A GUIDEBOOK FOR BRITISH COLUMBIA

Stormwater Planning

British Columbia
Ministry of Water, Land and Air Protection

Acknowledgements

From the outset, the production of this Guidebook has been a cooperative project involving several agencies and local governments who are challenging traditional stormwater management practices in British Columbia. The Project Steering Committee included: Peter Law (project manager), Laura Maclean, Chris Jenkins, Helene Roberge, Eric Bonham, John Finnie, Sean DePol and Brigid Reynolds.

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How to Use the Guidebook

The Stormwater Planning Guidebook is structured to meet the information needs of different audiences: from senior managers and elected officials… to those professional planning and engineering staff who are tasked with implementing early action… to land developers and the consulting community.

The Guidebook is Structured in Three Parts:

- ***Part A – The Problem and Principles*****:** written for senior managers, elected officials and those wanting a general introduction to integrated stormwater management.
- ***Part B – The Solutions*****:** written mainly for engineers and planners, this part provides examples of how to achieve integrated stormwater management at both planning and site levels.
- ***Part C – The Process*****:** written for administrators and the complete range of stakeholders who will be involved in making the move from planning to action, this part defines roles, methods, means and timing for integrated stormwater management.

For readers who are new to integrated stormwater management, Part A is required reading.

Readers looking for a sense of what integrated stormwater management means on the ground will enjoy the examples in Part B.

Those wanting to start or fund an integrated stormwater management plan or program will find organizational advice in Part C.

The Guidebook draws heavily on case study experience by leading local governments and developers in BC. The illustrations are adapted from projects by the authors.

The overall objective of this Guidebook is to offer a common sense, effective and affordable approach to integrated stormwater management.

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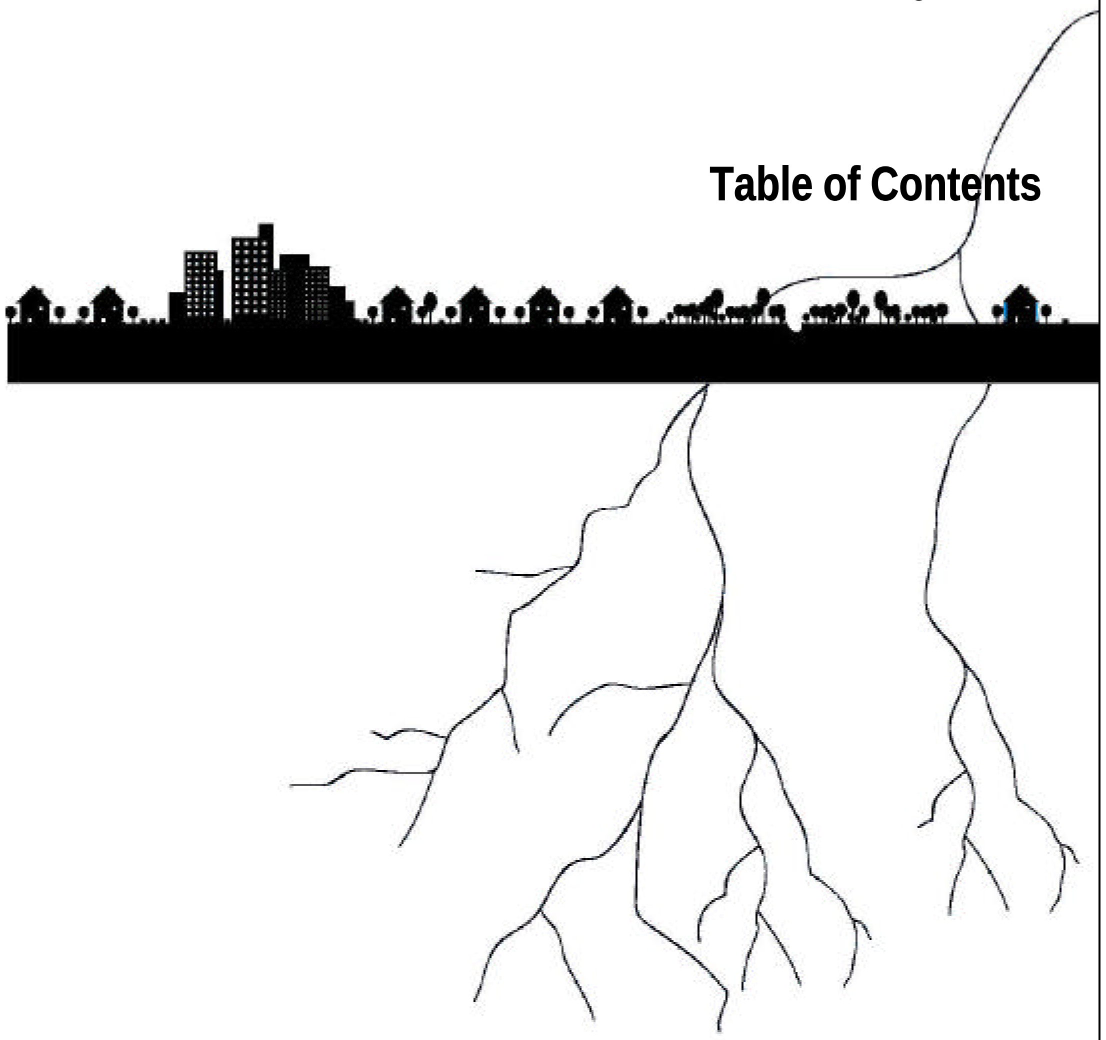

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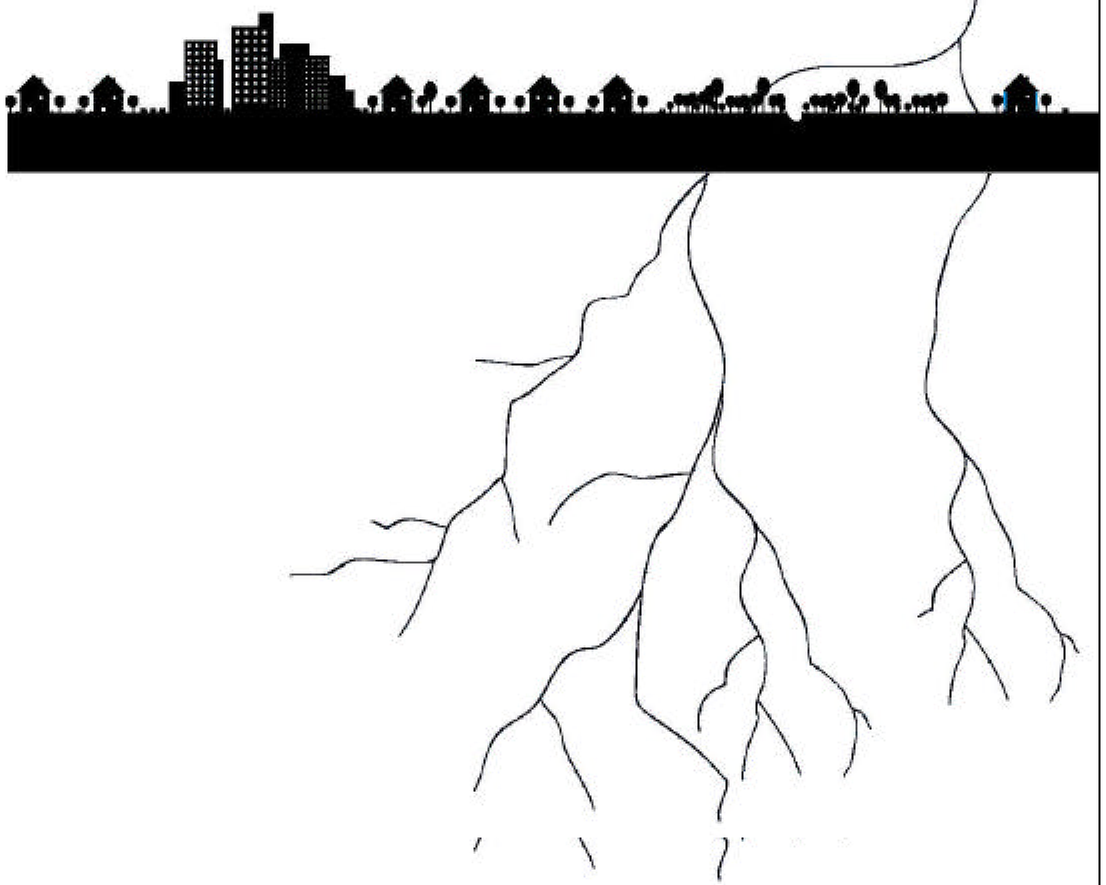

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Executive Summary

Stormwater management in British Columbia is a key component of protecting quality of life, property and aquatic ecosystems.

The science and practice of stormwater management is constantly evolving, in British Columbia and around the world. Within BC, the range of stormwater management activity varies from completely unplanned in many rural areas, to state-of-the-art in some metropolitan centres. The purpose of this Guidebook is to provide a framework for effective stormwater management that is usable in all areas of the province.

The Guidebook presents a methodology for moving from planning to action that focuses the limited financial and staff resources of governments, non-government organizations and the development community on implementing early action where it is most needed.

The Guidebook is organized in three parts: Part A defines the problem, Part B provides solutions and Part C defines the process.

The Guidebook provides a comprehensive understanding of the issues and a framework for implementing an integrated approach to stormwater management. Case study experience underpins the approaches and strategies that are presented in the Guidebook.

Stormwater Component of Liquid Waste Management Plans

In British Columbia, the *Local Government Act* has vested the responsibility for drainage with municipalities. With the statutory authority for drainage, local governments can be held liable for downstream impacts that result from changes to upstream drainage patterns – both volume and rate. The *Act* also enables local governments to be proactive in implementing stormwater management solutions that are more comprehensive than past practice.

Furthermore, a stormwater component is a requirement for approved *Liquid Waste Management Plans* (LWMPs). Guidelines for developing a LWMP were first published in 1992. LWMPs are created by local governments under a public process in co-operation with the Province.

An OCP Provides the Foundation for a LWMP

There is a clear link between the land use planning required of local governments in the *Local Government Act* and the LWMP process. In most cases where an *Official Community Plan* (OCP) is in place, the local government planning statement (bylaw) will form the basis for a LWMP. The purposes of a LWMP are to minimize the adverse environmental impact of the OCP and ensure that development is consistent with Provincial objectives.

OCPs tend to be led by planners, with input from engineers on infrastructure sections. LWMPs tend to be led by engineers, with little or no input from planners. Both processes involve approval by a Local Council or a Regional Board.

In some cases, a LWMP process may be a trigger that focuses attention on stormwater management. Public concern related to flooding or habitat loss may be the trigger. Or an OCP public process may communicate public interest in raising local environmental and habitat protection standards.

Whatever the driver, at the end of the process an OCP should include goals and objectives for stormwater management. These goals and objectives, or a variant of them, might first reside in a LWMP, and then be adapted to the OCP in the next review process. Or they may originate in the OCP process, and then be detailed through a LWMP. Either way is entirely acceptable.

Integrated Stormwater Management Planning

In British Columbia, the term *Integrated Stormwater Management Plan* (ISMP) has gained widespread acceptance by local governments and the environmental agencies to describe a comprehensive approach to stormwater planning. The purpose of an ISMP is to provide a clear picture of how to be proactive in applying land use planning tools to protect property and aquatic habitat, while at the same time accommodating land development and population growth.

Part A – Why Integrated Stormwater Management?

Part A identifies problems associated with traditional stormwater management and provides the rationale for a change from traditional to integrated stormwater management. Some guiding principles of integrated stormwater management are introduced.

Part A also builds a science-based understanding of how natural watersheds function and how this function is affected by land use change.

Part B – Integrated Stormwater Management Solutions

Part B outlines the scope and policy framework for integrated stormwater management, and presents a cost-effective methodology for developing stormwater solutions.

Step #1 - Identify At-Risk Drainage Catchments

A methodology is presented for identifying at-risk drainage catchments to focus priority action. The methodology relies on a roundtable process that brings together people with knowledge about future land use change, high-value ecological resources and chronic flooding problems. The key is effective integration of planning, engineering and ecological perspectives.

Step #2 - Set Preliminary Performance Targets

A methodology is presented for:

- Developing watershed performance targets based on site-specific rainfall data, supplemented by streamflow data (if available) and on-site soils investigations
- Translating these performance targets into design guidelines that can be applied at the site level to mitigate the impacts of land development

The Guidebook documents British Columbia case studies of stormwater policies and science-based performance targets applied to both greenfield and urban retrofit scenarios.

Step #3 - Select Appropriate Stormwater Management Site Design Solutions

Guidance is provided for selecting appropriate site design solutions to meet performance targets. Examples include:

- Design and performance of stormwater source controls for various land uses
- Watershed scale modeling of the effectiveness of site design solutions

British Columbia case studies are examined for greenfield and urban retrofit scenarios. A 'Water Balance Model' is also applied for linking performance targets to design guidelines for source control and runoff conveyance.

Part C – Moving from Planning to Action

Part C describes a process that will lead to better stormwater management solutions.

The role and design of action plans are introduced to bring a clear focus to what needs to be done, with what priority, by whom, with related budgets.

Tips are provided on processes that produce timely and high-quality decisions.

Part C also provides guidance for organizing an administrative system and financing strategy for stormwater management.

A final section on building consensus and implementing change describes how to develop a shared vision and overcome barriers to change.

Two acronyms provide a useful summary of the principles and elements of integrated stormwater management:

A D A P T

to the

C U R E

ADAPT –
The Guiding Principles of Integrated Stormwater Management

The acronym **ADAPT** summarizes five guiding principles for integrated stormwater management. The Guidebook is based upon these five principles.

ADAPT

Agree that stormwater is a resource

Design for the complete spectrum of rainfall events

Act on a priority basis in at-risk drainage catchments

Plan at four scales – regional, watershed, neighbourhood & site

Test solutions and reduce costs by adaptive management.

Guiding Principle 1 - Agree that Stormwater is a Resource

Stormwater is no longer seen as just a drainage or flood management issue but also a resource for:

- fish and other aquatic species
- groundwater recharge (for both stream summer flow and for potable water)
- water supply (e.g. for livestock or irrigation)
- aesthetic and recreational uses

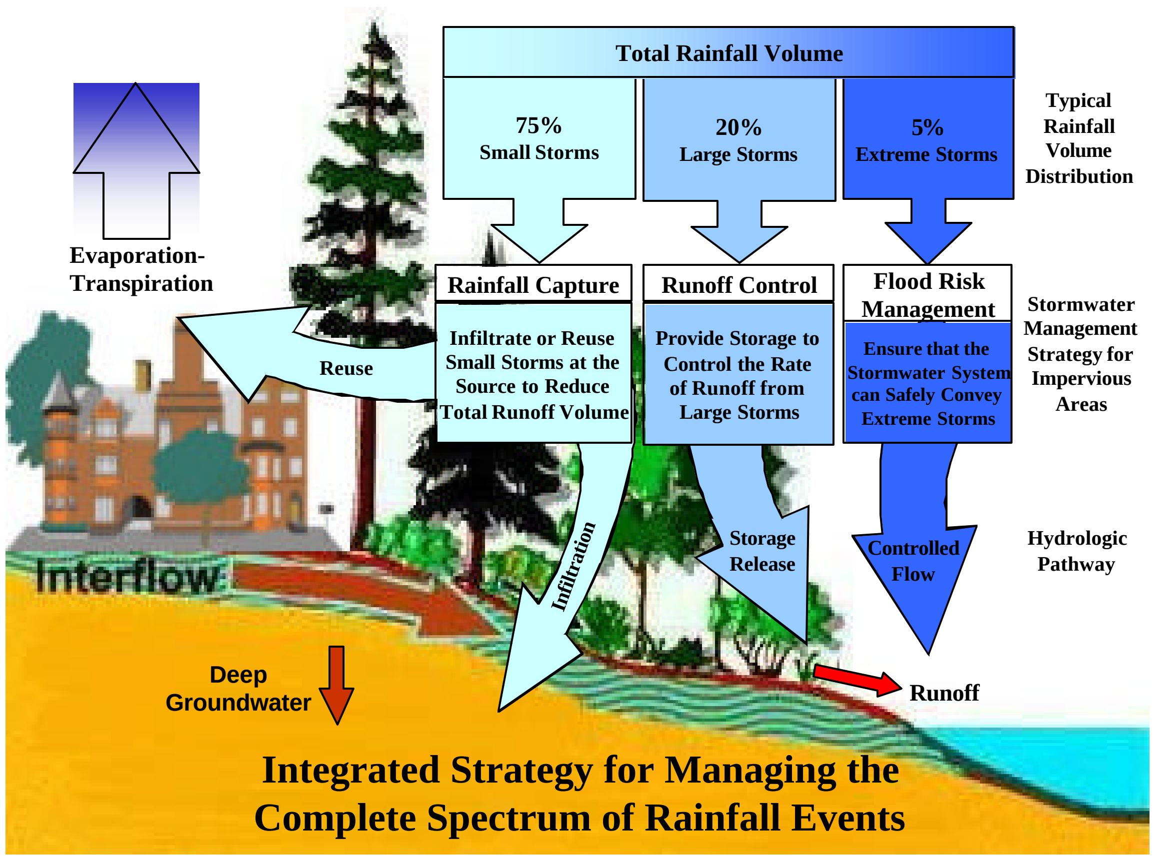
Guiding Principle 2 - Design for the Complete Spectrum of Rainfall Events

Integrated stormwater solutions require site design practices that provide:

- **Rainfall Capture for Small Storms (runoff volume reduction and water quality control)** – Capture the small frequently occurring rainfall events at the source (building lots and streets) for infiltration and/or re-use.
- **Runoff Control for Large Storms (runoff rate reduction)** – Store the runoff from the infrequent large storms (e.g. a mean annual rainfall), and release it a rate that approximates the natural forested condition.
- **Flood Risk Management for the Extreme Storms (peak flow conveyance)** – Ensure that the drainage system can safely convey extreme storms (e.g. a 100-year rainfall).

The Integrated Strategy

Guiding Principle 2 forms the foundation of integrated stormwater solutions that mimic the most effective stormwater management system of all - a naturally vegetated watershed. This means that rainfall from frequent small events must be infiltrated into the ground or re-used within the watershed, as illustrated below.



Comparison with Conventional Stormwater Management

Conventional 'flows-and-pipes' stormwater management is limited because it focuses only on the fast conveyance of the extreme storms and often creates substantial erosion and downstream flooding in receiving streams.

Similarly, a detention-based approach is only a partial solution because it allows the small storms that comprise the bulk of total rainfall volume to continue to create erosion and impacts on downstream aquatic ecosystems.

Neither of these approaches fully prevents the degradation of aquatic resources or flooding risks to property and public safety.

In contrast, the Guidebook approach is to eliminates the root cause of ecological and property impacts by designing for the complete spectrum of rainfall events. Solutions described in the Guidebook include conventional, detention, infiltration and re-use approaches for rainfall capture, runoff control and flood risk management.

Guiding Principle 3 - Act on a Priority Basis in At-Risk Drainage Catchments

Priority action should be focused in at-risk drainage basins where there is both high pressure for land use change and a driver for action. The latter can be either:

- a high-value ecological resource that is threatened, or
- an unacceptable drainage problem

The stormwater management policies and techniques implemented in at-risk catchments become demonstration projects.

Guiding Principle 4 - Plan at Four Scales – Regional, Watershed, Neighbourhood and Site

Integrated stormwater management must be addressed through long-term planning at each of the regional, watershed, neighbourhood and site scales.

- **At the Regional and Watershed Levels** – Establish stormwater management objectives and priorities
- **At the Neighbourhood Level** – Integrate stormwater management objectives into community and neighbourhood planning processes
- **At the Site Level** – Implement site design practices that reduce the volume and rate of surface runoff and improve water quality

Guiding Principle 5 - Test Solutions and Reduce Costs by Adaptive Management

Performance targets and stormwater management practices should be optimized over time based on:

- monitoring the performance of demonstration projects
- strategic data collection and modeling

As success in meeting performance targets is evaluated, the stormwater management program can be adjusted as required.

CURE – The Elements of an Action Plan

The acronym **CURE** focuses attention on the four key types of actions that must all work together to implement integrated stormwater management solutions:

- **C**APITAL INVESTMENT – Short-term capital investment will be needed to implement early action in at-risk drainage basins. Improvements to existing drainage system are often the most significant capital investments required. A financing plan should provide an ongoing source of funds for watershed improvements.
- **U**NDERSTANDING SCIENCE – Improved understanding of a watershed, the nature of its problems, and the effectiveness of technical solutions is key to an adaptive approach. Stormwater management practices can be optimized over time through the monitoring of demonstration projects, combined with selective data collection and modeling.
- **R**EGULATORY CHANGE – Changes in land use and development regulations are needed to achieve stormwater performance targets. Changes to land use planning and site design practices are needed to eliminate the root cause of stormwater related problems. These changes must be driven by regulation.
- **E**DUCATION AND CONSULTATION – Changes to land use planning and site design practices can only be implemented by building support among city staff, the general public and the development community through education and consultation.

Translating a Vision into Action

It is important to establish a long-term shared vision at the start of any watershed planning initiative. A vision that is shared by all stakeholders provides direction for a long-term process of change. The vision becomes a destination, and an action plan provides a map for getting there.

Actions plans must be long-term, corresponding to the time frame of the vision. Action plans must also evolve over time.

Ongoing monitoring and assessment of progress towards a long-term vision will improve understanding of the policy, science and site design components of integrated stormwater management. This improved understanding will:

- Lead to the evolution of better land development and stormwater management practices
- Enable action plans to be adjusted accordingly

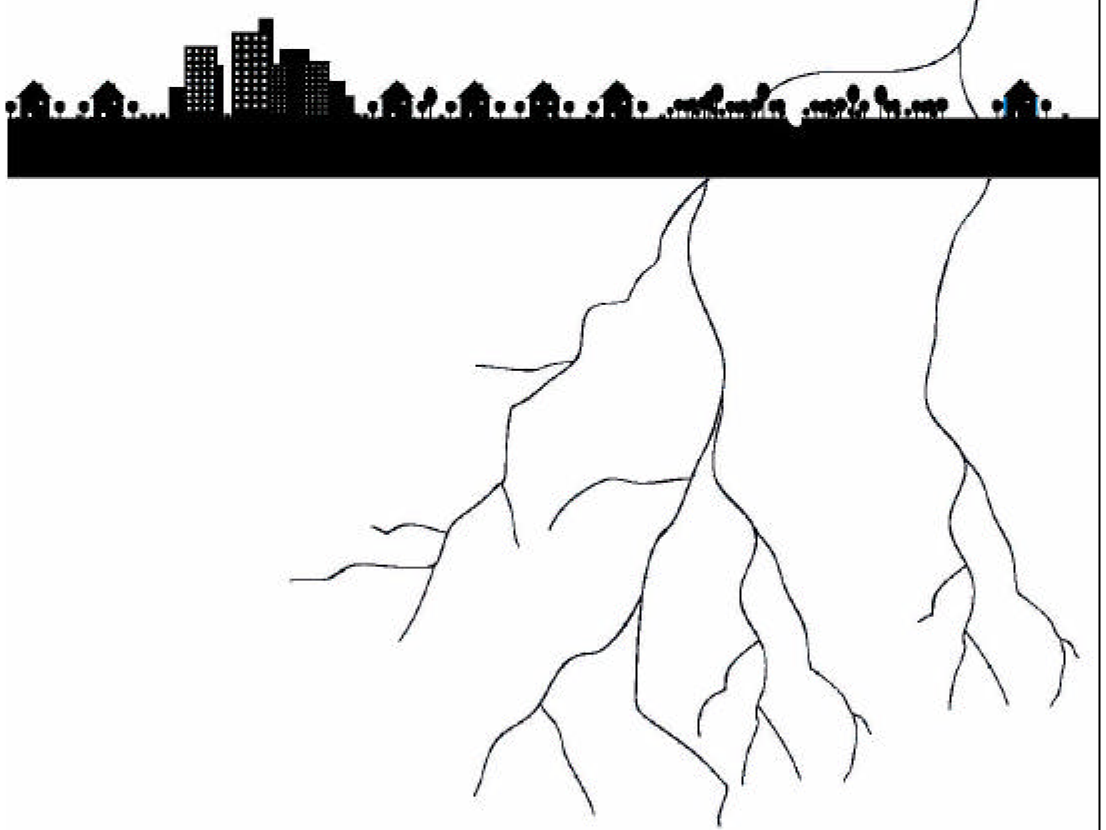
An adaptive management approach to changing stormwater management practices is founded on learning from experience and adjusting for constant improvement.

Building Blocks

The Guidebook elaborates on three fundamental objectives that become building blocks for a long-term process of change:

- **Achievable and Affordable Goals -** Apply a science-based approach to create a shared vision for improving the health of individual watersheds over time.
- **Participatory Decision Process** - Build stakeholder consensus and support for implementing change, and agree on expectations and performance targets.
- **Political Commitment** – Take action to integrate stormwater management with land use planning.

Land Use Change Drives Stormwater Management



Chapter One

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- Changes to the Natural Water Balance
- Property Impacts
- Ecological Impacts on Species at Risk
- Water Quality Impacts
- Financial Impacts
- Lessons Learned

1.2 Potential Stormwater Impacts will Accelerate Due to Population Growth Pressure and Climate Change

- Population Growth Pressure
- Climate Change

1.3 Integrating Stormwater Solutions with Land use Change

- Recent Approaches Have Only Provided Partial Solutions
- Preventing History from Repeating Itself

1.4 Local Government Responsibility for Drainage

- Liability for Downstream Impacts Due to Changes in the Water Balance
- Authority to Implement Integrated Solutions

1.5 History and Evolution of Stormwater Management

- North American Context
- British Columbia Context

1.1 Impacts Flow Down the Watershed

Figure 1-1 illustrates schematically how water is recycled in nature. Water evaporates from lakes, rivers and oceans. It then becomes water vapour and forms clouds. It falls to the earth as precipitation, then it evaporates again. This 'hydrological cycle' never stops. Water keeps moving and changing phases from solid to liquid to gas, over and over again. In this Guidebook, this process is described as the natural 'Water Balance'.

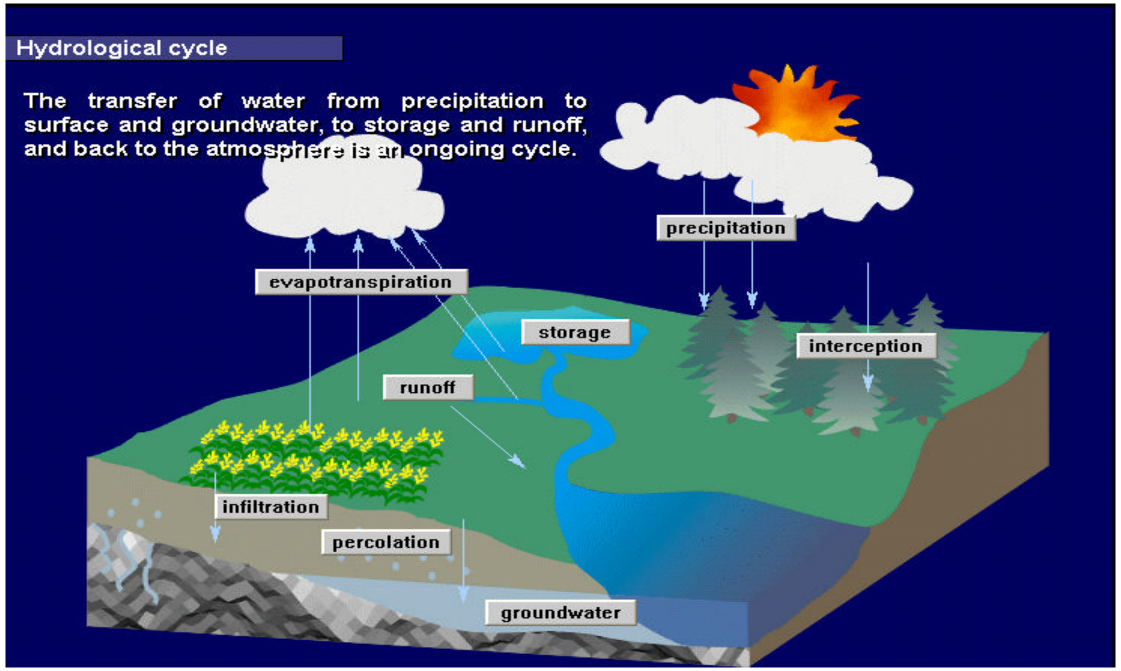


Figure 1-1 Components of the Natural Water Balance

Stormwater

Stormwater is the component of runoff that is generated by human activities. Stormwater is created when land development alters the natural Water Balance. When vegetation and soils are replaced with roads and buildings, less rainfall infiltrates into the ground, less gets taken up by vegetation and more becomes surface runoff.

The biggest increments of change - to the Water Balance in general, and to the surface runoff component in particular - occur when forested land is first cleared, then ditched, and finally paved or roofed over.

Until recently, the traditional approach to drainage has been to remove runoff as quickly as possible from developed areas. As a result, traditional urban design is very efficient in collecting, concentrating, conveying and discharging stormwater to receiving waters.

In British Columbia, stormwater management has traditionally been a function of local government or highway engineers, who have developed an expertise in conveying stormwater efficiently. Increasingly, stormwater management is becoming a shared responsibility with land use planners.

Guidebook Context

To mitigate the cumulative impacts of stormwater resulting from changes to the natural Water Balance, the British Columbia Ministry of Water, Land and Air Protection has developed this Guidebook to assist local governments, engineers and planners in clearly understanding the broader issues and the strategies currently available to correct stormwater-related problems.

A stormwater management component is a requirement for approved *Liquid Waste Management Plans* (LWMPs). The Ministry will encourage any progressive steps a local government may want to take to incorporate stormwater planning into their existing LWMP.

A core concept is that stormwater is a resource to be protected. Achieving this goal requires full integration of stormwater management with land use planning.

Changes to the Natural Water Balance

Runoff volume increases in proportion to impervious area (hard, non-absorbent surfaces). Land uses with extensive roof and paving areas create more runoff than land uses with extensive areas of absorbent soils and forest cover. Figure 1-2 illustrates the Water Balance for a natural forest. The examples on Figures 1-3 and 1-4 then illustrate what happens to the Water Balance when the forest is developed for residential and/or commercial uses, respectively.

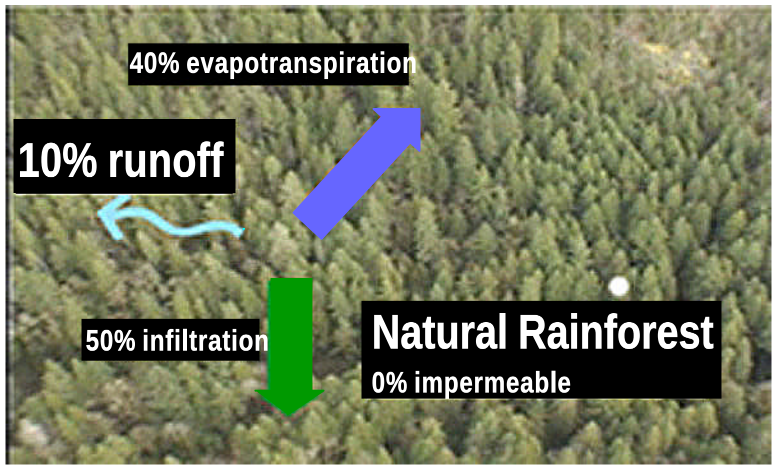


Figure 1-2 Natural Rainforest

Traditional ditch and pipe systems have been designed to remove runoff from impervious surfaces as quickly as possible and deliver it to receiving waters. The resulting stormwater arrives at the receiving waters much faster and in greater volume than under natural conditions. Changes in the natural Water Balance result in four categories of impacts: property, ecological, water quality and financial/political. An overview of each category is provided in the pages that follow.

Failure to manage stormwater resulting from land use change can cause flooding, loss of aquatic habitat and water pollution in downstream receiving waters.

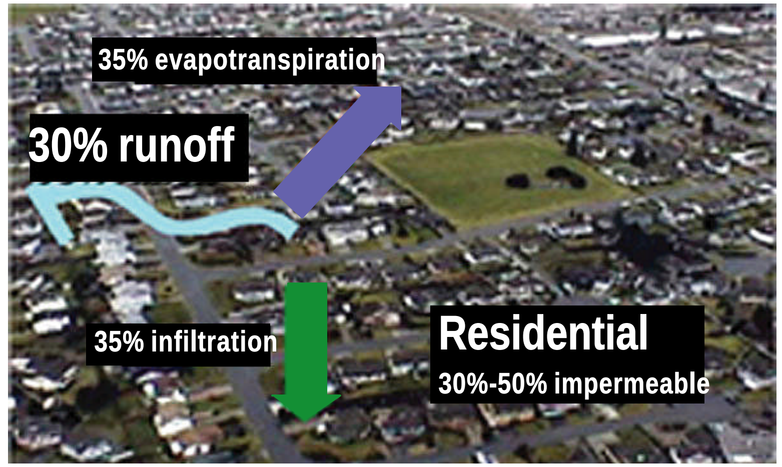


Figure 1-3 Single Family Development

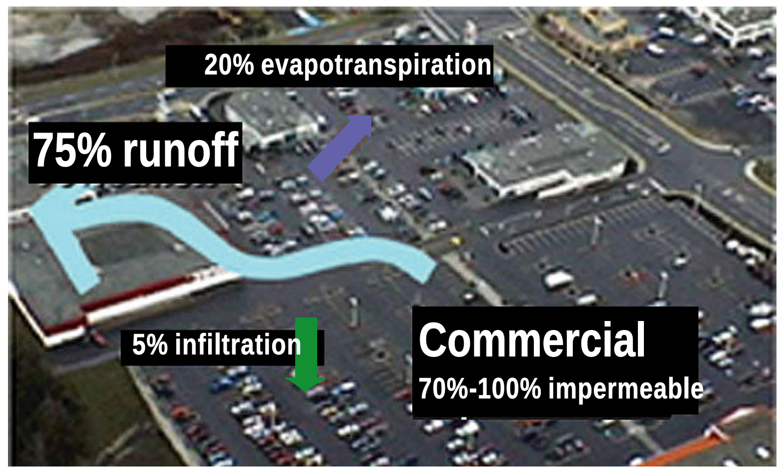


Figure 1-4 Commercial Development

Property Impacts

The width and depth of a stream are determined by the volume and rate of water that it conveys. Therefore, increases in flow volume and peak flow rates resulting from land development cause erosion on the sides and bottom of the channel. Figure 1-5 shows how additional culverts have been installed at a road crossing in order to handle the increased volume after upstream land clearing and ditching has occurred.

The material from these eroding banks (as shown on Figure 1-6) moves downstream as 'bedload', and settles out on the more gentle grades in the stream (Figure 1-7). These gentle grades are often located in the floodplain. These changes in stormwater flows and stream morphology often create both loss of property where erosion takes place, and increased flooding in the floodplain as it is filled in by sediments. This often results in damage to private property and agricultural land, and can pose a potential threat to public safety.

The most common property impact resulting from the increase in runoff is the accumulation of nuisance water on private property and public spaces downstream of development areas.

Figure 1-5 Multiple Drainage Culvert Installations

Figure 1-6 Channel Down-Cutting (due to increased volume)

Figure 1-7 Habitat Destruction (due to bedload deposition)

Ecological Impacts on Species at Risk

Figure 1-8 illustrates how:

- The cumulative effects of increasing impervious area in a watershed combined with loss of riparian corridor integrity (as shown in the first two rows), alter the natural Water Balance and impact stream corridor ecology (as shown in the last two rows).
- The resulting increase in runoff volume causes watercourse erosion and progressive degradation of the channel cross-section (refer to middle row).
- The consequence of these cumulative changes is a progressive decline in stream corridor biodiversity and abundance for cold-water fish and clear water indicators, and a progressive transition to warm-water species and pollutant indicators (as shown in the last two rows).

Eroded material (Figure 1-6) creates turbidity, or dirty water, that can irritate fish gills and make it difficult for fish to find their food. Eroded sediments can cover spawning beds, smothering fish eggs and young that reside in the gravel and possibly blocking access to spawning areas for the next generation (Figure 1-7).

The decrease in infiltration (due to replacement of soil and vegetation with hard surfaces) can also have impacts on fish because it reduces the slow, constant groundwater supply that keeps streams flowing in dry weather. This can lead to water levels that are inadequate to provide fish with access to their spawning areas, and can even cause streams to dry up in the summer.

Driving Force for New Approaches

Stemming and reversing the decline of wild salmon populations has led to questioning of the most basic assumptions that used to guide – and in many communities still guide – how we plan and manage development. This questioning has resulted in new approaches to land development and stormwater management. These new approaches are being advanced and implemented throughout the Pacific Northwest, and especially in the Georgia Basin.

The decline of wild fish populations is not limited to the Georgia Basin. In Okanagan Lake, for example, degradation of tributary streams and loss of aquatic habitat have similarly contributed to the decline of the kokanee fishery.

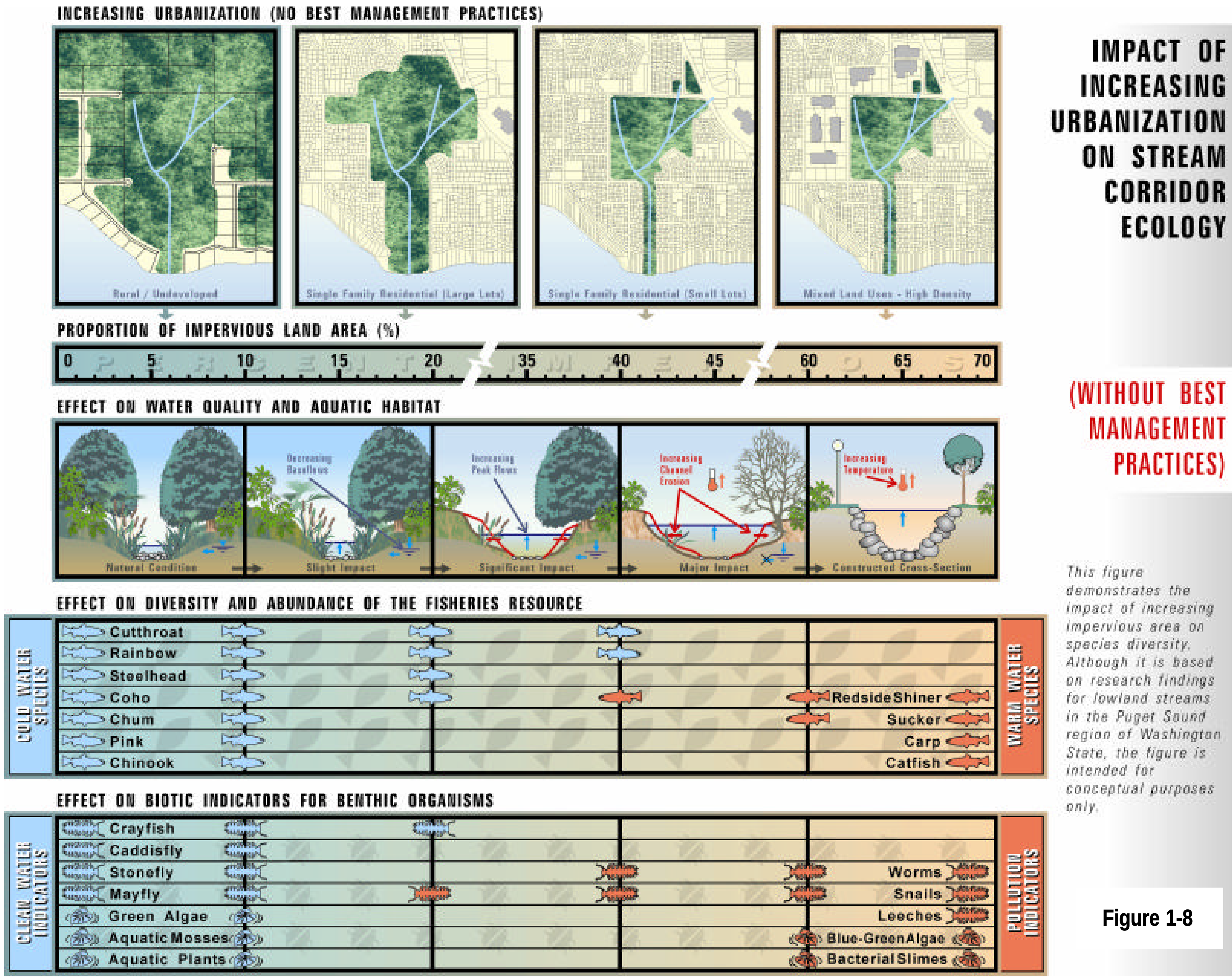

IMPACT OF INCREASING URBANIZATION ON STREAM CORRIDOR ECOLOGY
(WITHOUT BEST MANAGEMENT PRACTICES)
INCREASING URBANIZATION (NO BEST MANAGEMENT PRACTICES)
Rural / Undeveloped
Single Family Residential (Large Lots)
Single Family Residential (Small Lots)
Mixed Land Uses - High Density
PROPORTION OF IMPERVIOUS LAND AREA (%)
0
5
10
15
20
35
40
45
60
65
70
EFFECT ON WATER QUALITY AND AQUATIC HABITAT
Decreasing Baseflows
Increasing Peak Flows
Increasing Channel Erosion
Increasing Temperature
Natural Condition
Slight Impact
Significant Impact
Major Impact
Constructed Cross-Section
EFFECT ON DIVERSITY AND ABUNDANCE OF THE FISHERIES RESOURCE
COLD WATER SPECIES
Cutthroat
Rainbow
Steelhead
Coho
Chum
Pink
Chinook
WARM WATER SPECIES
Redside Shiner
Sucker
Carp
Catfish
EFFECT ON BIOTIC INDICATORS FOR BENTHIC ORGANISMS
CLEAR WATER INDICATORS
Crayfish
Caddisfly
Stonefly
Mayfly
Green Algae
Aquatic Mosses
Aquatic Plants
POLLUTION INDICATORS
Worms
Snails
Leeches
Blue-Green Algae
Bacterial Slimes
This figure demonstrates the impact of increasing impervious area on species diversity. Although it is based on research findings for lowland streams in the Puget Sound region of Washington State, the figure is intended for conceptual purposes only.

Figure 1-8

Water Quality Impacts

Although of BC's water quality is generally good, people are increasingly aware that the province is experiencing localized water pollution problems. Every year there are reports of public beach closures, contaminated sediments, algal blooms, aquatic weed infestations, fish kills, shellfish harvesting closures, boil-water advisories, outbreaks of waterborne diseases, and contaminated groundwater. BC's efforts to protect water quality by regulating 'end-of-pipe' point discharges from municipal and industrial outfalls have generally been successful.

It is now recognized that the major remaining cause of water pollution is from non-point sources (NPS), including stormwater runoff. Stormwater contains contaminants such as hydrocarbons and heavy metals derived from vehicle exhaust, brakes and leaked fluids, as well as nutrients, pesticides and bacteria from urban and agricultural land uses. When stormwater flows over large paved surfaces on warm days, it can increase to temperatures that are unsuitable for cold-water fish like salmon and trout. The result can be immediate fish kills in receiving streams, or chronic, long-term impairment of fish and other aquatic species.

Financial Impacts

Local governments and developers are finding that drainage costs are becoming a major portion of their capital outlay. The capital cost of land development with traditional piped solutions can be a significant detriment to affordable housing. In recent years, this has been one of the drivers for change. Reducing costs is providing an incentive for innovation. An example of this change in thinking is presented below:

> Although the Greater Vancouver region is spending about $33 million annually on stormwater management, "….in many areas of the region, current approaches to stormwater management and land development do not adequately protect the environment of small streams in watersheds experiencing significant population growth."
>
> *Source: page 1 of Executive Summary*
> *Stage 2 Liquid Waste Management Plan, 1999*
> *Greater Vancouver Regional District*

Finding a Better Way

Installation of drainage pipes without mitigating measures often creates erosion problems and/or flooding downstream in receiving watercourses. These risks can create threats to property and public safety, resulting in exposure to litigation.

To avoid further impacts and litigation, local governments are now beginning to address the cumulative erosion and flooding impacts resulting from development. This creates a further cost burden for additional drainage infrastructure, and for increased staff time devoted to maintenance of at-risk culverts and degraded floodplains.

In many cases, solving downstream problems by piping or armouring creeks is no longer environmentally acceptable, either to senior agencies or to the public.

This set of problems creates both financial and political imperatives to find a better way to develop land.

Lessons Learned

The essence of the foregoing discussion is captured below. These two 'lessons learned' provide a framework for developing land differently:

- **Universal Drivers for Change -** The risks and the impacts associated with stormwater have become drivers for change in the way stormwater is managed in British Columbia and in other jurisdictions around the world (e.g. the United States, Australia and New Zealand). It has been recognised that dealing with flooding and aquatic habitat issues must be integrated with decisions on land use change.
- **Complementary Objectives –** Integrated approaches to stormwater management acknowledge that protection of property, protection of aquatic resources, and protection of water quality are complementary objectives. Integrated approaches address each of these objectives.

1.2 Potential Stormwater Impacts will Accelerate Due to Population Growth Pressure and Climate Change

In the future, there will be more runoff volume to manage due to the combination of:

- **Population Growth** – resulting in more land development plus re-development / densification of existing urbanized areas
- **Climate / Weather Change** – resulting in both increased seasonal rainfall and more frequent 'cloudbursts'

Population Growth Pressure

Only about 5% of BC is suitable and/or available for human development. The majority of the land area – about 90% - is owned by the Crown and is mostly mountainous terrain. The balance (5%) is protected within the Agricultural Land Reserve. The limited supply of developable (and available) land is a driving force for change. The majority of the developable land in BC is located in the southwestern portion of the province.

As regional populations grow, more and more people will need to be accommodated in existing development areas. This will result in some rural areas becoming increasingly suburban. Similarly, suburban municipalities that are close to the major population centres will become more urban as they densify. The rate and scale of development in the 1990s has already transformed most suburban development areas, especially in southern BC.

Population-driven changes are most noticeable in the Georgia Basin, throughout the Okanagan, and in many parts of the Kootenays. The Georgia Basin is a bio-region that includes Greater Vancouver, the lower Fraser Valley east to Hope, and the East Coast of Vancouver Island. The total population has reached 3 million, or about 75% of the provincial total of 4 million, and is projected to double within the next 50 years.

If there were no change in the way that land development addressed stormwater, this increase in population would lead to an increase in impervious area, with resulting stormwater impacts.

The pending land use change brings into focus the need for more effective strategies to reduce stormwater-related impacts on property and aquatic ecosystems.

Need for Early Action

BC is 'land short'. Population growth pressure will lead to increased impervious area and will place pressure on species at risk. For these reasons, there is a need to accelerate the rate of change so that stormwater management is integrated with land use planning sooner rather than later. Figure 1-9 illustrates the potential for flooding in the urban environment.

Figure 1-9 Flooding in the Urban Environment

Climate Change

Rain gauge data for southwestern British Columbia suggest that precipitation frequency, intensity and duration are changing compared to the mid-20th century. Research by the University of British Columbia and Environment Canada implicate global climate change as the primary contributor to these observed trends.

Environment Canada models project increasing fall and winter precipitation, decreasing late spring-early summer precipitation, and more intense rainstorms (i.e. 'cloudbursts').

1.3 Integrating Stormwater Solutions with Land use Change

Many existing older urban areas in BC have been developed without stormwater management, and have suffered the related property and ecological impacts. Local governments in these areas are facing extraordinary costs and difficulties to reduce the impacts.

Recent Approaches Have Only Provided Partial Solutions

Emphasis in recent years has been on provision of community detention storage ponds in new developments. Although these ponds provide a partial solution, they only treat the consequences of increased impervious area, not the source.

Recent research by the University of Washington has shown that, in most cases, detention ponds mitigate flooding but do not prevent the ongoing channel erosion that creates property and fisheries impacts. Detention solutions also often do not support the sustained stream base flow that is critical to many fish populations in dry months.

In some areas of BC, especially in regional districts outside of the Greater Vancouver Regional District and the Capital Regional District, there is as yet little coordinated stormwater planning, even though urbanization and related impacts are accelerating.

Preventing Stormwater History from Repeating Itself

By examining past experience, it is evident that the contemporary approach to drainage is changing, from being reactive to being proactive. Now, the focus is on preventing problems at the source, by integrating stormwater management with land use planning so that:

- Decisions about land use change are made with a full awareness of the potential consequences for stormwater management
- Conversely, stormwater management principles influence the details of land use and site planning

The Stormwater Management Dilemma

Figure 1-10 illustrates the stormwater management dilemma – how can stormwater managers facilitate population growth and land development, while preserving the natural environment and preventing flooding in urban areas at the same time?

Figure 1-10 The Stormwater Dilemma

1.4 Local Government Responsibility for Drainage

The courts see the impact of drainage on property as a 'nuisance', where a landowner's use and enjoyment of his or her lands are interfered with as a result of actions or conduct on neighbouring lands. The courts have established precedents concerning the following:

- Right to drain land (allowing surface water to escape in a way provided by nature)
- Right to block drainage (surface water draining from higher land, as opposed to water in a natural stream)
- Measures of damages (damages will be awarded where liability is established)

In British Columbia, the *Local Government Act* has vested the responsibility for drainage with municipalities. This *Act* also enables local governments to address stormwater management much more comprehensively than in the past. The challenge is to use this legislation to achieve comprehensive goals and objectives in appropriate and effective ways. Division 6 of the Act (Sections 540 – 549) gives local government the direct power to manage stormwater: http://www.qp.gov.bc.ca/statreg/stat/L/96323_15.htm#part15_division6

Liability for Downstream Impacts Due to Changes in the Water Balance

With the statutory authority for drainage, local governments can be held liable for the nuisance caused by drainage to downstream property owners. To assist in understanding the scope of local government liability, three relatively recent cases are presented here. In all three cases, the Court of Appeal in the Province of BC has upheld the decisions. These cases underscore the responsibility of local government for stormwater volume management.

Case 1 - Indexed as: Kerlenmar Holdings v. Matsqui (District) and District of Abbotsford

Judgement - June 1991 (From British Columbia Law Reports 56 B.C.L. R. (2d) p. 377 – 387.)

A creek running through the plaintiff's farmland flooded regularly, and after 1971 the agricultural capacity of the land deteriorated as a result. The plaintiff brought an action in nuisance, attributing the flooding to increased urbanization in the two defendant municipalities, whose storm drains were releasing more and more water into the creek.

The trial judge awarded damages for loss of income and the municipality was required to purchase the plaintiff's lands.

Case 2 - Indexed as: Medomist Farms Ltd. v. Surrey (District)

Judgement – December 1991 (From British Columbia Law Reports 62 B.C.L. R. (2d) p. 168-177.)

The defendant municipality held a road allowance across the plaintiff's land, along which ran a drainage ditch. In 1979, the municipality permitted residential development on lands to the west of and above the plaintiff's land. The development reduced the surface area available to absorb water, causing more runoff into the drainage ditch.

Although the ditch previously overflowed during winter wet weather periods, it now occasionally overflowed during the growing season as well as a result of the upstream residential development. The trial judge awarded damages for crop losses and ordered construction of a permanent pumping station.

Case 3 - Indexed as: Peace Portal Properties Ltd. v. Corporation of the District of Surrey

Judgement - May 1990 (From Dominion Law Reports 70 D.L. R. (4th) p. 525-535.)

The plaintiff operated a golf course in the defendant municipality. A creek bisected the course. The municipality had incorporated the creek into its' drainage system. Because of increased urbanization there was a substantial increase in the flow in the creek, which caused erosion.

The plaintiff attempted to resolve the problem by replacing the natural channel of the creek with a concrete flume in the 1960s. This worked for a time, but with further urbanization and increased flow, new erosion occurred which also damaged the flume. The plaintiff proposed certain remedial work and sought contribution from the defendant. The defendant rejected the request.

The plaintiff completed the remedial work, in the process raising some of the greens and fairways. He then brought action against the municipality to recover the cost. The trial judge concluded that the evidence amply supported that nuisance of the increased flow caused the erosion and the municipality was held responsible.

Authority to Implement Integrated Stormwater Solutions

Local governments have extensive and very specific tools available to them. They also have the discretion to use them or not. Decisions about a local government's appropriate level of involvement in stormwater and stream corridor management must therefore be guided by a set of clear, broadly agreed-upon objectives, as well as an understanding of the need for balance with other competing objectives and interests.

Some key *Local Government Act* planning, regulation, development approval and servicing provisions applicable to stormwater management are summarized below:

Regional Growth Strategy and Official Community Plan Goals

Section 849 (2) provides goal statements for:

- Protecting environmentally sensitive areas
- Reducing and preventing air, land and water pollution
- Protecting the quality and quantity of groundwater and surface water

Prohibition of Pollution

Section 725.1 enables local governments to enact bylaws prohibiting water pollution and to impose penalties for contravening these.

Soil Deposit and Removal (Erosion Control)

Section 723 enables local governments to include erosion control and sediment retention requirements associated with soil deposition and removal.

Zoning

Section 903 enables the prohibition or siting of regulated land uses that, for instance, generate non-point source pollution.

Environmental Policies

Section 879 enables *Official Community Plans* (OCPs) to include "policies of the local government relating to the preservation, protection and enhancement of the natural environment, its ecosystems and biological diversity".

Development approval information areas or circumstances (Section 879.1) enable the designation of areas or circumstances, or areas for which in specified circumstances, development approval information may be required.

Runoff Control

Section 907 enables local governments to set maximum percentages of areas that can be covered by impermeable material and to set requirements for ongoing drainage management.

Landscaping

Section 909 enables local governments to set standards for and regulate the provision of landscaping for the purposes of preserving, protecting, or restoring and enhancing the natural environment (e.g. requiring streamside vegetation).

Development Permit Areas

Development permit areas designated in an Official Community Plan (see Section 919.1) cannot be altered, subdivided, or built on without a development permit. The permit can contain conditions for the protection of the environment.

Subdivision Servicing Requirements

Section 938 enables a local government to "require that, within a subdivision"… "a drainage collection or a drainage management system be provided, located and constructed in accordance with the standards established in the bylaw".

In addition to the above, other stormwater management powers can be found in provisions dealing with building regulations, contaminated sites, development cost charges, ditches and drainage, dikes, development works agreements, flood protection, farming, highways, improvement districts and specified areas, park land, regional district services, sewage systems, subdivision, temporary commercial and industrial use, tree cutting, utilities, water and waste management.

(Note: The section references quoted above are expected to change over time. Some of these changes will result from implementation of the Community Charter process in the near future.)

1.5 History and Evolution of Stormwater Management

The evolution of stormwater practice in North America is set against the backdrop of social change, and changes in stormwater management philosophy.

North American Context

Modern urban stormwater infrastructure was born in the post-World War I era, consisting of efficient drainage systems with catch basins and pipes leading to the nearest stream.

Some time after World War II it became apparent to engineers throughout North America that the fruit of an efficient stormwater system was downstream flooding and channel erosion. By the early 1970s, this resulted in a new idea to solve flooding forever: on-site detention.

In the 1970s, the literature began to reflect a new concept: stormwater master planning. The idea was that engineers could construct a hydrology model (how much water, how often?) and a hydraulic model (how fast and high does the water from the hydrology model go?) of a watershed and then analyze scenarios until they found the perfect solution to flooding problems – whether current problems or those only imagined.

By the mid-1980s, literally hundreds of master plans had been developed. But few were being implemented the way they were planned. The cycle was one where local governments typically proceeded from flooding to panic to planning, and then to procrastination and the next flood.

In the late 1980s, a new breed of approaches emerged as water quality and bio-assessment were added to the mix. Each solved the immediate problem of the past paradigm and created a more insidious problem of its own. Knowledge and technology created a real or perceived need for higher, more demanding levels of stormwater management – and regulation.

The 1990s saw the introduction of 'watershed-based' approaches and 'low impact development'.

Being aware of the changes in approach makes it increasingly less acceptable to do business as usual. The challenge ahead is to define and then actually demonstrate that a healthy watershed approach produces the full range of effective results in an efficient manner.

British Columbia Context

Before the 1970s, comprehensive urban drainage planning was a rarity in British Columbia, in part because there was no senior government funding for drainage projects. By the 1970s, however, drainage had emerged as an issue in the suburban areas because of flooding problems and resulting litigation. In the mid-1970s, the cities of Surrey, Nanaimo, West Vancouver (because of the July 1972 flooding that resulted in a catastrophic washout of the Upper Levels Highway during construction), and Kelowna were among the first municipalities to undertake major municipality-wide drainage studies. The history of modern stormwater management in British Columbia is summarized as follows:

- **A Flows-and-Pipes Approach**
  Master Drainage Plan (MDP) and Stormwater Management Plan (SMP) have tended to be used interchangeably in British Columbia over the past 25-plus years. A number of suburban municipalities (e.g. City of Surrey) continue to use the term MDP. The term SMP became popular in the late 1970s as 'management' became a catch-phrase for all infrastructure planning activities. The basic engineering approach did not materially change. Typically, an MDP was the 'flows-and-pipes' product resulting from a stormwater management strategy.
- **An Environmental Approach**
  In the 1989 through 1990 period, the City of Burnaby was the first municipality to apply what was initially called an 'environmental approach' to master drainage planning. This characterization reflected the evolution from a strictly engineering to an interdisciplinary team approach over a 6-year period for the Western versus Eastern Sectors, respectively, of the Big Bend Area in the Fraser River floodplain. The drivers for change were the impact of construction of the Marine Way arterial highway on existing market gardens, and the landfilling and conversion of undeveloped wetlands to industrial park uses.
- **A Stream Stewardship Approach**
  In 1992, the District of Maple Ridge adapted the Burnaby model in developing both a Stormwater Management Strategy and a Master Drainage Plan for the Cottonwood Area. At about the same time, the federal/provincial *Land Development Guidelines* and the provincial *Urban Runoff Quality Control Guidelines* were both published. Completed in 1994, the Cottonwood process showed how to make both sets of guidelines workable. The environmental agencies described it as a 'stewardship template' because it applied the concepts in the federal/provincial document titled *Stream Stewardship: A Guide for Planners and Developers*, also published in 1994.
- **Higher Levels of Interdisciplinary Integration**
  Integrated, ecosystem-based and watershed-based are terms that came into vogue at the end of the 1990s, and are interchangeable. Table 1-1 describes four case studies that took the Cottonwood template to successively higher levels of integration in terms of an interdisciplinary team approach.

  These case studies illustrate the transition from early environmental drainage to fully integrated stormwater management. They have given meaning to a comprehensive process for addressing hydrotechnical and environmental concerns in order to develop integrated solutions for the protection of property and habitat.

Integrated Stormwater Management Planning

In British Columbia, the term *Integrated Stormwater Management Plan* (ISMP) has gained widespread acceptance by local governments and the environmental agencies to describe a comprehensive, ecosystem-based approach to stormwater planning.

The purpose of an ISMP is to provide a clear picture of how to be proactive in applying land use planning tools to:

- protect property from flooding, and
- protect aquatic habitat from erosion and sedimentation

Use of the ISMP term is unique to British Columbia. The City of Kelowna first used the term in 1998 to make a clear distinction between 'suburban watershed management' and the Province's existing 'integrated watershed management' process for natural resource management in wilderness watersheds. This is an important distinction. Local government typically has control over stormwater in residential, commercial and industrial land uses. It does not necessarily have control over watersheds.

Local governments in British Columbia are changing. Those that are changing are providing models for others to adapt and further evolve.

Table 1-1 Origin and Evolution of Integrated Stormwater Management in British Columbia

Year	Municipality	Project Name and Relevance
1996	City of Kelowna	***Environmental Component of an Integrated Strategy for Stormwater and Stream Corridor Management:*** The term 'integrated stormwater management' originated with the Kelowna study. This distinction was important to the City. It captured the essence of what the City was trying to accomplish through its 'environmental approach' to watershed protection. In the Kelowna context, 'integrated' referred to the linkages between watershed actions and stream corridor consequences. The study was comprehensive in developing a science-based framework for broadly defining watershed management objectives for the City's nine drainage basins.
1997	City of Surrey	***Integrated Stormwater Management Strategy & Master Drainage Plan for the Bear Creek Watershed*** The Bear Creek study was undertaken in parallel with Kelowna. It considered all the runoff events comprising the annual hydrograph. The emphasis was on how to integrate the range of hydrologic criteria for sizing of stormwater control facilities that have different functional objectives. Two components were defined: 'hydro-technical' described the conventional engineering approach to conveyance of large runoff events; while 'enhanced hydro-technical' captured the environmental objectives in restoring the natural hydrology characteristic of the small runoff events.
1998	G.V.R.D City of Burnaby City of Coquitlam City of Port Moody	***Integrated Stormwater Management Strategy for Stoney Creek Watershed*** The Stoney Creek study was an inter-municipal pilot project, and built on the base provided by the Kelowna and Bear Creek experiences. The emphasis was on consensus-building (through a workshop process) to develop a shared vision that integrated a range of diverse viewpoints on the 10-person Steering Committee that also included a community representative. The foundation for strategy development was an assessment of the natural resources to be protected. The deliverables included a 20-Year Vision Plan and a 50-Year Vision Plan for stream preservation and watershed enhancement, respectively. These plans established targets for impervious area reduction.
2000	City of Coquitlam	***Como Creek Integrated Stormwater Management Plan – Flood Risk Management and Watershed Restoration*** Como Creek took the Stoney process to the next level of detail. Como is the first urban drainage study in the Greater Vancouver region to truly integrate the engineering, planning and ecological perspectives through an inter-departmental, interdisciplinary and inter-agency process that was guided by a Steering Committee of senior managers, and that included community involvement in development of the resulting plan. The goal was to develop an integrated plan that resolved a chronic flooding problem while over time restoring aquatic habitat. The focus was on how to implement changes in land use regulation that achieve the 50-year vision for impervious area reduction as the existing housing stock is replaced.

Provincial Enabling Initiatives

In 1992, the (then) Ministry of Environment, Lands and Parks published the *Urban Runoff Quality Guidelines* and the *Guidelines for Developing a Liquid Waste Management Plan* (LWMP).

In February 1994, the Ministry issued a policy statement to local government regarding the need to incorporate a stormwater component in LWMPs.

In July 1997, the Provincial Government enacted both the *Local Government Amendments Act* and the *Fish Protection Act* to give local governments new and improved tools to restore and enhance, as well as to protect, the natural environment.

In 1998, the Ministry published a document titled *Tackling Non-Point Source Water Pollution in British Columbia - An Action Plan*, which identified a series of tools and strategies available to reduce and prevent non-point source pollution in rural and urban areas.

The 1998 Non-Point Source Pollution (NPS) Action Plan

The 1998 Action Plan comprises six initiatives. The one that is particularly relevant to this Guidebook is *Land Use Planning, Coordination, and Local Action.* This initiative addresses both stormwater management and streamside protection. Local governments that have LWMPs are required to incorporate a stormwater management component. LWMPs may themselves be required in critical areas where, for example, NPS pollution affects aquatic resources.

Initiatives at the Regional Level

The Capital Regional District was the first jurisdiction to address stormwater quality in an LWMP for the Saanich Peninsula in 1996.

The Greater Vancouver Regional District formally embraced stormwater management in November 1994. This eventually led to formation of the inter-municipal and inter-agency Stormwater Task Group in 1997 to tackle stormwater quantity and quality issues. The ongoing role of this group is to formulate and guide implementation of a consistent regional approach to stormwater management planning as part of its LWMP.

The Science Behind Integrated Stormwater Management

Chapter Two

2.1 Developing a Common Understanding

- Research on the Effects of Urbanization on Fish
- A Science-Based Understanding

2.2 The Natural versus Urban Water Balance

- Where Rainfall Goes Before and After Development
- Distribution of Rainfall Over a Year
- Role of Soil, Vegetation and Trees in Capturing Rainfall

2.3 Understanding Changes in Hydrology

- Relationship Between Impervious Area and Runoff Volume
- Other Hydrology-Based Relationships
- Hydrology and Water Quality Objectives for Protection of Watershed Health

2.4 Factors that Limit the Health of Aquatic Resources

- Ranking of Limiting Factors
- Reference Impervious Area Levels for Land use Planning
- Measuring the Environmental Health of Creek Systems
- Other Washington State Research Findings

2.5 Managing Complexity

- Eliminate the Source of Problems
- What the Science is Telling Us
- What Can be Done at the Site Level to Protect Watershed Health
- Objectives for Protecting Watershed Health in an Urban Environment

2.1 Developing a Common Understanding

A science-based understanding of how land development impacts watershed hydrology and the functions of aquatic ecosystems provides a solid basis for making decisions to guide early action where it is most needed.

This chapter provides an overview of the science. It presents graphics that have helped diverse audiences reach a common understanding about hydrology and the factors limiting the ecological values of streams.

An understanding of the science is a critical underpinning of strategies to predict and manage the potential impacts of stormwater related to land use change.

Research on the Effects of Urbanization on Fish

Aquatic habitats that influence the abundance of salmon and trout are the outcome of physical, chemical and biological processes acting across various scales of time and space. The environmental conditions that result from these processes provide the habitat requirements for a variety of species and life history stages of fish and other stream organisms.

Decline of Wild Salmon

Whether in pristine or heavily urbanized watersheds, the basic requirements for survival of salmon and trout are the same. These basic requirements include: cool, flowing water free of pollutants and high in dissolved oxygen; gravel substrates low in fine sediment for reproduction; unimpeded access to and from spawning and rearing areas; adequate refuge and cover; and sufficient invertebrate organisms (insects) for food.

Over the past century, salmon have disappeared from over 40% of their historical range, and many of the remaining populations are severely depressed (Nehlsen *et al*. 1991). There is no one reason for this decline. The cumulative effects of land use practices, including timber harvesting, agriculture and urbanization have all contributed to significant declines in salmon abundance in British Columbia (Hartman *et al*. 2000)

Puget Sound Findings

In Puget Sound, a series of research projects have been underway for over 10 years to identify the factors that degrade urban streams and negatively influence aquatic productivity and fish survival. The streams and sites under examination represent a range of development intensities from nearly undisturbed watershed conditions to watersheds that are almost completely developed in residential and commercial land uses (Horner 1998).

For each watershed, detailed continuous simulation hydrologic models were prepared and calibrated to rainfall and runoff data. Physical stream habitat conditions, water quality, sediment composition, sediment contamination, and fish and benthic organism abundance and diversity were measured and documented for each site.

The studies found that stream channel instability is a result of the urbanization of watershed hydrology. The alteration of a natural stream's hydrograph is a leading cause of change in instream habitat conditions. The physical and biological measures generally changed most rapidly during the initial phase of watershed development, as total impervious area changed from 5% to 10%. With more intensive urban development in the watershed, habitat degradation and loss of biological productivity continues, but at a slower rate (Horner 1998).

The role of large woody debris in streams was recognized as a key factor in creating complex channel conditions and habitat diversity for fish. Both the prevalence and quality of large woody debris declined with increasing urbanization. In addition, development pressure has had a negative impact on streamside (riparian) forests and wetlands, which are critical to natural stream functioning.

The impacts of poor water quality and concentrations of metals in sediments did not show significant impact to aquatic biological communities until urbanization increased above approximately 50% total impervious area.

Instream habitat conditions had a significant influence on aquatic biota. Streambed quality, including fine sediment content and channel stability, affected the benthic macro invertebrate community (as measured by the multi-metric Benthic Index of Biological Integrity (B-IBI) developed by Karr (1991)). Negative impacts to fish and fish habitat from sedimentation related to urban development have been documented (Reid *et al*. 1999). The composition of the salmonid community was also influenced by a variety of instream physical and chemical attributes.

Summary of Puget Sound Findings

Alterations in the biological community of urban streams are a function of many variables representing conditions that are a result of both immediate and remote environmental conditions in a watershed. The research findings clearly demonstrate that the most important impacts of urbanization that degrade the health of streams, in order of importance, are:

- Changes in hydrology
- Changes in riparian corridor
- Changes in physical habitat within the stream, and
- Water quality

Further discussion of these impacts is contained in Section 2.4.

Georgia Basin Findings

Within the Georgia Basin, population pressures have caused urban sprawl, resulting in habitat loss (B.C. MELP 2000). Freshwater fish population declines in this region are a partial result of rapidly expanding urban development (Slaney 1996).

The aquatic ecosystems most directly affected by urbanization are the small streams and wetlands in the lowlands of the Georgia Basin and lower Fraser River Valley. These ecosystems are critical spawning and rearing habitat for several species of native salmonids (both resident and anadromous). In the Lower Fraser Valley, 71% of streams are considered threatened or endangered, and a further 15% have been lost altogether as a result of urban growth (B.C. MELP 2000).

A Science-Based Understanding

The widespread changes in thinking about stormwater impacts that began in the mid to late 1990s reflect new insights in two areas:

- Hydrology, and
- Aquatic ecology

These new insights are the result of improved understanding of the causes-and-effects of changes in hydrology brought about by urban development, and the consequences for aquatic ecology. As we gain new knowledge and understanding of what to do differently, a central issue for watershed protection becomes:

- What is the proper balance of science and policy that will ensure effective implementation and results?

King County in Washington State addressed this question in 1999 as part of the Tri-County response to the listing of chinook salmon as an endangered species in Puget Sound. A significant finding was that scientists and managers think and operate differently. This led to the following recommendations:

- An interface is needed to translate the complex products of science into achievable goals and implementable solutions for practical resource management. This interface is what we now call a science-based understanding.
- A reality for local government is that management decisions need to be made in the face of significant scientific uncertainties about how exactly ecosystems function, and the likely effectiveness of different recovery approaches.
- The best path forward is a dynamic, adaptive management approach that will allow local governments to monitor the effectiveness of their regulatory and management strategies and make adjustments as their understanding grows.
- In a co-evolving system of humans and nature, surprises are the rule, not the exception; hence, resilience and flexibility will need to be built into the management system.

Through a science-based understanding of the relationship between hydrology and aquatic ecology, this chapter derives a comprehensive set of watershed protection objectives that provide an over-arching framework for Parts B and C of this Guidebook.

2.2 The Natural versus Urban Water Balance

Rainfall landing on a site travels in four directions:

- Soaking into shallow ground and moving slowly through soils to streams - *interflow*
- Percolating vertically into *deep groundwater*
- Back up into the air – evaporation from surfaces and transpiration from leaves - *evapotranspiration*
- Flowing over the ground – *surface runoff*

Because the total volume of rainfall equals the sum of the four components, this relationship is known as the 'Water Balance'. It is a core hydrologic concept.

Urban drainage has traditionally focused on managing surface runoff**.** It is only recently that the other three components have begun to receive serious attention, with the emphasis on interflow. Although interflow was first defined in the 16th century, its significance has been largely ignored for over 400 years. It is now recognized that all four components need to be considered as part of a comprehensive and integrated approach to stormwater volume management.

Where Rainfall Goes Before and After Development

Figure 2-1 illustrates how the Water Balance changes when natural vegetated cover is replaced by suburban development. By providing example percentages, this drawing highlights the magnitude of the additional volume of water that must be handled by a drainage system after land is cleared. The actual percentages will vary from region to region, but the relationships are universal.

On an annual basis, surface runoff from a forested or naturally vegetated watershed in the Pacific Northwest is minimal as a proportion of total water volume. Before development, the flow that we observe in streams is actually interflow. After development, flow in streams typically originates as surface runoff.

As a watershed is cleared, surface runoff volume increases in proportion to the percentage of impervious surface area, defined as non-infiltrating surfaces (e.g. concrete, asphalt, rooftops, hard landscaping and exposed rock). Once a pipe system is installed to drain these impervious areas, almost every rainfall results in runoff.

Example Annual Water Balance

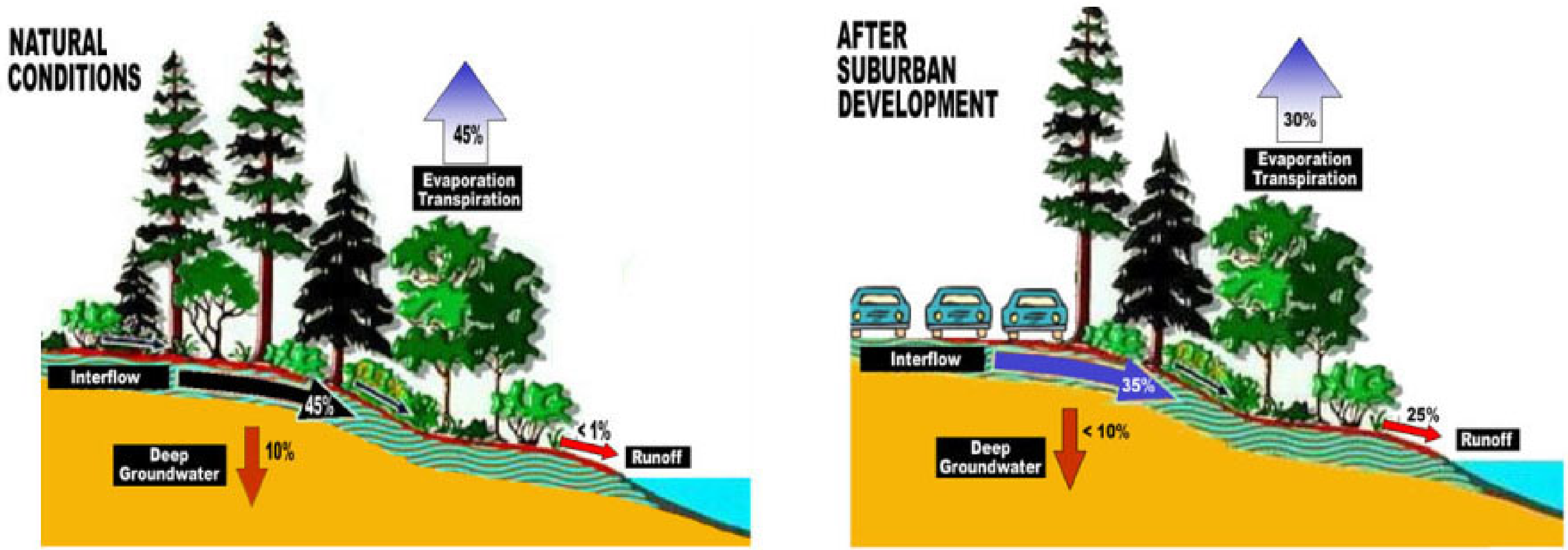


Figure 2-1

Distribution of Rainfall Over a Year

Understanding how rain falls over the course of a year is fundamental to understanding the Water Balance and how to manage its components. Figure 2-2 is an example of a typical distribution of annual rainfall volume. While total rainfall can vary significantly between regions, the distribution pattern is universal for British Columbia.

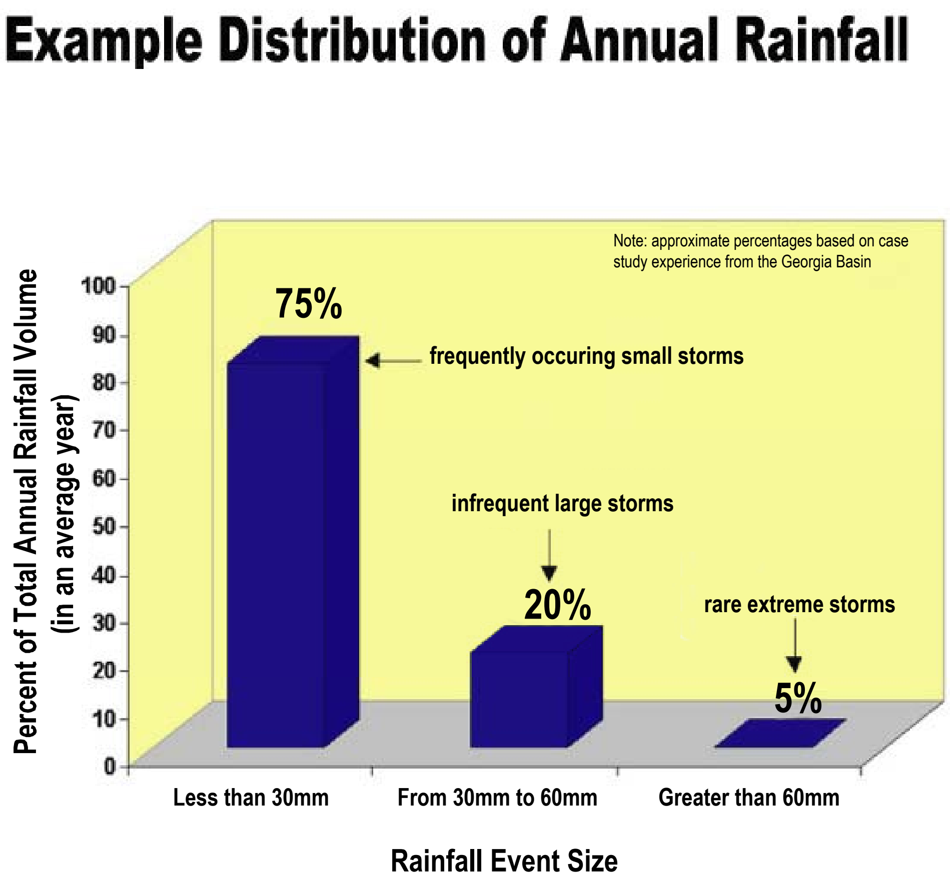


Figure 2-2

Role of Soil, Vegetation and Trees in Capturing Rainfall

The relevance of Figure 2-2 is in making the case that the frequently occurring small rainfall events hold the key to protecting the Water Balance in the urban environment. Small rainfall events typically account for 75% of the annual rainfall volume.

Because the majority of rain falls in small amounts, soil and vegetation are generally able to absorb and infiltrate it as it falls – this is why interflow and evapotranspiration are maximized and surface runoff is minimized in a forested environment.

In a natural condition, vegetated surface soil layers are highly permeable. As surface plants die and decompose, they provide a layer of organic matter which is stirred and mixed into the soil by earthworms and microbes. This soil ecosystem provides high infiltration rates and a basis for interflow.

Trees contribute to the soil ecosystem in two ways: the root zone creates a permeable environment; and the buildup of forest litter creates an absorbent layer.

In an urban situation, preservation and/or restoration of soil, vegetation and trees can help to:

- Recharge interflow
- Protect baseflow
- Minimize runoff

Water Balance Objectives for Protecting Watershed Health

In terms of preventing land development and related human settlement activities in the urban environment from impacting the Water Balance, British Columbia case study experience has resulted in identification of the following objectives for a truly healthy watershed:

- **Objective 1 -** Preserve and protect the water absorbing capabilities of soil, vegetation and trees.
- **Objective 2 -** Prevent the frequently occurring small rainfall events from becoming surface runoff.

2.3 Understanding Changes in Hydrology

Stormwater management practitioners now commonly use the phrase 'changes in hydrology'. Figure 2-3 presents a basic definition of this phrase:

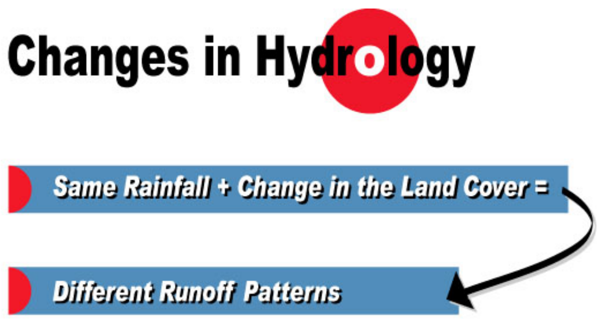


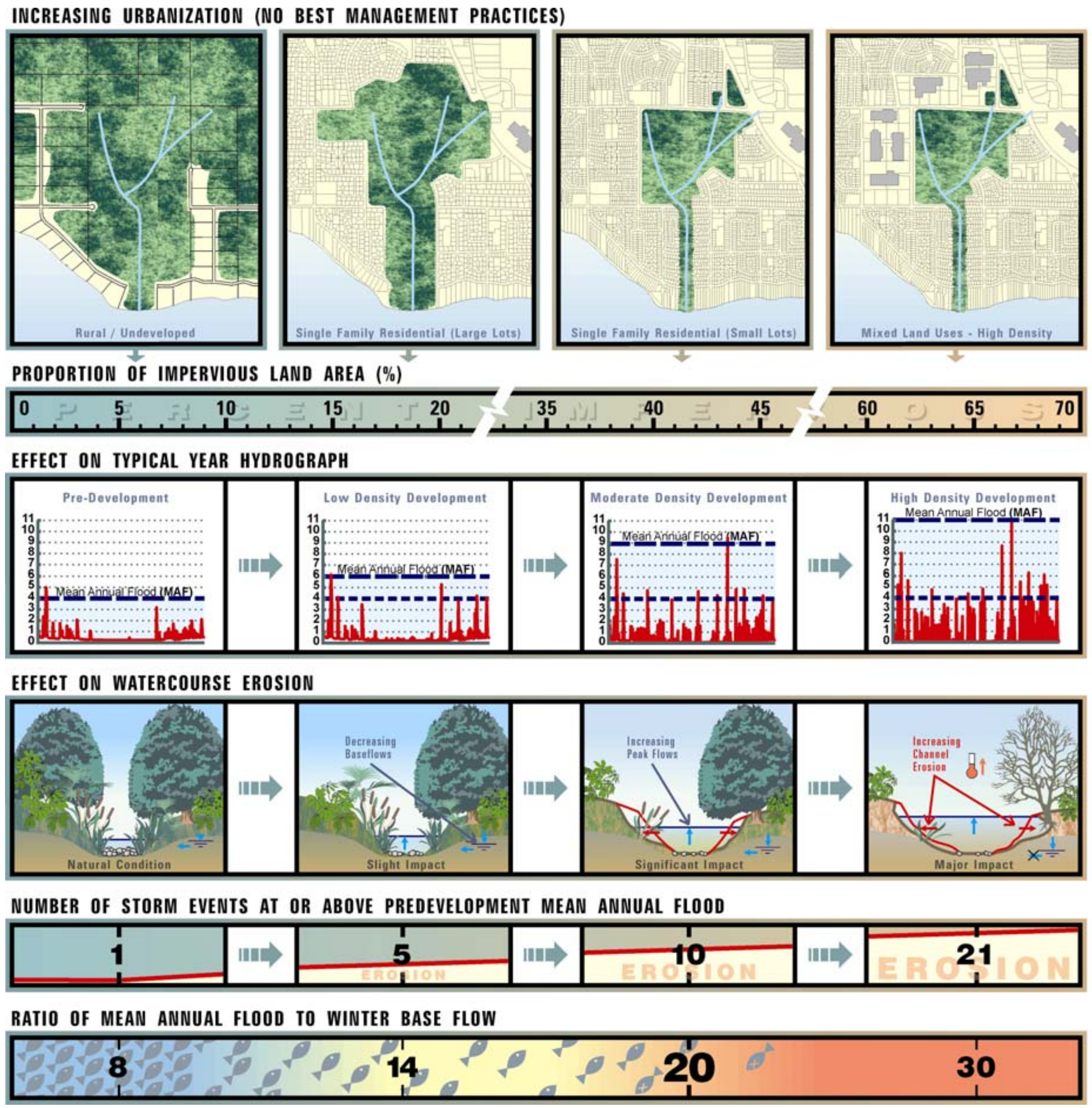
Figure 2-3

Relationship Between Impervious Area and Runoff Volume

Figure 2-4 illustrates the progressive changes in hydrology that result when land use change alters the Water Balance. Replacement of natural vegetation and soil with impervious surfaces reduces infiltration and evapotranspiration. The total runoff volume increases (as shown in red), and so does the Mean Annual Flood (MAF), a statistical rating of the annual peak flows in a creek system.

The MAF is defined as the channel-forming event because the cross-sections of stream channels tend to reach equilibrium with the MAF. When the MAF increases, the channel erodes to expand its cross-section. A critical parameter for watercourse erosion is the number of runoff events per year that equal or exceed the natural MAF. The more frequently the natural MAF is exceeded, the greater the channel instability, leading to habitat degradation as a result of erosion and sedimentation.

A second critical parameter is the ratio of the MAF to the winter baseflow. Washington State research indicates that 20:1 is a threshold ratio for coastal fisheries biodiversity and abundance.



IMPACT OF CHANGES IN HYDROLOGY ON WATERCOURSE EROSION AND BASE FLOW RELATIONSHIPS

(WITHOUT BEST MANAGEMENT PRACTICES)

This figure demonstrates the impact of increasing impervious area on the number of erosion-causing events, and increased peak flow impacts on channel stability.

Figure 2-4

Other Hydrology-Based Relationships

Impervious Area and Water Quality

Not only does more impervious surfaces mean more runoff volume, it also means there is more surface area (e.g. roads, parking lots) available to collect pollutants which then wash off into receiving streams when it rains. Most stormwater runoff receives no treatment before it is discharged to streams.

More runoff volume also means there will be more instream erosion and more frequent turbidity (or dirty water).

Another measure of changes in hydrology is the level of total suspended solids (TSS) in a creek system. TSS comprises the direct wash-off from impervious surfaces, plus sediment that erodes from stream bottoms and sides. TSS acts as a carrier of other pollutants such as organics, hydrocarbons and metals.

Interflow and Baseflow

Yet another measure of changes in hydrology is the Mean Annual Discharge (MAD). This is the average flow over the year. MAD is applied when assessing the relative magnitude of summer baseflows.

The interflow component of the Water Balance sustains baseflow. In fact, interflow can keep creeks flowing for months after winter rainfall stops. Interflow recharge depends on the integrated hydrologic function of soil, vegetation and trees. If interflow is reduced, baseflow is reduced.

When considering both community water supply and fisheries needs during periods of prolonged dry weather, a generally accepted criterion in British Columbia for Water Balance assessment purposes is that minimum baseflows should equal 10% of MAD.

Hydrology and Water Quality Objectives for Protecting Watershed Health

In terms of mitigating the impacts of impervious area on watershed hydrology, British Columbia case study experience has resulted in identification of the following hydrology-based objectives for a truly healthy watershed:

- **Objective 3 –** Provide runoff control so that the Mean Annual Flood (MAF) approaches that for natural conditions.
- **Objective 4 –** Minimize the number of times per year that the flow rate corresponding to the natural MAF is exceeded after a watershed is urbanized.
- **Objective 5 –** Establish a total suspended solids (TSS) loading rate (i.e. kilograms per hectare per year) that matches pre-development conditions.
- **Objective 6 –** Maintain a baseflow condition equal to 10% of the Mean Annual Discharge (MAD) in fisheries-sensitive systems.

2.4 Factors that Limit the Health of Aquatic Resources

A science-based understanding of the factors that limit the health of aquatic resources leads to reference levels of impervious area for planning purposes. This understanding provides the basis for setting performance targets and developing site design criteria.

Ranking of Limiting Factors

Research by the University of Washington (Horner and May 1996) clearly demonstrated that the factors limiting the ecological values of urban streams are, in order-of-priority:

1. **Changes in Hydrology** –
   Greater volume and rate of surface runoff caused by increased impervious area and densification of the road network.

2. **Disturbance and/or Loss of Integrity of the Riparian Corridor** –
   Clearing and removal of natural vegetation in riparian (streamside) areas.

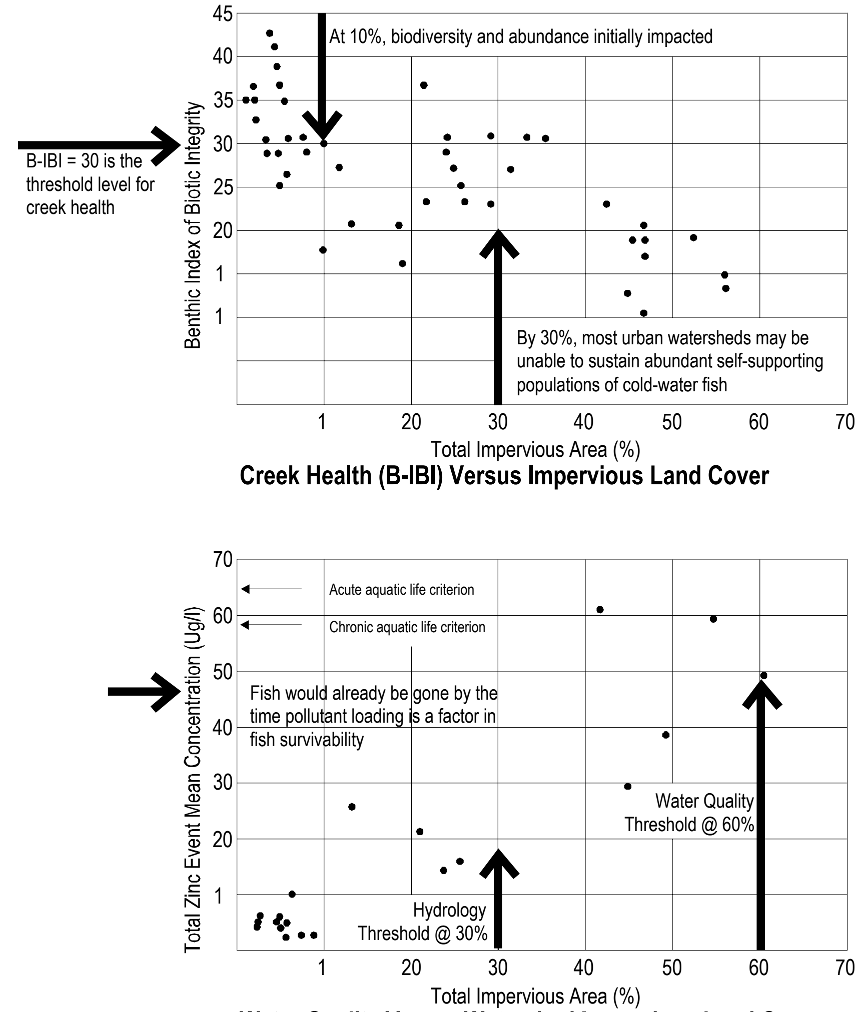
3. **Degradation and/or Loss of Aquatic Habitat within the Stream** –
   Caused by erosion and sedimentation processes, bank hardening, and removal of large organic debris; aquatic habitat degradation is a direct result of changes in hydrology (Factor #1).

4. **Deterioration of Water Quality** –
   Increased sediment load due to more runoff volume causing channel erosion. Pollutant wash-off from land uses, deliberate waste discharges and accidental spills.

Figure 2-5 illustrates the research findings for two of these factors: changes in hydrology (#1) and deterioration in water quality (#4).

The work of Horner and May has had a profound impact in changing the way stormwater professionals view the relationship between watershed impervious area and stream health. Their work has also resulted in a science-based understanding that, in turn, has enabled the definition of reference levels for land use planning.

Reference Levels for Land Use Planning



Creek Health (B-IBI) Versus Impervious Land Cover

Water Quality Versus Watershed Impervious Land Cover

Figure 2-5

Reference Impervious Area Levels for Land use Planning

The scientific correlations presented on Figure 2-5 are simplified in the table below. The objective is to provide points of reference for integration of stormwater management with land use planning. This simplification will at least enable informed decision making. In reality, land use and stream health changes occur along a continuum.

Impervious Percentage	Biophysical Significance of the Reference Level
10%	Fisheries biodiversity and abundance are initially and significantly impacted
30%	Most urban watersheds in the Pacific Northwest may be unable to sustain abundant self-supporting populations of cold-water fish
60%	Pollutant loading would theoretically be a significant factor in fish survival, except cold-water fish would likely already have been extirpated because of hydrological changes and related degradation of the aquatic habitat

Measuring the Environmental Health of Creek Systems

Figure 2-5 refers to a Benthic Index of Biological Integrity (B-IBI) score as an indicator of creek health. B-IBI is a multimetric benthic macroinvertebrate index designed and calibrated for use in the Pacific Northwest. Each of the metrics it incorporates (e.g. total number of taxa, number of pollution tolerant taxa) was chosen for its consistency in responding to several types of human disturbance, including urbanization, forestry, agriculture and recreation. B-IBI is also useful because it is very sensitive to slight changes in a watershed.

Benthic invertebrates are used because anadromous fish species in the Pacific Northwest are subject to significant environmental pressures unrelated to their home watershed. These outside influences affect their distribution, diversity and abundance, making it difficult to use fish population measures as indicators of stream health.

Other Washington State Research Findings

Riparian Corridor Integrity

In any given watershed or at any given site, any one of the four factors can limit biologic health. Research by the University of Washington (Karr and Morley 1999) as well as a series of studies summarized by Millar (1997) demonstrate the importance of healthy riparian corridors. The presence or absence of healthy riparian forest greatly affects a stream's biologic integrity in otherwise similar watersheds with similar total imperviousness.

A healthy, forested riparian corridor can partially compensate for impervious surfaces in a watershed. In contrast, a cleared riparian corridor results in a damaged stream even in a watershed with low impervious area.

Density of Road Networks

Another significant finding is that the density of road networks also provides an excellent way to closely track total impervious area and associated impacts. This is because of the drainage system pattern associated with nearly all roads.

Drainage ditches collect surface water and interflow and transport it immediately to streams. Resulting changes in stream-system hydrology are similar to the effects of increased impervious surfaces.

Biophysical Objectives for Protecting Watershed Health

In terms of preventing changes in hydrology from impacting aquatic resources, Washington State research has resulted in identification of four objectives for defining a truly healthy watershed – that is, one that can support self-sustaining populations of wild salmon:

- **Objective 7 -** Limit impervious area to less than 10% of total watershed area.
- **Objective 8 -** Retain 65% forest cover across the watershed.

2.5 Managing Complexity

There is a logical link between changes in hydrology and impacts on watershed health, whether those impacts are in the form of flooding or aquatic habitat degradation. The link is the volume of surface runoff that is created by human activities as the result of alteration of the natural landscape (i.e. through removal of soils, vegetation and trees).

Eliminate the Source of Problems

The key to protecting watershed health is to maintain the Water Balance as close to the natural condition as is achievable and feasible. But protecting the interflow and evapo-transpiration components requires major changes in the way we develop land (i.e. if we are to preserve and/or restore soils, vegetation and trees). Understanding the cause-and-effect relationship between hydrology and biology provides credibility for a change in approach from only dealing with consequences, to also eliminating the source of problems. This shift in thinking is illustrated by Figure 2-6 below.

Science-based credibility helps people accept new ways of thinking. But to maintain credibility, it is important to apply common sense to the science.

Figure 2-6

What the Science is Telling Us

The science is explicitly telling us that major biophysical changes occur once the impervious percentage of a watershed reaches about 10%. Beyond this threshold, the change in the Water Balance triggers watercourse erosion, which in turn degrades and/or eliminates aquatic habitat.

The science is implicitly telling us that where urban land use densities are produced, the focus should be on what needs to be done at the site level to effectively mimic a watershed with only 10% impervious area, and in doing so reduce runoff volume to the same 10% level.

The science is also implicitly telling us that capturing rainfall at the source for the frequent small events will in large part maintain or restore the natural Water Balance.

What Can be Done at the Site Level to Protect Watershed Health

The financial and staff resources of local government are limited. Therefore, those resources must be invested wisely to maximize the return-on-effort. Common sense says that the best return will be at the site level where local government exerts the most influence, and can therefore make a cumulative difference at the watershed scale.

A Starting Point for Early Action

Common sense says that we now have sufficient science-based knowledge and understanding for local government to make some decisions, and to get on with implementing early action in at-risk areas. More data to refine the science is desirable when there is time and resources, however, there will be situations where excessive data collection becomes a barrier to effective action in the face of an immediate risk.

Strategic data collection required is to understand the historic Water Balance, the current Water Balance if the watershed is partially developed, and the proposed changes to land use in the watershed.

Looking ahead to the discussion in Parts B and C, the objectives of most ISMPs will include trying to maintain or restore the natural Water Balance as development or re-development proceeds. Improved understanding of how to do that will evolve through demonstration projects that test and refine solutions to aquatic habitat and receiving water quality challenges.

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Objectives for Protecting Watershed Health in the Urban Environment

The three sets of objectives for a truly healthy urban watershed are brought forward from the previous sections and consolidated below. The purpose is to provide an integrated framework for guiding the actions of local governments within their sphere of responsibility and influence.

Water Balance

- **Objective 1 -** Preserve and protect the water absorbing capabilities of soil, vegetation and trees.
- **Objective 2 -** Prevent the frequently occurring small rainfall events from becoming surface runoff.

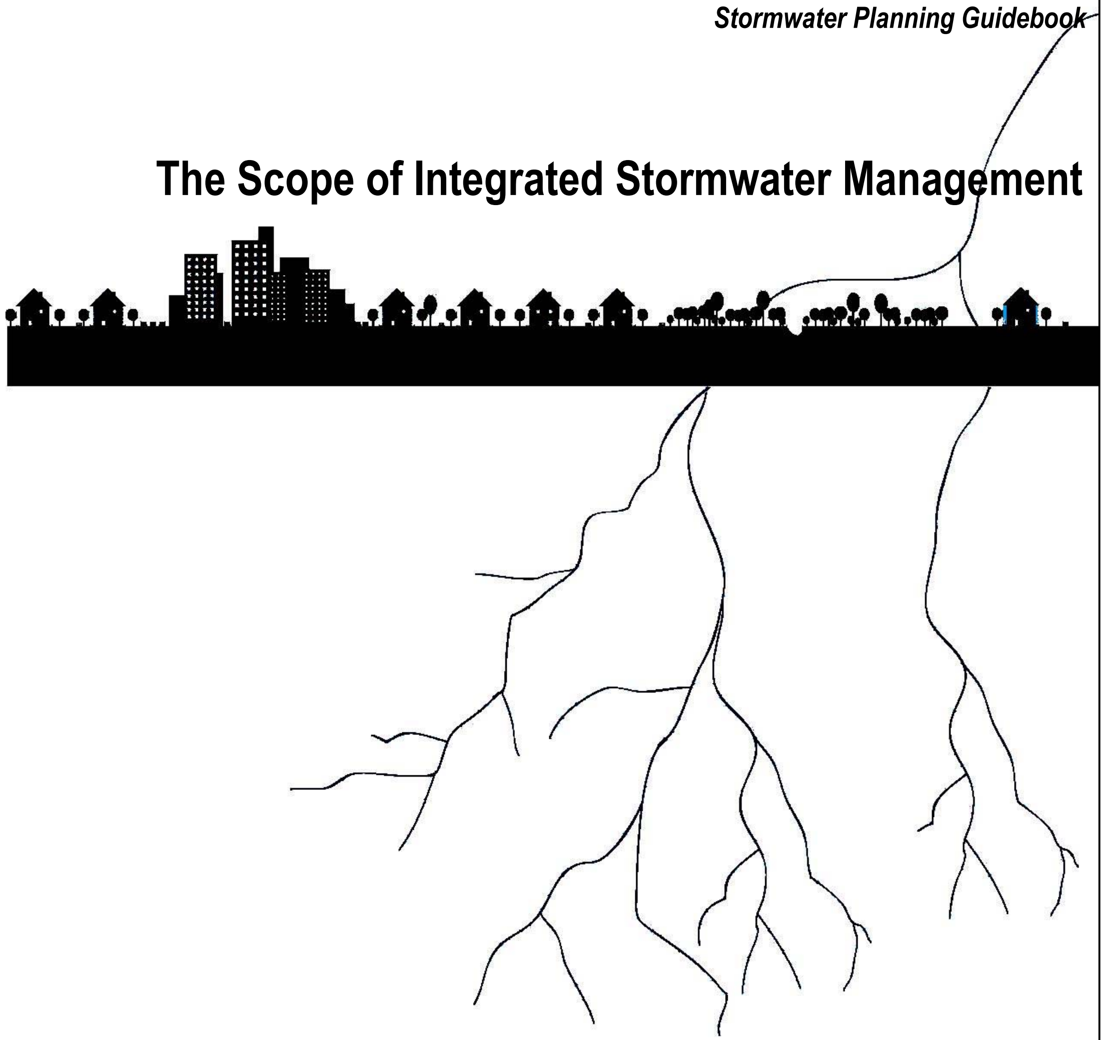
Hydrology / Water Quality

- **Objective 3 –** Provide runoff control so that the Mean Annual Flood (MAF) approaches that for natural conditions.
- **Objective 4 –** Minimize the number of times per year that the flow rate corresponding to the natural MAF is exceeded after a watershed is urbanized.
- **Objective 5 –** Establish a total suspended solids (TSS) loading rate (i.e. kilograms per hectare per year) that matches pre-development conditions.
- **Objective 6 –** Maintain a baseflow condition equal to 10% of the Mean Annual Discharge (MAD) in fisheries-sensitive systems.

Biophysical

- **Objective 7 -** Limit impervious area to less than 10% of total watershed area.
- **Objective 8 -** Retain 65% forest cover across the watershed.
- **Objective 9 -** Preserve a 30-metre wide intact riparian corridor along all streamside areas.
- **Objective 10 -** Maintain B-IBI (Benthic Index of Biological Integrity) score above 30.

The Scope of Integrated Stormwater Management



Chapter Three

3.1 Overview and Context

An integrated approach recognizes that land use changes outside a stream corridor result in changes within the corridor. The impact of land development in changing both stormwater quantity and quality can trigger progressive loss of biodiversity and abundance of aquatic species within the corridor.

Connecting the Natural and Built Environments

Integrated, or watershed-based, stormwater management recognizes the relationships between the natural environment and the built environment, and manages them as integrated components of the same watershed. These relationships are illustrated in Figure 3-1. Traditional drainage practices concentrated on peak flow rates and overlooked the importance of volume management. Integrated solutions manage both volume and flow rates.

Integration Means Tackling both Stormwater Quantity and Quality

Integrated stormwater management includes attention to both stormwater quality and quantity. Water quality impairments correlate with increased watershed percent imperviousness, as well as with increased population density. Rainfall washes fine sediment from hard surfaces into piped systems that discharge into receiving waters. As an area develops, the total volume of sediment loading increases.

The majority of trace metals and hydrocarbons, for example, are associated with suspended sediment. Hence, it is common sense that reducing stormwater volume will also reduce sediment loading and reduce aquatic pollution. When stormwater is infiltrated through soil, many sediment-bound contaminants are removed by filtration. Similarly, constructed wetlands can also act as settling ponds to remove and treat suspended sediments in runoff. Other stormwater treatment technologies are available commercially and may become important as development intensifies.

Programs that increase public awareness of common non-point source pollutants in the home and business will also contribute to reduced pollutant loads. Other more rigorous source control programs (e.g. bylaws) may also become necessary as land use intensifies.

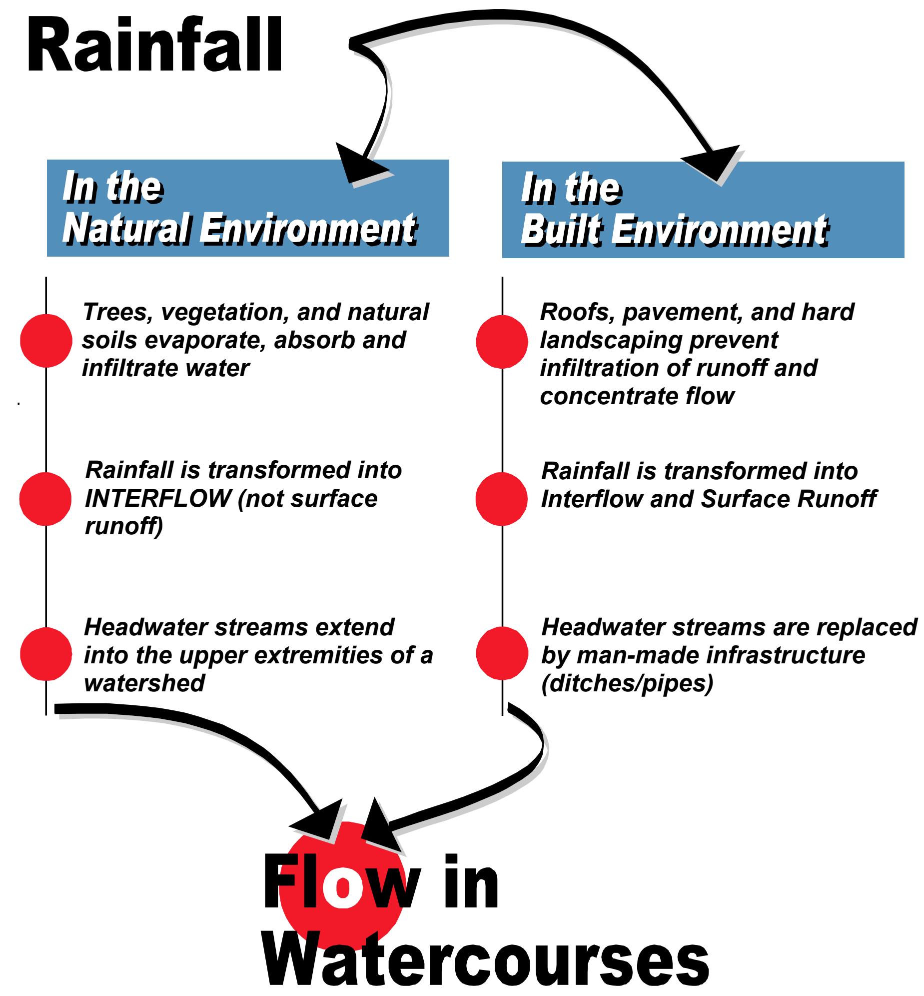


Figure 3-1

Blending Policy, Science and Site Design

Integrated stormwater management blends policy, science and site design through an integrated approach. Key steps are:

- **Policy** –
Identify goals, objectives, locations and guidelines for both land use development and stormwater management. Organize priorities and financial and administrative support.

- **Science** –
Build a science-based understanding of the link between urban development impacts, stream degradation, and other policy objectives. This understanding leads to realistic performance targets and design criteria for each watershed catchment.

- **Site Design** –
Identify site design practices that support the policy objectives and meet the performance targets. Once identified, these site design practices must be allowed and supported at the policy level. Changes to development standards and regulations are also needed to enable better site design practices.

Policy, science and site design are blended through a participatory and interactive process where technical products are developed and presented at a series of working sessions with stakeholders. The objective is to reach consensus on a shared vision that is practical and achievable, and that will be supported by the community. Community support is the key to moving from planning to action. Chapter 11 elaborates on this topic.

3.2 The Transition from Traditional to Integrated Stormwater Management

Evolution of the Integrated Approach

Stormwater management has evolved over the decades, and continues to evolve. The following comparison captures the key elements of the transition from a traditional, 1980s approach, to an integrated approach in the 2000s. The integrated approach still incorporates the traditional scope of engineering work, but builds on it to achieve environmental as well as drainage objectives, as the following table demonstrates:

TRADITIONAL is defined as:		INTEGRATED is defined as:
✓ Drainage Systems	⇨	✓ Ecosystems
✓ Reactive (Solve Problems)	⇨	✓ Proactive (Prevent Problems)
✓ Engineer-driven	⇨	✓ Interdisciplinary Team-driven
✓ Protect Property	⇨	✓ Protect Property and Resources
✓ Pipe and Convey	⇨	✓ Mimic Natural Processes
✓ Bureaucratic Decisions	⇨	✓ Consensus-based Decisions
✓ Local Government Ownership	⇨	✓ Partnerships with Others
✓ Narrow Scope of Work (drainage focus only)	⇨	✓ Holistic Scope of Work (stormwater integrated with land use)

An integrated approach to stormwater planning is inter-departmental, interdisciplinary and inter-agency. It also involves community representatives in the planning process. These elements and their significance are explained in later chapters in Part C.

Change in Approach: from Reactive to Proactive

Integrated stormwater solutions ensure protection of both property and ecosystems. Past drainage practices only dealt with the consequences of land development. An integrated approach also attempts to eliminate the source of problems.

Figure 3-2 illustrates what is involved in moving from an 'end-of-pipe' approach that solves problems after the fact, to one that is proactive in preventing problems from occurring.

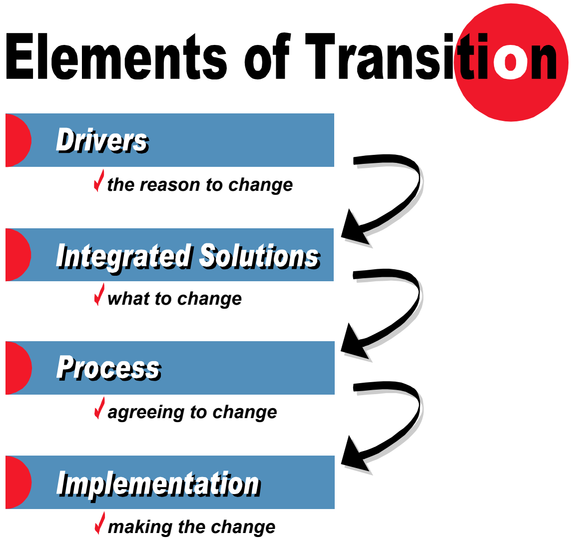


Figure 3-2

Volume Reduction is the Key to Property and Environmental Protection

To avoid aquatic habitat and water quality impacts and protect property, it is necessary to ***decrease the volume of runoff that flows to streams***, thereby creating a situation that mimics or approximates a naturally vegetated watershed. Past stormwater management practices did not accomplish this because they focused only on the conveyance and/or detention of the extreme storms.

Extreme storms occur rarely. Because the small, frequently occurring rainfall events represent the bulk of total rainfall, the key to ***runoff volume reduction*** is to capture those events at the source. If they can be captured and restored to their natural hydrologic pathways (through infiltration and re-use within a development site), then the majority of the total annual rainfall will be managed in a manner approximating a natural system.

Strategies to Reduce Runoff Volume and Flow Rate

Integrated solutions reduce the volume and the rate of surface runoff from the built environment by a combination of three strategies:

- Minimize creation of impervious area, e.g. by using pervious surfaces, narrower roads, skinny buildings, etc.
- Install hydraulic disconnects that return local runoff from impervious surfaces back into the ground or re-use it within the development site.
- Store runoff and release it slowly. Ideally this storage would discharge to an infiltration device prior to discharge to a watercourse.

In summary, integrated stormwater management recognizes that flood control, protection of aquatic habitat and improvement of water quality are all complementary objectives. They all have the same starting point – increased impervious area leads to increases in runoff.

The Evolving Role of Governments in Integrated Stormwater Management

The goal in BC is to develop integrated stormwater solutions that will ensure protection of life, property, aquatic habitat and water quality. Achieving this goal requires alignment of the roles and responsibilities of the different levels of government.

Local government has responsibility for land use decisions. Local government is also responsible for protection of property. Because of the direct relationship between land use development and stormwater impacts, local government must play a primary role in aquatic habitat protection and restoration related to stormwater management.

Recent changes to the *Local Government Act* have expanded the mandate for municipalities and regional districts to manage runoff and impervious area.

In view of the expanding role of local governments in stormwater management, a key objective of the Guidebook is to provide a pragmatic, integrated and science-based approach to stormwater planning. This will enable local governments and landowners to make long-term land use and development decisions with more confidence.

Providing Economy and Certainty During a Period of Transition

During this period of transition from traditional drainage practice to integrated stormwater management, there is uncertainty as to what roles various levels of government and the private sector should play in stormwater management, and who pays.

Part C of the document suggests partnerships among various levels of government. Senior governments recognize the importance of being proactive in developing strong and lasting partnerships with local governments.

The Guidebook presents an adaptive methodology for moving from planning to action. This methodology focuses the limited financial and staff resources of governments on implementing early action where it is needed most. It explains how to select conservative strategies to guide early action. It also provides a framework for reducing the costs of these strategies through ongoing monitoring and evaluation.

3.3 Plan at Four Scales – Regional, Watershed, Neighbourhood and Site

What the Cell is to the Body, the Site is to the Region

Just as the health of the human body is dependent on the health of the individual cells in it, so too is the health of the suburban region dependent on the health of the individual site – this is an over-arching theme.

A guiding principle is to plan at four scales to ensure that solutions are both integrated and cascading. The scales are the region, watershed, neighbourhood and site, as shown in the adjacent table.

Cascading Hierarchy for Integrated Solutions

The objectives for stormwater management are referenced to, and defined by, the cascading hierarchy shown to the right. Each successive level provides more specific details as to what is to be accomplished, and how to achieve a shared community vision for the region and/or watershed.

The planning scales are not mutually dependent. However, they work best when undertaken together. In the context of this Guidebook, watershed-based planning means that resource, land use, and community design decisions are made with an eye towards their potential impact on the watershed or drainage catchment. Therefore, what happens at the scale of the individual parcel and street affects what happens at the watershed scale.

Planning Scale	Description of Initiative	Opportunity for Implementing Stormwater Management
Regional	Regional Growth Strategy	Provide local government with enabling tools
Regional	Stormwater Component of Liquid Waste Management Plans (LWMPs)	Prioritize limited resources on key environmental stewardship issues
Regional	Official Community Plan (OCP)	Define over-arching community goals and objectives
Watershed	Watershed-Based Land Use Planning Process	Develop a stewardship-based 'watershed vision' that reflects OCP
Watershed	Integrated Stormwater Management Plan (ISMP)	Protect property, aquatic habitat and water quality
Neighbourhood	Neighbourhood Community Plan (NCP), or Local Area Plan (LAP)	Establish performance targets for subdivisions and site design
Site	Subdivision and Single Lot Development Plans	Implement performance targets for site design

3.4 Integrated Stormwater Management Planning

The evolving science of stormwater management has broadened the traditional engineering approach to one that integrates hydrologic and environmental concerns, and that is also proactive in managing risk. Hence, the term *Integrated Stormwater Management Plan* (ISMP) is gaining widespread acceptance in BC because it addresses two categories of risk management:

- Flood Risk – to protect life and property
- Environmental Risk – to protect habitat and property

Producing a Shared Vision

To address stormwater issues, it is critical that key stakeholders have a shared vision of the science and the appropriate solutions for the watershed under consideration. Stakeholders must understand that land use change alters the natural Water Balance, that the result is more surface runoff, and that the increase in both volume and flow rates has consequences.

The purpose of an ISMP is to create a clear picture of a desired outcome that will facilitate a broad understanding of integrated solutions – why they are needed, what they are, and how they can be practically and affordably accomplished. An ISMP implementation program will organize a transition from existing to revised standards that achieve the desired outcome.

An Action Plan with Four Components

Figure 3-3 illustrates how a process produces a shared vision that results in an action plan with four component plans. Chapter 10 elaborates on the concepts presented in this section.

The effectiveness of flood risk and environmental risk management depends on a ***Land Development Action Plan*** that integrates decisions about land use and on-site stormwater best management practices to protect and/or restore the natural Water Balance.

The purpose of a ***Flood Risk Mitigation Plan*** is to protect life and property. This is achieved by containing and conveying the floodflows that result from the extremely large rainstorms that rarely occur. This component has historically been called a Master Drainage Plan.

The purpose of a ***Habitat Enhancement Plan*** is to address environmental risk (to aquatic habitat and water quality). This means protecting stream corridor ecosystems from being progressively degraded by the erosion and sedimentation that result from the small rainfall events that occur all the time. This is achieved through a combination of retention (rainfall capture at the source) and detention (runoff control) strategies. This combination also indirectly addresses risks to water quality.

The purpose of a ***Financial and Implementation Plan*** is to provide cost sharing and control, funding and organization of the stakeholders to ensure effective implementation, monitoring, operating and maintenance.

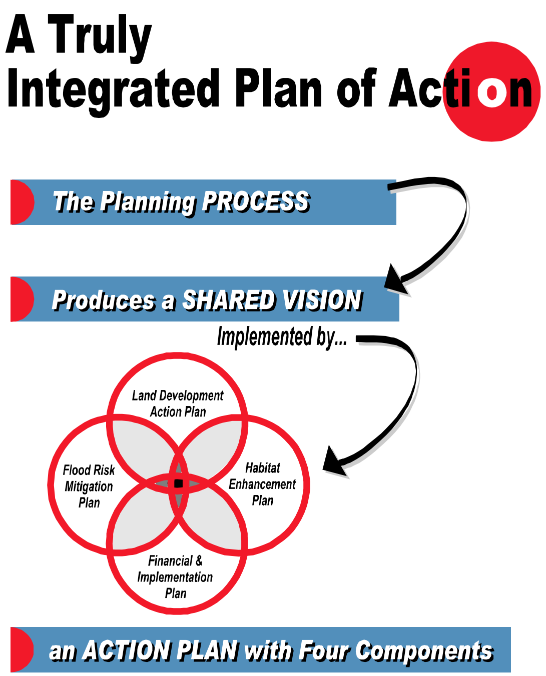


Figure 3-3

3.5 The Relationship between Stormwater and Land Use

As introduced in Chapter 2, the impacts of increasing impervious area on stream flows and fish habitat are cumulative. Changes in land use designations and zoning should consider how much change to effective impervious area is encouraged by the proposed land use.

Table 3-1 shows a typical, generalized relationship between imperviousness and land use, without mitigation by best management practices (BMPs). This illustrates how the area per dwelling unit decreases with density. For example, the impervious area per dwelling unit for a high-density multi-family development is about 1/8 of the per unit area for a 1960s suburban residential development.

Table 3-1 Presumed Relationship between Impervious Area and Land Use [1]

Land Use	Density (units / acre)	TIA (percent)	EIA (percent)	Land/1000 Dwellings (acres)	EIA / 1000 Dwellings (acres)
Rural Residential	0.5	10	4	2000	80
Estate Residential	1	20	10	1000	100
1960s Suburban	4	35	24	250	60
1990s Suburban*	5	55	45	200	90
Low Multi-family	8	60	48	125	60
High Multi-family** (underground parking)	50	60	48	20	10
Commercial/Industrial	n/a	90	86	n/a	n/a

[1] Extracted from Dinicola, 1989, Jackson and Booth, 1997

TIA = total impervious area and EIA = effective impervious area (i.e. directly connected to drainage system)
Refer to Chapter 6 for additional explanation regarding TIA versus EIA

* Source: Como Creek watershed, City of Coquitlam – airphoto interpretation
** Source: Burnaby Mountain Community, City of Burnaby – neighbourhood plan

Ten Principles

An improved understanding of the relationship between stormwater management and land use is important to make the case for closer integration of OCP and ISMP processes, and to break down barriers between planners and engineers. Table 3-2 identifies ten principles that help define the relationship between stormwater management and land use.

Looking ahead to Chapters 6 through 8, understanding the relationship between stormwater and land use is also important in deciding when, where and how stormwater management performance targets should be applied.

Table 3-2: Ten Principles that Define the Relationship between Stormwater Management and Land Use

1. 10% impervious area is a critical threshold - Stormwater impacts increase dramatically when land use creates over 10% impervious area in a watershed or drainage catchment.

2. Residential development has the greatest overall impact - Residential development often has the greatest cumulative impact on stormwater management because it covers the greatest land area.

3. Greater population = greater impact - The higher the population accommodated in a watershed or sub-watershed, the higher the likely water quantity and water quality impacts.

4. Same population, greater density = less impact - The greater the density of residential land use in a watershed for a given population, and the more remaining vegetated green space, the lower the likely stormwater impact.

5. Rule of thumb is to maintain catchment effective impervious area (EIA) below 10% - Generally, stormwater best management practices (BMPs) to manage flows should be triggered for all developments that involve more than 10% total impervious area. The objective of the BMPs would be to reduce the effective impervious area, and to meet designated targets for rainfall capture and runoff control.

6. BMPs are needed for residential densities exceed 1 unit per hectare - Most residential developments of densities greater than 1 unit per hectare will exceed the 10% impervious area trigger.

7. Industrial/commercial = greatest impervious area - Medium density commercial and industrial developments have high impervious area that needs to be mitigated. However, these developments often represent a small portion of the watershed when compared to other land uses (e.g. residential).

8. Large structures in forestry/agricultural areas may require mitigating BMPs - Very low density land uses such as agriculture or forestry will often have impervious area less than 10%, but can still have a major impact on watershed hydrology due to the consequences of clearing and ditching. In addition, local sites such as greenhouses or temporary industrial operations may trigger the need for specific stormwater management measures. At the same time, drainage from upland urban areas may have flooding impacts on agricultural lowland uses if not mitigated.

9. The impacts of impervious area are cumulative – An existing development that is not creating a problem may contribute to a future problem as adjacent development infills. For this reason, all development with >10% EIA should implement stormwater management, except in isolated cases where there is no likelihood of the total impervious area in a drainage catchment exceeding 10% (e.g. in completely rural areas).

10. Compact communities are most compatible with stormwater objectives - The most favorable land use pattern for minimum stormwater impacts is compact, dense, pedestrian-oriented development with effective stormwater BMPs, and with the majority of the watershed in vegetation and absorbent soils.

3.6 A Guide to Part B

Often it is the small or tributary drainage catchments that are heavily impacted by land use change. Since development activities can quickly transform a large portion of these at-risk catchments, it is important that integrated stormwater management programs be put in place quickly. Priority action in at-risk catchments has several advantages:

- Demonstrates that local government is taking immediate action
- Focuses attention on the types of stormwater problems that will have to be addressed in other areas
- Serves as a demonstration project for testing the effectiveness (and affordability) of stormwater management policies and techniques

Looking ahead, Chapter 4 describes two tools that can be used by local government to bring about policy changes that will result in integrated solutions.

Chapter 5 describes an approach for setting priorities for early action. This is called the *At-Risk Methodology* (ARM). This methodology relies on a roundtable process that brings together people with knowledge about future land use changes, high-value ecological resources, and locations that have chronic drainage problems. The Regional District of Nanaimo is the case study example.

Chapters 6 through 8 then lead the reader through a step-by-step discussion on the selection and application of achievable performance targets. Each chapter is a building block in a systematic process for translating performance targets into design criteria that can be implemented at the site level to achieve watershed objectives. The City of Chilliwack and the Greater Vancouver Regional District (GVRD) are the case study examples.

- Chapter 6 explains how science-based performance targets have been set for the City of Chilliwack, and shows how these targets have been translated into design criteria.
- Chapter 7 then demonstrates how Chilliwack has integrated performance targets with stormwater management policies.
- Finally, Chapter 8 illustrates how Chilliwack has incorporated performance targets into a set of *Design Guidelines for Stormwater Systems* that developers can understand and apply at the site level.

Case Studies

The targets, criteria, policies and guidelines are incorporated in the City of Chilliwack's *Policy and Design Criteria Manual for Surface Water Management.* This Manual has been developed as a case study application of the Guidebook content.

The GVRD case study (also presented in Chapter 8) evaluates a broad range of stormwater source control options that can be applied to achieve performance targets.

Policies for Integration of Land Use Planning and Stormwater Management

Chapter Four

4.1 Policy Tools for Implementing Integrated Stormwater Management Solutions

Achieving stormwater performance targets involves change, both at the land use level, and at the site design level.

Initiating change in stormwater management through land use or site design may involve two tools of local government: the *Official Community Plan* (OCP) and the *Liquid Waste Management Plan* (LWMP), and their related bylaw tools.

Official Community Plans tend to be led by planners, with input from engineers on infrastructure sections. Liquid Waste Management Plans tend to be led by engineers, with little or no input from planners. Both processes involve approval by a Local Council or a Regional Board.

Official Community Plans (OCPs)

Official Community Plans are statements of broad objective and policy to manage land use and growth in municipalities or in designated areas of regional districts. While these plans must designate land uses, they also may address social, environmental and sustainability issues at a broad level.

Related tools are Regional Growth Strategies, Neighbourhood Plans, Zoning Bylaws, Subdivision Bylaws and Development Permits, among others. While these tools are not centered on stormwater management, the provincial *Local Government Act* has expressly permitted local governments to use these tools to manage environmental impacts, runoff and impervious area.

Liquid Waste Management Plans (LWMPs)

Creating change in stormwater practices also may be triggered by a Liquid Waste Management Plan (LWMP). A Liquid Waste Management Plan charts a local government's proposed future course of action with respect to the management, collection, treatment and disposal of the sewage, stormwater and other wastewater effluents.

LWMPs are voluntary, and are created by local governments under a public process in co-operation with the Province. There are currently about 40 LWMPs adopted or in process in BC. Although the emphasis of most LWMPs has to date been on sanitary sewage, there will be an increasing emphasis on non-point-source pollution and stormwater in new LWMPs, or as existing LWMPs are updated or amended.

Case Study Applications

This chapter presents two case study applications that have developed content for the Guidebook:

- **Suburban Municipality** – the City of Chilliwack
- **Rural Regional District –** the Regional District of Nanaimo

These case studies have provided an opportunity to test and refine core concepts contained in this Guidebook with respect to integrating stormwater management with land use planning.

Integrating Stormwater and Land Use Strategies

Official Community Plans and Liquid Waste Management Plans, although often produced in isolation, are actually highly related exercises, as shown below:

Official Community Plan (OCP)	Liquid Waste Management Plan (LWMP)
Sets land use designations	Deals with sanitary sewage and stormwater consequences of land use designations
Adopted by Council/Board bylaw	Adopted by Council/Board bylaw
Involves public process	Involves public process
Updated periodically	Updated periodically
Planner-led	Engineer-led

Rather than view these as separate processes, it is useful to recognize the complementary and iterative nature of these two tools, as illustrated in Figure 4-1. Changes in land use policy create changes in liquid waste policy, and ecological or financial limitations on liquid waste systems may limit land use change.

Each local government will have a different Official Community Plan, Liquid Waste Management Plan, and other bylaws. As almost every bylaw comes up for review periodically, changing stormwater management policies is an opportunistic process; change will be made when the opportunity exists to make change.

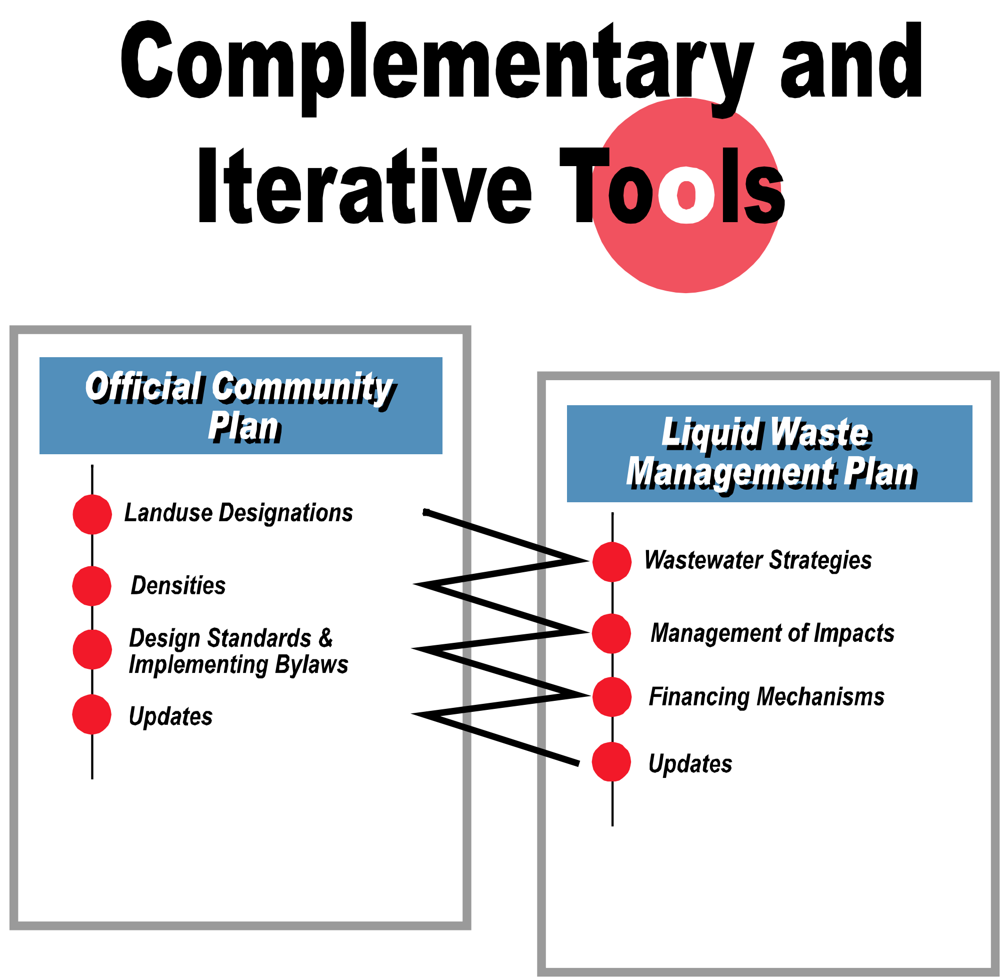


Figure 4-1

4.2 Liquid Waste Management Plans

The provincial *Waste Management Act* allows a municipality or regional district to develop an LWMP for approval by the Minister of Water, Land and Air Protection. The Minister can also order a local government to develop or revise an LWMP.

When the Guidelines for developing an LWMP were first published in 1992, urban stormwater runoff was included because the Ministry considered stormwater to be a resource to be protected. The 1992 Guidelines outlined a 3-stage process for developing an LWMP, and listed the various waste streams to be addressed, including non-point source pollution in stormwater runoff. The three stages are:

- Stage 1 - Identify Options
- Stage 2 - Evaluate Options
- Stage 3 – Prepare and Adopt Plan

Public participation is an integral component of each stage. This requirement provides an opportunity for a feedback loop that should also help broaden community support for the related but separate ISMP process for the stormwater component of an LWMP. A methodology to involve stakeholders in ISMP development is explained in Part C.

The Minister must be satisfied that there has been adequate public review and consultation with respect to the development, amendment and final content of the LWMP before providing sign-off. When approved, the LWMP authorizes disposal or re-use of municipal liquid waste. The local government then has the authority to spend the allocated public funds on the identified works and projects contained within the plan. Ideally, the LWMP should use a 20 to 40-year planning horizon.

The 1998 NPS Action Plan, introduced in Chapter 1, also identifies an LWMP as a tool to deal with pollution from stormwater runoff.

Stormwater Management Role of Regional Districts

To the date of writing, stormwater management in British Columbia has been focused on municipalities, not regional districts. The only regional districts that are highly active in stormwater management are the Greater Vancouver Regional District (GVRD) and the Capital Regional District (CRD). Within these two relatively urbanized regional districts, most of the land area falls within municipal boundaries. Therefore in the GVRD and the CRD, the regional district role is as a coordinator and economy of scale service provider, with the primary stormwater management role being provided by the member municipalities.

Outside of these two metropolitan regions and other municipalities, the great majority of the land area in British Columbia is administered as electoral areas within regional districts. Stormwater management in these relatively rural regional districts has been limited to date. In many cases, there is little active stormwater planning, other than that provided for drainage of roads administered by the provincial Ministry of Transportation and Highways.

Relationship between LWMP and ISMP Processes

There are two ways that the LWMP process potentially dovetails with stormwater management planning:

- **Regional Scale –** This is a macro view where a comprehensive approach is adopted; ISMPs are also part of the stormwater component of an overall LWMP.
- **Watershed Scale –** This is a micro view where the ISMP itself becomes the stormwater component of the LWMP; the ISMP delves into watershed-specific details

ISMP Technical Products

Looking ahead to Part C, an ISMP comprises three core technical products:

- ISMP Technical Product 1 **- Inventories** of the physical and biological systems
- ISMP Technical Product 2 **- Component plans** to protect the resources, resolve identified problems and accommodate land development and growth
- ISMP Technical Product 3 **-** An **implementation program** comprised of six elements:

✔ *Administration*	✔ *Community Education*
✔ *Projects, Phasing and Budgets*	✔ *Maintenance*
✔ *Financing Mechanism*	✔ *Performance Monitoring*

These three technical products generally parallel the three LWMP stages. The distribution of effort among the three products should be balanced. Often effort is concentrated on the inventory phase, and not enough effort is invested in the elements of an implementation program. The best plan, without a sound implementation strategy, can result in watershed conditions getting worse with time rather than better.

Input to Stormwater Component of Stage 1 LWMP

This is the stage where background information is gathered and the various options for resolving problems are explored. This includes identification of at-risk drainage catchments (refer to Chapter 4). The ISMP Technical Product 1 would be undertaken at this stage.

Input to Stormwater Component of Stage 2 LWMP

This is the stage at which a guiding philosophy for stormwater management is crystallized, policies are adopted and commitments are made to achieving performance targets (refer to Chapter 5) through integration with land use planning. Section 4.4 presents the elements of a policy framework to achieve integration.

This is also the stage at which options and/or approaches to stormwater management are studied in more detail in terms of cost and feasibility. This evaluation process should result in a final (one or two) best option(s) to advance to Stage 3. In short, ISMP Technical Product 2 could be a Draft Stormwater Plan within the overall LWMP.

Input to Stormwater Component of Stage 3 LWMP

This is the stage at which the stormwater component, as well as the overall LWMP itself, is finalized and adopted. The main focus is on developing an adaptive program that will enable local government to move from planning to action in an affordable manner (refer to Part C).

4.3 Relationship Between OCPs and LWMPs

There is a clear link between land use planning required of local governments in the *Local Government Act* (sections 944, 945) and waste management planning described in the *Waste Management Act* (part 1, section 16).

An OCP provides a clear statement to the public and the province about a local government's growth management objectives and provides the rationale for subsequent land use regulations.

An OCP Provides the Foundation for an LWMP

In most cases where OCPs are in place, the local government planning statement (bylaw) will form the basis of waste management plans. The purpose of an LWMP is to minimize the adverse environmental impact of the OCP and to ensure that development is consistent with Ministry of Water, Land and Air Protection objectives.

Local government land use planning is essentially a process of anticipating changes in land use and determining how to manage or influence these changes for the benefit of the community or region. In OCPs, local governments attempt to:

- Identify rural and urban development areas
- Assess the suitability of different areas for development
- Identify the expected sequence of urban and rural land development, including the proposed timing, location and phasing of sanitary and stormwater infrastructure

Where OCPs have been completed and adopted by bylaw, they should be used as a foundation for an LWMP.

LWMPs should be incorporated in total or in part as a schedule to an OCP. This will help to prevent land use decisions that eliminate or pre-empt future options for environmental management.

Take Whatever Step Comes First

In some cases, an LWMP process may be a trigger that focuses attention on stormwater management. Public concern related to flooding or habitat loss may be the trigger. Alternatively, an OCP public process may communicate public interest in raising local environmental and habitat protection standards.

Whatever the initial driver, at the end of the process a local government's Official Community Plan should include goals and objectives for stormwater management. These goals and objectives, or a variant of them, might first reside in a LWMP, and then be adapted to the OCP in the next review process. Or they may originate in the OCP process, and then be detailed through an LWMP. Either way is entirely acceptable.

The stormwater goals and objectives should be integrated into land use and growth management decisions that are embodied in the Official Community Plan, Regional Growth Management Strategy, and other local government bylaws.

The Link Between Land Development and Stream Protection

Local governments may consider directing growth away from sensitive areas, or zoning for land use that is compatible with stream protection. However, it is recognized that land use decisions are based on a broad range of considerations, among which stormwater is only one factor.

Where pre-existing land uses, or new designations, potentially impact sensitive watercourses, there will be a need to manage the development or re-development to meet a local government's goals and objectives for environmental protection and restoration.

The key to making land development compatible with stream protection is to apply appropriate stormwater source control strategies to reduce runoff volume and rate, as discussed in Chapter 7.

4.4 Stormwater Management Goals, Objectives and Policies

As discussed in Part A of the Guidebook, stormwater management and land use need to be integrated to address the source of stormwater-related problems. A critical step is to merge appropriate stormwater management goals, objectives and policies into a local government's OCP.

OCPs, and related Neighbourhood Plans, commonly set out broad goals, objectives and policies that guide implementation actions by local governments. Although OCPs do not bind a local government to a specific action, they prohibit the local government from acting contrary to the stated policies.

Establishing the right stormwater management policy framework and merging this framework with the OCP will ensure that land development decisions (at the planning and site design levels) address stormwater management objectives.

Case Study Example: Customizing a Framework

The City of Chilliwack's *Policy and Design Criteria Manual for Surface Water Management* (2002) includes stormwater management goals, objectives and policies that were developed through an inter-departmental and inter-agency process, which involved:

- City staff from both planning and engineering departments
- Representatives of senior government agencies (federal fisheries, provincial environment and agriculture ministries)

This process consisted of five working sessions where the core concepts of this Guidebook were presented to City staff and agency representatives. To provide context and relevance for participants, and to test the Guidebook concepts, local development projects were used as case study applications.

Outcome of Working Sessions

These sessions created a broad understanding of integrated stormwater management, which was the key to agreeing on:

- A stormwater management goal and a set of five related objectives
- A set of supporting policy statements to translate the goal and the objectives into action at three scales: the watershed, the neighbourhood and the site

The over-arching philosophy of the policy framework is that stormwater management and land use planning must be fully integrated to ensure complete solutions to stormwater-related problems.

This over-arching philosophy was endorsed through a series of working sessions with stakeholder focus groups, including:

- The Development Process Advisory Committee (representing the development community)
- The Agricultural Commission (representing the agricultural community)
- A Public Forum (representing the broader community)

Chilliwack's resulting stormwater management goals, objectives and policies are presented on the following pages. The detailed wording was refined through an iterative and interactive process with City staff and agency representatives.

Customizing Policies for the Local Situation

The goals, objectives and policies established through the Chilliwack process provide an example of what an appropriate policy framework could look like. However, each local government should adopt policies that reflect their individual situation, and that also reflect a long-term vision that is shared by all stakeholders (as discussed in Chapter 10).

Stormwater Management Goal
(for all watersheds in Chilliwack)

Implement integrated stormwater management that maintains or restores the Water Balance and water quality characteristics of a healthy watershed, manages flooding and geotechnical risks to protect life and property, and improves fish habitat values over time.

Stormwater Management Objectives

1. To manage development to maintain stormwater characteristics that emulate the pre-development natural watershed.

2. To predict the cumulative stormwater impacts of development and to integrate this information with other economic, land use and sustainability objectives and policies when considering land use change.

3. To regulate watershed-specific performance targets for rainfall capture, runoff control, and flood risk management during development, and to refine these targets over time through an adaptive management program.

4. To identify, by example and pilot studies, means of meeting the performance targets by application of best management practices, and to remove barriers to use of these practices.

5. To support innovation that leads to affordable, practical stormwater solutions and to increased awareness and application of these solutions.

These goals and objectives reflect the need for flexibility to account for variability in local conditions, and emphasize the importance of demonstration projects to prove the effectiveness of new approaches.

Each of these stormwater management objectives is supported by a set of policies. These are presented on the following pages.

Stormwater Management Objective #1

To manage development to maintain stormwater characteristics that emulate the pre-development natural watershed.

Supporting Discussion

Streams that are stable in their natural condition tend to become unstable after unmitigated urban development in the watershed, and become subject to instream erosion and sedimentation which impacts both flood risk and fish habitat.

These risks are often most pronounced in small catchments, which tend to be first order streams. This is because land use change may cause a high percentage change in impervious area in proportion to the size of a small catchment. This change results in a large change to flows in the stream, creating an unstable condition.

To avoid these impacts, it is necessary to mimic the characteristics of the pre-development hydrograph, including total flow volume, peak flows and hydrograph shape. Reaching this objective requires an integrated stormwater strategy that includes rainfall capture to reduce stormwater volume.

Changes in stream flow due to urbanization have greater impacts than changes in water quality, however, many of the best management practices (BMPs) that will provide rainfall capture and detention will also contribute to maintaining water quality.

Supporting Policies

1. Integrated stormwater management planning (ISMP) processes shall be undertaken to develop integrated master drainage plans (MDPs), first for the Chilliwack Creek Watershed, followed by the Hope River Watershed, and then the Sumas/Collinson Watershed.

2. Each master drainage plan shall develop a practical and affordable action plan for minimizing runoff volume, reducing both the rates and duration of peak flows, and sustaining baseflows.

3. Each action plan will integrate a practical and affordable strategy for protecting and/or improving water quality, and minimizing non-point sources of sediment and pollutant loading.

4. Within each watershed planning process, priority effort shall be focused in at-risk catchments, defined based on the risks of land use change in relation to the fisheries values and potential for flooding within the catchments.

5. For designated at-risk catchments, the City shall set stormwater performance targets and site design criteria based on site-specific rainfall and soils data.

6. Each master drainage plan shall include an adaptive management program to test and refine the stormwater performance targets and site design criteria over time, based on more detailed data collection, modeling, monitoring and analysis.

Stormwater Management Objective #2

To predict the cumulative stormwater impacts of development and to integrate this information with other economic, land use and sustainability objectives and policies when considering land use change.

Supporting Discussion

The stormwater impacts of land use change are incremental and cumulative. Land use decisions must be made with full awareness of both the incremental impacts of individual development projects and the cumulative impacts of building out existing zoning.

The guiding principles for integrated stormwater management should influence the details of land use and site planning.

Stormwater is one of many factors to be considered in land use decisions, but stormwater objectives will often be compatible with other development objectives.

Supporting Policies

1. When considering changes to its OCP or zoning bylaws, the City shall assess the cumulative impact of proposed development on stormwater flows and fish habitat and the potential for mitigation of these impacts through establishment of performance targets and application of best management practices.

2. The City will consider use of density bonus provisions to encourage more green space for developments in designated at-risk catchments.

3. For areas where the City has not yet established stormwater performance targets, applications for significant changes to OCP land use designations or zoning shall be required to include a stormwater management strategy with:

(a) a statement of cumulative impacts of stormwater on the receiving watershed and sub-catchment

(b) application of science-based performance targets for rainfall capture, runoff control and flood risk management

Stormwater Management Objective #3

To regulate catchment-specific performance targets for rainfall capture, runoff control, flood risk management, and water quality protection during development, and to refine these targets over time through an adaptive management program.

Supporting Discussion

Chapter 5 provides background information on the need for, role and basis for performance targets, and shows how to:

(a) set preliminary performance targets for rainfall capture, runoff control, flood risk management

(b) set up an adaptive management program for improving these preliminary targets over time.

Performance targets should be customized to each drainage catchment because the conditions, constraints, problems and opportunities will vary from one catchment to another (e.g. different rainfall characteristics, pattern of streams and lakes, drainage infrastructure, soil characteristics and development patterns). Appropriate strategies for meeting rainfall capture and runoff control targets will depend on local conditions, as illustrated by the following examples:

Example 1: Where there are few constraints to infiltration, and little space for community detention, both rainfall capture and runoff control may be handled by small-scale storage and infiltration systems on individual development parcels.

Example 2: Where infiltration opportunities are limited, more rainfall capture may be achieved by water re-use combined with some on-site infiltration. Runoff control would be then provided by community detention facilities, rather than on-parcel.

(Chapter 7 provides guidance for selecting stormwater source control practices are most appropriate for different land use types, soil conditions and rainfall characteristics).

Supporting Policies

1. Rainfall capture facilities that meet the rainfall capture performance targets must be provided for all new developments in designated catchments. Preference shall be given to water re-use and/or infiltration systems, backed up by small-scale storage facilities as required to support the re-use or infiltration rate of the site soils, where feasible.
2. Where site infiltration rates allow, runoff control performance targets may be met by increasing the storage capacity of rainfall capture facilities. In cases where on-site soils are not suitable, constructed wetlands (for drainage areas over 10 acres) or detention ponds (for smaller drainage areas) shall be provided to meet the runoff control performance targets.
3. In cases of new development, adequate conveyance routes for major storms shall be provided to meet the flood risk management performance targets.
4. For each designated catchment, as affordable, the hydrologic and water quality performance of representative rainfall capture and runoff control facilities shall be monitored, and the performance targets shall be adjusted for future development based on the monitoring results.
5. For each designated catchment, as affordable, early warning indicators shall be monitored to determine how well site level actions are maintaining or restoring a healthy catchment.

Stormwater Management Objective #4

To identify, through demonstration projects, means of meeting the performance targets by application of best management practices, and to remove barriers to use of these practices.

Supporting Discussion

The performance targets are intended to set minimum requirements, while allowing flexibility for applicants to be innovative and cost-effective in meeting the target.

The flexibility of this approach will be attractive for projects with sophisticated design teams.

However, during the learning curve associated with the performance standards, and for small projects, or those that do not normally involve a design team (e.g. a single family dwelling), there is a need for a set of examples that show how the performance targets can be met in a practical and affordable way.

Supporting Policies

1. The City will devise and maintain a manual of best management practices that illustrate how performance targets may be achieved.

2. Local demonstration projects will be encouraged on City land and private land to increase public and developer understanding of the best management practices, and to test their performance.

3. The City will review its existing bylaws to identify and remove clauses that would act as a barrier to the proposed best management practices. Refer to Part A for more detail.

Stormwater Management Objective #5

To support innovation that leads to affordable, practical stormwater solutions and to increased awareness and application of these solutions.

Supporting Discussion

New best management practices, and variations to existing practices, are constantly being developed. There is a need for a system that can adapt to this constant change.

There will also be a need for technical training of staff and the development community. This training will need to be updated and repeated to reflect new information and new participants.

Supporting Policies

1. Applicants shall be encouraged to propose alternative solutions to meet the performance targets, subject to the approval of City staff.

2. Educational events and training media shall be supported in co-operation with senior governments and other local governments.

4.5 Policy Transition in a Rural Regional District

Case Study Example: A Five-Year Stormwater Management Program

The Regional District of Nanaimo is entering a transition from having no role in stormwater management to playing a more active role, by creating a five-year Stormwater Action Plan.

This case study illustrates how a rural regional district is making the policy transition to such an active role.

Enhancing the Stormwater Component of an LWMP

The Regional District of Nanaimo (RDN) created a voluntary LWMP in 1997. The focus of the Plan was on wastewater treatment. The Plan was approved by the (then) Minister of Environment, Lands and Parks.

With the written encouragement of the Minister, the RDN proceeded to upgrade the stormwater management components of its Phase 3 LWMP in 2001.

To accomplish this task, the RDN partnered with the (current) Ministry of Water, Land and Air Protection and the Georgia Basin Ecosystem Initiative to develop a five-year Stormwater Action Plan.

The Need for Stormwater Management in Rural Regional Districts

To date the emphasis of stormwater planning in the RDN has been within the member municipalities of Nanaimo, Parksville and Qualicum Beach. While most of the RDN is resource land in forestry uses, there are extensive areas at lower elevations in the electoral areas that are developed. This development has created changes in stormwater flows and water quality, when compared to natural forested watersheds. Common changes resulting in altered flows and water quality are listed in Table 4-1.

Many of the land use changes identified in Table 4-1 do not create significant stormwater problems if the amount of change is small. However, the impacts are cumulative; as more land use change and densification occurs, stormwater impacts become more significant if they are not mitigated.

Table 4-1: Land Use Changes with Potential to Affect Stormwater Quantity and Quality	Agriculture and Acreage	Single and Multi Family Residential	Industrial, Commercial and Institutional
Removal of forest cover	X	X	X
Installation of open ditches or underdrainage	X	X	X
Removal of seasonal or permanent wetlands	X	X	X
Soil erosion during construction	X	X	X
Soil erosion from fields (if winter cover crops are not used)	X		
Introduction of chemical nutrients and pesticides	X	X	X
Application of manure	X		
Removal or compaction of absorbent soils in landscape areas		X	X
Paving of roads, streets, driveways, parking and yard areas and patios	X	X	X
Roof area drainage	X	X	X
Introduction of chemical pollutants, either as non-point-source runoff, or as point source pollution such as spills, accidents, and outflows	X	X	X

Stormwater Role for RDN

The RDN had a variety of reasons for deciding to take on a more active stormwater planning role, including:

1. Stormwater impacts will increase unless mitigated.

As land development in the electoral areas increases, stormwater impacts and related risks of flooding, property damage and degradation of aquatic ecosystems will increase.

2. Fish, shellfish and clean water are a part of the RDN's heritage and economic resources.

The RDN is bestowed with many productive salmon bearing streams and shellfish beaches. The lifestyle of its residents and the reputation of the region are enriched by these resources. Managing stormwater is a part of maintaining quality of life and attractiveness as a place for tourists and new residents.

3. Stormwater planning in electoral areas is not being done.

In many cases, stormwater planning can not be done efficiently for individual developments, since both the stormwater impacts and solutions involve large areas outside an individual site. Stormwater planning by the RDN can provide economy of scale. In addition, there is no other agency that provides watershed-scale stormwater planning in electoral areas. The stormwater activities of the provincial Ministry of Transportation and Highways are limited to drainage associated with roadways.

4. Many stormwater impacts can be avoided.

With proper stormwater planning and land development practices, mitigation of many stormwater impacts can be achieved. Since the RDN manages land use (other than agriculture and forestry), it has better tools than other agencies to address stormwater planning associated with land use development.

5. Stormwater planning now can avoid future public expense.

Unmanaged stormwater often leads, eventually, to major public expense in infrastructure to solve flooding or erosion problems, sometimes driven by litigation. Planning ahead can find less expensive solutions, minimize public expense by solving stormwater problems at the source – the development - and provide for financial mechanisms to fund stormwater infrastructure where it is necessary.

6. Stormwater flows across jurisdictions and land uses.

There are several cases in BC where successful litigation has been brought by farmers with flooded fields due to unmitigated upstream urban development. And there are cases like Walkerton, Ontario, where farm drainage has had a drastic impact on drinking water supply and human health. As municipalities in the Regional District of Nanaimo undertake stormwater management and drinking water projects, there is both an opportunity and a need for the RDN to plan co-operatively, especially where watersheds cross jurisdictional boundaries.

The promise of stormwater planning is that mitigation of many stormwater impacts can be achieved by management of the way that land is developed.

Focusing Rural Stormwater Planning Efforts

The proposed RDN Stormwater Action Plan will focus on stormwater education and co-ordination throughout the region, and stormwater planning in electoral areas. Emphasis will be on managing urban development to mitigate stormwater quantity problems, and on managing related non-point source pollution.

The need for stormwater management will vary within different areas of the RDN. For example, areas of the region that are not yet developed will not have urban stormwater concerns, and timber harvesting areas of the region are administered by the Province.

Two Levels of Effort

The RDN stormwater management program will have two levels of effort:

- **Integrated Stormwater Management for At-Risk Catchments:**

  The focus of stormwater management in the RDN will tend to be rapidly developing areas. A pilot study has identified at-risk drainage catchments (catchments where conditions combine existing and/or pending urban development with high risks of either drainage problems and/or environmental impacts). These at-risk catchments will be an opportunity for the RDN to test integrated stormwater management approaches.

  Integrated stormwater management means planning that recognizes the relationships between land use planning, stormwater quantity and quality, and environmental factors, creating a plan that balances all three for optimum results.

  It is possible that stormwater solutions in at-risk drainage catchments will require investment in public stormwater facilities.

- **Basic Stormwater Management for Other Developments and Agricultural Areas:**

  Outside of the at-risk catchments that require intensive planning, the RDN will take a proactive approach to basic stormwater management throughout its jurisdiction to avoid future public costs due to cumulative impacts of development. Basic stormwater BMPs and performance targets will be applied in all land uses and densities.

  For example:

  - Poorly designed developments may create unnecessary increases in runoff, resulting in flooding and downstream impacts and creating new at-risk drainage catchments over time with resulting taxpayer expense.
  - Water quality issues, like lack of erosion control during the construction period, are issues throughout the RDN.
  - Agricultural areas of the RDN may also have a need for basic stormwater management. Although agricultural areas are generally administered by the Province, there are potential stormwater impacts from agricultural drainage on downstream urban or fishery areas. Unmitigated urban development can also have dramatic flooding impacts on downstream agriculture.

  The basic stormwater management program will create public education programs, as well as broadly applicable regulations that will influence the way that private land is developed, with the intent to minimize the need for public investment in stormwater facilities.

Management Arrangements

Management arrangements in the RDN's stormwater management program include:

- Management of potential pollutants near drinking water sources should be the subject of a separate program.
- Regulation of forestry and agricultural practices is under the jurisdiction of the Province of British Columbia. The RDN will be cognizant of resource and stormwater planning by related Provincial agencies.
- The RDN will co-operate with its member municipalities to offer economy of scale in provision of stormwater information, and will support joint planning when stormwater issues cross electoral area or municipal boundaries.
- Drainage catchments that may already be impacted as the result of existing development may be the subject of stewardship and restoration efforts, often in co-operation with non-government organizations.

An Action Plan for the Transition to Stormwater Management

The RDN has opted for a gradual entry into an active stormwater management role. It will take several years to increase public awareness of stormwater issues and solutions and to determine an appropriate role and funding mechanism for stormwater management on lands within its jurisdiction.

While being methodical about entering stormwater management, it is also important that the RDN put stormwater management tools in place as soon as possible, so that further land development without stormwater mitigation does not occur at a large scale.

A five-year Stormwater Action Plan is proposed to allow the RDN to carefully plan its role in stormwater management. Table 4-2 provides an outline of the Plan.

Each Year will have a Focus

Implementing the Action Plan will be subject to approval of general stormwater program funding. Once started, each year in the Stormwater Action Plan has a focus:

Year One Focus: Getting Started

Year Two Focus: Revise Infrastructure Standards

Year Three Focus: Develop Training and Public Awareness Programs

Year Four Focus: Implement Actions

Year Five Focus: Review and Adjust Action Plan

The Action Plan allows for effective public consultation, outreach and training for the development community, demonstration projects, incentives, and co-operation with other levels of government and the private sector.

Regulatory Change

Careful consideration will be given to regulatory change – first, to remove barriers in existing regulations to better stormwater management, and second, to consider to what extent existing regulations should be refined (e.g. zoning and subdivision bylaws).

It is also envisioned that stormwater issues and policies would be considered as each Official Community Plan undergoes a regular review.

Transfer of Approval Powers from the Ministry of Transportation and Highways

The potential transfer of subdivision approval powers from the provincial Ministry of Transportation and Highways to rural regional districts may also provide a trigger for implementing stormwater management in the RDN. In the meantime, the Ministry is open to encouraging better stormwater performance in development applications, provided that the approach does not increase the costs to the Province of BC.

Updating of Action Plan

Adopting the Action Plan does not commit the Region to ongoing funding mechanisms. These will be considered as a part of the Action Plan process, with the intent that the RDN designs a practical and affordable system to address stormwater issues.

At the end of the five-year Action Plan, the RDN will have developed a clear understanding of appropriate stormwater management approaches that are customized to the local environment and acceptable to the development community.

It is envisioned that in the fifth year of the Action Plan, a new plan will be created for the following five year period or longer, based on the needs, opportunities and priorities that are apparent at the time. The Stormwater Action Plan is intended to be updated every five years as the program moves ahead.

Table 4-2: Regional District of Nanaimo Stormwater Action Plan

Priority	Projects	Lead Role	RDN Budget	Potential Additional Funding
1	**YEAR ONE FOCUS: GETTING STARTED**			
	Adopt the Stormwater Action Plan			
	Create introductory information and public outreach materials			
	Identify priorities and budget for RDN stormwater management planning in at-risk drainage basins, in consultation with member municipalities			
	Design and adopt stormwater funding and administrative mechanisms (e.g. region-wide service area for research, coordination, planning and public awareness; specific local service areas for capital and operating projects as required)			
2	**YEAR TWO FOCUS: REVISE INFRASTRUCTURE STANDARDS**			
	Participate with others (e.g. member municipalities) to create technical information materials on low impact stormwater standards and BMPs – print / web / video			
	Review existing bylaws and remove barriers to low impact standards and BMPs for better stormwater management			
3	**YEAR THREE FOCUS: DEVELOP TRANING AND PUBLIC AWARENESS PROGRAMS**			
	In partnership with member municipalities, train staff, developers, builders, NGOs and the public on low impact stormwater standards and BMPs			
	Consider need for, and design draft stormwater clauses including performance targets and example details as potential amendments to RDN bylaws in co-operation with appropriate provincial and federal agencies			
	Consider stormwater impacts as a factor in regular Official Community Plan or zoning reviews and amendments			
4	**YEAR FOUR FOCUS: IMPLEMENT ACTIONS**			
	If applicable, amend bylaws to include new stormwater clauses			
	In co-operation with member municipalities, senior governments and the private sector, complete demonstration BMP installation projects			
	For an at-risk watershed, complete an Integrated Stormwater Management Plan as a pilot project towards the creation of a stormwater local service area			
5	**YEAR FIVE FOCUS: REVIEW & ADJUST ACTION PLAN**			
	If appropriate, proceed to implement stormwater local service area			
	Create an awards program that recognizes excellence in stormwater management			
	Review the status and success of the Action Plan			
	Prepare an updated five-year Action Plan			

Administering the RDN Stormwater Management Program

The RDN is considering the funding of stormwater management at three levels:

Level One - Stormwater Public Facility Construction and Maintenance for at-risk catchments could be funded by a local service area approach. This would fund the capital and operating costs of public facilities related to the benefiting taxpayers. A local service area is established by a bylaw that describes the service, identifies the boundaries of the service area along with the municipalities and electoral areas that include participating areas, and sets out the costs and means of cost recovery for the service. If the local service area requires borrowing, the bylaw must receive the approval of affected voters.

Level Two - Basic Stormwater Planning and Public Awareness for the entire RDN would be funded through a region-wide service area or a stormwater utility. A relatively low investment per taxpayer could provide funding for the shared aspects of basic stormwater management. Shared aspects could include dissemination of public information, monitoring of risks, stormwater research and planning and regulation.

The basic stormwater management funding program may include identification of integrated stormwater planning for at-risk drainage catchments. By having this planning funding provided by the region-wide service area, sufficient information will be available for voters to consider specific capital and maintenance works to be funded through specific local service area initiatives.

Subject to legal review, a region-wide service area for stormwater management may be established through either the LWMP process or by the assent of the electors by either vote or counter petition opportunity.

As an option, a stormwater utility could also fund stormwater planning, works and services by fees and charges established under S. 363 of the *Local Government Act*. The Board may base the fee or charge on any factor specified in the bylaw, including by establishing different rates or levels of fees in relation to different factors such as parcel imperviousness.

Level Three - Regulation of Land Development provides a third form of funding for stormwater management. It is standard practice that rezoning or subdivision applications above a certain minimum size are required to provide stormwater works and services, since mitigation of stormwater impacts is a legitimate cost of development. This source of funding works well for larger, new developments, especially in greenfield situations.

Stormwater improvements may be paid for directly by the developer, or may be funded by development cost charges which pool funds for public projects that are made necessary by the development. The requirements for this type of developer-funded stormwater planning and stormwater works should be included in regional district bylaws.

Requirements may be added to regional district bylaws and administered in tandem with the Provincial Approving Officer of the Ministry of Transportation and Highways, or could be applied directly by the regional district if the subdivision approving function were held at the regional district level. However, in cases where substantial development or development approvals already exist, and the new development is small-scale densification or infill, there will be a need for stormwater planning to be funded by the regional district.

Partnerships for the RDN Stormwater Management Program

There are several agencies that could partner with the Regional District of Nanaimo to support implementation of the basic stormwater planning program:

- Member municipalities, for economy of scale in producing public outreach and technical information materials
- The provincial Ministry of Community, Aboriginal and Women's Services, through planning grants for planning and bylaw changes
- The Canada-BC Infrastructure Program, for design and capital assistance
- The Georgia Basin Ecosystem Initiative, for ongoing support of pilot and implementation programs
- The Federation of Canadian Municipalities Green Municipal Enabling Fund and related funds

Setting Priorities for Early Action

Chapter Five

5.1 Knowledge-Based Approach

Stormwater management may be driven by expressed goals, objectives and policies as outlined in Chapter 4, or it may be driven by evolving crises on the ground, or both. In either case, a key step for any municipality or regional district undertaking a stormwater planning process is to set priorities for action.

Setting priorities for action should be at two scales:

- **At the regional scale** – deciding which watersheds are priorities
- **At the watershed scale** – deciding which tributary drainage catchments to focus on within priority watersheds

Overview

This chapter presents a methodology for prioritizing action that focuses on low-cost results by getting the right people together in working sessions. This 'knowledge-based' approach contrasts with one that starts with extensive raw data collection and sophisticated mapping.

If the right people with the right knowledge are involved at the start, a knowledge-based approach will be both time-efficient and cost-effective. This combination should translate into cost savings that can be applied to stormwater solutions in the field.

There are many approaches to setting priorities, ranging from data-collection-intensive to knowledge-based. In regions where some watershed areas are at high risk, and others may not yet be priorities, the use of a knowledge-based approach to distinguish those catchments requiring early intervention can be an efficient way to initiate action where it is needed the most to avoid or mitigate stormwater threats.

As stormwater management actions are implemented, more rigorous long-term data collection through a monitoring program is appropriate to allow adaptive management of stormwater solutions.

5.2 At-Risk Methodology

The *At-Risk Methodology* (ARM) creates an early focus on areas that may need priority attention to avoid pending stormwater impacts.

Priority action should be focused in at-risk drainage catchments where there is both high pressure for land use change and a driver for action. The latter can be either:

- a high-value ecological resource that is threatened, or
- an unacceptable drainage problem

It is important to focus on areas of land use change because this is where problems can be turned into opportunities. Land use change is the root cause of stormwater's ecological and property impacts, and this root cause can be eliminated through land development practices that reduce the volume and rate of runoff at the source. Local governments also usually have jurisdiction over, and focus their attention on, areas experiencing land use change.

Integration of Knowledge

In order to identify at-risk drainage catchments it is important to integrate knowledge from each of the planning, ecology and engineering disciplines:

- **Planning** – to identify where the areas are with high pressure for land use change
- **Ecology** – to identify where there are significant aquatic resources.
- **Engineering** – to identify where there are chronic drainage problems

The integration of this information through discussion and brainstorming in an interdisciplinary roundtable process will enable the identification of at-risk drainage catchments – those where future land use change threatens to degrade high-value resources or exacerbate drainage problems.

Identification of Priorities

The result of the foregoing process will be identification of priority drainage catchment areas for stormwater planning and action. The top priority drainage catchment is particularly significant because of its potential to act as a demonstration project for remaining watersheds to demonstrate how:

- profitable land use can proceed while preventing stormwater-related problems
- land development practices that reduce runoff at the source can protect aquatic habitat and property from stormwater related impacts

By monitoring the performance of demonstration projects, land development and stormwater management practices can be improved over time for remaining watersheds.

Introduction to the Interdisciplinary Roundtable Process

The most effective and affordable way to identify at-risk watersheds for priority action is to tap the knowledge of people within any regional district or municipality who have the necessary planning, ecology and engineering knowledge. This can be accomplished through an interdisciplinary roundtable process that integrates planning, engineering, and ecological perspectives from the very beginning of a stormwater planning process.

The inputs and outcomes that define the interdisciplinary roundtable process are conceptualized in Figure 5-1. The knowledge-based mapping products from three focused working sessions (land use, ecology and engineering) feed into an interdisciplinary roundtable. This roundtable is where representatives from the three focused working sessions overlay key information on future land use, aquatic resources and drainage problems to identify at-risk drainage catchments and prioritize action.

The interdisciplinary roundtable is especially appropriate for a jurisdiction that has multiple watersheds. It need not be, and should not be, a lengthy process, especially if the goal is to achieve early action. The objective is to make initial decisions based on informed judgement.

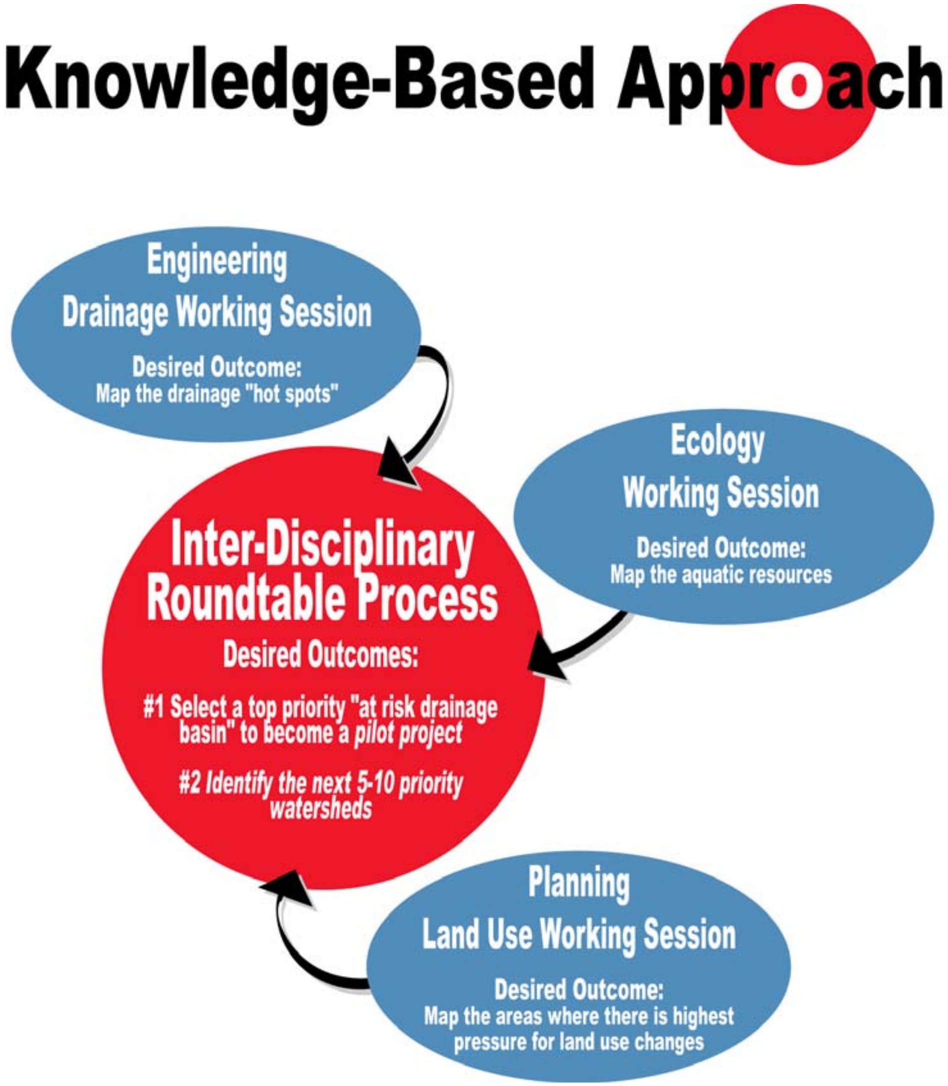


Figure 5-1

Timely Decision Making

Key decisions can be made in a relatively short period of time if:

- **The working session is focused on achieving a specific desired outcome –**

  For example, the desired outcome could be the selection of a top priority at-risk drainage catchment to focus early action. Once action is implemented, this catchment will become a demonstration project for remaining watersheds. A secondary desired outcome would be to identify the next 5 to 10 (say) priority watersheds to provide guidance for the longer-term stormwater management program.

- **The information that is key to achieving the desired outcome is presented -**

  The focused working sessions should produce overall maps of the stormwater planning region, highlighting the areas where:

  - there is the greatest pressure for land use change
  - ecological resources are concentrated or threatened
  - chronic drainage problems (i.e. 'hot spots') occur

  The overlay of this information allows an assessment of drainage catchment risk, which provides a focal point for action.

The focused working sessions should follow these same principles in order to ensure the entire process is effective and affordable.

Focused Working Sessions

The working sessions on land use, ecology and engineering are the foundation of the whole process for identifying at-risk drainage catchments and prioritizing action. For each of the focused working sessions it is important to identify the key participants, desired outcomes and technical information that could be presented at the working sessions to help achieve the desired outcomes. Table 5-1 summarizes this information.

It is recognized that many jurisdictions may not have access to all of the technical information suggested in Table 5-1. Not all of the listed technical information is necessarily required to make informed decisions. The success of the process depends mainly on the local knowledge and experience of working session participants. In the absence of hard data, it is acceptable to substitute value judgements that are knowledge-based.

Table 5-1 Structure for Focused Working Sessions

	Land Use Working Session	Drainage Working Session	Ecology Working Session
Desired Outcome	An overall map of the stormwater planning area (regional district or municipality) showing the areas where there is greatest pressure for future land use change	An overall map of the stormwater planning area (regional district or municipality) showing drainage 'hot spots'	An overall map of the stormwater planning area (regional district or municipality) showing aquatic habitat and species distribution
Key Participants	People who have knowledge about future land use change, including: ▪ planning staff representing all jurisdictions within the regional district or municipality ▪ First Nations ▪ representatives from the development community	People who have knowledge about drainage problems, including: ▪ engineering staff representing all jurisdictions within the regional district or municipality ▪ operations and maintenance staff from all jurisdictions ▪ community ratepayer associations	People who have knowledge about aquatic habitat and species, including: ▪ parks and environment staff representing all jurisdictions within the regional district or municipality ▪ representatives from senior government agencies (WLAP, Fisheries and Oceans Canada, Environment Canada), including habitat biologists and water quality specialists ▪ representatives from local stream stewardship groups and First Nations
Technical Information	Base maps or GIS layers showing key information that affects future land use change, including: ▪ OCP land use designations ▪ zoning polygons ▪ cadastral (lot) boundaries ▪ growth management strategies ▪ existing land cover characteristics, particularly impervious areas (air photos can provide this information) ▪ current development proposals ▪ limits of utility servicing or 'septic suitable' soils This information should be combined with maps showing watershed and sub-catchment boundaries. It would also be useful to assemble air photos showing existing and historic land use patterns in order to provide a perspective on past development patterns.	Base maps or GIS layers showing key factors that influence drainage problems, including: ▪ layout of existing drainage system (storm sewers and creeks) ▪ location of stream crossings, culverts and storm sewer outfalls ▪ location of known flooding incidents or other drainage-related problems ▪ floodplain mapping This information should be combined with maps showing watershed and sub-catchment boundaries. It would also be useful to provide air photos that show existing land uses.	Base maps or GIS layers showing key information that affects aquatic habitat and species, including: ▪ vegetation mapping, particularly for riparian areas ▪ watercourse classification and data, including fish presence ▪ relevant water quality data ▪ sensitive ecosystem polygons ▪ soils mapping ▪ floodplain mapping This information should be combined with maps showing watershed and sub-catchment boundaries. For certain regions, considerable biophysical mapping has already been done by senior government agencies.

5.3 Case Study: Stormwater Priorities in the Regional District of Nanaimo

The Regional District of Nanaimo (RDN) is typical of many rural/suburban regional districts in British Columbia. The majority of the regional district is in forestry uses, with growing pockets of agriculture and urban land uses at lower elevations.

Stormwater management activities to date have been concentrated in the member municipalities of Nanaimo, Parksville and Qualicum Beach. These activities have been primarily drainage-focused, and the RDN has not played a significant role in their delivery. Furthermore, there has been little planning for stormwater management in the electoral areas, other than that associated with road drainage.

Since there are development areas in the regional electoral areas that include urban densities of residential, commercial and industrial land uses, there are already stormwater impacts that likely require attention within the RDN. Stormwater issues will be exacerbated by projected urban growth increases in parts of the electoral areas.

Watersheds in the RDN

There are an estimated 50 watersheds within the developed areas of the RDN.

If a stormwater program were to commit to developing Integrated Stormwater Management Plans (ISMPs) for each of these watersheds, the program costs would be high, and political acceptance in this largely rural area would be problematic. Further, the benefits of such a comprehensive program would be limited for the RDN, because many of these watersheds are not at risk of urban stormwater impacts. In addition, the RDN does not have jurisdiction over forestry or agriculture land uses.

Clearly, rural regional districts like the RDN need to set priorities for stormwater planning that focus their efforts. The At-Risk Methodology was applied in the RDN as a means of determining these priorities.

Workshop Structure and Methodology

In general, the RDN followed the workshop structure and methodology outlined in this chapter, with one exception. Whereas the Land Use Workshop was held as a separate event, the Drainage and Aquatic Habitat Workshops were combined into a single event, for sake of time and cost efficiency and to allow for effective communication among the various disciplines involved in the process.

Land Use Workshop

Invited guests to the Land Use Workshop, in addition to members of a steering committee, included:

- Planners from the RDN
- Planners, Engineers and Approving Officers from member municipalities
- Approving Officers from the Ministry of Transportation and Highways
- Representatives of the Real Estate Board and local development associations
- Representatives of local agriculture associations

The agenda for the workshop included a review of stormwater management concepts, and the general context and objectives of the stormwater planning process.

General mapping provided at the workshop included watershed boundaries overlaying recent airphoto information, as well as cadastral and land use designations.

Identification of Land Use Change

Within this general context, participants were asked by a facilitator to identify areas in the RDN where rapid land use change was expected over the next 10 years. Specifically, participants identified areas where:

- urban development is anticipated
- zoning for 1 hectare (2.5 acre) parcels or smaller is in place but not yet built out
- utility servicing for such zoning is in place or imminent

- such land use change overlays a large portion of a drainage basin (two-thirds or more)
- time permitting, the group was also asked to identify areas of substantial expected re-development, as well as areas where lower density developments might be expected to have stormwater impacts

To record the information put forward by the group, the facilitators applied 'post-it' notes to the maps with notations. The group identified approximately twenty-one areas of rapid land use change in a half-day workshop.

Of these twenty-one areas, ten were eliminated from further consideration by the RDN since they were located entirely within the boundaries of member municipalities. The remaining eleven areas were summarized and forwarded to the Drainage and Aquatic Habitat Workshop.

There was considerable information exchange among the group, with many participants learning of pending land use changes for the first time.

Drainage and Aquatic Habitat Workshop

In the interest of time, the Drainage and Aquatic Habitat Workshops were combined into a single event.

In addition to the steering committee, invited guests for the Drainage Workshop component included:

- Engineers from the RDN
- Engineers from member municipalities
- Approving Officers and Operations Managers from the Ministry of Transportation and Highways
- Engineers from the Ministry of Water, Land and Air Protection
- Representatives of local agriculture associations
- Representatives of local consulting engineering firms

Invited guests for the Aquatic Habitat Workshop component included:

- Habitat Biologists and Water Quality Biologists from WLAP
- Habitat Biologists and Researchers from Fisheries and Oceans Canada
- Biologists from Environment Canada and the Canadian Wildlife Service
- Environmental Planners from member municipalities
- First Nations
- Representatives of local environmental consulting firms
- Representatives of local stewardship organizations, including land trusts, field naturalists and streamkeepers

The agenda for the Drainage and Aquatic Habitat Workshop included a review of stormwater management concepts for new participants, the general context and objectives of the stormwater planning process in the RDN, and the results of the Land Use Workshop.

Mapping was presented that showed the eleven candidate study areas that resulted from the Land Use Workshop in more detail. The mapping illustrated the extent of proposed land use change overlaid on watershed drainage boundaries and airphotos. In particular, mapping was used to identify land use changes that would cover a large proportion of a small drainage basin. Percentages of this expected cover were estimated. Maps also showed available information on drainage sub-catchment boundaries and watercourses.

Identification of Areas at Risk

Within this general context, participants were asked by a facilitator to review and comment on drainage or habitat risks related to the eleven candidate areas. Specifically, for each of the candidate areas, participants identified:

- areas of high risk for drainage-related problems like flooding or instream erosion and sedimentation
- risks to existing or potential fisheries and aquatic resources

After the identification of risks, participants were asked, as individuals, to rank the candidate areas by priority for integrated stormwater management (from 1 as highest to 11 as lowest). Tabulation of the results has provided the RDN with a sense of priority areas on which to focus. The next step for the RDN will be to develop an ISMP on some of these priority catchments. For a detailed discussion on developing an ISMP, refer to Chapter 10.

Reporting Results and Follow-Up Questionnaire

A third workshop was held to report the results of the process back to the participants.

This important step allowed for a presentation of the results in context along with the draft RDN five-year Stormwater Action Plan. The workshop allowed for discussion among the participants about the process and the results, and was especially important for discussion of minority opinions.

The RDN also distributed a follow-up questionnaire to confirm acceptance of the process and the results.

Strengths and Limitations of the At-Risk Methodology

The At-Risk Methodology was useful and successful for the RDN. The great majority of participants felt that it was appropriate and effective for making decisions about priorities. Strengths of the process include:

- low cost
- relative speed of decision making
- effectiveness of the process for selecting priorities and moving towards action without undue delay

Limitations of the process are:

- accuracy of the process relies on the level of knowledge of individuals participating
- subjective nature of the process can leave it open to challenge by competing interests

Building Support Through the Interdisciplinary Roundtable Process

A key byproduct of the At-Risk Methodology is the transfer of information among the participants.

It is a rare occasion that brings together into one room the key planning, engineering and environmental professionals and non-government organizations from across a region.

The RDN Interdisciplinary Roundtable provided a key opportunity for presentation of current stormwater management concepts to this interdisciplinary group. See Section 5.3 of this chapter for related information. The participants were able to understand and discuss how integrated stormwater management would involve co-operative effort.

Communication with the Interdisciplinary Roundtable should not end with the conclusion of the At-Risk Methodology. The communication and access to expertise that was established will be very important throughout the stormwater management process, including at both the neighbourhood and site planning scales when more detailed decisions become necessary.

A Look Ahead

As the RDN moves toward approval and implementation of its Stormwater Action Plan, the understanding created among professionals in the region through the At-Risk Methodology process will provide an important foundation for future success.

5.4 The Role of Mapping

Mapping the right information can provide a valuable tool to support decision making. However, mapping itself does not make the decisions; people make decisions. This is a distinction that often seems to be overlooked.

Keeping it Simple

Information presented must be directly relevant to the desired outcome of the working session. Maps should help participants achieve the desired outcome rather than divert attention away from it. This is particularly important for the Interdisciplinary Roundtable, where different types of information are integrated.

The maps of land use change, aquatic resources and drainage 'hot spots' produced as a result of the focused working sessions should only present the information needed to identify at-risk drainage basins. Ideally, there should only be three maps presented at the Interdisciplinary Roundtable, each one a distillation of the more detailed mapping presented at each of the three focused working sessions.

Graphic Overlay versus Geographic Information System (GIS)

The focused working sessions and the Interdisciplinary Roundtable rely on the overlay of maps with key information. This can be accomplished using:

- graphic overlay maps, or
- GIS ArcView layers

Both options will achieve the same basic objective, which is to illustrate the relationship between different types of information. While the data linkage and query options available with GIS provide greater opportunity for analysis, they also require greater time investment.

Use of Graphic Overlays

Relevant relationships may be obvious from a review of map overlays, and this may provide a more affordable analysis that is of equal effectiveness to the GIS data query. This is particularly true for the Interdisciplinary Roundtable, where the emphasis should be on simple maps that present only the relevant information. It will likely be obvious where areas with high pressure for land use change overlap areas with high habitat value or drainage 'hot spots'.

For smaller regional governments in particular, there is a likelihood that lack of GIS resources and training will lead to stormwater inertia if too much reliance is placed on technical sophistication in GIS.

Application of GIS

For jurisdictions that do have access to GIS, it provides a good tool for keeping accurate records of effective impervious area (EIA), which is a key determinant of watershed health. Using GIS, the EIA of each new development or retrofit area could be recorded at the subdivision or building permit stage. In this way an accurate record of EIA can be established over time. Airphoto or map interpretation methods cannot record EIA because they cannot differentiate impervious area that is hydraulically disconnected.

Setting Performance Targets and Design Guidelines

Chapter Six

6.1 The Role of Performance Targets

Performance targets provide the foundation for implementing common sense solutions that eliminate the source of stormwater related problems. This chapter presents a cost-effective framework for local governments to:

- establish performance targets that reflect science-based understanding to guide early action in at-risk catchments (see Chapter 5)
- translate these performance targets into design criteria and guidelines that can be applied at the site level to design stormwater systems that mitigate the impacts of land development

Performance targets provide a starting point to guide the actions of local government in the right direction. Site design criteria provide local government staff and developers with practical guidance for moving from planning to action.

For a performance target to be implemented and effective, it must be quantifiable. It must also have a feedback loop so that adjustments and course corrections can be made over time. To be understood and accepted, a performance target needs to synthesize complexity into a single number that is simple to understand and achieve, yet is comprehensive in its scope. A runoff volume-based performance target fulfils these criteria. This chapter presents a methodology for setting volume-based performance targets.

Volume-based thinking is an integral element of a paradigm-shift that views watersheds as a fully integrated system where creek headwaters originate at rooftops and roads. Looking ahead to the GVRD case study results presented in Chapter 7, the implications are far-reaching because a volume-based approach to stormwater management touches on virtually every aspect of land use planning and site design. Volume-based thinking leads directly into landscape architecture, green roofs, urban reforestation, interflow and groundwater recharge, and water re-use.

Constant Improvement through Adaptive Management

Performance targets and design criteria provide a basis for:

- integrating appropriate stormwater management policies with land use and community planning (see Chapter 4)
- selecting appropriate site design practices to reduce runoff and improve water quality at the source (see Chapter 7)

The policies and site design practices implemented in at-risk catchments become demonstration projects. Monitoring the performance of these demonstration projects provides the foundation for adaptive management, as illustrated in Figure 6-1.

The goal of adaptive management is to learn from experience and constantly improve land development and stormwater management practices over time. This requires ongoing monitoring of demonstration projects to assess progress towards performance targets and the shared watershed vision. The details of adaptive management are discussed further in Section 6.5.

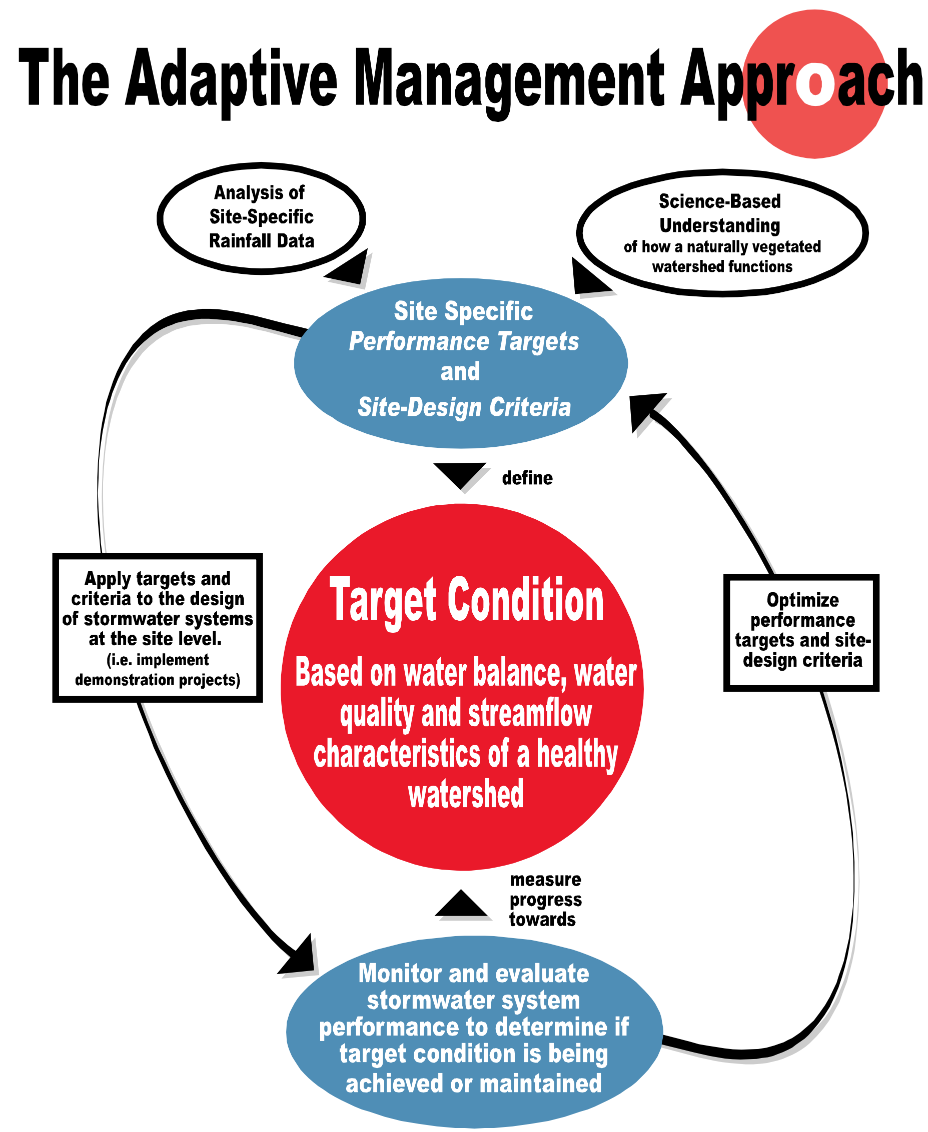


Figure 6-1

6.2 Defining a Target Condition

A biophysically-based target condition can be established based on an understanding of the characteristics of a healthy watershed.

In order to be achievable, a biophysically-based target condition must be translated into performance targets that can be applied to stormwater management practice.

Since changes in Water Balance and hydrology are the primary source of stormwater related impacts on watershed health (see Chapter 2), it is especially important to establish performance targets for managing:

- **Runoff Volume**, and
- **Runoff Rate**

Defining a Runoff Volume Target

Recent research from Washington State shows that stormwater related impacts on stream health start to occur once the impervious percentage of a watershed exceeds about 10% (see Chapter 2). Therefore, to ensure the health of aquatic systems, developments should be planned and built to function like watersheds with less than 10% total impervious area.

Stormwater-related impacts are a direct result of runoff from impervious surfaces that are directly connected to a storm drainage system or to downstream watercourses (often defined as effective impervious area (EIA)).

The Washington State research is based on data from watersheds with traditional ditch and pipe systems designed to remove runoff from impervious surfaces as quickly as possible, and deliver it to receiving waters.

When the impervious area of watersheds with traditional ditch and pipe systems reaches the 10% threshold, about 10% of the total rainfall volume becomes runoff that enters receiving waters; this runoff volume is the root cause of aquatic habitat degradation. Note that there is virtually no surface runoff from the naturally vegetated portion of a watershed, but nearly all rain that falls on directly connected impervious surfaces becomes runoff.

An appropriate performance target for managing runoff volume is to limit total runoff volume to 10% (or less) of total rainfall volume. This means that 90% of rainfall volume must be returned to natural hydrologic pathways, through infiltration, evapotranspiration or re-use on the development site. Managing 90% of the rainfall volume throughout a watershed should achieve the biophysical target condition for the watershed. Managing 90% of rainfall volume therefore becomes the volume-based performance target.

Defining a Runoff Rate Target

As discussed in Chapter 2, the Mean Annual Flood (MAF) is defined as the channel-forming event; as the MAF increases with development, stream channels erode to expand their cross-section, thereby degrading aquatic habitat. Therefore, an appropriate runoff rate target is to ensure that streamflow rates that correspond to the natural MAF occur no more than once per year, on average.

In order to achieve this target, stormwater systems should be designed to limit the frequency that the natural MAF is exceeded.

The MAF correlates roughly with the runoff from a Mean Annual Rainfall (MAR), which is defined as the rainfall event that occurs once per year, on average. The significance of the MAR is discussed further in Section 6.4.

Natural streamflow patterns can be approximated for the majority of rainfall conditions (all rainfall in an average year) by providing enough storage capacity to capture the runoff from a MAR, and releasing the stored runoff at a rate that mimics the rate of interflow in a naturally vegetated watershed.

Additional Performance Indicators

As discussed in Chapter 2, there are additional science-based indicators that could be used as performance targets for protecting watershed health, including:

- Maintain stream baseflow at a minimum of 10% of the Mean Annual Discharge (MAD).
- Maintain natural total suspended solids (TSS) loading rates.
- Maintain key indicators of aquatic ecosystem health (e.g. maintain Benthic Index of Biological Integrity (B-IBI) score above 30).
- Preserve a 30-metre wide intact riparian corridor along all streamside areas.
- Retain 65% forest cover across the watershed.

These indicators of watershed health can play an important role in comprehensive performance monitoring and adaptive management programs (as discussed in Section 6.5).

These indicators may also be used to help define a biophysically-based target condition for a healthy watershed. The GVRD's *Integrated Stormwater Management Planning Terms of Reference Template* (2002) provides an example of how some these indicators have been applied to define a target condition.

This Guidebook presents a methodology for setting performance to achieve the runoff volume target (i.e. limiting runoff volume to 10% of total rainfall) and runoff rate target (i.e. maintaining natural MAF). The runoff volume and rate targets have been selected as the primary basis for defining a biophysically-based target condition to guide stormwater planning and design because:

- They are based on scientifically defensible research that correlates watershed imperviousness and changes in hydrology with stream health.
- They provides an easily understood starting point for the design of stormwater systems at the site level (as described in this chapter). These targets can be directly managed at the site level.
- Achieving the 10% volume target should also achieve management objectives for stream baseflows, water quality and aquatic ecosystem health. This is a reasonable assumption because:
  - Infiltrating rainfall at the source is the most effective way to maintain stream baseflows.
  - Infiltration and other stormwater source control strategies provide effective treatment for the first flush of pollutants that wash off from developed areas.
  - Restoring the natural Water Balance eliminates the source of stream degradation and improves aquatic ecosystem health.

Monitoring the performance of demonstration projects will provide the opportunity to test how well alternative performance targets relating to baseflows, water quality and aquatic ecosystem health can be managed by achieving the runoff volume and rate targets (see Section 6.5).

Achieving the Target Condition at the Site Level

Degradation of watershed health is the result of the cumulative impact of individual land development projects on runoff volume and rate (i.e. incremental changes in Water Balance and hydrology). Each development project contributes to increased runoff volume and rate in downstream watercourses.

In order to achieve the target condition for a healthy watershed as a whole, cumulative impacts must be managed at the site level. This means that stormwater systems at the site level must be designed to achieve to achieve the runoff volume and rate targets.

The Role of Source Control

To achieve runoff volume and rate targets, development sites and their stormwater systems must be designed to replicate the functions of a naturally vegetated watershed (the most effective stormwater system). This requires stormwater source control strategies that capture rainfall at the source (on building lots or within road right-of-ways) and return it to natural hydrologic pathways - infiltration and evapotranspiration - or re-use it at the source. This creates hydraulic disconnects between impervious surfaces and watercourses (or storm drains), thus reducing the volume and rate of surface runoff.

Looking ahead, Chapter 7 presents a variety of source control solutions for maintaining or restoring natural runoff volume and rates, including:

- Preserving natural vegetation cover, natural stormwater management features (e.g. wetlands), and limiting the extent of impervious areas through low impact development practices
- Preserving or restoring natural infiltration capacity by infiltrating runoff from impervious surfaces and applying absorbent landscaping
- Preserving or restoring natural evapotranspiration capacity to the extent possible through conservation, landscaping and the application of green roofs
- Re-using rainwater for irrigation and for indoor uses

Chapter 7 provides guidance for selecting appropriate source control strategies for different land use types, soil conditions and rainfall characteristics.

Other Objectives for Managing Stream Health

To maintain or restore stream health, this Guidebook recommends focusing limited resources on managing runoff volume and rate. Scientific research on the subject recommends a broad range of strategies including:

- Preserve or restore natural vegetation along riparian corridors.
- Preserve or restore natural features, such as wetlands, that play a key role in maintaining the hydrologic and water quality characteristics of healthy streams.
- Preserve or restore instream features that are key to the health of aquatic ecosystems, such as channel complexity and adequate spawning gravel.
- Control sources of water pollution (point and non-point sources).

Integrated Stormwater Management Plans (ISMPs) should address these objectives, in addition to the runoff volume and rate targets.

Desired Outcomes for ISMPs

Integrated stormwater management plans (ISMPs) for individual watersheds should therefore:

- establish objectives for maintaining and/or restoring stream health
- develop comprehensive strategies to achieve these objectives, which not only deal with runoff volume and rate, but also address issues relating to water quality and preservation/restoration of key natural features (e.g. riparian forests, wetlands, in-stream features)

The elements of ISMPs are discussed further in Chapter 10.

A Widely Applicable Target Condition

The fact that performance targets are based on the characteristics of a healthy watershed is key. This means that the performance targets for any given watershed apply to:

- **new development *or* retrofit scenarios -** Appropriate land development practices can prevent the degradation of a healthy watershed or restore an unhealthy watershed. The target condition remains the same.
- **protection of environment *or* property -** Maintaining or restoring the ecological health of a watershed will also eliminate the source of flooding risk to property and public safety. Protecting aquatic resources and protecting property are complementary objectives. Even if property impacts are the driver for action, biophysically-based performance targets are still appropriate.

The Range of Case Study Experience

The methodology presented in this chapter for setting performance targets and design criteria evolved through recent integrated stormwater management experiences in British Columbia. Preliminary performance targets and site design criteria were developed using this methodology in three different catchments, all with different initial conditions, development types and drivers for action. The three case studies included the following development scenarios:

- **Urban -** High-density urban development at the top of a mountain, where protection of downstream aquatic habitat was the primary driver for action.
- **Suburban -** Fully developed suburban watershed, where the need for immediate flood relief was the driver for action.
- **Suburban/Rural** - A municipality comprising rural and suburban land uses, where future development areas (currently forested) drains to agricultural lowlands. Aquatic habitat protection was also a driver.

The methodology has been tested and accepted by the local governments in all three cases. The suburban/rural example (City of Chilliwack) is used as a case study for the remainder of this chapter to illustrate the methodology.

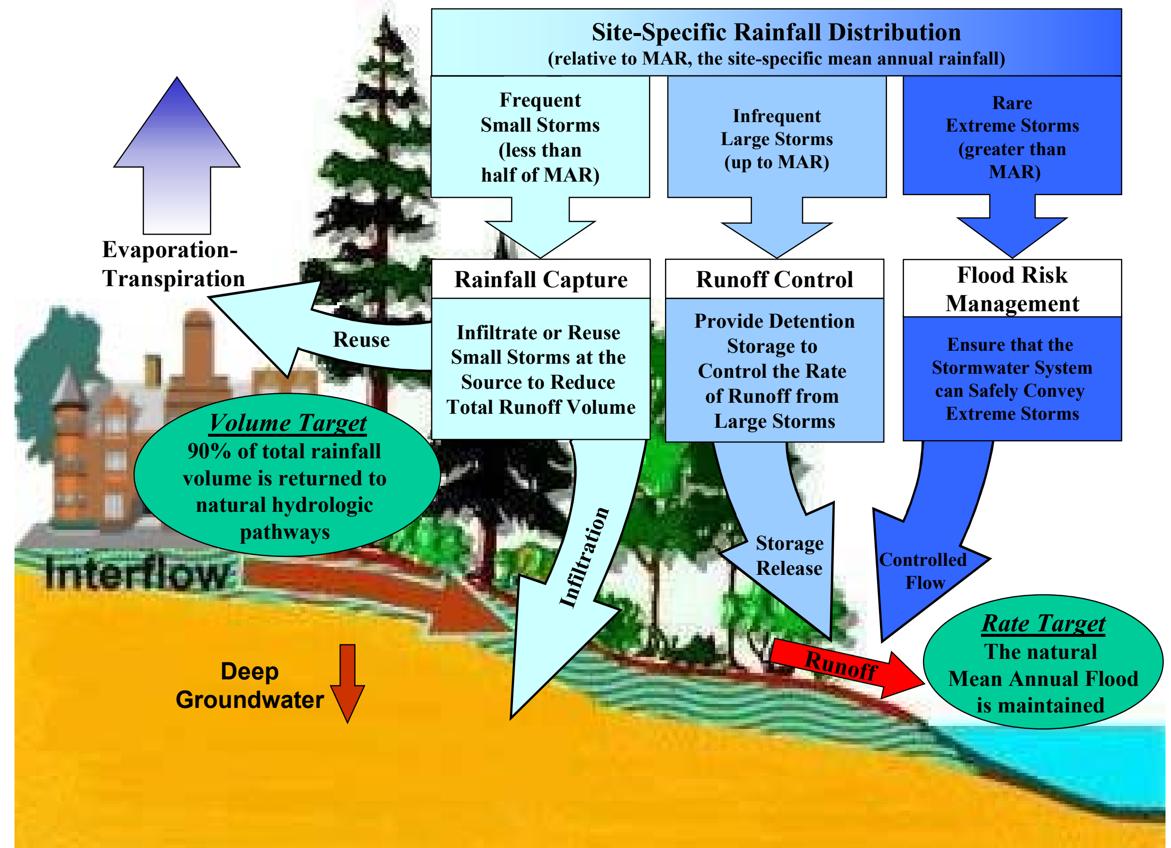
6.3 Moving from Science to Site Design

As shown below, the biophysically-based target condition provides a basis for a comprehensive stormwater management strategy (see Figure 6-3). Performance targets and site design criteria are needed to translate this strategy into action at the site level.

Biophysically-Based Target Condition

The target condition is based on the characteristics of a healthy watershed, and incorporates targets for maintaining the natural Water Balance (restore 90% of rainfall volume to natural hydrologic pathways) and hydrology (maintain natural MAF). Other characteristics of a healthy watershed (e.g. water quality, baseflow, riparian integrity) may also help define a target condition.

Leads to:



Science Based Strategy for Managing the Complete Spectrum of Rainfall Events

Stormwater impacts occur when land use change alters the water balance, thus increasing the volume and rate of surface runoff from *every rainfall event*. In order to maintain or move towards the target condition, the complete spectrum of rainfall events must be managed in a manner that approximates a naturally vegetated watershed.

Implementing this strategy requires:

Science-Based Performance Targets and Site Design Criteria

Translating the above strategy into an action plan requires performance targets and design criteria to guide stormwater management and development practices at the site level.

Performance targets and design criteria can be evaluated and optimized to reduce costs over time by monitoring the performance of demonstration projects.

Figure 6-2

The Need for Flexibility in Setting Performance Targets

Establishing performance targets provides a quantifiable way of measuring success in protecting or restoring a watershed, and for identifying what needs to be done to achieve a certain level of protection for a given watershed.

The runoff volume and rate targets presented in presented in Section 6.2 provide a reference point that is based on the Water Balance and hydrology of a healthy watershed. To determine whether these targets are realistic or achievable for a given watershed, an ISMP must answer the following questions:

- What is the existing level of annual runoff volume? What percentage of total annual rainfall volume does it represent? What is the existing Mean Annual Flood (MAF)?
- What are acceptable levels of runoff volume and rate in terms of flood risk and environmental risk? What are the consequences of increased or decreased flows related to land development? Are these consequences acceptable?
- What actions are needed to avoid flooding or environmental consequences?
- How can necessary actions be staged over time?
- Are the targets to maintain 10% runoff volume and maintain the natural MAF necessary or achievable over time? If not, what levels are?

Performance targets that are based on the characteristics of a healthy watershed, including targets for runoff volume, runoff rate, and any other indicators that may be used to define a target condition, should be used as a starting point. Performance targets should be customized for individual watersheds and catchments, based on what is effective and affordable in the context of watershed-specific conditions.

For example, the 10% runoff volume target may not be appropriate for a watershed with limited fisheries value. In this case it may be more appropriate to establish targets for reducing the volume and rate of runoff based on judgements regarding acceptable levels of flooding.

Continuous Water Balance modeling can be applied to determine what is effective and affordable. Further discussion of Water Balance modeling is found in Chapter 7.

6.4 Managing the Complete Rainfall Spectrum

A guiding principle of integrated stormwater management is to design for the complete spectrum of rainfall events (as shown in Figure 6-2). Designing for the complete spectrum of rainfall events provides the foundation for protecting both property and stream health.

Understanding the Rainfall Spectrum

A key parameter for describing the rainfall spectrum is the size of the Mean Annual Rainfall (MAR), the rainfall event that occurs once per year, on average. The distribution of rainfall events relative to the MAR is fairly constant throughout British Columbia.

The following rainfall tiers are the building blocks of an integrated strategy for managing the complete spectrum of rainfall events:

- **Tier A Events*** – The small rainfall events that are less than half the size of a MAR. About 90% of all rainfall events are Tier A events.
- **Tier B Events*** – The large rainfall events that are greater than half the size of a MAR, but smaller than a MAR. About 10% of all rainfall events are Tier B events.
- **Tier C Events*** – The extreme rainfall events exceeding a MAR. An extreme event may or may not occur in any given year.

* For the purpose of setting performance targets, a rainfall event is defined as total daily rainfall (i.e. mm of rainfall accumulated over 24 hours). This assumption results in conservative site design criteria, which can be optimized over time through continuous simulation modeling, and by monitoring the performance of demonstration projects (as discussed in Section 6.5).

These three rainfall tiers correspond to three components of an integrated strategy for managing the complete spectrum of rainfall events (see Figure 6-2); rainfall capture (source control), runoff control (detention), and flood risk management (contain and convey). These three components are discussed further in this section.

The Importance of Rainfall Tiers

Defining tiers is the key to the rainfall analysis. It enables a systematic approach to data processing and identification of rainfall patterns, distributions and frequencies. Establishing the MAR as a reference point provides a convenient way to divide the rainfall database into three groupings.

Table 6-1 below shows how the rainfall tiers vary across the regions of BC where the most development is occurring. In the Georgia Basin the MAR ranges from about 40 mm on the East Coast of Vancouver Island, to about 60 mm in the Fraser Valley (also representative of much of the Lower Mainland), to about 80 mm on the North Shore of Vancouver. For the Okanagan Region, the MAR is closer to 20 mm.

Table 6-1 – Rainfall Spectrum for Various Locations in BC

Location	Tier A Events (less than 50% of MAR)	Tier B Events (between 50% of MAR and MAR)	Tier C Events (Greater than MAR)
Vancouver (North Shore)	< 40 mm	40 to 80 mm	> 80 mm
Chilliwack	< 30 mm	30 to 60 mm	> 60 mm
Nanaimo	< 20 mm	20 to 40 mm	> 40 mm
Kelowna	< 10 mm	10 to 20 mm	> 20 mm

* approximate values based on statistical analyses using of 30+ years of rainfall data

One of these examples (Chilliwack) is used throughout this chapter to illustrate how to:

- use rainfall data to define MAR and the rainfall tiers
- apply the rainfall tiers to establish performance targets and site design guidelines

Managing Rainfall Volume at the Source

Tier A events make up the bulk of total annual rainfall events and rainfall volume (see Figures 6-3 and 6-4). Capturing these small events at the source is the key to reducing runoff volume and managing the Water Balance (i.e. rainfall capture).

Figures 6-3 and 6-4 illustrate both coastal and interior conditions. Regardless of location, the majority of rainfall events are small (less than 50% of MAR). This is a key observation with respect to the feasibility of approximating the natural Water Balance through infiltration and/or rainfall re-use.

Consistency with Current Stormwater Practice

Referencing the rainfall tiers to the Mean Annual Rainfall (MAR) provides consistency with criteria that became accepted practice in the 1990s.

In British Columbia, the *Land Development Guidelines for the Protection of Aquatic Habitat* (1992) focus on managing runoff from storms with a 2-year return period, which is approximately equal to the MAR.

Also, 50% of the MAR corresponds to what is called a ‘6-month storm’ in Washington State. The concept of the ‘6-month storm’ was introduced in Washington to provide context for managing the six to ten runoff events per year that have the most potential to cause watercourse erosion (i.e. Tier B events). At the time, this approach represented a major departure from traditional drainage practice.

Prior to the late 1990s, the focus of drainage planning was on the extreme events that rarely occurred (Tier C events).

The tiered approach marks a further shift in drainage practice, from managing 25% of the rainfall volume (Tier B and C) to managing 100% of the rainfall (i.e. the complete spectrum).

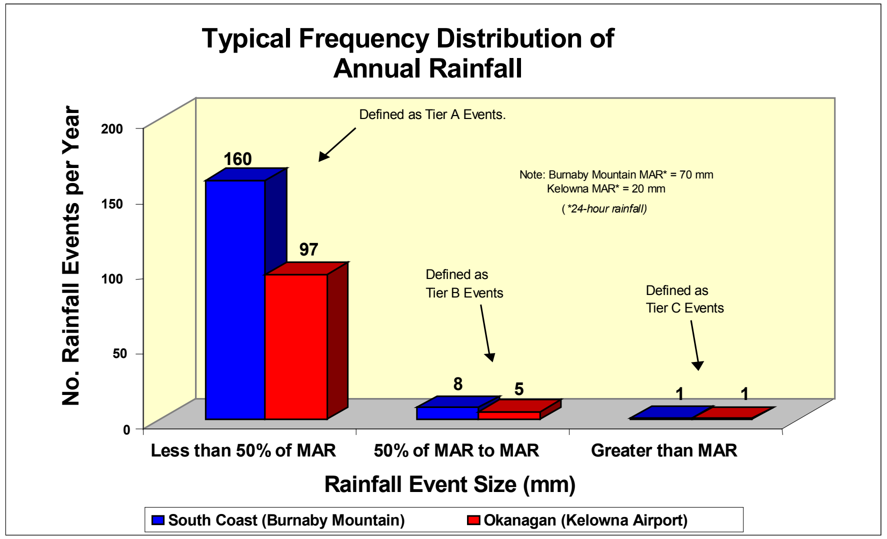


Figure 6-3

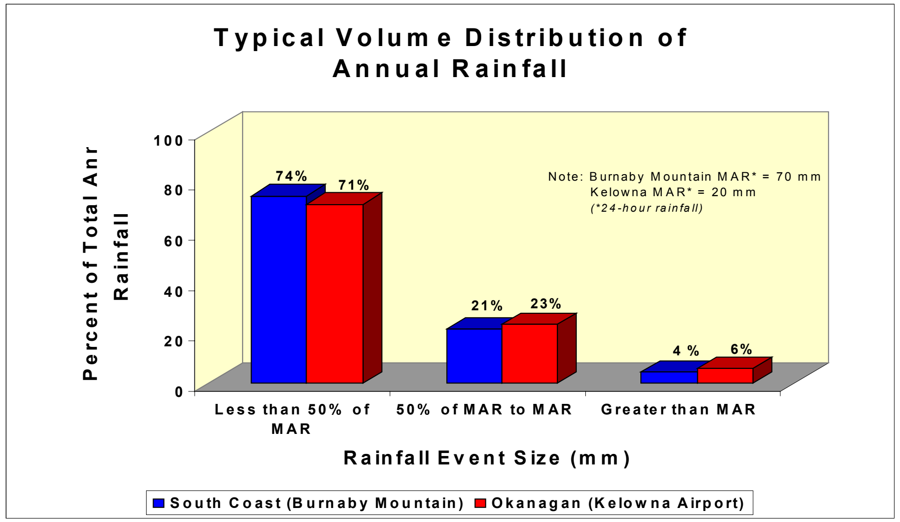


Figure 6-4

Components of an Integrated Strategy for Managing the Complete Spectrum of Rainfall

Each of the three rainfall tiers corresponds to a component of an integrated strategy:

1. *Rainfall Capture* (Source Control) to Manage the Small Tier A Rainfall Events

The key to runoff volume reduction and water quality improvement is capturing the small storm runoff (Tier A rainfall events) from rooftops and paved surfaces. This captured rainfall should be infiltrated, evapotranspired, and/or re-used at the source. Rainfall capture can be provided at the source with:

- **On-lot stormwater source control facilities** to capture runoff from rooftops, driveways, parking and other impervious areas for infiltration, evapo-transpiration and/or reuse.
- **On-street source control facilities** to capture and infiltrate runoff from paved roadways. These facilities must also be designed to convey extreme storms, similar to conventional storm sewers.

Chapter 7 describes specific source control options available for development parcels and roads, including specific examples.

2. *Runoff Control* (Detention) to Manage the Large Tier B Rainfall Events

The runoff resulting from the large Tier B events causes the most significant peak flows in downstream watercourses. Therefore, the key to runoff rate control is storing the runoff from impervious surfaces resulting from the large Tier B rainfall events and releasing it at a controlled rate. This controlled release will eliminate the ‘spikes’ that characterize the rapid response of runoff from impervious surfaces. Storage capacity for large Tier B storms can be provided:

- By increasing the storage capacity of on-parcel and on-street source control facilities (above the capacity required to achieve rainfall capture targets).
- In community detention facilities that serve sub-catchments of a watershed (can provide runoff control but not rainfall capture).

3. *Flood Risk Management* (Contain and Convey) for the Extreme Tier C Rainfall Events

Development sites must have adequate escape routes for runoff from extreme storms (combination of overland flow and flow collection and conveyance systems). Stream channels and stream crossing (e.g. culverts and bridges) must have sufficient capacity to contain and convey flood flows resulting from very large storms (e.g. the 100-year storm), without resulting in threats to public safety or property damage. A framework for flood risk management is presented in Section 6.5.

The Role of Continuous Simulation Modeling

Performance targets (i.e. a starting point) can be established based on simple rainfall analysis (see Section 6.5). The level of effort required to apply continuous simulation modeling is not appropriate for setting performance targets, but is appropriate for optimizing design solutions to achieve the performance targets.

As explained in Chapter 7, continuous simulation modeling is also appropriate for evaluating stormwater source control options and optimizing the design of stormwater system components.

Understanding Why Rainfall Capture is the Key

Runoff control without rainfall capture is the conventional detention-based approach to stormwater management. It is only a partial solution. It is now recognized that this approach does not protect downstream fish habitat because it does not maintain natural levels of erosion or support baseflows in watercourses.

The water released from conventional detention storage typically goes directly to downstream watercourses. This slows down the water and reduces peak runoff rates, but does not reduce the total runoff volume. Therefore, the total runoff volume is spread out over a longer period of time, which can result in erosive streamflows for longer periods of time.

Rainfall capture requires storage at the source, where runoff from impervious surfaces can be infiltrated into the ground, evapotranspired, or re-used rather than released directly to surface drainage systems. Infiltration not only reduces runoff volume, but also supports stream baseflow by partially restoring the natural Water Balance.

Detention facilities that serve sub-catchments of a watershed do not provide the opportunity for infiltration, evapotranspiration or re-use at the source. However, there may be opportunities to implement community source control facilities through neighbourhood planning (e.g. infiltration facilities that serve multiple dwelling units).

The objective of emphasizing rainfall capture is to place the stormwater management focus clearly on volume. Traditional drainage practice concentrated on peak flow rates and overlooked the importance of volume management.

The Importance of Rainfall Capture for Water Quality

Rainfall capture is important for improving water quality as well as for reducing runoff volume. The objective of rainfall capture is to infiltrate small storms and the first portion of large storms at the source. This means that the 'first flush' of pollutants that get washed off impervious surfaces at the beginning of rainfall events will be filtered and receive some treatment as they infiltrate into the ground.

Rainfall that is captured at the source for re-use may require a certain amount of treatment, depending on its intended use. Indoor uses, such as toilet flush water, would likely require some form of treatment to satisfy regulatory requirements for public health protection.

6.5 Methodology for Setting Performance Targets and Site Design Guidelines

Case Study Example: City of Chilliwack

The City of Chilliwack is used as a case study in this section to demonstrate how to set performance targets and translate these targets into site design criteria. Chilliwack has applied a 6-step process for setting performance targets and developing site design criteria (see Figure 6-5). These steps are described in this section.

Chapter 4 showed how Chilliwack has integrated performance targets with stormwater management policies. This is a first step towards integrating targets with the Official Community Plan.

Chapter 7 elaborates on how Chilliwack has translated performance targets into a series of *Design Guidelines for Stormwater Systems* that developers can apply at the site level.

Chilliwack started applying the Guidebook methodology in the spring of 2001. Over the year that followed, the Chilliwack case study provided an opportunity to test, validate and refine the Guidebook methodology. This process was undertaken in an inter-departmental and inter-agency environment, and used actual land development projects in the City to apply the methodology. The interaction with the development community was essential to making the methodology practical.

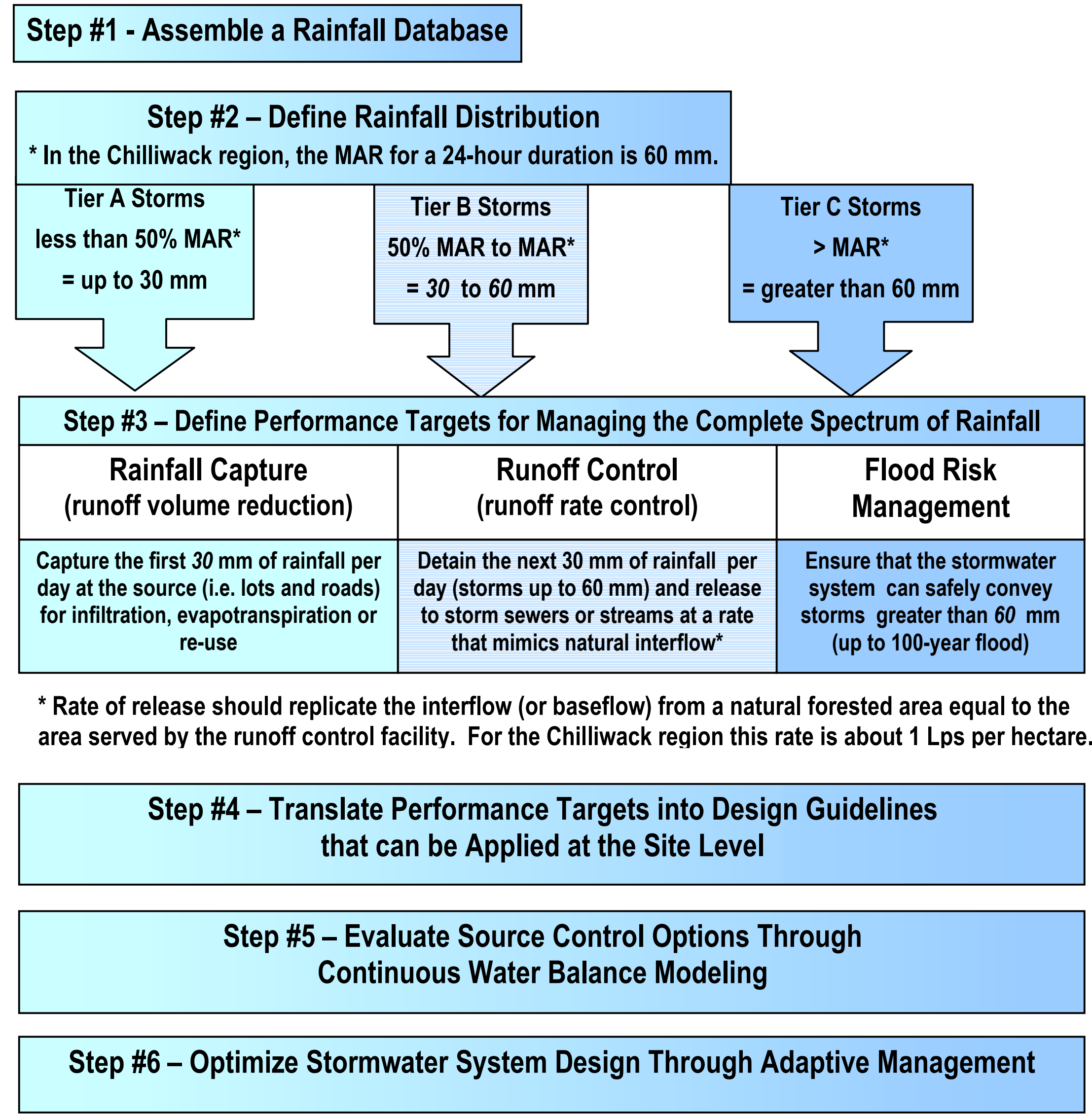


Figure 6-5

Step #1 - Assemble a Rainfall Database

Rainfall data is readily available in most jurisdictions. Environment Canada operates an extensive network of rainfall gauging stations across the province. Many regional districts and municipalities are beginning to operate their own stations, and in some cases local government-operated networks are in place.

Rainfall data should be obtained from a gauging stations as close as possible to the watershed where performance targets are being set.

Obtaining rainfall data from several stations in a region can provide a good idea of rainfall variability and enable the establishment of regional performance targets (as shown in the Chilliwack example).

For establishing performance targets, a rainfall data set should have a period of record that is long enough to enable statistical analysis (longer is better). The rainfall data must be put into a spreadsheet format to enable the necessary analysis (described on the following page).

A key principle is to assemble the best rainfall data available (i.e. longest period of record, closest to watersheds of interest) and to use this data to establish performance targets.

Even in the absence of rainfall data, the example rainfall tiers shown in Table 6-1 (from the relevant region) can be used to develop performance targets that provide a reasonable starting point for action. The values in Table 6-1 can also provide a check on analyses performed using data from rain gauges with short periods of record.

Daily versus Hourly Rainfall Data

Daily rainfall data is adequate for the basic analysis needed to set preliminary performance targets and site design criteria. However, hourly rainfall data provides a better description of local rainfall characteristics. Certain rainfall characteristics, such as rainfall intensity, can not be established based on daily data. Hourly data also enables more detailed monitoring and modeling (see Step #5 and #6).

Climate Change Concerns

Climate change projections show that total winter rainfall is likely to increase over time (thus increasing total runoff volume), and that the frequency of short intense storms, or cloudbursts, is also likely to increase. Chapter 7 shows how the implementation of stormwater source control strategies can mitigate the impacts of climate change.

Performance targets provide a starting point for evaluating source control options. It does not matter that these targets are based on historic rainfall data.

Case Study Example: Assembling Rainfall Data

Long-term rainfall data is available from three Environment Canada rainfall gauging stations in the greater Chilliwack area:

- **Agassiz** (on the north side of the Fraser River) – 109 years of record
- **Sardis** (near Vedder crossing) – 46 years of record
- **Chilliwack** (between Chilliwack City Center and Highway 1) – 90 years of record

Rainfall data from these three stations were used to establish general performance targets for the Chilliwack region. These targets can be customized for individual sub-catchments within the region by monitoring the performance of demonstration projects (see Step #6).

Since April 1999, the City has been operating two continuous rain gauges on a hillside area above the agricultural lowlands that is designated for future land development. These gauges are important for monitoring the change in rainfall-runoff response as land development progresses on the hillsides, and thus evaluating how well particular site design practices are mitigating the impacts of land development.

Step #2 – Define Rainfall Distribution

The rainfall event categories (Tier A, Tier B, and Tier C) form the basis for setting performance targets and developing site design criteria to manage the complete spectrum of rainfall events. In order to define the thresholds for these categories, the Mean Annual Rainfall (MAR) must be determined.

Methodology for Defining Mean Annual Rainfall (MAR)

The MAR for any watershed can be defined through the following process:

1. Calculate the peak daily rainfall (24-hr rainfall depth) for each year of record from the rainfall gauge. This can be done with a simple spreadsheet function.
2. Rank the rainfall maxima from highest to lowest and calculate a return period (T) for each using a standard plotting position formula (e.g. Weibull formula, T = [total # of rainfall maxima + 1]/rank).
3. Create a logarithmic plot of rainfall maxima vs. return period.
4. From this plot determine the rainfall maxima with a 2-year return period (R_2). This is approximately equal to the MAR (the statistical definition of MAR is the rainfall with a 2.33 year return period).

Since the preceding methodology is a statistical analysis, a long period of record (30 years or more) will ensure confidence in the results.

Defining Rainfall Tiers

Once the site-specific MAR is determined, rainfall event categories can be defined:

- Tier A = less than 50% of MAR
- Tier B = 50% MAR to MAR
- Tier C = greater than MAR

Illustrating the Rainfall Distribution

The site-specific rainfall frequency distribution (see Figure 6-3) can be determined by applying a spreadsheet query to the rainfall database (count the total # of Tier A, Tier B, and Tier C events). This will validate that the majority of rainfall events are small.

The site-specific rainfall volume distribution (see Figure 6-4) can also be determined using spreadsheet functions (add up the total depth of Tier A, Tier B, and Tier C events). This will validate that the small Tier A events account for the majority of total annual rainfall volume.

Case Study Example: Defining Rainfall Distribution

The MAR (24-hour duration) for Chilliwack was determined using data from the three long-term rainfall gauging stations. The points plotted on Figure 6-6 represent the peak annual rainfall event (24-hr rainfall depth) for each of the 90 years of record from the Chilliwack rainfall gauge. The same analysis was performed using the Sardis rainfall gauge and the Agassiz rainfall gauge.

Based on this analysis, the MAR at each of the three stations was determined to be:

- Chilliwack = 63 mm
- Agassiz = 60 mm
- Sardis = 55 mm

Therefore, the regional MAR for the Chilliwack area can be defined as 60 mm (over 24 hrs). This regional approximation provides the basis for specifying the following rainfall tiers:

- **Tier A** = less than 50% of MAR = less than 30 mm
- **Tier B** = 50% MAR to MAR = 30 mm to 60 mm
- **Tier C** = greater than MAR = greater than 60 mm

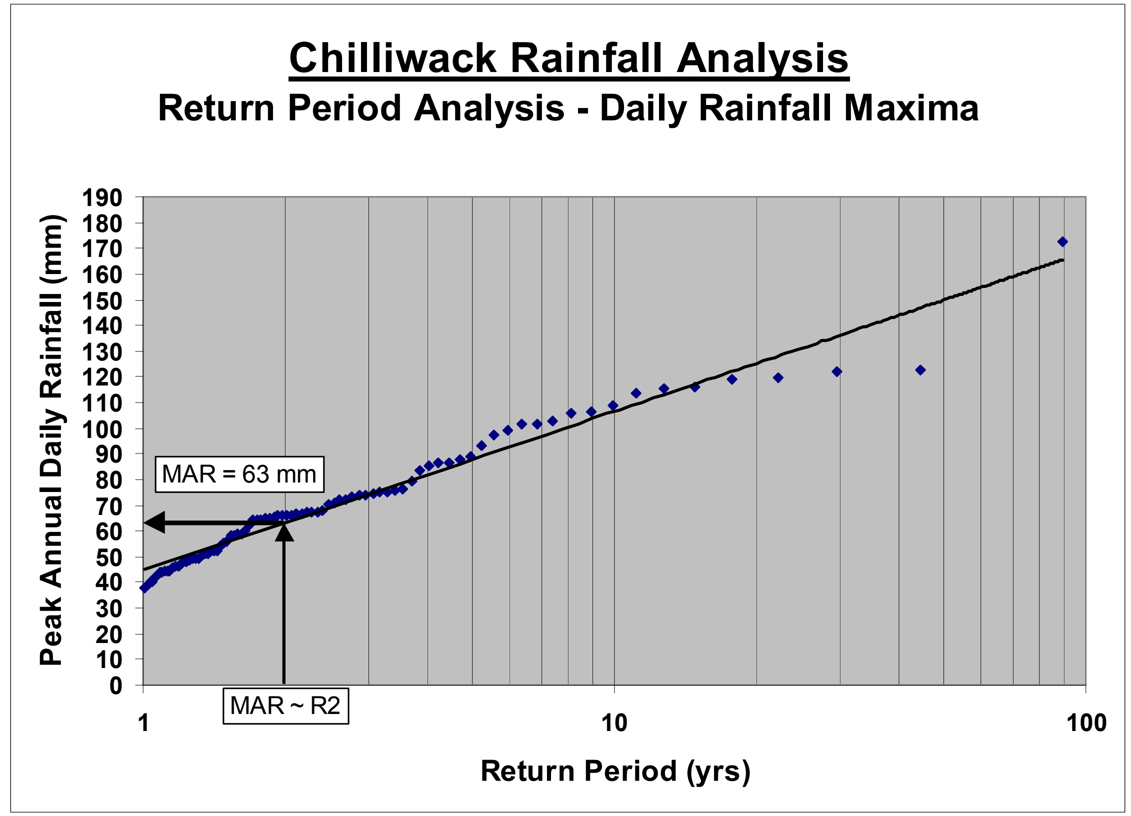


Figure 6-6

Step #3 – Define Performance Targets for Managing the Complete Spectrum of Rainfall Events

The rainfall tiers, established in Step #2, must be translated into performance targets for rainfall capture, runoff control and flood risk management.

Case Study Example: Translating Tiers into Targets

The City of Chilliwack's performance targets are presented below to illustrate how rainfall tiers translate into performance targets.

Rainfall Capture Performance Targets (for Tier A Events)

Capture the first 30 mm of rainfall per day (24 h) at the source (i.e. lots and roads) and restore to natural hydrologic pathways (infiltration and evapotranspiration) and/or re-use.

This relates to the following specific rainfall capture targets:

- **For impervious areas –** Provide stormwater source control facilities* on development lots, roads or neighbourhood sites that are designed to capture 30 mm of rainfall per day, and either infiltrate, evapotranspire, or re-use the captured rainfall.
- **For pervious areas –** Preserve as much undisturbed natural area as possible. For landscaped areas, provide an absorbent surface soil layer that has the capacity to store at least 60 mm of rainfall and infiltrate at the natural rate of local soils. This will ensure that pervious areas produce virtually no surface runoff (much like a naturally vegetated watershed).

* the selection and design of source controls must be based on site-specific conditions (see Steps #4 and #5)

Runoff Control Performance Targets (for Tier B Events)

Detain the next 30 mm per day (all rainfall events up to 60 mm over 24 h) and release to storm sewers or stream channels at a rate that approximates a natural forested watershed.

This relates to the following specific runoff control target:

- **For impervious areas –** Provide enough storage volume to detain the runoff resulting from rainfall events up to 60 mm per day, either in rainfall capture facilities and/or community detention facilities. Release the stored rainfall at a rate that replicates the interflow from a natural forested area* (equivalent to the area served by the runoff control facility).
- **For pervious areas –** Meeting the rainfall capture target also provides adequate runoff control (i.e. enough storage for 60 mm of rainfall).

* natural interflow can be defined based on streamflow monitoring in undeveloped catchments (see Step #4)

Flood Risk Management Performance Target (for Tier C Events)

Ensure the stormwater system is capable of safely conveying an extreme flood event that results from rainfall events greater than 60 mm (e.g. the 100-Year Flood, Q_{100}).

The runoff from extreme storms must be conveyed, through a combination of overland flow paths and flow collection and conveyance systems, without causing property damage, posing a threat to public safety, or causing unacceptable levels of flooding in agricultural areas.

Validating Performance Targets

As discussed in Section 6.2, achieving the biophysically-based target condition (a healthy watershed) means that 90% of total rainfall volume must be captured at the source to reduce total runoff volume to 10% or less of total rainfall volume.

Figure 6-7 relates the performance targets for rainfall capture, runoff control and flood risk management to rainfall volume distribution (at the Sardis gauge).

The same analysis was performed using data from the other two long-term rainfall stations (Chilliwack and Agassiz). The volume distribution for all three stations is summarized below.

Rainfall Station	Rainfall Capture Volume	Runoff Control Volume	Flood Control Volume
Chilliwack	89%	7%	4%
Agassiz	91%	6%	3%
Sardis	93%	5%	2%

Capturing the first 30 mm of rainfall per day (i.e. meeting Chilliwack's rainfall capture target) would result in capture of about 90% of the total volume of runoff from impervious areas. Also, implementing absorbent landscaping practices can virtually eliminate runoff from pervious areas (i.e. achieve close to 100% capture), as discussed in Chapter 7.

The key point is that meeting rainfall capture targets should achieve the biophysically-based target condition.

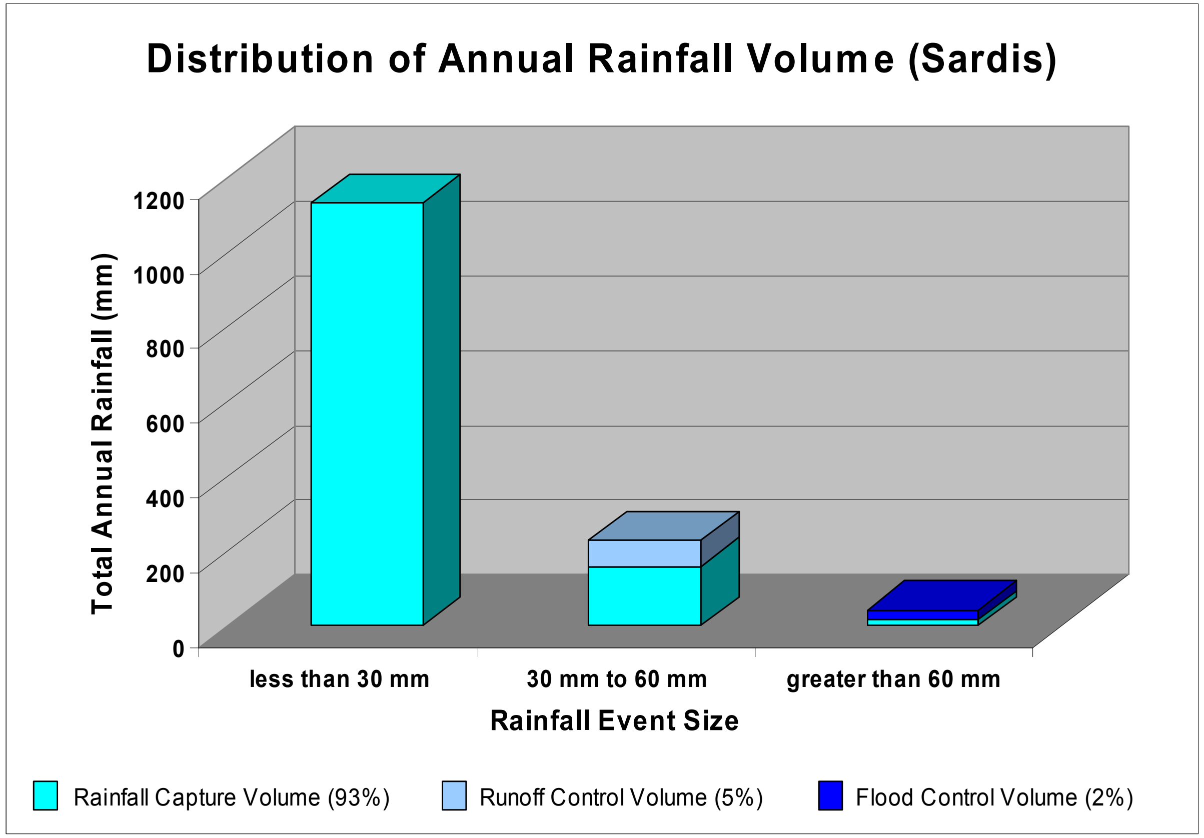


Figure 6-7

Step #4 – Translate Performance Targets into Design Guidelines that can be Applied at the Site Level

In order to achieve performance targets for rainfall capture, runoff control and flood risk management, the targets must be translated into achievable design guidelines that developers and local government staff can understand and apply at the site level.

Design Guidelines for Rainfall Capture (Managing Tier A Events)

Reducing runoff volume is the key to achieving performance targets for rainfall capture. The following volume reduction strategies should be applied:

- **Minimize the disturbance of natural soils and vegetation.** At the land use planning and site design levels, it is important to identify and preserve the natural areas that are most important to maintaining the natural Water Balance, such as wetlands, natural infiltration areas and riparian forests. Low impact site design practices that limit the creation of impervious area, the compaction of natural soils and the clearing of natural vegetation should also be applied.

- **Apply absorbent landscaping.** For landscaped areas, an absorbent surface soil layer should be provided. This absorbent soil layer should:
  - be deep enough to store the mean annual rainfall (24-h duration). Since most absorbent soils store about 20% of their volume in soil water, five times the MAR is an appropriate soil depth (e.g. for Chilliwack this would be 60 mm x 5 = 300 mm).
  - meet the BC Landscape Standard for medium or better landscape, which will ensure the type of hydrologic characteristics required for rainfall capture.

- **Implement stormwater source control practices to capture runoff from impervious surfaces.** Source control options include:
  - **Infiltration Facilities –** Infiltration is likely the only way achieve the target condition of restoring 90% of total rainfall volume to natural hydrologic pathways, and is the most appropriate source control for single family land uses, which is the dominant land use in most developed watersheds in the province.

    The level of reduction in the volume and rate of runoff that is achievable using infiltration depends on soil conditions, and therefore, soils information is key to the planning and design of infiltration facilities.
  - **Green Roofs –** The volume and rate of rooftop runoff can be reduced by installing absorbent landscaping on rooftops of buildings or parkades. Green roofs will store and evapotranspire rainfall from small events, and will slow the rate of release of medium-sized events. Green roofs are most effective for land uses with high levels of rooftop coverage, such as multiple family and commercial land uses (especially with underground or structured parkades).
  - **Rainwater Re-use –** Capturing and re-using rooftop runoff for greywater uses (e.g. toilets, laundry) or for irrigation can reduce runoff volume. The opportunities for volume reduction through re-use are most significant for high density residential and commercial land uses with high water use.

Chapter 7 provides quantitative information on the effectiveness of these stormwater source control options under various conditions (e.g. rainfall, land use, soil type), and also provides further guidance on low impact site design practices and absorbent landscaping.

Determining What is Achievable

Establishing a rainfall capture target, as shown in Step #3, provides a starting point that is based on the characteristics of a healthy watershed. The next step is to determine what is achievable and affordable based on assessments of constraints and opportunities in individual catchments.

Based on these assessments, catchment-specific performance targets and design guidelines for achieving these targets can be established. These catchment-specific targets and guidelines will then provide direction for all land development projects within each catchment.

The following information is key to assessing opportunities and constraints in any given catchment:

- **Soils Information -** Soil conditions govern the feasibility and affordability of using infiltration facilities to meet rainfall capture targets. At the watershed planning level, coarse level soils mapping can provide local government staff with the information needed to determine where infiltration makes sense, and to evaluate the level of runoff volume reduction that could be achieved through infiltration in various catchments. This will enable the establishment of catchment-specific performance targets.

  It is also important to evaluate soil conditions at the site level, in order to determine how much infiltration area is required to meet catchment-specific targets, and to identify the most suitable infiltration areas within a development site (see the case study example on the following page).

- **Land Use Information –** Land use information will provide local government staff with guidance regarding where source control options other than infiltration should be considered. In multiple family and commercial land uses, or where opportunities for infiltration are limited, there may be opportunities to achieve significant levels of runoff volume reduction by implementing green roofs or rainwater re-use.

Case Study Example: Design Guidelines for Infiltration Facilities

Since the majority of new development in the City of Chilliwack are likely to be single family residential, the City's guidelines for rainfall capture focus on infiltration.

The key design parameter for infiltration facilities is footprint area. Increasing the area of infiltration facilities improves their effectiveness at reducing runoff volume, but also increases their cost.

Determining What is Achievable Through Infiltration

Soil conditions govern the feasibility and affordability of using infiltration facilities to meet rainfall capture targets. Figure 6-8 shows that the amount of infiltration area required to meet Chilliwack's rainfall capture target becomes very large where the hydraulic conductivity of soils is low.

The City's rainfall capture target is not likely achievable through infiltration in areas where the hydraulic conductivity of local soils is less than about 5 mm/hr (typical of soils with high clay content). Also, infiltration is not likely feasible in areas where the regional water table is at or very near the ground surface. Where appropriate, alternative source control strategies (green roofs or rainwater re-use) should be considered in areas where the opportunities for infiltration are limited.

Chilliwack's approach allows for flexibility in setting catchment-specific performance targets that reflect what is achievable and affordable.

Catchment-Specific Performance Targets

Chilliwack has adopted three levels of stormwater planning: watershed, sub-watershed and catchment. Catchment-specific performance targets will be established through the master planning process (at the sub-watershed level) based on a planning-level assessment of soil and groundwater conditions in individual catchments. Having catchment-specific targets will then provide direction for all land development projects within that catchment.

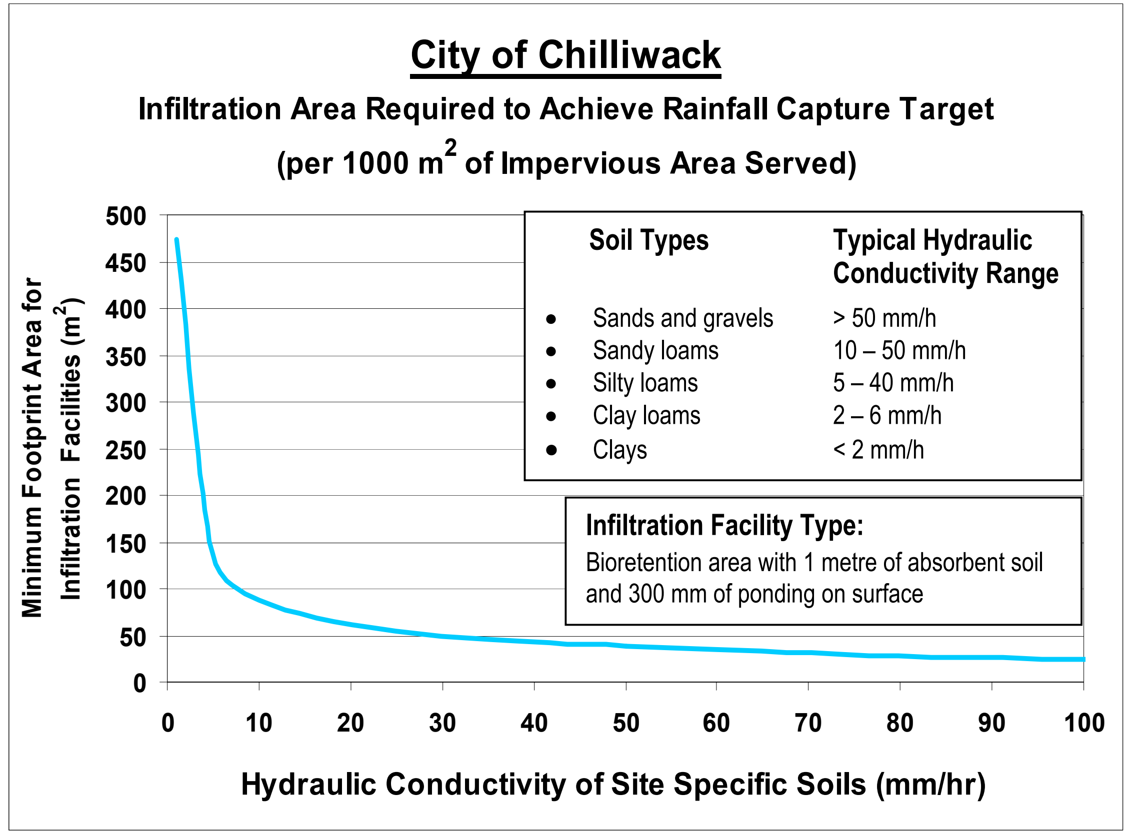


Figure 6-8

Communicating Performance Targets to Developers

Chilliwack's *Design Guidelines for Stormwater Systems* (see Chapter 7) include a step-by-step procedure for land developers to follow in order to design infiltration facilities that meet the City's rainfall capture performance targets. These Guidelines apply to all land development projects in catchments where the rainfall capture target is considered achievable.

Figure 6-8 shows an example design curve for sizing a particular type of facility based on the hydraulic conductivity of site specific soils.

Soils Information

Chilliwack has been building a database of the soils data submitted with development applications throughout the City. Using this information, coarse level soils mapping has been prepared to provide City staff and developers with guidance regarding where infiltration makes sense. This soils information will be used to develop catchment-specific performance targets.

At the site level, developers are required to perform soil investigations and percolation testing to identify the best infiltration areas and to design infiltration facilities.

Infiltration facilities should be sized based on site-specific estimates of saturated hydraulic conductivity. To obtain these estimates, on-site specific percolation tests should be performed at the location and depth of proposed infiltration facilities, and carried out under saturated soil conditions.

Developers may consider using areas with the best soil conditions to locate neighbourhood infiltration facilities serving multiple dwelling units.

Estimating Hydraulic Conductivity of Soils

The hydraulic conductivity of soils can initially be estimated through on-site percolation testing. These estimates can be improved over time by monitoring infiltration facility water levels and overflows (see Step #6).

It is also possible to estimate hydraulic conductivity based on soil texture and composition. A good reference is Washington State University's on-line *Soil Texture Triangle* (http://www.bsyse.wsu.edu/saxton/soilwater/), which estimates hydraulic conductivity based on approximate sand and clay content. The typical conductivity ranges shown on Figure 6-8 were obtained from this source.

The Importance of Protecting Infiltration Areas

Where infiltration facilities are to be located, it is critical to maintain soils in their natural, undisturbed state and to prevent sedimentation during construction. This requires:

- **sediment and erosion control** during construction to prevent clogging of rainfall capture facilities and their underlying soils
- **management of constructions sites** to prevent disturbance and compaction of infiltration areas; infiltration areas should be identified by fencing or other means

Failure to adequately protect infiltration areas during construction will likely result in failure to achieve rainfall capture targets.

Design Guidelines for Runoff Control (Managing Tier B Events)

In order to meet runoff control targets, the combination of source control facilities and community detention facilities should have the capacity to detain the MAR. Increasing the level of runoff reduction achieved through source control (i.e. rainfall capture) decreases the storage volume needed in community detention facilities.

For detention facilities, the operational objective is to replicate the hydrograph of an undeveloped drainage catchment as closely as possible. Therefore, the rate of release from detention facilities should approximate the natural streamflow rates that results from Tier B rainfall events (i.e. the target events for runoff control). Ideally, this release rate should be estimated based on streamflow monitoring from undeveloped catchments, as shown in the following case study example.

Case Study Example: Design Criteria for Runoff Control Facilities

Chilliwack has established preliminary detention storage and release criteria to achieve the City's runoff control target (i.e. detain rainfall events up to 60 mm per day and release at the natural interflow rate).

Storage Volumes

For development sites that achieve the City's rainfall capture target (i.e. capture the first 30 mm per day), an additional 300 m^3 of detention storage (i.e. 30 mm x 10 m^3 per mm) should be provided in community detention facilities.

Developers can reduce the size of detention facilities by increasing the size of infiltration facilities. The City's *Design Guidelines for Stormwater Systems* (see Chapter 7) provide a step-by-step procedure for designing integrated infiltration and detention systems and allow developers to make trade-offs between storage at the source and community storage.

Similarly, in catchments where the City's rainfall capture target cannot been achieved due to physical constraints (high water table, poor soils), more detention storage is required.

Release rate is not subtracted from storage volume criteria, which builds in a safety factor to account for back-to-back rainfall events. Performance monitoring may demonstrate that the safety factor is not needed in future development phases (see Step #6).

Release Rates

In 1999, the City of Chilliwack was proactive in setting up a network of streamflow monitoring stations, including two in natural forested catchments. This has enabled the City to establish the following detention release rate that approximates the natural forested condition.

Preliminary Release Rate for Detention Facilities in the City of Chilliwack
= 1 L/s per hectare (total area tributary to the detention facility)

Continued operation of the streamflow monitoring stations in the forested catchments (prior to development occurring in these catchments) will enable validation and refinement of this release rate. Post-development streamflow monitoring will enable the operation of detention facilities to be optimized (see Step #6).

Design Guidelines for Flood Risk Management (Managing Tier C Events)

Conveyance of peak flows from extreme storms and minimizing flood risk was the focus of traditional drainage engineering. While the focus has shifted to managing the complete spectrum of rainfall events (i.e. incorporating rainfall capture and runoff control), the flood risk management function is still an essential component of the overall strategy.

Providing Escape Routes for Extreme Storms

Flood risk management at the site level requires a common sense approach to site drainage. The objective is to ensure that the runoff from extreme rainfall events, such as a 100-year storm event, can escape to downstream watercourses without posing a threat to property or public safety. To achieve this objective, three design conditions must be addressed:

- All rainfall capture and runoff control facilities must include overflow escape routes to allow extreme storms to be routed to downstream watercourses, either as overland flow or via a storm drainage system (swales, ditches or pipes).
- Sites must be graded to ensure that any overland flow resulting from extreme storms is dispersed away from areas where flooding problems could otherwise result (e.g. residential properties in low-lying areas).
- The downstream storm drainage system must meet assessment criteria for both hydraulic and physical adequacy to handle the runoff from upstream development areas (refer to adjacent discussion).

Note that managing volume at the site through rainfall capture and runoff control will also reduce peak rates of stormwater runoff resulting from extreme storms.

Ensuring that Drainage Installations in Watercourses are Adequately Designed

Drainage system requirements for adequate containment and conveyance of stormwater runoff via watercourses are highly site-specific. However, the risk and acceptability of any drainage facility should be assessed in the context of two basic criteria:

- **Hydraulic Adequacy** – A comparison of rated capacity versus design flow
- **Physical Adequacy** – A qualitative judgement regarding physical constraints (e.g. culvert blockage) that could adversely impact hydraulic adequacy

Based on long-term experience, the governing criterion is almost always physical adequacy, with hydraulic adequacy generally being a secondary concern. Assessment of physical adequacy is a key input for any flood risk analysis.

Drainage problems often occur in small tributaries where stream crossings, such as culvert installations, are vulnerable to blockage (i.e. physically inadequate). Flooding may be a common occurrence at tributary stream crossings even though conventional analysis indicates that the conveyance capacity (i.e. hydraulic adequacy) is adequate.

Guiding Design Principle for Stream Crossings: Maintain Waterway Opening

A guiding principle for the design of stream crossings is to preserve or improve the cross-sectional area and gradient of the natural waterway. Clear span bridges are typically better than culverts.

A smooth flow condition should be maintained through culvert installations to minimize the degree of interference with creek processes. If this principle is followed, then the need for peak flow estimates to design culverts is diminished because it is of incidental interest. Physical acceptability governs.

Physical Acceptability of Culvert Installations in Watercourses

The high-risk locations for stormwater system failure are most often at culvert installations that are vulnerable to blockage (often on the smaller watercourses). Assessment of physical adequacy for culvert installations involves a 3-step process:

- **Conformance with Design Guidelines (Step #1):** Assess the overall conformance with the nine guidelines for effective culvert design presented below.

Nine Guidelines for Effective Culvert Design

1	Maintain line and grade of creek channel
2	Maintain the waterway opening by 'bridging' the creek channel
3	Construct inlet structure to provide direct entry and accelerated velocity
4	Ensure that culvert can pass trash, small debris and bedload material
5	Install debris interceptor upstream to provide protection from large debris
6	Provide scour protection to prevent undermining of the outlet structure
7	Incorporate provision for an overflow route in the event of a worst-case scenario
8	Provide equipment access for ease of maintenance (debris removal)
9	Consider environmental issues, such as fish passage

- **Vulnerability to Blockage (Step #2):** Assess culvert vulnerability and probability of culvert failure due to blockage. The potential for blockage reflects the bedload and debris characteristics of a creek.

- **Consequences of Failure (Step #3):** Assess the consequences of culvert failure due to blockage (e.g. road failure, damage to downstream properties)

The nine guidelines can be used to qualitatively assess the adequacy of existing facilities as either poor, fair, good or excellent. The outcome of Step #1 is an overall rating.

The results of Step #2 and Step #3 then determine the acceptability of the overall rating and whether or not to replace an existing facility.

The level of risk associated with the status quo then determines the need for and timing of replacement.

The Importance of Erosion Control for Flood Management

The culvert blockages that are often the cause of flooding problems on tributary streams can usually be traced back to two sources:

- erosion and deposition of bedload material
- transport of floatable debris such as branches and brush

Deposition of bedload material also results in the progressive reduction of drainage channel capacity, which increases flooding risk and can create an ongoing channel maintenance problem.

As discussed in Chapter 2, these physical processes are the result of increases in volume and rate of surface runoff. Therefore, providing rainfall capture and runoff control to reduce the volume and rate of runoff is an important part of flood risk management.

Flood Management Guidelines for Agricultural Areas

A primary flood management objective for agricultural areas is to provide adequate drainage to ensure that the frequency and duration of flooding in agricultural areas does not inhibit productivity. Meeting the following drainage criteria from the *Agri-Food Regional Development Subsidiary Agreement* (ARDSA) will ensure that flood management is adequate for agriculture:

- Flooding should be limited to a maximum of five days for the 10-year, 5-day winter storm (November to February).
- Flooding should be limited to a maximum of two days for the 10-year, 2-day growing season storm (March to October).
- Between storm events, the baseflow in ditches should be maintained at 1.2 m below the average ground level to provide free outlet for drains.

Note that these criteria are based on winter storms with a 10-year return period, which are significantly larger than a MAR (corresponds roughly to a 2-year return period).

The stormwater management practices required to achieve flood management criteria for agricultural areas will be highly watershed-specific, and should be evaluated as part of Integrated Stormwater Management Plans (ISMPs).

It is important to consider agricultural drainage objectives in the context of other objectives. For example, there may be a need to achieve a balance between the third ARDSA criterion defined above, and a fisheries objective of maintaining adequate low flows in channels to allow for fish passage, since agricultural drainage channels are often used as fish migration corridors.

Impacts from Upstream Areas

A key stormwater planning consideration is the potential impact that development could have on downstream agricultural areas (and vice versa). A common stormwater-related problem is the increase in frequency of flooding of agricultural areas as a result of increased runoff from upstream development areas. Implementing site design practices that meet rainfall capture and runoff control targets will mitigate this problem to a large extent.

Impacts on Downstream Areas

Agricultural areas can also have an impact on downstream urban and suburban land uses. This is often related to water quality impacts associated with agricultural land uses. Specific practices for managing water quality in agricultural areas (e.g. proper storage of manure) are beyond the scope of this Guidebook.

Step #5 – Evaluate Source Control Options Through Continuous Simulation Water Balance Modeling

The Importance of Continuous Simulation for Site Design

The most appropriate site design solutions for achieving rainfall capture targets on any given development site will depend on site-specific conditions such as soil type, land use type, rainfall and groundwater characteristics.

Continuous simulation modeling provides a tool to evaluate site design options under a full range of operating conditions (i.e. the complete rainfall spectrum).

While single event modeling provides an expedient way of establishing capacities and sizes for the design of conveyance facilities, it does not account for seasonal variation in hydrologic parameters such as antecedent soil moisture and evapotranspiration capacity. Nor does it account for the frequently occurring small rainfall events (the focus of rainfall capture). Chapter 7 provides a more detailed discussion on continuous simulation modeling for stormwater source controls.

Chapter 10 provides a more detailed discussion on the applications of single event and continuous simulation modeling in the context of integrated stormwater management plans (ISMPs).

Water Balance Modeling

Water Balance modeling using spreadsheets is a cost-effective method to ensure that the design of rainfall capture and runoff control facilities:

- meets performance targets for reducing runoff volume and rate
- is practical and achievable in the context of local conditions

Water Balance modeling for rainfall capture and runoff control facilities serves several purposes:

- **Validates preliminary design criteria** – Model outputs will provide confidence that preliminary design criteria meet (or exceed) performance targets for rainfall capture and runoff control.
- **Provides a benchmark for future evaluation** – Model outputs will guide the periodic evaluation of stormwater system performance and facilitate the process of optimizing design criteria (see Step #6).
- **Provides further design guidance for source control facilities** - The performance of source control options will depend on site-specific conditions such as soil conditions, land use and rainfall characteristics. Water Balance modeling helps with the selection of appropriate design options.

Case Study Example: Applying Water Balance Modeling to Evaluate the Effectiveness of Stormwater Source Control Options

The Water Balance Model (WBM) is a continuous simulation model that has been developed to simulate the hydrologic performance of stormwater source control options (i.e. how well they reduce the volume and rate of runoff). This model has evolved through case study applications of the Water Balance design approach presented in this Guidebook, including:

- developing design criteria for infiltration facilities in the City of Chilliwack (discussed in Step #4)
- evaluating the potential effectiveness of a broader range of stormwater source control options in the Greater Vancouver Regional District (GVRD), including:
  - absorbent landscaping
  - infiltration facilities (on lots and along roads)
  - green roofs
  - rainwater re-use

Key findings from the GVRD source control evaluation are presented in Chapter 7.

Step #6 - Optimize Stormwater System Design Through Adaptive Management

The performance targets and site design criteria presented in Steps #1 through #5 provide a starting point for the design of stormwater systems.

Stormwater system design criteria should be reviewed periodically (e.g. every 3 years), and optimized based on a detailed performance evaluation. The primary objective of this evaluation is to reduce stormwater-related costs while still achieving the defined goals and objectives for protecting downstream property, aquatic habitat and receiving water quality.

Performance Evaluation at the Site Level

Monitoring and evaluating the performance of demonstration projects at the site level is the primary basis for optimizing the design of stormwater systems. Figure 6-9 shows the indicators that should be monitored to enable a thorough evaluation of stormwater system performance.

Monitoring water level and flow in rainfall capture and runoff control facilities provides the basis for performance evaluation. A continuous record of water level and flow in rainfall capture and runoff control facilities (including road drainage flows) over an extended time period, combined with continuous rainfall data over the same time period, provides an accurate picture of how water moves through a stormwater system.

This continuous record will provide answers to key questions related to stormwater system performance, such as those shown in the adjacent table.

Framework for Performance Evaluation

For Rainfall Capture Facilities:	For Runoff Control Facilities:	For Road Infiltration/Drainage:
▪ What is the frequency and volume of overflow? ▪ Are targets for runoff volume reduction being achieved? ▪ How often does water accumulate? ▪ How fast does water level drop (i.e. infiltrate) under saturated soil conditions? ▪ What would be the effect of increasing/ or decreasing infiltration area? ▪ What would be the effect of decreasing storage volume?	▪ What is the frequency and volume of overflow? ▪ Are targets for runoff rate control being achieved? ▪ Do detention facilities empty prior to large rainfall events? ▪ What would be the effect of decreasing storage volume? ▪ Does the outflow hydrograph from detention facilities resemble the hydrographs observed at the streamflow monitoring stations in adjacent undeveloped catchments?	▪ Where does road runoff go? ▪ How much runoff discharges to detention ponds? storm sewers? directly to watercourses? ▪ How much infiltrates? ▪ How fast does road runoff and overflow from rainfall capture facilities enter the road drainage system? ▪ are the targets for runoff volume reduction and rate control being achieved?*

* These targets will depend on the road design objectives. Roads may be designed to provide rainfall capture or to be 'self-mitigating' (i.e. provide rainfall capture *and* runoff control).

Case Study Example: Communicating Performance Monitoring Requirements to Developers

The City of Chilliwack's *Design Guidelines for Stormwater Systems* (refer to Chapter 7) include requirements for performance monitoring, which correspond to Figure 6-9.

Performance Monitoring Requirements

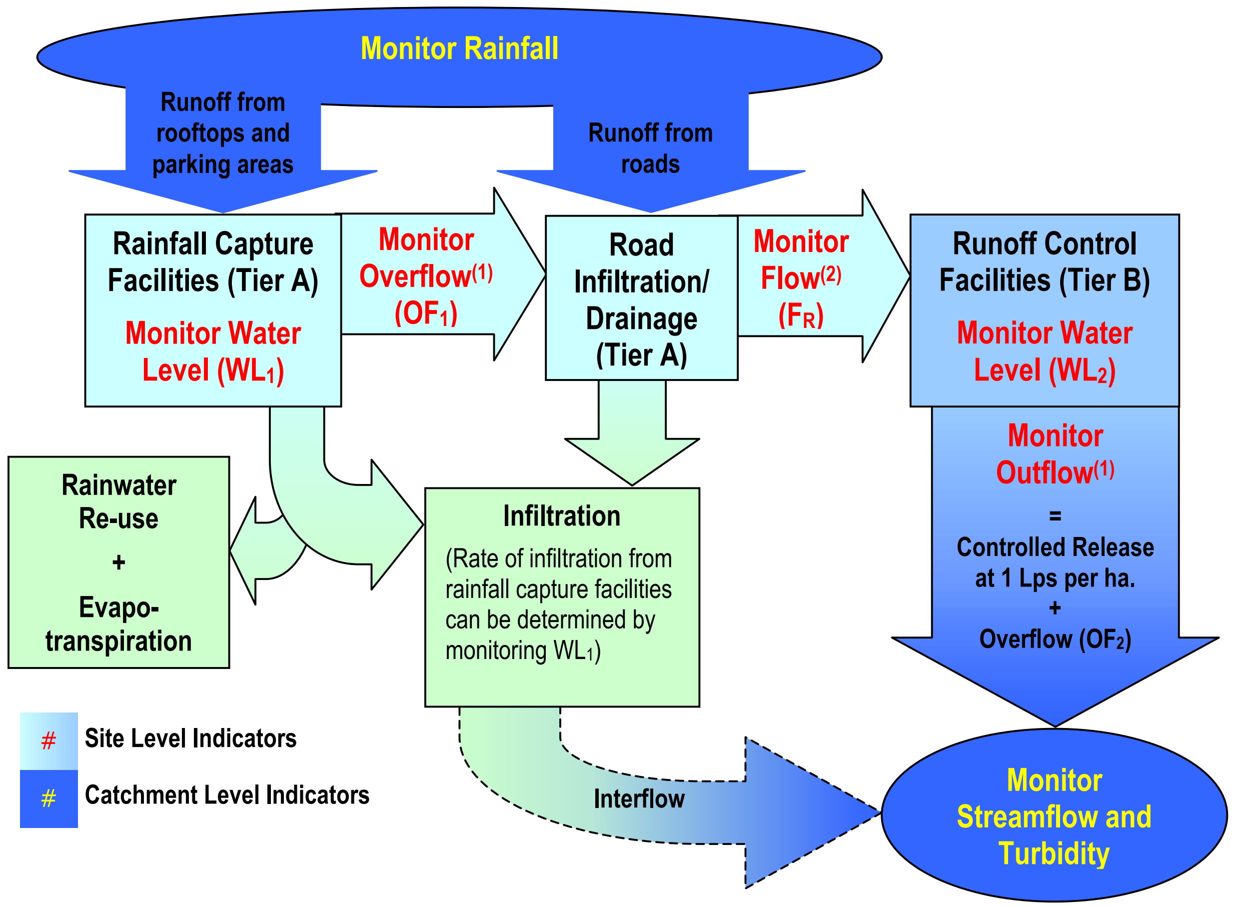


Figure 6-9

Indicator	OF_1	OF_2	Road Drainage	Streamflow
Performance Targets	➢ **Total overflow volume** should be about 10% of total runoff volume. ➢ **The frequency of overflows** should be about 6 to 8 times per year, on average.	➢ **Total overflow volume** should be about 3% of the total runoff volume. ➢ **The frequency of overflows** should be about once per year, on average.	➢ **total flow in the road drainage system** should meet the volume and frequency targets[(3)] for OF_1 or OF_2	➢ **The pre-development hydrograph** should be maintained in downstream watercourses.

Note: These overflow targets relate to the typical volume and frequency distribution of Tier A and Tier B rainfall events.

[(1)] Compound weir outlet structures will enable overflow from rainfall capture facilities and outflow from runoff control facilities to be correlated with water levels (WL_1 and WL_2, respectively). Overflow from runoff control facilities (OF_2) can be determined by subtracting controlled release (a known parameter) from total outflow.

[(2)] The amount of road runoff that infiltrates can be determined by subtracting F_R from total road runoff (and accounting for OF_1).

[(3)] If the design objective for roads is to provide rainfall capture, then the targets for OF_1 would apply. If the design objective is to make roads 'self-mitigating' (i.e. provide rainfall capture *and* runoff control), then the targets for OF_2 would apply. Note that storage does not need to be provided in runoff control facilities for self-mitigating roads.

Deciding Which Facilities to Monitor

To properly evaluate the performance of a demonstration stormwater management system, a comprehensive monitoring program should define the Water Balance of the development site served by that system. This means that the monitoring information must answer the following question:

- Where does the rain that falls on the site end up?

Not every rainfall and runoff control facility needs to be monitored, however, it is important to monitor a representative sample from each component of the stormwater system. For example, a comprehensive monitoring program for a residential subdivision may include:

- **On-lot rainfall capture monitoring (Tier A)** – Monitor water level and overflow from at least one on-lot rainfall capture facility.
- **Road infiltration/drainage monitoring (Tier A)** – Monitor the drainage from at least one section of road, which may include more than one drainage path (e.g. french drains and catch basins).
- **Community detention pond monitoring (Tier B) –** Monitor water level and outflow from a detention pond serving the entire subdivision.

The monitoring information from a stormwater system should enable the performance of each stormwater system component and the performance of the overall system to be evaluated separately based on the appropriate performance targets and design objectives.

Testing Conservative Assumptions

To deal with uncertainty, the preliminary stormwater system design criteria presented in Steps #1 through #5 are based on conservative assumptions:

- Detention storage volumes are conservative because they are based on long-duration rainfall events (24 hr) and do not account for release rate.
- Infiltration facility design criteria are based on conservative modeling assumptions.

Performance monitoring would be expected to confirm that initial assumptions are conservative and provide the certainty needed to reduce the size of facilities installed in subsequent developments. This should translate into cost savings over time.

Customizing Infiltration Criteria for Different Zones

The rate of infiltration from on-lot or on-road infiltration facilities, and from unlined detention ponds, depends on soil conditions.

Monitoring the water level in rainfall capture or runoff control facilities will demonstrate how much water actually infiltrates and how the infiltration rate varies throughout the year.

This site-specific information can be used to develop customized design criteria for zones that have similar soil types.

Performance Evaluation at the Catchment Level

Performance evaluation at the site level is the primary basis for optimizing the design of stormwater systems. Performance evaluation at the catchment level is also important to ensure that overall objectives for protecting aquatic habitat and receiving water quality are being achieved over time, and to improve stormwater management practices. Performance evaluation at the catchment level may require monitoring of:

- **Hydrologic Indicators** (e.g. change in rainfall-runoff response). Monitoring rainfall and runoff patterns provides an understanding of the effectiveness of source control strategies at maintaining or restoring the catchment's natural Water Balance and hydrology.
- **Water Quality Indicators** (e.g. change in total suspended solids (TSS)). Monitoring changes in TSS provides an indicator of improvements or declines in water quality. TSS acts as a 'carrier' for other pollutants such as heavy metals, and provides a direct measure of stream erosion and sedimentation rates.
- **Ecological Indicators** (e.g. abundance of benthic invertebrate community). Monitoring the characteristics of benthic invertebrate communities can provide a direct measure of changes in stream health over time.

Hydrologic Performance Evaluation

A key performance objective is to maintain, as closely as possible, the characteristics of the natural hydrograph (i.e. hydrograph of the catchment in its undeveloped state), including:

- total flow volume
- peak flow rates
- baseflow rates (i.e. interflow)
- hydrograph shape

Note that when natural forest cover is removed a certain amount of natural evapo-transpiration capacity is lost. Therefore, an increase in total flow volume is almost always expected from developed catchments (unless rainwater re-use is implemented). This underscores the importance of land development practices that preserve and/or restore as much natural forest cover as possible. The use of green roofs can also limit, though not replace, the loss of natural evapotranspiration capacity.

Continued streamflow monitoring at the catchment level will answer the following key performance evaluation question:

- How well are stormwater management practices at the site level maintaining the characteristics of a natural hydrograph as development proceeds within a catchment?

Water Quality Performance Evaluation

Another performance objective is to maintain pre-development water quality. Turbidity and total suspended solids (TSS) are key water quality indicators that can be monitored at the catchment level. Because turbidity can be correlated with TSS, turbidity monitoring could be effectively integrated with streamflow monitoring.

A water quality baseline should be established by measuring turbidity and TSS prior to development proceeding in a catchment. This will enable future water quality monitoring to answer the following performance evaluation question:

- How well are stormwater management practices at the site level maintaining the pre-development water quality?

Benthic Monitoring as an Early Warning Indicator

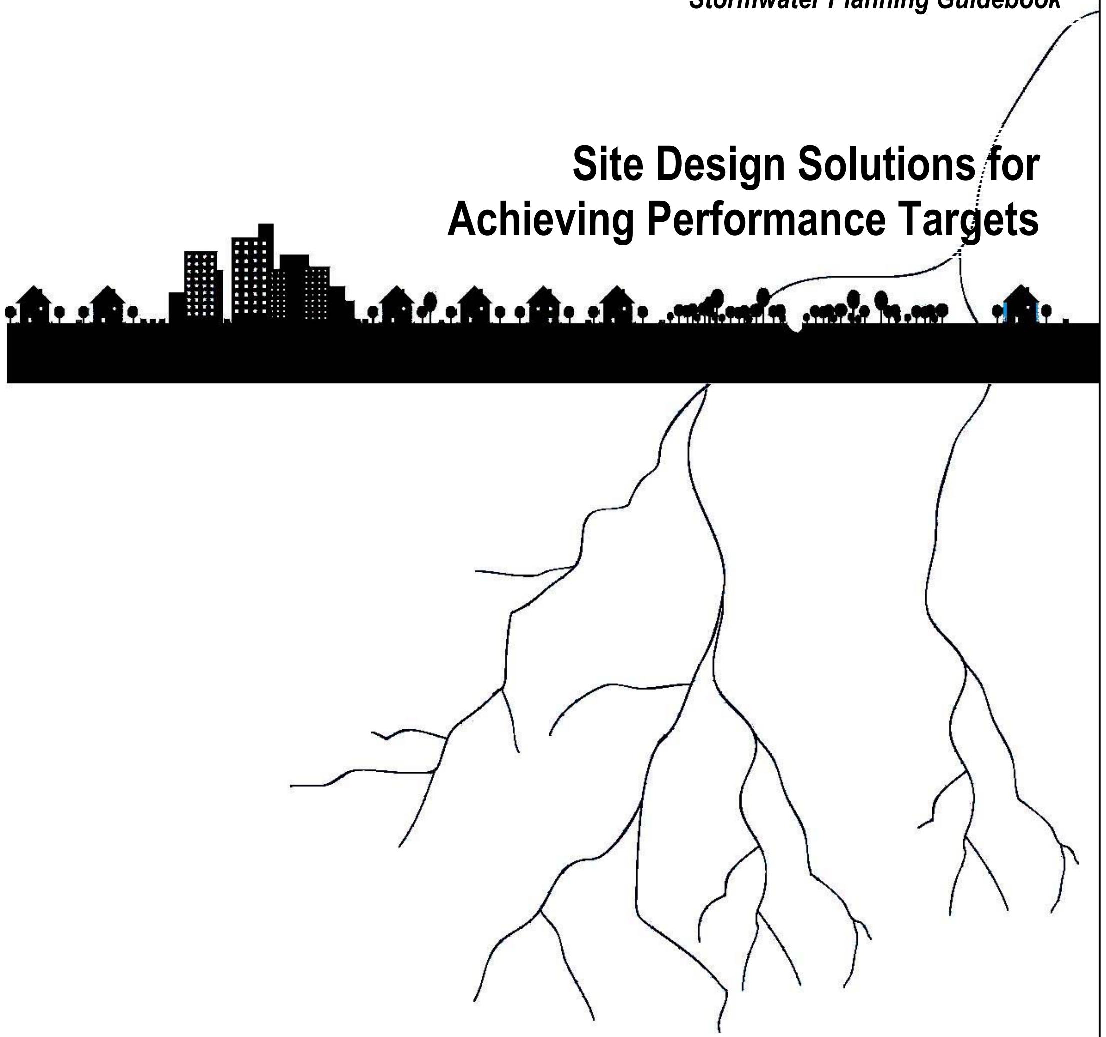
The Benthic Index of Biological Integrity (B-IBI) is a direct indicator of stream health. For streams that are seen as highly valuable (by citizens or environmental agencies), establishing a B-IBI baseline and implementing an ongoing monitoring program would provide an 'early warning' of stream degradation, and signal the need for action.

A Look Ahead

Chapter 10 elaborates on environmental monitoring techniques that can be used to measure success at the catchment scale. This includes a discussion of the suite of tools that comprise a comprehensive approach, and an overview of the appropriate scale on which to use them.

The key message is that this suite of indicators accurately represents the environmental state of both the surface drainage function and the ecological function of receiving waters and can therefore be used to evaluate and optimize stormwater management strategies over time.

Site Design Solutions for Achieving Performance Targets



Chapter Seven

7.5 Type 2 Source Control - Infiltration Facilities

- The Importance of Disconnecting Impervious Surfaces
- Different Types of Infiltration Facilities
- Factors that Affect the Performance of Infiltration Facilities
- The Effectiveness of Infiltration under Different Rainfall Conditions
- Selecting Infiltration Facility Depth
- The Importance of Infiltration Area and Soil Type
- Determining What is Feasible and Affordable
- Infiltration Facilities for Land Uses with High Impervious Coverage
- Performance of Infiltration Facilities for a Range of Land Use Types
- Performance of Infiltration Facilities on Roads
- Achievable Level of Runoff Volume Reduction for Different Land Use Types
- Creating Hard Surfaces that Infiltrate
- Applying Combination of Infiltration Strategies
- Cost Implications of Infiltration Facilities
- Design and Construction Tips for Infiltration Facilities
- Operation and Maintenance Tips for Infiltration Facilities

7.6 Type 3 Source Control - Green Roofs

- The Effectiveness of Green Roofs under Different Rainfall Conditions
- The Importance of Green Roof Soil Depth
- Benefits of Green Roofs for Different Land Uses
- Cost Implications of Green Roofs
- Design and Construction Tips for Green Roofs
- Operation and Maintenance Tips for Green Roofs

7.7 Type 4 Source Control - Rainwater Re-use

- Benefits of Rainwater Re-use for Different Land Uses
- The Effectiveness of Rainwater Re-use under Different Rainfall Conditions
- Selecting an Appropriate Storage Volume
- Cost Implications of Rainwater Re-use
- Design and Construction Tips for Rainwater Re-use
- Operation and Maintenance Tips for Rainwater Re-use

7.8 Applying Source Controls to Mitigate Extreme Cloudbursts

7.9 Communicating Performance Targets to Developers

- Case Study Example: Design Guidelines for Developers

7.1 Overview of Site Design Strategies for Achieving Performance Targets

Chapter 6 showed how to establish performance targets. This chapter presents site design strategies for achieving performance targets, including:

- **Low Impact Development Practices** that:
  - minimize the creation of impervious cover (i.e. reduce total impervious area (TIA)) and other land cover changes that are detrimental to downstream watercourses, such as clearing of natural vegetation and compaction of soils.
  - preserve natural features that are key to maintaining healthy aquatic ecosystems, such as riparian forests and wetlands.
- **Stormwater Source Control Practices** that capture rainfall at the source (on building lots, road right-of-ways, or in neighbourhood facilities) and return it to natural hydrologic pathways - infiltration and evapotranspiration - or re-use it at the source. Source controls create hydraulic disconnects that reduce effective impervious area (EIA).

Catchment-specific performance targets for rainfall capture and runoff control may be achieved at the site level through some combination of these strategies.

Section 7.2 discusses low impact site design practices, and Sections 7.3 through 7.8 provide guidance for selecting appropriate stormwater source control options.

Section 7.9 shows how to communicate performance targets and related design guidelines to developers so that they can be applied at the site level.

7.2 Low Impact Development Practices

Reducing Total Impervious Area

Runoff from impervious surfaces is the primary cause of drainage-related problems such as stream degradation and flooding risk. Limiting impervious coverage can reduce runoff volume and partially mitigate these problems.

At the Land Use Planning Level

Impervious coverage can be controlled at the land use planning level by controlling where certain land use types are permitted. Limiting the amount of development, or controlling the type of development, in catchments where local and downstream ecosystem values could be negatively impacted, can be a science-based strategy to support stormwater management goals.

However, stormwater is just one of many factors that need to be considered when making land use decisions.

At the Site Design Level

There are a number of site design practices that can reduce impervious coverage for a wide range of land uses, including:

- **Reducing Road Widths** – Paved roadways are often larger than they need to be. Reducing road width not only reduces impervious area, but also reduces motor vehicle speeds, improves pedestrians and bicycle safety, reduces infrastructure costs and allows more of the paved surface to be shaded by overarching tree canopy.
- **Reducing Building Footprints** – Building footprints can be reduced (thus reducing rooftop area) without compromising floor area by relaxing building height limitations. Taller, more slender building forms provide greater flexibility to develop building layouts that preserve naturally vegetated areas and provide space for infiltration facilities. This also has important implications for integrating source control into site design, as discussed in Section 7.5.
- **Reducing Parking Standards -** Reducing parking standards reduces the amount of space devoted to parking (driveways, parking lots and parkades). In compact and/or high density communities where dwelling units are within walking distance to transit and services, parking standards may be reduced to 1.3 or even as low as 1 space per dwelling unit. There are other factors that could reduce the need for parking, including a high proportion of low income housing units, the implementation of transportation demand management strategies, and high parking costs. Reducing parking standards not only reduces impervious area, but also reduces parking-related development cost, and facilitates the provision of affordable housing.
- **Limiting the Amount of Surface Parking** – The more parking provided within the building envelope (e.g. underneath other land uses), the less additional lot area will be needed for parking. For parking outside the building envelope, surface parking typically creates far more impervious coverage than parkades. There is also greater opportunity to mitigate the runoff from parkades using green roofs or rainwater re-use (see Sections 7.6 and 7.7). Generally, underground parking only occurs where land economics favour residential or commercial development over surface parking.
- **Building Compact Communities –** Building compact communities enables more natural area to be preserved, thus reducing impervious coverage at the watershed scale. In a compact community pattern, there can be up to 75% less roadway pavement per dwelling unit. The need for parking is also reduced in compact communities, as discussed previously.

Site design practices that reduce total impervious areas also reduce clearing of natural vegetation and the compaction of natural soils (total site disturbance is reduced).

Reducing Impervious Area Improves Source Control Effectiveness

Reducing impervious coverage on lots and roads can improve the effectiveness of stormwater source controls, particularly infiltration facilities. Less impervious coverage on roads and building lots means that:

- less runoff becomes concentrated into infiltration facilities
- more space is available to locate infiltration facilities

This can significantly improve the effectiveness of infiltration facilities, as discussed in Section 7.5.

Stormwater Source Control – A Key Element of Site Design

Implementing low impact site design practices that reduce impervious coverage is not enough to protect downstream watercourses and prevent drainage-related problems. Even low levels of impervious coverage can cause significant stormwater-related impacts. For example, the volume of runoff from low-density single family land uses far exceeds the target condition for Water Balance management (i.e. the 10% runoff volume target).

Source controls are needed to further reduce runoff from impervious surfaces on development parcels (rooftops, driveways, parking lots) and roads (paved roadway and sidewalks).

Consistency with Other Low Impact Development Objectives

Site design practices that achieve stormwater objectives (reducing impervious area, forest clearing and soil compaction) are highly compatible with other low impact development objectives, including:

- Compact communities and cluster development that encourage walking, cycling and transit use
- Smaller streets that are more pedestrian and cyclist-oriented
- Continuous riparian corridors and open space systems (greenways)
- Preservation of environmentally significant areas
- Tree retention
- Community parks and recreation areas
- Construction practices that minimize soil and vegetation disturbance
- Lower expenditures on infrastructure

Preserving Significant Natural Features

Preserving natural vegetation and soils in their undisturbed state is key to minimizing changes in the natural Water Balance (i.e. loss of evapotranspiration and infiltration capacity). There are certain natural features that are especially important for maintaining the health of aquatic ecosystems, including riparian forests, wetlands, natural infiltration areas and floodplains. These features can also have significant benefits in terms of reducing flood risk.

A key component of an integrated strategy to manage stream health and flood risk is to identify significant key natural features at a watershed scale, and protect these features through growth management, land use planning, and development policies and regulations.

Significant natural features should also be identified at the site design level, and preserved through creative site design practices that integrate significant natural features with community open spaces.

Riparian Forests

As discussed in Chapter 2, riparian forests are key to maintaining the health of aquatic ecosystems. Preserving riparian forests enables overland flow to infiltrate and directly feed stream baseflow, thus helping to maintain the natural Water Balance.

Wetlands

Wetlands play a key role in maintaining natural Water Balance and hydrology. They retain large volumes of water, and promote recharge of the interflow zone and evapotranspiration from wetland vegetation. The vegetation in wetlands also improves water quality by removing sediments, nutrients and other contaminants such as heavy metals. Wetlands are typically very productive ecosystems that provide high quality habitat for waterfowl, fish and other wildlife. Constructed wetlands can be used to manage runoff from developed areas.

Natural Infiltration Areas

Natural areas where large volumes of rainfall infiltrate (e.g. natural depressions with highly permeable soils) are key to maintaining the natural Water Balance and should be preserved. Natural infiltration areas that directly feed stream baseflow (e.g. riparian corridors) are particularly important. These areas may also be used to infiltrate runoff from impervious surfaces.

Floodplains

Natural floodplains provide the space for streams and rivers to expand during periods of high rainfall and/or snowmelt. Floodplains provide natural flood control by dissipating the energy of high peak flows. Confining watercourses using flood protection structures such as dykes prevents this natural energy dissipation, and increases the risk of downstream flooding.

The periodic flooding of floodplain areas is also key to maintaining important ecosystems, including riparian forests and wetlands.

The hydrologic functions of natural floodplains can be preserved by limiting development, or by promoting ‘flood-friendly’ land uses (e.g. types of agriculture that can support periodic flooding, buildings that are flood-proofed) in floodplain areas.

7.3 Stormwater Source Control Practices

The Role of Source Control

Stormwater source control practices can play a key role in achieving performance targets for rainfall capture, runoff control and flood risk management.

The primary objective of source control is to reduce runoff volume (i.e. provide rainfall capture) by managing the Water Balance at the site level. Source control can also have significant benefits in terms of reducing runoff rates (i.e. provide runoff control and flood risk management).

Source controls can be very effective at reducing runoff volumes and at reducing peak runoff rates from relatively large storms (e.g. 5-year storms) or from very intense short duration storms (e.g. 100-year cloudburst). However, the ability of source controls to reduce peak runoff rates from very large, long duration storms (e.g. a 100-year winter storm) is limited. Even with source controls, stormwater systems must be designed to safely convey these extreme events.

The Need for Information on Source Control Effectiveness

In order to select appropriate source control options to achieve catchment-specific performance targets, there is a need for information on how well different types of source controls perform under different conditions (e.g. land use types, soil and rainfall conditions).

There is a lack of scientifically defensible data on the long-term effectiveness and benefits of different types of stormwater source controls. To bridge this information gap, in the Greater Vancouver Regional District (GVRD) commissioned a report titled *Effectiveness of Stormwater Source Controls* (2002) to assess the potential effectiveness of various source control options (as measured by their ability to reduce runoff volume and peak rate).

The GVRD report provides a quantitative reference on the effectiveness of the following categories of stormwater source controls:

- **Type 1 - Absorbent Landscaping -** refer to Section 7.4
- **Type 2 - Infiltration Facilities (on lots and along roads) -** refer to Section 7.5
- **Type 3 - Green Roofs -** refer to Section 7.6
- **Type 4 - Rainwater Re-use -** refer to Section 7.7

Guidance for Selecting Appropriate Source Controls

Sections 7.4 to 7.7 present key information from the GVRD report to show how the hydrologic performance of each source control category (i.e. their ability to reduce the volume and rate of runoff) varies depending on land use type, soil conditions, rainfall characteristics and source control design.

For each source control category, these sections also provide design guidance, discuss cost implications and review operation and maintenance requirements.

The information provided in Sections 7.4 to 7.7 is intended to help local governments:

- identify opportunities to manage stream health and/or stormwater infrastructure by applying various types of stormwater source controls
- determine what can realistically be achieved through the application of source controls
- determine which source control options are worth pursuing, and
- estimate the likely return on investment

This provides a starting point for integrating stormwater source control strategies into:

- long-range land use and infrastructure planning decisions
- the design of stormwater systems at the site level

The most appropriate source control options and source control design features for any given development or re-development site will depend on site-specific conditions.

The selection of source controls to meet catchment-specific performance targets should be flexible to allow for innovation. Local government staff, consulting professionals, or developers that select source control options should consider the need for these options, site constraints to their use, expected performance and benefits, maintenance considerations and costs implications (both positive and negative).

This chapter helps evaluate these factors. For more detailed information on the effectiveness of stormwater source controls refer to the GVRD report.

Modeling the Effectiveness of Source Controls

The commonly used hydrologic modeling applications were developed when flow-based thinking dominated stormwater management and surface water modeling. Therefore, none of these models are well suited for modeling Water Balance volumes at the site level.

The Water Balance Model (WBM), introduced in Chapter 6, was used to simulate the performance of source controls under a range of conditions.

Overview of the Water Balance Model

The WBM provides a continuous simulation of the runoff from a development (or re-development) area, or from a watershed (or sub-catchment) with multiple land uses, given the following inputs:

- **Continuous rainfall data** (time increment of one hour or less) and **evapo-transpiration data** (daily) over a long period of record (at least a year). Historic rainfall data can be modified to create climate change scenarios.
- **Site design parameters** for each land use type being modeled (e.g. road width, rooftop coverage, surface parking coverage, population density).
- **Source control information** for each land use type, including:
  - extent of source control application (e.g. % of road and % of building lots with a certain types of source controls)
  - source control design parameters (e.g. area and depth of infiltration facilities, soil depth for green roofs or absorbent landscaping, volume of rainwater re-use cisterns)
- **Soils information**, including:
  - surface soil parameters (e.g. maximum water content, vegetation rooting depth)
  - sub-surface soil parameters (e.g. saturated hydraulic conductivity)

Scenario Modeling

The WBM was used to generate a series of scenarios that demonstrate how a range of factors (e.g. rainfall, land use type, soil conditions) affect the hydrologic performance of the various source control categories.

The source control modeling was based on the best available knowledge of source control performance, but has not been calibrated with measured hydrologic performance data. Performance monitoring from source control demonstration projects will improve understanding of how well source controls can reduce runoff under a variety of conditions, and provide the data needed to calibrate the source control models.

The source control scenarios presented in this chapter are examples, and do not reflect the complete range of available source control options. The examples are intended to provide a starting point for evaluating the potential for source control application, and should not limit innovation in applying combinations and types of source controls.

Chapter 8 presents the results of scenario modeling for case study watersheds to demonstrate what is achievable at the watershed scale through the application of source controls.

Integrating Source Controls into ISMPs

Source controls are applied at the site level, but must be implemented in the context of an Integrated Stormwater Management Plan (ISMP). At the planning level it is important to:

- **Identify stormwater related issues**
  - significant resources to be protected and/or restored
  - drainage problems, such as high flooding risk
- **Characterize development pressures that could affect aquatic ecosystem values or drainage system performance**
  - are there plans for new development in existing natural areas?
  - are there older development areas where re-development is imminent?
- **Evaluate the opportunities for implementing stormwater source controls to:**
  - avoid further stream degradation
  - avoid worsening of drainage problems
  - improve water quality
  - restore watershed health over time

Performance targets, such as the 10% runoff volume target, provide a reference point based on the characteristics of a healthy watershed. The ISMP process will determine what is achievable and affordable in the context of each individual watershed.

Chapter 8 presents case study examples that show how watershed restoration could be achieved over a 50-year timeline through the application of source controls.

Evaluating the Cost of Source Controls

This chapter discusses cost implications of each source control category and provides order-of-magnitude cost estimates. Detailed cost estimates can only be obtained based on the characteristics of each individual development site.

Site-specific costs should be evaluated relative to the potential benefits gained, in terms of protecting or improving watershed health and/or in terms of flood risk management. The information in this chapter helps evaluate the benefits of using source control options.

Cost estimates can be misleading if they are not considered in the context of the overall development process. For example, there may be excavation costs associated with the construction of an infiltration facility on a particular lot, but much of this cost may be incurred through the site grading process (even without infiltration).

It is also important to consider the potential cost savings of source controls. For example, applying infiltration facilities may reduce the cost of storm sewer pipes needed for a new development project, avoid the need for ongoing maintenance of eroded channels, or avoid the need for drainage infrastructure upgrades.

Ensuring the Long-Term Performance of Source Controls

Source control facilities typically require ongoing maintenance to ensure that they continue to function effectively over the long term. While this report discusses operation and maintenance requirements and costs for each source control category, there is a need for further research to better define the:

- operation and maintenance practices required to maintain source control performance over the long term
- cost of these operation and maintenance practices

To address these research needs and provide further guidance on how maintain the long-term performance of source controls, it is important to continue monitoring the performance of source control demonstration projects over long periods of time and to keep accurate records of ongoing operation and maintenance practices.

Operation and Maintenance Implications

New source control practices raise concerns about associated operations, maintenance and liability issues. It is important during any adoption of new design standards to involve operations and maintenance personnel, and to use their creative and practical talents to anticipate and solve these issues.

Demonstration projects are an excellent way to solve real operations and maintenance problems, and to allay false fears.

Certain types of source control facilities may be operated and maintained by local government staff (e.g. infiltration facilities within road right-of-ways). However, many source control facilities are likely to be on private property (e.g. on-lot infiltration facilities, re-use facilities or green roofs). Responsibility for maintaining these facilities shifts to individual landowners or strata corporations, which places a greater reliance on the conscientiousness of individuals.

An on-lot stormwater system is similar to an on-lot septic sewage system, in that owners must be given basic information about operation and maintenance requirements.

There are potential liability issues related to operation and maintenance responsibility (e.g. who is responsible in the event of a failure?). Local governments should resolve these issues in collaboration with landowners and the development community. There are parallel issues relating to water supply and sanitary sewer systems (e.g. sewer cross connections) that local governments have been dealing with for years and could use as precedents.

Education of local government staff, developers and the general public regarding the need for source controls, as well as their long-term operation and maintenance requirements, is essential to the successful implementation of stormwater source controls.

Section 8 provides further discussion and guidance on how to facilitate the changes in standard practice that are needed to promote the widespread implementation of source controls.

Water Quality Benefits of Source Control

Stormwater source controls capture the first flush of pollutants that wash off from impervious surfaces. This is particularly important for roads and parking areas because pollutants from motor vehicles and road maintenance can accumulate on these surfaces.

Infiltration facilities are particularly beneficial in terms of improving water quality at the source. Absorption of stormwater runoff in the shallow soil zone filters out sediments and many pollutants, thus improving downstream water quality.

This chapter focuses on the effectiveness of source controls at reducing runoff volume and rate, because this information enables source control to be evaluated relative to performance targets for rainfall capture and runoff control. Further research is needed to provide similar quantitative modeling of the effectiveness of source controls for improving groundwater and surface water quality.

This research should start with a good understanding of the source of water quality problems (e.g. runoff from roadways, lawns and agriculture areas). This understanding will enable the selection of appropriate water quality indicators and the development of an appropriate water quality model.

As a parallel example, the evaluation of hydrologic effectiveness presented in this report started with a good understanding of the source of water quantity problems (i.e. an increase in the volume and rate of runoff). This understanding led to selection of appropriate hydrologic performance indicators and development of the Water Balance Model.

7.4 Type 1 Source Control - Absorbent Landscaping

The Importance of Surface Soil and Vegetation

Surface soil structure plays a fundamental role in stormwater management. Minimizing surface soil disturbance and using absorbent landscaping can significantly reduce the volume and rate of runoff from developed areas.

In a natural condition, surface soil layers are highly permeable. Surface plants provide a layer of organic matter which populations of earthworms and microbes stir and mix into the soil. This soil ecosystem provides high infiltration rates and a basis for interflow that supports the baseflow needs of aquatic ecosystems.

In an urbanized condition, it is common practice to remove the surface soil layers, to regrade and heavily compact the site, and then to replace only a thin layer (often 50mm or less) of imported topsoil. This practice creates a surface condition that results in significant amount of runoff from lawn and landscape areas.

Absorbent Soil and Vegetation Characteristics

Vegetation and organic matter improve soil structure and contribute to macropore development. This is essential for promoting and maintaining infiltration and evapo-transpiration capacity. To optimize infiltration, the surface absorbent soil layer should have high organic content (about 10 to 25%). Surface vegetation should be either herbaceous with a thickly matted rooting zone (shrubs or grass), deciduous trees (high leaf density is best), or evergreens.

A range of soil and vegetation characteristics is acceptable depending on whether the area is to be covered by lawn, shrubs or trees. The soils required by the BC Landscape Standard for medium or better landscape will provide the required hydrologic characteristics. Often this standard can be achieved by adding organic matter to existing top soils on a residential site.

Figure 7-1 shows the mixing of soil and organic matter to create a good landscape soil.

A range of acceptable absorbent soil compositions are shown in Section 7.9.

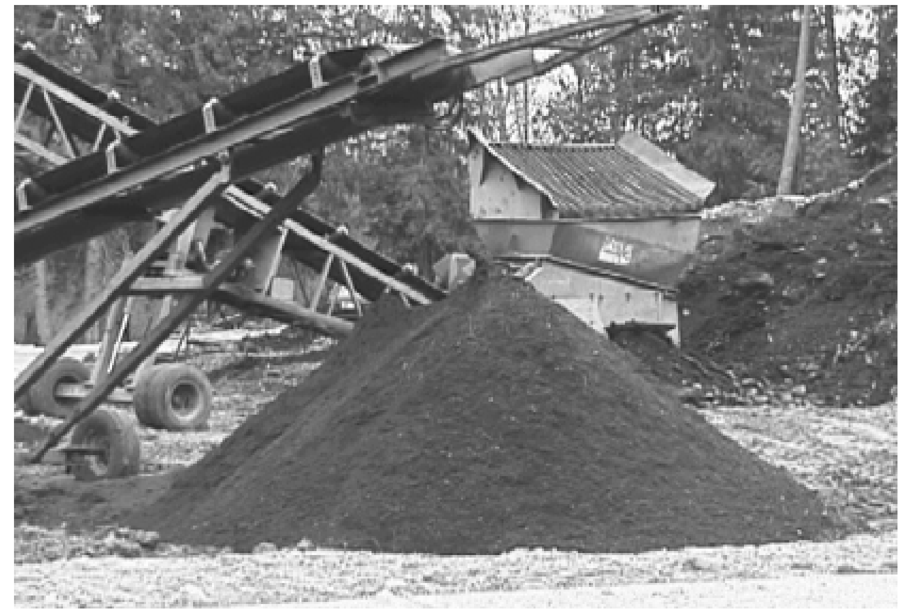


Figure 7-1 Creation of Landscape Soil

Absorbent Soil Depth

Figure 7-2 shows that runoff from landscaped areas can be virtually eliminated by providing a 300 mm layer of landscaped absorbent soil, even under very wet conditions where the hydraulic conductivity of the underlying soil is low.

The Figure assumes that the rooting zone of the surface vegetation extends to the depth of the absorbent soil layer, and that absorbent landscaping covers all undeveloped areas.

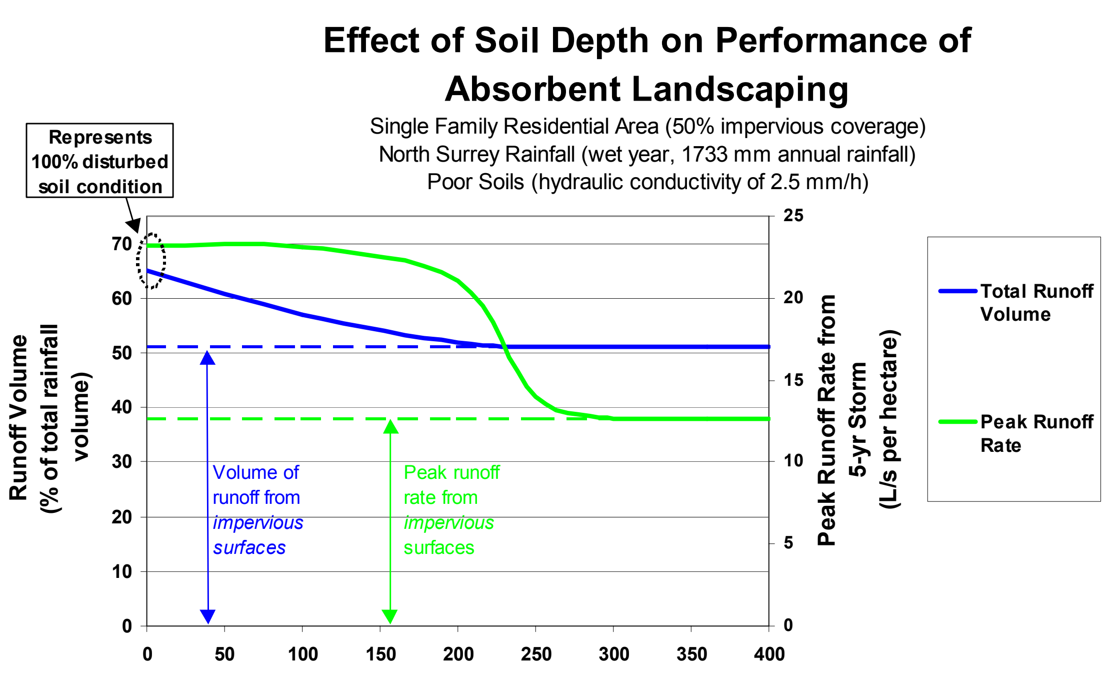


Figure 7-2

The Importance of Forests

Forests are the most effective form of absorbent landscaping. Since trees typically have very deep rooting zones (often in the range of 2 metres), there is virtually no surface runoff from forested areas. Tree canopies that shade impervious surfaces (e.g. roadways) can reduce the runoff from these surfaces by intercepting rainfall.

Preserving and/or restoring as much forested area as possible through implementation of an urban forestry strategy is an effective way to reduce runoff volumes and rates.

The thick layers of absorbent soil in forested areas typically have the capacity to retain and infiltrate large volumes of runoff (in addition to direct rainfall). Dispersing runoff from rooftops or paved surfaces over forested areas can be an effective infiltration strategy, as discussed in Section 7.5.

The Benefits of Absorbent Landscaping for Different Rainfall Conditions

Figure 7-3 shows that absorbent landscaping is most beneficial for high rainfall locations. This is because increased rainfall typically leads to greater volumes of runoff from disturbed soil, but not from absorbent landscaping.

Absorbent landscaping (300 mm soil depth or more) can virtually eliminate surface runoff from undeveloped areas, even in the wettest conditions. This has significant benefits in terms of reducing peak runoff rates from extreme rainfall events, as shown on the following page.

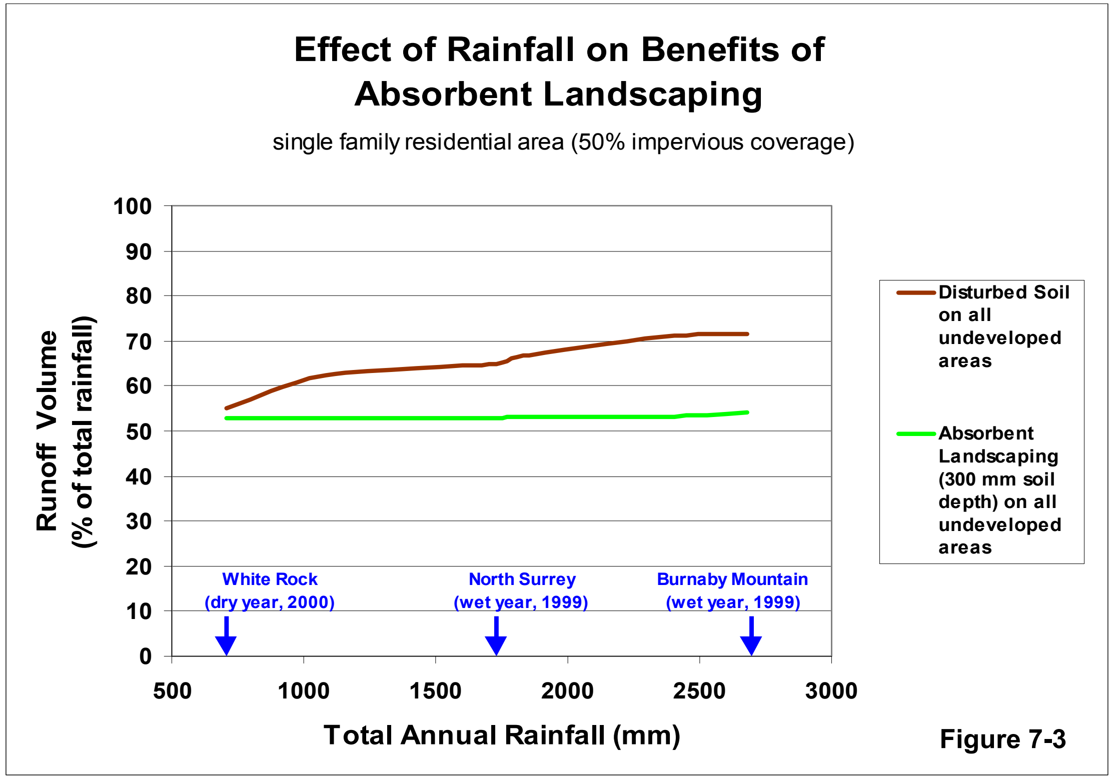


Figure 7-3

Benefits of Absorbent Landscaping for Different Land Use Types

The benefits of absorbent landscaping are more significant for land uses with lower levels of impervious site coverage and higher proportions of undeveloped area (e.g. single family residential), as shown in Figures 7-4 and 7-5.

These figures show the simulated runoff volumes and peak runoff rates during a very wet year (1999) in North Surrey. A total of 1733 mm of rainfall fell during this year, and the most extreme rainfall event was a long duration, wet weather storm with a 5-year return period.

Figure 7-4 shows that absorbent landscaping is particularly beneficial in terms of reducing peak runoff rates. During large rainfall events (e.g. a 5-year storm), disturbed soil can generate nearly as much runoff as impervious surfaces, whereas an absorbent soil layer (300 mm depth) can continue to absorb rainfall. Therefore, absorbent soil can significantly reduce peak runoff rates from large storms, especially for land uses with large amounts of undeveloped space.

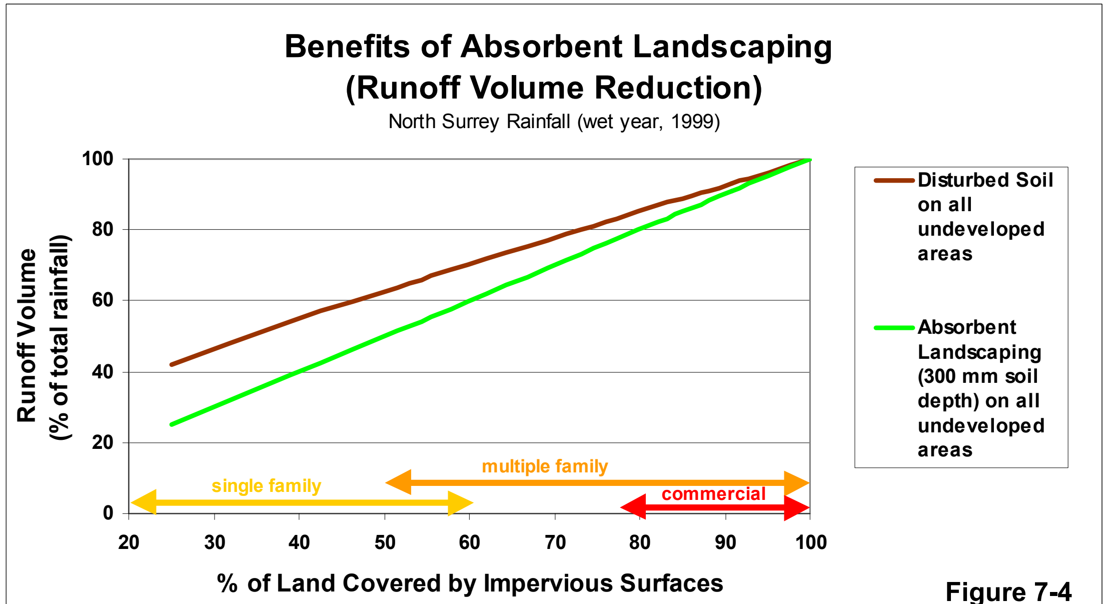


Figure 7-4

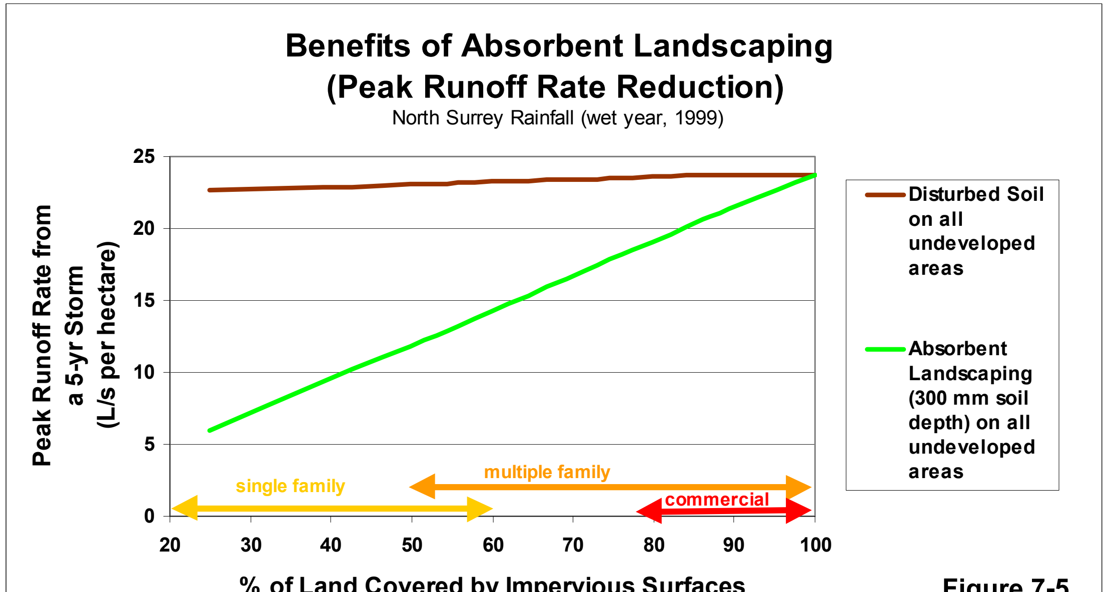


Figure 7-5

Cost Implications of Absorbent Landscaping

The costs of absorbent landscaping are highly variable and depend on site-specific conditions such as vegetation type. This reflects the customized nature of individual site landscaping plans.

Typical costs for absorbent landscaping range from about \$25 - \$70 per m^2. In the lower cost ranges, the absorbent soil depth would be about 150 mm, with turf cover and some trees. In the upper ranges, soil depth would be about 450mm, with shrubs or groundcover and trees.

Maintenance Tips for Absorbent Landscaping

- Maintaining the absorbency of soils is an advantage both to turf and plant health and to stormwater management. Normal landscape maintenance of absorbent soils will generally produce an absorbent landscape surface.
- In shrub beds, regular application of bark mulch, natural leaf drop or other organic inputs will keep burrowing insect populations high and maintain soil permeability.
- In lawn areas, use of proper sandy topsoil will avoid compaction problems. Aerating techniques can assist air and water exchange in locally compacted areas.
- Bare soils should not be left uncovered (e.g. during construction) because rainfall impact can create a relatively impermeable surface crust, even in sandy soils.
- Dry season watering of plants is essential, especially when plants are first becoming established.
- Maintenance requirements (and costs) are typically highest in the first year when plants may require more watering, weeding and some replacement.

Rehabilitation of Disturbed Soil

There are a number of ways to convert a disturbed surface soil layer into absorbent soil that has good hydrologic properties, including:

- Mixing in organic content (e.g. compost); this is the most effective soil rehabilitation technique
- Mechanical tilling or scarifying of the surface soil
- Soil aeration, which requires specialized equipment

Immediate replanting of the surface soil layer is an essential part of any soil rehabilitation project.

7.5 Type 2 Source Control - Infiltration Facilities

The Importance of Disconnecting Impervious Surfaces

Direct runoff from impervious surfaces is the primary cause of drainage-related problems (e.g. stream degradation, flooding risk). This direct runoff can be eliminated to a large extent by infiltrating runoff from impervious surfaces on development parcels (rooftops, driveways, parking lots) and roads (paved roadways and sidewalks).

Figure 7-6a and 7-6b show the runoff volume and rate reduction benefits that can be achieved in one of the wettest parts of the province (North Vancouver) during a very wet year (2355 mm of annual rainfall) by disconnecting impervious surfaces. These figures show that the benefits vary significantly depending on the type of surface and the amount of space available to infiltrate runoff (discussed further on the following pages).

Simple Disconnections

There is very little benefit gained by impervious surface disconnection if the runoff is simply dispersed over an area with disturbed surface soil.

Dispersing runoff over an area with absorbent landscaping can result in significant runoff volume reduction, even if the underlying soils have poor hydraulic conductivity. However, this is not likely to reduce peak runoff rates resulting from large, long duration rainfall events (e.g. a 5-year winter storm). Concentrating runoff from an impervious surface area onto a smaller area of absorbent landscape causes the surface soil to become saturated during prolonged rainfall. There must be an adequate collection and conveyance system (e.g. lawn basins) to ensure that runoff from saturated soils does not cause water damage, nuisance problems, or inconvenience to the public.

The most significant reduction in runoff volume and peak rates can be achieved by dispersing runoff over a forested area. The rooting depth of trees provides significant storage capacity to retain runoff for extended periods of time and allow it to seep into the ground.

Infiltration Facilities

The hydrologic function of a forested infiltration area can be approximated using infiltration facilities (e.g. bioretention areas) that are designed to retain runoff and provide time for it to infiltrate. Different types of infiltration facilities are discussed on the following page.

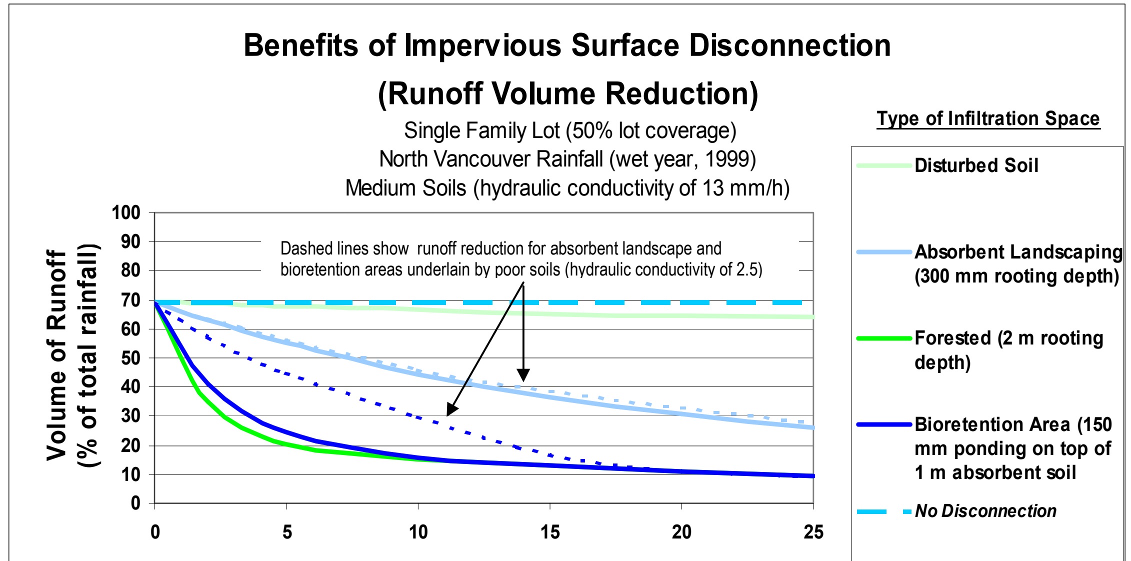


Figure 7-6a

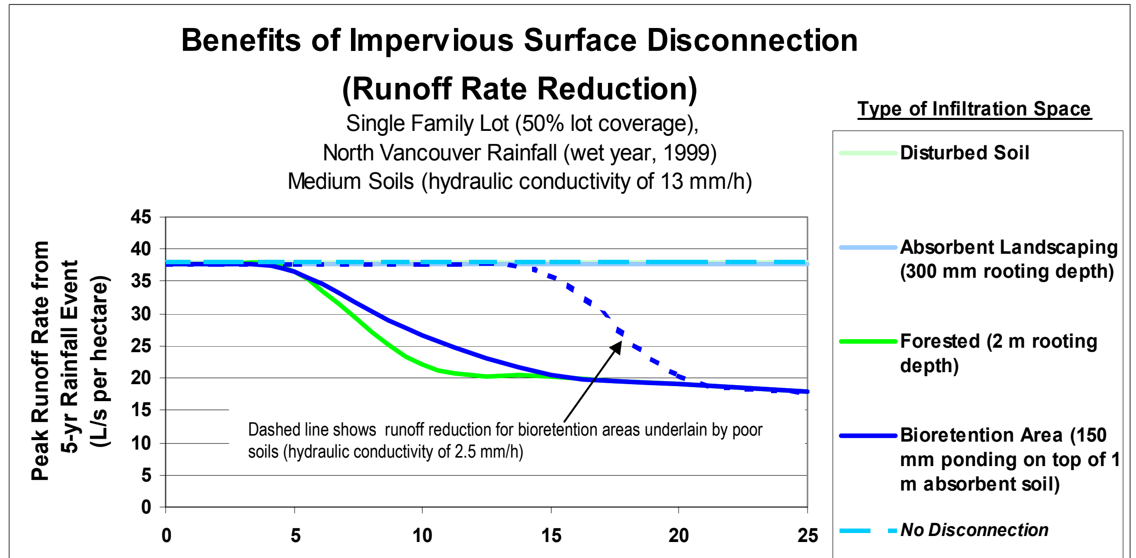


Figure 7-6b

Different Types of Infiltration Facilities

The storage capacity needed to retain impervious surface runoff and allow it to infiltrate can be provided:

- in the void space of absorbent soil, sand or gravel layers
- on the ground surface (i.e. ponding)
- in infiltration chambers (see Figures 7-7a and 7-7b)
- in storage structures, such as cisterns; runoff stored in structures must eventually be released to an infiltration area

Note that the amount of area provided for infiltration is a more important design parameter than storage volume.

There are two general categories of infiltration facilities:

- **Surface Facilities** – Runoff is stored in a layer of absorbent soil, sand or gravel, and/or on the ground surface in a ponding area. Surface facilities can be aesthetically landscaped and integrated into the design of open spaces (often called bioretention facilities or rain gardens). Figure 7-8a shows an example of a bioretention facility in the form of a terraced landscape feature on a hillside. Figure 7-8b shows an example of parking lot runoff draining to linear bioretention areas (landscaped islands in the parking lot). Bioretention can also be applied at the neighbourhood scale (e.g. constructed wetlands serving multiple dwelling units).

  Surfaces facilities can also be infiltration trenches, which store runoff in a layer of clean gravel or stone (see Figure 7-9).

- **Sub-surface Facilities –** Runoff is stored in sub-surface layers of gravel, sand or drain rock and/or in infiltration chambers (e.g. inverted plastic half pipes). Absorbent landscaping can be installed over the surface, and with proper engineering, pavement and light vehicle traffic may be allowed on the surface (e.g. a soakaway pit under a driveway).

Note that infiltration facilities can also be a combination of the two types described above. For example, infiltration swales along roads (see Figure 7-10) may consist of an absorbent soil layer (surface swale) on top of a sub-surface infiltration trench (gravel filled soakaway).

Design, construction, and operation and maintenance tips for different types of infiltration facilities are provided later in this section.

The Need for Escape Routes

All infiltration facilities must have overflow pipes or channels to ensure that runoff from extreme storms can escape to downstream watercourses without posing a threat to property or public safety. Infiltration facilities along roads (e.g. swales and infiltration trenches) must also be designed to convey extreme storms from the development areas they serve (as conventional storm sewers do).

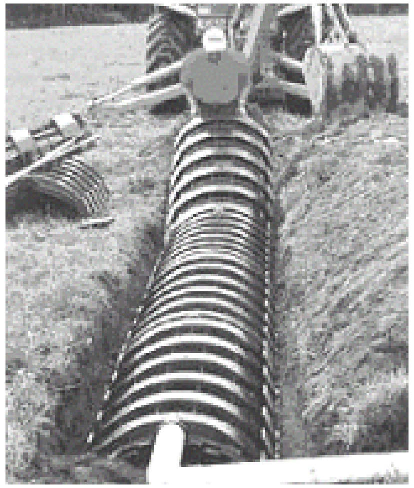


Figure 7-7a
Infiltration Chamber

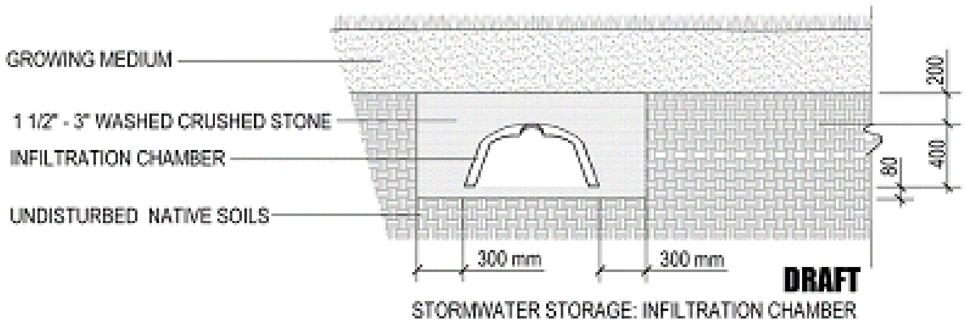


Figure 7-7b

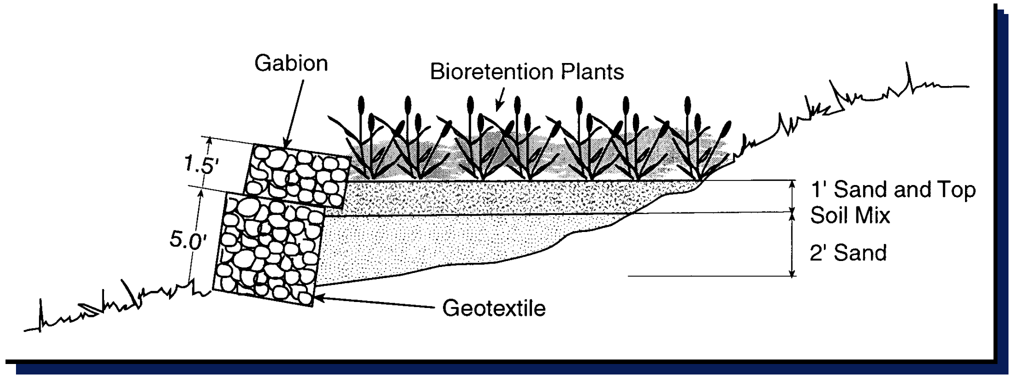


Figure 7-8a Bioretention Landscaping Feature

Figure 7-8b Bioretention for a Parking Lot

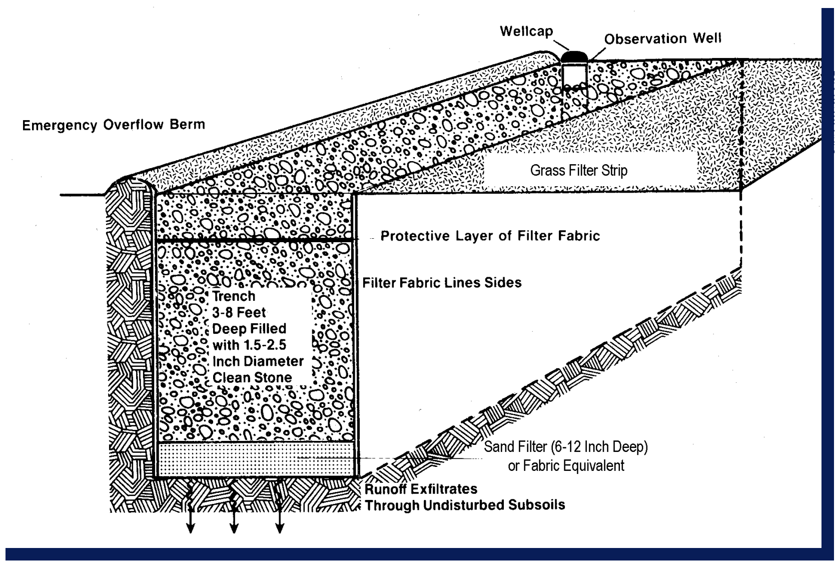


Figure 7-9 Infiltration Trench

Figure 7-10 Infiltration Swale Along Roadway

Factors that Affect the Performance of Infiltration Facilities

The hydrologic effectiveness of infiltration facilities (i.e. amount of reduction in runoff volume and rate) varies depending on the following factors:

- **Land Use Type –** Infiltration is more challenging for land uses with higher levels of impervious surface coverage (e.g. commercial or high-density residential uses). On high coverage land uses there is more surface runoff (thus concentrating more water into infiltration facilities), and less space available to locate infiltration facilities.
- **Soil Type –** The maximum rate at which water can exfiltrate from infiltration facilities is controlled by the hydraulic conductivity of soils.
- **Amount of Area Provided for Infiltration –** Footprint area is the most important design parameter for infiltration facilities. Increasing infiltration area reduces runoff volume and rate by:
  - dispersing runoff over a larger area, and thus reducing the concentration of runoff (governed by the ratio of impervious surface to infiltration area)
  - increasing the rate at which this runoff can exfiltrate
- **Rainfall Characteristics –** The effectiveness of infiltration facilities typically decreases as rainfall increases. This is because more rainfall results in more runoff to be concentrated into infiltration facilities, which leads to more overflow (i.e. greater volumes and rates of runoff).
- **Depth and Type of Infiltration Facility –** Increasing the depth and/or void space for storage in an infiltration facility increases the retention storage capacity, thus decreasing the amount of overflow (i.e. runoff). In general, infiltration area is a more important parameter than depth.
- **Depth to Groundwater –** In order for infiltration facilities to be effective, the bottom of the facility must be a reasonable depth (at least 0.5 m) above the groundwater table. Infiltration facilities are not appropriate in areas where the water table is at or near the ground surface

The graphs presented on the following pages illustrate how these factors affect the performance of infiltration facilities.

The Effectiveness of Infiltration under Different Rainfall Conditions

Figure 7-11 illustrates how the performance of infiltration facilities (in terms of runoff volume reduction) decreases as total annual rainfall increases.

More infiltration area is required to achieve the same level of runoff volume reduction in a wetter location (or year) than in a drier location (or year). For example, in order to reduce the total runoff volume from a typical single family lot (on poor soils) to 10% or less of total rainfall volume (i.e. the target condition):

- in a location where the annual rainfall is around 700 mm, about 3% of the lot would have to be provided for infiltration
- in a location where the annual rainfall is around 1800 mm, about 15% of the lot would have to be provided for infiltration

Variability in soil type and land use also has a big effect on the amount of area required to meet a given volume reduction target (e.g. the 10% target), as discussed on the following pages.

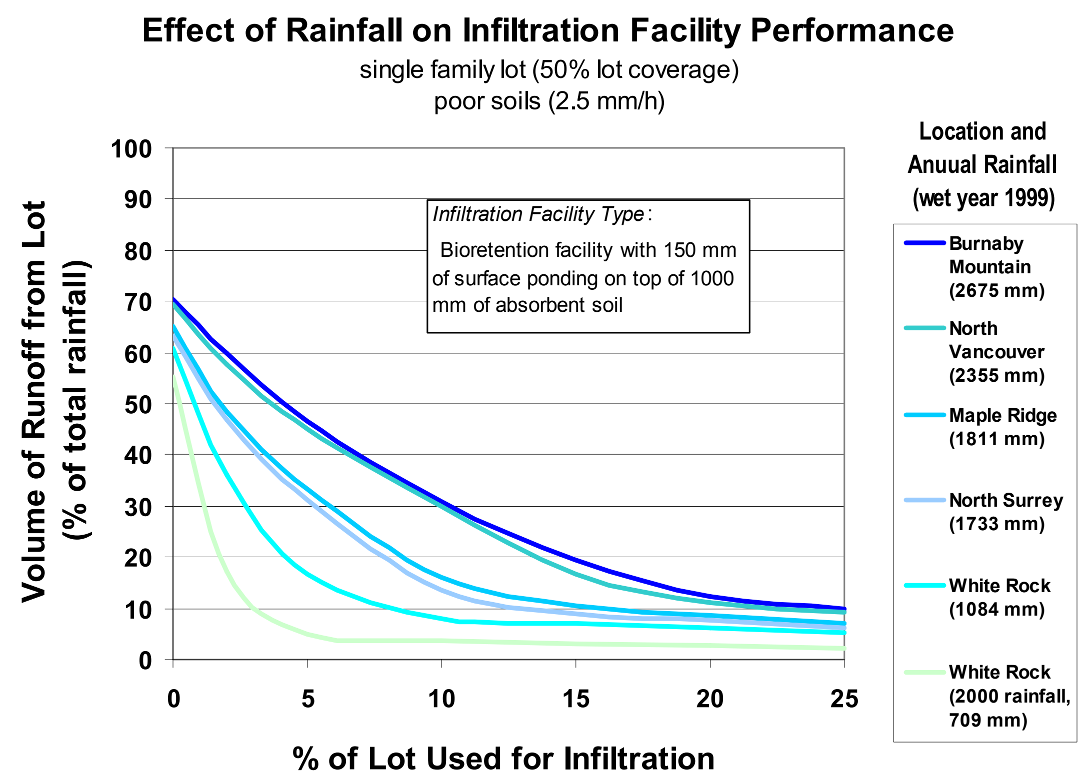


Figure 7-11

Selecting Infiltration Facility Depth

Figure 7-12 illustrates how the depth of an infiltration facility (i.e. distance from the bottom of the facility to the overflow level) increases the level of runoff volume reduction that can be achieved for different types of facilities.

The benefits of increasing facility depth diminish beyond a certain threshold (around 500 mm). Beyond this threshold, the area of an infiltration facility has a much greater impact on performance than its depth (as discussed on the following pages).

It is important to note that shallow infiltration facilities typically provide the best opportunity for recharging the soil interflow zone. In addition, the hydraulic conductivity of soils tends to be higher closer to the surface.

Constraints on Facility Depth

Appropriate depths for infiltration facilities must be selected based on site-specific characteristics and constraints.

As noted previously, the bottom of an infiltration facility should be at least 0.5 m above the local groundwater table. The depth to bedrock or to relatively impermeable soil layers may also govern the feasible depth of infiltration facilities.

Appropriate ponding depths for surface infiltration facilities may also be governed by safety or aesthetic considerations.

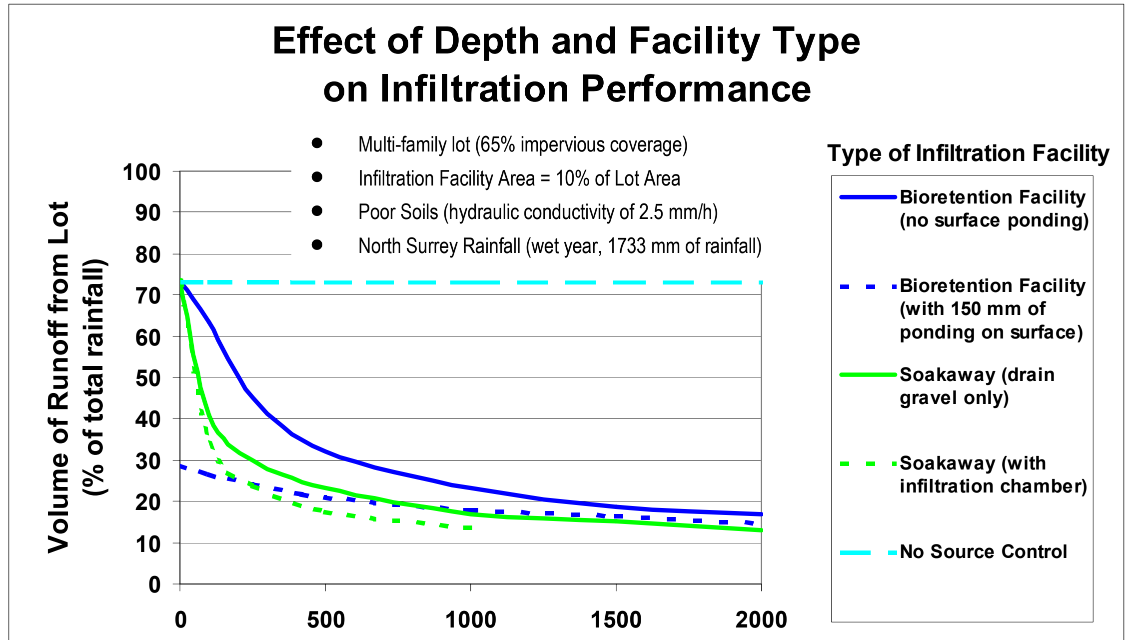


Figure 7-12

Comparing Different Types of Infiltration Facilities

Figure 7-12 shows that a soakaway pit would be slightly more effective than a bioretention facility of the same depth (with no surface ponding), because gravel stores more runoff per unit volume than absorbent soil (i.e. it has higher void space storage).

Placing an infiltration chamber in a soakaway trench (as shown in Figure 7-7b) increases its storage volume, and slightly improves its effectiveness. Similarly, surface ponding increases the storage capacity and improves the effectiveness of bioretention facilities, particularly for facilities with fairly low absorbent soil depth (e.g. less than about 500 mm).

The Importance of Infiltration Area and Soil Type

Figures 7-13a and 7-13b show how the level of reduction in runoff volume and rate that can be achieved using infiltration facilities is highly dependent on the hydraulic conductivity of local soils and on the amount of area provided for infiltration.

For example, providing 10% of a single family lot area for infiltration could:

- reduce total runoff to about 10% of total rainfall and reduce the peak runoff rate from a 5-year storm by about 45%, where soils have good hydraulic conductivity (greater than about 13 mm/h)
- reduce total runoff to about 35% of total rainfall but achieve virtually no reduction in the peak runoff rate from a 5-year storm, where soils have very poor hydraulic conductivity (about 1 mm/h)

Note that these graphs are based on Water Balance Model simulations for a very wet year in North Surrey (1999). In locations and/or years with less rainfall, infiltration facilities can be expected to perform better than the graphs indicate (and vice versa).

These graphs assume that all undeveloped areas have disturbed surface soil (i.e. no absorbent landscaping), and that runoff from disturbed soils on building lots is not captured by bioretention facilities.

Determining What is Feasible and Affordable

The size of infiltration facility that can be provided in any given situation will depend on:

- the physical constraints associated with the available undeveloped space (feasibility thresholds), and/or
- willingness to pay (affordability thresholds)

Affordability thresholds will likely govern infiltration facility sizes for lower coverage land uses (e.g. single family residential) and feasibility threshold will likely govern for higher coverage land uses (e.g. commercial land uses).

The affordability thresholds shown on the adjacent infiltration performance curves are for illustration purposes only, and reflect judgement as to what seems appropriate. Further discussion on how to establish affordability and feasibility thresholds is provided on the following page.

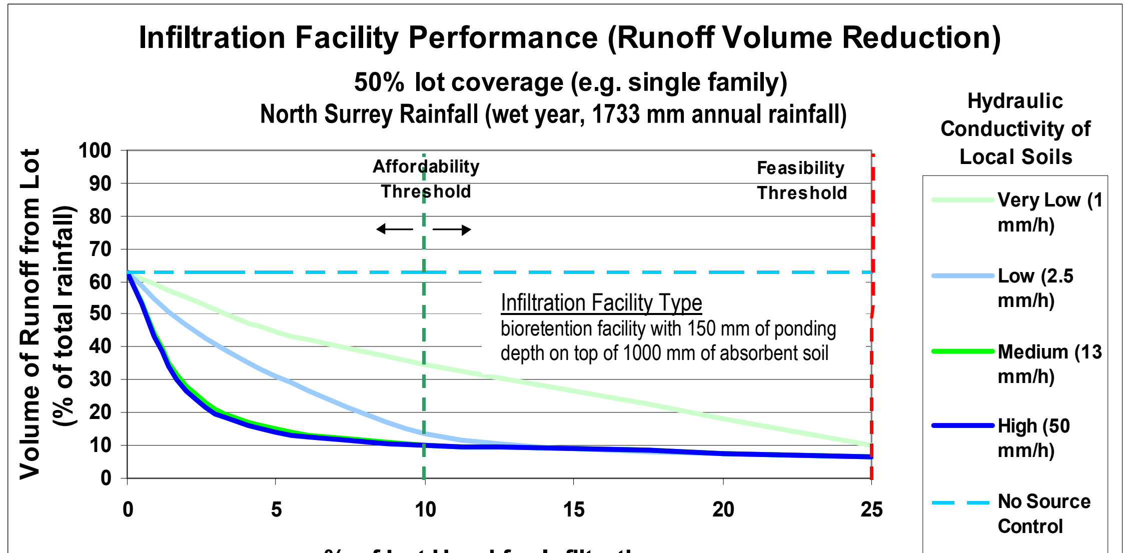


Figure 7-13a

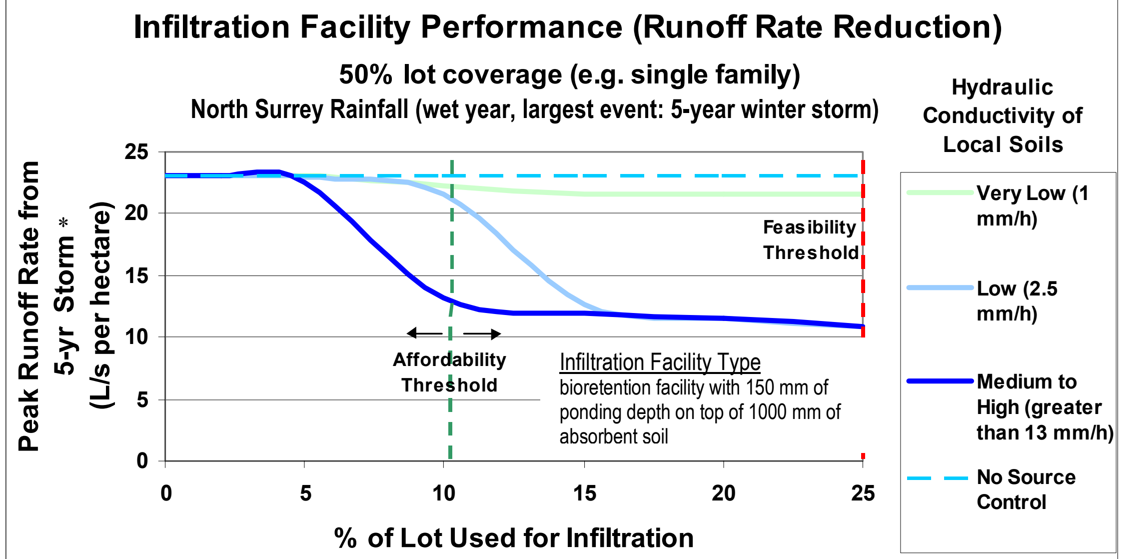


Figure 7-13b

* refers to the rate of runoff from an entire development area (i.e. building lots *and* the roads serving these lots).

Feasibility Thresholds

As lot coverage increases there is less space available to locate infiltration facilities. The feasibility threshold refers to the maximum amount of physical space that could be used for infiltration.

These thresholds will be highly site-specific because they depend on the layout of impervious and pervious spaces within a lot (or road), as well as on soil type.

It is typically not possible to use all undeveloped lot space for infiltration facilities. Feasibility thresholds can be estimated at about 50% of undeveloped lot space to provide a starting point for planning purposes.

Since constant wetting can cause localized expansion of clay soils, a certain amount of clearance between infiltration facilities and building foundations (and property boundaries) is needed to prevent potential damage. A clearance distance of 3 m or more should be used in any soils with significant clay content. For heavy clay soils, the clearance distance should be about 5 m.

With proper engineering, it may be feasible to use nearly all of the undeveloped space within road right-of-ways for infiltration.

Affordability Thresholds

Increasing the size of infiltration facilities improves their effectiveness (as shown in Figures 7-13a and 7-13b), but also increases their cost. Local governments must establish affordability thresholds based on the community's willingness to pay, and on the potential benefits of the infiltration facilities.

Note that reductions in runoff volume and rate are indicators of hydrologic benefits, which translate into benefits for a community in the form of stream protection and restoration, avoided flooding, or other avoided drainage costs.

Establishing Affordability Thresholds

Figure 7-14 shows an example of how order-of-magnitude cost estimates can provide a starting point for answering the questions:

- what can realistically be achieved through infiltration?
- are infiltration source controls worth pursuing?
- what is the likely return on investment?

The costs of infiltration facilities can be highly variable depending on site-specific conditions, such as amount and type of material that needs to excavated. The benefits of infiltration facilities are also highly dependent on site-specific conditions, and therefore, site-specific cost-benefit analyses are essential. The costs and benefits of infiltration facilities must be considered in the context of an Integrated Stormwater Management Plan (ISMP).

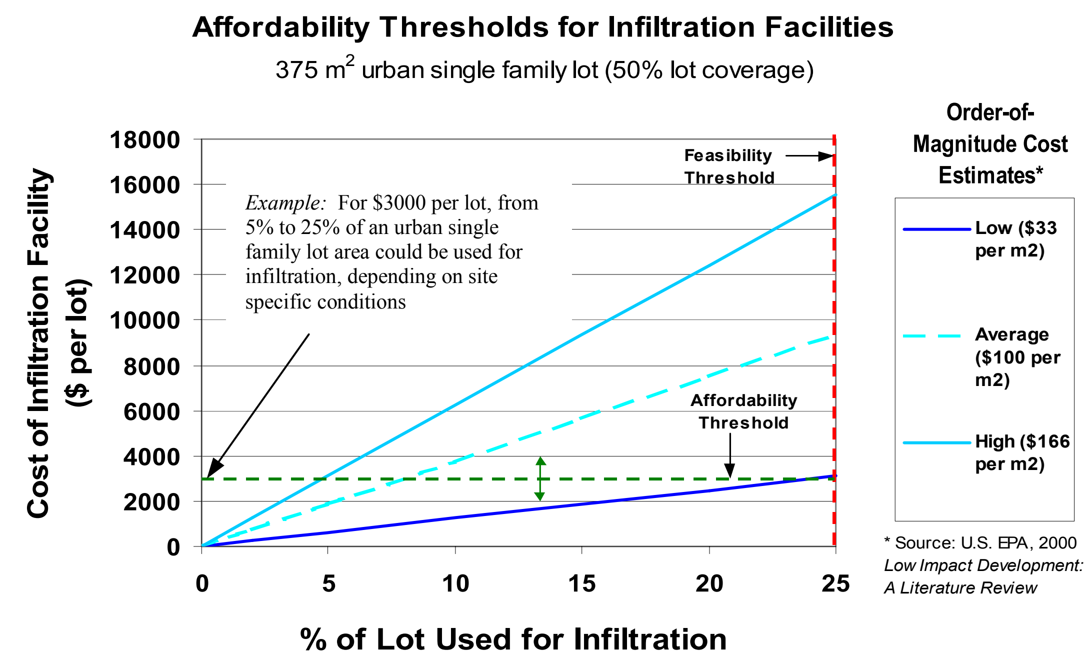


Figure 7-14

Infiltration Facilities for Land Uses with High Impervious Coverage

Figures 7-15a and 7-15b show the level of runoff volume and rate reduction that could be achieved for land uses with relatively high impervious coverage, such as high-density multiple family or commercial land uses.

In this case, the feasibility threshold rather than the affordability threshold governs the amount of infiltration area that can be provided.

By providing the feasible amount of infiltration area (about 7.5% of the lot area), the volume of runoff volume from a high coverage lot could be reduced to:

- about 10% of total rainfall, where soils have good hydraulic conductivity (greater than about 13 mm/h)
- about 60% of total rainfall, where soils have very poor hydraulic conductivity (about 1 mm/h)

The peak runoff rate from a 5-year, long duration winter storm could not be reduced using infiltration facilities on high coverage land uses, even where soils have good hydraulic conductivity. This conclusion does not necessarily apply to lower rainfall locations.

The effectiveness of infiltration facilities on land uses with high impervious coverage can be improved by providing additional storage structures such as cisterns, and releasing stored runoff to infiltration areas at a controlled rate.

Performance of Infiltration Facilities for a Range of Land Use Types

The GVRD report on the *Effectiveness of Stormwater Source Control* includes infiltration performance curves (similar to Figures 7-13 a-b and 7-15 a-b) for eight different land use types, with total lot coverage ranging from 30% (e.g. low-density single family) to 98% (e.g. town centre commercial).

The GVRD report also provides infiltration performance curves for four road types, with paved roadway widths ranging from 8.5 m (e.g. local roads) to 16 m (e.g. divided arterials). Sample infiltration performance curves for roads are shown on the following page.

For a given land use or road type and soil condition, these curves can be used to estimate the hydrologic benefits (i.e. runoff volume and rate reduction) of providing a certain amount of infiltration area.

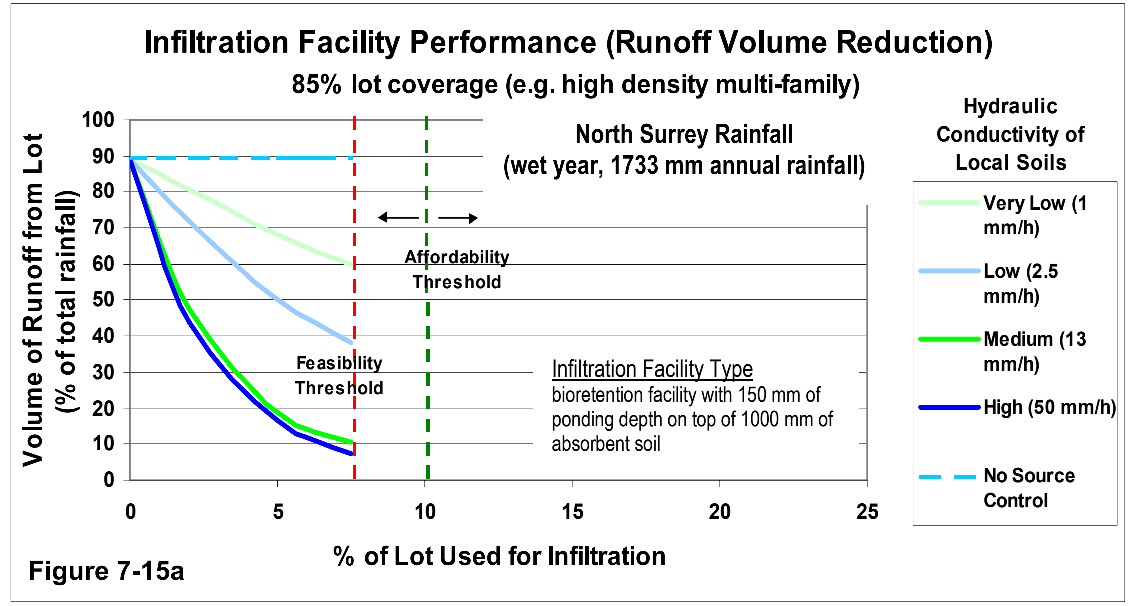


Figure 7-15a

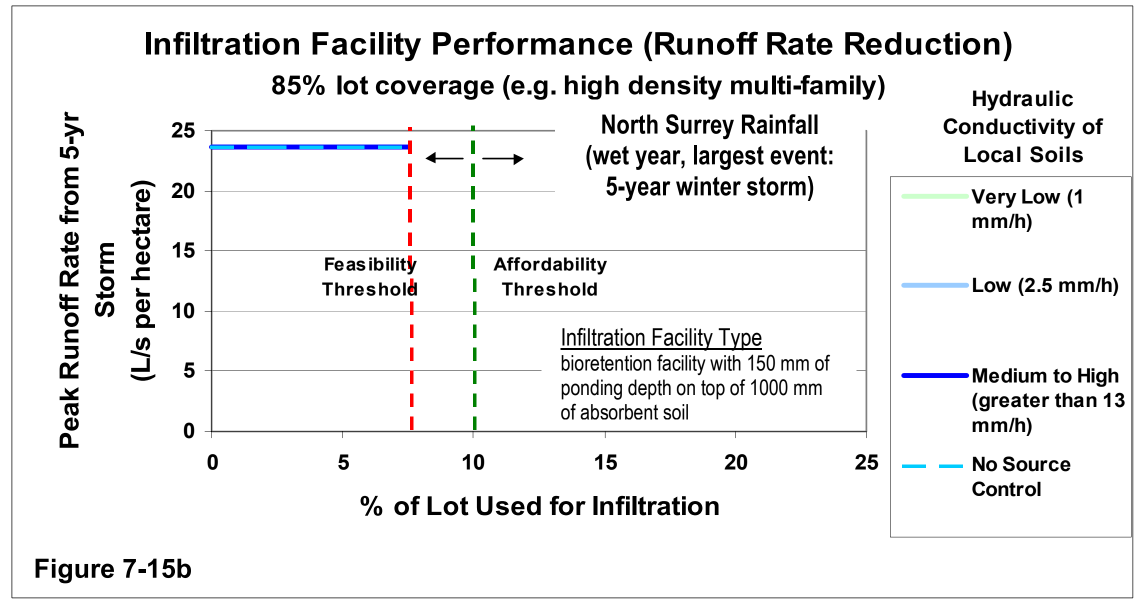


Figure 7-15b

Performance of Infiltration Facilities on Roads

Figures 7-16a and 7-16b show the reduction in runoff volume and rate that could be achieved using infiltration facilities on roads. These graphs show the simulated performance of two-layer swale and infiltration trench systems, assuming:

- top layer (surface swale) = 300 mm of absorbent soil
- bottom layer (infiltration trench) = gravel-filled trench with perforated overflow pipe 300 mm above the trench bottom

The performance curves show that the runoff from a typical local road could be virtually eliminated (even during a very wet year) by dispersing roadway runoff to:

- a 2 m wide swale/trench (or two 1 m swales) along the road, where soils have very good hydraulic conductivity (around 50 mm/h)
- a 4 m wide swale/trench (or two 2 m swales) along the road, where soils have good hydraulic conductivity (around 13 mm/h)

Even where soils have very poor hydraulic conductivity (around 1 mm/h), a 4 m swale/trench could reduce the volume of runoff from a typical local road to about 25% of total rainfall.

In general, infiltration facilities along roads are more effective than on-lot infiltration facilities because there is typically less concentration of runoff (i.e. the ratio of impervious area to infiltration area tends to be lower).

Note that the affordability thresholds shown on Figure 7-16a and 7-16b are provided for illustration purposes only. Local governments should establish their own thresholds by evaluating costs, benefits and willingness to pay.

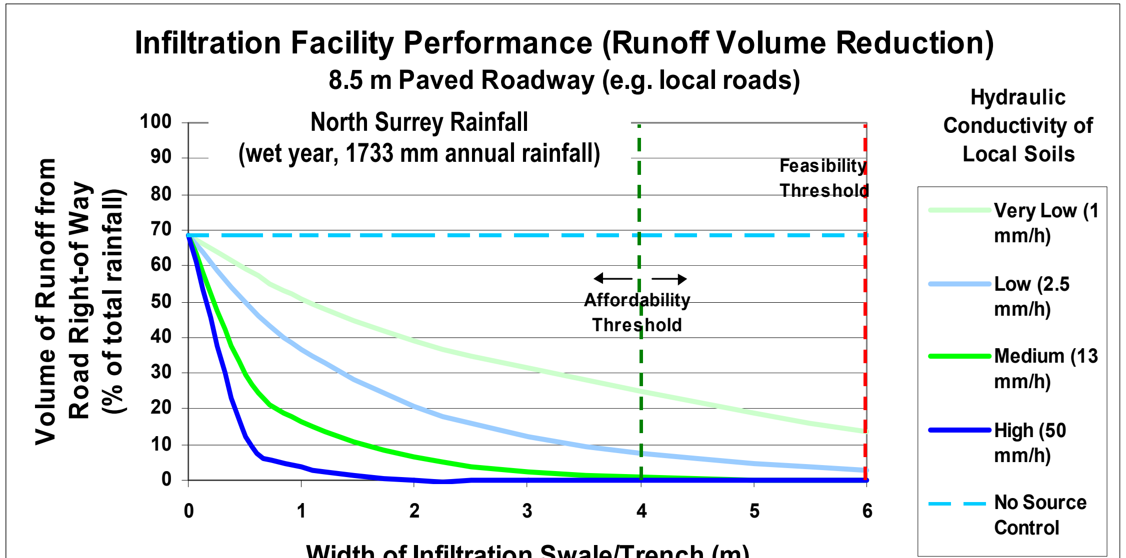


Figure 7-16a

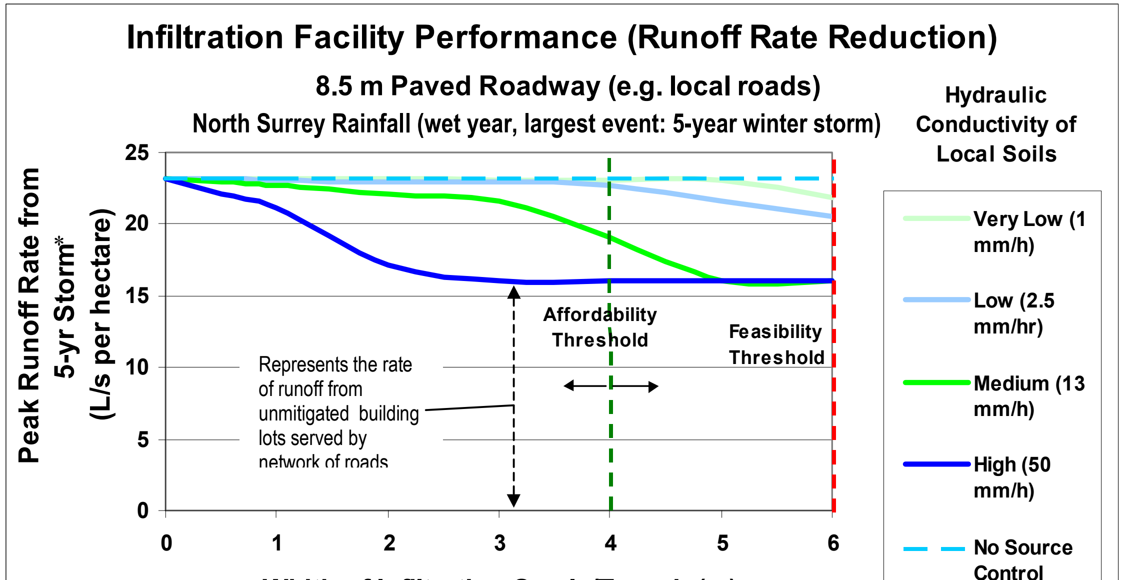


Figure 7-16b

* refers to the rate of runoff from an entire development area (i.e. building lots *and* the roads serving these lots).

Achievable Level of Runoff Volume Reduction for Different Land Use Types

Figure 7-17 provides an estimate of the level of runoff volume reduction that could be achieved using infiltration facilities (during a wet year in the South Coast climate) for a range of land use types, under different soil conditions. This figure assumes that infiltration facility size is based on the governing threshold for each land use type (i.e. either feasibility or affordability).

Where soils have medium or better hydraulic conductivity (greater than about 13 mm/h), runoff volume could be reduced to about 10% of total rainfall (i.e. the target condition for a healthy watershed) for all but the highest coverage land uses (high density multiple family or commercial).

To achieve the 10% target for lower coverage single family land uses, absorbent landscaping would be required in addition to infiltration facilities. This is because lots with lower impervious coverage typically have more runoff volume from disturbed soil (Figure 7-13 assumes that undeveloped areas are covered by disturbed soil).

Significant levels of runoff volume reduction can also be achieved in soils with poor conductivity (around 2.5 mm/h), for all but the highest coverage land uses. Even where the hydraulic conductivity of soils is very poor (around 1 mm/h), runoff volume can be reduced by about 40 to 50% on single family and low to medium-density multiple family land uses.

Note that greater levels of runoff volume reduction would likely be achievable in locations and/or years with less rainfall (and vice versa).

Typical hydraulic conductivity ranges for different soil types are provided below for reference purposes.

Soil Type	Typical Hydraulic Conductivity Range*
• Sands and gravels	> 50 mm/h
• Sandy loams	10 – 50 mm/h
• Silty loams	5 – 40 mm/h
• Clay loams	2 – 6 mm/h
• Clays	< 2 mm/h

* Source: Soil Texture Triangle: Hydraulic Properties Calculator, Washington State University (http://www.bsyse.wsu.edu/saxton/soilwater/)

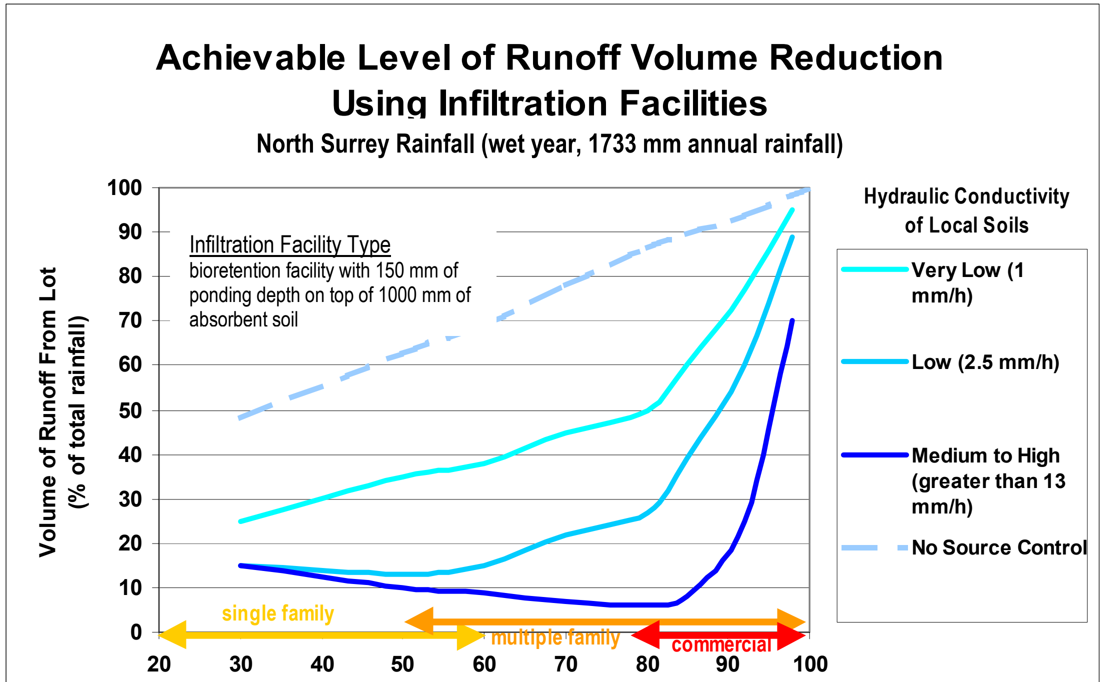


Figure 7-17

Creating Hard Surfaces that Infiltrate

Pervious Paving

Runoff from paved surfaces can be virtually eliminated by replacing impervious pavement with pervious pavers that allow rainwater infiltrate through cracks between the pavers. Figure 7-18 shows an example of pervious paving.

Pervious pavers are placed over a reservoir base course of fractured drain rock (similar to railway ballast), which can be sized to store a given design storm. For example, to store a 60mm storm, the reservoir part of the base course would have to be about 180 mm deep (33% void space).

Pervious paving can be applied on areas with light (or no) vehicle traffic (e.g. driveways, shoulders of roadways, sidewalks, overflow parking areas).

Figure 7-19 provides an example of how pervious paving options for roadways can reduce runoff volume.

Since pervious paving effectively reduces the impervious coverage on lots or road right-of-ways, applying pervious paving can also improve the effectiveness of infiltration facilities (by reducing the concentration of runoff discharged into these facilities).

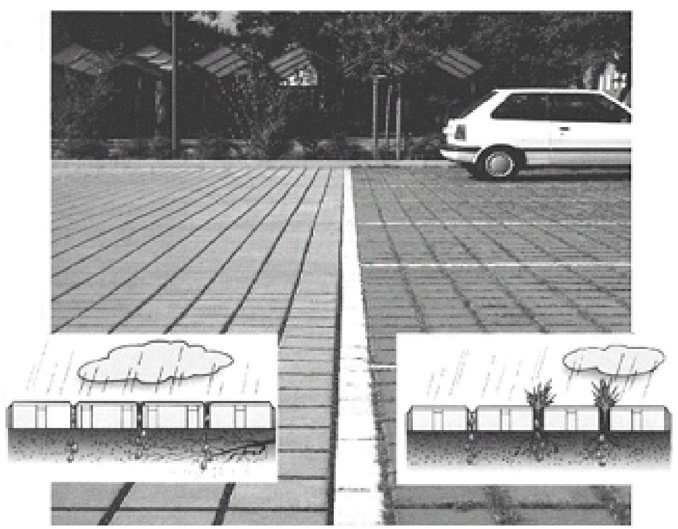


Figure 7-18 Pervious Pavers

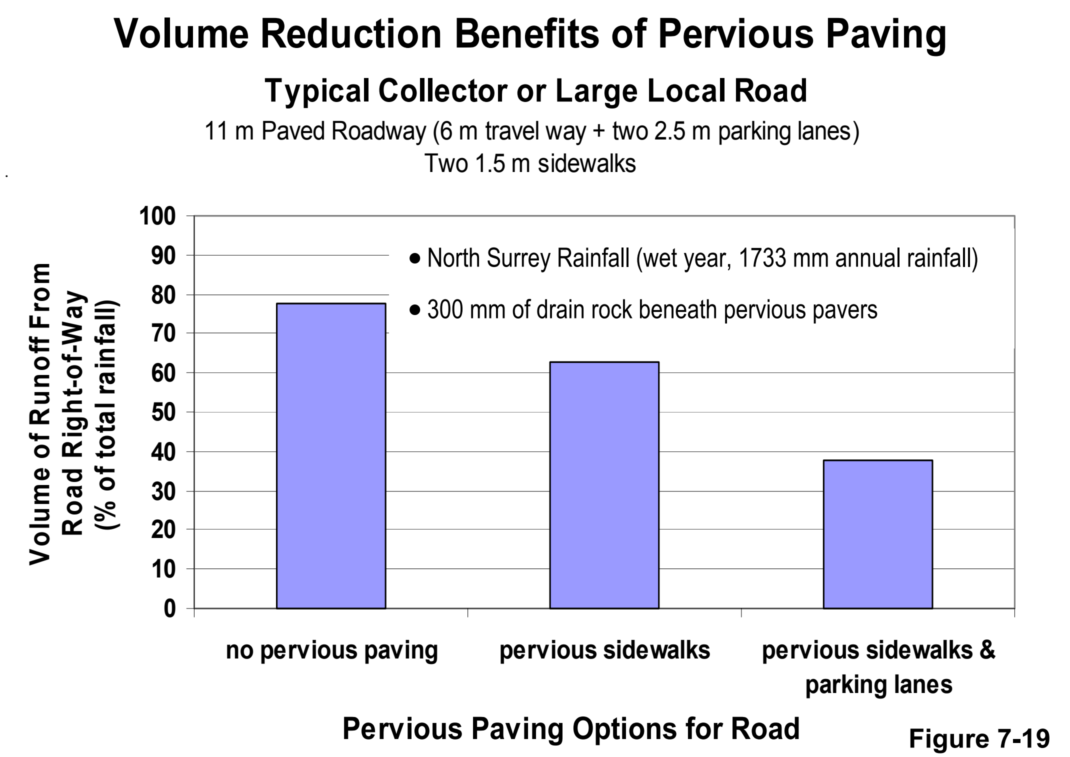


Figure 7-19

Pervious Decks

Runoff from decks or patios can be virtually eliminated by using wood decks with space between the boards (see Figure 7-20) rather than impervious surfaces such as concrete.

Rainfall hitting a spaced wood deck flows to the ground below, and provided there is a reasonable depth of absorbent soil beneath the deck, runoff from the deck is eliminated.

This is an example of a simple, well-known, site design strategy that can effectively reduce impervious coverage and promote infiltration.

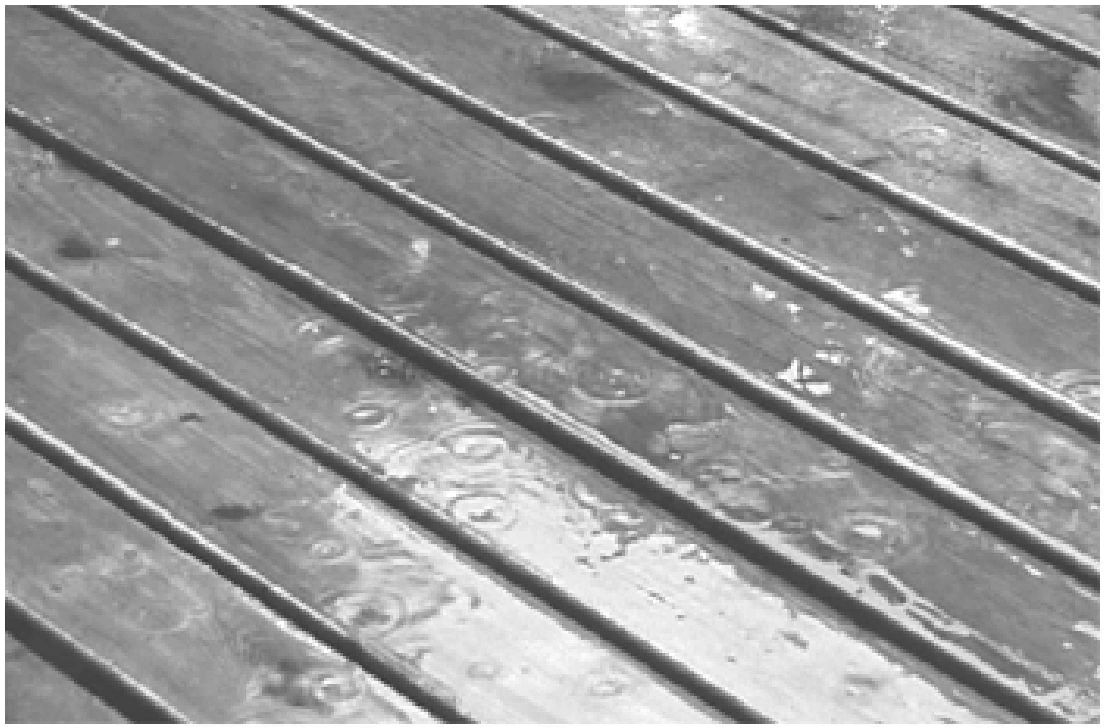


Figure 7-20 Pervious Decks

Applying Combinations of Infiltration Strategies

Figure 7-21 illustrates an example of the installation of selected infiltration techniques on a typical single-family lot, where the performance target is to capture and infiltrate 60 mm of rainfall per day in order to provide both rainfall capture and runoff control in an on-parcel system.

- Roof drain leaders outfall through a debris catcher to an array of infiltration chambers (see Figures 7-7a and 7-7b) in the front lawn. In order to infiltrate the runoff from the 280 m^2 roof, a 7.6 m x 6 m infiltration areas is provided. This could be entirely in the front yard, or could be split over various locations in the yard based on soil characteristics and landscaping objectives.
- The infiltrator chambers have an overflow pipe connected to the street storm drain system that allows rainfall events that exceed the storage capacity to overflow.
- The plan also shows an interceptor perforated drain along the downstream property boundary. This is shown as an illustration only. It could be installed as required on lots with steep slopes or seepage problems to remove surface water and shallow interflow and deliver it to the storm drain system. Ideally, there should be at least 9 m between the infiltration chamber and the perforated drain. This would provide an approximately 30-day delay between the time that water is absorbed as interflow and the time it is removed by the perforated drain. The 30-day delay is based on a moderate 12.5 mm/h infiltration and interflow rate. Delays between infiltration chamber and footing drains would follow a similar pattern, where each foot of interflow distance represents a day or more of delay.
- The bulk of the site is maintained with absorbent soils. Special care is taken to ensure that the top 300 mm of soil are highly absorbent, by avoiding compaction and ensuring high organic matter content.
- Driveway and surface paving is shown as permeable pavers, with a reservoir base course. This ensures that rainfall landing on the driveway is stored underground and allowed to soak into the underlying soils.
- The rear outdoor living area is a spaced wood deck over absorbent ground. This allows rainfall to bypass the deck and infiltrate into the ground below. See Figure 7-20 for details.
- Reducing the building roof area on the site would reduce the amount of infiltration chamber area required.

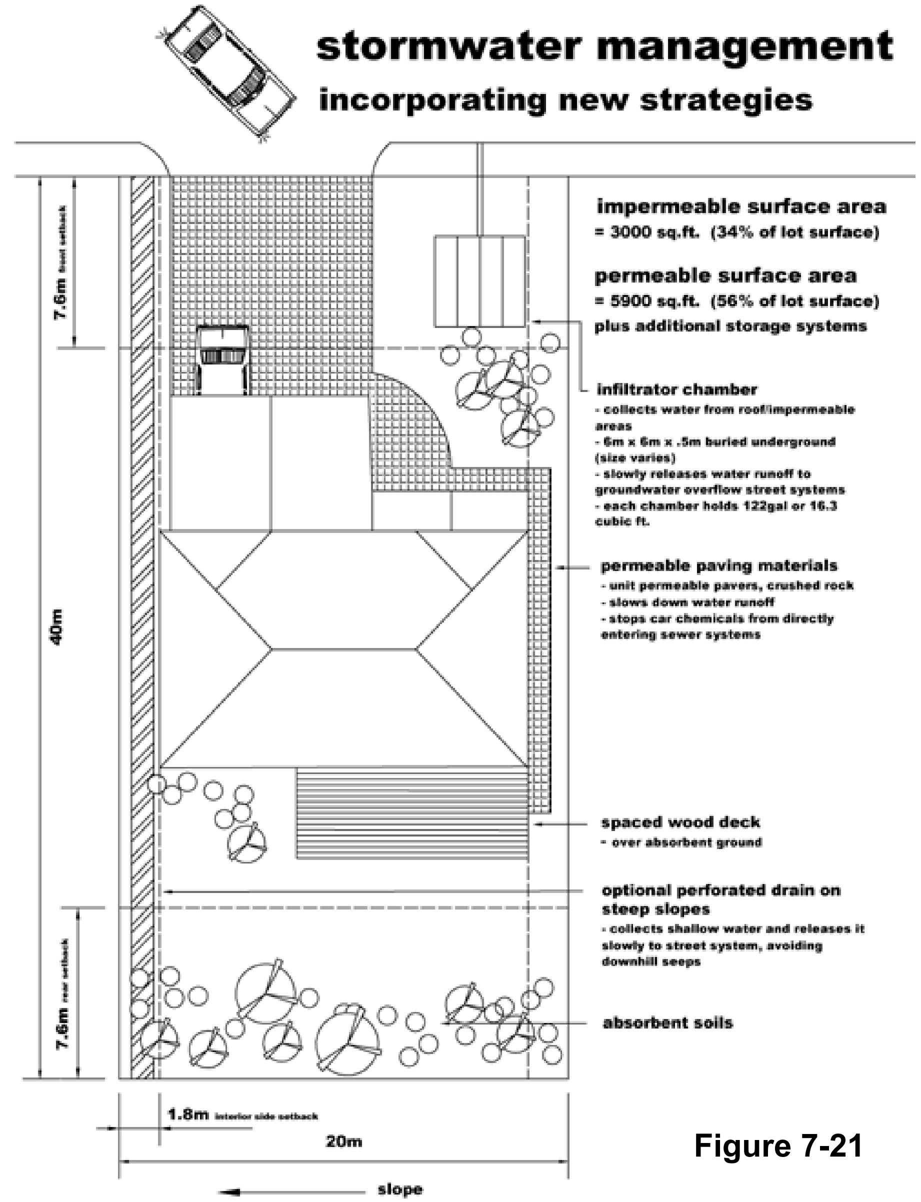


Figure 7-21

Infiltration Strategies for Land Uses with High Levels of Surface Parking

Figure 7-22 shows an example of infiltration strategies for a typical commercial land use with extensive surface parking areas. This Figure shows how a combination of swales with infiltration trenches and bioretention areas could be integrated into parking lot design to infiltrate runoff from rooftops and paved surfaces.

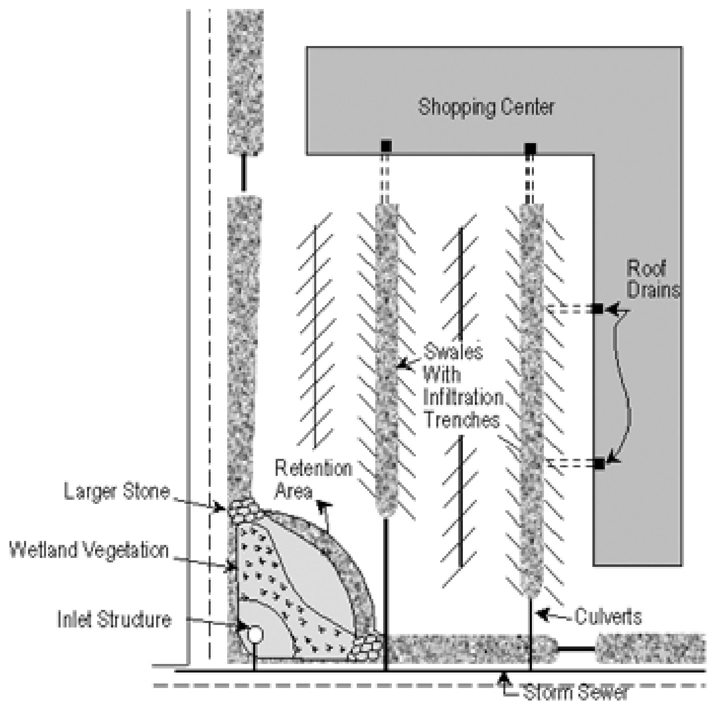


Figure 7-22 Designing Parking Lots that Infiltrate

Cost Implications of Infiltration Facilities

The costs of infiltration facilities are highly variable and depend on site-specific conditions such as soil type, topography, the scale of installation, and infiltration facility design. Typical installation costs for infiltration facilities range from about \$30 - \$170 per m^2 .

The operation and maintenance requirements for surface facilities are mainly aesthetic (e.g. landscape maintenance). Annual operation and maintenance costs for surface infiltration facilities are typically in the range of 5-10% of capital costs.

Operation and maintenance requirements for sub-surface facilities are less frequent but can be more costly (e.g. periodic cleaning of soakaway trenches). Annual operation and maintenance costs for sub-surface infiltration facilities are typically in the range of 5-20% of capital costs.

Pervious Paving Costs

The cost of installing of pervious paving is typically in the range of \$20 - \$30 per m^2, depending on the design and site conditions. This is significantly more expensive than conventional paving (approximately \$5 - \$10 per m^2). Also, the operation and maintenance costs associated with vacuum sweeping may be substantial if a community does not already have the necessary equipment.

Design and Construction Tips for Infiltration Facilities

- Site-specific percolation tests should be carried out (ideally under saturated soil conditions) to determine the hydraulic conductivity of soils on a development site, and to identify suitable infiltration areas. Percolation tests should be performed at the depth of proposed infiltration facilities.
- Infiltration facility sites should be protected during construction from compaction and sedimentation, by pre-identifying and fencing, or other means. Inadvertent compaction should be removed by ripping or scarifying the site prior to installation of infiltration facilities.
- Infiltration facilities should be placed over undisturbed or lightly compacted ground (about 80% modified proctor density) to maximize exfiltration of rainfall into the underlying subsoil.
- Adequate sediment and erosion control during construction is essential to prevent clogging of infiltration facilities and underlying soils.
- Pipes leading to infiltration facilities should be fitted with debris catchers and cleanouts to minimize the movement of sediment and debris into the facilities. This is particularly important for sub-surface infiltration facilities.
- Infiltration facilities should be designed with pathways to allow overflow to escape to downstream watercourses via a storm drain system or overland flow.

Tips for Bioretention Facilities

- Low points of bioretention facilities should be planted with flood-tolerant plants.
- Higher areas should be planted with streamside or upland species. Examples of appropriate bioretention plants are shown below:

Frequency of Flooding	Botanical Name	Common Name
Winter standing water	Juncus spp.	Rush
Occasional standing water	Carex spp.	Sedge
Rare flooding	Spiraea douglasii	Hardhack
No flooding	Rosa spp.	Shrub rose

  These plants would work best in coastal climates, but may also be used in other parts of the province. Appropriate plant species will vary across the province depending on biogeoclimatic zone.

- Soils in bioretention areas should have the characteristics of absorbent soils, discussed in Section 7-3.
- Bioretention facilities should be constructed in the dry season whenever possible, or they should be totally isolated from flows during construction, to protect other parts of the drainage catchment form sedimentation.
- In areas where soils are relatively impermeable, bioretention facilities can be designed with a sub-drain to slowly remove water that infiltrates through the absorbent soil layer. This filters out sediments and many pollutants.

Tips for Pervious Pavers

- Pervious paving systems are at risk of being plugged by silt or organic debris that washes onto the surface layer. To avoid this risk, careful attention should be paid to protecting the pervious paving from sedimentation during construction. In addition, most pervious pavement systems are designed with a high factor of safety for permeability e.g. often the permeability at time of construction is 10 times that required for the successful performance of the pavement (i.e. a Factor Of Safety of 10).
- The pervious paving system includes a special base course under the paving designed to hold the stormwater until it has time to soak into the ground below. This 'reservoir' base course is often made of fractured drain rock (railway ballast) that has about 33% void. The depth of the base course is designed with the storage capacity for stormwater as one consideration, with the surface live load and bearing capacity of the underlying soils as other factors. Generally, the deeper the base course, the more stormwater holding capacity and the greater the structural strength. Slope on the pervious pavers should be between 1% and 6%. Calculation of the reservoir capacity should consider any drainage areas flowing to the pavement.
- Pervious paving should not be used on any stormwater quality 'hot spot' where surface contaminants may be concentrated and enter the groundwater (e.g. gas stations, wrecking yard, fleet storage yards, or other sites that store hazardous materials).
- A vertical pipe inlet should be installed so that the reservoir base course overflows to a storm drain when full.

Operation and Maintenance Tips for Infiltration Facilities

- Sediment and debris must be regularly removed from debris catchers and cleanouts.
- Periodic cleaning of infiltration facilities will likely be required to remove accumulated sediment and maintain hydraulic performance.

Tips for Bioretention Facilities

- Provisions for dry season watering of plants in bioretention facilities is essential, especially in the plant establishment period.
- Normal landscape maintenance, with an emphasis on minimum inputs of fertilizer and integrated pest management is appropriate.

Tips for Pervious Pavers

- Where pervious paving is used, regular street sweeping with vacuum and brush machinery is needed to remove surface sediment and organics that may enter the cracks and reduce permeability.
- Low traffic areas (e.g. roadway medians) may experience some weed growth in the cracks (which is a problem for any paved surface). Steam-based weeding systems are available to efficiently manage weed growth without use of herbicides.
- Snow clearing of properly installed pervious pavements can be achieved with standard equipment. Following the manufacturer's design specifications should eliminate any significant freeze-thaw issues.

7.6 Type 3 Source Control - Green Roofs

Replacing impervious rooftops with green roofs can significantly reduce the volume and rate of runoff from building lots. A layer of absorbent soil and vegetation on top of building and parkade rooftops can retain rainfall and allow it to evaporate or transpire. The runoff from a green roof passes through the absorbent soil layer to an underdrain layer (there is no surface runoff), and thereby attenuates peak runoff rates.

Green roofs are classed into two categories: *extensive* green roofs which typically have a shallow soil profile of 20 to 100 mm and support mosses, grasses and sedums; and *intensive* green roofs with soil depths greater than 100 mm able to support substantial vegetation (shrubs, trees, etc.). Intensive green roofs are typically landscaped features that require more maintenance than extensive green roofs.

Green roofs are common in many parts of Europe and are becoming more common in North America. They are often applied for reasons other than stormwater management; engineered green roofs may also provide heating or cooling savings by insulating buildings, as well as aesthetic benefits, air quality benefits, and reductions in the 'urban heat island' effect.

Figure 7-23 shows a lightweight extensive green roof on an airport building. Figure 7-24 shows an example cross-section of an intensive green roof over a parking garage.

Figure 7-23 Lightweight Extensive Green Roof

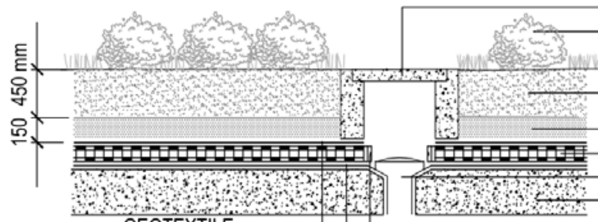


Figure 7-24

The Effectiveness of Green Roofs under Different Rainfall Conditions

Figure 7-25 shows that green roofs provide more significant reduction in runoff volume where (and when) total annual rainfall is lower. As total rainfall decreases, a greater percentage of total rainfall becomes evapotranspiration.

Green roofs would be most effective at reducing runoff volumes in drier parts of the province, and would be more effective in drier years as opposed to wet years.

In terms of reducing runoff volume, extensive green roofs can be almost as effective as intensive green roofs.

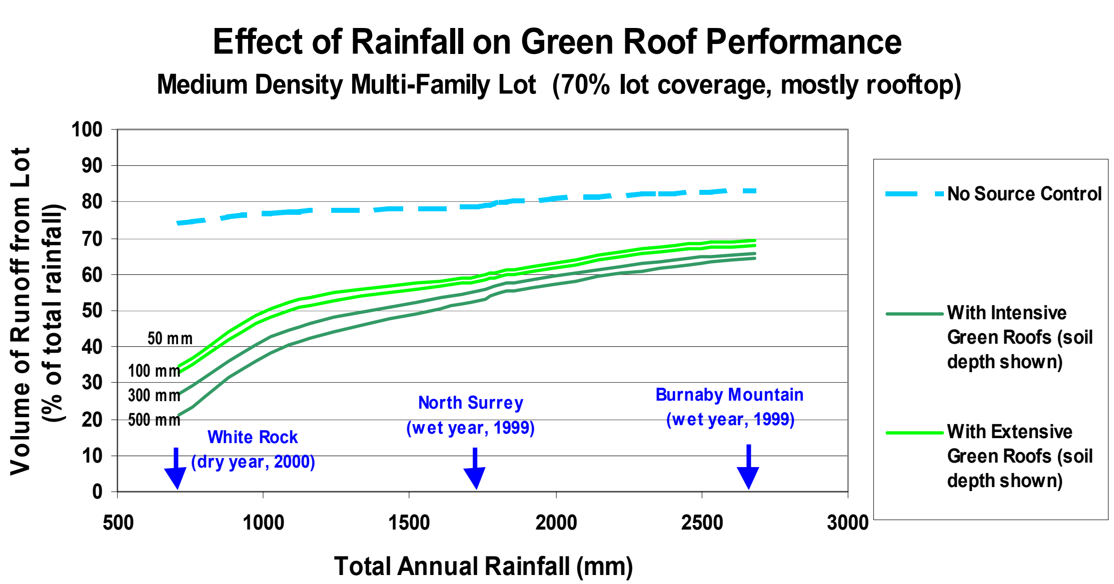


Figure 7-25

The Importance of Green Roof Soil Depth

Increasing the depth of absorbent soil increases the retention capacity of green roofs. This decreases the volume and rate of green roof runoff, as shown in Figures 7-26a and 7-26b.

The volume reduction benefits of increasing green roof soil depth diminish beyond about 70 mm.

In order to maximize the reduction in runoff rates from large, prolonged storms that occur during wet weather periods, intensive green roofs with about 300 mm of soil depth are needed (see Figure 7-26a). Where building structural limitations do not permit this soil depth, green roofs with shallower soil profiles may still be able to achieve significant reductions in runoff rates from long duration wet weather storms that are less extreme and/or in locations with less rainfall.

Significant reduction in runoff rates from short intense storms (i.e. cloudbursts) that occur during dry weather periods can be achieved using extensive green roofs with 100 m of soil depth (see Figure 7-26b).

Figure 7-26b shows the runoff rate from an extremely intense cloudburst (100-year return period) that occurred in White Rock on June 8th, 1999. This event is discussed in more detail in Section 7.8.

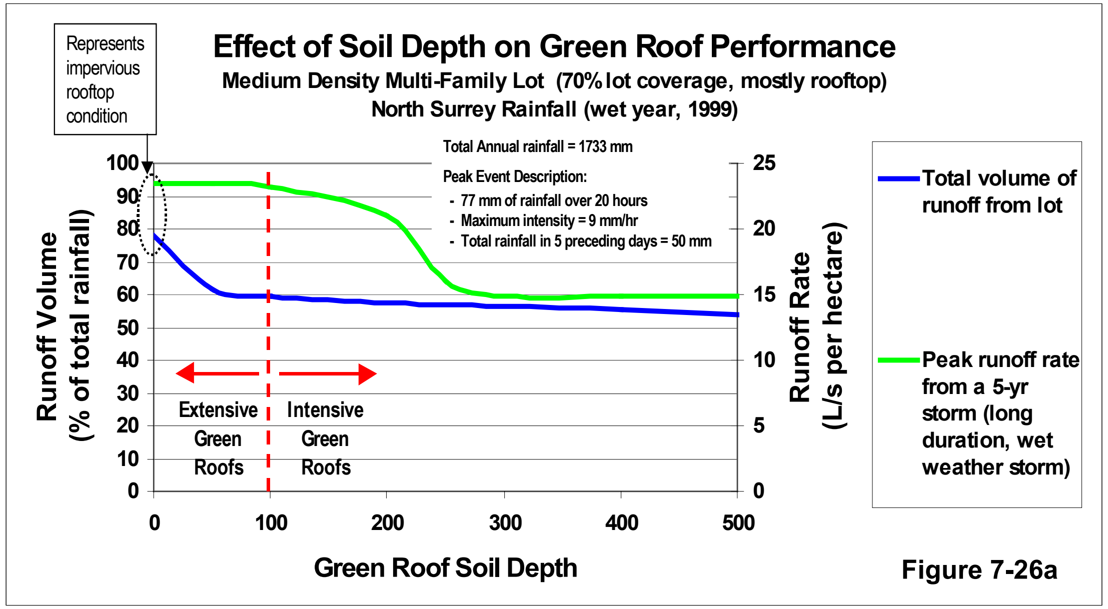


Figure 7-26a

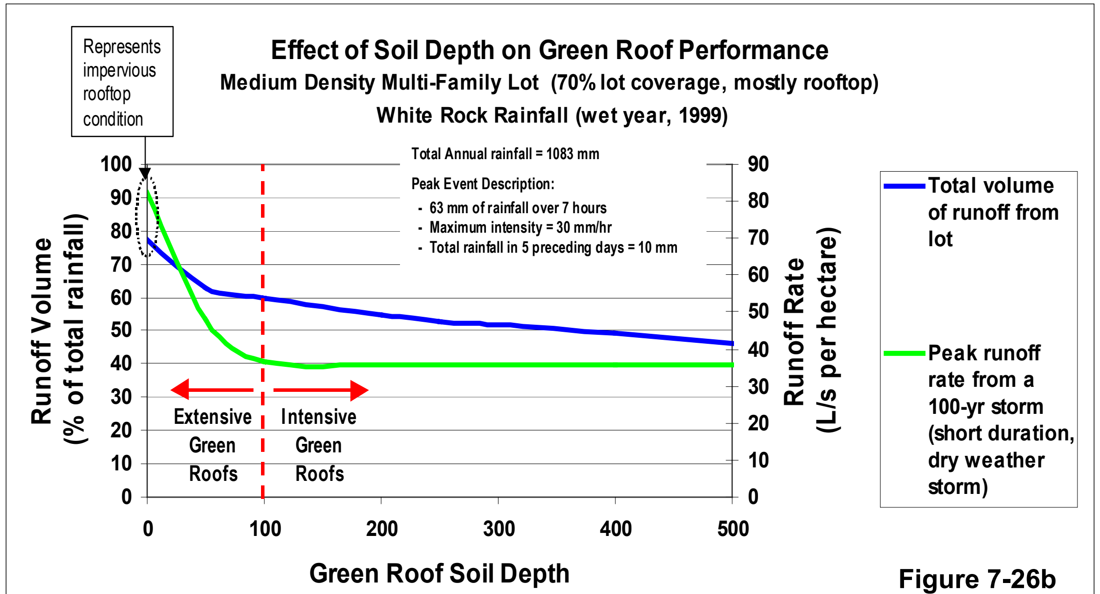


Figure 7-26b

Benefits of Green Roofs for Different Land Uses

Figures 7-27a and 7-27b show that the benefits of green roofs, in terms of reducing runoff volume and rate, is most significant for land uses with high percentages of rooftop coverage, such as high density multi-family or commercial uses (without substantial surface parking). Green roofs have less benefit for single family land uses, and it is likely less feasible to implement green roofs on single family buildings.

The Importance of Parking Type

Note that the type of parking provided for multi-family and commercial land uses has a big impact on the potential benefits of green roofs (green roofs can be applied to parkades but not to surface parking). Figures 7-27a and b show modeling results for multi-family and commercial land uses with limited surface parking (i.e. rooftop coverage is approximately equal to impervious coverage).

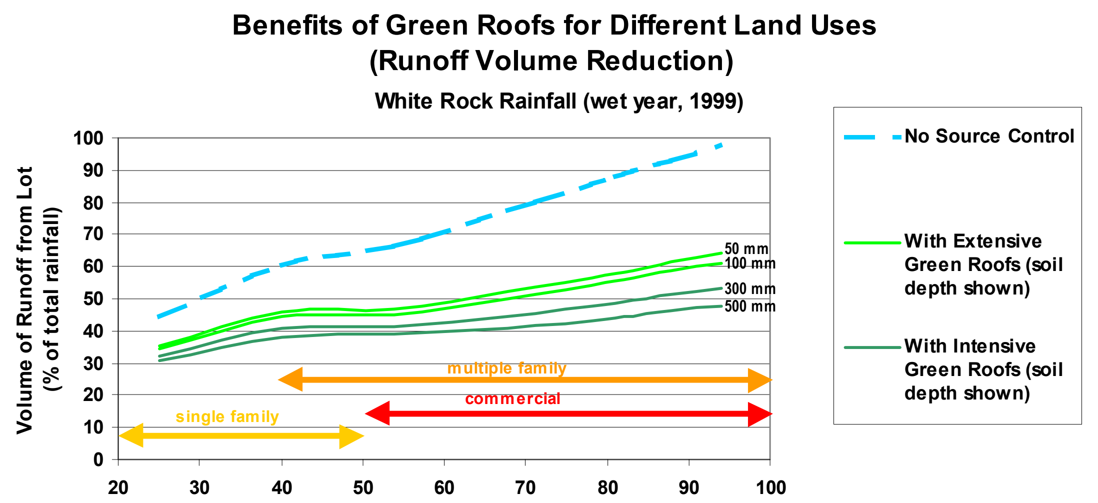


Figure 7-27a

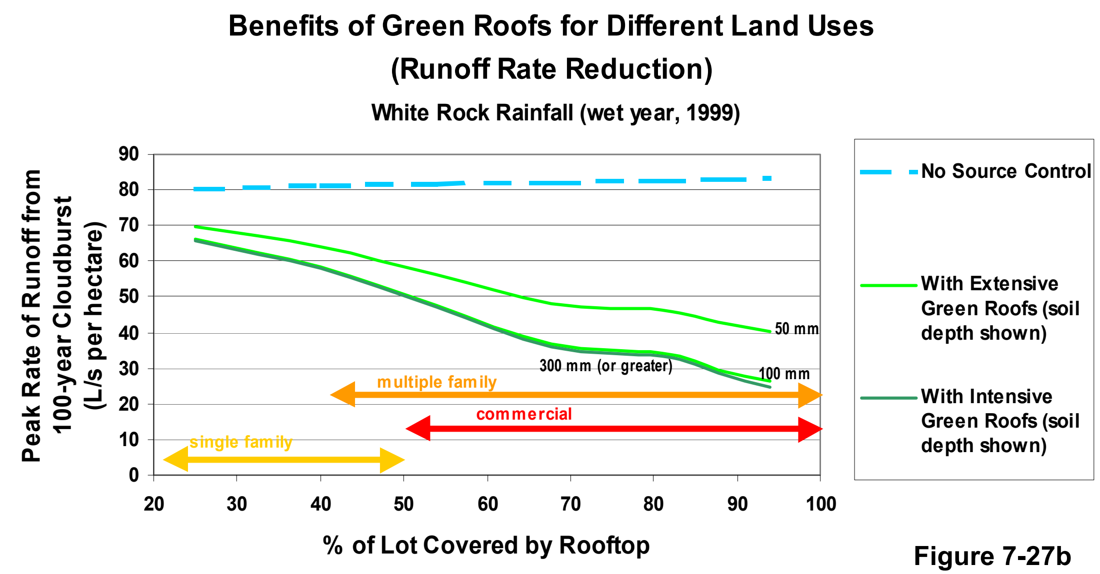


Figure 7-27b

Cost Implications for Green Roofs

The costs of green roofs are highly variable and depend on site-specific conditions, such as the scale of installation, vegetation type and green roof design. Typical installation costs for green roofs infiltration facilities range from about \$60 to \$150 per m^2 (intensive green roofs with 300 mm or more of soil depth are likely to be near the high end of this range). There may also be increased structural costs (although this is not likely a factor for concrete buildings).

Note that the scale of the installation alone can influence the installation cost of green roofs by a factor of 3 or more. This is a direct consequence of the fact that the present market for green roofs in North America is too small to be economically efficient. The cost of installing green roofs in Germany (where a mature green roof industry exists) is typically half the cost of a similar installation in North America.

Annual operation and maintenance costs for green roofs are typically in the range of \$1 to \$2.50 per m^2. Operation and maintenance costs are typically highest in the first year when plants may require establishment watering, weeding, and some replacement.

Design and Construction Tips for Green Roofs

- To reduce structural costs, the design of the absorbent soils over the parking garage lid or roof may use a light weight growing medium. The depth of the soil related to its absorbency may also be fine-tuned for structural load efficiency.
- If light-weight soils are used, they can be subject to wind erosion when they dry out. Appropriate scheduling of soil placement, and temporary protection of the soils until planted or watered should be arranged.
- Roof water should be kept separate from runoff from paved surfaces, which can be polluted with hydrocarbons and heavy metals. Whereas paved surface runoff may require treatment, most green roof runoff will be clean enough to be released directly to storage and receiving waters.
- Proper waterproofing and flashing are essential for green roofs.
- Most green roof systems include a root growth inhibitor to keep roots from invading the waterproof membrane area.
- The most successful green roof systems use drought tolerant plants, and avoid grasses.
- Establishment watering may be required, using either surface standard watering devices, or an automatic irrigation system. Watering requirements will vary based on the green roof system chosen.

Operation and Maintenance Tips for Green Roofs

- Intensive roofs are typically landscaped features that require a higher level of maintenance than extensive green roofs. Through proper plant selection, it may be possible to design extensive green roofs that are essentially self-sustaining and require very little maintenance.
- Irrigation, fertilization and pesticide/herbicide application should be kept to a minimum. Occasional weeding of wind-blown seeded plants may be required.
- Storage in a plastic drainage layer, or equivalent storage volume in drain rock, under the green roof soil can increase the effective rainfall capture and storage volume.
- The drainage outflow from the parking garage lid should be connected to infiltration facilities, in suitable areas of the site off the parking garage, with an overflow to the storm drain system.
- Drain inlets from green roofs will require regular inspection (as is normal practice).
- Normal landscape maintenance techniques should suffice for the absorbent soils on green roofs. Landscaping contractors must be made aware of the need to avoid damaging roof membranes during maintenance activities.

7.7 Type 4 Source Control - Rainwater Re-use

Just as the trees in a forest use a significant portion of rainfall, capturing rainfall for human re-use can play a key role in managing the Water Balance at the site level. The benefits of rainwater re-use go beyond stormwater management (i.e. reducing the volume and rate of runoff from developed areas). Re-use can also reduce the amount of water drawn from reservoirs and reduce the costs of water supply infrastructure.

In general, the most significant reductions in runoff volume can be achieved by capturing and re-using rainwater for indoor greywater type uses, particularly for land uses with high rates of water use. Re-using rainwater for irrigation typically provides less benefit in terms runoff reduction because the demand for irrigation water occurs during the dry weather periods, and most runoff occurs during wet weather periods.

For rainwater re-use on single family residential land uses, rooftop runoff is typically stored in rain barrels (see Figure 7-28a). For re-use on multiple family, commercial or institutional land uses, rooftop runoff is typically stored in cisterns or detention vaults (e.g. see Figure 7-28b).

Rainwater re-use systems can be combined with infiltration facilities as shown schematically in Figure 7-28b. In catchments where maintaining stream base flows is a key objective, first priority may be given to groundwater recharge, with only surplus water applied to in-building re-use.

Figure 7-28a Rainwater Re-use using Rain Barrels

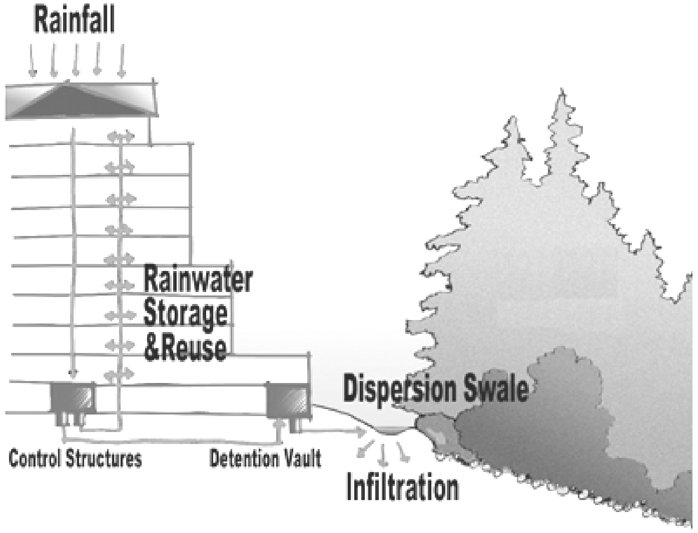


Figure 7-28b Rainwater Re-use using Cisterns

Benefits of Rainwater Re-use for Different Land Uses

Significant reductions in runoff volume can be achieved on high-density residential land uses by capturing and re-using rooftop runoff for toilets and washing machines, as shown in Figure 7-29a. As population density increases, residential water use rates increase, and therefore, the level of reduction in runoff volume that can be achieved through rainwater re-use increases.

The level of volume reduction that can be achieved by re-using rainwater for greywater uses (toilets and washing machines) on commercial land uses varies significantly depending on the type of commercial land use, as shown in Figure 7-29b. Commercial land use types with high water use rates, such as restaurants and bars, can achieve significant runoff reduction, even where density is low (e.g. local commercial).

Note that rainwater re-use for greywater uses is most beneficial on high-coverage land uses where opportunities for infiltration are most limited.

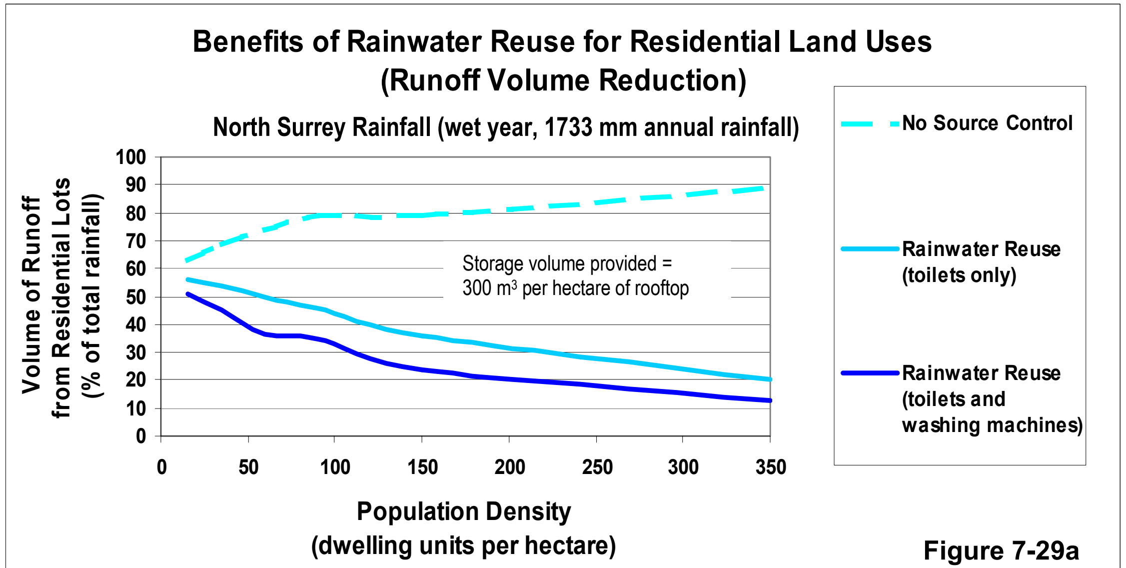


Figure 7-29a

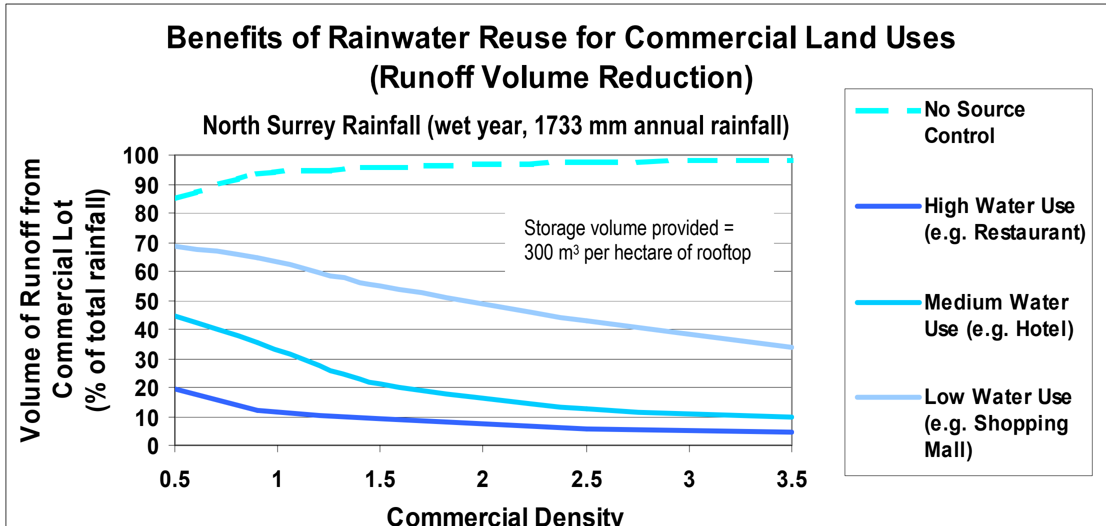


Figure 7-29b

The Impact of Surface Parking

The potential benefits of rainwater re-use are significantly less for land uses that have significant amounts of surface parking, as shown in Figures 7-30. This reflects the assumption that runoff from paved surfaces is less suitable for indoor re-use, primarily due to water quality concerns (although it may be possible with appropriate treatment).

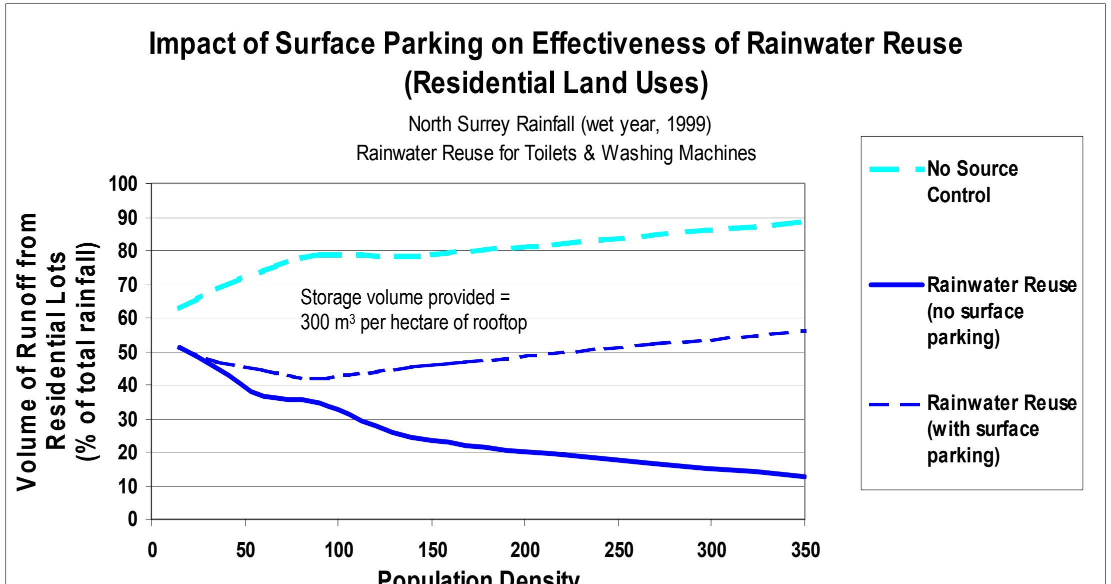


Figure 7-30

The Effectiveness of Rainwater Re-use under Different Rainfall Conditions

Greater reductions in runoff volume can be achieved through rainwater re-use where (and when) total annual rainfall is lower, as shown in Figure 7-31. As total rainfall decreases, water use rates (a function of land use type) become a greater percentage of total rainfall.

In certain situations it may be possible to re-use virtually all rooftop runoff. However, it is important that rainwater re-use systems be designed to ensure that adequate baseflow is maintained in downstream watercourses.

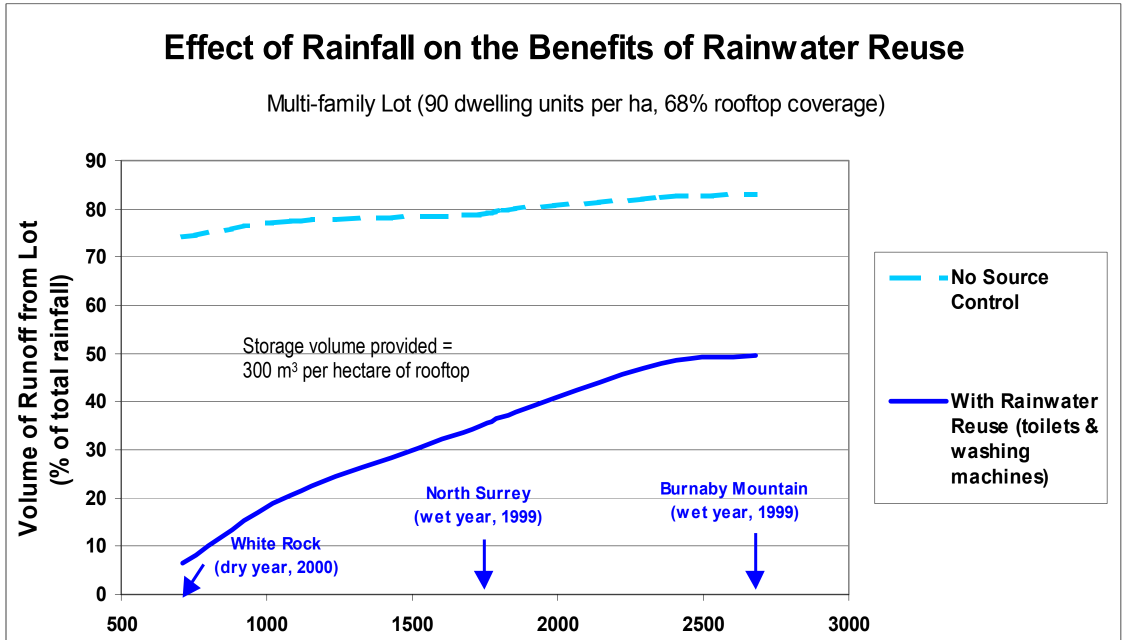


Figure 7-31

Selecting an Appropriate Storage Volume

Increasing storage volume (i.e. size of rain barrels or cisterns) can improve the hydrologic benefits of rainwater re-use, as shown in Figure 7-32. The volume reduction benefits of providing additional storage capacity diminish beyond a relatively low threshold (about 100 m^3 per hectare of rooftop). Beyond this threshold, runoff volume reduction is primarily a function of land use characteristics (e.g. population density, commercial density, land use type and type of parking).

Figure 7-32 also shows that very large storage volumes are needed to achieve any significant reduction in peak runoff rates from extreme rainfall events (e.g. a 5-year winter storm).

Note that this figure is based on Water Balance Model simulations for a very wet year in the GVRD (1733 mm annual rainfall). In locations and/or years with less rainfall, it is likely that the same benefits could be achieved using with less storage volume (and vice versa).

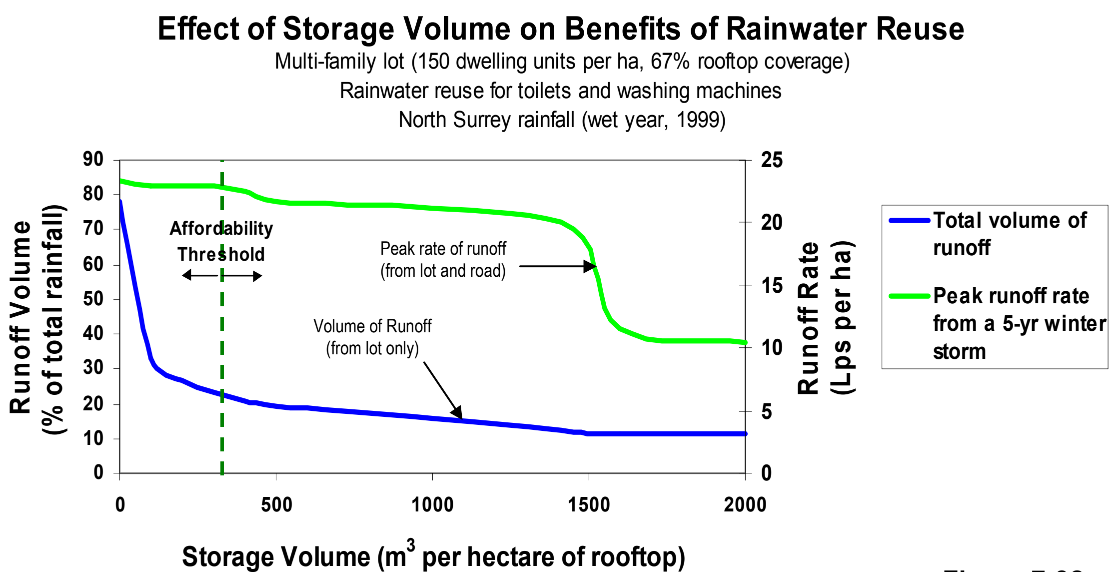


Figure 7-32

Cost Implications of Rainwater Re-use

The design and costs of rainwater re-use systems must be considered in the context of site-specific characteristics, including:

- nature of the development (e.g. water use characteristics, design of individual buildings)
- site-specific rainfall patterns
- characteristics of both stormwater and water supply infrastructure (existing or planned)

Costs implications must be considered at the scale of individual building (e.g. cisterns, additional pipe), as well as at the larger site (or regional) scale (e.g. water use savings, reduction in size of water supply and/or stormwater infrastructure). It is not possible to provide generalized costs estimates for rainwater re-use.

Design and Construction Tips for Rainwater Re-use

- Rainwater re-use systems may be designed to slowly release small amounts of water in order to maintain stream baseflows.
- Rainwater re-use systems in major buildings would require mechanical engineering design.
- There are traditional and evolving new systems for use in single family or small buildings. Some store rainwater right at the eaves, and more traditional systems include rain barrels or plastic vaults with either gravity or pump feed.
- Refer to publications on the subject for details of cistern pre-treatment and dewatering systems. Access for vacuum hose cleaning from a truck is advisable.
- Storage cistern designs are subject to waterproofing and structural engineering.

Operation and Maintenance Tips for Rainwater Re-use

- To reduce contamination of water stored in cisterns, the source of water should generally only be roofs, or other clean sources.
- Occasional cleaning of cisterns may be necessary. This is usually performed by vacuum hose.
- Regular inspection of cisterns is required to ensure that control structures continue to function properly.

7.8 Applying Source Controls to Mitigate Extreme Cloudbursts

One of the anticipated effects of climate change is an increase in the frequency of cloudbursts – high intensity short duration storms - which could cause significant drainage problems.

An extremely intense cloudburst (100 year short duration storm) occurred in White Rock on June 8th, 1999 and caused extensive flood damage. The simulated runoff hydrographs (from a typical multi-family neighbourhood) shown in Figure 7-33 demonstrate how effective the following source control scenarios would be at reducing the runoff from this event:

- **Scenario 1: No Source Control -** All impervious area is directly connected to a storm sewer system and pervious areas are covered by disturbed soil.
- **Scenario 2: Absorbent Landscaping** - Disturbed soil is replaced with 300 mm of absorbent landscaping; peak runoff rate would be reduced by about 27%.
- **Scenario 3: Absorbent Landscaping plus On-Lot Infiltration Facilities** – Same as Scenario 2 except that all lots have bioretention facilities (150 mm of surface ponding on top of 1 m of absorbent soil) covering 10% of lot area; peak runoff rate would be reduced by about 70%.
- **Scenario 4: Absorbent Landscaping plus Intensive Green Roofs -** Same as Scenario 2 except that all residential buildings and parkades have green roofs with 300 mm of soil depth; peak runoff rate would be reduced by about 80%. Note that the same level of runoff rate reduction could be achieved using green roofs with extensive green roofs that have 100 mm of soil depth (see Section 7.6).
- **Scenario 5: Absorbent Landscaping plus Intensive Green Roofs plus On-Street Infiltration Facilities** – Same as Scenario 4 except that all roads have one 3 m wide infiltration swale/trench system (as described in Section 7.5) within road right-of-ways; peak runoff rate would be reduced by about 92%.

This case study shows that source controls can be very effective at reducing runoff rate from cloudbursts, and thus partially mitigating some of the anticipated effects of climate change.

Another anticipated effect of climate change is an increase in the amount of fall/winter rainfall, which will increase total runoff volume. The watershed case studies presented in Chapter 8 show that source controls can also be effective at mitigating this effect of climate change.

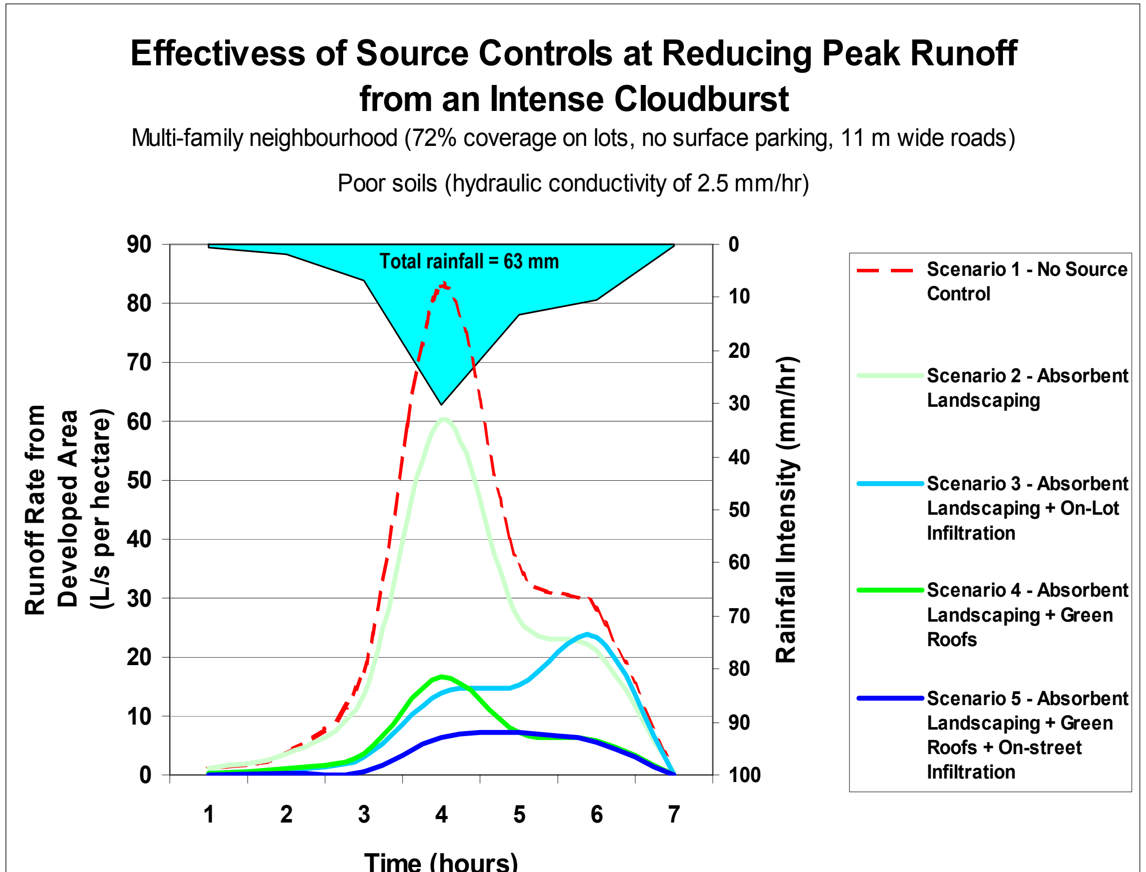


Figure 7-33

7.9 Communicating Performance Targets to Developers

To achieve performance targets, appropriate stormwater management practices must be integrated with site design. For this to happen, performance targets must be clearly communicated to developers in a format that they can apply to the design of stormwater systems at the site level.

Case Study Example: Design Guidelines for Developers

Infiltration has been identified as the most applicable source control option in the City of Chilliwack.

Chilliwack's *Design Guidelines for Stormwater Systems* provide step-by-step procedures for land developers to follow in order to design infiltration and detention systems that meet the City's design criteria for rainfall capture and runoff control. This example shows how to communicate performance targets and design criteria to developers. These Guidelines also specify performance monitoring requirements.

The Design Guidelines consist of the following forms:

- **Form 1 - Development Site Summary Characteristics**
- **Form 2 – Criteria for Absorbent Landscaping**
- **Form 3 – Design of Infiltration Facilities**
- **Form 4 – Design of Detention Facilities**
- **Form 5 – Performance Monitoring Requirements**

These forms are reproduced on the following pages.

City of Chilliwack – Design Guidelines for Stormwater Systems

Procedure for Sizing Infiltration and Detention Facilities

Form 1 – Development Site Summary Characteristics

Total development site area:

- $\mathbf{A_{total}}$ = _______ ha

Minimum hydraulic conductivity of on-site soils (from on-site percolation testing):

- **H** = _______ mm/hr

Total impervious area on development parcels (excluding green roofs):

- $\mathbf{IA_{on\text{-}lot}}$ = _______ ha

Total impervious area on roads (excluding pervious paving):

- $\mathbf{IA_{road}}$ = _______ ha

Total impervious area on development site

- $\mathbf{IA_{total} = IA_{on\text{-}lot} + IA_{road}}$ = _______ha

Total pervious area on development site

- $\mathbf{PA_{total} = A_{total} - IA_{total}}$ = _______ha

Site and Key Plan

Form 2 - Criteria for Absorbent Landscaping

The design guidelines presented in Forms 3 and 4 are based on *impervious areas only*.

On-site pervious areas must be ‘self-mitigating’ (i.e. meet rainfall capture and runoff control targets). In order to achieve this:

- ❑ **Minimum depth of absorbent soil* for on-site pervious area = 300 mm**

  * must meet *BC Landscape Standard* for medium or better landscape. The range of acceptable soil textures is shown below:

Lightest Soil:	Heaviest Soil:	Typical Design Soil:
Sand 90% Silt/Clay 5% Organic Matter 5%	Sand 55% Silt/Clay 25% Organic Matter 20%	Sand 75% Silt/Clay 15% Organic Matter 10%

Form 3 – Design of Infiltration Facilities

Rainfall capture criteria: capture and infiltrate 300 m^3 of rainfall per day per impervious hectare

Infiltration facilities are to be provided as follows:

- On individual development parcels to capture runoff from rooftops and parking areas (e.g. by means of on-lot soakaways)
- Within road right-of ways to capture runoff from paved roadway (e.g. by means of roadside infiltration trenches)

Sizing Infiltration Facilities (applies for both development parcels(1) and roads)

Step 1) *Select Design Depth,* **D**

D = _____ m

D = distance from bottom of infiltration facility to the maximum water level (the point where overflow occurs)

Step 2) *Select Facility Type and Determine Effective Depth,* $\mathbf{D_{eff}}$

$\mathbf{D_{eff}}$ **= [D x VS] =** _____m

VS = void space storage, the ratio of the volume of water retained per unit volume of the infiltration facility. Typical values for different types of infiltration facilities are shown in Table B on the following page.

Step 3) *Determine Minimum Footprint Area,* **A** *(i.e. bottom area) needed to meet rainfall capture target*

$\mathbf{A_{min}}$ = [(____ m^2, *from Table A*) *x* (_____ m^2 of IA served)] / 1000

A = the total area (in plan view) covered by the infiltration facility

(1) A typical facility size may be developed for multiple lots that have similar soil characteristics and similar amounts of IA.

Conveyance of Overflow from Infiltration Facilities

Overflow from infiltration facilities (on-lot and on-road) should be conveyed into runoff control facilities (refer to Form 3) via a stormwater drainage system, most likely within the road ROW. Road drainage may consist of:

a) a perforated pipe at the top of an infiltration trench
b) a catch basin connected to storm sewer pipe
c) a surface swale

Providing Runoff Control Storage in Infiltration Facilities (Optional)

Increasing the dimensions of infiltration facilities (whether they are on on-lot or on-road above the minimum requirement (i.e. $A > A_{min}$) reduces the storage volume that must be provided in off-lot runoff control facilities (refer to Form 4).

The amount of runoff control volume provided by on-lot and on-road facilities can be calculated as follows:

- $\mathbf{V_{on\text{-}site}}$ **= [**Facility depth **(D)** x Footprint Area **($\mathbf{A_{actual}}$)] – [D** x $\mathbf{A_{min}}$**] =** ____ m^3

The total runoff control volume provided by all on-lot and on-road facilities **(Σ $\mathbf{V_{on\text{-}site}}$)** can then be subtracted from community detention requirements (refer to Form 4).

Table A - Required Footprint Area (in m^2) for Infiltration Facilities (per 1000 m^2 of impervious area served by the facility)

Effective Depth of Infiltration Facility[1]	Hydraulic Conductivity of On-Site Soils[2] (mm per hour)				
	5	10	25	50	> 100
0.25 m	175	125	75	50	30
0.5 m	140	90	55	40	25
1.0 m	120	70	40	30	20
1.5 m	110	65	35	25	15
2.0 m	100	60	30	20	15

[1] Depths for rainfall capture facilities must be selected based on site-specific characteristics and constraints. The feasible depth may be governed by physical constraints (e.g. depth to the water table or to bedrock). The effective depth is equal to total depth multiplied by void space, and will depend on facility type (see Table A).

[2] Based on percolation tests from the development site (ideally carried out under saturated conditions, following periods of extended rainfall). Sizing of rainfall capture facilities should normally be based on the *minimum* percolation test results from a development site. Tests should be performed at the locations and depths of proposed infiltration facilities.

Table B - Typical Void Space Storage Values (VS)

Infiltration Facility Type[3]	Storage Medium	Typical Void Space (VS)
Retention ponds	Open	1.0
Bioretention facilities	Absorbent soil	0.2
Soakaways (infiltration trenches/pits)	Gravel or drain rock	0.33
Infiltration Chambers	Sub-surface chambers & surrounding gravel	0.55

[3] Infiltration facilities may be a combination of types. In this case, effective depth of the facility is the sum of total depth multiplied by VS, for each layer. For example, a bioretention facility with 0.3 m of ponding depth on top of a 1.5 m absorbent soil layer would have effective depth, D_{eff} = [1.5 m x 0.2] + [0.3 m x 1] = 0.6 m.

Form 4 – Design of Detention Facilities

Runoff Control Criteria: Detain an additional 300 m³ of rainfall per impervious hectare and release at 1 Lps per hectare (total site area)

Designing Community Detention Facilities

The storage volume that must be provided in community detention storage facilities (e.g. wet or dry detention ponds) is:

- **$V_{off\text{-}site}$ = [IA_{total} x 300 m^3/ha] – [Σ $V_{on\text{-}site}$] = _____** m^3

The rate of release from detention storage is:

- **R = A_{total} x 1 L/s per ha = _____** L/s

Form 5 – Performance Monitoring Requirements

Target: to provide an accurate picture of how rainfall moves through the stormwater system to enable future evaluation of system performance and optimization of design criteria

) Monitoring within Development Sites

The City will select certain development sites as demonstration projects and develop a comprehensive monitoring plan for these sites. The costs of installation and continued operation of monitoring equipment will be funded through Development Cost Charges.

The purpose of monitoring within development sites is to evaluate and refine the City's design criteria and customize criteria for different zones within Chilliwack. In order to properly evaluate the performance of a stormwater system, the Water Balance of the development site served by that system must be defined. Therefore, it is important to monitor a representative sample from each component of the stormwater system, including:

- **On-Lot Rainfall Capture Facility monitoring** – Monitor water levels and overflow from at least one on-lot rainfall capture facility.
  - for surface facilities - install a compound weir, water level sensor and data logger at the overflow point
  - for sub-surface facilities – install a piezometer (to measure water level) and data logger
- **Road Infiltration/Drainage monitoring** – Monitor the road drainage flow from at least one section of road. This may include more than one drainage path (e.g. perforated pipe plus catch basins connected to a storm sewer).
  - install a compound weir, water level sensor, and data logger in a manhole at the downstream end of the road
- **Runoff Control Facility monitoring** – Monitor water levels and outflow from detention facilities (e.g. community detention ponds)
  - install a compound weir, water level sensor and data logger in the outlet control manhole

B) Monitoring at the Catchment Level

The City will install streamflow and TSS monitoring stations downstream of catchments where land development is occurring to verify that development practices are adequately protecting downstream hydrology and water quality. The costs of installation and continued operation of monitoring equipment will be funded through Development Cost Charges.

Refer to Figure 5-8, in Chapter 5 for illustration of a comprehensive monitoring program.

Watershed Context for Site Design Solutions

Chapter Eight

8.1 Determining What is Achievable at the Watershed Scale

- The Value of Watershed Retrofit Scenarios
- The Need for an ISMP Context

8.2 Watershed Retrofit Case Studies

- Indicators of Watershed Restoration
- Source Control Scenarios
- Case Study #1: McKinney Creek Watershed, Maple Ridge
- Case Study #2: Quibble Creek Watershed, Surrey

8.3 Achieving Watershed Protection or Restoration

- Changing Development Standards
- Facilitating Stormwater Source Control Applications

8.1 Determining What is Achievable at the Watershed Scale

The purpose of applying site design solutions is to ultimately achieve benefits (in terms of watershed health and/or flood risk management) at the watershed scale.

Determining what is achievable at the watershed scale is key to developing a shared long-term vision for a watershed. This long-term vision then provides a context for all planning, data collection, capital expenditures and regulatory changes.

Section 8.2 presents case studies that show what can be achieved at the watershed scale through the application of stormwater source controls.

Section 8.3 illustrates what is needed to achieve the widespread application of source controls that are required to achieve significant benefits at the watershed scale.

The Value of Watershed Retrofit Scenarios

Watershed retrofit scenarios were modeled using the Water Balance Model (see Chapter 7) for three developed watersheds in the Greater Vancouver Regional District (GVRD). The purpose of the watershed modeling was to answer the questions:

- How can implementation of stormwater source controls on all new developments and re-developments over a long time period, on a watershed-wide basis, benefit flood management and urban stream health?
- Are there specific stormwater source controls that work better in theory than others?

The modeling results from two of the GVRD case study watersheds are presented in Section 8.2. These results demonstrate that it is achievable to significantly improve and potentially restore watershed health over a 50-year timeline by applying stormwater source controls to re-development projects.

In general, restoring a degraded watershed is more challenging than preserving a healthy watershed. The GVRD case studies demonstrate that watershed restoration is achievable through source control (in one of the wettest parts of the province). This also demonstrates that watershed protection is achievable through stormwater source control.

Drivers for the Watershed Retrofit Evaluation

The Greater Vancouver Region is projected to experience significant population growth over the next 50 years (possible doubling). This will lead to densification of existing land uses and some development of existing natural areas, which will increase the volume and rate of stormwater runoff discharged into watercourses in the GVRD. The increased runoff is likely to result in:

- the need for upgrades and/or repairs to drainage infrastructure in many parts of the GVRD
- further degradation of aquatic ecosystems in urban watersheds
- further water quality deterioration (also a result of population increase)
- increased flooding risk to life and property

The effects of climate change are likely to exacerbate these impacts. The amount of fall and winter rainfall in the GVRD is anticipated to increase over the next 50 years due to climate change, which will further increase runoff. Climate change is also expected to increase the frequency of high-intensity rainfall events (cloudbursts), thus increasing the potential for flash flooding.

A key objective of the GVRD's *Effectiveness of Stormwater Source Control* report (2002) was to determine how:

- the impacts of increased runoff and more frequent cloudbursts could be avoided by applying stormwater source controls on future development and re-development projects within the GVRD
- the application of source controls on re-development projects could support restoration of aquatic ecosystems and decrease flooding risk over time, thus turning a potential problem (the combination of densification and climate change) into an opportunity (watershed restoration).

The Need for an ISMP Context

This chapter provides a broad overview of the potential benefits of source control (at a watershed scale), but does not evaluate source control options in the context of an Integrated Stormwater Management Plan (ISMP) – that is the next step (see Chapter 10). The ISMP process will determine what is achievable and affordable in the context of each individual watershed.

A key objective of any ISMP is to develop a source control strategy that is watershed-specific.

The ISMP process should identify where there is significant aquatic habitat to be protected or restored, and whether there are drainage problems, such as erosion of ravines or chronic flooding. A more detailed assessment of source control opportunities should focus on areas where land use change could cause or exacerbate stormwater-related problems. An ISMP should evaluate opportunities to mitigate potential negative impacts or to improve conditions through the application of source control.

An analysis of the land use in these catchments will provide an estimate of the expected time frame for new development or re-development over the next 50 years.

The costs and benefits of implementing source control options in these catchments must be evaluated based on more detailed information on soil conditions, hydrogeology, rainfall, streamflow, drainage infrastructure, land use and site design.

8.2 Watershed Retrofit Case Studies

This section summarizes the results of watershed retrofit modeling for two developed watersheds in the GVRD (see Figure 8-1), including:

- a watershed that is predominantly single family land use (McKinney Creek, Maple Ridge), and
- a watershed where re-development to higher density commercial and multiple family land uses is expected (Quibble Creek, Surrey)

The reference publication for these case study examples is the report *Effectiveness of Stormwater Source Control* (CH2M Hill Canada, 2002).

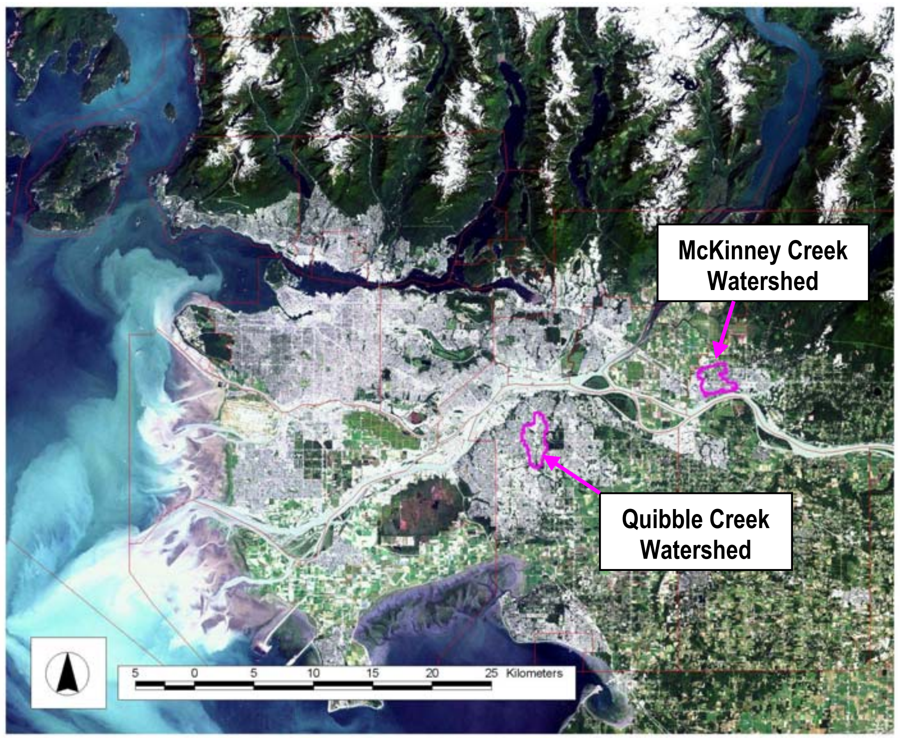


Figure 8-1 GVRD Case Study Watersheds

Indicators of Watershed Restoration

The watershed retrofit scenarios were evaluated based the following indicators of success:

- **Total runoff volume** - The primary watershed restoration target is to limit total runoff volume to 10% (or less) of total rainfall volume. This runoff volume target is based on the Water Balance of a healthy watershed (see Chapter 6).
- **Number of times the natural Mean Annual Flood (MAF) is exceeded** – The peak runoff rates from developed areas should only exceed the MAF that occurred under natural conditions about once per year, on average (more often during wet years). This runoff rate target is based on the hydrology of a healthy watershed (see Chapter 6).
- **Peak runoff rate from extreme rainfall events** – Reduction of peak runoff rates from extreme storms (e.g. from a 5-year storm) reduces watercourse erosion and flooding risk. Specific targets for flood risk management are highly watershed-specific.

The first two indicators show how well stream health is being restored, while the third provides an indication of how well flood risk is being managed over time.

Note that these are simply indicators of potential benefits. A more detailed evaluation of source control benefits for a particular watershed must consider the value of aquatic resources and the condition of drainage infrastructure throughout the watershed.

Without stormwater source control, land use densification, new development, and climate change will increase all of these indicators, resulting in watershed degradation.

Source Control Scenarios

The following source control scenarios were modeled using the Water Balance Model for each case study watershed, and evaluated relative to the three indicators of watershed restoration:

- **Scenario 1: Unmitigated** – Re-development is assumed to occur according to the standard practice of land development and stormwater management (i.e. no source controls applied).
- **Scenario 2: Unmitigated with Climate Change** – Same as Scenario 1, except that the anticipated effect of climate change on rainfall patterns is factored into the future scenarios.
- **Scenario 3: Absorbent Landscaping plus Infiltration Facilities** – For all future re-development projects, it is assumed that undeveloped areas are covered by absorbent landscaping (300 mm soil depth) and infiltration facilities are provided for all impervious surfaces (infiltration swales on all roads and bioretention facilities on all building lots). The size of infiltration facilities used for each land use type and road type were adjusted until the 10% runoff volume target was achieved or until the feasibility threshold was exceeded.
- **Scenario 4: Intensive Green Roofs plus Absorbent Landscaping plus Infiltration Facilities** – Same as Scenario 3, except that all re-developed multiple family and commercial buildings are designed with intensive green roofs (300 mm of soil depth). The runoff from green roofs is directed to infiltration facilities (sized as described in Scenario 3). All re-developed single family homes have impervious roofs connected to infiltration facilities. Intensive green roofs are not considered feasible for single family land uses.
- **Scenario 5: Rainwater Re-use plus Absorbent Landscaping plus Infiltration Facilities** – Same as Scenario 3, except that all re-developed buildings (including single family) incorporate rainwater re-use cisterns (300 m^3 of storage per hectare of rooftop, water re-used for toilets and washing machines). Overflow from the re-use cisterns is directed to infiltration facilities (sized as described in Scenario 3).

The cumulative hydrologic benefits (or impacts) associated with implementing these source control scenarios were modeled over a 50-year timeline.

Information and Assumptions Applied to Scenarios

The source control scenarios were modeled based on information and assumptions regarding:

- **Land use within the watersheds -** Local government staff (from the District of Maple Ridge and the City of Surrey) provided statistical data on the distribution of land use types within their respective watersheds. Surrey provided information on both existing zoning and future Official Community Plan zoning, which provided a basis for quantifying future land use change (densification). The site design characteristics for each land use type were estimated based on information on zoning bylaws and development standards (also provided by local government staff).
- **Expected timeframe for re-development –** For the McKinney Creek watershed, the age of existing development within the watershed was estimated based on discussion with the local government staff and field investigation. For the Quibble Creek watershed, the City of Surrey provided data showing the date of servicing for individual development parcels (a good approximation of building age). A 50-year re-development cycle was assumed for all watersheds.
- **Soil conditions –** There was limited soils information available for the case study watersheds. Conservative assumptions were made regarding the hydraulic conductivity of soils, which resulted in conservative findings regarding what is achievable using infiltration facilities.
- **Rainfall -** Rainfall data from the GVRD gauges closest to each case study watershed were used to simulate the performance of the source control scenarios. A year of continuous rainfall data from a very wet year (1999) was used to simulate the scenarios for each watershed.
- **Climate change -** Climate change scenarios were generated by applying climate change factors (developed by the Canadian Centre for Climate Modeling and Analysis) to the rainfall data for each watershed for a very wet year (1999).

Case Study #1: McKinney Creek Watershed, Maple Ridge

Land Use

The majority of land use in the 517 hectare McKinney Creek watershed (about 72%) is single family residential. With the exception of a small amount of housing in the northern portion of the watershed, most of this single family housing is relatively old (pre-1980s) with relatively low levels of lot coverage (around 30%). The remaining watershed area comprises some multi-family housing (about 8% of the watershed), some commercial land use along the highways (about 6%), and some other land uses (about 14%), including agriculture, schools and community parks.

Rainfall

Hourly rainfall data from GVRD rainfall gauge DM44 in Maple Ridge was used to simulate the performance of the source control scenarios. Rainfall data from a wet year was used (total annual rainfall = 1811 mm).

Soils Information

The available soils information included Geologic Survey of Canada mapping, and some soils mapping that was done in conjunction with a sub-surface drainage assessment (at a fairly coarse level). Based on this information, a conservative assumption was made that soils in the watershed have poor to medium hydraulic conductivity (around 6 mm/hr). There was little basis for estimating the variability of soil conditions throughout the watershed.

The District of Maple Ridge has reports that indicate the potential for fairly high water table conditions in a localized region of the watershed. The depth of all infiltration facilities was reduced to reflect this information.

Results

The primary form of re-development that is likely to occur over the 50-year time horizon in the McKinney Creek watershed is re-development of older (relatively low coverage) single family lots to higher coverage single family lots. This will likely be the result of larger homes and driveways being placed on existing lots and/or existing large lots being subdivided into smaller lots.

Figure 8-2 shows the difference in impervious coverage between a typical older single family development (on the left) and a typical newer single family development (on the right).

Without source control (Scenarios 1 and 2), this re-development is expected to increase total runoff volume, peak runoff rates, and the number of times the natural MAF is exceeded (see Figures 8-3a, 8-3b and 8-3c). The effects of climate change are likely to exacerbate the increase in runoff volume and rate.

Based on the stated assumptions, the 10% runoff volume target could be achieved with infiltration facilities and absorbent landscaping (source control Scenario 3) for all residential land uses, though not for commercial land uses. However, since commercial land uses represent a relatively small portion of the total watershed area, the application of infiltration facilities and absorbent landscaping could come very close to achieving the 10% runoff volume target at a watershed scale over the 50-year re-development cycle.

At the watershed scale, there would be little additional benefit gained by adding rainwater re-use or green roofs. The addition of green roofs could significantly improve the reduction in peak runoff rates from multiple family and commercial land uses. However, since most of the watershed is single family, this translates into a relatively small benefit at the watershed scale. Similarly, rainwater re-use would improve the reduction in runoff volume from commercial land uses, but this translates into a small benefit at the watershed scale.

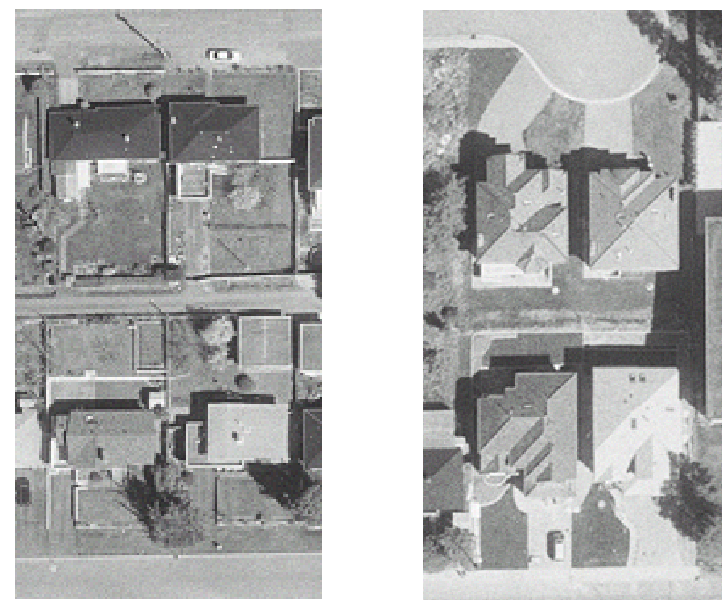


Figure 8-2:

Re-development impacts in the McKinney Creek watershed

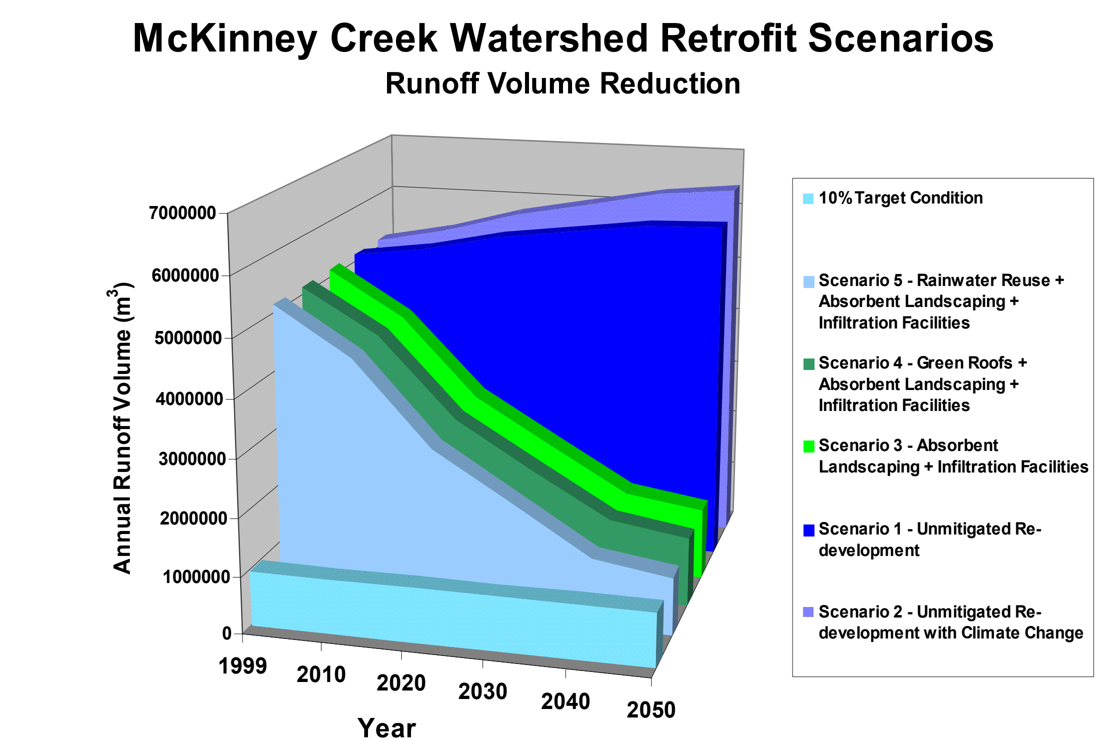


Figure 8-3a

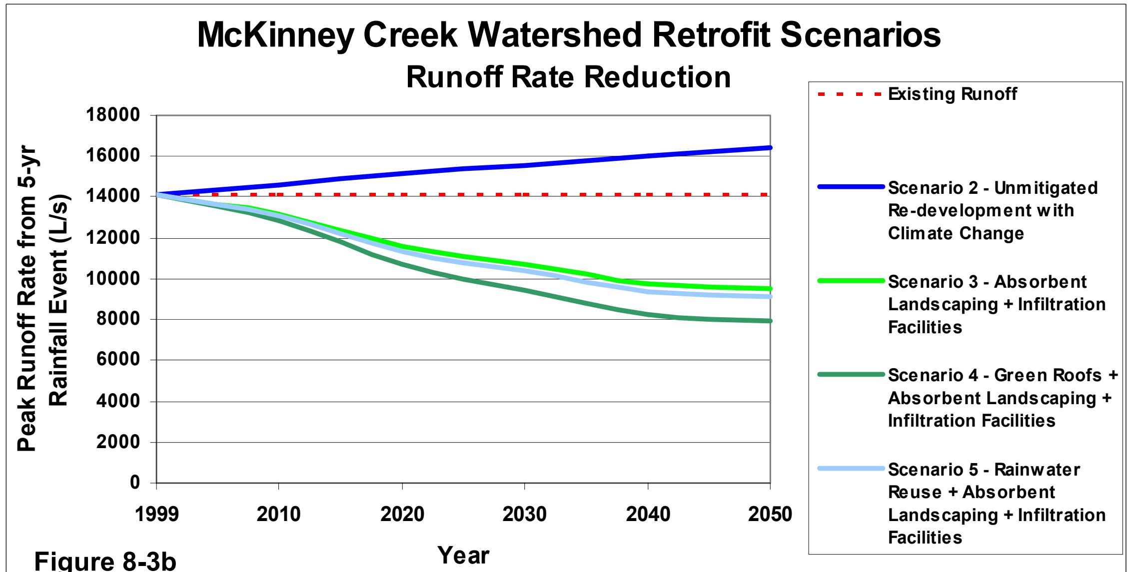


Figure 8-3b

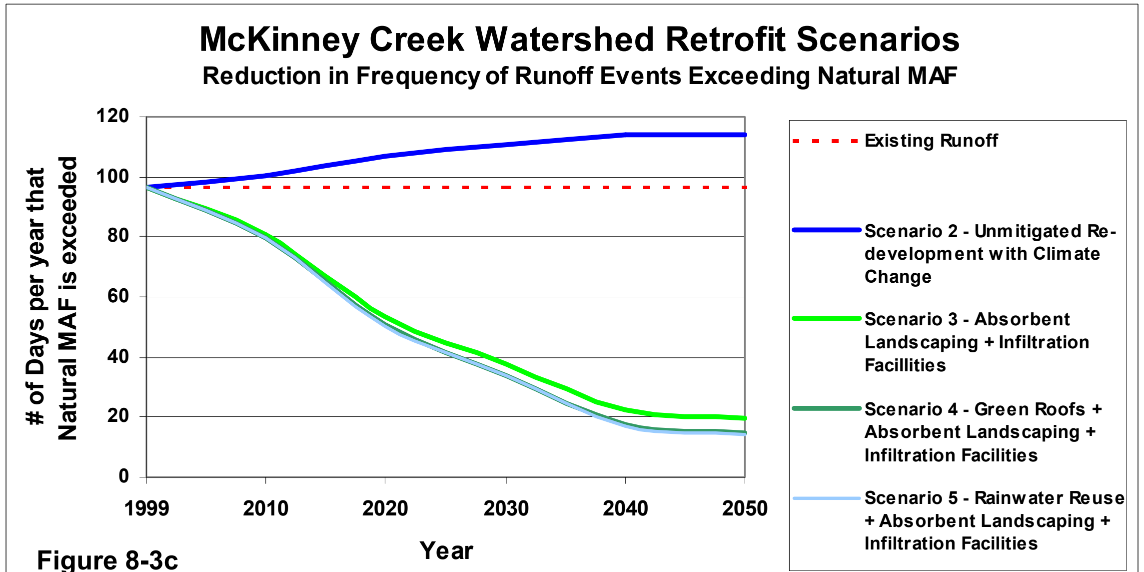


Figure 8-3c

Case Study #2: Quibble Creek Watershed, Surrey

Land Use

A substantial portion of land use in the 622 hectare Quibble Creek watershed (about 54%) is currently single family. A significant portion of the single family homes are relatively new (post-1980). The remaining watershed area comprises commercial land uses (about 20% of the watershed area), some multi-family housing (about 8%), and conservation areas (about 18%) that are not likely to develop in the future.

The City of Surrey's Official Community Plan calls for significant densification in the Quibble Creek watershed. About two-thirds of the existing single family housing in the watershed is expected to re-develop into multiple family land uses (a range of densities). The amount of commercial land is not likely to increase substantially, but existing local and community commercial land uses are expected to re-develop as higher-density town centre commercial.

Rainfall

Hourly rainfall data from GVRD rainfall gauge SU56 in North Surrey was used to simulate the performance of the source control scenarios. Rainfall data from a wet year was used (total rainfall = 1733 mm).

Soils Information

The only soils information available for the watershed was the Geologic Survey of Canada soils mapping (1:50,000 scale). This mapping shows about half of the watershed to be high conductivity soils and the other half to be low conductivity soils. Based on this information, a conservative assumption was made that soils have poor hydraulic conductivity (around 2.5 mm/hr). Aside from the coarse level GSC mapping, there was no basis for estimating the variability of soil conditions throughout the watershed.

Results

The primary impact of densification in the Quibble Creek watershed is likely to result from the re-development of single family land uses to multi-family land uses with higher impervious coverage (see Figure 8-4). Commercial densification also increases impervious coverage but to a lesser extent (even local commercial land uses have relatively high levels of impervious coverage).

Without source control (Scenarios 1 and 2), densification and the effects of climate change are expected to increase total runoff volume, peak runoff rates, and the number of times the natural MAF is exceeded (as shown in Figures 8-5a, 8-5b and 8-5c on the following page).

The 10% runoff volume target could be achieved with infiltration facilities and absorbent landscaping for all land uses except those with greater than about 80% impervious coverage (includes the highest density multi-family land uses and nearly all commercial land uses). At the watershed scale, the application of absorbent landscaping and infiltration facilities (i.e. Scenario 3) could reduce runoff volume to about 20% of total rainfall. In order to achieve the 10% target, it would be necessary to apply rainwater re-use to the high coverage land uses (i.e. Scenario 5).

Green roofs and rainwater re-use would have more significant runoff reduction benefits for the Quibble Creek watershed than for the McKinney Creek watershed (Case Study #1) because high coverage land uses (high density multi-family and commercial) represent a larger portion of the total watershed area. The benefits of rainwater re-use are most significant in terms of reducing runoff volume. The benefit of green roofs are most significant in terms of reducing peak runoff rates from extreme rainfall events.

Since much of the development in the Quibble Creek watershed is relatively new, the opportunity to apply source control to re-development projects is likely limited in the short term (over the next 10 years).

Figure 8-4:

Projected densification in Quibble Creek watershed

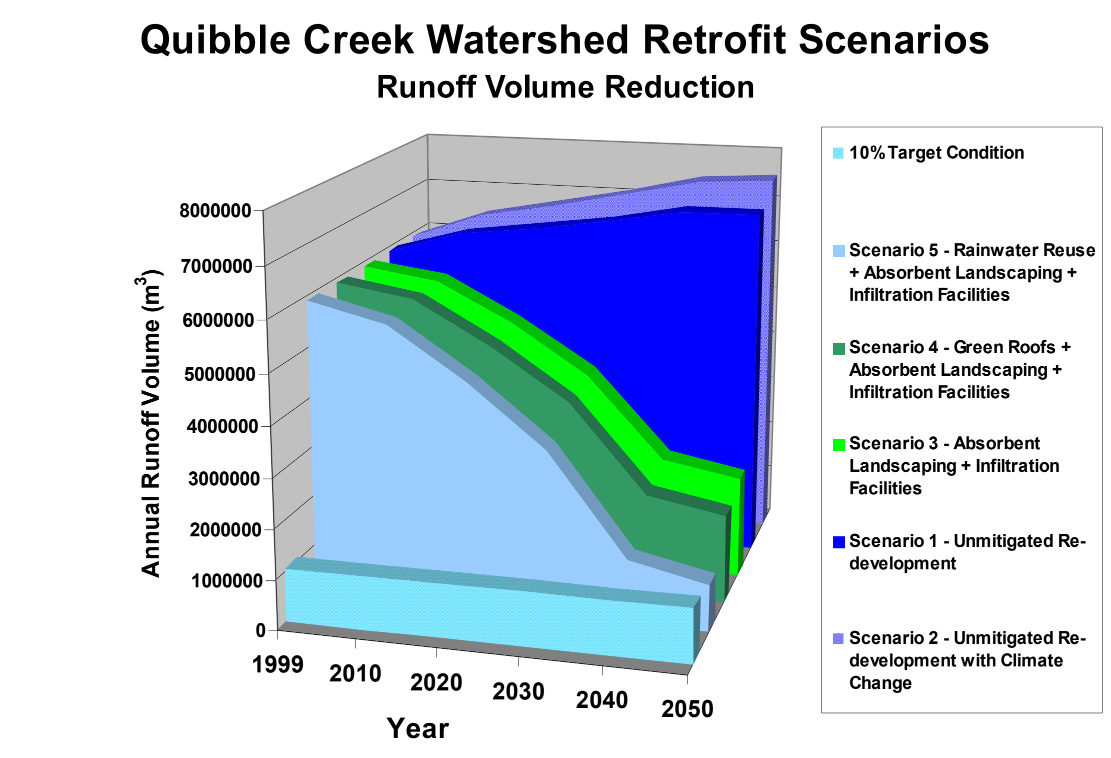


Figure 8-5a

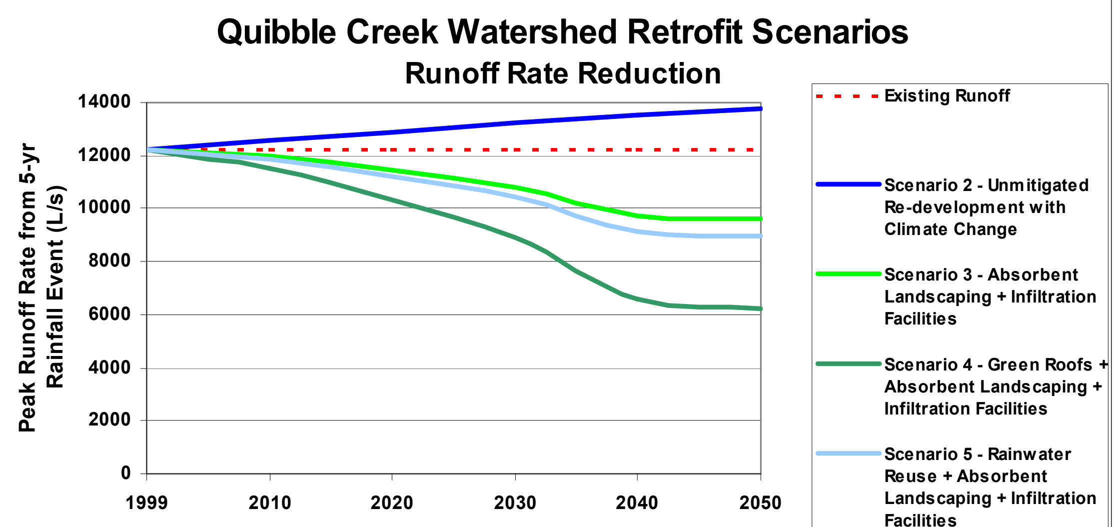


Figure 8-5b

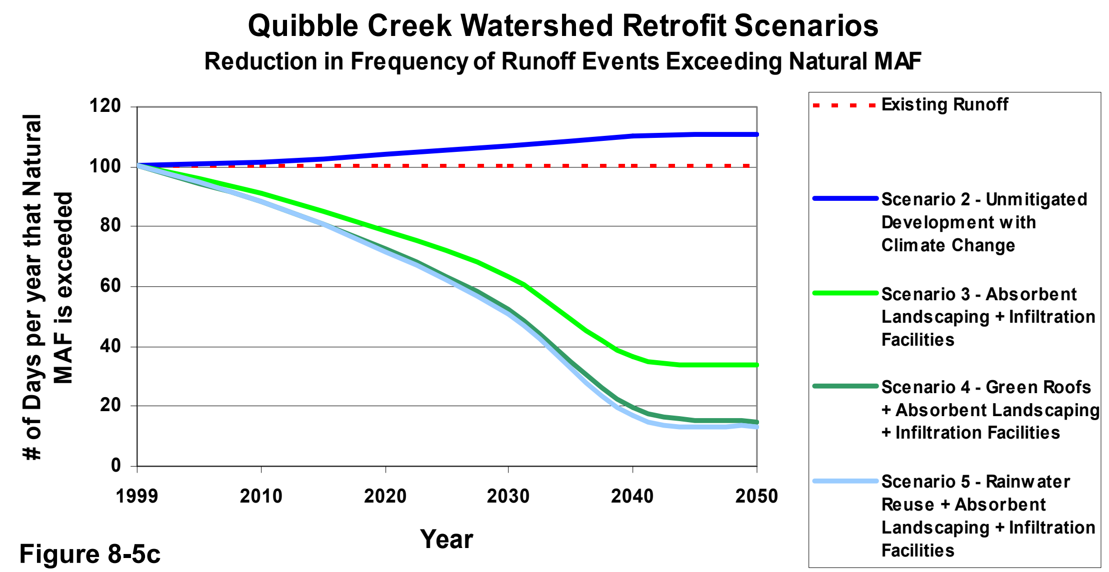


Figure 8-5c

8.3 Achieving Watershed Protection or Restoration

Widespread application of stormwater source control is needed to protect or restore watershed health. This will require changes to the standard practice of land development and stormwater management.

The details of these changes will vary from one watershed to the next. Watershed-specific source control strategies should be developed through the ISMP process (see Chapter 10) based on an assessment of watershed-specific opportunities and constraints.

The core objective is to identify options to change the way that land is developed and re-developed, so that people, property and natural systems can be better protected; and over time, stormwater infrastructure can be managed more efficiently and watersheds can be protected or restored.

Changing Development Standards

An ISMP may identify the need for changes to development standards and regulations in order to implement a watershed-specific source control strategy. The level of support from the public and from all levels of government, as well as the ability of the development community to adapt to new standards, will set the pace of change and influence the pace of ISMP implementation.

This support can only happen if there is a broad understanding among all players, the development community in particular and public in general, about the changes in standard practices - why they are needed, what they are, and how they can be practically accomplished.

Facilitating Stormwater Source Control Applications

The first large-scale applications of stormwater source controls and supporting policies may be implemented as demonstration projects. Local governments (independently or collectively) will need to take the lead in implementing and monitoring these initial demonstration projects (e.g. public works projects, neighbourhood concept plans, progressive ISMPs).

Local government leadership is important for demonstrating to developers, the community and senior government regulators that proposed actions at the site level are both effective and affordable. This will build support for the regulatory, professional and industry changes that will enable the realization of long-term stormwater infrastructure planning and management.

Monitoring demonstration projects provides the foundation for adaptive management. The goal is to learn from experience and constantly improve land development and stormwater management practices. Hydrologic monitoring is fundamental to adaptive management, since it is the hydrologic indicators that provide the information needed to improve the way we develop land and manage stormwater at the site level.

In order to build and maintain trust between local governments, landowners, developers and senior government agencies, the rules of adaptive management must be established at the ISMP stage. These rules must define requirements and consequences of monitoring. In many instances, either prior to or concurrent with the first demonstration projects, there will be a need to change current standards and administrative processes to accommodate these new standards. The following steps will facilitate this process of change:

- **Step 1 - Establish an enabling regulatory framework** – Make regulatory changes that will facilitate the approval process for development and re-development projects that capture rainfall at the source for infiltration, evapotranspiration and/or re-use.
- **Step 2 - Ensure that new design standards reflect local conditions** - Through the implementation and monitoring of demonstration projects, establish the design options for source control that will be most effective in the context of site-specific conditions (i.e. soils, precipitation, planned land use, etc).
- **Step 3 - Adopt a collaborative approach to change** – Consult with citizens and the development industry to determine:
  - preferred design options for stormwater source control
  - appropriate implementation strategies for regulatory change
  - appropriate financing strategies for rainfall capture and runoff control

- **Step 4 - Incorporate the most effective and acceptable design options into engineering standards -** Revisions to engineering standards should reflect local conditions as well as the preferences of the community and the development industry. Although new engineering standards for source controls can be incorporated into the relevant development regulations (Subdivision Bylaws, Building Bylaws, Zoning Bylaws, Development Permit Guidelines), it is also possible that standards could be performance-based, leaving the determination of appropriate source control strategies to the proponent as part of their development application.

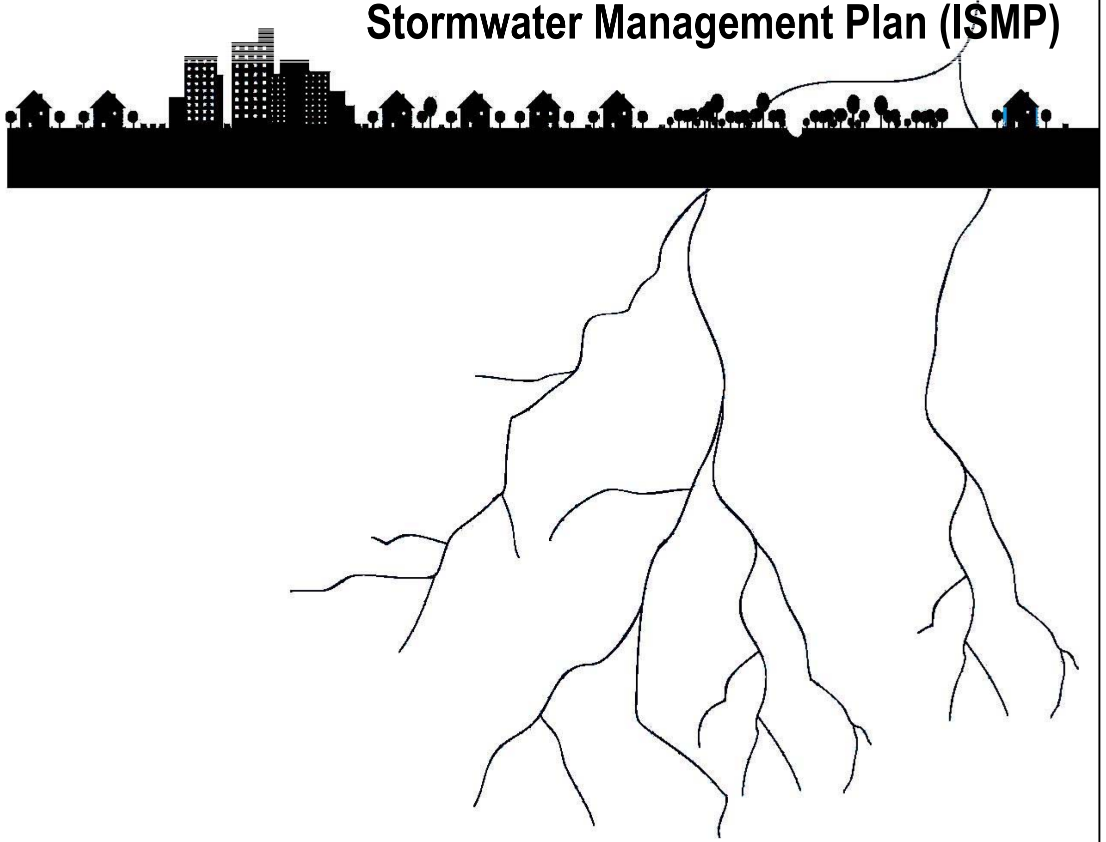
- **Step 5 - Make the details of new design standards readily available -** Create a technical manual of options for on-lot stormwater source control, including details and specifications of design standards, and make it available on-line.

- **Step 6 - Facilitate procurement of materials needed to implement new design standards -** Implement a bulk purchase/re-sale program that makes it easy and affordable for developers to obtain the specialty products needed to implement stormwater source control. Also, provide a cheap source of material for absorbent soils through a local government composting program.

- **Step 7 - Build support through education -** Implement education programs to inform city staff, the development community and the general public about the need for changes in development practices and how to implement them.

In summary, these seven initiatives form the basis for a developing an action plan (see Chapter 9) which provides a framework for removing barriers and reaching the target condition for a watershed over a period of years.

Developing and Implementing an Integrated Stormwater Management Plan (ISMP)



Chapter Nine

9.1 Overview of ISMPs

- Objectives of an ISMP
- Elements of the ISMP Process
- Layered Approach to Developing an ISMP
- ISMP Technical Products
- Political Commitment to the ISMP Process
- Case Study Example: GVRD Template for ISMPs

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- Case Study Example: Brunette Basin Plan and Stoney Creek ISMP

9.3 Step #1: Secure Political Interest and Support

- Framework for ISMP Process
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9.5 Step #3: Develop Objectives and Alternative Scenarios

- Developing a Shared Vision
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- Using Performance Targets to Quantify Watershed Objectives
- Modeling Alternative Scenarios

9.6 Step #4: Collect Meaningful Data and Refine Scenarios

- Be Strategic When Investing In Data Collection
- Data on Soils and Groundwater
- Data on Drainage Facilities
- Data on Fish and their Habitats
- Water Quality Data
- Sources of Data

9.7 Step #5: Evaluate Alternatives and Develop Component Plans

- Habitat Enhancement Plan
- Flood Risk Mitigation Plan
- Land Development Action Plan
- Adding the Dimension of Time

9.8 Step #6: Develop An Implementation Program

- Financial Plan and Implementation Program

9.9 Step #7: Refine Through Adaptive Management

- Defining the Rules of Adaptive Management
- Adaptive Management Roles and Responsibilities
- Types of Monitoring
- The Role of Effectiveness Monitoring
- Managing Drainage from an Ecological Perspective

9.10 Synopsis of the Seven-Step Process for ISMP Development and Implementation

- Build the Vision, Create a Legacy

9.1 Overview of ISMPs

The focus of Part B was on developing integrated solutions at the site level, where the source of stream degradation and flooding problems can be eliminated. The purpose of this chapter is to:

- Show how these site level solutions fit in to a larger watershed context, and are complemented by a range of other watershed protection and flood risk management tools.
- Provide a framework for developing an ISMP. This framework is adapted from a range of BC case study experiences.

In general, an ISMP process must address the following fundamental question:

- How can the ecological values of stream corridors and receiving waters be protected and/or enhanced, and drainage-related problems prevented, while at the same time facilitating land development and/or redevelopment?

Objectives of an ISMP

The objectives of an ISMP will be watershed-specific, but will generally encompass the following:

- **Drainage Objectives** - Alleviate existing and/or potential drainage, erosion, and flooding concerns.
- **Stream Protection Objectives** - Protect and/or restore stream health, including riparian and aquatic habitat.
- **Water Quality Objectives** - Remediate existing and/or potential water quality problems.

The ISMP focus is on the integration of stormwater management and land use planning. An ISMP is an integral component of a local government's land development and growth management strategy because upstream activities (land use change) have downstream consequences (flood risk and environmental risk).

Elements of the ISMP Process

This chapter presents a process for developing an ISMP for a watershed and its constituent drainage catchments. Through this process, watershed stakeholders collectively answer the questions listed below and illustrated as Figure 9-1:

- ***"What do we have?"*** - understanding the watershed issues
- ***"What do we want?"*** - setting achievable performance targets
- ***"How do we get there?"*** - developing an ISMP implementation program

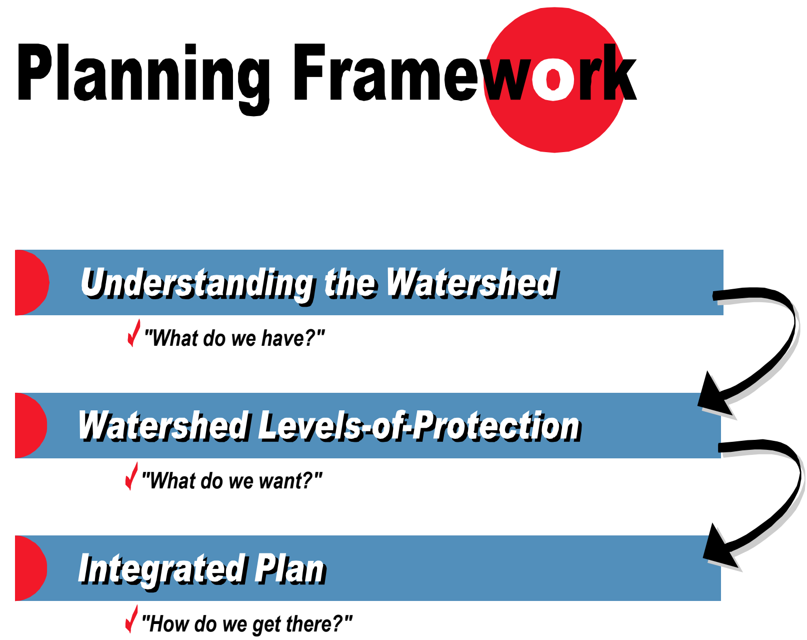


Figure 9-1

Layered Approach to Developing an ISMP

Figure 9-2 conceptualizes the building blocks that are the essence of an integrated approach to stormwater management. It was originally developed to guide an ISMP process for the City of Kelowna.

Figure 9-2 also illustrates how the bridge is built between environmental goals (as defined by community expectations and legislative initiatives) and a stormwater management and stream stewardship strategy (as defined by an ISMP). This involves a layered approach:

- **First Layer** – Identify the stormwater-related objectives for a watershed (e.g. protection of aquatic resources, protection of life and property, protection of water quality). These objectives define what the ISMP is striving to achieve.
- **Second Layer** – Develop strategies to achieve the watershed objectives. This includes setting performance targets to guide selection of site design solutions.
- **Third Layer** – Implement appropriate site design solutions (e.g. source controls) for achieving performance targets that suit local objectives and conditions.

To select appropriate stormwater management strategies and site design solutions, it is first necessary to identify the resources to be protected, the threats to those resources, and the alternative management strategies for resource protection. The foundation for this approach is found in the At-Risk Methodology presented in Chapter 5.

ISMP Technical Products

An ISMP includes three core deliverables or 'technical products' – an inventory, component plans, and an implementation program - as shown in the table part of Figure 9-2. These technical products were introduced in Chapter 4.

The distribution of effort among the three products should be balanced. Often effort is concentrated on the inventory phase, and not enough effort is invested in the elements of an implementation program. The best plan, without a sound implementation program, can result in watershed conditions getting worse with time rather than better.

The remainder of this chapter presents the process for developing and implementing an ISMP for either a watershed or its component drainage catchments.

Political Commitment to the ISMP Process

If site level solutions are to successfully fit into a larger watershed context, political will and commitment are essential inputs at two critical points in the ISMP development process:

- **Launching the ISMP Process** – Unless there is a political buy-in to do things differently, the process will not be effective.
- **Implementing the ISMP Action Plan** - Political will is crucial if there is to be a move from planning to action.

Integrated solutions transcend technical analyses. This chapter discusses how to secure political support and commitment to first develop and then implement an ISMP. Looking ahead, Chapter 11 elaborates on the ingredients for building consensus and creating change.

Community Expectations and Legislative Initiatives

Community expectations and legislative initiatives provide the driving force for political action to launch the ISMP process. Community expectations are reflected in both an Official Community Plan and a Liquid Waste Management Plan. This is the first building block as shown in Figure 9-2.

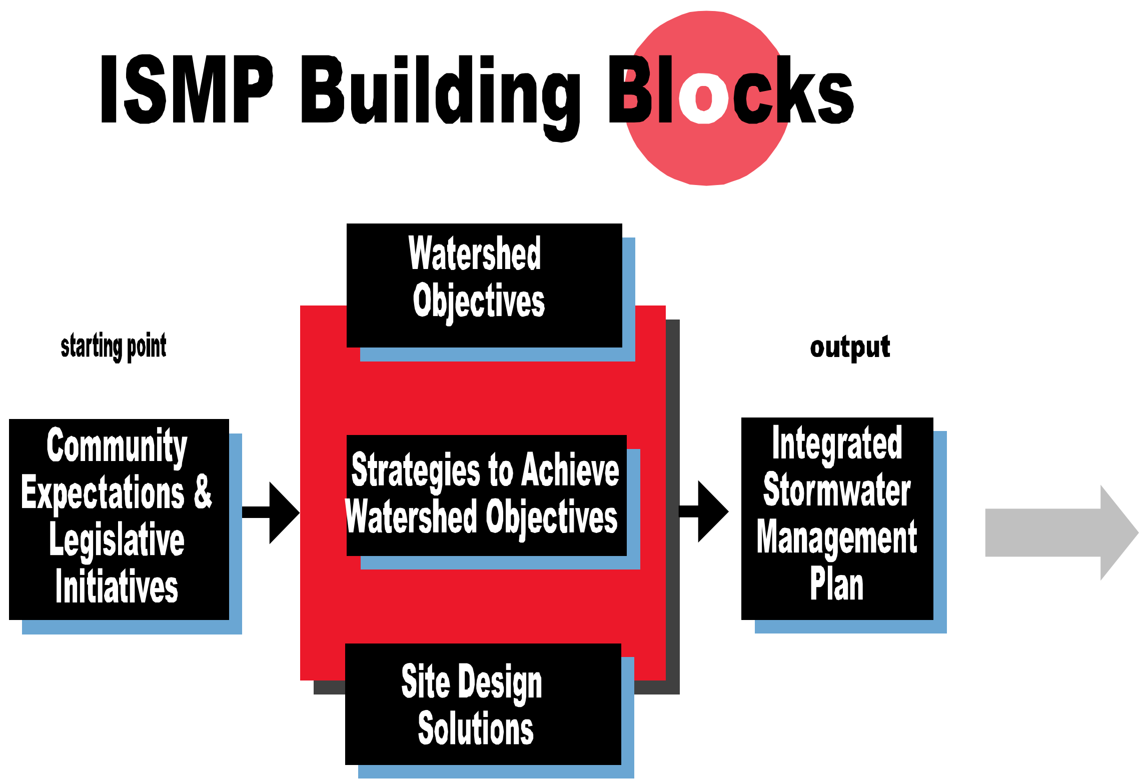


Figure 9-2

ISMP DELIVERABLE	SCOPE OF DELIVERABLE
An inventory of the physical and biological systems	• streams, rivers, and drainage systems • wetlands, ponds and lakes • infiltration areas and aquifers • land use information • flooding and erosion problem areas • water quality problems
Component plans to protect key resources, resolve identified problems, and accommodate development	• plan for integrating appropriate source controls with land development, including a description of any required regulatory changes • plan for improvements to drainage systems and stream reaches • plan for ongoing data collection and monitoring • cost estimates for all planned actions
An implementation program	• administration • projects, phasing and budgets • financing mechanisms • community education • maintenance activities, standards and schedules • performance monitoring

Case Study Example: GVRD Template for ISMPs

The Greater Vancouver Regional District (GVRD) has developed a *Terms of Reference Template for Integrated Stormwater Management Planning* (2002) to provide a standardized process that includes all of the key stormwater components. These are listed in Table 9-1, and are categorized in terms of three disciplines – engineering, planning and environmental. The work effort is organized as four phases:

- Information Gathering (15 tasks)
- Analysis (9 tasks)
- Alternatives (6 tasks)
- ISMP (5 tasks)

A municipality can decide which components are applicable, and establish the level of effort required based on risk and local conditions. Not all of the components may be relevant for a given watershed or drainage catchment.

*Legend of Codes for ISMP Components

E1	=	Engineering item
P	=	Planning item
E2	=	Environmental item
S	=	Stakeholder/Public Process
I	=	Integration of all disciplines

Table 9-1: ISMP Components (from GVRD Template)

		ISMP Component	Code*
Information Gathering	1	Establish Framework	I
	2	Mapping/Information Gathering	I
	△	Stakeholder/Public Notification & Consultation	S
	3	Hydrometric Data Collection	E1
	4	Drainage System Inventory	E1
	5	Hydrogeology/Geotechnical Assessment	E1
	6	Land Use Information	P
	7	Agricultural Lands	P
	8	Recreation Opportunities & Public Access	P
	9	Biophysical Inventory	E2
	10	Riparian Corridor Assessment	E2
	11	Wildlife Assessment	E2
	12	Benthic Community Sampling	E2
	13	Water Quality Analysis	E2
	14	Baseplan Mapping	I
	15	Existing Stormwater Program	I
Analysis	16	Hydrological Analysis (Tool 1)	E1
	17	Hydraulic Analysis (Tool 2)	E1
	18	Channel Erosion	E1
	19	Agricultural-Upland/Lowland Analysis	E1
	20	Natural Hazard Assessment	E1
	21	Land Use Sensitivity Analysis	P
	22	Recreation & Public Access Analysis	P
	23	Environmental Parameters	E2
	24	Ecological Health Analysis (Tool 3)	E2
Alternatives	25	Flood/Erosion Management Alternatives	E1
	26	Land Use Alternatives	P
	27	Stormwater Management Alternatives	E2
	28	Water Quality Alternatives	E2
	29	Evaluate Alternatives	I
	30	Stormwater Program	I
	△	Stakeholder/Public Consultation	S
ISMP	31	ISMP	I
	32	Implementation Strategy	I
	33	Integrate with Other Municipal Master Plans	I
	34	Develop Adaptive Management Program	I
	35	Draft/Final Report	I
	△	Stakeholder/Public Consultation	S

9.2 Process for Developing and Implementing an ISMP

Figure 9-3 illustrates a seven-step process for developing and implementing an ISMP. The objective is to reach the target condition over time. This process is based on a proven approach to decision making for complex issues. This process underpinned the four ISMP case studies introduced in Table 1-1.

The first six steps ultimately lead to implementation of integrated solutions for a watershed. These steps are described in Sections 9.3 to 9.8. Overcoming barriers in order to get from Step #5 to Step #6 is described in the context of moving from planning to action.

In Step #7, the ISMP process is revisited in a greater level of detail to validate and refine the integrated solutions. Step #7 will involve successive cycles of adaptive management over time. This step is discussed in Section 9.9.

Case Study Example: Brunette Basin Plan and the Stoney Creek ISMP

The Stoney Creek ISMP established a British Columbia precedent for application of all steps in the seven-step process to move from planning at the watershed scale to action at the site level. This was a pilot project that was completed in 1999 as part of the GVRD's Brunette Basin Plan (reference: Table 1-1). Success at each level has been accomplished through a working session process that resulted in a shared vision of what is achievable, both in the short-term and over the long-term.

Develop a Shared Watershed Vision

The Brunette River is an inter-municipal waterway that is managed by the Greater Vancouver Region District. It receives runoff from five cities: Vancouver, Burnaby, New Westminster, Coquitlam, and Port Moody.

The Brunette River Basin Plan was developed through an inter-municipal pilot process for consensus-based watershed planning in the Greater Vancouver Region. All five municipalities agreed to the vision, goals and objectives for catchments within the Basin. To determine how to achieve the shared watershed vision, the Stoney Creek catchment was selected as a pilot program for ISMP development.

Selecting an At-Risk Drainage Catchment

Stoney Creek was selected for three reasons: it has the highest value aquatic resources; these resources are at risk due to pending residential development in the Burnaby Mountain headwaters; plus it has an active and proactive streamkeeper group. The Stoney Creek pilot program was also directed by an inter-municipal and inter-agency Steering Committee.

The purpose of the pilot program was to test the principles of a watershed-based approach to integrating stormwater and riparian corridor management. The Stoney Creek process resulted in a philosophy and hydrologic criteria for watershed protection and restoration over a 50-year timeline. By consulting the streamkeeper group and applying their expert knowledge, an aquatic habitat rating was established for each creek reach. The critical reaches drove selection of the plan elements for stormwater management.

Protect the Natural Water Balance at the Site Level

A high-density urban community for 10,000 people is being built at the top of Burnaby Mountain, the headwaters of Stoney Creek, over a 20-year period. Hence, this is where early action has been focused to blend policy, science and site design. The resulting *Burnaby Mountain Watercourse and Stormwater Management Plan* (2002) is a pilot project for stormwater volume reduction at the source. The Plan has been developed under the umbrella of an inter-agency advisory committee. The Plan:

- translates the Stoney Creek vision and hydrologic criteria into performance targets and design criteria that are being applied at the neighbourhood level
- translates the performance targets and criteria into specific stormwater management and site design practices

The performance of the Burnaby Mountain stormwater management system will be monitored as development proceeds. In this way, stormwater management and site design practices can be improved for future development within the Brunette Basin, and elsewhere.

Step	Description and Scope
1	**Secure Political Interest and Support** ❑ Inter-departmental & inter-agency steering committee ❑ Political and public support ❑ Stakeholder focus groups
2	**Frame the Watershed Problems and Opportunities** ❑ Assemble existing information ❑ Identify and prioritize problems (knowledge-based approach)
3	**Develop Objectives and Alternative Scenarios** ❑ Establish desired levels of environmental protection and other objectives ❑ Set appropriate performance targets ❑ Model alternative scenarios for achieving targets
4	**Collect Meaningful Data and Refine Scenarios** ❑ Collect data needed to: ▪ refine scenario models ▪ evaluate effectiveness and affordability ▪ e.g. hydrometric data, soils data
5	**Evaluate Alternatives & Develop ISMP Component Plans** ❑ Land Development Action Plan ❑ Habitat Enhancement Plan ❑ Flood Risk Mitigation Plan
6	**Develop an Implementation Program** ❑ Finance and implement ISMP actions
7	**Refine Through Adaptive Management** ❑ Define adaptive management rules, roles and responsibilities ❑ Constantly improve integrated solutions

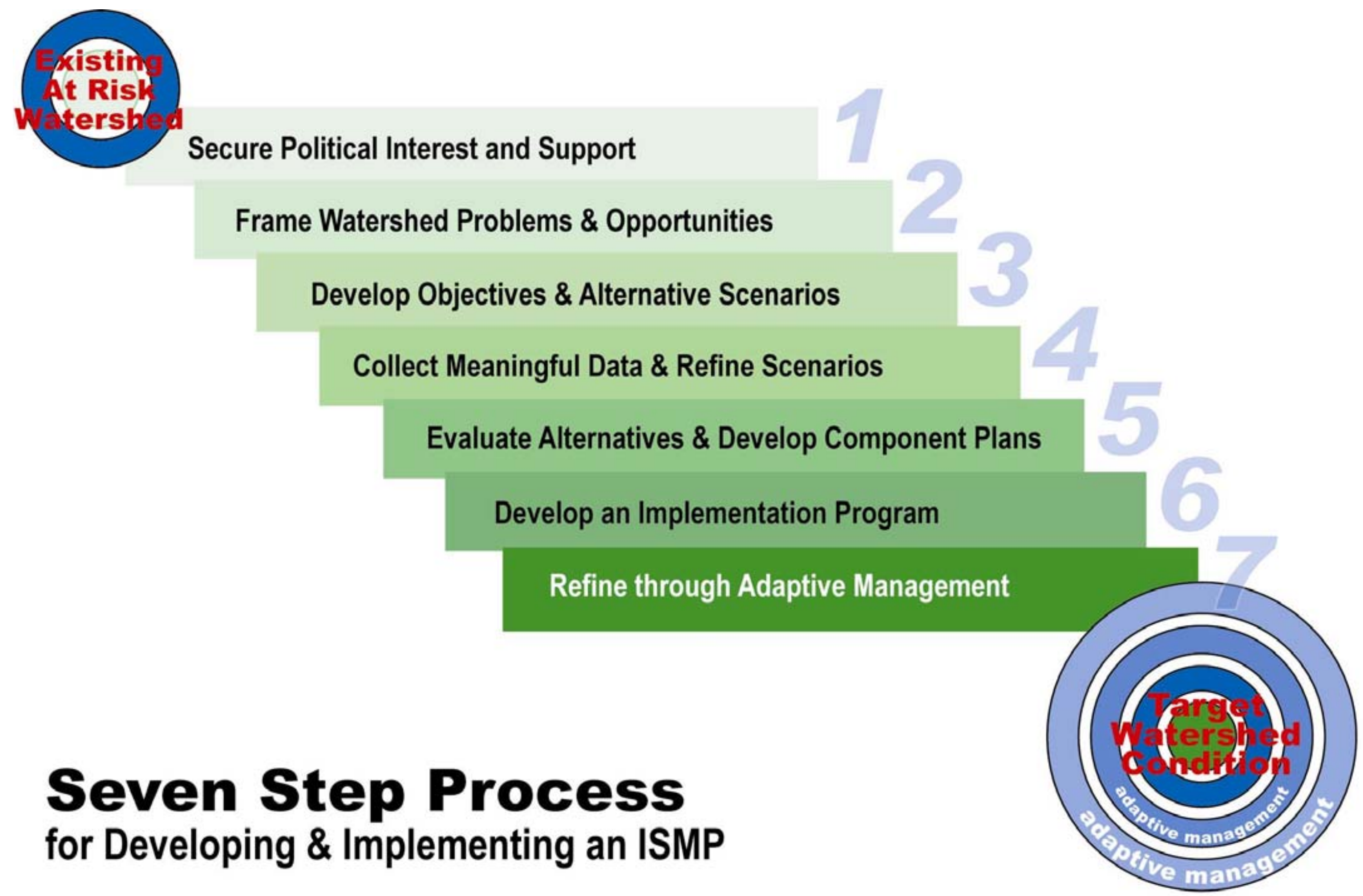


Figure 9-3

9.3 Step #1: Secure Political Interest and Support

An ISMP process starts with a high-level political commitment to protecting property, water quality and aquatic habitat. This policy commitment is made through an over-arching OCP and/or LWMP. Step #1 in the actual ISMP process is to convert high-level policy statements into concrete action so that there will be a flow of funding for the ISMP process.

To accomplish this objective requires a different level of political support, especially when there are multiple watersheds and the financial commitment is multi-year. Without political support for funding, there will be no ISMP process. Once funding is assured, however, a key to a successful outcome is that there be a commitment by all stakeholders to make the ISMP process work.

Framework for ISMP Process

Before elected officials can be expected to commit to a long-term investment in an ISMP process for multiple watersheds, local government managers must be able to provide a clear and convincing case that answers four questions:

- Why do it?
- What will it cost?
- What are the benefits?
- Why should this take priority over other community needs?

These questions are best addressed through front-end development of an over-arching or framework document that:

- Defines a drainage planning philosophy
- Formulates a set of supporting policy statements
- Establishes design criteria to achieve the policies

This approach provides elected officials with an informed basis for making the decision to fund and proceed with the first ISMP (Step #2). The purpose of the over-arching document is to demonstrate to elected officials that there has been stakeholder input, that stakeholders have endorsed the process, and that stakeholder input is reflected in the policy content.

Case Study Example: City of Chilliwack Surface Water Management Manual

The City of Chilliwack has developed a *Policy and Design Criteria Manual for Surface Water Management* (2002) that serves two purposes:

- **At the Watershed Scale -** Provides a comprehensive framework that will guide the development of individual ISMPs over a multi-year period.
- **At the Neighbourhood and Site Scales -** Provides land developers with specific direction in undertaking the stormwater component of sustainable urban design.

The Manual was developed and vetted through an inter-departmental and inter-agency process that also included community participation. It took nine months to complete, and culminated with an interactive session with Chilliwack City Council.

The Manual presents key information that elected officials, City staff, and land developers need in order to understand and implement the City's approach to stormwater management. The Manual includes a five-year Action Plan for removing barriers and undertaking ISMPs.

Case Study Example: Regional District of Nanaimo Action Plan

Chapters 4 and 5 described how the stormwater component of the Regional District of Nanaimo's (RDN) Liquid Waste Management Plan was developed through a roundtable process. This resulted in a five-year Action Plan for gradual phase-in of stormwater management.

At the end of the five-year period, the RDN will have developed a clear understanding of appropriate stormwater management approaches that are customized to the local environment and are acceptable the development community.

The objective of the RDN is to take small steps that build community and political support for undertaking ISMPs. It is proposed that a pilot ISMP be completed in year four.

Time-Frame for Launching an ISMP Process

The RDN timeframe is consistent with the experience of Chilliwack and other communities. It typically takes 3 to 5 years of sustained effort for local government to generate the momentum needed to launch a new program. In part, this reflects the budget cycle. When a need is first identified, it may take a year or two to obtain initial funding. There are often delays in funding subsequent steps in the process.

Communicating Relevant Information to Elected Officials

Securing political approval and commitment to proceed to Step#2 requires that the need for action be communicated in clear and concise terms. Presented below is an example of a single page synopsis of the supporting rationale for a Resolution by Council to adopt an Action Plan that will guide City of Chilliwack staff for the next five-year period.

Case Study Example: City of Chilliwack Staff Report

- **Manage the Complete Spectrum of Rainfall Events –** The City's approach to stormwater management is evolving, from a reactive approach that only dealt with the consequences of extreme events, to one that is proactive in managing all 170 rainfall events that occur in a year. The objective is to control runoff volume so that watersheds behave as though they have less than 10% impervious area.

  Reducing runoff volume at the source – where the rain falls - is the key to protecting property, habitat and water quality.

- **Five-Year Action Plan for Integration of Stormwater Management and Land Use Planning –** In 2000, Council accepted a Process Flowchart and Timeline for moving forward with master drainage planning. The Manual is a milestone in that process. It identifies and organizes the actions required over the next five years to achieve the City's stormwater management objectives.

  Implementation of regulatory change should proceed on a phased-in basis, with ISMPs providing a mechanism to study, test and adapt proposed regulations to suit the range of needs and conditions in Chilliwack.

- **Submission Requirements for Land Development Projects –** To provide clarity and conciseness regarding the City's expectations and requirements for subdivision design, the Manual defines the technical information that land developers must submit to the City in order to obtain development approvals. The Manual also includes Design Guidelines that illustrate how to comply with performance targets for stormwater source control, detention and conveyance.

  Having a comprehensive checklist will help proponents think through the drainage details of project implementation, and will ensure consistency in the way information is presented for review and evaluation by the City.

Leadership and Inter-Departmental Commitment

Leadership is established through the formation of a Steering Committee that has inter-departmental representation. Also, there must be a champion within local government (refer to Chapter 11) to provide the energy and organizational drive needed to move the ISMP process through the various steps.

The integration of disciplines and departmental objectives must be the beginning and foundation of any ISMP. Only then should each discipline focus on its specific analytical skills and tools.

The objective is to benefit from the synergies that result from brainstorming and the sharing of interdisciplinary perspectives. Thus, it is important to create an atmosphere that is conducive to free thinking and open discussion.

Too often the reverse is used where disciplines work independently, and at best integration becomes merely a lateral process or something added at the end to appease stakeholders.

Stakeholder Involvement

Because of the implications for land use planning and aquatic habitat, senior government agencies and other affected stakeholders need to be represented in the ISMP development process. Chapter 11 elaborates on how to involve stakeholders in a Focus Group so that they can contribute to development of integrated solutions.

Looking ahead to Chapter 11, the stakeholder involvement process is described as the second track in a 'Two-Track Approach' because technical analysis feeds into working sessions with the Steering Committee and Focus Group.

9.4 Step #2: Frame the Watershed Problems and Opportunities

Step #2 is critical. This involves application of an interdisciplinary roundtable process (refer back to Chapter 5) to identify and rank the problems and opportunities in a watershed. Sufficient time must be invested at this stage to ensure that there is a clear understanding of the problems to be solved. This understanding will then guide the rest of the ISMP process.

All too often, technical people go directly to Step #4 (Collect Data) without first asking what they are trying to accomplish, and why. As a result, they solve the wrong problem, and then wonder why elected officials and/or the public takes issue with the proposed solution.

Applying a Knowledge-Based Approach

It is important to identify where problems are in relation to areas where future land use change is likely (new development or re-development), because land use change can:

- create or exacerbate stormwater-related problems (e.g. degrade aquatic resources or increase flooding risk)
- present opportunities to restore stream health, improve water quality, or reduce drainage-related problems through the application of source controls

The knowledge-based approach described in Chapter 5 should be applied to determine what the existing and/or potential problems and issues are in a watershed, and the level of concern related to these problems and issues.

Existing knowledge and information about a watershed should be adequate to determine where in the watershed there are general indicators of existing or potential problems, such as:

- flood hazards
- stream channel erosion
- aquatic habitat degradation
- water quality deterioration

The roundtable approach relies on the knowledge of local residents and key experts (from the planning, ecology and engineering disciplines), combined with a local government's existing information on land use, aquatic resources and drainage systems.

Making Use of Available Information

Available information can and should be used to provide a better understanding of the watershed. The following information is useful in helping to define the watershed issues and frame the problems:

- **Watershed Base Map** - the first building block
- **Watershed Issues Summary** - where and what are the identified problems
- **Sensitive Ecosystem Inventory** - what is to be protected
- **Land Use Map** - what are the existing and future generators of runoff
- **Drainage System Inventory** - how the conveyance system functions
- **Concurrent Rainfall and Streamflow Data** - how the watershed responds to rainfall
- **Soils and Groundwater Maps** – where might infiltration be feasible

The foregoing are the core deliverables resulting from Step #2. This set of graphics provides a picture of the watershed. Visual presentation helps develop a common understanding among ISMP participants. Section 9.5 explains why this is so.

All available information should be assembled at this stage to help frame the problems, but further investment in data collection should not be made at this stage. Once watershed objectives and catchment-specific performance targets are established (see Step #3), the investment in data collection can be directed where it will be most useful and effective. Data collection is discussed in depth in Step #4.

Broad-Brush Ranking of Issues

In Step #2, the approach is broad-brush. The objective is to create understanding and an intuitive feel for conditions in the watershed. This will then guide follow-up investigations that achieve greater levels of detail where it is required.

An outcome of Step #2 should be a preliminary ranking of watershed issues. This ranking would reflect a generalized assessment of questions such as: Is flooding the dominant concern? Or is it aquatic habitat degradation? Is water quality a real or perceived problem? Where can existing and/or potential problems be turned into opportunities?

Case Study Examples: Creating a Picture of Stream Habitat Conditions

The evolving science of stormwater management has broadened the traditional engineering approach to one that integrates flooding and aquatic habitat concerns. Whereas flooding and erosion problems are normally obvious to all, habitat concerns can be subtle in nature. Hence, assessing aquatic habitat at an overview level is a key part of framing the problems in a watershed. This helps to focus subsequent effort.

The Bear Creek and Stoney Creek case studies introduced in Table 1-1 resulted in development of a five-task process for creating a reach-by-reach picture of aquatic habitat conditions. This process applies the knowledge-based approach described in Chapter 5, and goes to another layer of detail in assessing conditions reach-by-reach. The desired outcome is a mapping tool that serves two purposes - planning and communication.

- **Task #1 - Develop an Ecosystem Overview:** Review all existing biophysical information for stream corridors.
- **Task #2 – Identify and Fill Critical Data Gaps:** Fill any critical information gaps with a reconnaissance inspection of specific locations or reaches.
- **Task #3 – Create a Planning Tool:** Prepare an overview map of the stream that identifies spawning and rearing habitat and highlights aquatic habitat concerns related to readily apparent sedimentation and erosion, barriers to fish movement and point sources of pollution.
- **Task #4 - Prioritize Ecosystem Values:** Convene a workshop for individuals with practical, hands-on experience in the watershed to refine the stream map and build consensus on stream corridor and/or aquatic habitat values and threats.
- **Task #5 - Integrate Ecosystem Values:** Analyze and integrate the habitat and fisheries constraints with the engineering requirements and a land use map that breaks the stream into reaches for stormwater planning.

Task #4 is pivotal as it provides the foundation for the habitat component of an ISMP. To build local government commitment and secure financial support for habitat protection and/or enhancement initiatives, it is first necessary to demonstrate what is to be protected, and why.

9.5 Step #3: Develop Objectives and Alternative Scenarios

Step #3 involves further application of the interdisciplinary roundtable process to:

- determine which problems and/or opportunities are priorities for action
- establish objectives for dealing with these priority problems/opportunities
- develop alternative scenarios for achieving the objectives

Developing a common understanding among participants in the ISMP process is key to developing a shared vision of what is desirable, practical and achievable.

Developing a Shared Vision

People typically learn best in one of three ways: either by seeing, by hearing or by doing. Hence, it is important to use a variety of communication techniques to ensure clarity of understanding. Looking ahead, Chapter 11 elaborates on this topic. In general, a common understanding is achieved in a workshop setting by:

- illustrating concepts through the use of graphics
- guiding individuals to blend concepts with their own experience

The graphic presented on Figure 9-4 translates scientific findings on the impacts of land use change into a decision making tool for stormwater goals and objectives. It illustrates the consequences for stream corridor ecology of various attitudes towards stormwater management.

Figure 9-4 was at the heart of the stakeholder visioning process for all four ISMP case studies introduced in Table 1-1. Participants were provided with clear visual choices regarding a desired ISMP outcome.

To reach consensus on a shared vision of what is desirable and achievable for watershed protection, ISMP participants need a picture of what a stream corridor could and/or should look like. Figure 9-4 fulfils this need. The visioning process boils down to whether or not a stream corridor will have a functioning aquatic ecosystem.

ALTERNATIVE VISIONS FOR THE LONG-TERM ENVIRONMENTAL HEALTH OF STREAM CORRIDORS

Conceptual Framwork for Selection of ISMP Level

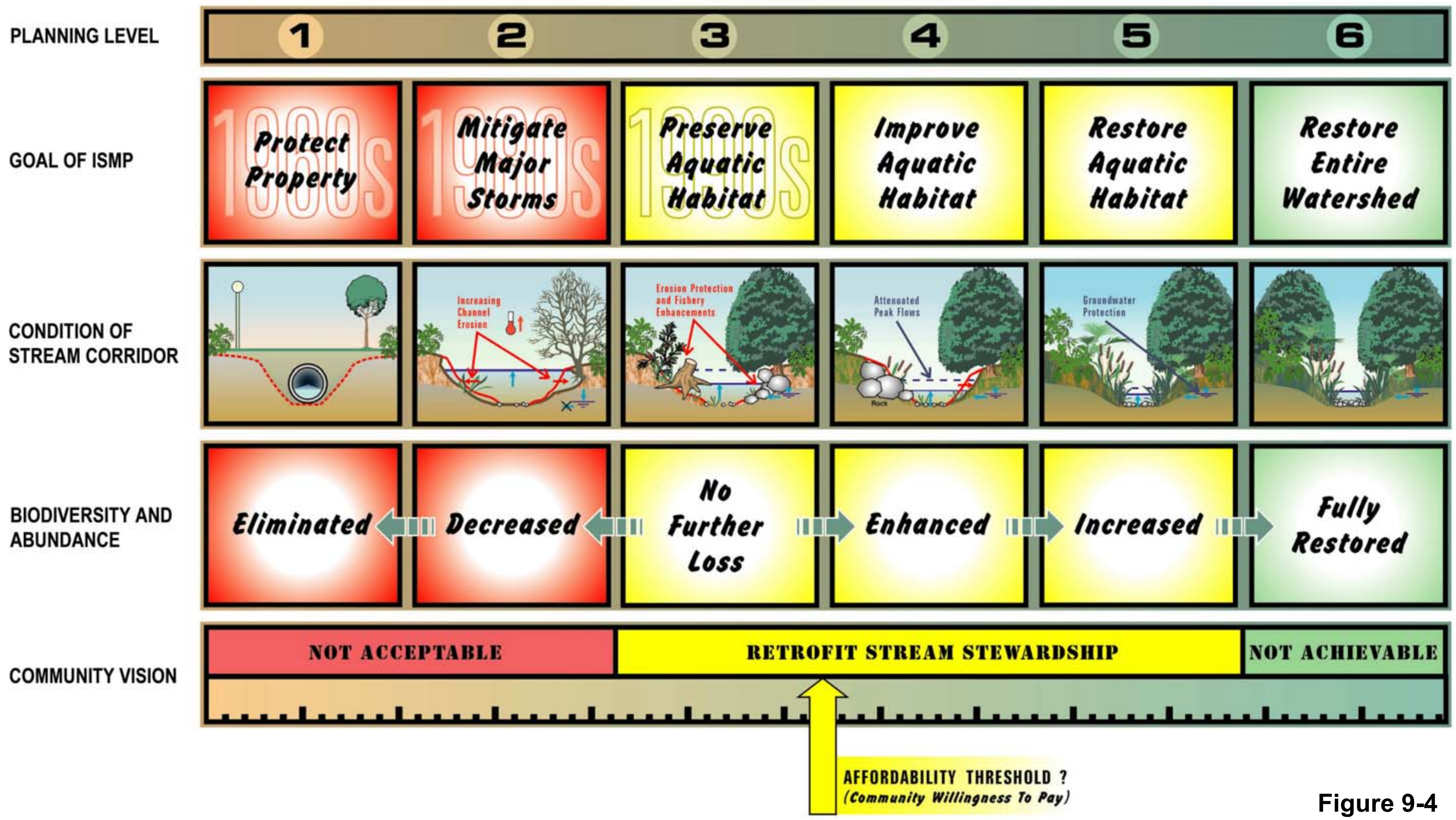


Figure 9-4

Identify Alternatives and Make Choices

Figure 9-4 captures the evolution of drainage planning philosophy over the decades for watersheds that include some prior development. It provides a framework for defining strategic objectives and identifying management practices for achieving those objectives.

Figure 9-4 provides a starting point for an interdisciplinary roundtable to make choices and agree on a guiding philosophy for integrated stormwater management for specific watersheds. It can also be employed to assess whether technical solutions are environmentally and politically acceptable. The choices can be considered to lie on a spectrum of:

(Allow to) Worsen ←------------"Hold the Line" ---------------------→ Improve

The process of determining an appropriate shared vision balances what is desired (or ideal) with what is technically feasible, affordable and politically palatable.

Integration of Aquatic Habitat Condition Assessment

The results of the five-task aquatic habitat condition assessment in Step #2 provide both a frame of reference and a starting point for scenario development in Step #3. The reach-by-reach picture enables ISMP participants to ask two questions:

- Where are we now?
- Where do we wish to be in future?

In general, priority effort should generally be directed where the best habitat is threatened by pending or potential land use change.

Starting Point for an Action Plan

For developed watersheds, Level 3 (from Figure 9-4) would be the likely starting point for an action plan, with the objective of moving from left to right over time (i.e. to improve conditions).

For an undeveloped watershed, the starting point would likely be Level 5, with the objective of 'holding the line' to preserve and protect existing habitat values in the short term, with restoration of aquatic habitat over the long term.

Case Study Example: Scenarios for Stoney Creek ISMP

Based on Figure 9-4, the alternative watershed visions listed below were defined for Stoney Creek:

- **SCENARIO A - Status Quo Strategy for Stream Management (Level 2)**

  Maintain the status quo for local government decision making around development practices. Existing regulations and procedures would continue, and habitat values would continue their present downward trend.

- **SCENARIO B - Hold the Line and Accommodate Growth Strategy for Stream Management (Level 3)**

  Sustain existing environmental conditions as development and re-development proceeds, with associated additional program requirements and financial costs.

- **SCENARIO C - Enhance Aquatic Conditions and Accommodate Growth Strategy for Stream Management (Level 4)**

  Enhance existing aquatic environmental conditions, but at substantial additional cost for regional facilities and increased requirements for on-site facilities to manage stormwater from new development and redevelopment.

The application of these scenarios to make decisions is discussed next. These scenarios provided the basis for Resolutions by all three City Councils that embraced Scenario B as the 20-year vision, and Scenario C as the 50-year vision.

Case Study Example: Evaluate Scenarios and Make Choices

Table 9-2 is the Stoney Creek example of how to apply a decision making matrix for evaluating alternative scenarios. The decision criteria are the management objectives. To decide which level of environmental protection is preferred, the decision maker must determine how well each scenario achieves each objective and balance the trade-offs and conflicts.

With the matrix, each criterion can be considered for each scenario and the results can be visualized, compared and recorded. In a workshop setting, roundtable participants can evaluate and discuss each alternative and select a preferred approach.

Because data are often limited, and in view of the complexities of dealing with natural systems, each decision maker has to rely in part on his/her own informed, professional judgement to evaluate the alternatives.

Adding the Dimension of Time

Change takes time. What is not achievable in the next five years may be quite achievable over fifty years. Integration of stormwater management with land use planning involves a timeline. General time-related objectives can be defined as follows:

- **20-Year Vision (Preservation)** – Develop policies and implement demonstration projects that show how to succeed in achieving stream preservation (i.e. 'hold the line'), thereby building support for the 50-year vision to improve watershed and stream conditions.
- **50-Year Vision (Improvement)** – Continue to implement changes in land use and regulation that mitigate changes in hydrology at the source (i.e. improve conditions), thereby enabling watershed protection/restoration and lasting stream improvement.

Ongoing monitoring and assessment of progress towards a long-term vision will improve the understanding of how to blend policy, science and site design to achieve the shared vision for property, water quality and habitat protection. Building on initial successes, local governments may well decide to advance the schedule and strive for improvement within the 20-year horizon.

Table 9-2 Decision Criteria to Select Strategies for Stream Management

OBJECTIVES OR DECISION CRITERIA		IMPORTANCE?❶	HOW WELL DOES EACH SCENARIO ACHIEVE EACH OBJECTIVE?❷		
			SCENARIO A (LEVEL 2)	SCENARIO B (LEVEL 3)	SCENARIO C (LEVEL 4)
As Established by the Brunette Basin Task Group			STATUS QUO, CONTINUED DECLINES IN FISH	HOLD THE LINE, SUSTAIN TROUT AND HATCHERY SALMON	ENHANCE HABITAT, SUSTAIN WILD SALMON
1.	Protect or enhance biodiversity	very important	low	medium	high
2.	Protect or enhance aquatic habitat*	very important	low	medium	high
3.	Protect or enhance terrestrial habitat	moderate importance	low	medium	high
4.	Enhance recreation opportunities	moderate importance	low	medium	high
5.	Minimize health and safety impacts	very important	high	high	high
6.	Minimize total costs	very important	high (no change in existing costs)	medium (increased costs)	low (high cost)
7.	Minimize property damage	very important	medium	high	high
8.	Increase scientific and management understanding	least important	medium	high	high
9.	Increase opportunity for public learning	least important	medium	high	high

❶ Three judgmental choices are provided for rating each objective: very important, moderate importance, and least important.
❷ Three judgmental choices are provided for rating each scenario: low, medium and high.

Using Performance Targets to Quantify Watershed Objectives

Performance targets provide a quantifiable way of measuring success in protecting (or restoring) a watershed, and for identifying what needs to be done to achieve a given environmental protection objective.

- Desired protection objectives for significant stream reaches should be translated into performance targets for the catchments draining into those reaches. For example, to maintain or restore the health of a stream reach, an appropriate performance target would be to limit the volume of runoff from land uses in the drainage catchment to 10% or less of total rainfall volume.
- For catchments upstream of drainage 'hot spots' (e.g. chronic flooding locations), a more appropriate performance target may be to reduce peak runoff rates from large rainfall events (e.g. 5-year storms).
- Other performance targets relating to the preservation/restoration of significant natural features (e.g. riparian forests, wetlands), measurement of stream health (e.g. B-IBI), protection/improvement of water quality, or instream enhancements (e.g. for habitat or fish passage) should also be established.

A key principle is to establish performance targets that relate directly to the watershed objectives. Refer back to Chapter 6 for further guidance on setting performance targets.

The selected targets should also be monitored over time to ensure that the ISMP is achieving the desired results. Refer to Section 9.9 for more detail on this topic.

Setting Performance Targets

To establish realistic performance targets for a given watershed, an ISMP must answer questions such as those introduced in Chapter 6 and reiterated below:

- What is the existing level of annual runoff volume? What percentage of total annual rainfall volume does it represent? What is the existing Mean Annual Flood (MAF)?
- What are acceptable levels of runoff volume and rate in terms of flood risk and environmental risk? What are the consequences of increased or decreased flows related to land development? Are these consequences acceptable?
- What actions are needed to avoid flooding or environmental consequences?
- How can the necessary actions be staged over time?
- Are the targets to maintain 10% runoff volume and maintain the natural MAF necessary or achievable over time? If not, what levels are?

Modeling Alternative Scenarios

Scenario modeling can be used to assess a range of performance targets, and evaluate options for achieving these targets.

Scenario modeling involves consideration of the complete spectrum of rainfall events that typically occur in a year. (Refer back to Chapter 6 for further details regarding the three tiers.) An integrated approach to managing these events comprises three components:

- retain the small events (Tier A) at the source,
- detain the large events (Tier B) in detention facilities
- safely convey the extreme events (Tier C)

Relationship of Rainfall Spectrum to Watershed Objectives

The balance between the above three components depends on the watershed objectives.

- Stream protection/restoration objectives would likely govern scenarios that emphasize source control (e.g. infiltration, rainwater re-use), along with other possible options, such as riparian corridor protection.
- Flood management objectives would likely govern scenarios that place more emphasis on detention and conveyance.

The key is to determine which scenario or blend of scenarios has the best 'fit' to address a range of watershed objectives.

A key aspect of scenario development will be to consider what can be done at the site level to retain the small events, given constraints such as soil conditions, hydrogeology, topography and land use. Further data collection may be required to assess the feasibility of achieving performance targets (see Step #4).

Modeling Hierarchy

A computer model is a decision support tool. A model can help evaluate alternative scenarios, but it does not make decisions. Sometimes there is a tendency to over-emphasize the value of modeling. The reliability of model output depends on the quality of the input data, and especially on the judgement of the modeler in making critical assumptions.

A fundamental principle is that the level and/or detail of modeling should reflect the information needed by decision makers to make an informed decision. The modeler must always take a step back and ask three key questions:

1. Why is the model being built?
2. How will the model be applied?
3. What problems will the model help us solve?

Figure 9-5 illustrates the four main levels (or applications) of drainage modeling. Moving down the pyramid reflects an increasing level of detail, and hence investment of resources.

At this stage of the ISMP process, modeling should be at a strategic (i.e. conceptual or overview) level to provide basic information to support the decision making process.

Modeling tools take on added importance once the focus shifts to the functional planning and design of proposed stormwater management facilities. More data is required at this level of modeling.

Data Requirements for Strategic Level Scenario Modeling

Continuous rainfall data (in time increments of one hour or less) is the key data requirement for scenario modeling. Ideally, site-specific rainfall data should be used, but even data from a location with similar rainfall characteristics can be used at this stage.

At this strategic level of modeling, the other model inputs (e.g. regarding land use and soil conditions) should be estimated based on the best available information (assembled in Step #2). Where there is high degree of uncertainty regarding certain parameters, a range of assumptions may be tested, and data collection efforts can then be targeted to refine these assumptions (see Step #4).

The appropriate type of modeling will depend on the characteristics of the scenarios being modeled, as discussed on the following page.

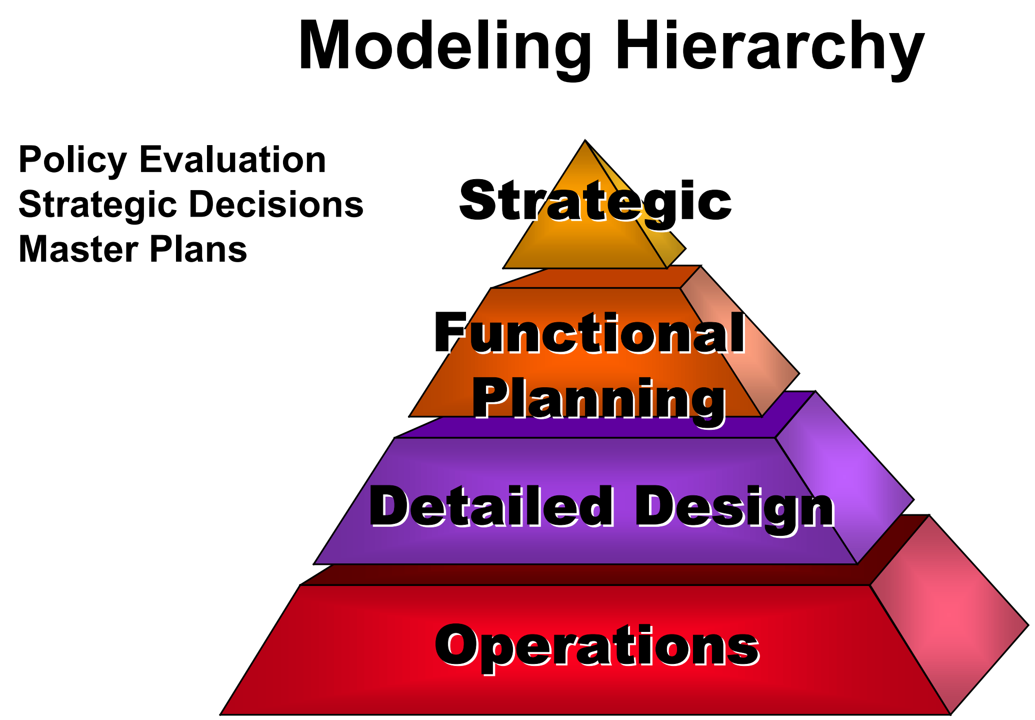


Figure 9-5

Types of Modeling: Single Event versus Continuous Simulation

There are two types of modeling: 'single event' and 'continuous simulation'. Single event typically means a storm duration up to 24 hours. Continuous simulation typically covers a year or a multi-year period, with time-steps up to 1 hour. Their respective applications are summarized as follows:

- **Single Event Modeling –** acceptable for most applications of Tier C flood risk management
- **Continuous Simulation Modeling –** required for Tier A rainfall capture, Tier B runoff control, and some applications of Tier C flood risk management

For both types of modeling, measured rainfall data (rather than artificial 'design storms') should be used as input data. Refer back to Chapter 6 for further discussion on the three rainfall tiers.

Continuous Simulation for Source Control (Tier A) and Detention (Tier B)

The distinction between Tier A and Tier B modeling is that Tier A requires volume-based thinking, whereas Tier B involves flow-based thinking. Conventional modeling packages are flow-based, and thus most appropriate for modeling detention (Tier B) and conveyance (Tier C) scenarios.

Models may be hydrologic (i.e. simulate runoff response), hydraulic (i.e. perform flow routing functions), or both. A selection of flow-based models is provided below for reference purposes. The appropriate model type depends on the scenario being modeled.

Model Name	Does it have Continuous Simulation Capabilities?	Is it a Hydrologic and/or Hydraulic Model?
HEC-1	No	Hydrologic
HEC-RAS	No	Hydraulic
HYDSYS	No	Both
OTTHYMO	No	Hydrologic
QUALHYMO	Yes	Hydrologic
HSPF	Yes	Hydrologic
SWMM	Yes	Both
MOUSE	Yes	Both

Note that the level of effort and amount data required to apply these models is highly variable. Some of these models require a high level effort, which may not be suitable for scenario modeling applications at the strategic level. The GVRD ISMP Template provides further details on these models.

Because Tier A simulation is volume-based, it is described as Water Balance modeling (refer back to Chapter 7 for further details). Since the focus of stormwater source control is on runoff volume reduction, Water Balance Modeling is most appropriate for source control scenarios. The Water Balance Model (WBM) is an example application (refer back to Chapter 7 for details).

Source Control Scenario Modeling

Whereas the use of conveyance and detention are relatively well understood stormwater management strategies, the use of source control is less well-known. Discussion among ISMP participants is likely to focus on whether source controls are effective or practical in the context of watershed-specific conditions.

Generating source control scenarios through Water Balance modeling can be a critical tool in informing this discussion (refer back to both Chapters 7 and 8).

Model scenarios can provide guidance for selecting source control options to achieve catchment-specific performance targets. Further data collection should focus on collecting the information needed to determine whether these options are achievable (see Step #4). For example, if infiltration is identified as an option for achieving performance targets in a particular drainage catchment, a key information need would be to determine soil conditions in that catchment.

Flood Management Scenario Modeling

The primary purpose of modeling for flood management purposes (i.e. Tier C) is to assess the conveyance capacity of drainage facilities installed at stream crossings. The level of preciseness in quantifying design flows is not critical because rated capacity is not the governing consideration.

Physical adequacy normally governs the acceptability of a drainage installation (refer back to Chapter 6). Hence, the real purpose in comparing design flows to rated capacities is to provide a relative measure of the degree of risk. This comparison helps elected officials make decisions to invest in drainage facility upgrades and/or replacement.

For certain flood management scenarios, continuous simulation modeling would be more appropriate. For example, continuous simulation would be needed to provide an idea of the extent and duration of flooding over an extended period of time under different detention and/or flow conveyance scenarios.

9.6 Step #4: Collect Meaningful Data and Refine Scenarios

Step #4 is to collect the additional data that may be needed to evaluate the effectiveness, feasibility and affordability of implementing the scenarios identified in Step #3 for meeting watershed objectives.

This step may involve collecting site-specific data to refine the assumptions of the scenario models generated in Step #3 (e.g. site-specific data on soils or drainage system components).

Be Strategic When Investing in Data Collection

The level and/or detail of data collection should reflect the information needed by the decision maker to make an informed decision. This principle is framed by these three questions:

- Why do we need the data?
- How will the data be applied?
- What problems will the data help us solve?

The impacts of changes in land use are generally understood. At this point, the investment in data collection needs to be strategic. We know that restoring the natural Water Balance and hydrology is required to address the source of stormwater-related problems. Data collection should focus on improving understanding of how to do so in the context of local conditions.

Before investing in data collection, there needs to be a clear understanding of the methodology to ensure that data collection is done right. Consistency and rigour are important to allow the data to be used as a baseline for comparison with future data.

Concurrent Rainfall and Streamflow Data

Having reliable rainfall and streamflow data is the key to a performance-based approach to ISMP development, implementation and effectiveness monitoring.

The minimum requirements are a streamflow station at the drainage outlet of watersheds or catchments of concern, and a strategically located rainfall station.

Concurrent and continuous records of rainfall and streamflow data provide a picture of the characteristic rainfall-runoff response of a neighbourhood, a drainage catchment or a watershed. Having a picture creates understanding. Understanding is required for two conditions in particular:

- 'rainfall-runoff response' during wet weather periods
- 'runoff decline' during dry weather periods

The latter is key to baseflow analysis. Baseflow availability is likely to be the limiting factor for fish survival in small streams during dry weather periods.

Rainfall and streamflow data play a key role in an adaptive management program (see Step #7 and also refer back to Chapter 6). Monitoring the change in rainfall-runoff response as land development progresses in a catchment will indicate the effectiveness of site design solutions.

Concurrent rainfall and streamflow data is also needed to calibrate and verify computer models. This is key to refining the scenarios developed in Step #3.

Streamflow Data from Undeveloped Catchments

Monitoring streamflow in undeveloped catchments (i.e. under natural conditions) provides valuable information because it defines the target hydrograph. The key objective for the design and operation of stormwater systems is to replicate this target hydrograph as closely as possible in catchments where development is occurring.

Streamflow data from undeveloped catchments also provide the best basis for establishing release rates for detention facilities (refer back to Chapter 6). Monitoring also provides a baseline for evaluating any future changes in hydrology due to development in these catchments.

Data on Soils and Groundwater

Soil and groundwater conditions govern the feasibility and affordability of using infiltration facilities to meet catchment-specific performance targets for runoff volume or rate reduction.

If not already available, soils information should be collected in catchments where infiltration is identified as an option for achieving stream protection and/or flood management objectives. This will enable a more detailed assessment of what is actually achievable in these catchments.

It is also important to collect basic groundwater information to identify areas where the groundwater table is very high, since infiltration is not likely feasible in these areas.

Refer back to Chapters 6 for details regarding the importance of soils information in setting catchment-specific performance targets. Refer back to Chapter 7 for details on the relationship between soils and infiltration performance.

Data on Drainage Facilities

Scenario modeling may identify flood management concerns relating to certain drainage system components. Data collection should then focus on characterizing these critical drainage system components and evaluating the effectiveness of improvement options.

For example, if the conveyance capacity of a particular culvert installation is identified as a high risk flooding location, data collection may focus on determining the effectiveness of options for improving physical and/or hydraulic acceptability of that culvert.

Data on Fish and their Habitats

Where watershed objectives focus on the protection and/or restoration of fish and their habitats, there may be a need to collect additional data to define the value of these resources and evaluate options for their protection or restoration.

For example, if restoration of a critical stream reach is established as an objective, detailed surveys of this reach would likely be required to evaluate restoration options.

Water Quality Data

If surface water or groundwater pollution is identified as a key issue in a catchment, there may be a need to collect water quality data in order to provide a better understanding of the types and sources of pollution. This would become important for evaluating options to manage the sources of water quality problems.

For example, high nutrient loading in watercourses may indicate the need to manage runoff quality from upstream agricultural areas.

Monitoring turbidity (and correlating with TSS) can provide a good indicator of changes in water quality and watercourse erosion rates over time. This can play an important role in evaluating the effectiveness of integrated solutions that are implemented in a watershed (refer back to Chapter 6).

Also, performance targets can be established based on total suspended solids (TSS) loading, using natural loading rates as a baseline. Note that TSS targets are closely related to runoff volume targets (increase in runoff volume is the primary cause of watercourse erosion).

Sources of Data

Data can typically be obtained by contacting the federal and provincial agencies listed below:

- Rainfall – from the Atmospheric Environment Service (Environment Canada)
- Streamflow – either from the Water Survey of Canada (Environment Canada) or the provincial Ministry of Water, Land and Air Protection (MWLAP)
- Species and Habitats of Concern – either from Fisheries and Oceans Canada or the Environmental Stewardship Division of MWALP
- Water Quality - from the Environmental Protection Division of MWALP

9.7 Step #5: Evaluate Alternatives and Develop Component Plans

Once watershed objectives have been established, alternative scenarios for achieving those objectives have been generated, and the data needed to evaluate the effectiveness of these scenarios has been collected, the next step is to evaluate the alternatives and make decisions.

These decisions will provide the basis for developing plans for habitat enhancement, flood risk mitigation and relevant land development actions. These are all related components of an ISMP, as shown in Figure 9-6. These component plans are described in this section.

The fourth component is a financial and implementation program (see Step #6), which is essential for moving from planning to action.

Habitat Enhancement Plan

The Habitat Enhancement Plan should identify:

- key wetlands or sensitive ecosystem areas needing protection
- riparian setback objectives
- schematic alignment for creek relocations, with corresponding riparian restoration and land requirements
- streamside and instream complexing features to be incorporated
- location and description of barriers to fish passage, and prescriptions to remove barriers where advisable

A companion report would provide cost estimates, land acquisition costs, logical phasing and logistics of the planned habitat improvements. It should outline a monitoring and maintenance program that addresses jurisdiction and ownership of stream corridors, and requirements for agency approvals.

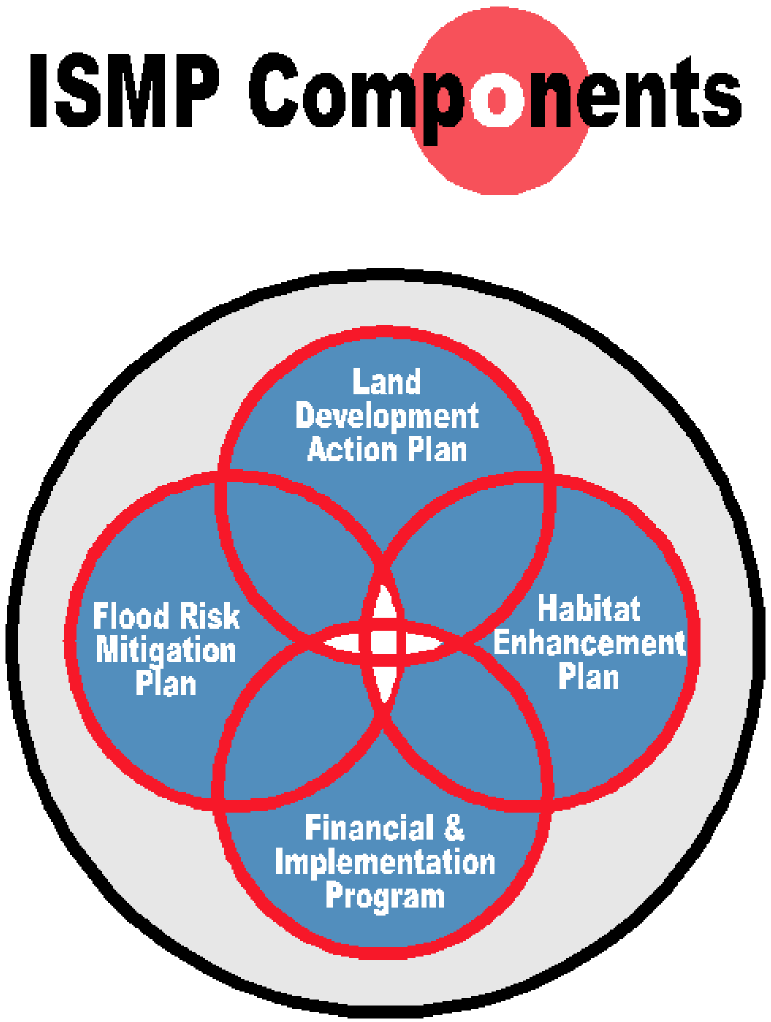


Figure 9-6

Flood Risk Mitigation Plan

The Flood Risk Mitigation Plan should identify:

- required stormwater storage facilities
- proposed split between storage budgets in community detention facilities and private developments
- type and distribution of stormwater infiltration and storage facilities
- flow paths for major events
- piped sections, or high-flow pipe diversion works
- conceptual cross-sections of major stream diversions

A companion report would provide a description of the elements and cost estimates for land acquisition and capital works, suitable for use in development cost charge (DCC) bylaws and capital works plans.

Land Development Action Plan

A Land Development Action Plan should illustrate the relationship between the proposed habitat enhancement and flood mitigation works and existing and proposed land use in the watershed. Recommended changes to land use designations should be highlighted for consideration in Neighbourhood Plans and the Official Community Plan.

Location and routing of flood control works, stream relocations and riparian leave strips should be developed within a strategy for land acquisition or regulatory protection. The Land Development Action Plan should show the location of required lands and outline a strategy to achieve their protection over the long-term.

The Land Development Action Plan should also identify the distribution of stormwater source control use in the watershed. Some source controls may be targeted to only part of the watershed (e.g. infiltration only in certain soil conditions). Other source controls may vary in application by zoning (e.g. green roofs only on commercial or multiple family buildings).

Adding the Dimension of Time

Changes take time. What is not achievable over the next five years may be quite achievable over a twenty-year or fifty-year timeline. Action plans to integrate stormwater management with land use planning should be framed in terms of long-term visions and time-related objectives (e.g. what do we want to achieve over the next 5, 20 and 50 years). Refer back to Section 9.5 for further discussion of planning horizons.

9.8 Step #6: Develop an Implementation Program

Step #6 is essential for moving from planning to action, yet many planning processes never get to this step. Without an implementation program and financial plan, watershed objectives will not be achieved.

Financial Plan and Implementation Program

The purpose of an ISMP is to identify the risks, what needs to be done to manage the risks, who should be responsible, and lay out a general timeline for implementation.

The Financial Plan and Implementation Program should therefore outline how the land acquisition and capital financing of the elements can be achieved. Tools might include negotiations during zoning changes, land exchange, density bonuses, adjustment of existing DCCs or other means. Strategies will be specific to the properties in question.

In addition to capital financing, the regulatory framework is another component of implementation to be used in balance with public awareness and capital works programs.

There many questions related to regulatory change that must be resolved, including:

- What is the role of various regulatory tools (e.g. zoning negotiations, development permits for protection of the natural environmental, ecosystems and biodiversity, tree protection bylaws, watercourse protection bylaws, engineering standards and specifications)?
- How can regulatory tools work together, without overlap or excessive red tape?

Chapter 11 provides guidance regarding the types of regulatory changes that may be needed to achieve stormwater management objectives.

Recommended Bylaw Approach

A key objective of the ISMP process is to create a recommended bylaw approach. This would define the bylaw that each stormwater source control or policy is to be implemented through, and the relationship between bylaws. The product would be a point form outline of each proposed bylaw change. The outline should be relatively specific, and should address:

- Enabling legislation
- Principles behind the bylaw change
- Key bylaw requirements
- Key definitions needed
- Key illustrations or engineering details needed
- Key filter and exemption clauses
- Key application information requirements
- Enforcement options

This product should provide clear direction for subsequent work by separate assignment to write and provide legal review of the actual bylaw changes. Land use regulation should reflect a pragmatic approach that is based on these guiding principles:

- **Principle #1 -** Recognize the body of existing local bylaws, and identify how they can be adapted to suit new objectives.
- **Principle #2 -** Create the simplest possible regulatory system. Watch out for overlap or conflicting bylaws. Try to reduce the number of permits required.
- **Principle #3 -** Understand that bylaws will only succeed if the solid majority of the public supports them.

The last principle underscores the importance of public awareness programs that provide the public and the development community with the information they need in order to decide whether to support new regulations.

9.9 Step #7: Refine Through Adaptive Management

Step #7 is key to resolving stakeholder uncertainty associated with changes in standard practice. This objective is achieved through an adaptive management framework as illustrated by Figure 9-7. This will be ongoing through time.

Monitoring and evaluating the performance of demonstration projects will provide confidence in new approaches. It will also provide the basis for optimizing stormwater system design to reduce costs while still achieving defined goals for protecting downstream property, aquatic habitat and receiving water quality (refer back to Chapter 6).

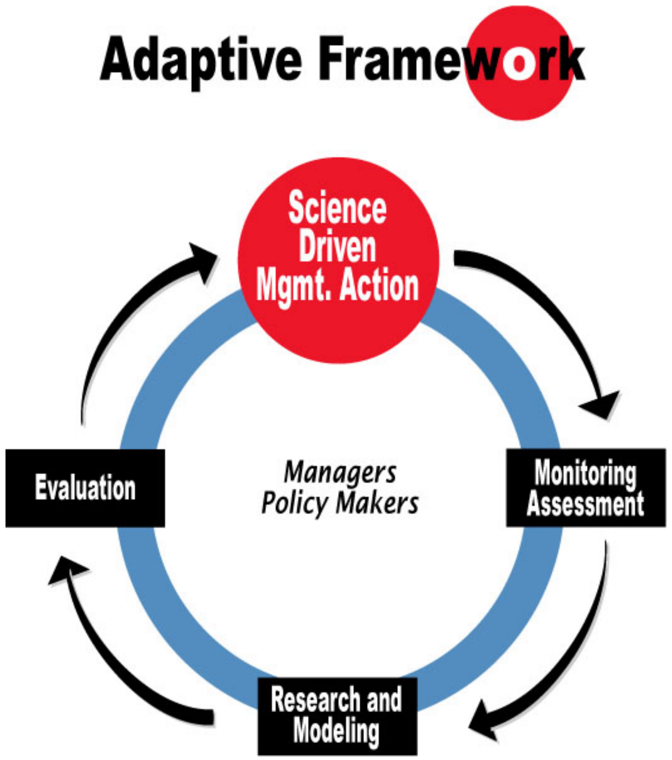


Figure 9-7

Defining the Rules of Adaptive Management

An ISMP implementation plan must define:

- **Early Actions** - the integrated stormwater management solutions to be implemented in priority (at-risk) catchments
- **Rules of Adaptive Management** – a clear set of rules that define monitoring requirements and consequences to allow for improving integrated solutions over time

Build and Maintain Trust

In order to build and maintain trust between local governments, landowners, developers and senior government agencies, the following questions must be answered at the plan development stage:

- What needs to be monitored?
- How will monitoring results:

  a) define better stormwater management and development practices?

  b) lead to changes in development standards and regulations?

The adaptive management framework presented in Chapter 6 provides a starting point for establishing a set of rules that answer the above questions. This must be a collaborative process, so that the rules are understood and supported by all stakeholders.

Desired Outcomes

A clearly understood and widely supported set of adaptive management rules will:

- Enable landowners and developers to make long-term land use and investment decisions with more confidence.
- Provide senior government agencies with regulatory certainty as new approaches are tested and refined.
- Ensure that the investments of local governments (both staff and financial resources) will lead to constant improvement.

Adaptive Management Roles and Responsibilities

An implementation plan must clearly define who is responsible for monitoring what, and establish regular intervals (e.g. every year) for working sessions to review monitoring results. These working sessions are critical to the ongoing process of change, because this is where decisions will be made regarding what to change and how these changes will be made.

Local governments may need to take the lead in implementing and monitoring the initial demonstration projects (e.g. on public works projects). Local government leadership is important for demonstrating to developers, landowners and senior government regulators that proposed actions at the site level are both effective and affordable. This will build support for regulatory changes that enable or require these site level actions.

Stewardship groups also have a role to play in monitoring the catchment and watershed scale effectiveness of new land development practices.

Types of Monitoring

The following types of monitoring should all be included in a comprehensive adaptive management program.

- **Effectiveness Monitoring** – Determines the extent to which the completed actions have achieved the management objectives (for example, monitor the volume and frequency of overflow from an on-site facility and compare with the performance targets).
- **Compliance Monitoring** – Identifies whether or not the implementing parties have completed the actions they agreed to complete in the planning phase (for example, confirm that developers are incorporating properly sized on-site storage and infiltration facilities).
- **Validation Monitoring –** Measures the extent to which completion of the objectives (actions) has been successful at achieving the goal (for example, monitor annual watershed runoff volume and compare with the performance target established for runoff volume reduction).

Effectiveness monitoring is the key to learning from experience and constantly improving land development and stormwater management practices.

The Role of Effectiveness Monitoring

Chapter 6 included a discussion on performance monitoring in the section about optimization of stormwater system design. Chapter 6 also introduced the need for performance monitoring at different scales. This section elaborates on that discussion.

Proper assessment of the effectiveness of site design practices in a watershed context requires monitoring at three scales:

- **Site Level - Monitor Volume and Frequency of Overflow from Individual Facilities**

  The performance of individual rainfall capture and runoff control facilities must be monitored to determine if targets for runoff volume reduction and rate control are being met.

- **Neighbourhood Level - Monitor the Change in Rainfall-Runoff Response from Development Areas**

  It is important to monitor flow at the drainage outlet (e.g. outfall to a stream) of a development area serving an integrated network of rainfall capture and runoff control facilities. This will enable an assessment of how well this integrated system achieves the performance target for volume reduction.

- **Catchment Level - Monitor Early Warning Indicators of Stream Health**

  It is important to determine how well actions at the site level are maintaining or restoring a healthy catchment. This can be accomplished by monitoring the following indicators:

  - Water Balance - streamflow at the downstream end of the catchment
  - Water quality - turbidity and total suspended solids (TSS)
  - Biophysical - Benthic Index of Biological Integrity (B-IBI)

Managing Drainage from an Ecological Perspective

This section elaborates on indicators that can be used to provide a warning system regarding the impacts of human actions on the environmental health of stream corridors so that corrective action can be taken when they are required.

The governing consideration is that indicators accurately represent the environmental state of both the surface drainage function and the ecological function of the receiving waters.

Elements of an Integrated Program for Monitoring Stream Health

In recent years stormwater managers have recognized the need for a stream health monitoring program that is sensitive to changes in hydrology and habitat. The need arose because traditional chemical and physical monitoring did not produce the type of information needed to understand the overall environmental health of a stream corridor and manage drainage from an ecological perspective.

A comprehensive approach combines simplified chemical and physical monitoring with annual monitoring of physical changes to habitat and a biological index of benthic organisms.

An *Integrated Monitoring Program* would comprise ambient biological monitoring, continuous rainfall and streamflow recording, some chemical and habitat measurements, and possible microbiological monitoring to allow the identification of fecal coliform sources.

Description of Ambient Monitoring

A baseline ambient monitoring program would comprise Benthic Index of Biological Integrity (B-IBI) scores at selected sites, plus concurrent field measurements of conductivity and temperature, plus physical measurements of stream and habitat elements.

For chemical parameters, conductivity has the best correlation with urban impacts. Also, it can be measured inexpensively in the field. TSS and zinc also have good correlation, but provide little additional information over that provided by conductivity alone.

9.10 Synopsis of the Seven-Step Process for ISMP Development and Implementation

Table 9-3 provides a synopsis of the seven-step process. For each step the scope, desired outcome, and deliverables are summarized. The overall aim of this process is to achieve healthier urban watersheds over time.

Build the Vision, Create a Legacy

A shared long-term vision is needed to focus the effort that will create a legacy. This vision provides a context for all planning, data collection, sensitivity analyses, capital expenditures and regulatory changes. Prioritizing goals and actions (ideally through consensus) provides a road map for moving towards a target condition by identifying:

- the interconnected nature of goals, values and expectations
- risks and opportunities
- what needs to be done to manage the risks and achieve the opportunities
- who should be responsible
- a general timeline for implementation

This framework addresses the goal of identifying options to change the way that land is developed and re-developed, so that people, property and natural systems can be better protected and over time, infrastructure can be managed more efficiently and watersheds can become healthier.

Table 9-3 Synopsis of the Seven-Step Process for ISMP Development and Implementation

Step	Scope	Outcome	Deliverable
1	Secure Political Interest and Support	❑ Define a guiding philosophy ❑ Formulate supporting policies ❑ Establish design criteria to achieve policies	❑ Document 1 - Policy and Design Criteria Manual
2	Frame the Watershed Problems and Opportunities (Apply the Knowledge-Based Approach) ❑ Land Use Working Session ❑ Drainage Working Session ❑ Ecology Working Session ❑ Interdisciplinary Roundtable Session	❑ Identify resources to be protected ❑ Establish an order of priority for plan development at the sub-watershed scale	❑ Document 2 – Understanding the Watershed • Watershed Base Map • Watershed Issues Summary • Sensitive Ecosystem Inventory • Land Use Map • Drainage System Inventory • Soils and Groundwater Map
3	Develop Objectives and Alternative Scenarios ❑ Flood Management Scenario Modeling ❑ Source Control Scenario Modeling	❑ Identify inadequate drainage facilities ❑ Establish a customized performance target for each sub-watershed	❑ Document 3 – Results of Flood Management Scenario Modeling ❑ Document 4 – Results of Source Control Scenario Modeling
4	Collect Meaningful Data and Refine Scenarios ❑ Concurrent Rainfall and Streamflow Data ❑ Data on Soils and Groundwater ❑ Water Quality Data ❑ Data on Fish and Their Habitats	❑ Identify gaps ❑ Supplement existing programs	❑ Document 5 – Data Collection Framework
5	Evaluate Alternatives and Develop Component Plans	❑ Make decisions	❑ Document 6 – Flood Risk Mitigation Plan ❑ Document 7 – Habitat Enhancement Plan ❑ Document 8 – Land Development Action Plan
6	Develop an Implementation Program	❑ Consolidate supporting documents ❑ Develop financial plan ❑ Create a recommended bylaw approach	❑ Document 9 - Implementation Report
7	Refine Through Adaptive Management	❑ Establish rules of adaptive management ❑ Implement comprehensive monitoring program	❑ Document 10 - Performance Evaluation Plan

Funding an Integrated Stormwater Management Plan (ISMP)

Chapter Ten

10.1 Framing the Question

- Taxpayer Willingness to Pay
- Taxpayer Ability to Pay

10.2 Making Choices

- Dealing with Complexity
- Measuring Risk

10.3 Who Pays?

- Division of Responsibility
- Cost Sharing Between Developers and Local Government
- Supporting Innovation and Leadership
- Responsibility for Operation and Maintenance

10.4 Sources of Funding

- Overview

10.5 Setting up a Stormwater Utility

- Legislative Authority
- Scope of a Utility
- Benefits of a Utility
- Revenue and Billing

10.6 Regional Approach

- Cross-Jurisdictional Funding of Watershed Action Plans
- Other British Columbia Experience

10.1 Framing the Question

In developing and funding a stormwater program, local governments are faced with the challenge of balancing risks of flooding and environmental degradation against community willingness to pay. This chapter provides strategies to address this challenge.

Since the primary source of revenue for local government is property taxes, stormwater program budgets will be largely governed by taxpayer 'willingness to pay' and taxpayer 'ability to pay'. Since local governments always face competing priorities, a thorough consideration of risks and consequences becomes critical when establishing spending priorities.

A related issue is due diligence; once a risk is identified, local government has a responsibility and an obligation to address that risk. As introduced in Chapter 1, an Integrated Stormwater Management Plan (ISMP) provides a framework for addressing risk and moving towards a target condition by identifying:

- the risks
- what needs to be done to manage the risks
- who should be responsible
- a general timeline for implementation

Taxpayer Willingness to Pay

Willingness to pay is refers to the level of increase in taxation rate that taxpayers are prepared to accept in order to pay for a particular service, in this case, stormwater planning and management. Willingness to pay will be governed by taxpayers' understanding of what is at risk. Local governments must be proactive in explaining the potential consequences (both in terms of flooding and property damage and habitat and species loss) of delaying or avoiding implementation of stormwater plans, to ensure that taxpayer willingness to pay is balanced against risk.

Taxpayer Ability to Pay

Willingness to pay is linked directly to ability to pay. Hence, it is important to understand the cost implications of what it means to embrace a stream stewardship philosophy. Fundamental questions that will need to be answered when building public understanding and support for a funding plan are:

- What level of aquatic resource protection is achievable and sustainable, and which elements of stream stewardship are applicable?
- What is the local government liability and financial exposure in accepting senior government directives for protection/enhancement of aquatic habitat?
- Will the societal benefits justify the costs incurred? (i.e. is there a payback?)

Addressing these questions upfront will enable a local government to judge what level of stream stewardship is achievable and sustainable at an affordable cost.

10.2 Making Choices

The extent of a stormwater funding program will be influenced by willingness to pay, level of protection versus expenditures, ability to raise revenue, and level of investment versus risk reduction.

Potential sources of revenue for local government are explained in the next section. These sources include general revenue, development cost charges (DCCs), specified area charges, stormwater utilities and senior government grants.

Dealing with Complexity

Two distinct core concepts that must be integrated in any stormwater funding program are summarized below:

- **Expenditures versus Revenue -** There is a cost to taxpayers to construct facilities that protect property and sustain the natural environment. As local government takes on more responsibility, funding must be provided to fulfil the commitments that have been made. This is a comparatively straightforward relationship to quantify.
- **Willingness to Pay versus Environmental Consequences -** The less the public is willing to invest in property and habitat protection, the greater the likelihood that problems will worsen. Conversely, more investment should improve the situation, provided the investment is strategic and addresses the sources of problems. This is a much more complex relationship to quantify because it involves value judgements.

Both components implicitly provide local government with flexibility to match willingness to pay to an affordable level of protection. The third dimension is time, as discussed in Chapter 9. Thinking in terms of a long-term time horizon provides the opportunity to achieve cumulative net benefits over time.

Measuring Risk

The less that the public is willing to pay, the higher the risk there will be of adverse environmental consequences. This is a concept that local governments are only just beginning to consider. Deciding not to invest in stormwater management does not necessarily equate to cost savings, since there is a cost associated with the status quo if it means watershed conditions will deteriorate. Deteriorating watershed conditions result in flood damage and channel stabilization costs, as well as habitat loss and water quality impairment.

Underlying the issue of risk is the question of liability and due diligence. For example, if a local government knows that either the status quo or inaction will result in consequences that can be foreseen, they can be held legally liable for those consequences. On the other hand, if a local government demonstrates due diligence in developing a plan to forestall those consequences, this should normally relieve the liability. It then becomes a matter of matching the timing of plan implementation to ability to pay.

10.3 Who Pays?

The tiered approach is one of the cornerstones of this Guidebook. It provides a logical and appropriate basis for assigning responsibilities and determining who pays for what.

Division of Responsibility

Table 10-1 suggests a division of responsibility (i.e. who pays) for implementing the three stormwater management 'tiers' - retain, detain and convey. The issue of who should pay for stormwater management is directly related to the following question:

- Are stormwater-related problems (habitat degradation, flooding) the result of past development, future development, or some combination?

For new development in an undisturbed watershed or catchment, the land developer would be expected to bear the cost for managing the complete spectrum of rainfall events. For urban retrofit scenarios where there are existing problems (degraded habitat, flooding) as a result of past development, local governments (i.e. existing landowners and taxpayers) would typically be expected to bear much of the cost. In most situations some level of cost sharing between developers and local governments will be appropriate.

For Table 10-1 to be applicable to a regional district, the regional district would first have to apply for drainage authority.

Cost Sharing Between Developers and Local Government

Regardless of the initial land use in a particular catchment, new development or re-development projects should be responsible for managing Tier A events using rainfall capture strategies on private property. The responsibility for new developments should also include designing roads in new subdivisions to be self-mitigating (i.e. provide rainfall capture *and* runoff control) for Tier A events.

Local government would clearly be responsible for retrofitting existing roads as part of a long-term watershed or drainage catchment restoration strategy.

New developments and local government should each contribute a proportionate share of the cost for providing runoff control for Tier B events and flood risk management for Tier C events, depending on the relative impacts of existing and future development.

Table 10-1 Who Pays for Stormwater Management Infrastructure?

Component of Integrated Strategy for Managing the Complete Rainfall Spectrum	Land Development Scenario		
	New subdivision within a mainly undeveloped catchment	New subdivision within a partially developed catchment	Re-development within a fully developed catchment
Rainfall Capture for the small Tier A Events (on-lot retention)	developers/ landowners	developers/ landowners	developers/ landowners
Rainfall Capture for the small Tier A Events (on-street retention)	developers	developers for roads within subdivision local government for existing roads	local government (i.e. municipalities)
Runoff Control for the large Tier B Events (detention)	developers*	cost sharing between developers and local government on an area basis*	local government* (i.e. municipalities)
Flood Risk Management for Tier C Events (contain and convey)	developers	cost sharing between developers and local government (i.e. municipalities)	local government (i.e. municipalities)

* Runoff control targets can either be met by providing larger rainfall capture facilities (Tier A) or by providing community detention facilities.

For re-development scenarios this choice can have implications for who pays. The more on-lot storage that developers/landowners provide, the less local government funded community storage will be required.

Supporting Innovation and Leadership

Innovation and leadership is being provided at the local government level. But moving towards a new standard practice for suburban design requires a considerable investment of staff time and financial resources to successfully implement and monitor demonstration projects.

During the transition period, it seems reasonable to suggest that senior governments should support innovation and leadership by funding demonstration projects. This is the most effective way for senior governments to limit the risk and liability associated with being innovative. The lessons learned will benefit all local governments. Therefore, it seems reasonable that the leaders be supported in their efforts to implement change.

Responsibility for Operation and Maintenance

Table 10-2 parallels the previous table and summarizes who is responsible for operating and maintaining each tier of stormwater infrastructure.

Under the present system, subdivision developers are responsible for infrastructure integrity for a set period of time (typically one year) before a municipality formally takes possession of the completed works. Property owners have responsibility for maintenance of any drainage works that are located on private property.

During the transition period to a new standard practice, local governments have the option to extend the performance monitoring period for rainfall capture and runoff control facilities, for example, from one year to three years. A precedent is the Burnaby Mountain sustainable community that is being built by Simon Fraser University.

Table 10-2 Who Operates and Maintains Stormwater Management Infrastructure?

Component of Integrated Strategy for Managing the Complete Rainfall Spectrum	Land Development Scenario		
	New subdivision within a mainly undeveloped catchment	New subdivision within a partially developed catchment	Re-development within a fully developed catchment
Rainfall Capture for the small Tier A Events (on-lot retention)	property owners	property owners	property owners
Rainfall Capture for the small Tier A Events (on-street retention)	local government (i.e. municipalities)	local government (i.e. municipalities)	local government (i.e. municipalities)
Runoff Control for the large Tier B Events (detention)	local government (i.e. municipalities)	local government (i.e. municipalities)	local government (i.e. municipalities)
Flood Risk Management for Tier C Events (contain and convey)	local government (i.e. municipalities)	local government (i.e. municipalities)	local government (i.e. municipalities)

10.4 Sources of Funding

Five sources of funding that are potentially available to municipalities to pay for implementation of ISMPs are listed as follows:

- General Revenue – from all taxpayers
- Development Cost Charges – from land developers
- Specified Area Charge – from local neighbourhoods
- Stormwater Utility – from all property owners
- Senior Governments – via grant programs

Regional districts are limited in their ability to raise money. Funding must be tied to a specific function that is delegated by the municipalities; that function can only be assigned by referendum.

Overview

From a funding perspective, the focus of local government is on how to pay for runoff control for Tier B events and flood risk management for Tier C events. This applies mainly to a scenario where municipalities must finance the retrofitting of a catchment with detention and conveyance facilities. This also applies to the maintenance of infrastructure that a municipality inherits in new subdivisions.

Each of the potential sources of stormwater funding is described briefly below. Of the five possibilities, a stormwater utility offers the best long-term option for stability and continuity. Hence, a detailed discussion of utilities is provided in the next section.

General Revenue

This refers to a local government's annual budget, which is derived from property taxes. Historically, this is how drainage projects were funded. In many municipalities, this is still the funding source for drainage programs. Implementing a major capital program can therefore have a measurable and noticeable impact on property taxes. Furthermore, drainage then becomes one of a number of competing priorities for Councils to balance. Unless there is a demonstrated threat to life and property, it can be difficult to gain the necessary political support to proceed with major capital programs.

Development Cost Charges

Development cost charges (DCCs) were introduced by the Provincial Government in the 1970s to ensure that new development paid its fair share of the off-site costs required to service the development. In the case of drainage, it may be many years before a municipality collects sufficient money from individual developers to enable a project to proceed. Hence, a watercourse may be subjected to the cumulative adverse effects of erosion and sedimentation.

Specified Area Charge

Local governments have the option to create Specified Areas for the purpose of recovering the cost of providing a specific service. An example would be a *Local Initiatives Program* for road and drainage improvements.

Stormwater Utility

The purpose of any local utility is to provide a self-sustaining source of revenue to fund implementation of capital and maintenance programs over a multi-year period. BC municipalities have historically had both water and sanitary utilities. Funding is raised through a user fee.

Although stormwater utilities are often discussed in BC, there has been a lack of will at the local government level to implement them. In recent years, however, several municipalities (notably the cities of Surrey and North Vancouver) have broadened the scope of their sanitary sewer utilities to encompass drainage. This has enabled those municipalities to proceed with major capital projects.

Washington State municipalities, including Bellingham and Bellevue, have adopted stormwater utilities. The Bellevue utility was one of the first such utilities in North America.

Senior Governments

Historically, senior governments have not provided funding for drainage in BC, other than the Fraser River dyking program and flood disaster response programs. The Federal Government's newly created *Green Municipal Enabling Fund* is the first opportunity for some local governments to access funding for stormwater management in the suburban regions.

10. 5 Setting Up a Stormwater Utility

A stormwater (or drainage) utility may be defined as a self-liquidating entity that has a focused purpose for stable and dedicated funding for surface water quantity and quality management, operations and maintenance, rehabilitation and enhancements.

The information presented in this section is included courtesy of the District of Maple Ridge. It is adapted from a staff presentation to Council in 2001.

Legislative Authority

A stormwater utility is permitted under the following sections of the *Local Government Act*:

- Section 363.(1) – A Council may, by bylaw, impose a fee or charge payable in respect of full or part of a service of the municipality
- Section 517.(1) – Subject to the specific limitations and conditions established by or under this *Act*, a municipality may operate any service that the Council considers necessary or desirable for all or part of the municipality
- Section 518.(1) – A bylaw under this Part may (a) establish different classes of persons, places, activities or things, and (b) make different provisions for different classes and for different areas of the municipality

Scope of a Utility

Stormwater utilities typically include a network of pipes, streams, ponds and lakes for detention and water quality control. The utility is set up to address both:

- the built stormwater system – pipes, pump stations, outfalls
- the natural stormwater system – creeks and streams

Its purposes are primarily flood protection, erosion control and environmental protection.

Addressing Public Concerns

Public concerns that a utility would typically address include:

- flooding
- water pollution
- property damage
- stream erosion
- habitat impacts
- wetland acquisition
- stormwater detention

Utility Focus

Typical programs for a stormwater utility include:

- water quality control, including education
- operations and maintenance
- development regulation
- capital improvements

Objectives and Services

Stormwater quality protection objectives may include:

- water quality for safety and enjoyment of residents
- preservation of aquatic and wildlife habitat

Particular services a utility may provide include:

- 24-hour emergency response for flooding and hazardous spills
- residential and other built connections to the utility's drainage system
- erosion control
- operation and maintenance of drainage systems
- flood warning systems
- water quality and environmental monitoring

Financing Principles

Financing principles for utilities include:

- user fees (and demand management)
- charge based on benefits or cost of service

The total revenue is derived from utility rates/fees as well as DCCs.

Benefits of a Stormwater Utility

Benefits fall into two categories: environmental and functional.

The environmental benefits are:

- habitat protection
- habitat rehabilitation
- ecological enhancement

The functional benefits include:

- stable and dedicated funding for long-term initiatives and public goals
- equitable distribution of costs to users
- ability to finance and implement innovative technologies and solutions
- ability to upgrade systems and eliminate deficiencies
- long-term strategic planning for sustainability and flexibility

Challenges for a Utility

In setting up a utility, challenges that need to be overcome include:

- perception of 'inflexible' funds
- perception of another tax
- not eligible for Home Owners Grant
- service may not always be transparent
- user ability to pay

Determining the Purpose

In forming a utility, a major consideration is deciding its purpose(s). The choices include:

- flood control
- water quality protection and pollution prevention
- natural stream and water body management
- erosion and sedimentation control
- combined sewers for sanitary and storm drainage

Revenue and Billing

Deciding on the utility purpose(s) leads to revenue and billing considerations:

- Initial revenue requirements –
  - Which programs are to be undertaken first and which will be phased in?
  - Where will the working capital for starting up the utility come from?

- Billing structure and mechanism –
  - What are the classifications or rates?
  - Can the existing billing system accommodate this?

Timing and Rates

Questions related to implementation that must be addressed include:

- Timing – It usually takes two to three years to start up a utility – what is the long-term financial plan for the utility?
- Initial rates – What is the appropriate level, and phase in?

Stormwater Utility Rates

Examples of annual stormwater utility rates include: City of Surrey ($55+); City of Bellevue, Washington State ($130+), and Snohomish County, Washington State ($30+).

10.6 Regional Approach

Local government has responsibility for land use decisions. Local government is also responsible for protection of property. Because it is better positioned to protect the environment, local government is now being called on to play a primary role in aquatic habitat protection, restoration and management. During this period of transition, however, there is uncertainty as to what this change means, and who pays. BC can learn from the Washington State experience.

Cross-Jurisdictional Funding of Watershed Action Plans

Watercourses cross local government boundaries. This raises a host of inter-jurisdictional issues. Commencing in 1994, the thirty-nine cities in King County, Washington State, have been attempting to address watershed management issues (flooding, fish habitat and water quality) through Inter-Local Agreements. Notable accomplishments to date include:

- trust has been built incrementally
- Watershed Forums have been created
- Regional Funding Principles have been adopted (1997)
- policy guidelines have been defined for a co-operative approach

Lessons that can be learned from the King County experience are distilled as follows:

- need regional decision-making for investments
- need regional funding
- need multi-level forums

While a voluntary approach in King County has been successful at developing consensus and community priorities, it has failed to deliver:

- regional funding
- certainty - due to the governance issue
- ability to do new regional projects

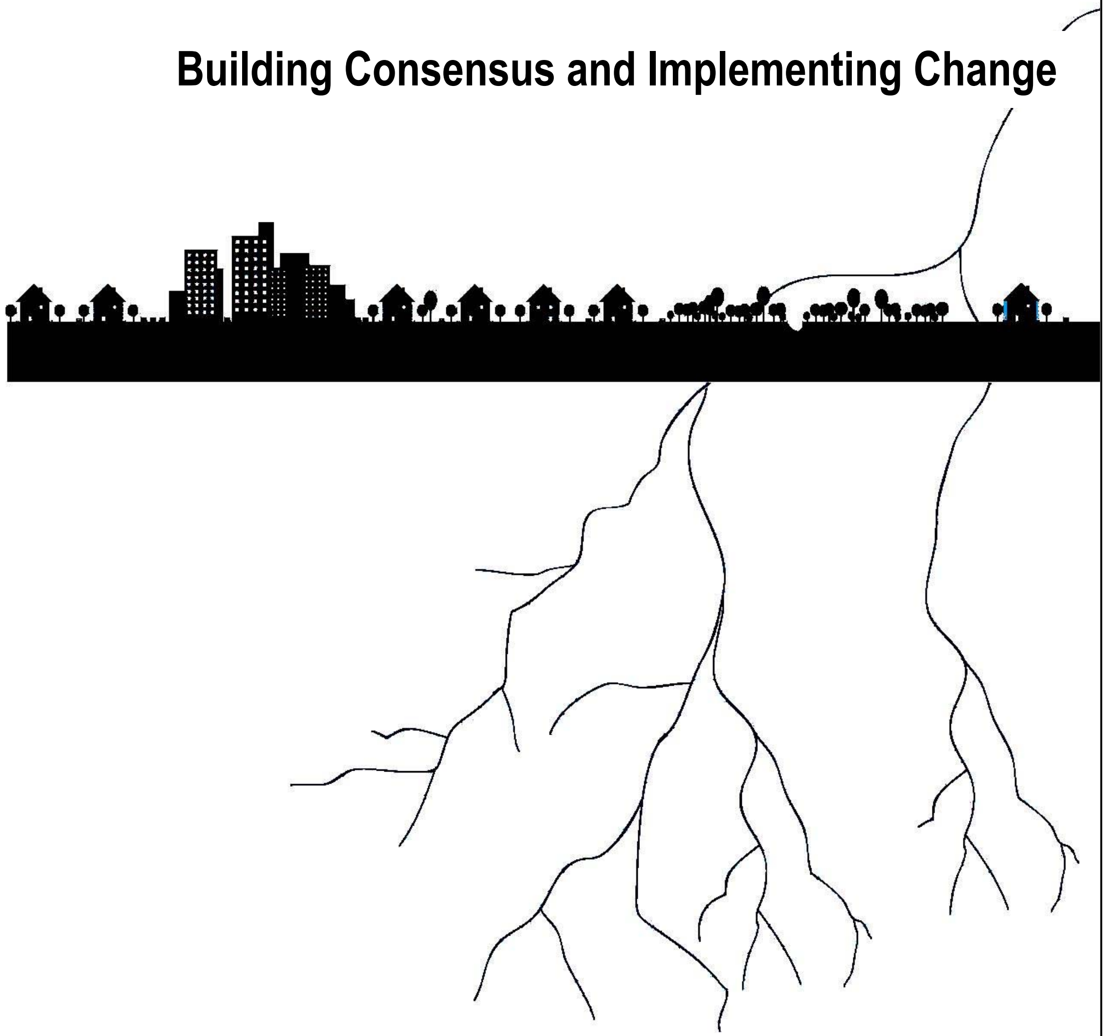
Based on the King County experience, ensuring success at the watershed scale means there must be an over-arching decision authority in place plus senior government funding.

Other British Columbia Experience

Three regional districts (Greater Vancouver, Capital Region, and Nanaimo) have developed or are in the process of developing regional approaches to ensure consistency in municipal stormwater management strategies. These are a component of Liquid Waste Management Plans (LWMPs). However, there is no precedent in British Columbia for inter-municipal funding of implementation plans for cross-boundary watershed protection or restoration.

Quasi-precedents for cross-jurisdictional stormwater funding in British Columbia may be found in regional water supply and wastewater treatment systems. Typically, this means that member municipalities have designated responsibility to regional districts (through 'letters patent') for these functions. Based on a cost sharing formula, the municipalities contribute funding for capital improvements and operation and maintenance of the regional function. This arrangement offers a possible template for a regional approach to stormwater funding.

Building Consensus and Implementing Change



Chapter Eleven

11.6 Administering an Action Plan

- Track #3 – Finance and Administration
- Constant Improvement

11.7 Defining Roles and Aligning Responsibilities

- Local Government
- Senior Levels of Government
- The Private Sector
- The Public
- Inter-Governmental Co-operation Agreements

11.8 Creating Change Through Public Communication

- Communicating the Need for Change
- Ingredients to Build Consensus

11.1 Developing a Shared Vision

Successful implementation of Integrated Stormwater Management Plans (ISMPs) depends on having the support of the community. If the public and elected officials have a shared vision for integrating stormwater management with land use planning, funding and implementation are far more likely to follow.

With participation of the regulatory agencies in the visioning process, senior governments are far more likely to support a local government's efforts and less likely to impose burdensome requirements.

Benchmarking a Watershed Vision to an Official Community Plan

An Official Community Plan (OCP) presents a vision of the future, and provides a benchmark for referencing the goals and objectives of the stormwater planning process. An OCP is an official statement of policy and reflects community values. A representative OCP Vision Statement is presented below:

> ***"The City shares the goal of sustainable development, and believes that good ecology is fundamental to…preserving the City's vision of an urban community in a sea of green"***

Source: 1990 City of Chilliwack OCP

The purpose of an ISMP is to translate the OCP vision into a stewardship-based watershed vision. Stream stewardship is the act of taking responsibility for the well-being of streams and stream corridors, and carrying out works to protect or restore that well-being.

How Do We Get There?

Protecting property, accommodating growth and development and sustaining natural systems is a balancing act. Achieving this balance through an ISMP process involves a 3-step process:

- first, there has to be a perceived need
- this then establishes the goals in developing a strategy
- finally, implementation requires public support in order to generate political action

To be effective, a watershed (or catchment) strategy must be based on a clear definition of shared goals and realistic expectations for achieving them.

Critical Success Factors for Developing a Watershed Vision

Fundamental ingredients to build consensus and ultimately implement a watershed vision are listed below:

- **Achievable and Affordable Goals -** Apply a science-based approach to create a shared vision for improving the health of individual watersheds over time.
- **Participatory Decision Process** - Build stakeholder consensus and support for implementing change, and agree on expectations and performance targets.
- **Political Commitment** – Secure political agreement on the need for action.

Long-Term Vision and Priorities for Action

A shared long-term vision is required to focus effort. This vision provides a context for all planning, data collection, capital expenditures and regulatory changes that result from an ISMP.

Prioritizing goals and actions (through consensus) provides a roadmap for moving towards the long-term vision.

Providing a Clear Picture of the Watershed Vision

Figure 11-1 provides a picture of the shared 50-year vision for the Como Creek watershed in the City of Coquitlam. This watershed comprises an upper benchland and a lower floodplain. There has been a history of flooding problems in the lowlands. A series of drainage reports on the lowland problems had been completed over a 25-year period. However, the overall picture provided by those reports was complex and confusing.

The first priority was to develop a common understanding of the nature of the problem. Upstream urbanization in the Como Creek watershed has resulted in more surface runoff, flow is concentrated at a single drainage outlet, and the Trans-Canada Highway acts as a barrier that restricts the rate of outflow from the watershed. Once the nature of the problem was understood by all participants, it quickly became possible to reach consensus on how to provide flood relief and restore aquatic habitat.

Figure 11-1 presents the three elements of the Como Watershed Vision, and three supporting actions for one of those elements.

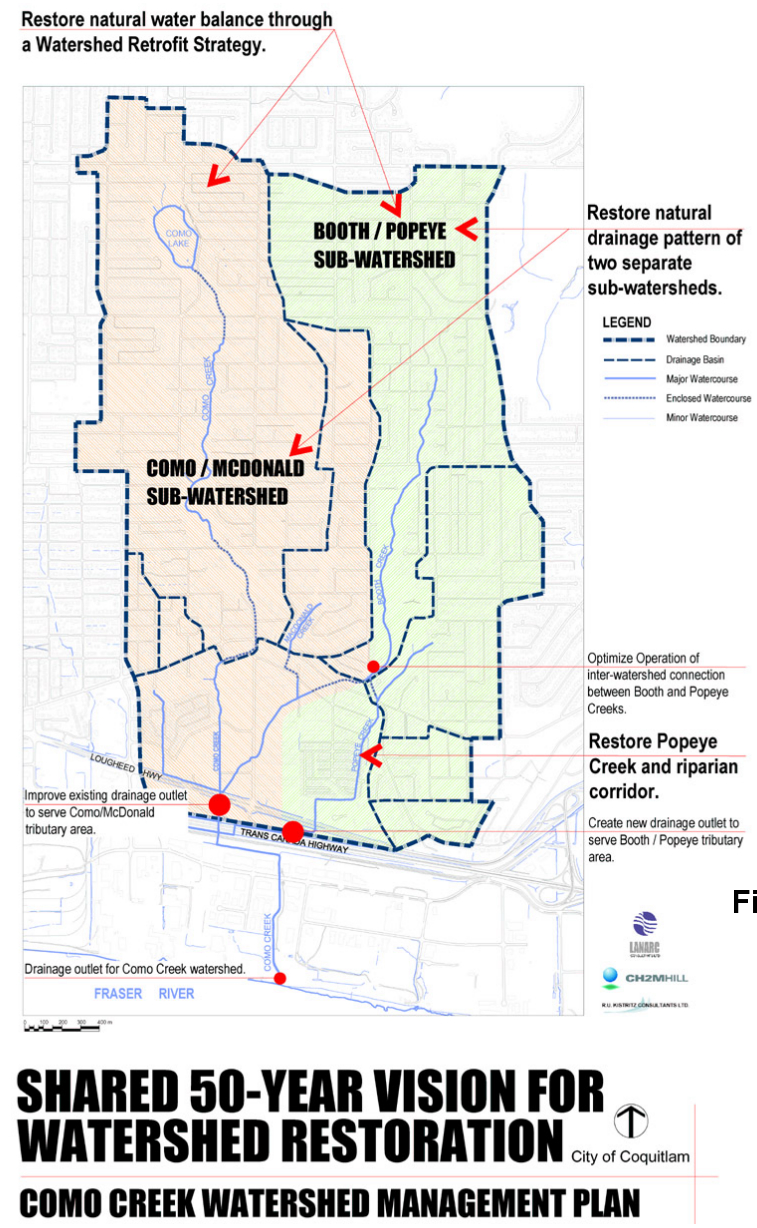


Figure 11-1

11.2 Overcoming Barriers to Implementation

Effective integration of engineering, planning and environmental solutions is often discussed but rarely achieved. Figure 11-2 on the next page illustrates the results of an American survey that identified the top ten reasons that decisions fail. The first four relate directly to human behaviour, with the #1 reason being the lack of a 'decision process'.

Barriers to Change in Local Government

It has been recognized that dealing with stormwater and aquatic habitat issues must be integrated with decisions about land use change. But making this a reality is easier said than done. There are a number of barriers that make bringing about change difficult, including:

- **Lack of a Champion**
- Lack of Trust ("Why should I believe you?")
- Liability ("What if it doesn't work?")
- Access to Resources (staff and money)
- Uncertainty About How to Go Forward
- Attitudinal ("Who cares?" or "Why change?")
- Jurisdictional Conflicts (internal and external)
- Educational (i.e. how new ideas are accepted)

Guiding Principles to Overcome Barriers

The risks and the impacts have become drivers for change in the way stormwater is managed in BC. Once a champion is identified to provide leadership, following these principles will create the momentum needed to build support to implement change:

- **Build Trust**
- Solve the Right Problem
- Avoid Useless Data
- Manage Risk and Liability
- Put Interest and Values First
- Avoid Advocacy Positions
- Find Lowest Cost Solution
- Track Progress
- Ensure Effective Communication
- Learn from Mistakes
- Share Lessons Learned

Gaining Political Commitment through Consensus-Building

Bringing about voluntary change by local government involves a systematic process as summarized below:

- **Demonstrate the Need for Action**
- Integrate Diverse Perspectives
- Align Roles and Responsibilities
- Communicate with Stakeholders
- Partner with Regulatory Agencies
- Implement a Participatory Process

Technical people have to demonstrate cost-effectiveness in order to transform political acceptability into the political will needed to implement change and spend money.

Figure 11-2 Most Decisions Fail Because of Organizational Rather than Analytical Issues

11.3 Moving From Planning To Action

The history of drainage is that floods occur, post-mortem reports are written, the sense of urgency wanes, and there is inaction until the next flood serves as a reminder that the issue remains unresolved. This historical reality provides a frame of reference for overcoming the challenges involved in implementing integrated solutions.

Critical Success Factors for Moving from Planning to Action

Bridging the gap between planning and action requires that three critical success factors be in alignment:

- **Political Commitment –** to take action to integrate stormwater management with land use planning
- **A Champion Within Local Government –** to provide energy and organizational drive and to stimulate willingness to change
- **Trust –** between individuals, and between levels of government

Section 11.6 provides guidance for organizing an administrative system and financing strategy for moving from planning to action. The roles and responsibilities of various levels of government, the private sector and the public are defined in Section 11.7.

Integration of OCP and LWMP Processes

The Official Community Planning process is planner-led. The Liquid Waste Management Planning process is engineer-led. Yet the two processes are highly related, and are in fact complementary. This underscores the need for integration to breakdown inter-departmental barriers.

Accomplishing Institutional Change

Risk aversion is usually given as the reason that governments are reluctant to embrace innovation and integrated solutions. However, as demonstrated by Figure 11-2, the #1 organizational factor that results in failure to move from planning to action is the lack of a decision process. Understanding this reality leads to the following principles:

- **Principle #1: Melt the Opposition** – Obtain commitment from key stakeholders to support change (i.e. new values and beliefs).
- **Principle #2: Implement the Change** – A good idea is immediate, but preparation for implementation can take 5 to 10 years. Change will then take place quickly (e.g. within 6 months).
- **Principle #3: Re-Freeze –** Reinforce new values and institutionalize the change.

Principle #1 can only be accomplished through a participatory and collaborative decision process for building consensus as explained in the following sections. A desired outcome is to align the roles and responsibilities of all levels of government to achieve a shared goal.

Organizational Requirements

A lead organization is needed for watershed and drainage catchment planning. The range of possibilities is summarized as follows:

- local government for larger municipalities
- regional districts for smaller municipalities and rural areas
- First Nations on large reserve lands

Other levels of government and stakeholders (besides the lead organization) will be integrated through the consensus process that is discussed next.

A key to future success in ISMP implementation is the ability of departments to communicate with other departments and disciplines to achieve effective changes in the way local governments plan and design neighbourhoods.

11.4 Translating a Shared Vision into Action

A Three-Track Process

ISMP development and implementation requires a three-track process, where technical analysis feeds into working sessions with all stakeholders, and a financing and administration plan is built to support implementation.

- **Track #1: Technical Products** – Identify watershed characteristics, problems and potential management solutions through a technical analysis process that combines the analytical skills and tools from engineering, planning and ecology. Assess strategies and model implementation scenarios. Computer simulation may help identify what is achievable.
- **Track #2: Working Sessions** – Present and refine technical products at a series of workshops and working sessions with all stakeholders. These sessions will improve understanding and enable informed, consensus-based decision making regarding a shared, long-term watershed vision, appropriate strategies for achieving the vision and roles and responsibilities for implementation.
- **Track #3: Finance and Administration** – Organize an administrative system and financial vehicle that is appropriate to the scale of the stormwater management program. In some rural areas, regulation may suffice on its own. In urbanizing areas, a means of collecting and organizing for capital investment and operations will likely be necessary.

Adaptive Process

It is important for all stakeholders to be working towards the same long-term vision (e.g. 50 years) at all stages of the process. The three tracks of effort must work within an adaptive framework to constantly measure success (the effectiveness of technical solutions and progress towards the long-term vision) and optimize management actions.

Integration of Perspectives

The goal and the challenge is to achieve full integration of the engineering, planning and ecological perspectives. The ISMP must be based on science, but it must also achieve consensus among stakeholders at many levels. As a result, Tracks #1 and #2 must happen in parallel to both inform and balance the many perspectives at the table.

Technical analysis in isolation of stakeholder understanding will not survive the agency and political approval processes. Conversely, stakeholder decisions that are made on technically faulty information are at high risk of failure. However, when the two tracks of technical products and working sessions are used together simultaneously, both processes lead to better understanding and better decisions with more stakeholder support.

The remainder of this section outlines how Tracks #1 and #2 work together; Track #3 is discussed further in Section 11-6.

First Priority is to Understand the Watershed

Having an on-the-ground understanding of a watershed is a core critical success factor. Examples of technical products (Track #1) were introduced in Chapter 9 and include:

- Watershed Base Map - the first building block
- Watershed Issues Summary - where and what are the identified problems
- Sensitive Ecosystem Inventory - what is to be protected
- Concurrent Rainfall and Streamflow Data - how the watershed responds to rainfall
- Drainage System Inventory - how the conveyance system functions
- Land Use Map - what are the existing and future generators of runoff
- Soil Infiltration Map – where might infiltration be feasible

Stakeholder Involvement

There are three tiers of stakeholders:

- **Group One: ISMP Steering Committee** – comprises inter-departmental representatives from planning, engineering, development services, parks, environmental planning and finance
- **Group Two: ISMP Focus Group** – comprises representatives from federal and provincial agencies as well as from key community advisory groups (e.g. streamkeepers, neighbourhood associations and local business associations)
- **Group Three: Watershed Forum –** the general public

Working sessions should typically involve both the Steering Committee and the Focus Group. The objective in having the agencies and others participate in a learning environment is to obtain early buy-in to solutions and strategies. Some technical workshops may involve only the Steering Committee where the focus is to be on contract, property or financial issues.

Watershed Forum

Group Three would be only involved at events where the purpose is essentially information presentation, with limited discussion. The size of Group Three would make it difficult for informal discussion. A more structured approach involving questionnaires and small group breakout sessions could make Group Three consultation more focused and productive.

Collaborative Process

Table 11-1 on the next page outlines how Tracks #1 and #2 work together to achieve understanding of and commitment to the ISMP process.

Table 11-1 Adaptive and Collaborative Process for Translating a Shared Vision into Action

Track #1 – Technical Products

Step 1 - Basic Mapping and Problem Identification

Map ecological, drainage and land use information to identify at-risk catchments where land use change:

- threatens high-value ecological resources
- could cause unacceptable drainage problems.

(refer to Chapter 5)

Step 2A - Performance targets and site design criteria for achieving shared goals*

Analyze site-specific rainfall data to set performance targets for rainfall capture, runoff control and flood risk management. Translate performance targets into design criteria that can be applied at the site level (refer to Chapter 6).

**set targets and design criteria for priority catchments first*

Step 2B - Alternative strategies for achieving these targets and design criteria

Chapters 7 and 8 provide guidance for selecting appropriate strategies at the land use and community planning level, and at the site design level (including specific examples).

Step 3A - Implementation and monitoring of demonstration projects in at-risk catchments

Test the effectiveness (and affordability) of various site design options, while taking immediate action to achieve priority goals.

Step 3B - Evaluation of local development standards and regulations

Identify development standards and regulations that impede better stormwater management and land development practices (e.g. rainfall capture at the source, narrow roads).

Step 4 - Monitoring of progress towards performance targets and the long-term vision

Requires strategic collection of data to track indicators of success and enable ongoing assessment of progress towards performance targets and the long-term vision.

Track #2 – Deliverables for Working Sessions

Step 1 - Shared Vision, Goals, and Priorities

Develop a long-term vision that is shared by all stakeholders, and establish the key goals and objectives that correspond to this vision.

Achieve consensus on a priority at-risk catchment to focus early action, as well as the next priorities for action.

Step 2 – Strategies for achieving performance targets* and long-term vision

Achieve consensus on the strategies that would be most practical and achievable in the context of:

- Local conditions
- The needs and interests of all stakeholders

**appropriate strategies for achieving performance targets should be defined in priority at-risk catchments first*

Step 3 - Changes to local development standards and regulations:

- to require that development and re-development projects incorporate source control (recommend the most effective and affordable options)
- to remove regulatory barriers to better stormwater management and land development practices

Change must occur through consultation with all stakeholders, particularly developers and landowners.

Step 4 - Optimize stormwater management actions

Improve community planning and site design practices based on stakeholder response to the ongoing assessment process.

Stakeholder participation is key to defining success and developing indicators of success.

11.5 Using Working Sessions to Build Consensus

Consensus Explained

There are usually complex trade-offs involved in choosing the appropriate integrated solution. Many of the decisions about choice of solution require judgement – about public values and priorities, about the pace of change, and even about environmental conditions based on the currently available scientific information. Choices, especially, involve balance among competing objectives.

The best tool to find this balance is consensus. The word consensus is defined in many different ways, but a working definition can be 'the lack of violent objection'.

The same values might be given different emphasis by different stakeholders – engineering, operations, planning, fisheries, land use development, parks, recreation, homeowners, highways or stewardship groups. The differences in values and emphasis usually stem from what we have been taught and what we have experienced. Consensus is important because it incorporates relevant education and experience from all disciplines and all experience at the table.

How Adults Take Up New Ideas and Approaches

Figure 11-3 illustrates how education leads to implementation. The Figure elements can be read in both the horizontal and vertical directions. Education leads to shared, achievable goals. In turn, these goals culminate in action and implementation.

An understanding of how adults learn can help to explain why and how new ideas are accepted, and why some adults accept them faster than others. Learning is a gradual process. Adults take in new information, reflect on it, blend it with their own experience, test it, and eventually apply it in making decisions.

The differences in the way people accept new ideas, and the fact that learning is a gradual process, underscores the necessity and value of workshops and working sessions. Properly structured, they break down barriers, promote communication and transfer of knowledge, and make it possible to bring people along at different rates of acceptance.

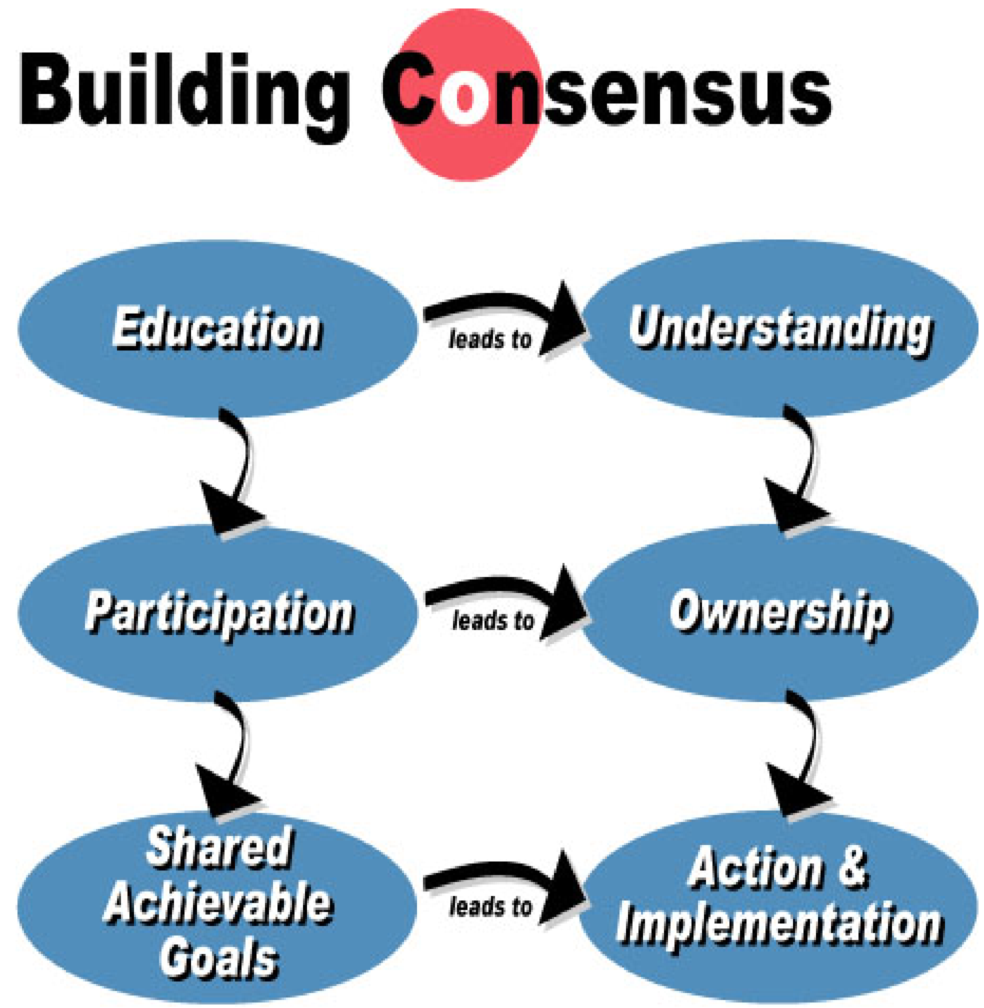


Figure 11-3

Working Sessions Result in Knowledge Transfer

Examples of themes for working sessions to develop consensus around watershed objectives are listed below. Each session would have a product or expected outcome to maintain the focus. Each product is a building block in the broader ISMP process. Since the sessions are interactive, they also provide an effective feedback loop to evaluate the process itself. As well, working sessions facilitate incremental buy-in to a shared vision.

EXAMPLE SESSION THEME	SESSION PURPOSE
Project Initiation and Chartering	Clarify goals, expectations and deliverables
Watershed Issues Workshop	Define issues, needs and driving forces
Hydrology Workshop	Develop a common understanding of issues
Fisheries and Ecology Workshop	Confirm habitat values and limitations
Watershed Vision Workshop	Evaluate performance targets
BMP Workshop	Focus on green infrastructure costs and benefits
Strategy Development Workshop	Develop framework for the integrated plan
Elements of an Integrated Plan - I	Brainstorm pros and cons of the plan elements
Elements of an Integrated Plan - 2	Reach consensus on the plan elements
Regulatory and Communications Plan	Address regulatory and public awareness roles
Implementation Plan	Finalize plan details

This list is only intended to provide a starting point for customizing an appropriate stakeholder program for individual watersheds or catchments. Based on experience, a minimum of four sessions is usually needed for participants to become comfortable with each other and reach consensus.

Structure and Documentation

The agenda for each working session should state the purpose in meeting, define a set of objectives, and indicate the desired outcome. The session should comprise a series of short presentations of the relevant technical analyses, with each presentation segment followed by a question and discussion period. A facilitator can be useful to keep the sessions focused on the desired outcome. Note that:

- **Structure** is provided by a set of presentation slides that guide the discussion. These slides can then become part of the record of the session.
- **Focus** is provided by means of presentation material and/or drawings (i.e. technical products from Track #1).
- **Documentation** is provided through a short-form and succinct session summary that can be included as an appendix to the ISMP.

Working sessions are an effective forum for sharing information, experience and knowledge. Structured sessions foster a learning environment that results in improved communication that in turn leads to enhanced understanding and acceptance.

11.6 Administering an Action Plan

Developing an ISMP is an intensive and extensive process. There is a lot for the participants to remember. The information would be overwhelming if conveyed in its entirety to elected officials. To make decisions related to ISMP implementation, elected officials need relevant information in a concise format.

Track #3 - Finance and Administration

Section 11.4 outlined a three-track approach to building, planning and implementing integrated stormwater management solutions. Table 11-2 is a checklist that summarizes the scope of what is involved in Track #3 - Finance and Administration. The focus is on creating an action plan that identifies the specific activities or projects that need to be completed. The scope of a watershed-specific action plan is summarized below.

Scope of an Action Plan

From an elected official perspective, the key deliverable for any watershed or catchment planning initiative is the action plan that defines the specific activities required to achieve the long-term vision. It is important to provide the following information for each proposed activity:

- Time-frame for implementation
- Management objectives
- Priority (relative to other action items)
- Who takes the lead role?
- Estimated cost and financing strategy

An action plan should cover the 5-year, 20-year and 50-year implementation timeframes. To illustrate this, an Action Plan that resulted from the City of Coquitlam's Como Creek ISMP is presented in Table 11-3.

Table 11-2 Finance and Administration Protocol for Implementing an Action Plan

1. Review existing administrative systems to identify potential departmental organization for stormwater management.
2. Create a summary Action Plan that identifies the actions or projects that need to be completed.
3. Select or create a lead department for integrated stormwater management.
4. Clearly identify what actions are to be led by which department and related budget requirements.
5. Identify the capital and operating financing required, and relate to schedule and other priorities.
6. Review fundraising options and implications.
7. Obtain political and public review in draft form.
8. Refine the Action Plan.
9. Formalize the Action Plan.
10. Consider and adopt the Action Plan.

Constant Improvement

Action plans should be long-term, corresponding to the time frame of the watershed vision, but must be revisited periodically (e.g. every 5 years) and updated based on the ongoing assessment of progress towards the shared vision. This is the foundation of an adaptive approach.

The 50-year vision reflects the long time frame required for change. Over time, as better development practices evolve and as a watershed is gradually retrofitted with rainfall capture and runoff control measures, it will be important to monitor the success of watershed protection and restoration. This is essential for the adaptive approach to work.

The ongoing assessment process will provide better understanding of the policy, science and site design aspects of integrated stormwater management. This will enable constant improvement of integrated solutions.

Table 11- 3 Implementation Actions for the Como Creek ISMP

Time-frame	Action Items	Management Objective	Lead Role	Budget
	Short-term Flood Risk Management	**Provide Immediate Flood Relief**		
Short-term (0-5 years)	**Improve Lowlands Drainage System** a) Remove Booth Creek channel constrictions at and below Lucille Starr Way. b) Expand the rainfall and streamflow monitoring network. c) Build a calibrated hydraulic model for the Lowlands drainage system. d) Upgrade the Booth/Popeye Inter-Watershed Connection. e) Implement the Inter-Watershed Flow Control System at theTrans-Canada Highway. f) Create a separate drainage outlet for Booth Creek under the Lougheed Highway.	a) Eliminate chronic flood overflows onto Schoolhouse Street. b) Monitor watershed changes over time; provide the data needed to calibrate models. c) Develop operating rules for effective flow management in the Lowlands. d) Transfer peak flows and eventually restore two separate sub-watersheds. e) Improve capacity of Como Creek system to reduce risk of flooding above the highways. f) Improve capacity of Como Creek system to reduce flooding; create fish habitat.	Operations Operations Operations Operations Operations Operations	
Short-term (0-5 years)	**Upgrade High-Risk Culverts and Provide Bedload Interception** a) Upgrade the Como Creek culvert at Rochester Ave. and provide bedload interception. b) Upgrade the Booth Creek culvert at Austin Ave. and provide bedload interception. c) Upgrade the Como Creek culvert at Austin Ave. and provide bedload interception.	a) Reduce risk of localized flooding and potential road washout; reduce downstream deposition. b) Reduce risk of localized flooding and potential road washout; reduce downstream deposition. c) Reduce risk of localized flooding and potential road washout; reduce downstream deposition.	Operations Operations Operations	
Short-term (0-5 years)	**Provide Community Storage Facilities** a) Implement the Como Lake Storage and Flow Regulation Modifications. b) Construct Popeye Detention Pond on BC Hydro Site.	a) Reduce erosion in Como Creek Ravine; reduce downstream deposition and flooding risk. b) Improve the effectiveness of the Booth/Popeye inter-watershed connection.	Operations Operations	
	Long-Term Watershed Restoration	**Eventually Restore the Health of the Watershed**		
Short-term (0-5 years)	**Identify Targets & Design Options for Source Storage and Infiltration** a) Implement the Casey Place Bedload Management Plan. b) Build a calibrated hydrology model for the Como Creek watershed. c) Complete a hydrogeologic investigation of the Como Creek watershed. d) Implement and monitor source storage and infiltration pilot projects on public works. e) Establish a consultation process with landowners and the development community. f) Create an on-line technical manual of options for on-lot storage and infiltration.	a) Reduce bedload deposition and flooding risk in the Lowlands. b) Establish target conditions for long-term watershed restoration; optimize management solutions. c) Identify areas within the watershed that are suitable for infiltration at the source. d) Identify appropriate source storage and infiltration targets and identify the best design options. e) Identify design options acceptable to landowners and developers. f) Make design details for source storage retrofit readily available.	Operations Operations Operations Operations Dev. Services Dev. Services	

Table 11- 3 Implementation Actions for the Como Creek ISMP

Page 2 of 2

Time-frame	Action Items	Management Objective	Lead Role	Budget
Short-term (0-5 years)	**Build Support for Watershed Retrofits Through Education** a) Provide a self-guided training program including tours, fact sheets, videos and website information. b) Offer training workshops and seminars to the development community. c) Work with other agencies to design a one-day watershed training and certification program. d) Require that all public works staff and contractors become watershed-certified.	a) Educate development community, city staff and public about the need for changes in development practices. b) Educate development community about how to implement changes in development practices. c) Educate city staff about need for changes in development practices and how to implement them. d) Ensure that City staff can lead by example.	Parks & Env Parks & Env Parks & Env Operations	
Short-term (0-5 years)	**Change Development Regulations to Ensure that Source Storage Retrofit will Occur in Conjunction with Future Re-development** a) Remove barriers to source storage and infiltration in existing development regulations. b) Incorporate the most appropriate targets and design options into the Engineering Standards. c) Incorporate the new Engineering Standards into the Subdivision Bylaw, Building Bylaw, Zoning Bylaw and Development Permit Guidelines.	a) Ensure that the regulatory framework does not discourage source storage retrofit. b) Ensure that the watershed will be restored through source storage retrofit as re-development occurs. c) Ensure that the watershed will be restored through source storage retrofit as re-development occurs.	Dev Services Operations Dev Services	
Short-term (0-5 years)	**Demonstrate a Commitment to Watershed Restoration** a) Implement a water quality source control program in the Lowlands. b) Implement the East Surge Channel Habitat Bank.	a) Improve water quality in the Lowlands by eliminating sources of leachate. b) Create new fish habitat in the Como Creek system; provide compensation for future projects in the watershed.	Operations Operations	
Medium-term (5-20 years)	**Facilitate the Implementation of Source Storage Retrofit Strategy** a) Provide expedited approvals on private sector projects that implement source storage. b) Implement a composting program to provide low-cost organic matter for absorbent soils. c) Implement a program for bulk purchase and resale of storage and infiltration products. d) Continuously monitor rainfall-runoff response and other indicators of watershed health.	a) Facilitate approval process for re-development projects that implement source storage and infiltration. b) Facilitate the procurement of absorbent soils needed to provide infiltration at the source. c) Facilitate the procurement of materials needed to retrofit individual re-development projects. d) Assess the effectiveness of the source storage retrofit strategy in achieving watershed restoration.	Dev Services Parks & Env Operations Operations	
Medium-term (5-20 years)	**Restore the Natural Watershed Drainage Pattern** a) Create a new drainage outlet at the highways for the Booth/Popeye sub-watershed.	a) Achieve the overall vision for two separate sub-watersheds, (Como/MacDonald and Booth/Popeye).	Operations	
Long-term (20-50 years)	**Restore Watercourses to Their Natural State** a) Restore the Popeye Creek stream corridor between Brunette and Lougheed Highway. b) Daylight the piped section of Booth Creek between Sheridan and Myrnam. c) Daylight the piped section of Como Creek below Como Lake. d) Daylight the piped section of Booth Creek below Foster. e) Daylight the piped section of Como Creek below Rochester.	a) Restore healthy aquatic and riparian ecosystems in the Popeye Creek system. b) Restore Booth Creek to its natural state; create a neighbourhood amenity. c) Restore Como Creek to its natural state; create a neighbourhood amenity. d) Restore Booth Creek to its natural state; create a neighbourhood amenity. e) Restore Como Creek to its natural state; create a neighbourhood amenity.	Operations Operations Operations Operations Operations	

11.7 Defining Roles and Aligning Responsibilities

Once there is agreement to move from planning to action, the next step is to define roles and align responsibilities, both for individuals and levels of government.

Local Government

Local governments are the primary players. They control land use decisions, have a comprehensive mandate and are directly accountable to local citizens. Their key responsibilities include:

- Supporting stormwater management objectives through land use planning and growth management.
- Changing municipal development standards and regulations (e.g. engineering standards, zoning bylaws, development permit guidelines, etc.) to enable low impact development and stormwater management.
- Making details of changes readily available to the development community.
- Financing capital works projects (e.g. drainage system improvements, community detention).
- Taking a leadership role by implementing demonstration projects for rainfall capture best management practices (BMPs) on public works.
- Facilitating the procurement of products needed for source-control BMPs.

Senior Levels of Government

Key responsibilities include:

- Providing financial support through provincial and federal programs.
- Providing technical support as required (e.g. the Stewardship series of documents).
- Streamlining the agency approval process.
- Facilitating integration where stormwater management issues cross jurisdictional boundaries.

The Private Sector

The key role for developers is to incorporate rainfall capture BMPs into development and re-development projects. Developers are ultimately responsible for on-the-ground implementation of low impact development and stormwater management practices at the site level. Developers can also play a key role in finding creative and affordable solutions to achieve stormwater performance targets.

The Public

Building public support through education is key. This public support translates into political will for change. An educated public can stimulate action. All levels of government have a role in building public support through stormwater education initiatives.

Inter-Governmental Co-operation Agreements

Inter-Governmental Co-operation Agreements (IGCA) provide a vehicle for aligning responsibilities among all levels of government. The intent of an IGCA is to bring all parties which share a goal – or who are essential players in achieving other jurisdictions' goals – together so that they can apply their various mandates, resources, and capabilities to do the job both efficiently and effectively for all concerned. Important principles and factors to consider in developing such agreements are listed below:

1. **Define Reasons for Intergovernmental Collaboration -** Purpose, topic, scope, benefits to be gained (in 'whereas' statements).

2. **Recognition of Roles and Responsibilities -** By definition, collaboration is not about hierarchical power-based relationships, but partnerships irrespective of who has power. Acknowledge independence (with respect to constituency and related accountabilities) and then deal with collaboration among independent parties acting with reference to mutual interests.

3. **Principles and points for consideration in collaboration -**

   - commitment to action with reference to jurisdictional roles, responsibilities and accountability (clarity on who does what, where, when)
   - partnerships based on strengths and capabilities (co-operation and harmonization with respect to legislation, regulations, policies, programs and projects)
   - consultation on and confirmation of resources needed to do job (impact assessment of costs and benefits and their incidence and resolution of potential issues regarding funding, liability and resources)
   - flexibility (to adapt to conditions that may arise in the administration of a collaborative initiative)
   - notification and consultation (to address any changes that may emerge)
   - information sharing
   - dispute resolution
   - involvement of civil society (who, how, when, by whom)
   - implementation sub-agreements (to address specific topics or actions)
   - administration of agreement (committee(s) and review process to monitor performance and renew, revise or refine agreement(s))

Local governments have now been unequivocally called on by senior governments and the public to protect fish habitat in British Columbia. Principle-based agreements will receive increasing attention as a key ingredient in achieving multi-jurisdictional community development and stream health protection objectives.

11.8 Creating Change through Public Communication

An ISMP may identify required changes to land use regulations in order to implement a stormwater strategy. But public support and the political system will determine the timing and phasing of those changes.

Furthermore, public attitudes and the ability of the development community to adapt will set the pace of change. The pace can be accelerated by intensive public awareness and information campaigns. Accordingly, a communications strategy is an essential element of an ISMP. Such a strategy starts by determining what type of information and training are needed to support the associated Land Development Action Plan.

Communicating the Need for Change

Once BMPs that are appropriate for a catchment have been selected by consensus, and their target areas identified, it is natural to assume that the 'job is done'. Although ISMP development may be largely complete, the job of protection and restoration has just begun. Table 11-4 presents guidelines for creating change through public communication to sustain these protection and restoration efforts.

Initial flood risk management may be accomplished largely by government capital projects. However, the long-range reduction of environmental risk in a catchment will require a permanent change in the way that land is developed and/or re-developed. To accomplish this requires fundamental changes in development, construction and operations standards.

This can only be achieved if there is a broad understanding, within the development community in particular, and the public in general, about best management practices – what they are, why they are needed and how they can be practically accomplished. To create this fundamental change requires reaching a large number of people, many of whom may not be a motivated audience.

Table 11-4 Creating Change Through Public Communication

- There are many different audiences (e.g. politicians, various disciplines of professionals and scientists, students of different levels, volunteer groups, homeowners, construction supervisors and machine operators, builders and labourers). Education materials must be appropriate for each audience, in terms of their prior knowledge and their learning level. Educators must understand the audience, and begin at their level of understanding.
- Different people have different learning styles. Some learn best by seeing, others by hearing, and others still by doing. An education program must therefore target each of these learning styles.
- Most adults will not remember a message until they have heard it at least three times, presented in three different ways.
- Awareness fades with time, and as new people enter the system. A message needs to be repeated to refresh memories, increase awareness and to reach new participants.
- The choice of educational media should respect the audience's preferences, time and available technology.
- Motivation is a key to learning. What's in it for me? When is the teachable moment? For example, in addition to an awareness workshop, a bylaw review may create a teachable moment. So might a requirement for a permit.

Ingredients to Build Consensus

Public awareness will not be changed in a single event. There is an ongoing need for a stewardship communication campaign that is designed to reach the spectrum of audiences in the watershed. This awareness program needs to allow for repetition and reinforcement over time. A communications campaign needs to draw from the experience of educators. It also includes ingredients of marketing. Both bodies of knowledge support the concepts summarized in Table 11-5.

Change in behaviour comes hard and slow. But adaptable human behaviour has been the secret to human success over the millennia. The key to change lies in understanding why change is necessary.

Effective communication, using a variety of media and a series of events with increasing levels of detail, is fundamental to implementing watershed stewardship. When one considers actions with a 20-year or 50-year time horizon, a communication plan must provide for rapid advances in technology, including increased reliance on the Internet. However, the strategy must also consider the role of traditional school and university education, as well as adult education and 'tail-gate' contractor instruction in creating change.

Table 11-5 Ingredients to Build Consensus

- Respect each other's objectives and responsibilities.
- Use plain English and eliminate jargon.
- Create understanding by using practical examples (e.g. flooding hot spots, developer complaints, Councillor representations, fish kills, etc.).
- Focus on problems and solutions, not on personalities.
- Target solutions to specific areas; many solutions will work in only part of the watershed (e.g. infiltration on favourable soils).
- Target solutions by timeline; some can be achieved immediately, some require 20-year or 50-year time horizons.
- Set clear priorities as a group, based on need and cost-benefit analysis, but also on 'full-cost accounting' that also recognizes non-monetary values.
- Recognize solutions that overlap jurisdictions or disciplines; use this process as a way to co-ordinate across departments; what can not be achieved by one department may be possible with two or more departments working in tandem.
- Give solutions a home; for inter-departmental solutions, it is especially important to define the sub-tasks and roles that each department will contribute in detail; otherwise, there is a chance of inertia or duplication if departmental mandates are unclear.
- Focus on what needs to change; watershed management is so broad, it can feel like everything is being reinvented; focus instead on items that need to change; this might mean a series of minor wording changes to bylaws, or relatively minor changes to construction practices that are phased in as the industry is educated to be prepared for them.

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