depth is a function of safety and convenience to users and should be designed accordingly. Flow control chambers should be used to control the water depth.
- Overflows to the storm drainage system, or a surface flood route, should be provided at the maximum operating level.

Underground Detention Structures

Underground detention can be built into the design of stormwater systems by utilizing oversized piping or off-line tanks controlled by a suitable device to limit outflow.

- Underground tanks, pipes or culverts may be used as detention storage facilities.
- All such underground facilities should have an access point for inspection and maintenance. All underground tanks should have an air space, equal to 20% of the maximum depth, connected to the atmosphere by a vent.
- The outlet structure should have a flow control orifice and overflow which is set at the maximum operating water level (to pass storm runoff in excess of the two year (1:2) storm event, and to provide an alternative outlet in the case of orifice blockage).
- Underground tanks: minimum of 0.5 meters cover and capable of CS-600 loads.

Infiltration Systems

Stormwater systems that utilize infiltration can provide many benefits to the hydrology and water quality of an urbanized stream. Infiltration systems can provide retention of runoff through groundwater recharge in addition to runoff peak flow control. The soil, through which the stormwater runoff passes, acts as a filter removing a large percentage of the common pollutants normally discharged to the stream or creek. Infiltration can provide recharge to the local area groundwater which in turn feeds smaller streams and creeks. This groundwater is slowly discharged back into streams and can constitute all or part of the stream's baseflow. Maintaining this baseflow can be critical for fish and fish habitat during extended periods of little or no precipitation and runoff. In many applications, stormwater runoff from the developed site can be collected and discharged into an infiltration system where there is no infrastructure to support conventional stormwater removal systems, with the added benefit of reduced costs of providing offsite conveyance.

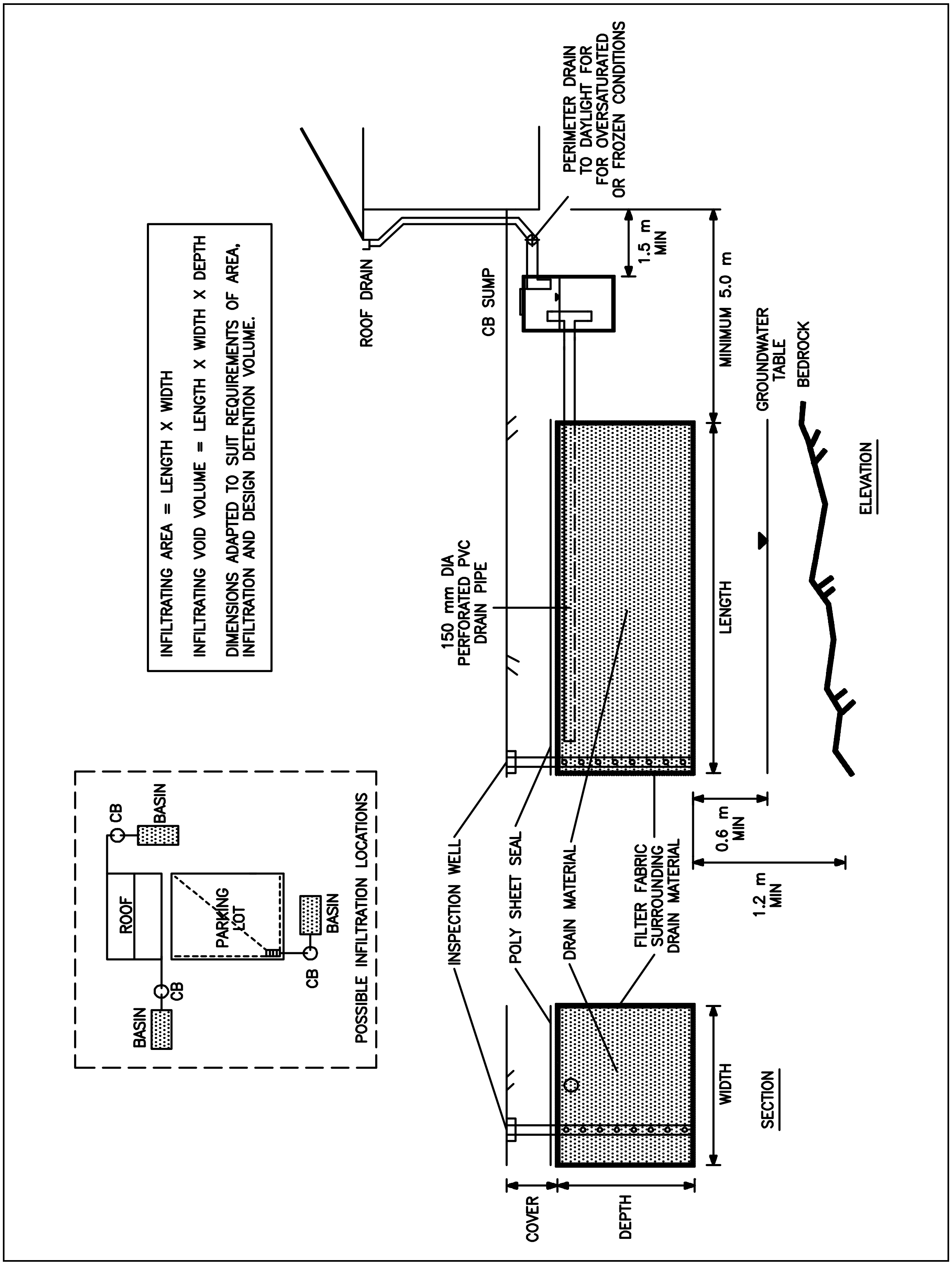
Application of Infiltration Systems

- Infiltration basins may be used as a method of stormwater detention only if required detention volumes are relatively small.
- In larger applications, a series of infiltration basins may be necessary, each serving a small collection area. Utilizing several galleries may reduce collection and piping costs normally associated with conventional stormwater systems. Infiltration basins should not be built under parking lots or other multi-use areas.
- Ponding and detention can be incorporated into the design of the infiltration system. Conversely, infiltration can be used in combination with other detention technologies to provide retention of runoff.
- Infiltration systems should not be used if any of the following site conditions are found:
    - The seasonal high groundwater table is within 0.6 meters of the infiltrating surface.
    - Bedrock is locatedwithin 1.2 meters of the infiltrating surface.
    - The infiltrating surface is located on top of fill material.
    - The adjacent or underlying soils have a fully saturated percolation rate of less than 0.5 inches per hour.
- The following conditions should be followed in siting an infiltration system:
    - Subgrade foundation or basement is not located within 5.0 meters.
    - A water supply well is not located within 30 meters.
    - Infiltration systems should not be placed on slopes greater than 5H:1V due to downslope seepage, saturation and slope failure potential.

Design and Construction of Infiltration Systems

- The storage volume available is calculated from the effective porosity of the infiltration fill material. The total void volume should equal the storage required for the two year (1:2) design storm runoff associated with the developed catchment area.
- The 24 hour sustained saturated percolation rate should be used to calculate the basin area requirement in order to drain the system within 2 days (48 hours). The basin bottom area should be used as the infiltrating surface to calculate the required area.
- Provision for overland flow during frozen ground conditions or oversaturation should be made.
- A pretreatment sump or vegetative filter should be used to limit sediment inputs into the infiltration system and maintain its exfiltration capacity.
- Drain materials should be screened and washed, inert, natural gravels. The design void space ratio can be calculated by measuring the volume of water required to fill a known volume of drain rock (void ratios are typically 0.3 to 0.4 for a graded screened gravel).
- A good quality commercial filter fabric or geotextile should be used to completely surround the drain rock. This minimizes migration of fines into the drain rock, maintaining the void volume required for storage of the runoff. A suitable geotextile is a non-woven, synthetic, needle punched polypropylene.
    - Minimum permeability 1.2 x 10^{-2} cm/s.
    - Minimum grab tensile strength 750 N.
    - Equivalent opening size 0.125 mm.
- See Figure 4.4 for the application and design of a small infiltration system.

Figure 4.4 Infiltration System Design and Typical Application

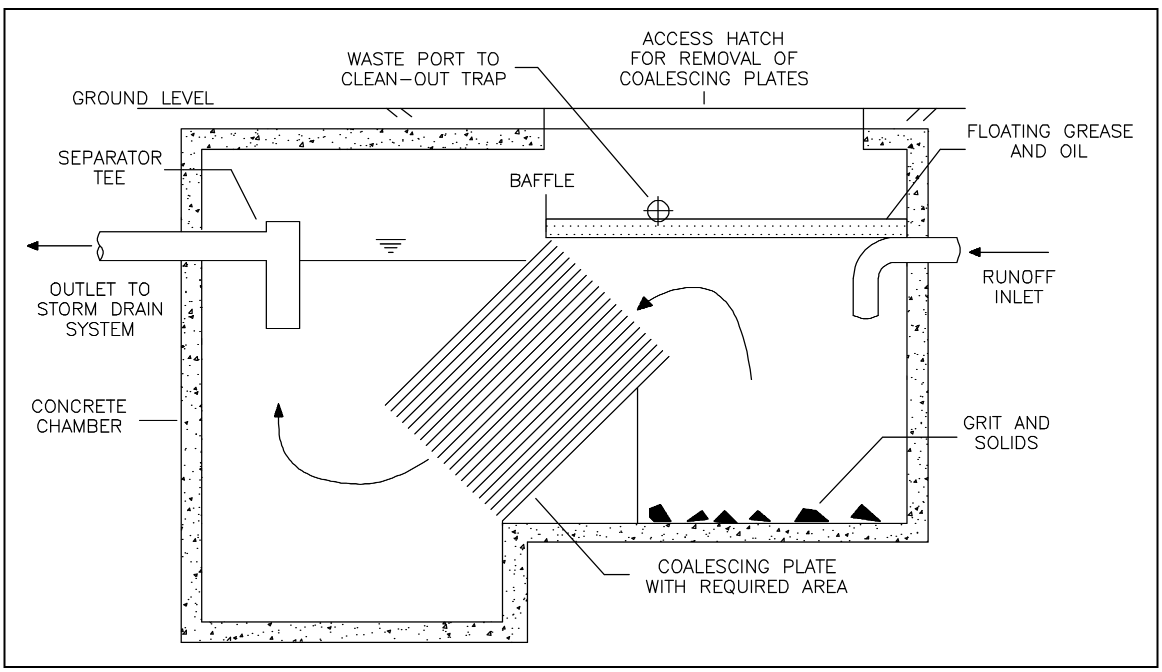


Oil-Water Separators

Oil-water separators are suitable for the removal of floatable petroleum-based contaminants from small areas of concentrated activity, such as gas stations, automotive service areas and parking lots. Oil-water separators have a limited ability to remove floatable petroleum contaminants in typical large-scale stormwater runoff applications and their application should be limited to these small area generation sites. Removal of these contaminants is best achieved using a coalescing plate oil/water separator (CPS). The coalescing plate separator uses a packed plate media and is effective in removing oil droplets 60 microns and larger, which constitute up to 85% of the oil volume in commercial applications (Gibb et al., 1991).The required area and number of plates are determined by the design inflow into the CPS unit.

- The design flows into the separator should be based on the 1:2 year post-development flows, when the detention requirements of these guidelines are not provided for the catchment area.
- Where detention is provided to the 1:2 predevelopment flow rate, the oil-water separator should be installed downstream of the detention structure.
- Spill control separators (similar to Figure 4.3) also limit the impact of uncontrolled spills of pollutants, and should be installed as required in storm drainage catch basins.
- Oil absorbent pads should be installed to aid in the removal of floatable petroleum contaminants. The absorbent pads should be replaced on a regular basis and disposed of in a safe manner

Figure 4.5 Coalescing Plate Oil-Water Separator



Stormwater Runoff Water Quality Objectives

The changes in land use, increase in impervious area, and introduction of pollutants related to human activity all contribute to reduced water quality impacting fish and fish habitat. Currently, the *Fisheries Act* regulates the general discharge of deleterious substances into waters containing fish or fish habitat (see Appendix **I** for definitions of "deleterious substances"). Future guidelines and regulation by MOELP, DOE and DFO of stormwater runoff water quality and discharges are expected within the next generation of these guidelines (e.g. the development of best management practices, technologies and regulated contaminant levels). References included in the back of these guidelines are sources of additional information stormwater runoff water quality management techniques and technologies.

Stormwater Runoff Water Quality Best Management Practices

Where stormwater runoff water quality objectives are required for receiving water quality, and protection of fish and fish habitat, the following stormwater management strategies should be implemented as **best management practices** (BMP). BMPs are physical, structural or management practices that reduce or prevent water quality degradation. Source control remains a key method for reducing introduction of pollutants, such as toxic/hazardous materials, organic and inorganic contaminants, resulting from human land and water use, or spills, especially in the commercial and industrial environments. Without source control, runoff water quality standards are limited by the effectiveness of expensive treatment technology.

Source Controls

Education and information regarding the problems and potential solutions of stormwater pollution, and its impact on the fisheries resource and environment, should be presented to the public. Programs and alternatives to eliminate the use or production of deleterious substances should be promoted (e.g. leaded gasoline). Practices to remove materials from the environment before interception and transport by precipitation runoff or through the storm drainage system should be adopted (e.g. enhanced street sweeping, covered parking areas). Land and water users should adopt a watershed planning process with DFO and MOELP to avoid potential conflicts with the fisheries resource.

Treatment Controls

Treatment controls should be designed on a site-specific basis, after examining the alternative treatment technologies, and selecting the best available based on cost and effectiveness. These controls should be designed and constructed, with monitoring of the operation and performance of the technology, as well as the impact on receiving water quality.

Stormwater Runoff Water Quality Best Practical Technologies

Several technologies have the ability to provide both water quality benefits and runoff control. Water quality benefits are based on contaminant removal mechanisms using biological and physical processes. Runoff control is provided by improved detention and retention of stormwater flows for reduction in peak runoff rates and volumes of runoff. The following stormwater treatment technologies should be implemented as **best practical technologies** (BPT). BPTs are technologies that provide cost-effective contaminant removal and treatment.

Wet Detention Ponds

Permanent wet ponds can provide deleterious substance removal through biological activity: uptake and conversion by plants, microbial degradation, and by physical processes: sedimentation, filtration, absorption and adsorption. In addition, wet ponds can provide detention/retention requirements of stormwater flows. As a general guideline for water quality design, the permanent pond should have a minimum surface area equal to 1.5% of the catchment area and have a permanent pond volume equal to the design storm runoff volume. Design parameters also include: vegetation types (floating, emergent and submergent vegetation) and area coverage, water depth and area coverage, and detailed pond operation parameters.

Infiltration Systems

Infiltration systems can provide retention of highly contaminated initial flows (i.e. "first flush" events). Physical removal of deleterious substances by filtration and adsorption, as well as conversion of soluble pollutants by bacteria, occurs within the infiltrating soils. It is possible to use infiltration in conjunction with other technologies (e.g. detention ponds) to meet water quality and quantity objectives.

Constructed Wetlands

Wetlands can be constructed specifically to treat stormwater runoff and provide similar biological and physical removal mechanisms as found in wet permanent ponds. Constructed wetlands can also provide buffering and retention of runoff flows. Constructed wetlands are treatment systems, but can also provide additional benefits for aquatic and wildlife habitat. The use of existing natural wetlands to provide stormwater treatment is not acceptable. General design requirements for constructed wetlands include: vegetation types and area coverage (floating, emergent and submergent vegetation), water depth and drainage design. Vegetation management, including fall harvest of plant growth, should be considered to prevent release of nutrients and BOD related to vegetation decomposition. As a general guideline for water quality design, the constructed wetland should have a minimum surface area equal to 1.5% of the catchment area.

Biofilters

Biofilters are vegetated filter strips and swales that provide physical removal of deleterious substances, notably particulate contaminants, with some biological removal mechanisms. Biofilter technology is suitable for sheet flow runoff, typical of large linear impervious developments like roadways and parking lots.

Urban Forests and Leave Strips

Depending on the extent of tree canopy and ground cover retained, runoff reduction and deleterious substance removal can be achieved by the use of forested areas. Removal processes include filtration, absorption, and biological uptake and conversion by plant life. Riparian leave strips, especially surrounding aquatic habitat, promote the conservation and protection of fish and wildlife habitat.

Guidelines for Implementation of Stormwater Water Quality Objectives

- Use the best management practices (BMP) and best practical technology (BPT) for control of stormwater runoff water quality where runoff has detrimental impacts on fish and/or fish habitat.
- Use technologies that provide both physical and biological removal of contaminants, in addition to detention and retention of stormwater runoff.

Storm Drain Marking Program

The marking of curbside storm drains with bright yellow fish is to remind people that most drains empty into a nearby creeks that likely contains fish habitat. Local community groups and schools across B.C. are involved in the program, initiated by DFO and MOELP, to encourage understanding of the effects of urbanization and stormwater pollution on our local streams and their fish populations. Information on the storm drain marking program can be obtained from your local DFO or MOELP office. Information pamphlets and storm drain marking should be initiated in all new developments where runoff drains into streams containing fish habitat.

SECTION 5
INSTREAM WORK

Objective

It is recognized that at times it may be necessary to perform instream work as part of the process of developing land. The objective of the instream work guidelines is to promote careful planning and construction practices to limit the potential for impacts on the aquatic environment. Instream work is any work performed below the high water mark, either within or above the wetted perimeter, of any feature within the FSZ. **Prior to commencement of any instream work and with sufficient lead time, proponents should consult with DFO/MOELP for information regarding FSZ species timing windows and construction methods**. Because instream work has the potential to be extremely destructive to fish habitat, methods and procedures to minimize instream activities should be considered during the planning and design stages of a project. The procedures should be specifically designed to achieve the following objectives throughout the project.

- Protect the natural stream conditions and structure to promote stability of bank and bed structures, and retain riparian vegetation.
- Provide the instream conditions required for unhindered fish passage upstream and downstream.
- Prevent introduction of pollutants and deleterious substances by controlling construction activities and site conditions.
- Prevent generation of sediment, impacting fish and aquatic habitat, by utilizing the proper instream construction technique and supervision.

Guidelines for Instream Work

General guidelines for instream work include:

- Consult with local DFO/MOELP staff regarding presence, distribution and timing of migrations of fish species in the stream or watercourse, and FSZ window (Appendix III).
- Plan instream work for periods within the confirmed FSZ window that will minimize disturbance and impact on fish and fish habitat.
- Plan instream work for periods of suitable stream and environmental conditions, determined in consultation with DFO/MOELP.
- Minimize the duration of the instream activities.
- All material placed within the wetted perimeter must be coarse, non-erodible, and non-toxic to fish. Do not remove gravels, rock or debris from any stream without the approval of DFO/MOELP.

- Minimize disturbance to stream banks where equipment enters and leaves the watercourse. Reconstruct and revegetate stream banks to their original condition as soon as activity has finished (see Section 2).
- Use the proper equipment for the proposed construction activity. Avoid damage caused by stuck equipment or delays because of insufficient capacity for proposed work.
- Ensure that all construction equipment is mechanically sound to avoid leaks of oil, gasoline, hydraulic fluids and grease. Consider steam cleaning and check-up of construction equipment prior to use instream.
- Require the use of biodegradable hydraulic fluids for machinery used for instream work.

Timing of Instream Work

It must always be assumed that fish are present in a watercourse since the utilization and residency times for different species vary widely in accordance with their spawning and rearing cycle requirements. The windows of allowable times when instream work can be tolerated are often based on the reduced sensitivity of the fish to disturbances rather than the absence of fish during these times. The work should be coordinated and timed so that conflict with the fish populations is minimized. Appendix III contains information on the species-specific freshwater FSZ timing windows. The utilization of various habitats (freshwater lakes, rivers, estuarine and marine environments) by both resident and anadromous fish populations place restrictions on instream work. **Timing windows of allowable instream work should always be confirmed with DFO/MOELP personnel responsible for the local area in which the proposed development is located**. Site specific differences exist and DFO/MOELP staff should be consulted early as possible in the planning process.

Instream Work and Construction Practices

Methods such as sheet pile isolation, coffer damming, fluming and stream diversion are often acceptable temporary containment practices to minimize aquatic disturbance during instream construction. Instream containment and dewatering at work sites located within fish bearing streams are commonly required for instream construction. Isolation from flowing water is usually a requirement for maintaining water quality. When dewatering of the site is required, this work should proceed in the presence of a DFO/MOELP representative or Environmental Monitor who should make the final decision regarding the need for a fish salvage program. Should a salvage program proceed, the proponent shall assist in the recovery of fish and the transporting of them to a safe area outside the influence of the work site.

Coffer Dams and Sheet Piling

Coffer dams and sheet piling are used to isolate the work area from the aquatic environment and limit the disturbing activities associated with construction activities. They should not reduce the stream width by an amount that will lead to erosion of banks both upstream and downstream of the site or impede the movement of migrating fish. Only clean, silt free materials shall be used as the fill materials for coffer dams, and all bags and materials must be removed after construction is completed. All water pumped from contained work areas within coffer dams must be discharged on an upland site to allow sediment removal before it re-enters any watercourse.

Flumes

Flumes are most often heavy gauge steel pipe(s) that will carry the flowing water over the total distance of the isolated work site. The fluming pipes should be sized to handle the maximum expected discharge recognizing the maximum practical fluming capacity is about 3 cubic meters per second (106 cfs). The design of the flume should include consideration of the flow capacity, size and length of fluming, area and depth of excavated area, and stability of the stream bed substrate during excavation.

Temporary Stream Diversions

Temporary stream diversions or channelization should always be excavated in isolation of stream flow, starting from the bottom end of the diversion channel and working upstream to minimize sediment production. Any dewatering flows should be directed to a settling pond to remove sediments. Channel diversion shall only commence in the presence of a DFO/MOELP representative and should be completed as quickly as possible, preferably within a single day during the low flow period. Upon completion of the instream work, the stream shall be restored to its original configuration and stabilized to prevent bank erosion around the temporary diversion.

Water Intakes

Water intakes in fish bearing streams shall be screened to Federal Fisheries specifications to prevent the possibility of juvenile fish mortality. For detailed information refer to DFO's *Fish Screening Directive* (1990).

Construction Materials and Instream Work

Special care is required in the use of some common, but highly toxic, construction materials in and around areas of instream work. Wood preservatives, paint and concrete are potential contaminants frequently used near watercourses.

Wood Preservatives

Wood preservatives containing chemicals such as creosote, chlorophenols and zinc or copper napthanate solutions are extremely toxic to aquatic organisms. However, based on information on mobility, persistence, and aquatic toxicity, it is suggested that CCA (chromated copper arsenate) treatment is rated as the preferred wood preservative treatment in freshwater environments, and creosote is the preferred wood treatment in marine environments. With CCA treatments, the treated dry wood should be rinsed after application and drying, with wash waters contained or recycled, and weathered or seasoned for a minimum of 45 days before it is used in or near any water body. Pressure treated lumber containing CCA should be allowed to fully react and also weathered for a minimum of 45 days. Application of treatment solutions to installed materials on or over water is not recommended under any circumstances. Creosote applications should include steam treating to reduce loss of preservative into the marine environment.

Paints

All paints are toxic and should only be applied when tarpaulins have been installed beneath work areas. This will allow for the collection of any excess liquid or scrapings and the subsequent careful removal to a safe disposal location. Paint removal scrapings and sandblasting slag should also be contained.

Cast-In-Place Concrete

Concrete, which contains lime in the cement, can kill fish by substantially altering the pH in stream water. All cast-in-place concrete should be totally isolated from flowing water for a minimum 48 hour period to allow the pH to reach neutral levels before continuing instream work. Pre-cast concrete should be used whenever applicable for the construction required.

Sediment and Erosion Control during Instream Work

Sediment Control

The temporary containment and removal of sediment-laden water will probably be necessary during instream work, even when isolation techniques are used. Contaminated water within the work site must be pumped onto a land site where it will not re-enter the creek, or will do so only after filtration and settling has taken place.

Instream Machine Crossings

Where no alternate access to the opposite side of a watercourse exists, where it is impossible to do certain instream work from the banks, or where it is not feasible to isolate a worksite during construction, it may be necessary to take machinery and/or equipment into or through a flowing stream. In such situations, the local fisheries agencies must be consulted beforehand. Access should be arranged for the period of flow with the least impact to fish and fish habitat. All vehicles and equipment must be clean and in good repair to avoid leakage of petroleum products. Access by fording should be restricted to one crossing location, and traffic should be limited. Instream control measures and engineered roads using clean fill materials may be necessary. The access site must be chosen with care, where banks are low, the stream substrate is suitable, and the water shallow. Upon completion, the banks should be restored, restabilized and revegetated to prevent erosion.

Erosion Control and Streambank Rehabilitation

Any time a bank or the channel bottom is disturbed, restorative action should be taken to prevent erosion, siltation and to replace lost fish habitat. If adequate site selection and careful construction techniques are implemented, minimal disturbance and rehabilitation should be required to the riparian zone and the stream. Each site needs to be assessed individually at the planning stage to determine what rehabilitation will be needed. Erosion control materials should not encroach into the stream's cross-sectional width. Encroachment can create backwatering (flooding) and increase stream velocities that may cause scouring and erosion. It may be possible to reuse excavated materials. In some cases, however, they may have to be totally replaced with materials more suitable for fish habitat (i.e. using washed, silt-free gravel as backfill). Acceptable bank erosion control methods include hand seeding, hydroseeding, silt blankets, rock riprap and revegetation using plantings. Scalping existing instream material, like gravel bars or large rocks, will not be permitted. The top of banks and the riparian zone may also need to be stabilized, commonly by planting trees, shrubs, and various bushy types of vegetation. Native species should be used for all revegetation projects.

Explosives

The use of explosives in or near fish habitat must be approved by DFO/MOELP. Each application will be considered individually on the site specific conditions and circumstances. Explosives may only be used when other, less detrimental, methods are not feasible. Some general considerations to consider are:

- Schedule blasting for periods when fish are not present in the blast influence area.
- No blasting should take place near known spawning areas when eggs or alevins are still in the gravels.
- Minimize blast energy by using low velocity charges, multiple charges and special detonation techniques.
- Minimize damage to surroundings by the use of blasting mats and blast deflectors.

In some situations, it will be necessary to physically remove juvenile salmonids from, and block their re-entry back into, the blast zone. The underwater blast zone generally encompasses the area within a 400 meter radius of the detonation site depending on blast energy and materials. The proponent or developer must conduct such removal activities only with the direction and assistance of a qualified professional biologist. Information on explosives use can be found in Munday et al. (1986).

Maintenance of Instream Structures

Well designed and constructed instream structures should require minimum maintenance. Frequent inspections, particularly during high runoff periods, are very important. Improper functioning of a structure during or after a major storm event may indicate the need for minor repairs or modifications. It is advisable to perform such minor repairs immediately in order to prevent the need for major repairs later, and to ensure safety and reduce the environmental impact. General maintenance should be carried out according to an agreed schedule of works and agency contact procedure. If emergency measures are required, only justifiable essential preventative actions should be taken to protect life and major losses of property. If time allows, contact the fisheries agencies before carrying out emergency repairs.

Permanent Watercourse Diversion or Relocation

The permanent diversion or relocation of streams or watercourses is strongly discouraged and only in unusual circumstances will it be considered by DFO/MOELP. Where a permanent diversion or relocation is absolutely necessary, a compensation diversion channel shall be designed in detail under the guidance of a fish biologist and other specialists. This compensation habitat is to provide no net loss of the productive capacity of the aquatic fish habitat. The diversion or relocation must display hydraulic similarity to the existing stream or watercourse in order to ensure minimum morphological change to the stream reach. This requires careful evaluation and cataloguing of the existing features in advance of the relocation design. The construction of the compensation channel shall be carried out in dry conditions without connection to the existing stream or watercourse. Once the construction is completed and revegetation has been established, the connection to the existing watercourse, downstream and upstream of the diversion or relocation, will be permitted. The connection shall be made only during the approved timing windows for instream work and under DFO/MOELP supervision. Sufficient notice shall be provided to the local DFO/MOELP offices to permit reconnaissance, planning and inspection of the diversion before connection to the stream takes place. The proponent will provide the means and expertise to relocate resident fish stocks from the section of stream or watercourse to be abandoned to the new section being brought into service. This relocation shall be carried out quickly and with a minimum of stress to the fish stocks once the connection work is finished and the new stream reach has stabilized to a degree acceptable to the DFO/MOELP. Re-inspections and evaluations of the success and effectiveness of the diversion or relocation shall be made at specified intervals after its placement into service, and the necessary corrections and adjustments made by the development proponent where such are deemed necessary by DFO/MOELP personnel. A formal written agreement will be necessary between the developer and DFO/MOELP, setting out the detailed conditions of approval.

SECTION 6
FISH PASSAGE AND CULVERTS

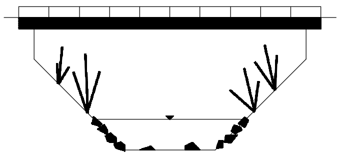
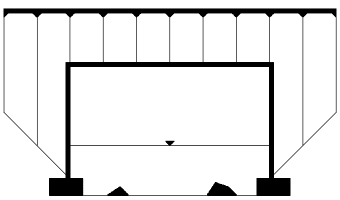
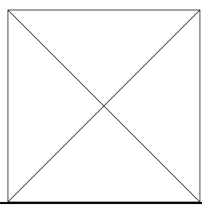
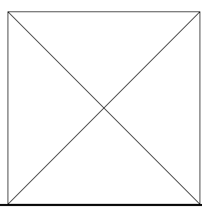
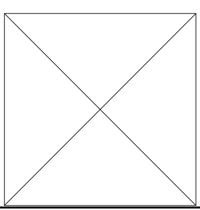
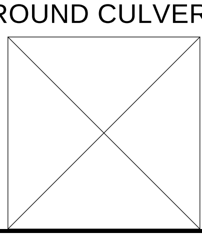
Objective

The objective of these guidelines is to maintain migratory fish movements in watercourses to ensure that the various phases in the life cycle of fish can be carried out without undue stress or hazards that would affect the productivity of present and future populations. Barriers that prevent fish from moving upstream to spawning or restrict access to rearing and feeding areas can take many forms which may not be obvious. They include: dams of materials and debris, increased flow velocities over long reaches of stream, lack of jump pools at drops in the stream channel and insufficient water depth because of sedimentation or channelization. Natural migratory fish movement should be maintained by the provisions of these guidelines which are intended to minimize changes to the natural stream morphology and hydraulic conditions, and maintain adequate water quantity and quality.

Natural Fish Migration

Fish migration occurs in response to a need, whether to spawn and reproduce, find food items and feed, or to escape predators. The migration event may involve a large or small population of individuals moving over a short or prolonged time period, up or downstream. Where the various lifestages of fish migrate naturally, the stream flow conditions, hydraulics and morphology provide a certain set of conditions suitable for their passage. Development should have no impact on that natural set of predevelopment conditions. Blockages and delays in migration, whether caused by complete or partial obstructions, can have devastating effects on a population of fish. Various permanent and temporary structures are constructed to allow the passage of vehicles and people over streams, lakes and rivers. Where options exist for the type of structure to be used, a spanning bridge which maintains the natural bank and bed structure is preferred from a fisheries perspective. Clear span bridging permits the retention of riparian vegetation around the crossing site owing to a small footprint (area covered by the structure's footing and fill) on the crossing area. Bridges allow unrestricted movement of bed load by maintaining the natural stream bottom and bed structure. Additionally, bridging allows free passage of salmonids at various water levels by maintaining the natural hydraulic conditions that existed before development. Encroachment of piers and footings can impact the stream by reducing the wetted perimeter causing local scour of the bed and erosion of the stream banks. Table 6.1 illustrates the preferred ranking of crossing structures as well as some of the associated design and fisheries-related features.

Table 6.1 - Fisheries and Design Considerations for Stream Crossing Structures

TYPE OF STRUCTURE	FISHERIES CONSIDERATIONS	DESIGN CONSIDERATIONS
BRIDGE 	- Can retain existing bottom substrate, bank structure and riparian vegetation. - Does not alter LOD or bed load transport capacity of stream reach. - Can retain natural fish passage stream qualities.	- No limit to stream hydraulic capacity if encroachment of piers or footings is limited. - Ability to cross large streams and rivers. - Structure can be designed with no instream work required.
OPEN BOTTOM CULVERT 	- Does not limit fish passage if properly designed and constructed. - Retains natural stream substrate. - Water velocities are not significantly changed if as wide as the natural stream. - Loss of riparian vegetation because of infilling around culvert.	- Design to normal stream width. - Can be placed in multiple units to provide wider section and larger end area. - Provide suitable footing for wall section to prevent undermining by stream erosion.
BOX CULVERT 	- Can limit fish passage at low flows by reduced water depth in culvert (with no baffles). - Baffles can be easily installed to provide fish passage. - Wide bottom area allows retention of bottom substrates.	- Can be designed to maintain normal stream width. - Can be placed in multiple units to provide wider section and larger end area. - Precast units can be installed quickly limiting instream construction time.
PIPE ARCH CULVERT 	- Can limit fish passage at low flows due to reduced water depth in culvert (with no baffles). - Baffles can be installed to provide fish passage. - Wide bottom area allows retention of bottom substrates.	- Wide bottom area provides good flow capacity with limited depth increase. - Good for low clearance installations. - Multiple units can be installed to provide greater capacity. - Reduced depths at low flows may require backwatering.
STACKED CULVERTS 	- Can provide fish passage over a wider range of flows, depths and water velocities than a single culvert. - Fish passage must be provided in lowest culvert for low flow conditions. - Possible to backwater lowest culvert to reduce velocities and allow fish passage.	- Same hydraulic properties as a single culvert. - Flows may be excessive in single culvert at low flow conditions. - Lowest culvert may plug with bed load if culvert grade is unsuitable.
ROUND CULVERT 	- Difficult to provide passage in small diameters. - Concentrates flow and velocities. - Generally poor for fish passage situations. - Loss of habitat because of infilling around culvert as with all fill structures.	- Concentrates flows and increases velocities and potential scour at high flows. - Reduced depths at low flows may require backwatering. - Can have poor bed load transport through culvert.

Culvert Design and Installation

Culverts, when properly designed and installed correctly, may have little impact on fish migration. Culverts are ideal for low volume, intermittent or ephemeral streams, or high gradient streams with no fish migration or fish habitat values. Their use for major crossings, large streams or streams with high fish habitat values is discouraged. Due to the lack of detailed streamflow data for small streams, and the wide variation in the timing of upstream migration of fish in different watersheds, it is important that an adequate hydrological analysis and culvert design be undertaken. To ensure the fisheries resource is not adversely affected by interruption of upstream migration at a culvert and access to habitat is provided, certain conditions must be maintained at the culvert. These conditions include: minimizing culvert lengths, provision of outlet pools and baffles, maintaining minimum water levels, and limiting culvert grades and water velocities. **DFO/MOELP staff should be contacted if provision for adult or juvenile passage is required at a development site**.

Figure 6.1 illustrates poor culvert installation limiting fish passage upstream. The small, round culvert lacks adequate baffling for low flows, and would have excessive velocities at high flows. The outlet conditions do not provide ready access to the culvert from the outlet pool resulting in severely restricted access for upstream migration.

Figure 6.1 Culvert Installation Limiting Fish Access

Figure 6.2 illustrates the application of fish passage requirements to the same culvert shown in Figure 6.1. The round culvert has been replaced with a concrete box culvert with baffles installed to aid upstream passage. A small fishway has also been installed to allow ready access from the stream to the culvert outlet.

Figure 6.2 Culvert Providing Upstream Fish Passage

Multiple Culvert Installations

When more than one culvert is provided at the same site, fish passage criteria need only be applied to one of the culverts. That culvert to which fish passage criteria are applied should be installed at least 0.31 meters lower than the other culvert(s). Often the installation of culverts at different elevations will provide fish passage over a range of water levels and hydraulic conditions.

Passage Design Criteria for Adult Fish

Generally, migrations of adult fish are upstream spawning migrations required to continue the life cycle of the population. Where culverts are used and upstream fish migrations occur, culvert design should include features and design to allow the free passage of adult fish. Culvert design should take into account their upstream swimming capabilities (Table 6.2) as well as design criteria for fish passage requirements. The following is a summation of criteria for adult fish passage from *Fisheries and Marine Service Technical Report #811* (Dane 1978).

- The diameter of a culvert used in any watercourse providing for the passage of fish should not be less than 0.45 meters.
- The average water velocity in the culvert should not exceed the following values:
    - 1.2 m/s for culverts less than 24.4 meters in length
    - 0.9 m/s for culverts greater than 24.4 meters in length
    - for culverts greater than 61 meters in length, special consideration will have to be given on a site specific basis by DFO and MOELP.
- The depth of water should not be less than 0.23 meters at any point within the culvert.
- Any sudden drop in the water surface profile at any point within the culvert influence should not exceed 0.31 meters.
- During the period of upstream fish migration, the length of time during which the foregoing conditions are **not** met at the culvert site should not exceed 3 consecutive days in an average year.
- All culvert facilities through which salmonid migration occurs should be designed to accommodate the 100 year flood (1:100), which is defined as that estimated discharge event having a recurrence interval of 100 years.
- During the design flood event, the headwater depth (HW) measured at the upstream end of the culvert should not exceed the height or diameter (D) of the culvert.
- The effective slope (mean slope of the water surface from the culvert inlet to the tailwater control point) of the culvert should not exceed:
    - 0.5% for a culvert greater than 24 meters in length, unless baffles are added
    - 1.0% for a culvert less than 24 meters in length, unless baffles are added
    - 5.0% at any time, even with the addition of baffles.
- The culvert should be installed so that it has a constant slope through its length, except for an appropriate camber allowance where settlement is anticipated.
- The culvert should be installed so that the bottom (invert) is at least 0.31 meters below the grade line of the natural bed of the stream.
- An outlet pool with tailwater control should be provided at the culvert exit.

Passage Design Criteria for Juvenile Fish

Barriers often block access to rearing areas utilized by juvenile fish. These rearing areas, often small creeks, channels and ditches, are critical habitat and are often made inaccessible by improper culvert installation. Generally, fry and juvenile fish have limited swimming capability, in comparison to adults of the same species, with swimming speeds proportional to their body length. While the majority of juvenile fish migrations are downstream, juvenile fish may move upstream in search of food items, to escape predators or to avoid unsuitable stream conditions (e.g. in nature, certain races of sockeye salmon fry and lake-outlet spawning rainbow trout fry swim very close to the shore or bottom utilizing the small eddies and channel roughness in order to move upstream to lake rearing areas). Additionally, migrations of juvenile fish are difficult to detect because they may occur during darkness and in lower densities in comparison to adult migrations. Presence and access to juvenile fish habitat is often overlooked. This important habitat may include swampy areas, wetlands, small streams and side channels or intermittently wetted areas

Figure 6.3 Culvert Installation for a Small Creek with Provision for Fry Passage

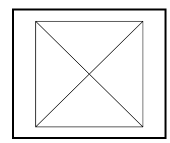


Table 6.2 - Sustained, Prolonged and Burst Swimming Speeds For Various Fish

Species and Life Stage (size - mm)		Sustained* Speed (m/s)	Prolonged* Speed (m/s)	Burst* Speed (m/s)
Coho:	Adults	0.0 - 2.7	2.7 - 3.2	3.2 - 6.6
	Juveniles (120 mm)		0.4 - 0.6	
	Juveniles (90 mm)		0.3 - 0.5	
	Juveniles (50 mm)		0.2 - 0.4	
Sockeye:	Adults	0.0 - 1.0	1.0 - 3.1	3.1 - 6.3
	Juveniles (130 mm)	0.0 - 0.5	0.5 - 0.7	
	Juveniles (50 mm)	0.0 - 0.2	0.2 - 0.4	0.4 - 0.6
Chinook:	Adults	0.0 - 2.7	2.7 - 3.3	3.3 - 6.8
Steelhead: (Use Rainbow Trout juvenile data)	Adults	0.0 - 1.4	1.4 - 4.2	4.2 - 8.1
Rainbow Trout:	Adults	0.0 - 0.9	0.9 - 1.8	1.8 - 4.3
	Juveniles (125 mm)	0.0 - 0.38	0.38 - 0.75	0.75 - 1.13
	Juveniles (50 mm)	0.0 - 0.15	0.15 - 0.3	0.3 - 0.45
Brown Trout:	Adults	0.0 - 0.7	0.7 - 1.9	1.9 - 3.9
	Juveniles (>75 mm)	0.0 - 0.6		
Cutthroat Trout: (Use Rainbow Trout juvenile data)	Adults	0.0 - 0.9	0.9 - 1.8	1.8 - 4.3
Arctic Char:	Adults		0.6 - 1.1	
Arctic Grayling:	Adults	0 - 0.8	0.8 - 2.1	2.1 - 4.3
Whitefish:	Adults	0 - 0.4	0.4 - 1.3	1.3 - 2.7
Walleye:	Adults (230 - 410 mm)		0.0 - 1.1	
Carp:	Adults	0 - 0.4	0.4 - 1.2	1.2 - 2.6
Suckers:	Adults	0 - 0.4	0.4 - 1.6	1.6 - 3.1

* Sustained speed can be maintained indefinitely.

Prolonged speed can be maintained for up to 200 minutes.

Burst speed can be maintained for up to 165 seconds.

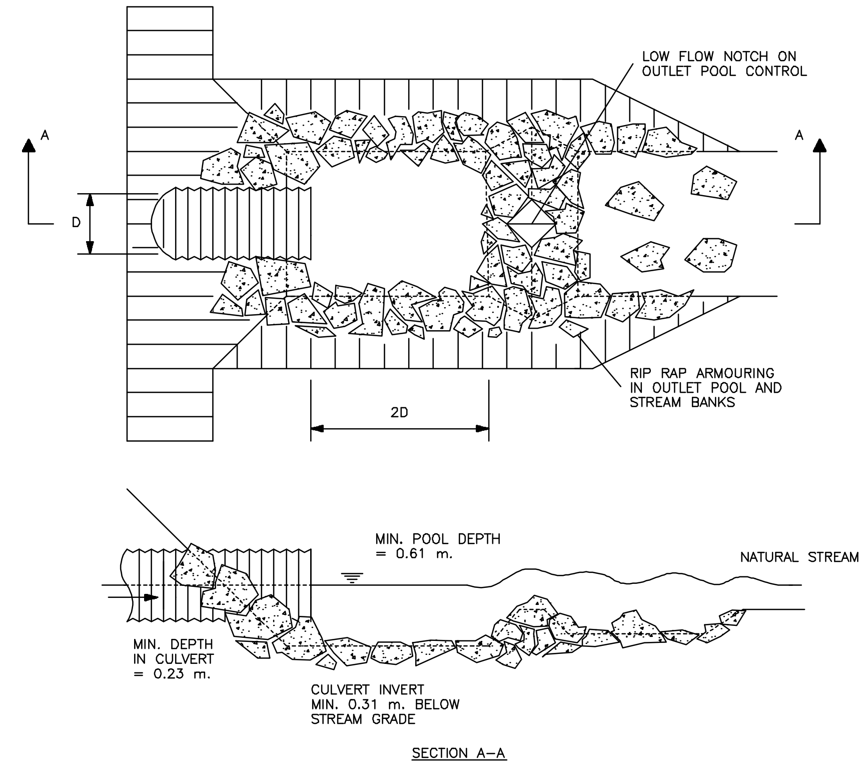
(Katopodis, 1991)

Outlet Pool and Tailwater Control

An outlet pool and tailwater control should be constructed at the downstream end of the culvert to maintain the desired water level within the culvert and backwater the culvert at higher flows to reduce the culvert velocities. See Figure 6.4 for details of a rock outlet pool with tailwater control.

- The dimensions of the outlet pool can be varied to create specific hydraulic conditions in response to unusual site constraints. Usually, the recommended width of the pool approximates the natural width of the stream, and the sides will coincide with the stream banks, which can be appropriately armoured to prevent erosion. The bottom elevation of the pool should be at least 0.61 meters below the invert elevation of the culvert at the outlet.
- A tailwater control device should be constructed at the downstream end of the outlet pool to provide a minimum depth of 0.23 meters throughout the culvert during the lowest condition of stream discharge anticipated at the site, or at least 0.23 meters above the lowest elevation in the culvert.
- The tailwater/outlet pool should reduce velocities in the culvert barrel or at the entrance to the culvert by backwatering.
- A low flow channel or notch, 0.61 meters wide and 0.31 meters in depth, in the tailwater control structure should be provided and should extend downstream connecting with the deepest part of the natural stream bed.
- The outlet pool should control erosion at the downstream end of the culvert by dissipating the energy of the flow and provide a transition zone between the culvert and the natural stream channel.

Figure 6.4 Diagram and Photo of a Rock Outlet Pool and Tailwater Control Structure

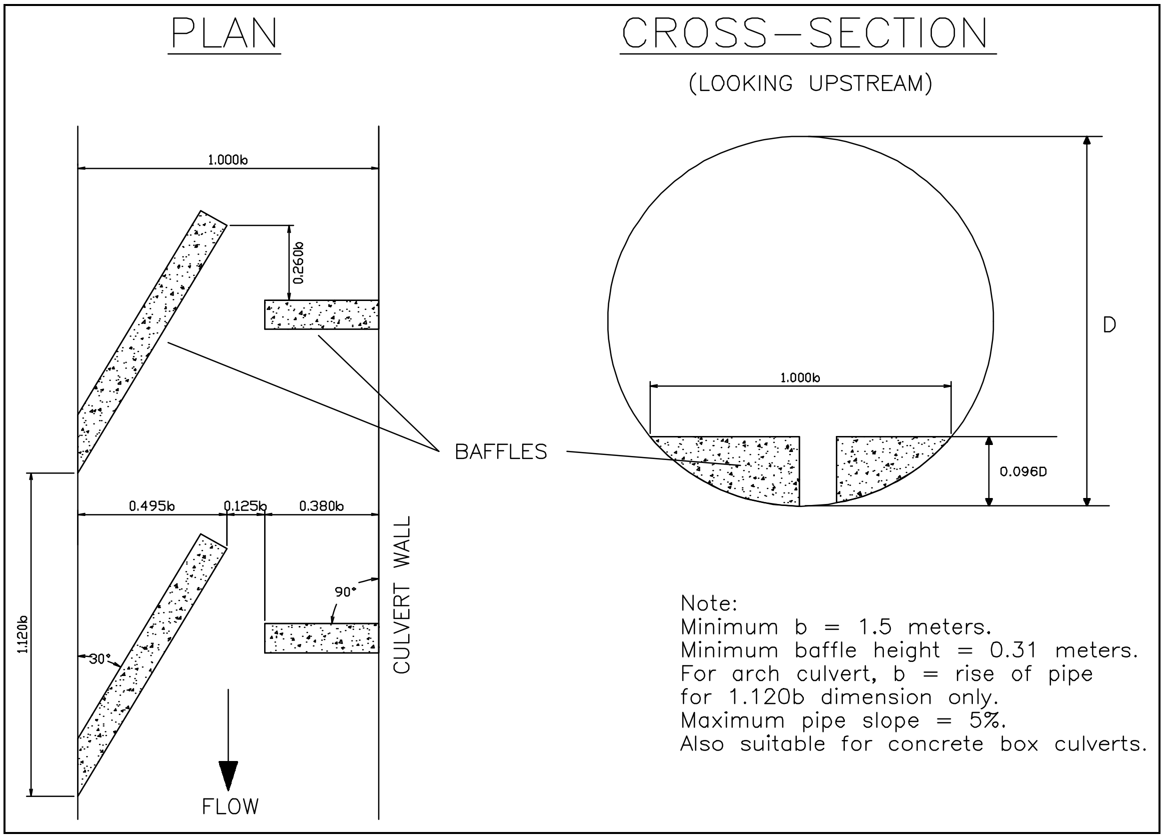


Baffles

Culvert baffles are flow interference structures, usually in the form of low weirs, which extend partially or entirely across the culvert cross-section. Such structures either interrupt the flow pattern and provide the fish with a series of resting areas or create a continuous zone or route of controlled velocities through which the fish can swim.

- Baffles should be constructed in the culvert barrel if the slope of the culvert exceeds the criteria outlined in Passage Design Criteria for Adult Fish.
- The most successful baffle configuration has been the offset baffle design, developed and model-tested by McKinley and Webb (1956). The offset baffle configuration consists of 'paired' baffles attached to the sides and bottom of the culvert and extending out into the flow of water. The baffles produce a flow pattern compatible with fish migration while minimizing interference with debris or bed load movement (see Figure 6.5 for general layout dimensions for offset baffle arrangement).
- Baffles significantly reduce the hydraulic efficiency of the culvert. When making capacity calculations, the reduced efficiency can be estimated by subtracting the cross-sectional area displaced by the baffles from the cross-sectional area of the culvert, and increasing the roughness coefficient.

Figure 6.5 Diagram and Photo of Typical Culvert Baffle Layout and Installation



SECTION 7
IMPLEMENTING THE LAND DEVELOPMENT GUIDELINES

Objective

This section deals with the steps, procedures and items required to prepare a land development impact assessment in order to substantiate the practical implementation of the guidelines for DFO and MOELP fish habitat impact assessment purposes. This document should be part of the overall development plan and be included in the development/construction specifications. Recognition by the land development proponent of the impacts on the aquatic environment that may be created by the project is one of the most important steps in preventing the loss of fish spawning, incubation and rearing capability in streams and watercourses. The land development proponent should "take stock" of the natural conditions prevailing in waters on and adjacent to the site, prior to the commencement of any work. This will create an awareness, and respect for this resource and a recognition of the necessity and responsibility to preserve it.

The planning process provides both the agencies and the proponent a framework to assess development activities, potential impacts and effects of the proposed control measures. An accurate assessment of the impacts is important, and the proponent should prepare an assessment containing at least the information outlined in this section.

Understanding the characteristics of the fisheries resource (Appendix II) is an important step in determining what impact a proposed land development project will have on the spawning and rearing capabilities of the streams and watercourses in the immediate or downstream vicinity. The determination of the impacts, both positive and negative, can be assisted by assessment of the natural conditions of the proposed development site prior to commencement of any design or construction work. While it is not mandatory to provide an environmental impact statement to the approving authorities, such a statement can be required at the discretion of the Minister of Fisheries and Oceans (*Fisheries Act*, Section 37(1)). In areas of extremely sensitive fisheries habitat values, land development may not be possible if DFO's policy of no net loss of the productive capacity of those habitats is to be satisfied.

The above considerations should be adopted by regional and municipal governments as they determine their own land use policies. Increased environmental awareness by all people regarding the use of the finite land and water resources makes protection of fish and fish habitat a paramount issue. If sustainable development is achieved, people will continue to enjoy all the values associated with productive aquatic habitat and the fisheries resource in and around developed urbanized areas.

Application of Land Development Guidelines

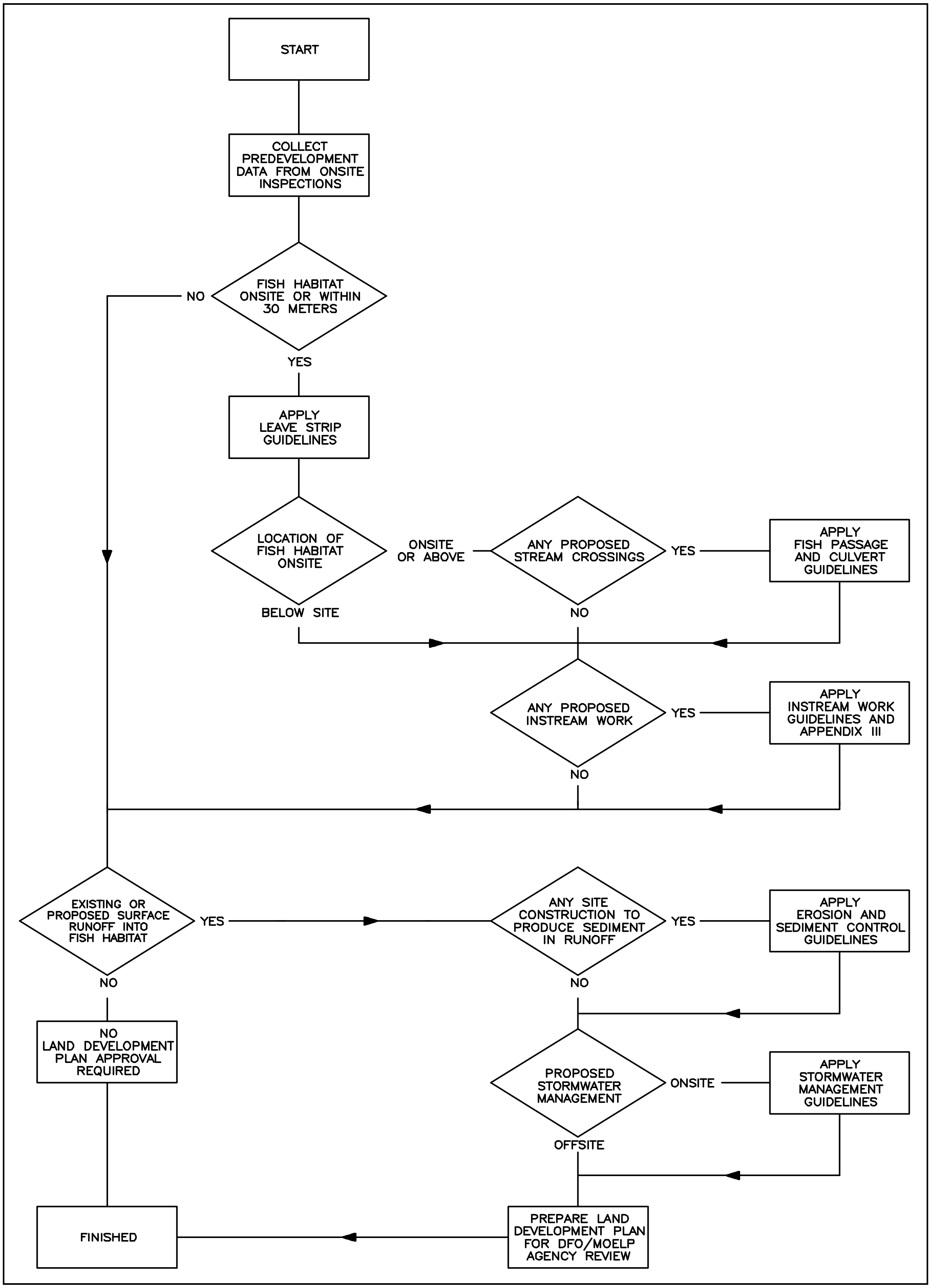
These land development guidelines should be applied to all new developments and expansions or re-developments of existing areas. Land developments that do not have fish habitat onsite nor any potential impact, through construction activities, land use or stormwater discharges, on fish habitat off site or downstream are screened out of the guidelines. Generally, small land development parcels, such as building lots, with no onsite fish habitat, but whose development activities and runoff ultimately impact fish habitat, will require a summary document outlining practical implementation of the guidelines and site plan similar to Figure 3.6. Areas greater than 2.0 hectares or having watercourses containing fish habitat will require a full impact assessment document and both predevelopment site features and land development guideline implementation plans. The screening flow chart in Figure 7.1 should be used to determine the appropriate sections of the Land Development Guidelines that are applicable to the development. Preparation of the document and implementation of the guidelines can be completed in four steps.

- Collect initial predevelopment data for assessment.
- Analyze site data with implementation of land development guidelines objectives.
- Prepare site map(s) with key information.
- Prepare written impact assessment/feature document and specifications.

Collecting Predevelopment Data

The predevelopment information should be collected onsite through site inspections. A record of site conditions should be kept with photographs and diary. An aerial photograph of the site is useful in gaining an overall perspective. A written record or inventory of the items described should also be completed. Projects can be initially evaluated by a layperson. For projects that must implement sections of the guidelines (i.e. in one form or another they have the potential to impact fish habitat and are screened into the referral process), it may be prudent to enlist the services of a qualified environmental consultant to assist in preparing an assessment and to advise on the precautionary or mitigative steps necessary to preserve fish and fish habitat. Generally, information should be collected and analyzed by a person qualified or knowledgeable in the areas investigated and could include: biologists, civil engineers, botanists, geotechnical engineers, arborists, hydrologists, surveyors, etc. The predevelopment information should be catalogued and displayed on the predevelopment map.

Figure 7.1 Land Development Guidelines Screening and Application Chart



Location and Topography

An accurate topographic map should form the basis of any kind of land development plan. The site map should be accurate and of the appropriate size and scale to show all of the required features. Predevelopment data and land development features will be overlaid onto the base map to provide a visual development plan. Topographical maps can be obtained from government sources or derived from site surveys. For a single lot development, an accurate hand-drawn sketch illustrating the relevant features will be sufficient.

Watercourses, Drainage and Aquatic Habitat

Overland runoff and channel flow elements should be marked on the base map and detailed in the written plan. Existing streams and channels should be detailed, as well as watershed areas and drainage areas for intermittent and permanent waterways and for calculation of contributory areas for sediment and detention designs. Streams, channels , ponds and wet lands should be classified for their aquatic habitat values, sensitivities and utilization by fish. Information on the distribution of salmonids and other freshwater fish can be obtained from the Federal/Provincial Stream Summary Cataloguesavailable at local DFO and MOELP offices. Initial determination of utilization and sensitivity of aquatic habitat can be evaluated by a qualified biologist or through consultation with DFO/MOELP habitat staff through the regional offices.

Climatic Information

Rainfall data is utilized to design erosion control, sediment control ponds and detention features. In most instances, IDF (intensity-duration-frequency) curves for precipitation at the development location can be used. Municipalities and Regional Governments often provide standard design storm events or design IDF curves. The Department of Environment - Atmospheric Environment Service has IDF data and curves for 98 stations across BC and an atlas to interpret areas between stations.

Soils and Vegetation

Information collected should include soil types, ground cover and vegetation. Soils data should outline areas of highly erodible materials and analysis for use in the design of sediment control facilities and erosion control strategies. Unstable slopes and remedial measures should be analyzed, designed and detailed using geotechnical engineering services. Existing ground cover and vegetation such as trees and shrubs should be detailed and used in determining runoff factors. Trees and other forms of vegetation are important aesthetic and environmental factors as well as an effective form of erosion control. Preservation of undisturbed ground cover, trees and shrubs within the leave strips bordering streams is essential for maintaining the integrity of the FSZ.

Current and Future Land Use

A description of the current and future land use of both the site and adjacent areas should be included. Offsite features should also include streams and drainage, current and potential future land use and encroachments. The evaluation should identify and address the following details.

- The legal description, registered ownership, options and covenants on the land involved.
- Official community plan (OCP) designation for present and future land use of the site.
- Required OCP changes for proposed development.
- Required rezoning for proposed development, date of application, and application number.
- Total size of project in hectares.
- Designation of water supply, drainage and sewerage systems to be onsite or provided by municipal or offsite hook-ups.
- Siting locations for storm water detention and sediment control facilities on the site.
- Siting and location of utility and access encroachments.
- Potential soils contamination if the project site was previously used for commercial or industrial purposes (Contact MOELP Waste Management Branch for direction regarding investigation and disposal of contaminated soil).
- Visible signs of pollution in or along the watercourses on or adjacent to the proposed site. (If pollution is visible, please contact MOELP, DOE or DFO immediately).

Assessment and Implementation

This procedure involves the analysis of the predevelopment information and preparation of the land development impact assessment. This procedure may involve application of one or more sections of the guidelines, which may include:

- Provision and Protection of Leave Strips
- Erosion and Sediment Control
- Stormwater Management
- Instream Work Guidelines
- Fish Passage and Culvert Requirements

Once the sections of the Land Development Guidelines have been applied and analysis is complete, the following information should be transferred onto an Implementation Map

- developed and undeveloped terrain, pervious and impervious surfaces
- building sites, roadways, utility corridors and other land use
- retained vegetation and leave strips (showing method of distinguishing clearing limits)
- altered drainage and slopes (showing runoff factors and areas used for calculations)
- instream work areas and fish passage features (if required)

- erosion and sediment control features, location, sizes and capacities
- stormwater management facilities, location, size and capacities.

The document that accompanies the predevelopment and implementation maps is an impact assessment document. It describes in written form the predevelopment data, and analysis and implementation of the guidelines. It also details the following:

- The various development activities that affect the site and sensitive areas (for aquatic habitat) on the site.
- A schedule of the activities involved with the development of the site, including assessment, permitting, development and construction activities.
- A list and location of all guidelines features and provisions including erosion and sediment control plans, stormwater management plans, instream work windows, etc., cross-referenced to the construction/activity schedule as per date and order of installation or construction.
- A maintenance program and schedule for the various features including detailing who is responsible for what features and conditions of maintenance.
- A contact list of the various parties involved including the owner, developer, companies involved, prime contractor, subcontractors, consultants, etc, if known.
- The design and calculations used for the engineering and design of the erosion and sediment control structures, stormwater management features and pollution control works.
- Specifications that will be supplied to the contractor for the design, construction and maintenance of the various Land Development Guideline features

If prepared as described above, the impact assessment will now contain the information generally required to substantiate the operational implementation of the Land Development Guidelines for DFO and MOELP fisheries habitat impact assessment purposes. They should be included as part of the overall development plan and attached to the development/construction specifications for bidding and contract purposes. The completed plan should be distributed to the various parties involved in the development process (contact list) including the field construction supervisors and workers. Use and practical implementation of the guidelines will require onsite supervision and revision to meet the changing, site-specific conditions encountered.

Environmental Monitoring

In accordance with current practice, and where considered appropriate by government agencies, the proponent should employ environmental monitors to ensure a high standard of environmental protection during construction. Construction can be either continuously monitored or periodically inspected, depending on site sensitivity and the nature of construction. The monitor should have the authority to modify or stop operations in the case of non-compliance with approval conditions or where unforeseen circumstances cause environmental problems. The monitor also provides the following services as required:

- Acting as an intermediary between the proponent and regulatory bodies.
- Briefing the contractor on site-specific environmental requirements.
- provides basic environmental education and construction guidelines to all field personnel.
- closely supervises construction activity to ensure compliance with construction guidelines.
- Participating in meetings between proponent, agency personnel and the contractor(s).
- Defining environmental standards for construction.
- Mapping and marking sensitive areas in advance of actual construction.
- Reporting to the proponent and the regulatory agencies on the environmental performance of the contractor.

The proponent, by allowing the monitor to represent agency concerns, benefits since this allows the proponent to avoid shutdowns and other costly complications that would otherwise result from preventable environmental violations. Regulatory agency personnel may overrule the environmental monitor, and have final authority in determining whether or not construction standards are being met by the contractor.

SECTION 8
LAND DEVELOPMENT EXAMPLE

Objective

This design example illustrates the application of the Land Development Guidelines to a small development site. In the application of the erosion and sediment control guidelines, an interceptor ditch/swale and sediment control pond are designed. Also, this design example utilizes the rational method, simplified unit hydrograph and alternate infiltration system in the design of the stormwater management requirements. Where possible, information is included to provide additional background and detail to the methods used. The methodologies used are examples and illustrations, not endorsements or minimum requirements, for calculating requirements outlined in the Land Development Guidelines.

Predevelopment Data (see Figure 8.1 Predevelopment Map)

Location and Topography

The development site is located near Campbell River at Willow Point, west of the main highway on Vancouver Island. The site slopes generally to the west, with a small section near the highway draining to the east. The change in elevation onsite is from 60.5 m. to 52 m. (above datum).

Drainage

Current runoff is by overland flow following the slope of the site. A small gully is located off the property near the SW corner which appears to have concentrated channel flow during runoff events. The small section at the east end of the site currently drains onto the road r/w. There is no generation of runoff onto the development area from offsite precipitation.

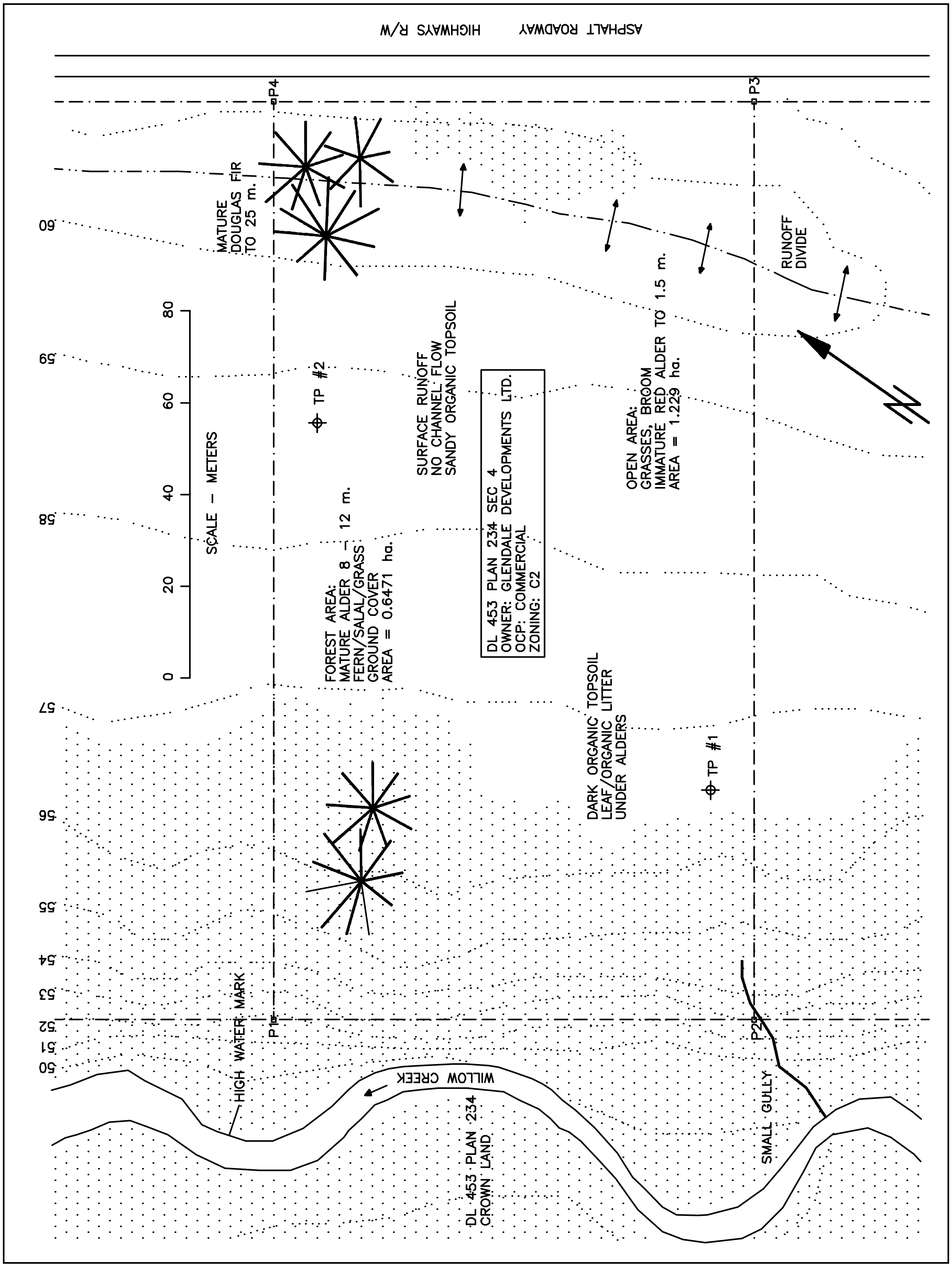
Soils and Vegetation

The site is overlain with a sandy organic topsoil in the open areas, and a darker organic humus with leaf litter under the alder canopy. Test pits were dug at locations indicated and soil logs are included. The south third of the property has a mature alder forest 8 to 12 meters high with a fern/salal/grass ground cover. The other two thirds of the property is vegetated with open grasses, broom and small alder.

Streams and Aquatic Habitat

There are no permanent or intermittent streams or watercourses onsite. There is a large stream, Willow Creek, offsite near the west end of the property which, according to the Stream Summary Catalogue, is utilized by salmonids (copy of catalogue data is enclosed).

Figure 8.1 Predevelopment Map



Description

Stream Name: Willow Creek

Local Name: Swansky/Ford Creek

Watershed Code: 92-2645

Location: Flows NE into Discovery Passage at Willow Point, SE of Campbell River.

Distribution Summary

CO Coho Salmon Throughout (above site).

CM Chum Salmon Presence Noted (above site).

CT Cutthroat Trout Presence Noted (above site).

FSZ Area: **Area 1**

FSZ Window: **Aug 1 - Sep 15** (Final window to be determined with DFO/MOELP consultation)

Climatic Information

IDF curves for development site were derived from Environment Canada - Atmospheric Environment Service *Rainfall Frequency Atlas for Canada* (1985) using estimates of mean rainfall, standard deviation and frequency factors from rainfall frequency maps.

Current/Future Land Use

The current zoning and OCP designation allows for development of a light commercial/business center. The total site area is 2.2 hectares. Water supply and sewerage are provided along the frontage with the r/w together with site access and utilities hook-ups. Site stormwater management is to be provided onsite with discharge to creek after treatment/detention.

Development/Construction Schedule

Table 8.1 - Example Development Construction Schedule

Construction/Development Activity	Start Date	Finish Date	Responsibility
Site access construction	May 5	May 8	Contractor
Clearing, earthworks and grading	May 9	May 15	Contractor
Erosion and sediment control features	May 13	May 20	Contractor
Site services/foundations	May 21	June 10	Contractor
Building construction	June 10	July 31	Contractor
Stormwater facilities	Aug 1	Aug 7	Contractor
Stormwater outfall (FSZ)	Aug 8	Aug 14	Contractor
Paving/landscaping	Aug 15	Aug 30	Contractor

Controlled Activities/Construction Zones

There will be no work or disturbance with thirty (30) meters of the existing high water mark of Willow Creek along the entire western boundary of the development site. This area will be maintained as a leave strip and protected by orange construction fence during development and removed after final DFO inspection. There is no instream work planned for the development of this site. Existing runoff gully is to be widened and armoured during FSZ window to be confirmed and approved with DFO Fisheries Officer and MOELP. Controlled construction techniques include the use of hand labour and no machinery. The gully is being widened and armoured to prevent erosion due to stormwater flows from the detention pond.

LDG Features and Construction Schedule

Leave Strip

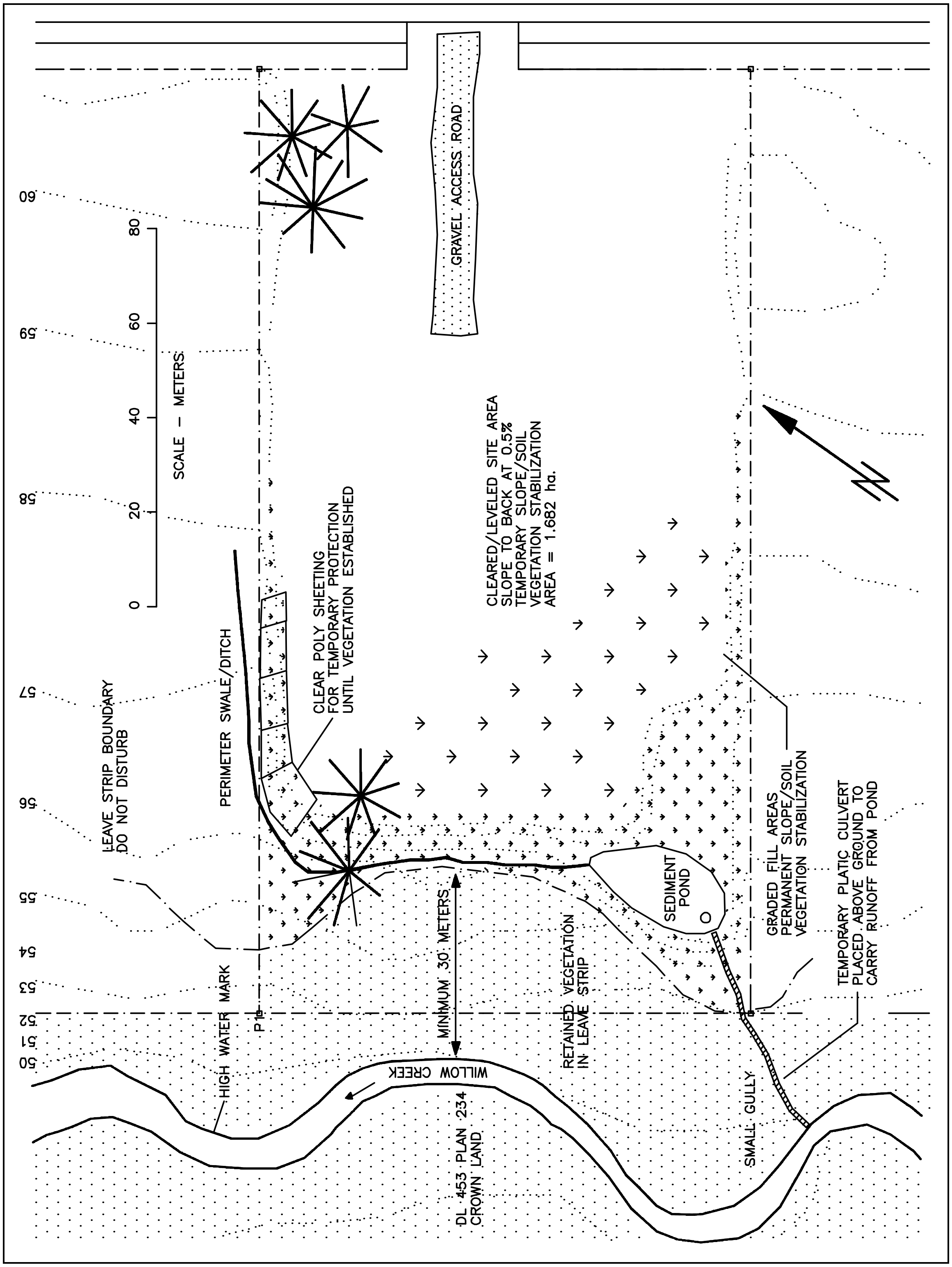
- Provision and protection of a minimum 30 meters from existing high water mark of Willow Creek.
- Installation of landscaped area next to leave strip as buffer area to developed site.
- Barrier fencing will be placed at initial site meeting and removed after final DFO inspection.

Erosion and Sediment Control and Construction Practices

(see Figure 8.2 Erosion and Sediment Control Map)

- Temporary re-vegetation of developed area between initial site earthworks and construction.
- Installation of lined interceptor ditch around disturbed area to control runoff.
- Tarping of exposed fill slopes until permanent vegetation is established to minimize erosion.
- Limit construction access and install working road to minimize soil disturbance.
- Removal of excess fill materials offsite.
- Installation of sediment control pond.
- Improvement of existing offsite gully to prevent erosion due to concentrated runoff flows.
- Installation of permanent landscaping at earliest possible date after construction.
- Onsite control of waste materials and installation of recycling/waste control area for contractors/subcontractors.
- Enforcement of good housekeeping, Worker's Compensation Board, and relevant codes and by-laws, for site services and conditions.

Figure 8.2 Erosion and Sediment Control Map



Stormwater Management (see Figure 8.3 Developed Site Map)

- Installation of a wet detention pond to control runoff rates to 1:2 storm event predevelopment conditions.
- Detention facilities to be operational before completion of storm drainage system and site paving.
- Installation of spill-control type inlet and outlet structures and oil absorbent pads in wet pond.

Maintenance Schedule

Contractor shall be responsible for maintenance of the features as listed below and on the site drawings during construction. Owner assumes responsibility of all features upon final inspection. Maintenance items include:

- Erosion control tarping and re-vegetation.
- Interceptor ditch.
- Sediment control pond.
- Wet detention pond.
- Site waste and access control.

Contact List

- Registered Owner
- Prime Contractor
- Land Development Consultant

Figure 8.3 Developed Site Map

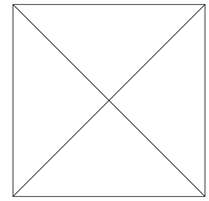


Figure 8.4 Stream Information Summary (SIS) Report Data for Land Development Example

Calculation of Runoff Flows in Land Development Guidelines Example

To determine flows in the design example, it is assumed that runoff flows via two modes. The first is overland in the form of sheet and shallow channel flow. Flow of this nature can be calculated using time of concentration, IDF precipitation data and the rational formula. The second mode of runoff type is open channel flow where Manning's equation can be used, or Bernoulli's equation can be used for pressurized flow in a pipe. In this design example, the rational method is used to determine overland flows used to size the erosion and sediment control features, and the stormwater detention facilities. Suitable factors of safety should be added to features calculated in terms of capacity of flow and volume to ensure protection of the structures, the public, and the environment (e.g. freeboard on ponds and channels, emergency spillways, etc). The use of the rational formula and time of concentration methodology has limitations, and should be considered the minimum required standard for computation of stormwater runoff flows. In large land developments with complex drainage systems, it is prudent to use a more involved computational method, like the SCS (U.S. Soil Conservation Service) unit hydrograph method or continuous simulation hydrograph-based methods, to compute stormwater flows and detention requirements.

Rational Formula

The rational formula used in this design example takes the form:

$$Q = \frac{RIA}{360}$$

where Q equals runoff flow (m^3/s), R (or C) is the runoff factor, A is the catchment area (ha) and I equals the precipitation intensity (mm/hr). The maximum catchment area suitable for application of the rational formula is 10 hectares. In the selection of R or C factors for the rational formula and overland flow characteristics, care and thought should be used in regard to type, function and lifetime of the structure being designed. In this example, the table of runoff coefficients used was as follows:

Table 8.2 - Land Cover Factors used for Rational Formula

Land Cover Type	R	Land Cover Type	R
Dense Forest	0.05 - 0.15	Unpacked/Rough Soils	0.30 - 0.50
Light Forest	0.15 - 0.25	Graded/Smooth Soils	0.40 - 0.60
Range/Pasture	0.20 - 0.30	Impervious Surfaces	0.80 - 0.95
Lawn/Grassed Areas	0.15 - 0.35	Open water	1.0

These ranges of values illustrate the variability in runoff factors and the caution required when selecting the value for the land form type. Higher values in the range generally correspond to steeper sloped sites, frozen conditions, or relative poor underlying soil permeability or drainage.

Time of Concentration - Tc

Time of concentration (Tc) is the estimate of the time required for runoff to contribute from the total area, and is equal to the time of runoff travel from the farthest point in the catchment area to the point under consideration. Theoretically, a storm event with a duration equal to Tc will develop the peak runoff rates equal to the intensity of precipitation of that duration over that catchment area. Generally, storm events of longer duration (larger Tc) will have lower precipitation intensities and peak runoff rates, but often similar total volume of runoff, in comparison to shorter, more intense storms. For application to the rational formula, the minimum catchment Tc is 5 minutes and the maximum catchment Tc is 100 minutes. The minimum Tc ensures that runoff is generated from smaller, less pervious areas, and the maximum Tc limits the size of the catchment area and length of flow path. One example of calculating time of concentration values is by using a nomograph based on slope and rational formula runoff coefficients (example of Tc nomograph, pg. 4.20, Goldman et al.). A second method uses a basic formula based generally on Manning's equation and adapted to overland flow conditions. The formula method adapted for use in the Land Development Guidelines design example was derived from the *Draft Stormwater Management Manual for the Puget Sound Basin*. The formula calculates the Tc (minutes) for overland flow conditions and is intended for use with use with the Rational formula:

$$Tc = \frac{L}{60K\sqrt{s}}$$

where L is the flow path length (m), s is the slope (m/m), and K is the land cover factor.

Table 8.3 - Land Cover Factors used in Overland Flow Tc Calculation

Land Cover Type	K	Land Cover Type	K
Forest	0.76	Unpacked/Rough Soils	3.1
Range/Pasture	1.4	Packed/Smooth Soils	4.6
Lawn/Grassed Areas	2.1	Impervious Surfaces	6.1

Note that for open water, the time of concentration is assumed equal to zero. Density of vegetation and presence of channelization will result in variations to these average K values.

Recurrence Intervals

The recurrence interval is used to determine the design storm event for interceptor ditches, sediment control ponds and detention structures. The recurrence interval or return period is the number of years between events (e.g. floods, precipitation, snowfall) of a certain duration and intensity. In the design of hydraulic structures, engineering-economic analysis provides the basis for the design of a structure's capacity to be periodically exceeded rather than having to build a larger, more costly structure whose capacity would never be reached. In the design of temporary facilities, a lower recurrence interval is used, accepting a higher risk of failure because of the relatively short time the facility is operational. For permanent facilities, and those whose failure would result in direct impacts to property and people, a higher recurrence interval with lower associated risk is used. In the design of detention facilities, the lower recurrence interval (predevelopment 1:2 year) was selected to prevent environmental damage resulting from floods greater than the mean annual (occurring approximately every 1:2 years) generated from developed areas in a watershed. The emergency spillway capacities of pond structures, whose structural failure would have a great impact downstream on property, people and the environment, are designed for a 1:100 year event. Below is a summary of the design requirements for the Land Development Guidelines according to recurrence interval and area.

Table 8.4 - Recurrence Intervals and Catchment Areas

Structure	Recurrence Interval	Area
IC Ditch	1:2	Catchment
Sediment Pond Area	1:2	Catchment
Sediment Pond Outlet/Spillway	1:100	Catchment
Detention Pond Volume	1:2	Pre and Post-development
Detention Pond Outlet/Spillway	1:100	Post-development

Additional factors of safety, including: provision of freeboard around ponds and channels, additional storage in detention structures, increased settling area for sediment control ponds and reduced design infiltration rates for infiltration systems, are used to ensure safe and long-term operation.

Calculations for Land Development Guidelines Example

Calculations for the design example include:

- Calculation of design storm events from IDF data derived from AES rainfall charts.
- Design of interceptor ditch for erosion and sediment control.
- Design of sediment control pond for erosion and sediment control.
- Calculation of design flows for predevelopment conditions, developed conditions and detention requirements using rational method and IDF data.
- Design of wet detention pond for detention requirements.
- Design of alternate infiltration system for detention requirements.

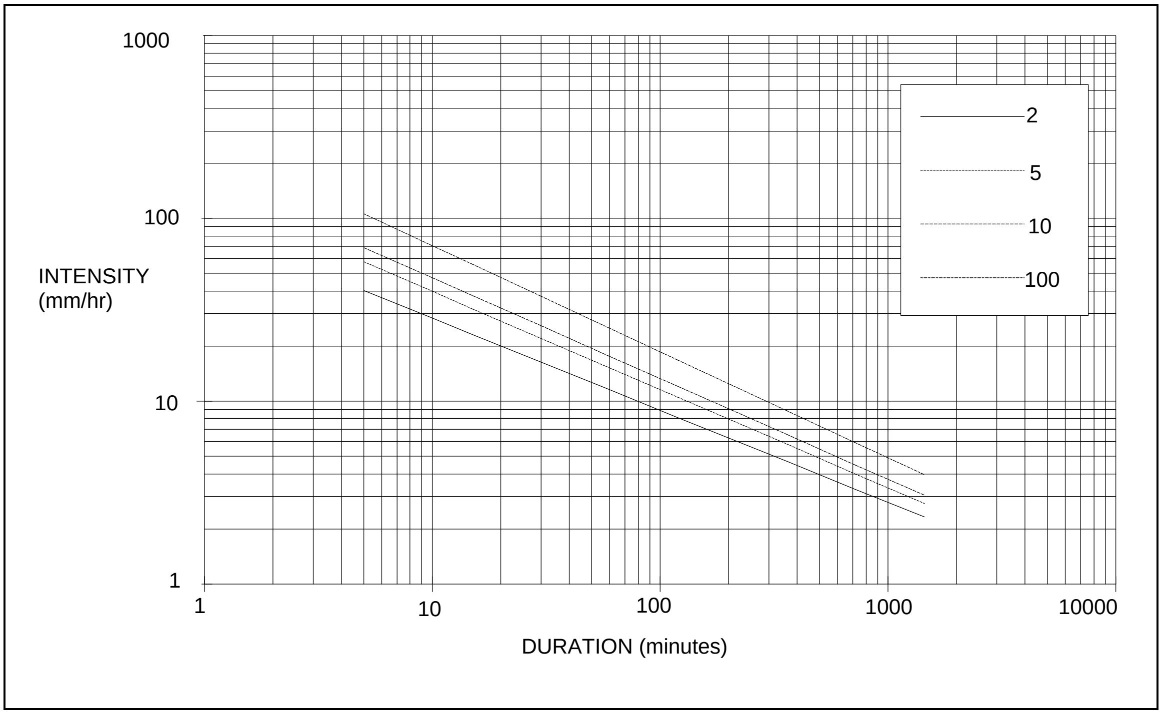
Intensity-Duration-Frequency Data for Development Site

For the location of the site, values of the mean and standard deviation for annual extremes of rainfall (mm/hour) were extracted from the AES *Rainfall Frequency Atlas for Canada*. Distance between isolines was estimated and values for the various durations were recorded. Using the appropriate frequency factors for the frequency or recurrence intervals, intensities in mm/hour for the various durations were calculated. Note that according to Table 1, pg. 9 of the atlas, an augmentation factor for orographic precipitation is applied for storms of certain durations (i.e. mountainous regions have an multiplication factor applied to precipitation values). Simple linear regression of a log-log plot of IDF data produces a graph. The graph can be used to calculate precipitation intensities for storms of a certain duration and frequency. For example, a 2 year (1:2) storm with a 20 minute duration has an intensity of 20 mm/hour.

Table 8.5 - Land Development Example IDF Data

Precipitation Duration (min)	Mean Precipitation (mm)	Std. Deviation of Precipitation (mm)
5	2.9	1.5
10	4.5	1.7
15	5.5	1.9
30	7.5	3
60	12	5
120	17	4
360	32	8
720	45	8
1440	55	15

Figure 8.5 Land Development Example Site IDF Curves



Design of Interceptor Ditch

The interceptor ditch is designed for the runoff resulting from a 2 year (1:2) storm event. From the erosion and sediment control map, the data required to determine the runoff is:

• Area	1.628 hectares
• Runoff Factor (R or C)	0.4
• Overland flow path	155 meters
• Recurrence Interval	2 years (1:2)
• Area slope	0.5%
• Land Cover Factor (K)	2.5.

Using the formula, a time of concentration value of approximately 15 minutes was derived. From our site IDF curves, this results in a precipitation event of 23 mm/hour. Using the rational formula, the total peak overland flow that must be carried is calculated to be 0.042 m^3/s or 1.5 cfs. Using Manning's formula for open channel flow and the worst case conditions, we can calculate the depth of water resulting from the overland flow and design our interceptor ditch according to the guideline parameters. In this case, we have chosen to line the ditch with polyethylene.

The worst slope (i.e. flattest) is along the back of the site estimated at 1%. Assuming a v-notch (90°) channel is constructed, Manning's n=0.013 for the lining, a slope = 0.01, and channel length = 100 meters and:

$$Q = \frac{AR^{\frac{2}{3}}S^{\frac{1}{2}}}{n} \text{ and } R = \frac{d}{2\sqrt{2}} \text{ and } A = d^2$$

then:

$$Q = 0.042\ m^3/s = \frac{AR^{\frac{2}{3}}S^{\frac{1}{2}}}{n} = \frac{d^{\frac{8}{3}}S^{\frac{1}{2}}}{2n}$$

Therefore the lined ditch should be 0.18 meters deep + freeboard of 0.30 meters = 0.48 meters in depth and the resulting velocity would be:

$$V = \frac{R^{\frac{2}{3}}S^{\frac{1}{2}}}{n} = \frac{d^{\frac{2}{3}}S^{\frac{1}{2}}}{2n} = 1.24\ m/s$$

Based on the resulting velocity and length of ditch we can estimate channel travel time to check that the initial estimate for time of concentration is accurate. Therefore:

Time of Concentration = Overland Flow Time + Channel Flow Time

$$Tc = \text{Initial } Tc + \frac{L}{60V} = 15 + \frac{100}{60 \times 1.24} = 15 + 1.3 = 16.3 \text{ minutes}$$

Re-checking the flows, the 1:2 precipitation intensity for Tc equal to 16.3 minutes is approximately equal to the intensity for 15 minutes, and our initial flow estimate is correct.

Design of Sediment Control Pond

In this design, the resulting pond design peak inflow is 0.042 m^3/s based on a recurrence interval of 2 years. According to the guidelines area requirement for settling ponds:

$$A = \frac{1.2Q}{Vs} = 250\ m^2$$

Using the factor for effective length-to-width ratio of 5:1 and $5w^2 = 250\ m^2$, the resulting effective width should be equal to 7.1 meters and the effective length equal to 35.5 meters. Checking the required area for minimum hydraulic detention time of 40 minutes:

$$A = \frac{2400Q}{0.5 \text{ depth}} = 201.6\ m^2$$

Area required for particle settling governs and the average effective pond area at design flows should be equal to 250 m^2.

To design the correct orifice area requirement for the sediment pond drawdown ports:

$$= \frac{A \sqrt{2h}}{Cd3600T \sqrt{g}}$$

where T equals drawdown time required (48 hours), orifice coefficient of discharge (Cd) equal 0.6, A equals average pond area (250 m^2), and h equals pond depth (0.5 meters). Substituting values into the equation yields a drawdown port area of 770 mm^2 or hole diameter equal to 31 mm. The riser is designed for the 1:100 year runoff, which results in a precipitation intensity of 57 mm/hour and a design peak flow of 0.10 m^3/s. By using the sharp-crested weir equation the design water elevation above the riser stack can be determined. Assuming a 450 mm diameter riser pipe, C (weir coefficient) is set at 3.4 and L is equal to πd, the head above the riser crest can be calculated:

$$H = \left| \frac{Q}{Cd\pi} \right|^{\frac{2}{3}}$$

The resulting head above the riser pipe at 1:100 year runoff rates is 0.08 meters. The emergency spillway is also designed for a 1:100 event, in case the riser outflow is blocked. The last design check is to ensure the mean horizontal pond velocity is below the critical suspension velocity of the design particle. The horizontal velocity is equal to:

$$Vh = \frac{Q}{wd} = 0.025 \text{ m/s} < 0.075 \text{ m/s} = \text{design particle critical scour velocity.}$$

The pond design guidelines will determine final physical sediment pond lay-out and size. The riser design details, maintenance requirements and interval, and location should be detailed on pond plan.

Calculation of Detention Requirements

The objective of the Land Development Guidelines is to limit the peak post-development runoff to the 1:2 predevelopment levels. First, the predevelopment 1:2 peak runoff rate must be determined using, in this case, the rational formula and an analysis of the land cover type, area and slopes. By following the contours, the general overland flow is across the site, with no discrete channel flow elements. The area-weighted runoff factors and times of concentration, using the Tc formula, were calculated on a spreadsheet (Figure 8.6). The 1:2 peak predevelopment flow, derived with IDF data and the rational method, was calculated to be 0.022 m^3/s. Next the post development conditions were analyzed, and a peak post-development discharge of 0.097 m^3/s was obtained. In order to calculate the detention requirements, a simplified hydrograph for the site was developed. Time dependent rates of runoff were calculated using the rational formula and IDF data. It was assumed that the predevelopment rate of runoff continues at peak rates for storms of duration greater than Tc predevelopment. Post-development runoff rates decreased as intensities decreased with greater duration (time).

Figure 8.6 Calculation of Predevelopment and Post-development Peak Flows for Land Development Example

Predevelopment Condition

Overland Flow Sub-basin Number	Sub-basin Land Cover Type	Sub-basin Area (ha)	Runoff Factor R	Overland Flow Path (meters)	Land Cover Factor (K)	Slope			Tc (min)
1	forest	1.229	0.25	119	0.75	0.03			15
2	forest	0.6471	0.15	71	0.75	0.07			6
TOTAL		**1.8761**	**0.22**						**21**
	Peak Flow (m3/s)	**0.022**							

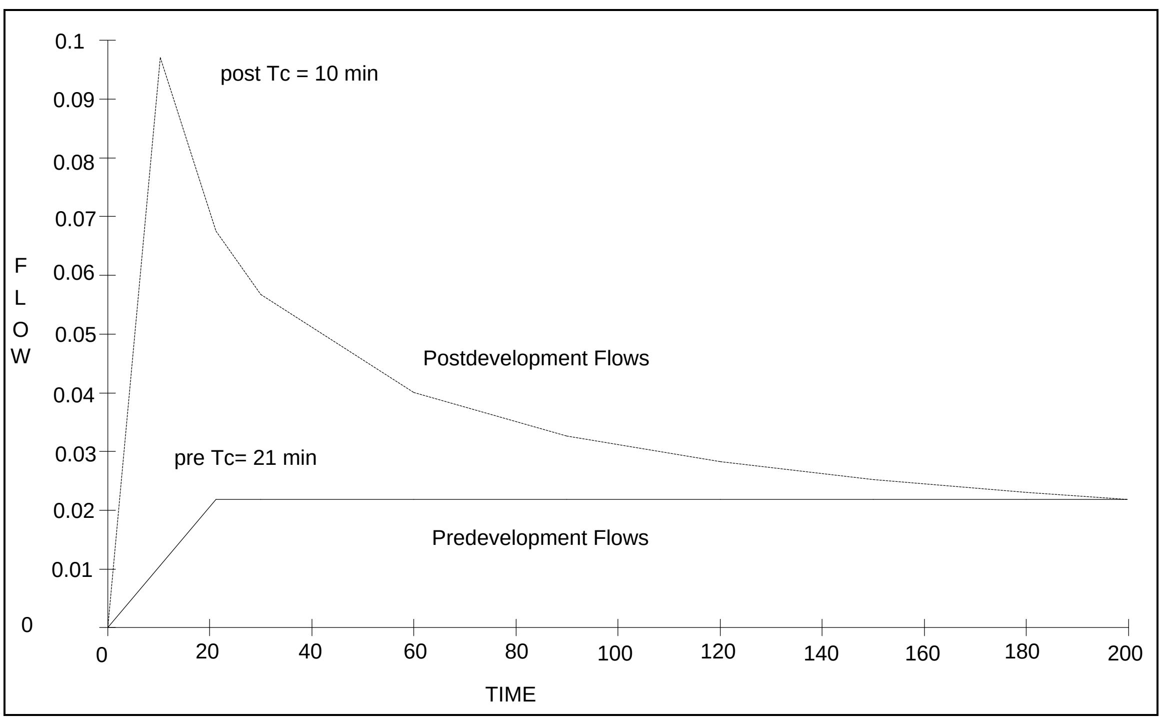
Post-development Condition

Overland Flow Sub-basin Number	Sub-basin Land Cover Type	Sub-basin Area (ha)	Runoff Factor R	Overland Flow Path (meters)	Land Cover Factor (K)	Slope			Tc (min)
1	roof/pavement	1.271	0.90	155	5	0.01			5
2	tree/grass	0.71	0.15	75	0.8	0.11			5
Channel Flow From - To Sub-basin	**Calculated Sub-basin Flow (m3/s)**	**Manning's n**	**Slope**	**Pipe Dia (m)**	**Area (m2)**	**Depth (m)**	**Velocity (m/s)**	**Flow Path (m)**	**Tc (min)**
1 - 2	0.126	0.020	0.050	0.6	0.09	0.22	2.75	75	0.45
TOTAL		**1.981**	**0.63**						**10**
	Peak Flow (m3/s)	**0.097**							

The difference between the predevelopment and the post-development rates of runoff is the stormwater runoff that must be detained in order to meet the objectives of the guidelines. This detention volume was calculated by multiplying the difference between the two runoff rates with elapsed time, and the resulting cumulative volume was calculated in the spreadsheet (see Figure 8.7). The difference in the predevelopment and post-development rates of runoff is visually represented by the two simplified hydrographs. For the design example, the required detention volume was calculated to be 194.2 cubic meters.

Figure 8.7 Calculation Spreadsheet and Simplified Hydrograph for Detention Volume Requirements

Time (minutes)	Predevelopment Flows (m3/s)	Post-development Flows (m3/s)	PreD Volume (m3)	PostD Volume (m3)	Volume to Detention (m3)	Cumulative Volume (m3)
0	0.000	0.000	0.0	0.0	0.0	0.0
10	0.011	0.097	3.3	30.1	26.8	26.8
21	0.022	0.068	10.6	53.8	43.2	70.0
30	0.022	0.057	11.5	32.7	21.2	91.2
60	0.022	0.040	39.3	87.1	47.8	139.0
90	0.022	0.033	39.3	65.4	26.1	165.1
120	0.022	0.028	39.3	54.8	15.5	180.6
150	0.022	0.025	39.3	48.1	8.8	189.4
180	0.022	0.023	39.3	43.4	4.1	193.5
200	0.022	0.022	25.9	26.6	0.7	194.2
					Detention Volume	**194.2 m3**



Design of a Wet Detention Pond

When calculating the required detention volume, an additional volume is added for a factor of safety to account for increased runoff or future development. In the design example, the calculated detention volume is multiplied by 1.5 to achieve a design volume of 300 m^3. For a dry detention pond, the average pond area would be approximately 300 m^2 based on a maximum pond depth of 1.0 meters. The physical size and dimensions of the dry pond structure would be determined by the guideline parameters. For a wet detention pond, the average pond area would depend on the maximum active detention zone depth. Assuming an active detention zone depth of 1.0 meters, a design detention volume: V, a bench slope of 1:7, and a permanent pool effective length equal to 5 x effective width, the average area (A) required is equal to:

$$A = \frac{V}{d} = \frac{300}{1.0} = 300 = \frac{(W \times 5W) + [(W + 7) \times (5W + 7)]}{2}$$

The resulting quadratic equation is:

$$10W^2 + 42W - 551 = 0$$

By solution, the dimensions of the wet pond are:

- Permanent pool 5.6 m. x 28.0 m.
- Design full pool 12.6 m. x 35.0 m.
- Permanent pool depth should vary from 0 to 1.2 m.
- Detention storage depth 1.0 m.

Based on a design riser height (h) of 1.0 meters over the orifice and the orifice equation, the port area required to limit the pond flow to the peak predevelopment level at full riser depth is:

$$Aport\ (m^2) = \frac{preQ}{Cd\sqrt{2gh}} = \frac{0.0\,22}{0.6\ \sqrt{2 \times 9.81 \times 1.0}} = 0.0083\ m^2 = 103\ \text{mm diameter orifice}$$

The time to drain the detention volume can be calculated:

$$T = \frac{300\sqrt{2 \times 10}}{0.6 \times 3600 \times 0.0083\sqrt{9.81}} = 7.56\ \text{hours}$$

The riser is designed for the 1:100 year runoff, which results in a precipitation intensity of 70 mm/hour and a design peak flow of 0.244 m^3/s. By using the sharp-crested weir equation the design water elevation above the riser stack can be determined. Assuming a 450 mm diameter riser pipe, C (weir coefficient) is set at 3.4 and L is equal to πd, the head above the riser crest can be calculated:

$$H = \left|\frac{Q}{Cd\pi}\right|^{\frac{2}{3}}$$

The resulting head above the riser crest is equal to 0.15 meters. The emergency spillway is also designed for a 1:100 event, in case the riser outflow is blocked.

Design of Alternate Infiltration System

Using the design detention volume of 300 m^3, a field saturated percolation rate (at the infiltrating surface at depth) of 20 cm/hour, and a void ratio of infiltrating media of 0.4, the calculated required volume of media to retain 1:2 year detention volume.

$$\text{Volume Infiltration Gallery (LxWxD)} = \frac{\text{Detention Volume}}{\text{Design Void Ratio}} = \frac{300}{0.4} = 750\ m^3$$

$$\text{Minimum Infiltration Area (LxW)} = \frac{\text{2 x Detention}}{\text{48 x Perc.}} = \frac{2 \times 300}{48 \times 0.2} = 62.5\ m^2$$

Calculate Minimum Dimensions for suitable Infiltration Gallery:

- D 3.5 meters
- L = W 15.0 meters.

As the design area is approximately 3.5 times that required, the gallery will dewater sufficiently between storms. The low hydraulic loading rate will also prolong the effective lifetime of the infiltration gallery. Ensure drainage from the site in frozen or oversaturated conditions with the provision of a channel or pipe. Location, dimensions and site conditions should meet guidelines recommendations. Inflows should be treated in a small settling basin or sump to remove sediments that could clog exfiltrating soils and reduce void volume of infiltrating media.

APPENDIX I
REGULATIONS

Habitat-Related Sections of the *Fisheries Act (Canada)*

The sections of the *Fisheries Act* (R.S.C., 1985, c. F-14; as amended by Statutes of Canada 1988, c. 49) which are pertinent to land development purposes are provided herein for reference and it is recommended that the reader refer to a copy of the Act for further details and understanding.

Section 22(2): Protection of fish passage during construction.

The owner or occupier of any obstruction shall make such provision as the Minister determines to be necessary for the free passage of both ascending and descending migratory fish during the period of construction thereof.

Section 26(1): Main channel not to be obstructed.

One-third of the width of any river or stream and not less than two-thirds of the width of the main channel at low tide in every tidal stream shall be always left open, and no kind of net or other fishing apparatus, logs or any material of any kind shall be used or placed therein.

Section 28: Use of explosives prohibited.

No one shall hunt or kill fish or marine mammals of any kind, other than porpoises, whales, walruses, sealions and hair seals, by means of rockets, explosive materials, explosive projectiles or shells.

Section 32: Destruction of fish.

No person shall destroy fish by any means other than fishing except as authorized by the Minister or under regulations made by the Governor in Council under this Act.

Section 34(1): Definitions.

For the purposes of sections 35 to 43, "deleterious substance" means

(a) any substance that, if added to any water, would degrade or alter or form part of a process of degradation or alteration of the quality of that water so that it is rendered or is likely to be rendered deleterious to fish or fish habitat or to the use by man of fish that frequent that water, or

(b) any water that contains a substance in such quantity or concentration, or that has been so treated, processed or changed, by heat or other means, from a natural state that it would, if added to any other water, degrade or alter or form part of a process of degradation or alteration of the quality of that water so that it is rendered or is likely to be rendered deleterious to fish or fish habitat or to the use by man of fish that frequent that water, and without limiting the generality of the foregoing includes

(c) any substance or class of substances prescribed pursuant to paragraph (2)(a),

(d) any water that contains any substance or class of substances in a quantity or concentration that is equal to or in excess of a quantity or concentration prescribed in respect of that substance or class of substances pursuant to paragraph (2)(b), and

(e) any water that has been subjected to a treatment, process or change prescribed pursuant to paragraph (2)(c);

"deposit" means any discharging, spraying, releasing, spilling, leaking, seeping, pouring, emitting, emptying, throwing, dumping or placing;

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

Section 35(1): Harmful alteration, etc., of fish habitat prohibited.

No person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat. (See s. 40(1) for "Offence & Punishment" section)

Section 35(2): Alteration, etc., of fish habitat authorized.

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.

Section 36(3): Deposit of deleterious substance prohibited.

Subject to subsection (4), no person shall deposit or permit the deposit of a deleterious substance of any type in water frequented by fish or in any place under any conditions where the deleterious substance or any other deleterious substance that results from the deposit of the deleterious substance may enter any such water. (See s. 40(2) for "Offence & Punishment" section)

Section 37(1): Minister may require plans and specifications.

Where a person carries on or proposes to carry on any work or undertaking that results or is likely to result in the alteration, disruption or destruction of fish habitat, or in the deposit of a deleterious substance in water frequented by fish or in any place under any conditions where that deleterious substance or any other deleterious substance that results from the deposit of that deleterious substance may enter any such waters, the person shall, on the request of the Minister or without request in the manner and circumstances prescribed by regulations made under paragraph (3)(a), provide the Minister with such plans, specifications, studies, procedures, schedules, analyses, samples or other information relating to the work or undertaking and with such analyses, samples, evaluations, studies or other information relating to the water, place or fish habitat that is or is likely to be affected by the work or undertaking as will enable the Minister to determine

(a) whether the work or undertaking results or is likely to result in any alteration, disruption or destruction of fish habitat that constitutes or would constitute an offence under subsection 40(1) and what measures, if any, would prevent that result or mitigate the effects thereof; or

(b) whether there is or is likely to be a deposit of a deleterious substance by reason of the work or undertaking that constitutes or would constitute an offence under subsection 40(2) and what measures, if any, would prevent that deposit or mitigate the effects thereof.

Section 37(2): Powers of Minister.

If, after reviewing any material or information provided under subsection (1) and affording the persons who provided it a reasonable opportunity to make representations, the Minister or a person designated by the Minister is of the opinion that an offence under subsection 40(1) or (2) is being or is likely to be committed, the Minister or a person designated by the Minister may, by order, subject to regulations made pursuant to paragraph (3)(b), or, if there are no such regulations in force, with the approval of the Governor in Council,

(a) require such modifications or additions to the work or undertaking or such modifications to any plans, specifications, procedures or schedules relating thereto as the Minister or a person designated by the Minister considers necessary in the circumstances, or

(b) restrict the operation of the work or undertaking,

and, with the approval of the Governor in Council in any case, direct the closing of the work or undertaking for such period as the Minister or a person designated by the Minister considers necessary in the circumstances.

Section 38(4): Duty to report.

Where, out of the normal course of events, there occurs a deposit of deleterious substance in a water frequented by fish or a serious and imminent danger thereof by reason of any condition, and where any damage or danger to fish habitat or fish or the use by man of fish results or may reasonably be expected to result therefrom, any person who at any material time

(a) owns the deleterious substance or has the charge, management or control thereof, or

(b) causes or contributes to the causation of the deposit or danger thereof,

shall, in accordance with any regulations applicable thereto, report such occurrence to an inspector or such other person or authority as is prescribed by the regulation.

Section 38(5): Duty to take all reasonable measures.

Every person referred to in paragraph (4)(a) or (b) shall, as soon as possible in the circumstances, take all reasonable measures consistent with safety and the conservation of fish and fish habitat to prevent any occurrence referred to in subsection (4) or to counteract, mitigate or remedy any adverse effects that result or may reasonably be expected to result therefrom.

Section 38(6): Power to take or direct remedial measures.

Where an inspector, whether or not a report has been made under subsection (4), is satisfied on reasonable grounds that there is an occurrence referred to in subsection (4) and that immediate action is necessary in order to carry out ant reasonable measures referred to in subsection (5), he may, subject to subsection (7) and the regulations, take any such measures or direct that they may be taken by any person referred to in paragraph (4)(a) or (b).

Section 40(1): Offence and punishment (s. 35).

Every person who contravenes subsection 35(1) is guilty of

(a) an offence punishable on summary conviction and liable, for a first offence, to a fine not exceeding three hundred thousand dollars and, for any subsequent offence, to a fine not exceeding three hundred thousand dollars or to imprisonment for a term not exceeding six months, or to both; or

(b) an indictable offence and liable, for a first offence, to a fine not exceeding one million dollars and, for any subsequent offence, to a fine not exceeding one million dollars or to imprisonment for a term not exceeding three years, or to both.

Section 40(2): Offence and punishment (s. 36).

Any person who contravenes subsection 36(1) or (3) is guilty of

(a) an offence punishable on summary conviction and liable, for a first offence, to a fine not exceeding three hundred thousand dollars and, for any subsequent offence, to a fine not exceeding three hundred thousand dollars or to imprisonment for a term not exceeding six months, or to both; or

(b) an indictable offence and liable, for a first offence, to a fine not exceeding one million dollars and, for any subsequent offence, to a fine not exceeding one million dollars or to imprisonment for a term not exceeding three years, or to both.

Section 40(3): Other offences (s. 37 - 38).

Every person who

(a) fails to provide the Minister with any material or information requested pursuant to subsection 37(1) within a reasonable time after the request is made,

(b) fails to provide or submit any material, information or report that is to be provided or submitted under regulations made pursuant to subsection 37(3),

(c) fails to make a report that he is required to make under subsection 38(4),

(d) carries on any work or undertaking described in subsection 37(1)

  (i) otherwise than in accordance with any material or information relating to the work or undertaking that he provides to the Minister under subsection 37(1),

  (ii) otherwise than in accordancewith any such material or information as required to be modified by any order of the Minister under paragraph 37(2)(a), or

(iii) contrary to any order made by the Minister under subsection 37(2),

(e) fails to take any reasonable measures that he is required to take under subsection 38(5) or fails to take such measures in the required manner,

(f) fails to comply with the whole or any part of a direction of an inspector under subsection 38(6), or

is guilty of an offence punishable on summary conviction and liable, for a first offence, to a fine not exceeding two hundred thousand dollars and, for any subsequent offence, to a fine not exceeding two hundred thousand dollars or to imprisonment for a term not exceeding six months, or to both.

Section 40(5): Matters of proof.

For the purpose of any proceedings for an offence under subsection (2) or (3),

(a) a "deposit" as defined in subsection 34(1) takes place whether or not any act or omission resulting in the deposit is intentional; and

(b) no water is "water frequented by fish" as defined in subsection 34(1), where proof is made that at all times material to the proceedings the water is not, has not been and is not likely to be frequented in fact by fish.

Section 78.1: Successive days separate offences.

Where any contravention of this Act or any of the regulations is committed or continued on more than one day, it constitutes a separate offence for each day on which the contravention is committed or continued.

Section 78.2: Offences by corporate officers, etc.

Where a corporation commits an offence under this Act, any officer, director or agent of the corporation who directed, authorized, assented to, acquiesced in or participated in the commission of the offence is a part to and guilty of the offence and is liable on conviction to the punishment provided for the offence, whether or not the corporation has been prosecuted.

Section 78.3: Offence by employers.

In any prosecution for an offence under this Act, it is sufficient proof of the offence to establish that it was committed by an employee or agent of the accused, whether or not the employee or agent is identified or has been prosecuted for the offence, unless the accused established that the offence was committed without the knowledge or consent of the accused.

Excerpts from the *Water Act* (British Columbia)
CHAPTER 429
(Consolidated February 29, 1988)

Interpretation

In this Act

"divert", or a word of similar import, means taking water from a stream, and includes causing water to leave the channel of a stream and making a change in or about the channel that permits water to leave it;

"engineer" means an engineer appointed under section 28 and includes the regional water manager;

"stream" includes a natural watercourse or source of water supply, whether usually containing water or not, ground water, and a lake, river, creek, spring, ravine, swamp and gulch;

"works" means anything capable of or useful for diverting, storing, measuring, conserving, conveying, retarding, continuing or using water, or for producing, measuring, transmitting or using electricity, or for collecting, conveying or disposing of sewage or garbage or for preventing or extinguishing fire, and includes access roads to any of them, and includes the placing of booms and piles in and the removal of obstructions from the banks and beds of streams.

Approvals by comptroller or regional water manager

7.(1) The comptroller or the regional water manager may, without issuing a licence, approve the diversion or use, or both, of water on the conditions he considers advisable where

(a) non-recurrent use of water is required for a term not exceeding a period of 6 months;

(b) a municipality desires to exercise its powers, subject to the *Water Act,* under Division (3) of Part 13 of the *Municipal Act;*

(c) a public corporate body or a person desires to make changes in and about a stream;

(d) a minister of the Crown, either of Canada or the Province, desires to make changes in and about a stream;

but the water may only be used subject to the same provisions as if the approval were a licence.

7.(2) Notwithstanding that a licence has not been issued, a person is not prohibited from diverting or using water in accordance with an approval given under this section.

Powers of engineer

37.(1) In addition to all other powers given under this Act and the regulations, every engineer may

(a) enter at any time on any land;

(b) inspect, regulate, close or lock any works;

(c) determine what constitutes beneficial use of water;

(d) order the repair, alteration, improvement, removal of or addition to any works;

(e) order the construction, installation and maintenance of any measuring device;

(f) regulate, in person or through a water bailiff, the diversion, storage, carriage, distribution and use of water;

(g) determine allowances of water to offset evaporation and seepage;

(h) order the release of stored or impounded water that he considers a danger to life or property;

(i) order a person to cease putting or not to put any sawdust, timber, tailings, gravel, refuse, carcass or other thing or substance into a stream; and

(j) order a person to remove from a stream any substance or thing that he has put into or permitted to get into the stream.

Offences

41.(1) A person commits an offence who

(a) wilfully hinders, interrupts or causes or procures to be hindered or interrupted, a licensee or his managers, contractors, servants, agents, workers or any of them, in the lawful exercise of a right granted under this Act or a licence;

(b) wilfully destroys, injures or interferes with the works of a licensee without lawful authority;

(c) opens or closes without authority a hydrant used for fire protection, or obstructs free access to a hydrant stop cock or hydrant accessory, or damages a hydrant stop cock or hydrant accessory;

(d) lays or causes to be laid a pipe, or constructs or causes to be constructed a ditch or other conduit to connect with the works of a licensee without authority from the comptroller, engineer or the licensee;

(e) molests, interferes with, delays, obstructs or otherwise impedes the comptroller or an engineer, water bailiff or other officer in the discharge or performance of a duty or the exercise of an authority under this Act;

(f) destroys, injures or tampers with

(i) works; or

(ii) a gauge, weir, measuring device, structure, appliance, cable, boat, instrument or tool belonging to or placed in position by an applicant, licensee or official of Canada or of the Province;

(g) places, maintains or makes use of an obstruction in the channel of a stream without authority;

(h) engages in the business of operating works to carry water for others without holding a licence or other authority issued in that behalf under this or a former Act;

(i) wilfully interferes with a headgate, ditch or controlling works which an engineer or water bailiff has regulated, or destroys a notice posted by an applicant, engineer or water bailiff;

(j) constructs, maintains, operates or uses works without authority;

(k) puts into a stream any sawdust, timber, tailings, gravel, refuse, carcass or other thing or substance after having been ordered by the engineer or water recorder not to do so;

(l) diverts water from a stream without authority.

Right to use unrecorded water

42.(1) It is not an offence for a person to divert water from a stream for extinguishing a fire, but any flow so diverted shall be promptly restored to its original channel when the fire is extinguished.

42.(2) It is not an offence for a person to divert unrecorded water for domestic purpose or for prospecting for mineral, but in a prosecution under this Act the person diverting the water must prove that the water is unrecorded.

APPENDIX II
SALMONID HABITAT

Salmonid Resource

B.C. and Yukon freshwater systems support 11 salmonid species, including five species of salmon (chum, coho, chinook, sockeye and pink), three species of trout (rainbow, cutthroat and brown), and three species of char (Dolly Varden, lake trout and brook trout). The trout, char and several other resident freshwater species, including Arctic grayling, kokanee, burbot and several whitefish species, share habitats and have similar environmental requirements as salmon. Although this reference focuses on salmonids and their habitat, much of its content applies to all species that share the same freshwater systems.

Salmonid Life Histories

Anadromous salmonids utilize the ocean for a major portion of their growth, but depend on freshwater for reproduction. Perhaps the most significant characteristic of anadromous salmonids is their habit of returning from the ocean to spawn in their natal streams, where they were spawned and reared. This homing characteristic enables the development of distinct and separate stocks or populations, each adapted to the particular conditions of its natal stream. One of the more obvious manifestations is the difference between populations in the seasonal timing of adult migration and spawning in freshwater. Each of the salmonid species is unique with respect to its life cycle and habitat requirements in the freshwater phase. All species of anadromous salmonids require a freshwater environment for spawning and embryonic development, but the species differ in the extent to which they rear in freshwater after emerging from the gravel as fry. Pink and chum salmon, for example, migrate to sea immediately following emergence, whereas the other species may rear in streams, lakes or estuaries for periods of months to several years before entering saltwater. The generalized life cycle of the anadromous salmonid is shown in Figure A2.1.

There are significant differences in the life histories of the Pacific salmon, trout and char. While Pacific salmon die after spawning, trout and char may survive to spawn more than once. Salmon and char characteristically spawn in the fall, on declining temperatures, but trout spawn in winter or spring, generally on a rising temperature regime. All species use the gravel bottom of streams or upwelling groundwater sources for spawning. The spawning nest or redd, which is constructed by the female, consists of a series of pockets in the gravel in which the fertilized eggs are deposited to a depth of 20 to 50 cm. Development of the embryo goes through the egg stage to hatching, then through alevin development to full absorption of the yolk sac and subsequent emergence of fry from the gravel. The period from spawning to fry emergence may range from as little as 2 months in the case of spring-spawning trout, to as much as 9 months for those Pacific salmon populations spawning in colder periods, where temperatures close to 0°C prevail through most of the winter. In the latter case, spawning would likely occur in early to mid September, eggs would reach the eyed stage (when the eyes, head and body form of the embryo first become apparent) during October, hatching would occur in the following March and April, and the fry would emerge during May. With the exception of the coastal cutthroat trout and anadromous Dolly Varden char which utilize nearshore intertidal and estuarine areas, many races of anadromous salmonid species undertake extensive feeding migrations in the Pacific Ocean, between northern California and the Gulf of Alaska, and can be found up to 1600 km offshore. Conversely, other races of salmonid species remain and feed in coastal waters, such as Georgia Strait, throughout their marine life. In addition, several species of trout and char have exclusively freshwater life histories with adult migration, spawning, incubation and rearing occurring in and between lakes, rivers and streams.

Figure A2.1 Anadromous Salmonid Life Cycle

Salmonid Habitat Requirements

Salmonids are a group of fishes adapted to the variable habitat of north temperate, "recently" deglaciated regions. Individually, they often have to cope with severe and variable conditions and might be thought of as an especially "tough" or "insensitive" group of species. Certainly they appear to be remarkably resilient in habitat use, in feeding, growth and reproduction, as well as in many other ecological and behavioural characteristics. Despite this, they are environmentally sensitive fishes; particularly in terms of the habitat and water quality requirements of the incubating and rearing portions of their life cycle. The typical food items for those species that utilize streams for nursery purposes are terrestrial and aquatic invertebrate animals whose own life cycles depend on similar habitat and water quality values as salmonids.

In general, salmonids require fairly cool, well-oxygenated water, a clean gravel substrate, and abundant cover and shade. They require special conditions for successful spawning, for the development and hatching of eggs and for growth and survival of their young. Salmonids have different requirements for spawning, rearing and migration. Fry and juveniles move to different habitats as they grow older, and hence they require access up and down the stream and into smaller tributaries. This may include swampy areas, wetlands, small streams and side channels or intermittently wetted areas. As spawning adults, salmonids require adequate flow and access to return to spawning areas to complete their life cycle.

The range and diversity of aquatic environments the various salmonids inhabit throughout their life history combine to make them much more vulnerable to environmental changes. These changes are generally associated with water use and impacts of land use activities on the aquatic environment. Water diversions and pollution, hydroelectric projects, forest harvesting, road construction and land development are the most predominant. The use by salmonids of habitat varies widely not only with species but also with races of a species, between discrete populations and even between individuals of the same population. This makes any generalization about their areas of preference and habitat requirements difficult. Furthermore it means that ideally their protection and management must be based on specific and up-to-date information about local populations and conditions.

Specific environmental requirements of salmonids vary with species; in fact, the requirements of certain species may be in direct conflict (e.g. a small log jam may create a nursery area for coho salmon but remove a spawning area from chum or pink salmon). However, an attempt has been made below to generalize the optimum requirements under the simple headings of the habitat characteristics and water conditions of the salmonid freshwater environment.

Access

The spawning and nursery areas of streams must be accessible to adult salmonids migrating upstream, and to fry and juveniles seeking rearing habitat. This includes small feeder streams, wetlands and side channels which provide valuable habitat in the stream or river environment.

Stream Flow

A relatively stable flow without extreme freshets and droughts characterizes the best salmon and trout streams. Stable stream flow is characterized by a minimum of freshets and floods causing excessive bed load transport and bank instability, consequently destroying benthos or any developing embryos or alevins that might be in the substrate. While too much water might be detrimental, too little is also damaging. A sufficient flow of water is required for each life stage. Sufficient flows are required during the normal low flow period of late August and September to provide adequate nursery area for the young salmonids and access for returning spawners, and also during the winter, when embryos and alevins in the gravel could be exposed to freezing.

Stream Substrate

For successful spawning, salmonids require clean stable gravel, typically located in riffles or runs, depending on fish size and species. High quality gravel will permit redd building and an intragravel flow of water adequate to provide each embryo and alevin with a high concentration of dissolved oxygen and to remove metabolic wastes such as carbon dioxide and ammonia. Clean spawning gravel, from 5 mm to 150 mm in diameter, and larger rocks and cobbles, found on the stream bottom and banks, is required for production of aquatic insects and habitat for young juvenile salmonids.

Riparian Cover and Stream Structure

Stream salmonids require cover in the form of undercut banks, logs, rubble substrate, turbulence, deep pools and overhanging streamside vegetation as found in a viable healthy riparian area. Such cover is used by juveniles for feeding areas, as a source of food items, refuge for escape and over-wintering. Adult salmonids use cover such as deep pools for resting and escape during spawning migrations. Research has also shown that in order to have substantial mixed populations of salmonids such as the commonly found associations of steelhead trout and coho salmon or cutthroat trout and coho, a stream with a stepped gradient and high proportion of both riffles and pools is required. LOD (large organic debris) or CWD (coarse woody debris) form an integral part of the stream morphology by stabilizing the stream bed and by providing habitat, by altering the stream structure with scours and pools. Naturally occurring LOD, in the form of fallen logs, root wads and small jams, should not be altered or removed.

Water Temperature

A temperature between 12 and 14°C is preferred by the young of all salmon species with marked avoidance of temperatures above 15°C and lethal temperature of about 24-25°C. Increased stream temperature means more dissolved oxygen is needed for the increased metabolic rate of fish. However, dissolved oxygen saturation levels decrease with increasing temperature which leads to overall lower concentrations of dissolved oxygen available at higher temperatures.

Dissolved Oxygen (DO)

Stream-dwelling salmonids require high levels of dissolved oxygen (DO) in both the intragravel and surface waters. It is difficult to set down useful minimum oxygen requirements for stream salmonids given the great diversity of requirements for different lifestages, activities and stresses any population experiences. However, it must be stressed that temperature and water quality markedly affect the levels of DO saturation (% of total saturation at a given temperature) and concentration (mg/l) in stream waters. Generally, optimum DO saturation is ≥ 90% and minimum optimum DO concentration is ≥ 8 mg/l.

Water Clarity and Suspended Sediment

Stream water must be clear enough to permit the sunlight to reach the stream bottom and the algal community where most of the primary production of a stream occurs. Elimination of such production may severely reduce the invertebrate fauna of a stream. Salmonids feed by sight and can have difficulty finding food items in highly turbid water. High concentrations of suspended solids may also directly damage invertebrates and fish, primarily their fragile gill structures. Additional impacts can occur if suspended sediments settle onto stream bottoms and suffocate salmonid eggs and alevins, and destroy benthic invertebrate populations.

APPENDIX III
OPERATING WINDOWS FOR FISHERIES SENSITIVE ZONES

Purpose

The purpose of this Appendix is to provide development proponents with general information on the allowable operating windows within Fisheries Sensitive Zones based on FSZ area and fish species present. To assist in the presentation of this information, the Appendix has been divided into two sections.

Fisheries Sensitive Zone Areas of British Columbia

Figure A3.1 is a map of British Columbia dividing the province into nine (9) FSZ areas to illustrate the regional variations in fish presence and use of Fisheries Sensitive Zones (FSZ). The rationale underlying this division was initially ecological, as per Demarchi's *Ecoregions of British Columbia* (1988)[1]. However, it was found to be necessary to adjust the ecological basis to reflect major drainage basins and fish species distribution[2], and to reflect some major administrative regions[3]. To aid in habitat protection, Fisheries Sensitive Zones (FSZ) were defined as the out-of-stream features of fish habitat, such as side channels, wetlands and riparian areas, in addition to instream fish habitat features.

Fisheries Sensitive Zone Species Timing Windows

Table A3.1, titled **Fisheries Sensitive Zone Species Timing Windows**, gives time periods of reduced risk for important commercial, sport, and resident fish species within each of the nine FSZ areas shown on the FSZ Area map. Within each FSZ Area, there are defined operating windows for fish species within that region based on the biological life histories within each of the areas. The period noted in the table is considered to be that time span when there are no fish eggs or alevins present in the substrates of the rivers in the designated area for the species of fish indicated (i.e. the start date of the window coincides with the **end** of alevin emergence and the end date of the window coincides with the **start** of spawning by the species in question).

1 Shown by the inclusion of the headwaters of the Klinaklini and Dean Rivers within Area 4 rather than Area 1.

2 Shown by the exclusion of the upper Fraser River from Area 3, which now generally covers the Columbia River basin, and by the division of the northern portion of the province into the Peace River basin, the Liard River basin and the Alaska Panhandle transboundary rivers area.

3 Shown by the division of the mainland coast into a southern portion, included with Vancouver Island in Area 1, and a northern portion, included with the Skeena and Nass drainage basins in Area 5.

The use of the **Operating Windows for Fisheries Sensitive Zone Areas** is governed by the following principles:

- The individual life history windows noted in the table are general approximations only for a particular species over an entire specified area. Given the great extent of many of the nine areas, variations from the noted windows should be expected. Depending on the area, the location of a particular river system within that area, the species of concern, and expected conditions (e.g. stream temperature, fry emergence and migration, etc.) during the proposed work period, the **actual permissible window** for work in the FSZ will likely be defined and negotiated with input from both federal and provincial fisheries agencies, with decisions being based on the physical and biological parameters of the ecosystem. For instance, in some cases, it may be necessary to consider hydraulic conditions in conjunction with the biological life histories. Times when sensitive life history stages (including organisms other than fish) are absent may also be times of low flow. Any suspended solids generated by work in the FSZ at these times may not be flushed out of the system quickly and the subsequent degradation of fish habitat and water quality could impact future migrating, spawning, and rearing populations as well as their food sources. Potential impacts on existing populations may have to be balanced with those on future populations. In any case, the goal will be the protection of fish and fish habitat through stringent safeguards to prevent the introduction of deleterious substances, including sediment, into the FSZ.
- The reduced-risk windows noted in the table are those periods when fish eggs and alevins are absent from the substrates. Juvenile fish and/or migrating/resident adults will probably still be present in the river during the period of reduced risk. Although a work period for a particular FSZ may be identified and approved, the actual work still must be carried out in a manner that, as clearly stated above, avoids the degradation of fish habitat. The reduced-risk windows noted in the matrix do not give "carte blanche" permission for poor or careless work practices; the objective is to always avoid adverse impacts on fish and fish habitat. Reduced-risk is **not** no-risk.
- The presentation of those fish species listed in the timing window matrix is not intended to imply that other fish species will be excluded from consideration when actual permissible windows are being negotiated. It is quite possible that the protection of rare or endangered species, or of specific populations of such species, and of their habitats will assume greater importance than that of the listed species.

The windows in the table are provided as an aid for initial planning only. Given the likelihood that actual permissible windows will have to be determined by both federal and provincial officials, development proponents are strongly encouraged to contact

local DFO and MOELP fisheries regional staff early in the planning process to discuss site-specific details of any work in Fisheries Sensitive Zones.

Figure A3.1 Fisheries Sensitive Zone Areas of British Columbia

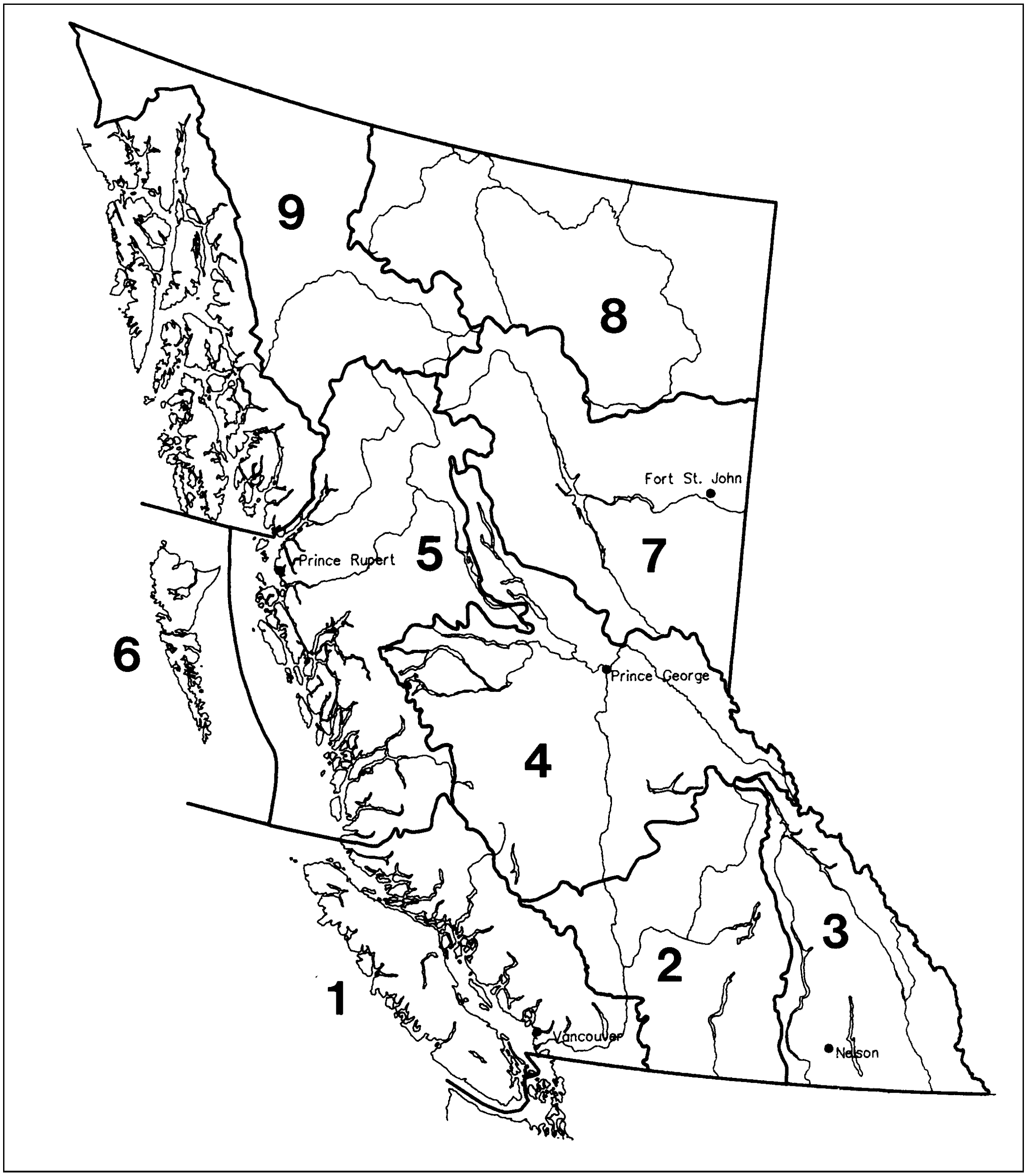


Table A3.1 - Fisheries Sensitive Zone Species Timing Windows

REFERENCES

Dane, B.G. 1978. *Culvert Guidelines: Recommendations for the Design and Installation of Culverts in British Columbia to avoid conflict with Anadromous Fish*. Tech. Rep. No. 811. Fisheries and Marine Service. Fisheries and Environment Canada.

Design of Urban Runoff Quality Controls: Proceedings of an Engineering Foundation Conference on Current Practice and Design Criteria for Urban Quality Control. 1989. ASCE. New York.

Elbe, H. and R. Olmsted. *Guidelines for the Protection of the Aquatic Environment during Land Development Activities*. 1990. Prepared for Department of Fisheries and Oceans and Ministry of Environment.

Erosion and Sediment Control - Westwood Plateau Coquitlam, BC. Prepared for Westbild Enterprises Ltd by Terrasol and Hardy BBT Geotechnical Engineers Ltd. 1990.

Facts Sheets prepared for B.C. Ministry of Transportation and Highways - Seminar on Highway Maintenance. May 1990. Prepared by Department of Fisheries and Oceans. 1989.

Fish Screening Directive. 1990. Department of Fisheries and Oceans Canada.

Gibb, A., B. Bennett and A. Birkbeck. 1991. *Urban Runoff Quality and Treatment: A Comprehensive Review.* BC Research. Vancouver.

Goldman, S.J., K. Jackson and T.A. Bursztynsky. 1986. *Erosion and Sediment Control Handbook.* McGraw-Hill Book Company. New York.

Gray, D.H. 1982. *Biotechnical Slope Protection and Erosion Control*. Van Nostrand Reinhold Co. New York.

Hogg, W.D. and D.A. Carr. 1985. *Rainfall Frequency Atlas for Canada.* Atmospheric Environment Service. Environment Canada.

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

Loukidelis, D and A. Hillyer. *Using Conservation Covenants to Preserve Private Land in British Columbia*. 1992. West Coast Environmental Law Research Foundation. Vancouver.

McKinley, W.R. and R.D. Webb. 1956. *A Proposed Correction of Migratory Fish Problems at Box Culverts*. Department of Fisheries. State of Washington.

Munday, D.R., G.L. Ennis, D.G. Wright, D.C. Jefferies, E.R. McGreer, and J.S. Mathers, 1986. *Development and Evaluation of a Model to Predict Effects of Buried Underwater Blasting Charges on Fish Populations in Shallow Water Areas*. Can. Tech. Rep. Fisheries and Aquatic Sciences No. 1418.

Nonpoint Source Watershed Workshop. 1991. U.S. Environmental Protection Agency.

Policy for the Managment of Fish Habitat. 1986a. Department of Fisheries and Oceans Canada.

Powers, P.D. 1990. *Stormwater Detention Performance based on Dominant Discharge*. Department of Fisheries. State of Washington.

Powers, P.D. 1991. *Stormwater Management Guidelines for the Protection of Fish Habitat*. Department of Fisheries. State of Washington.

Stormwater Management Manual for the Puget Sound Basin. Draft 1991. Department of Ecology. State of Washington.

Urban Development: Guidelines for the Protection of Fish Habitat in Insular Newfoundland. 1983. Department of Fisheries and Oceans.

Urban Hydrology for Small Watersheds Technical Release 55. 1986. Soil Conservation Service. U.S. Dept. of Agriculture.

Urban Runoff Quality Control Guidelines for the Province of British Columbia. Draft 1992. Municipal Liquid and Industrial Waste Managment Branch. Province of British Columbia.

Urban Storm Drainage Criteria Manual - Volume 3 - Best Management Practices. Urban Drainage and Flood Control District. Denver, Colorado. 1992.

Vancouver Island Highway Project - Guidelines for Environmental Design of Highway Drainage. Prepared for the B.C. Ministry of Transportation and Highways by KPA Engineering Ltd. 1992.

Westwood Plateau Development Plan. 1990. Westbild Enterprises Ltd.