Okanagan Basin WATER BOARD

the partnership for water sustainability in bc

Convening for Action in British Columbia

Sustainable Rainwater Management: What Does It Look Like?

Water Balance Model Training Workshop on March 1, 2012

Hosted by Okanagan Basin Water Board at Power Concepts Computer Lab, Kelowna

Integrating the Site with the Watershed and the Stream

Use Effective Green Infrastructure, Lighten the 'Water Footprint',
Achieve More at Less Cost, and Protect Stream Health

An initiative under the umbrella of the Water Sustainability Action Plan for British Columbia

Water Balance Model Training Workshop

Integrating the Site with the Watershed and the Stream

	Sustainable Rainwater Management: What Does It Look Like?
Abstract:	Land development practices and actions at the site scale can result in either cumulative impacts or cumulative benefits at the watershed scale. Hence, the unifying theme for the WBM training workshop is: *Sustainable Rainwater Management --- Integrate the Site with the Watershed and Stream to Protect Watershed and Stream Health* The water balance methodology links rainfall to flows in the stream. The methodology addresses the interaction of runoff (both volume and duration) with the physical aspects considered important to the aquatic environment. The web-based WBM is a scenario comparison tool. It was developed as an extension of *Stormwater Planning: A Guidebook for British Columbia*. The WBM is used to assess performance targets for managing RUNOFF VOLUME and RUNOFF RATE. The workshop is in a computer lab and is hands-on. Participants will learn how to apply the WBM so that they can quantify the hydrologic effectiveness of green infrastructure practices, such as: absorbent landscapes, rain gardens and infiltration facilities. **NOTE:** Hosted by the Okanagan Basin Water Board, the WBM Training Workshop is a companion event to the FreshOutlook Foundation's *Building SustainAble Communities Conference*. The Sustainable Infrastructure Delivery and Sustainable Rainwater panel sessions on February 28th will provide context for the WBM workshop on March 1st.
Regulatory Context:	The WBM supports government's position as stated on p 43 of **Living Water Smart, BC's Water Plan.** This is the lynch-pin for a collaborative and consistent approach that aligns local government policies and actions with provincial and regional goals: ☐ *By 2012, all land and water managers will know what makes a stream healthy, and therefore be able to help land and water users factor in new approaches to securing stream health and the full range of stream benefits.*
Instructors:	Kim A Stephens, P.Eng., Executive Director, Partnership for Water Sustainability Jim Dumont, P.Eng., Engineering Applications Authority, WBM Partnership

Structure for an Interactive Knowledge-Transfer Session	
Part 1 - What Do You Know? (First Hour)	**Scope:** Introduce core concepts and test the knowledge of the class re: rainfall spectrum, water balance methodology, stream erosion, stream health, and targets. **Educational Objective:** *Participants will have a common understanding of the "retain, detain, convey" integrated strategy, and the factors affecting stream health*
Part 2 - What Do You Wonder? (Core 2½ hours)	**Scope:** Guide the class step-by-step through a case study application of the WBM at the SITE scale, and demonstrate how to do scenario comparisons. **Educational Objective:** *Participants will be able to use the WBM effectively to enter input data and generate outputs*
Part 3 - What Have You Learned? (Last ½ hour)	**Scope:** Ask the class to share their 'Ah-Ha Moments' and how they anticipate applying what they have learned in order to: build effective green infrastructure, lighten the 'Water Footprint', achieve more at less cost, and protect stream health. **Educational Objective:** *Participants will understand the capabilities of the WBM to evaluate rainwater source controls and how to achieve performance targets*

Attachment A:

Water Balance Model Methodology

Partnership for Water Sustainability in British Columbia

Beyond the Guidebook:

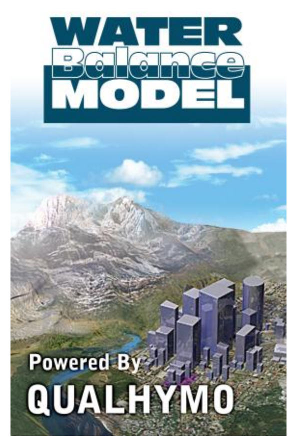
Water Balance Model powered by QUALHYMO

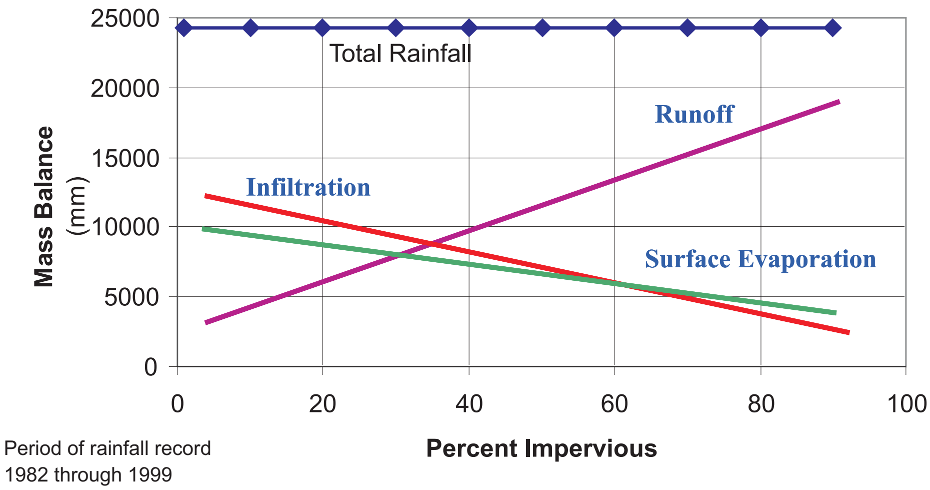
One of the tools developed under the umbrella of the Water Sustainability Action Plan is the **Water Balance Model for British Columbia**.

Developed by an Inter-Governmental Partnership (IGP) as an extension of **Stormwater Planning: A Guidebook for British Columbia**, the Water Balance Model enables users to visualize how to implement green infrastructure solutions that achieve rainwater runoff source control at the site scale.

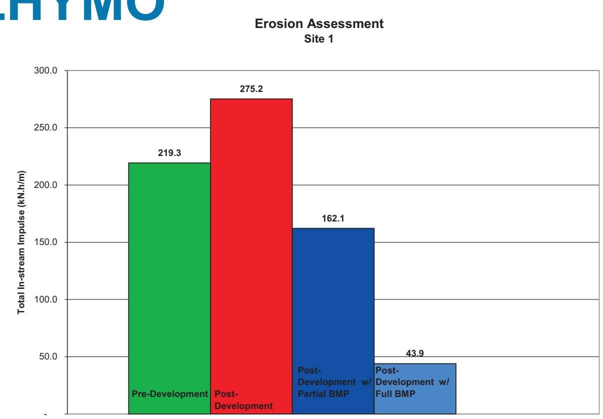
The Guidebook's premise that **land development and watershed protection can be compatible** represented a radical shift in thinking in 2002. The Guidebook recognized that water volume is something over which local government has control through its infrastructure policies, practices and standards.

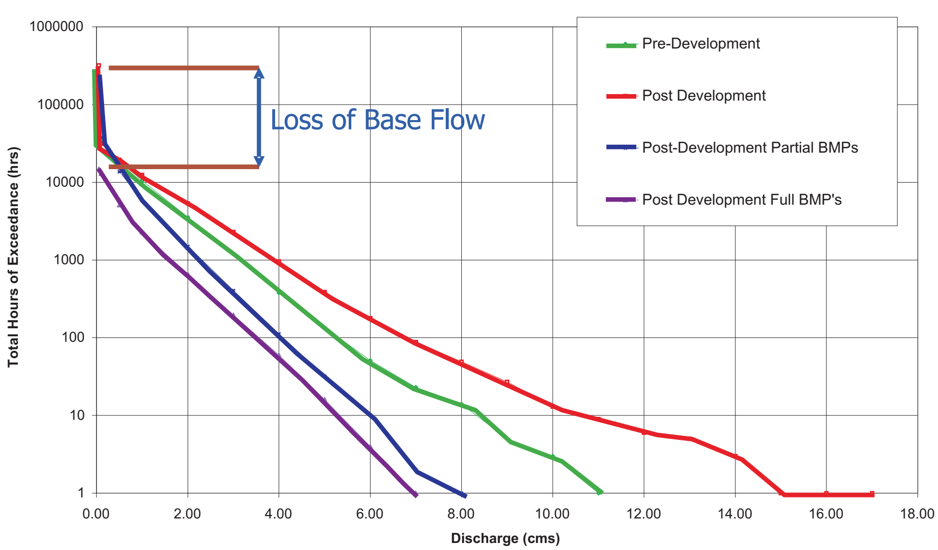
Beyond the Guidebook is an initiative that builds on this foundation by advancing a runoff-based approach and tool – the '**Water Balance Model powered by QUALHYMO'** – to help local governments achieve desired urban stream health and environmental protection outcomes at a watershed scale.





METHODOLOGY FOR MODELLING DEVELOPMENT IMPACTS AND MITIGATION WITH QUALHYMO





May 15,2011

Hydrologic Impact Assessment

1. Use continuous simulation to assess the mass balance of rainfall, runoff, infiltration and evaporation.

2. Graphically represent the mass balance analysis.

3. Use the continuous simulation to estimate discharge exceedances. These would be the values of runoff plus groundwater return to the system.

4. Present results of flow exceedance analysis results in tabular or graphical format.

5. Use BMP's to achieve the desired objectives.

Establish Targets

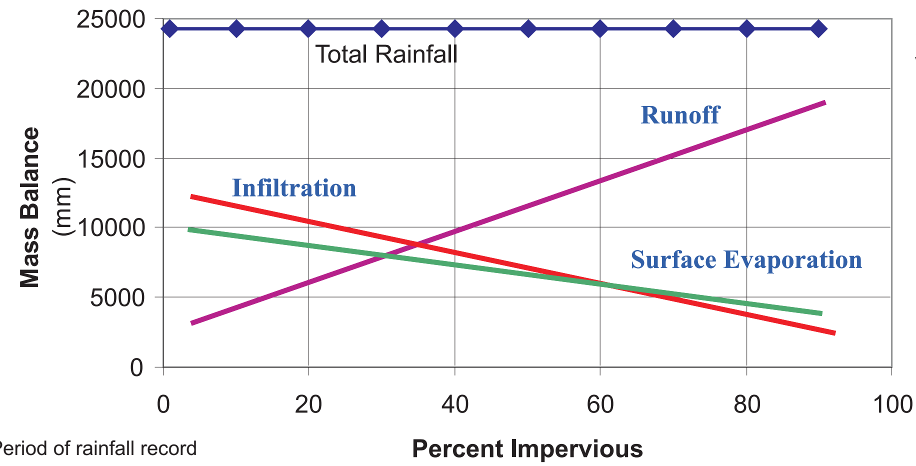
Two methods can be used to establish targets used for design of runoff volume reduction systems and facilities.

1. Use the volume of runoff from redevelopment or existing watershed conditions, or

2. Use the stream flow duration and exceedance analysis combined with the stream erosion potential to establish discharge rate and volume targets.

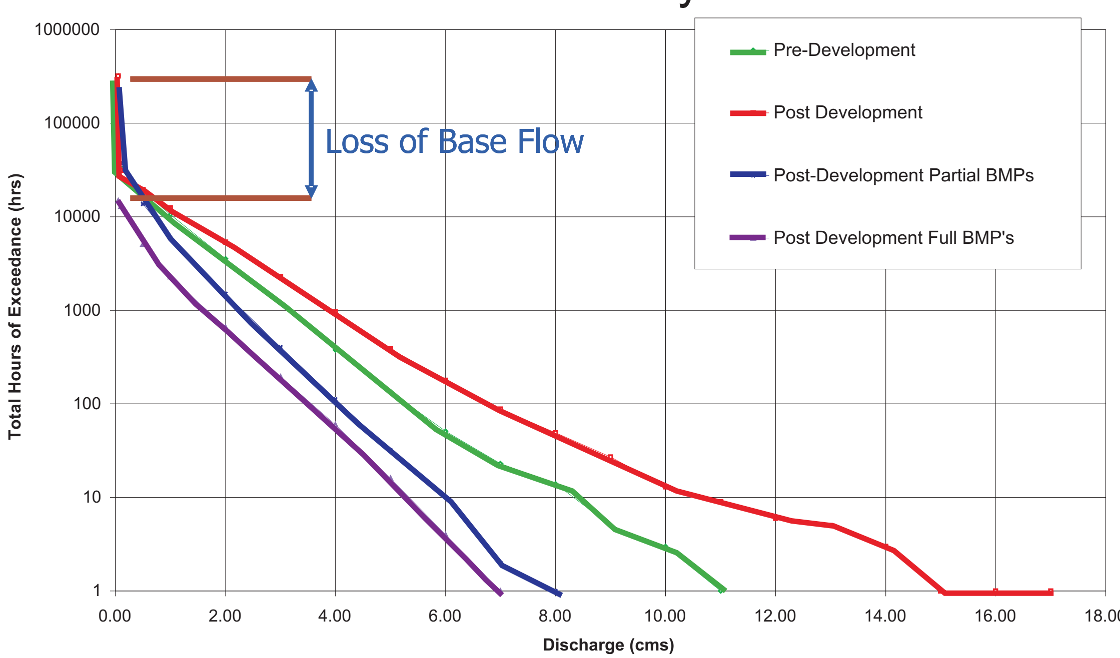
Test and optimize the size and the operation of the runoff volume reduction systems and facilities in the watershed to achieve the desired objectives and targets.

Mass Balance Analysis

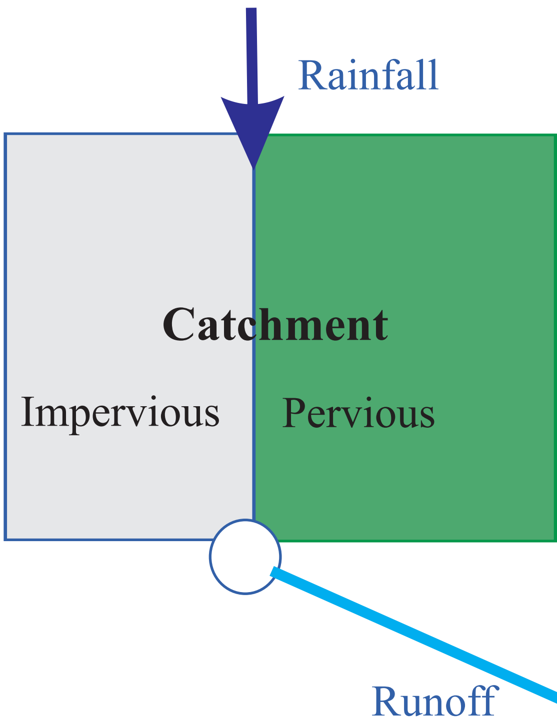


Period of rainfall record
1982 through 1999

Flow Exceedance Analysis



Hydrologic Change Assessment



Watershed Discharge

Changing the watershed surface characteristics, or catchment parameters, can provide an assessment of changes in hydrologic function of watersheds resulting from development.

Several volume reduction methods can also be assessed using altered catchment parameters. Facilities or systems falling into this category consist of augmented or enhanced surface conditions that include:

- increased top soil depth
- soil porosity or moisture holding capacity
- surface infiltration rates
- vegetation and ground cover
- imperviousness
- surface roughness

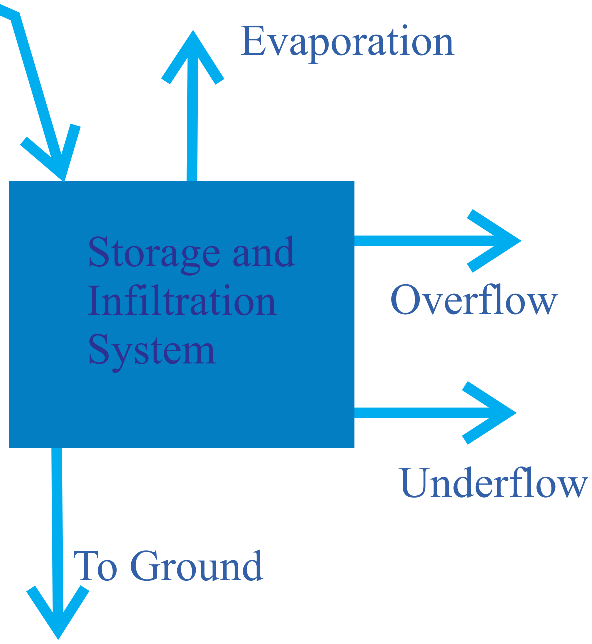
Similarly, alterations of the surface conditions such as increased imperviousness can also be analyzed using these techniques.

Discharge Volume Reduction Systems

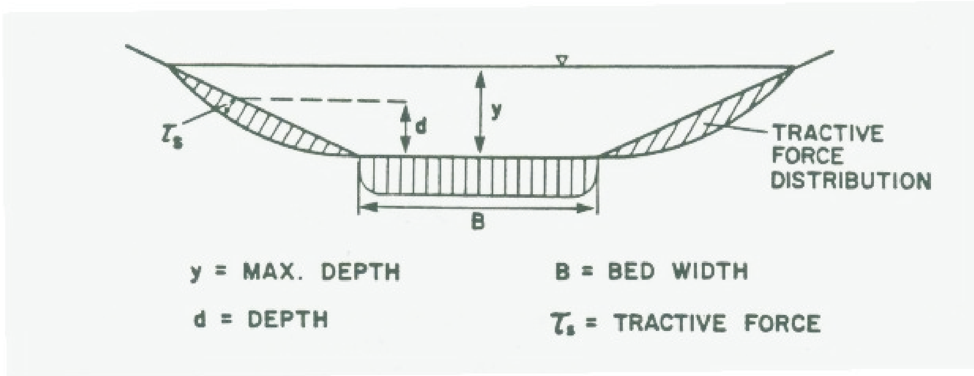
Any runoff control facility or system that provides discharge control or reduces surface runoff volumes must be analyzed following the calculations of catchment hydrology. These systems typically include a storage volume and can include infiltration to ground. The infiltration will be in addition to the surface infiltration calculated for the catchment. Systems falling into this category include:

- infiltration galleries
- rain gardens
- retention ponds
- some forms of green roof
- most bio-filtration swales

The key to this analysis involves a reduction of surface runoff after it occurs and there is a volume of stored water within the systems.



Detention Ponds can be added to control discharge rates and limit potential flooding impacts to downstream areas.



Steps in the stream assessment

1. Estimate the Tractive Force applied to the stream bed and banks for a range of discharge values.
2. Estimate the critical tractive force below which erosion will not occur. Use only the tractive forces in excess of the critical in the next steps.
3. Use the continuous simulation to estimate the duration of discharge for a range of occurring stream flows.
4. Estimate the Impulse by applying the discharge and estimating the tractive force applied at the section over the duration of the simulation. The impulse is the sum of the tractive force over time
5. Present results for different watershed conditions or runoff volume reduction system alternatives in tabular or graphical format.

Tractive Force

$\tau = \sigma Rs$, where

σ = unit weight of water

R = hydraulic radius of flow, and

s = slope of channel

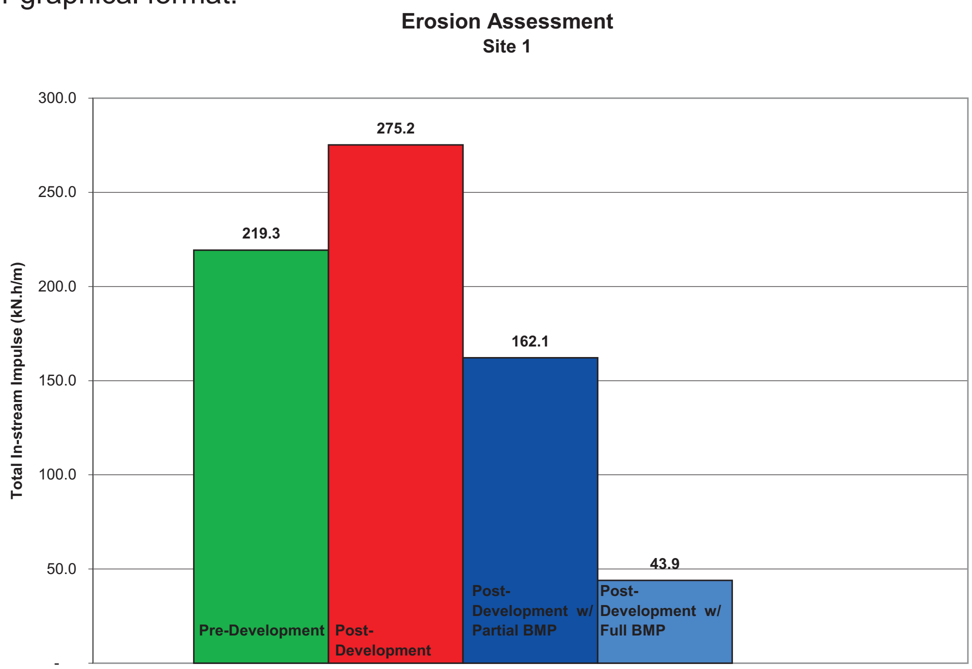
Impulse

$I = \sum(\tau PT)$, where

τ = Tractive Force

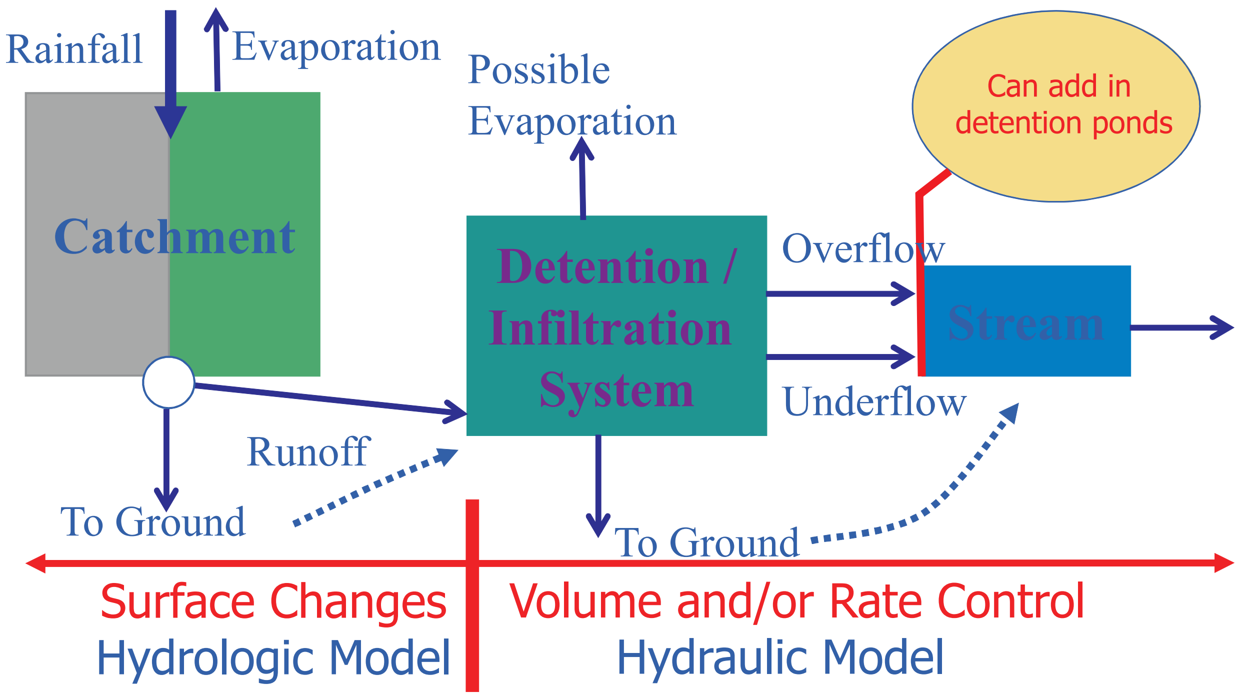
P = wetted perimeter

T = time



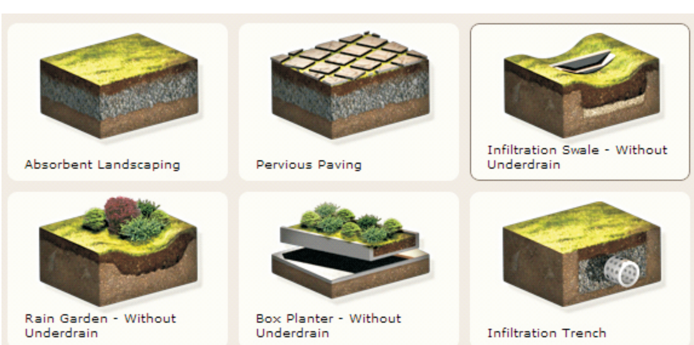
Stream Impact Assessment

WBM Model Process Diagram



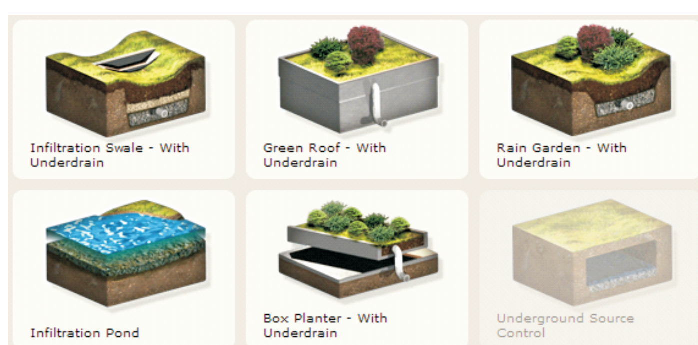
Modelling Surface Changes - Hydrologic Model

Mitigation with Absorbent Landscapes
- Tree cover density
- Increased top soil depth
- Porous pavement
- Green Roof – Typical
- Some infiltration swales – without storage



Modelling Runoff Reduction - Hydraulic Model

Capture surface runoff and STORE it for infiltration to reduce discharge volume
- Rain gardens with storage
- Infiltration swales with storage
- Surface or subsurface storage
- Infiltration ponds
- Underground galleries



Attachment B:

PowerPoint Slides

An Introduction to the Water Balance Model for BC

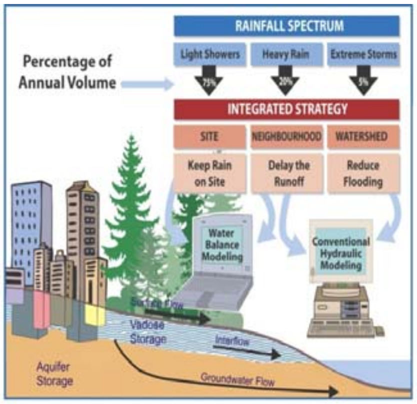
The Province is going down a pathway that will integrate regulatory compliance and collaboration

"Regulatory requirements provide a driver for local governments to protect and/or restore watershed health over time. We also recognize that solutions will be achieved through partnerships, collaboration and regional alignment of efforts."

Avtar Sundher
Government and Compliance Section Head
Environmental Protection Division, South Coast
Ministry of Environment

October 2011

How Does Water Get to a Stream?



Surface runoff
- *Minutes to hours*

Shallow groundwater
- *Days to seasons*

Deep Groundwater
- *Years to centuries*

In this workshop,
you will learn that the Water Balance Model
is a scenario comparison tool that…..

1. Supports 'sustainable rainwater management' because it:
   - Promotes an understanding of how water moves thru soil
   - Promotes an understanding of how trees intercept rainfall
   - Is used to evaluate performance targets
   - Links rainfall to stream health
2. Creates a vision of a future watershed because it:
   - Bridges engineering, planning and ecology
   - Promotes integration of perspectives
   - Enables informed decisions about land use choices
   - Enables informed decisions about green infrastructure practices

Road Map for Workshop

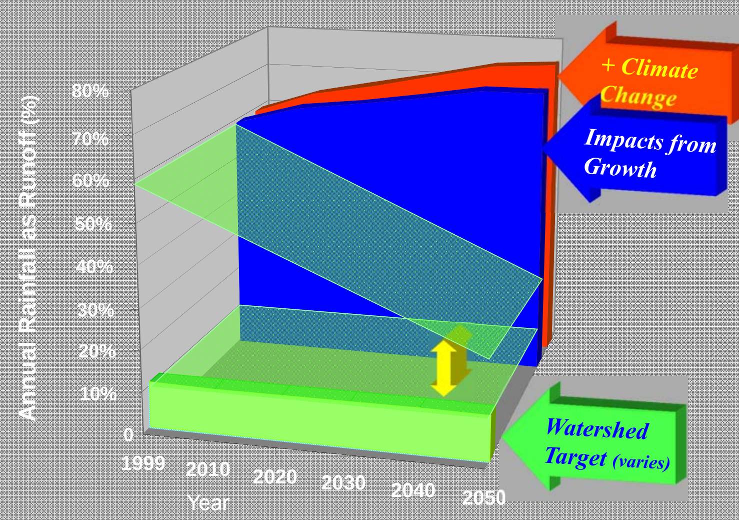
Part 1 – What Do You Know?
Introduce Core Concepts. Test Your Knowledge

Part 2 – What Do You Wonder?
Guide You Step-by-Step. Show You How to Use the Model

Part 3 – What Have You Learned?
Share Your Ah-Ha Moments. How You Will Apply the WBM

Genesis for Water Balance Model in 2000:

Demonstrate that we could make a difference at a watershed scale, over time, one property at a time



Historical Context for WBM Evolution

- 2000 – Water Balance Methodology developed
- 2001 – prototype WBM implemented on a spreadsheet platform
- 2001 – Water Balance Methodology incorporated in Guidebook
- 2002 – Stormwater Guidebook released by Province
- 2003 – web-based WBM launched at UBCM Annual Convention
- 2004 – outreach program rolled out in multiple regions
- 2007 – interface integrated with QUALHYMO engine
- 2008 – "Version 1.0" rolled out with "Living Water Smart"
- 2009 – received "Premier's Award for Innovation & Excellence"
- 2009 – "The Plan for the Future" released
- 2010 – federal / provincial RAC program funded 4 new modules
- 2011 – "Version 2.1" rebuilt on a Linux / Wordpress platform
- 2012 – "WBM Express for Homeowners" coming next

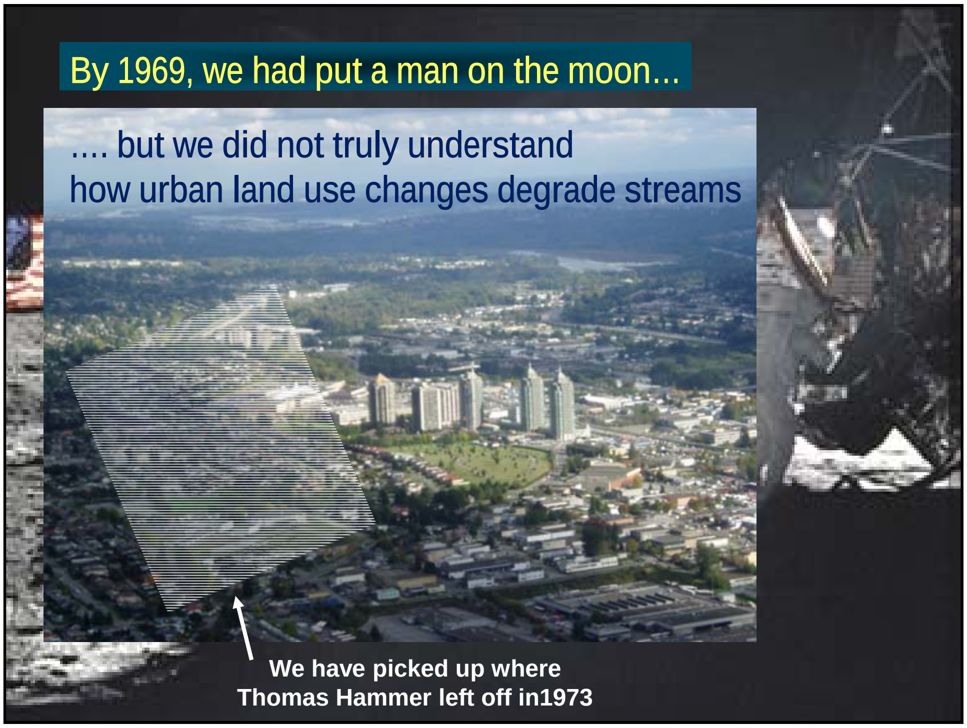
The Inter-Governmental Partnership developed the web-based WBM as an extension of the Guidebook to demonstrate HOW to achieve a lighter "water footprint"

Developed to support the "stormwater component" of a Liquid Waste Management Plan, the Guidebook…

- Provides
  - Direction
  - Principles and objectives
  - Guidance on how to do integrated planning
- Introduced
  - Rainfall spectrum
  - The "retain, detain, convey" strategy
  - Water balance methodology
  - Performance targets
  - Adaptive management framework

Historical Context for Evolution of Science-Based Methodologies

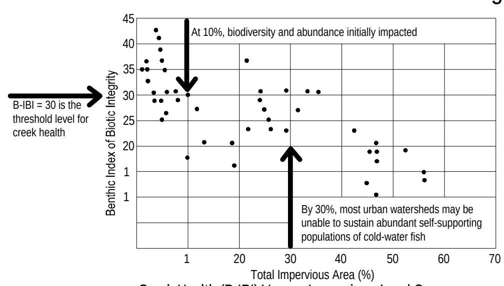
- 1973 – A glimmer of understanding when Thomas Hammer publishes his research findings on the relationship between land use changes and stream erosion
- 1996 – A year of breakthroughs by a number of pioneers results in a roadmap for integrated rainwater management
- 2000 – The need to re-invent urban hydrology to protect stream health in the Still Creek watershed in Metro Vancouver results in the "Water Balance Methodology"
- 2007 - The foundation for *Beyond the Guidebook*, the "Stream Health Methodology" brings together all the pieces to link the site to the watershed to



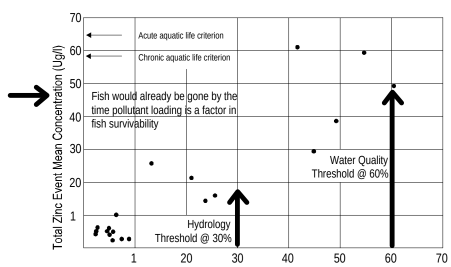
In 1996, Richard Horner and Chris May provided us with this road map for Integrated Rainwater Management:

1. Changes in Hydrology
2. Disturbance to Riparian Corridor
3. Degradation of In-Stream Habitat
4. Deterioration of Water Quality

Reference Levels for Land Use Planning

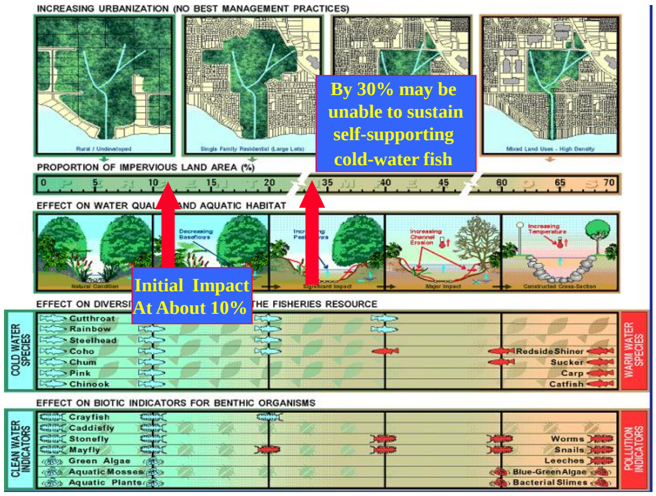


Creek Health (B-IBI) Versus Impervious Land Cover



Water Quality Versus Watershed Impervious Land Cover

First, we translated the 1996 Washington State biology research



Washington State Stormwater Managers Committee and the Center for Urban Water Resources Management, provided early access to the research findings and showed how to communicate what they meant

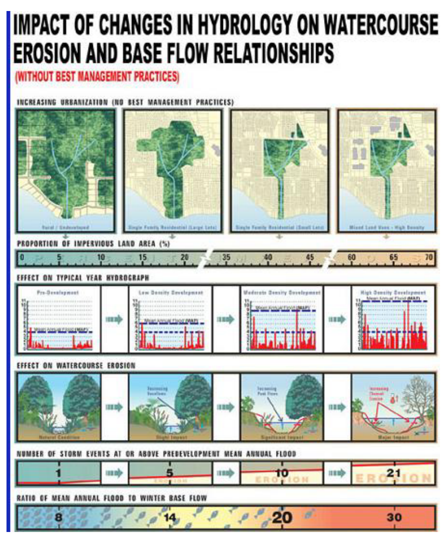
Then, we stepped back and looked at the relationship between hydrology and biology

Increasing Volume

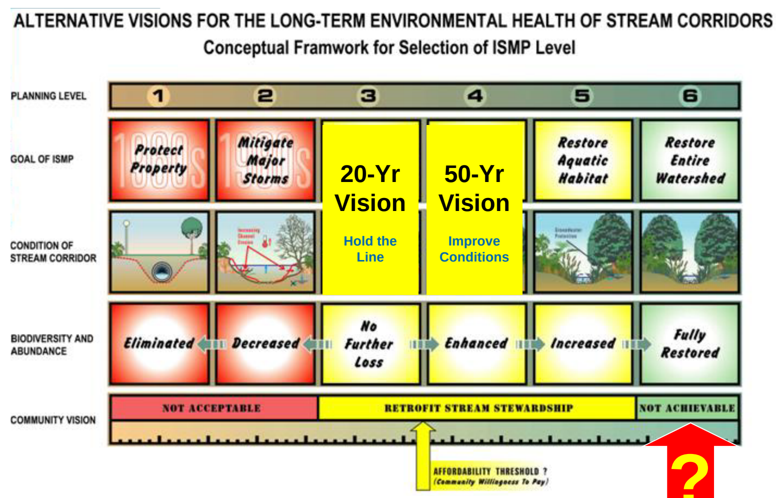
The Mean Annual Flood (MAF) is the 'channel-forming event'

When the MAF increases, the channel erodes to convey the additional volume

A consequence of channel instability is habitat degradation

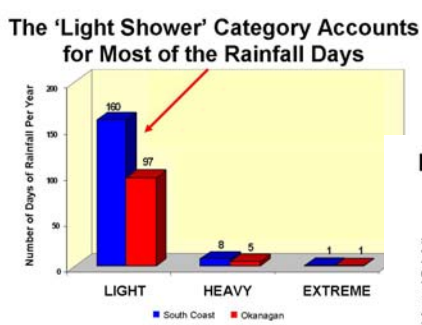


After that, we converted this science-based understanding into our first decision tool

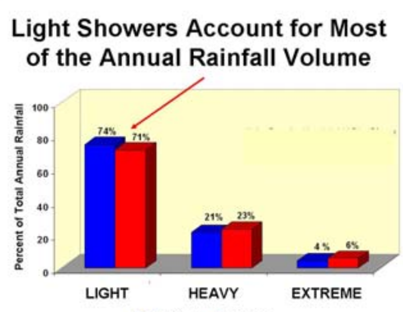


Now achievable?

In 2000, we went back to basics and developed the concept of a Rainfall Spectrum. This helped overcome fear and doubt.

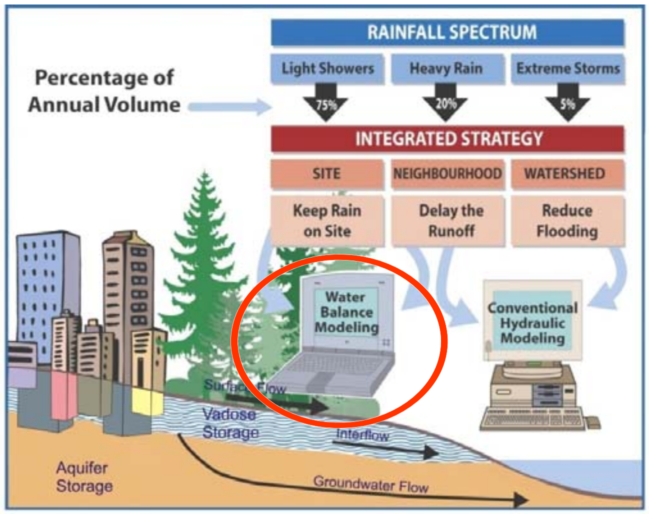


Days

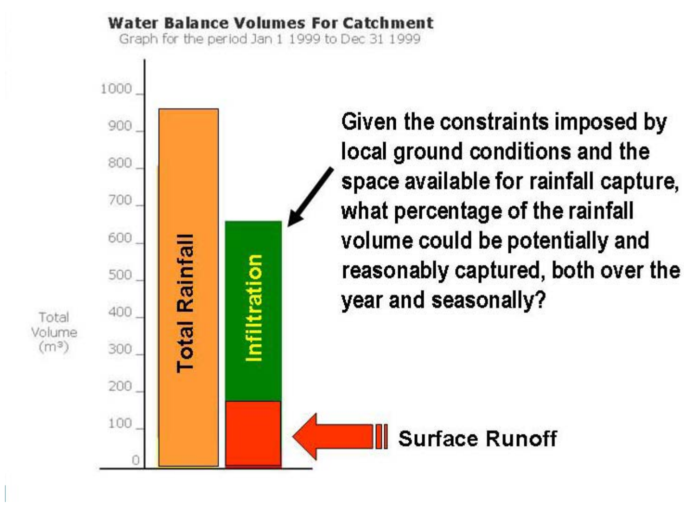


Volume

Understanding rainfall patterns resulted in the next decision tool:
Integrated Strategy for Managing Rainfall Spectrum



The Rainfall Spectrum then led into the concept of Performance Targets for rainwater runoff capture



WBM – Modelling Basics

What you should know:

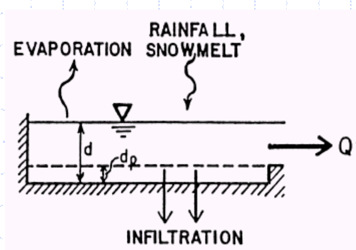
- Continuous Modelling
- Moisture Balance
- Soil Moisture Properties
- Stream Erosion
- Landscape-Based Measures for Volume Reduction and Flow Control
  - sometimes described as "LID" / "BMP" / "mitigation works"

WBM

- Data required
  - Rainfall
  - Precipitation
  - Temperature
  - Evaporation
  - Surface conditions
  - Soils – native and otherwise

How is Continuous Modelling Different?

Single Event Model

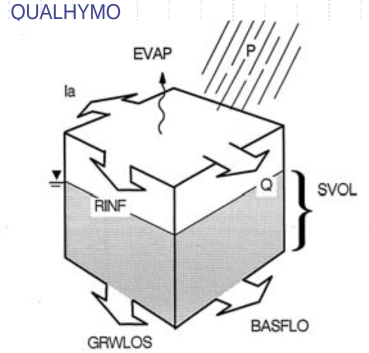


Source USEPA SWMM Manual

Only sees surface runoff

Continuous Model

QUALHYMO



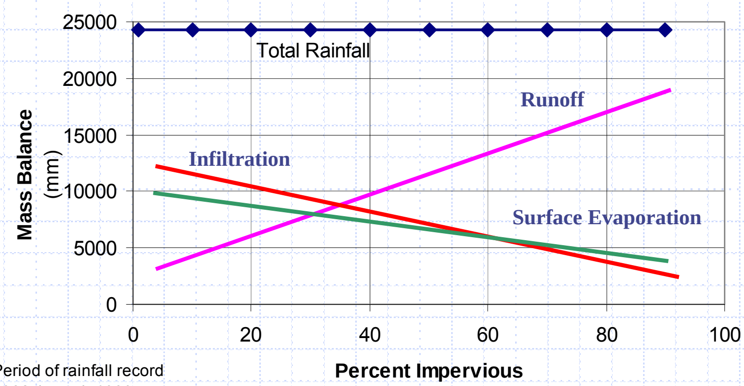
Includes shallow groundwater flow

More than just runoff

Continuous Simulation

- Objective to maintain stream flow duration
- Flow duration for habitat availability
- Use Tractive Force and Impulse to measure potential erosion
- Optimize systems to manage the impacts of the altered hydrologic cycle
- Can easily add sediment washoff to evaluate water quality

Hydrologic Change

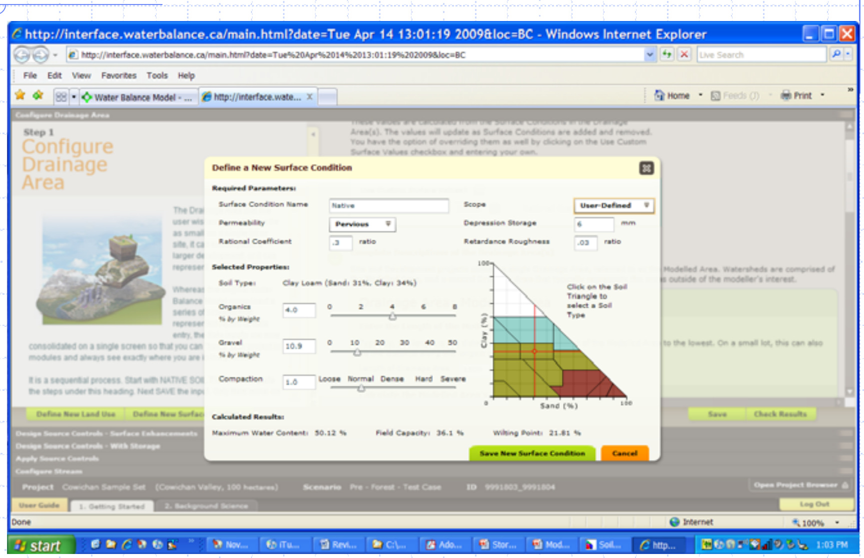


Period of rainfall record
1982 through 1999

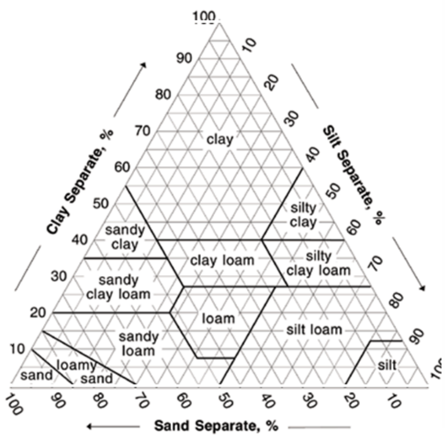
What is a native soil?

- Native soils are the surface soils that, in their natural location and condition, have been modified by weathering and have an accumulation of organic matter
- The Canadian System of Soil Classification describes the soil horizons above the Parent Geological Material
- These have regular exposure to surface water and can be very shallow or very deep
  - Typically about 600 mm

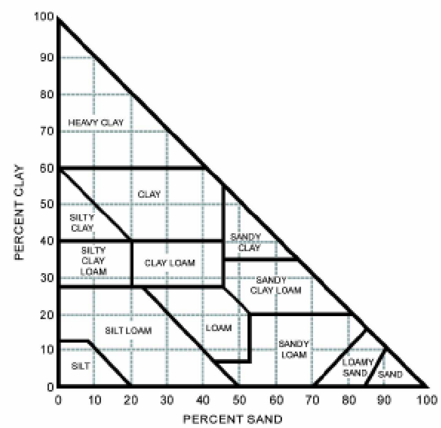
Soil Calculator in WBM



Soil Texture

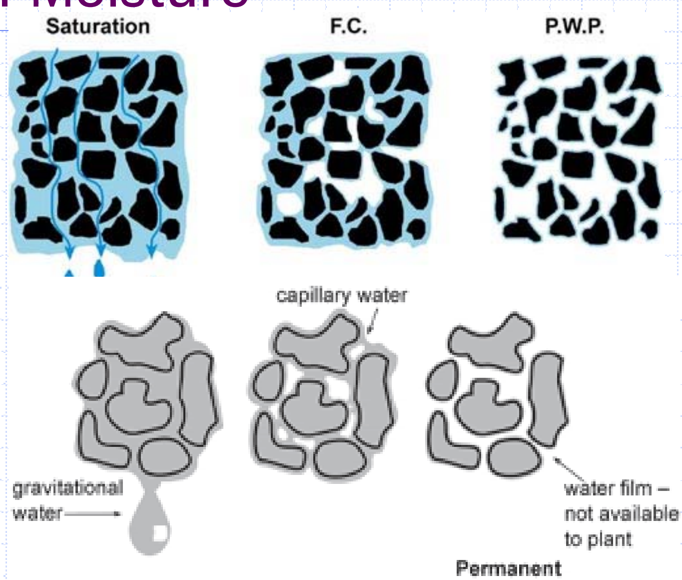


US Version

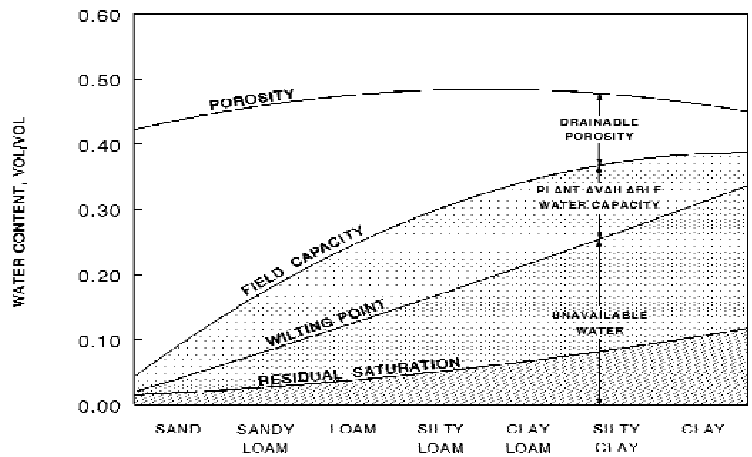


Canadian Version

Soil Moisture



Soil Moisture Relationships



Texture Class		Clay	Clay Loam	Loam	Loamy Sand	Sand	Sandy Clay	Sandy Clay Loam	Sandy Loam	Silt	Silty Clay	Silty Clay Loam	Silty Loam
Wilting Point	% volume	31.3	23.9	17.1	12.3	11.7	27.8	20.9	13.7	15.4	29.5	24.0	18.5
Field Capacity	% volume	41.8	35.9	28.6	14.5	12.1	37.7	29.9	20.3	33.9	41.3	38.5	33.7
Saturation	% volume	49.4	49.9	50.2	49.6	49.8	45.0	45.7	49.3	55.5	55.0	54.5	53.2
Saturated Hydraulic Conductivity	mm / hour	1.1	6.8	26.1	100.7	121.2	1.0	9.4	60.5	36.1	6.1	10.4	20.6
Bulk Density	g/cm³	1.34	1.33	1.32	1.33	1.33	1.46	1.44	1.34	1.18	1.19	1.21	1.24

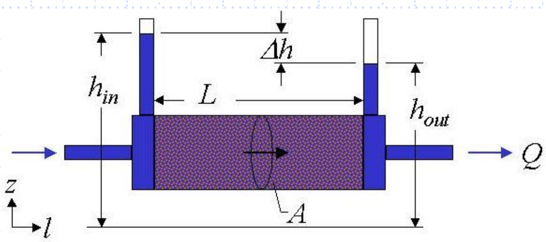
Infiltration or Permeability?

- Needed for Volume Reduction Systems
- Infiltration rate is not permeability
- Both have similar units
  - (distance / time)
- Infiltration measures flow crossing a surface boundary
- Permeability is saturated flow velocity through a porous media

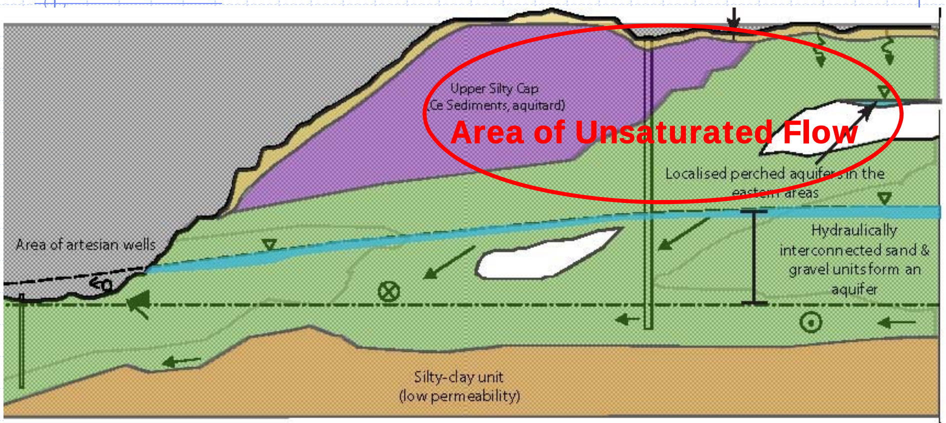
Darcy's Law

$Q = AK\,(\Delta h/\,l)$ (m³/s), or $V = K\,(\Delta h/\,l)$ (m/s)

A = flow area perpendicular to L (m²)
K = hydraulic permeability (m/s)
l = flow path length (m)
Δh = change in hydraulic head over the path L (m/m)



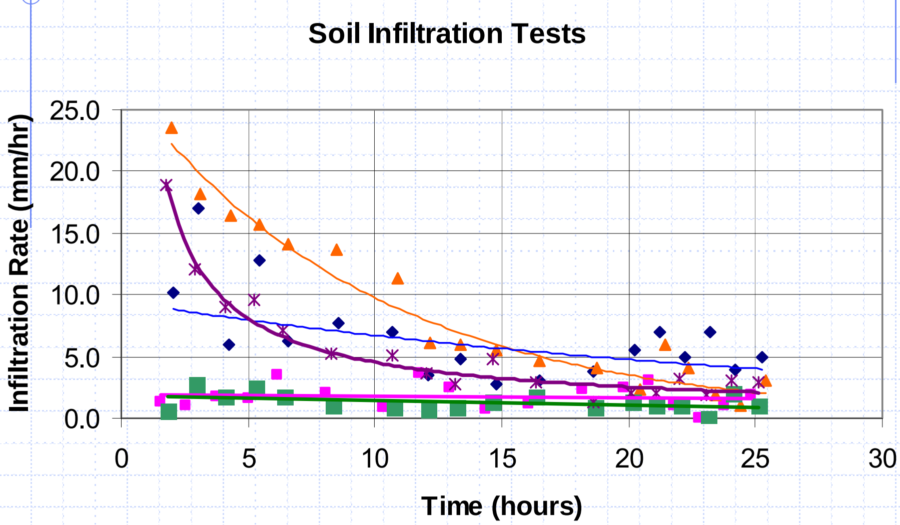
Groundwater



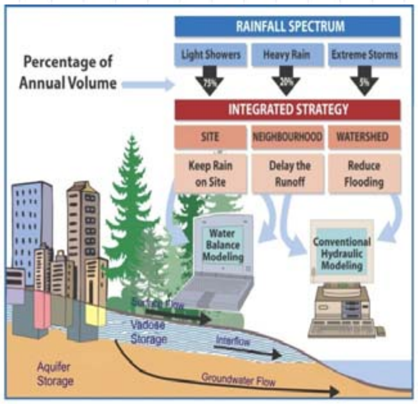
Source: Piteau East Clayton NCP Engineering Support Documentation

- East Clayton uplands to lowlands transition

Typical Subsurface Infiltration



How Does Water Get to a Stream?

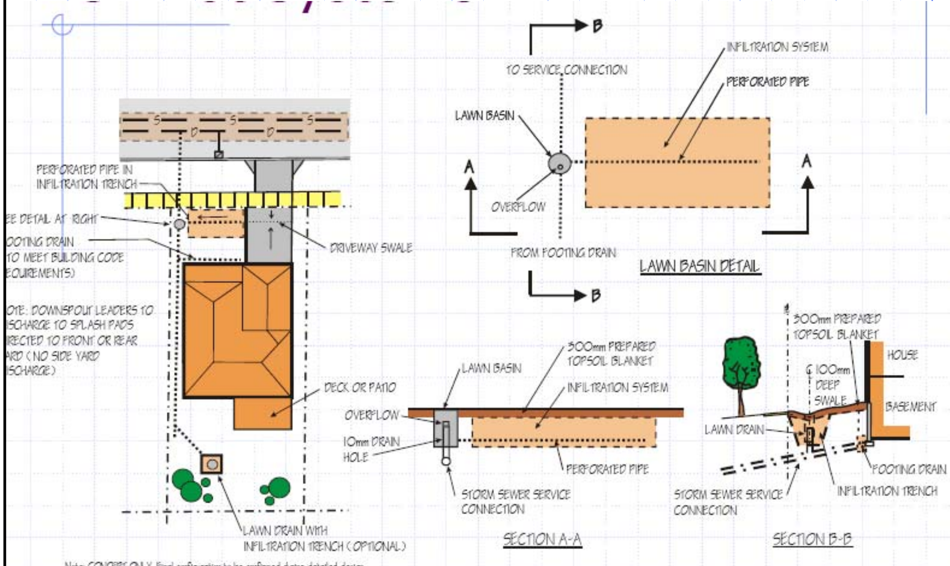


Surface runoff
- *Minutes to hours*

Shallow groundwater
- *Days to seasons*

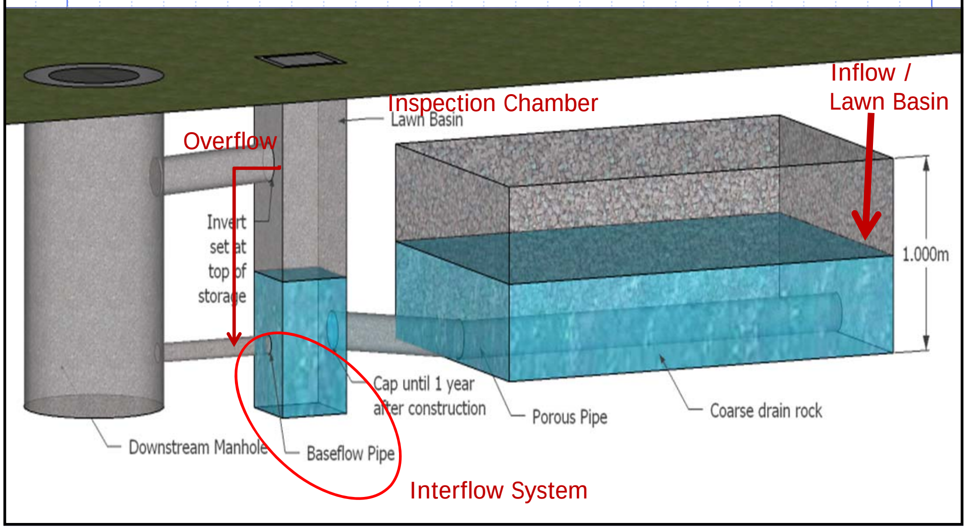
Deep Groundwater
- *Years to centuries*

On Lot Systems



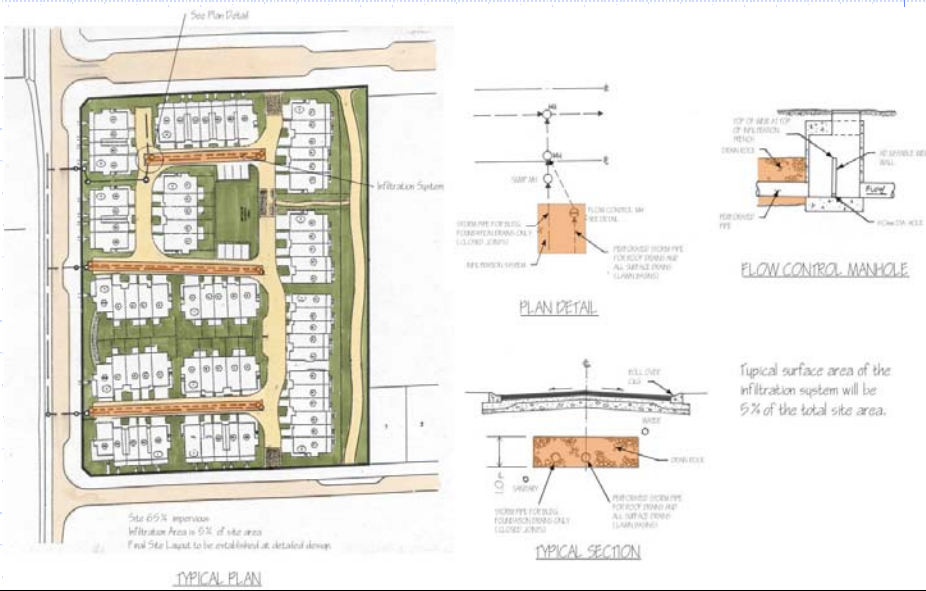
On Lot System

Important lessons:
1. Move the inflow upstream to allow treatment and minimize blockage of controls
2. Allow Interflow

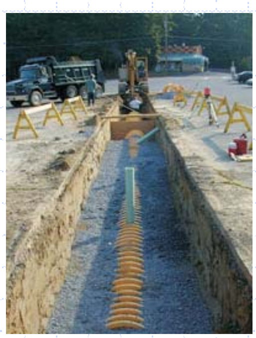


Atlantis Rain Tank

Typical Multi Family Lot



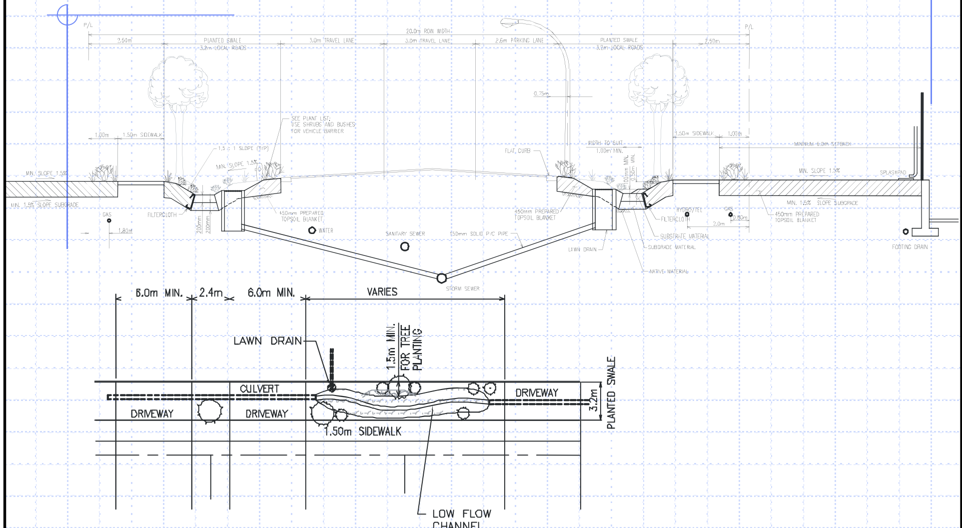
Stormtech



Green Street

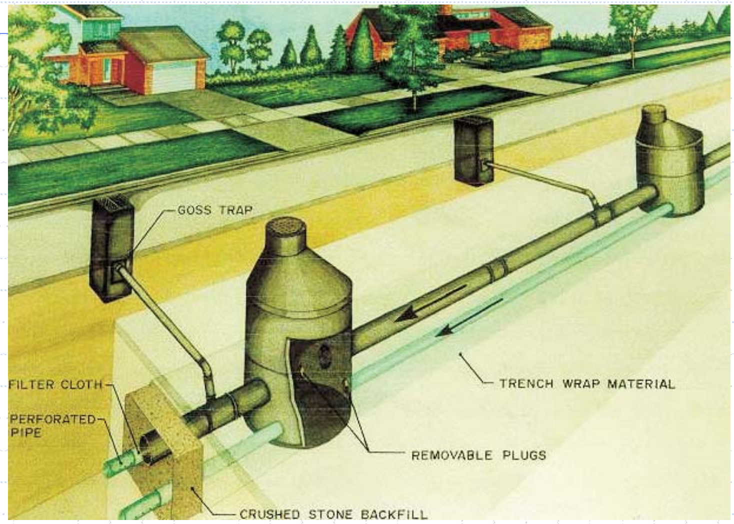
- Sea Street (Street Edge Alternative)

Green Street



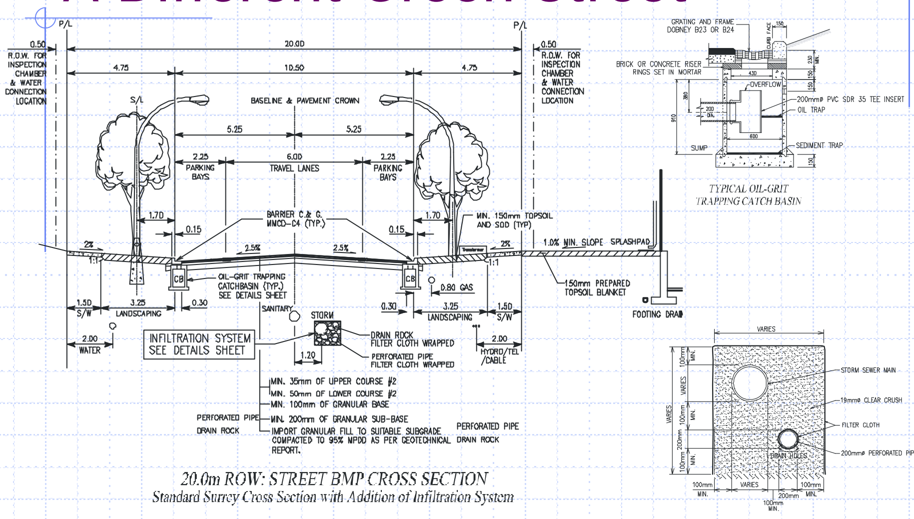
Swale Plan View (Typical)

Etobicoke Example



http://www.civil.ryerson.ca/urban/techno/stormwater/source/10-2-8/index.html

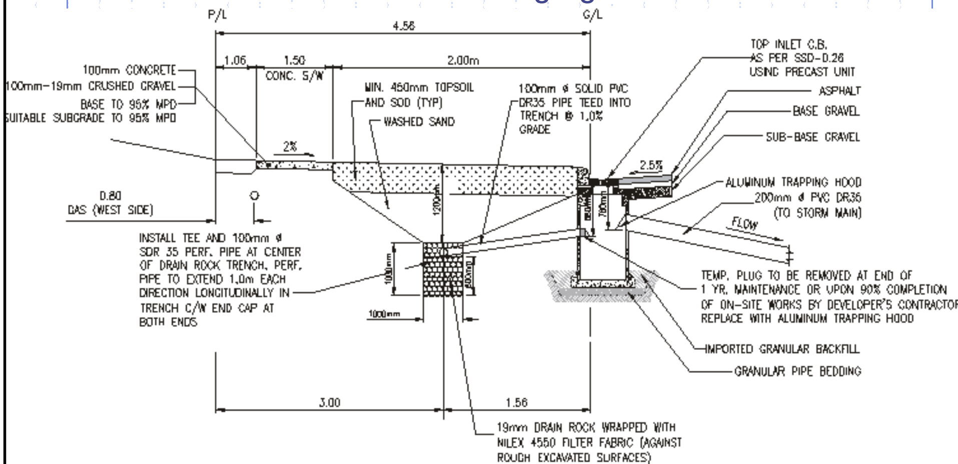
A Different Green Street



Implementing Etobicoke Example

Different Details

Infiltration system behind sidewalk
- High groundwater levels



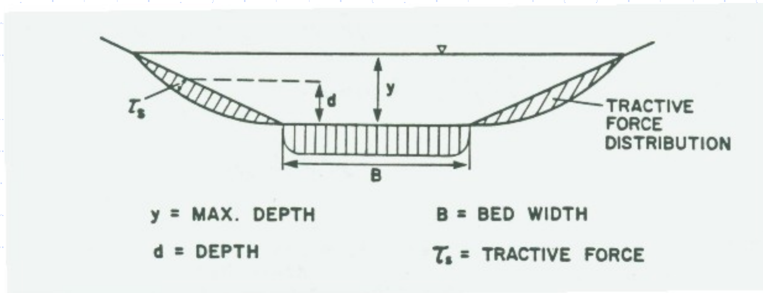
SUSTAINABLE DRAINAGE DETAIL X-SECTION

N.T.S.

Stream Erosion Calculations

Tractive Force

Based upon Tractive Force calculations



Tractive Force Equation

$\tau = \sigma R s$, where

σ = unit weight of water

R = hydraulic radius of flow, and

s = slope of channel

- Simple equation
  - Applicable for a wide, open channels
- Include banks for narrow channels
  - Banks are often the critical part

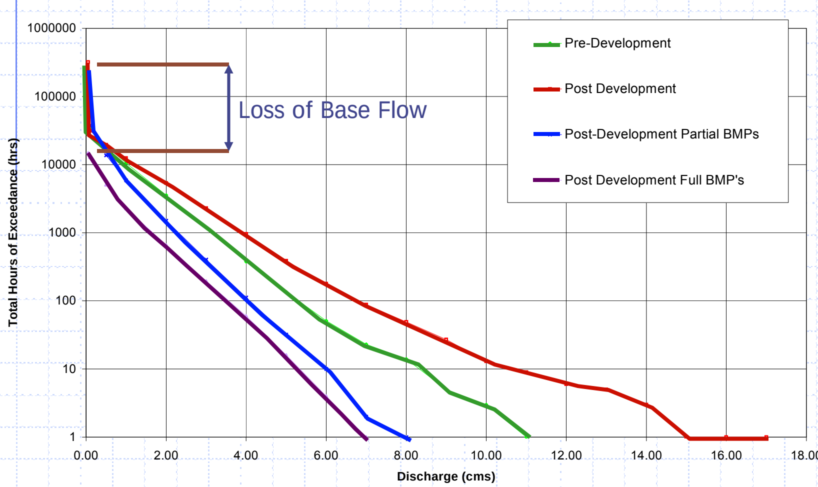
Impulse Equation

$I = \sum \tau P T$, where

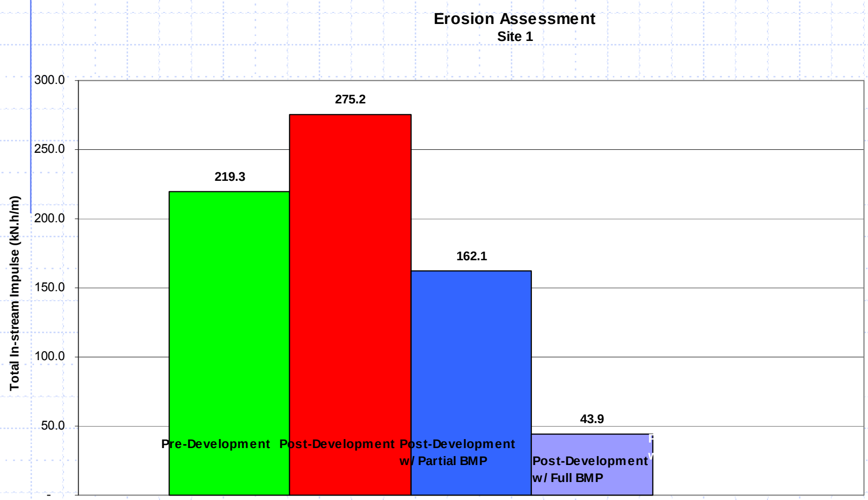
- τ = Tractive Force
- P = wetted perimeter
- T = time

- A measure of energy applied to the stream cross section in the form of friction
- Use duration of flow to estimate total Impulse for a range of flow depths
- Can exclude non-erosive tractive force
- Easy to include in continuous modelling

Exceedance - Fergus Creek



Stream Erosion - Fergus Creek



Road Map for Workshop

Part 1 – What Do You Know?

Introduce Core Concepts. Test Your Knowledge

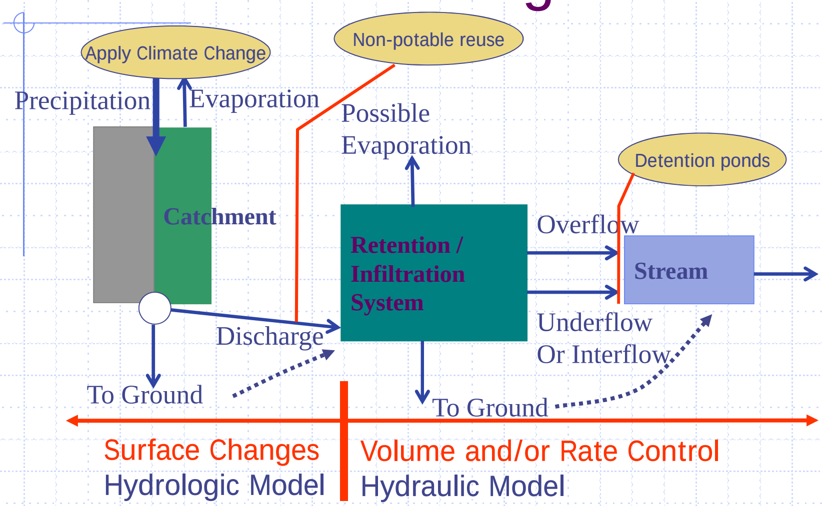
Part 2 – What Do You Wonder?

Guide You Step-by-Step. Show You How to Use the Model

Part 3 – What Have You Learned?

Share Your Ah-Ha Moments. How You Will Apply the WBM

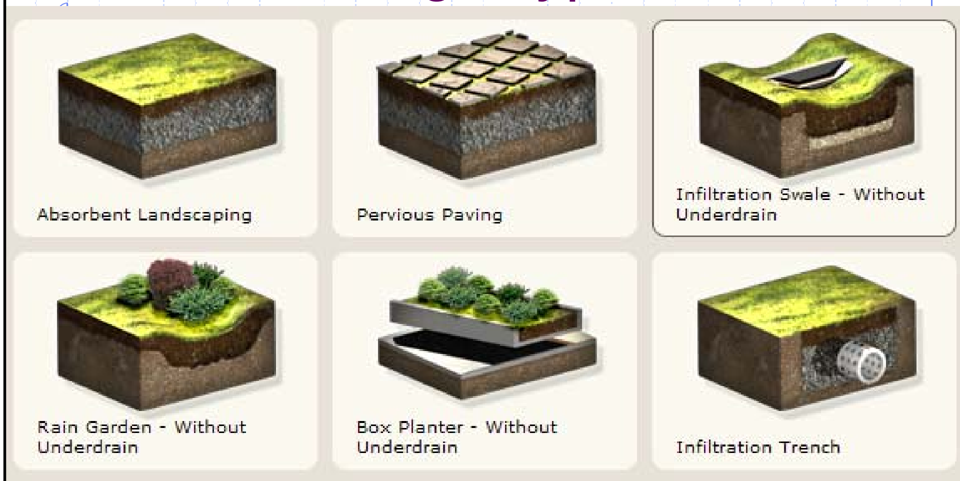
Model Process Diagram



Surface Changes

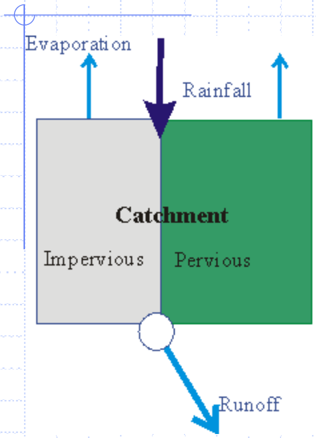
- Model Impacts and Mitigation
- Mitigation with Absorbent Landscapes
  - Tree cover density
  - Increased top soil depth
  - Porous pavement
  - Green Roof – Typical
  - Some infiltration swales – without storage

Surface Change Types



Replaces the area to which they are applied

Model Surface Changes



OPERATION

Modifies the surface to change absorption and runoff characteristics.

Alterations occur in:

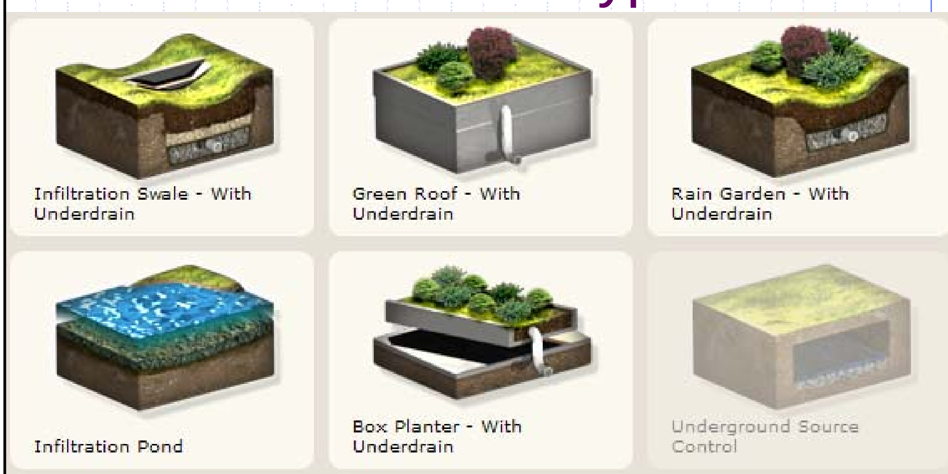
- Imperviousness
- Surface roughness
- Infiltration rates
- Soil moisture reservoir storage and potential capture

HYDROLOGIC MODEL

Volume Reduction Systems

- Capture discharge and **STORE** it
- Infiltration for volume reduction
  - Rain gardens
  - Infiltration swales with storage
    - Surface or subsurface storage
  - Infiltration ponds
  - Underground galleries

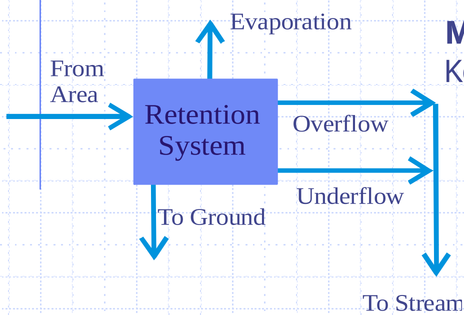
Volume Reduction Types



Surface types have evaporation, underground systems do not

Surface types replace the area to which they are applied

Model Volume Reduction Systems



OPERATION

Modifies runoff

Key parameters:

- •Volume of storage
  - depth and area
- •Infiltration rate to ground
- •Underflow rate - baseflow
- •Overflow rate
- •Surface or subsurface
  - evaporation or not

HYDRAULIC MODEL

Process:

Qin = Qout + Change in storage

They all work the same way

Hydrologic Design - DFO Guidelines 2004

- "Runoff will be modelled using continuous simulation"
- "Single event models are acceptable for preliminary sizing of BMP's and conveyance systems if multiple event scenarios are modelled"

This is our starting point

WBM

- Data required
  - Rainfall
  - Precipitation
  - Temperature
  - Evaporation
  - Surface conditions
  - Soils – native and otherwise
  - Stream information

WBM Supplies (Rainfall, Precipitation, Temperature, Evaporation)

User Supplies Project Data (Surface conditions, Soils – native and otherwise, Stream information)

Road Map for Workshop

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Attachment C:

Article in Stormwater Magazine

November 2011

Rainwater Management in a Watershed Context

What's the goal?

BY KIM A. STEPHENS AND JIM DUMONT

This article is written from a British Columbia perspective. It connects the dots between recent developments in the United States, such as *A Strategic Agenda to Protect Waters and Build More Livable Communities Through Green Infrastructure* released by EPA in April 2011, and comparable initiatives that have been underway in British Columbia for the past decade. A key message is that we are observing a convergence of understanding. On both sides of the 49th parallel, light bulbs are going on about the inter-connectedness of green infrastructure and water sustainability, and the implications for watershed health. We hope that this article will stimulate a cross-border discussion on the relative effectiveness of an educational versus prescriptive approach to leading and implementing change.

The View From British Columbia

In both Canada and the US, there is a growing green infrastructure movement. This reflects a heightened public awareness of the need to build our communities differently. Also, land use and infrastructure professionals increasingly appreciate that effective green infrastructure is at the heart of responsible rainwater management. As a result, there is a shift away from pipe-and-convey solutions to ones that embody "designing with nature" to protect our streams and fishery resource.

Looking back, 2008 was a defining year for green infrastructure on Canada's west coast. The government of British Columbia put in place a policy framework that is a "call to action" on the part of local governments. This call to action is underpinned by the notion of shared responsibility—that is, everyone needs to understand and care about the goal. If all the players know their role in relation to the goal, then together we can create the future that we all want.

A key message is this: *A science-based understanding of the rainfall-runoff process is the foundation for designing with nature and implementing green infrastructure that is truly effective in protecting watershed and stream health.*

Similar Vocabulary, Different Goals. From our British Columbia vantage point, it has been fascinating to observe the evolution in American practitioner thinking in recent years. While land-use and infrastructure professionals are using a similar vocabulary on both sides of the border, our goals appear different. The apparent divergence has significant implications for rainwater management in a watershed context. The genesis for this divergence is found in geography and governance:

- Geography: British Columbia is primarily a mountainous region. Headwater tributary streams are a predominant feature. Watershed health is very much about protection of aquatic habitat. This contrasts with the water-quality emphasis in the US.
- Governance: The American approach is top-down and prescriptive. British Columbia has embraced a bottom-up approach that relies on education, enabling tools and consensus to turn ideas into action.

We are culturally different, yet we can learn from each other, and we each can adapt lessons learned by the other. The power of the enabling approach is the ability to leapfrog ahead when the science leads us to a better way. Cross-border sharing between British Columbia and Washington state, for example, has led to breakthroughs in understanding the cause-and-effect relationship between land use change and stream health.

The approach we have taken in British Columbia differs from that of the United States EPA, due to the nature of the root problems being solved. The critical issue in British Columbia is the damage and loss of habitat caused by development and erosion of the headwater streams. The focus is in direct response to Canada's Fisheries Act that prohibits damage of fish habitat.

EPA has focused upon water quality in the main stems and coastal waters and seeks to restore the resources of those waters through the goals and objectives of the Clean Water Act. The EPA focus has led to initiatives such as a State Nitrogen and Phosphorus Reduction Framework that states can use to develop strategies that address the degradation of drinking water and environmental quality, developing "pollution diets" for impaired waters, and controlling polluted runoff in the Chesapeake Bay.

Same Science, Different Paths Forward. In this article, we tell the story of how British Columbia and Washington state had the same understanding of the science in the late 1990s, but then moved along diverging pathways. This divergence reflects the markedly different roles played by the federal government in each of our two countries.

Genesis for Cross-Border Collaboration With Washington State

Washington state and British Columbia are geographically similar, with a wet coast and a relatively dry interior separated by mountain ranges. On the coast, Washington's Puget Sound and British Columbia's Georgia Basin together comprise the Salish Sea. The bulk of the two populations reside in this Pacific Northwest bioregion. In terms of how rainwater management in a watershed context has evolved, there is a history of cross-border sharing and collaboration.

A Shared Goal to Protect Salmon Habitat. The catalyst for collaboration was the salmon crisis of the 1990s. On both sides of the border, the salmon is an icon. It is also the early warning system that there is a problem. Coastal salmon runs such as coho, chum, and pink spawn and rear in the headwater streams, which are typically small, and their ecosystem value was not fully appreciated a generation ago. The result: streams were being lost as a consequence of rapid population growth and land development. This lack of understanding and respect contributed to the decline of many wild salmon populations. And so the goal of protecting stream health became a driver for action on both sides of the border. An environmental ethic led some water resource practitioners to rethink how we design and build communities.

Among those leading change, Bill Derry has had a profound influence on both sides of the border. In the 1980s, he was one of the first stormwater utility managers in Washington state. He believed so strongly in the need for scientifically defensible research that he convinced his fellow utility managers to organize and fund a research centre at the University of Washington. He was a founding director of the Center For Urban Water Resources Management. Though he is now retired, the mission continues: Currently, Bill Derry is president of People for Puget Sound.

A Science-Based Road Map for Integrated Rainwater Management. In 1996, the Center for Urban Water Resources Management published the landmark findings of Richard Horner and Chris May. Their seminal paper synthesized a decade of research to identify the factors that degrade urban streams and negatively influence aquatic productivity and fish survival. The four factors limiting stream health are shown in Table 1 in order of priority.

Table 1. Factors Limiting Stream Health

Ranking	Limiting Factor
1	Changes in hydrology
2	Distrubance and/or loss of integrity of the riparian corridor
2	Degradation and/or loss of aquatic habitat within the stream
4	Deterioration of water quality

When published, this ranking shook conventional stormwater management wisdom in the Pacific Northwest to its foundation. If the goal is protection of aquatic resources, it proved that a water-quality-driven program would not achieve the goal. Figure 1 illustrates the research findings for changes in hydrology (#1) and deterioration in water quality (#4). Two key messages flowed from this research: salmon would already be gone by the time pollutant loading is a factor in salmon survivability; if we get the hydrology right, water

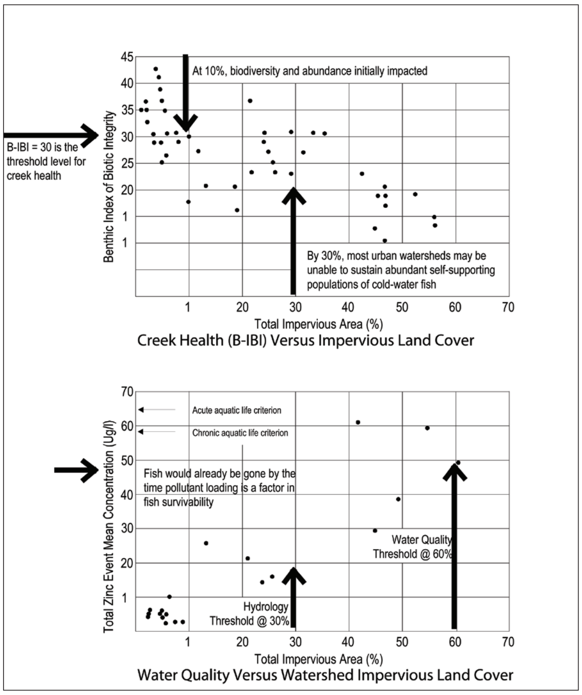

Figure 1. Reference levels for land-use planning

quality typically takes care of itself. The four factors provide a road map for integrated rainwater management.

A Springboard to British Columbia's Guidebook. Derry communicated the science in a way that was easy for his audiences to embrace. His teaching resonated with local governments in British Columbia. A series of workshops and forums in the late 1990s jump-started an ecosystem approach that integrates rainwater/stormwater management and land use planning. In particular, the stream health findings by Horner and May gave British Columbians a springboard to reinvent urban hydrology. Released by the Province in June 2002, *Stormwater Planning: A Guidebook for British Columbia* is a transformational document. It quickly became a catalyst to implement a "design with nature" approach to rainwater management and green infrastructure.

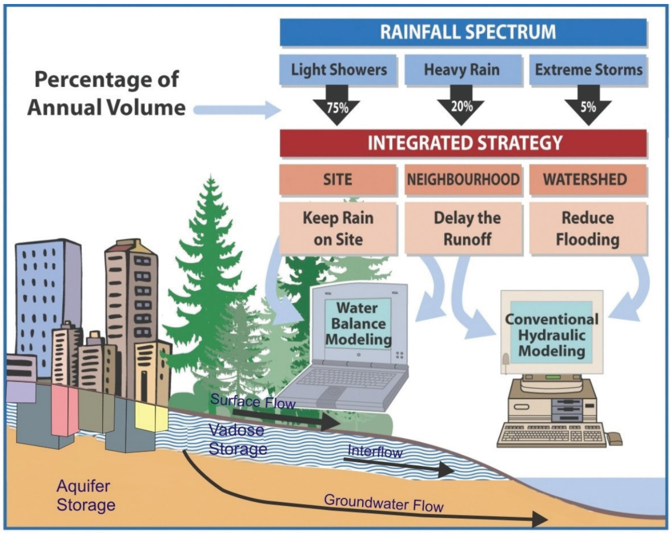

Figure 2. Rainfall and groundwater flow

Stormwater Planning: A Guidebook for British Columbia

The Guidebook advanced this provocative premise: *Land development and watershed protection can be compatible.* In 2002, this radical shift in practitioner thinking resulted from recognition of how a science-based understanding could bridge the gap between high-level policy objectives and site design practices. A key to the breakthrough in thinking and approach was developing the concept of the rainfall spectrum and translating the concept into an integrating strategy (Figure 2).

The Guidebook was a catalyst for action, providing:

- direction
- science-based principles and objectives
- guidance on how to do integrated planning

It introduced these core concepts:

- rainfall spectrum
- the "retain, detain, convey" integrated strategy
- water balance methodology
- performance targets
- a "learn by doing" adaptive framework

Watershed Restoration Is Achievable. The Guidebook applied a science-based understanding to show that we can lighten the hydrologic footprint, developed the water balance methodology to establish performance targets for rainfall capture, and demonstrated that urban watershed restoration could be accomplished over a 50-year timeframe as and when communities redevelop.

Over the next five years, British Columbia practitioners became comfortable with what "rainfall capture" meant in practice. The evolution in watershed thinking was captured in *Beyond the Guidebook: Context for Rainwater Management and Green Infrastructure in British Columbia*, released in June 2007. By addressing the relationship between rainfall capture and resulting flow rates in streams, *Beyond the Guidebook* picked up where the Guidebook left off in 2002. Where the Guidebook emphasizes rainfall capture (volume control) at the site scale, *Beyond the Guidebook* focuses on the relationship between volume control and resulting flow rates in streams.

Beyond the Guidebook foreshadowed *Living Water Smart, British Columbia's Water Plan* and the *Green Communities Initiative*, both of which were launched by the province in 2008. These established an over-arching provincial "design with nature" policy framework. There is now clear guidance for aligning local actions with provincial and regional goals.

British Columbia and Washington State on Diverging Paths

Later in 2007, a cross-border panel session at a joint Washington State-British Columbia conference held in Seattle created an opportunity to take stock of how each region had progressed a decade after the work of Horner and May had provided a common point of departure. The panel introduced this question: Is rainwater management on diverging paths in British Columbia and Washington state? Subsequently, the panel collaborated on a paper for the American Water Resources Association that reflected on the American *top-down prescriptive* approach versus a Canadian *bottom-up educational* approach.

In October 2011, the Salish Sea Conference creates another opportunity to compare notes on what each region has accomplished since 2007.

What Is Holding Washington State Back? Ed O'Brien, representing the Washington State Department of Ecology on the panel, posed and answered this question in 2007: *What is holding Washington state back?* "Locally, our knowledge was and still is way ahead of the federal game because of Puget Sound Plan initiatives and a few forward-thinking local governments. The federal rules impede our progress in implementing strategies and requirements that we know are necessary.

"In Washington State, we cannot achieve environmental protection using current methods of development. Not many new developments are applying low impact development techniques. There isn't a land use dictator who can demand change. It will take public education to instill a culture change for us to have any hope that we can protect aquatic resources in the urban environment," concluded O'Brien.

In 2011, Derry reflected on the Washington state situation as follows: "In the late 1970s and 1980s, Washington state jumped out ahead of most of the nation because several stormwater utilities were formed (the first in the nation). Formation of the stormwater utilities resulted in financial, technical, and staff resources that were focused on stormwater issues. Local stormwater managers recognized the need for more technical information to help make more informed stormwater management decisions. This led to the formation of the Center For Urban Water Resources at the University of Washington. This Center conducted and disseminated the seminal body of work now used internationally by stormwater managers. Many municipalities used this information to update their regulations and management practices. But there was a wide disparity between local municipalities in their regulations and management practices.

"Due to political pressures many jurisdictions will not adopt the necessary programs to protect environmental resources until required to do so. Once a state permit program was initiated, the previously cooperative approach between the state and local municipalities became adversarial. There are extended negotiations over the requirements of the permits. Now after several years of living with state municipal stormwater permits there is more consistency between jurisdictions, but the bar has been lowered for environmental protection. For example, a recently proposed regulation to require Low Impact Development (mandated by court order) is so full of exemptions that it is essentially voluntary.

"The American system seems based on political compromise which means that with each compromised decision environmental resources lose some more," concluded Derry.

How British Columbia Is Creating Change. Kim Stephens provided this British Columbia perspective in 2007: "We are creating change through on-the-ground partnerships. Finding the right solution is an outcome of sharing a vision about what we want our communities to look like, not because a government agency prescribed a regulation. For us, *designing with nature* has become a rallying cry. In British Columbia, we have made a conscious decision to go the educational route. It is all about establishing expectations and creating an environment that encourages innovation and gets practitioners excited about what they are doing. The culture is changing."

Take Stock and Look Ahead. Our impression is that the efforts of both EPA and British Columbia may be moving closer. The National Lakes Assessment, the first-ever comprehensive assessment of lakes in the United States, found that habitat loss and nitrogen and phosphorus pollution are leading causes of impairment. Similarly, the objectives of *A Strategic Agenda to Protect Waters and Build More Livable Communities Through Green Infrastructure* could lead the United States to pay closer attention to the pioneering work of Horner and May and others. Perhaps when EPA focus shifts from water quality to include habitat loss, the lessons learned in British Columbia can be reviewed and incorporated into the policies and objectives of EPA.

In British Columbia, our focus has been on stream habitat (for the reasons explained earlier in this article). Looking ahead, our emphasis may shift to include water quality once the efforts to mitigate habitat damage become universal and effective practice. This could lead to the next evolution in creating a greener and more sustainable environment for each unique watershed.

"Cross-border communities, stream keepers, and First Nations (Tribes) have been meeting to discuss shared waters issues and to share information since the 1990s. Some combined projects have gone forward looking at circulation and pollutant transport pathways plus coordinated monitoring specifically for data sharing. By working together with available resources and sharing findings, we can better meet watershed goals of improved water quality and ecological health on both sides of the border," observes Carrie Baron, manager of Drainage and Environment with the City of Surrey, British Columbia's second largest city.

Science-Based Foundation for Designing With Nature

In British Columbia, we have built on the foundation provided by the pioneering work of Horner and May and others, including Derek Booth, R. Christian Jones, John Maxted, Craig MacRae, and Ivan Lorent. They questioned common wisdom, they undertook original research, and they provided us with a science-based understanding of the importance of changes in hydrology. Their work yielded guiding principles that are standing the test of time. We continue to enhance their pioneering work.

Given the foregoing frame of reference, the authors of this article wish to inform or remind today's water resource practitioners of the lasting value of this pioneer work. This is the foundation of our evolving knowledge of the impacts of urban development and the impacts upon the aquatic environment. Our understanding of the current state of knowledge allows us to question our common wisdom and to apply corrections where appropriate. In this manner we are continuously improving and including sound reasoning backed up by demonstrable science.

Next, we introduce and briefly describe building blocks that constitute the science-based foundation for rainwater management in a watershed context. We:

- highlight the significance of the pioneer research,
- elaborate on how the concept of the rainfall spectrum has led us look at rainfall differently in British Columbia,
- examine the hydrograph for a typical year,
- describe the relationship between stream erosion and stream health, and
- explore the implications of disrupting how rainfall reaches the stream.

Truly understanding the rainfall-runoff process allows us to implement "design with nature" designs that soften the footprint of development.

Learn from the Pioneers. 1996 stands out as a year of breakthroughs. We have already discussed the significance of the Horner and May contribution in demonstrating the order-of-priority for factors limiting the ecological values of urban streams. In that same year Jones, Maxted, MacRae, Horner, Booth, Azous, and May presented papers at an Engineering Foundation Conference sponsored by the Urban Water Resources Research Council of the American Society of Civil Engineers. Their research findings are important because:

- Jones and Maxted indicated that the biological stream community were impacted by urban development in spite of the engineering application and implementation of stormwater best practices.
- MacRae indicated that the use of detention basins to simply restrict flows to predevelopment rates would increase the rate of stream erosion and that different criteria were needed, and proposed an alternative based upon maintaining the distribution of shear stress across the channel from pre to post development conditions.
- Horner, Booth, Azous, and May condensed the findings of a number of studies to conclude that coho salmon populations were greatly affected by development that included less than 10% impervious area, and water quality and concentration of metals in sediments did not change much until imperviousness approached 50%. As urbanization increases above the 60% impervious level, water and sediment chemistry will become biologically more important.

The findings by MacRae validated the earlier work of Ivan Lorent, published by the Ontario Ministry of Natural Resources in 1982. Lorent undertook a study to clarify the understanding and the processes involved in stream erosion. He questioned the common wisdom that suggested matching pre- and post-development discharge rates was an adequate method of avoiding environmental impacts. In 1982, Lorent demonstrated that the design standard using rate control to match post-development flow rates to predevelopment rates could result in increased stream erosion.

Understand the Rainfall Spectrum. Figure 2 shows the rainfall spectrum graphic that is the branding for the Water Balance Methodology presented in the Guidebook. This was the outcome of looking at rainfall differently in British Columbia. Our reassessment of rainfall has led us to a better understanding of how rainfall fits into the overall picture:

- Typical Frequency Distribution of Annual Rainfall: Figure 3 shows the number of days with rainfall. These are divided into three volume categories based upon the mean annual rainfall (MAR) event. The vast majority of wet days would have small amounts of rainfall, and statistically only a single day would typically equal or exceed the MAR amount. This underscores that the impacts to streams are driven by small events, not those used in designing drainage conveyance systems or flood protection works.
- Typical Volume Distribution of Annual Rainfall: When we compare the volume of rainfall associated with the size of the event in Figure 4 we can see even more interesting indications of the source of the impacts. The majority of the rainfall volume occurs in very small events, with only about 5% coming from the larger return period events that might be approaching the size of those used for design of drainage systems and flood protection.

The insight gained from examining rainfall patterns leads us to ask whether it is appropriate, or even correct, to use less-frequent events with a greater return period to examine the impacts to streams. A typical year of rainfall and stream discharge is shown in Figure 5. This illustrates a core concept underpinning *Beyond the Guidebook.*

Understand What Happens During a Typical Year. Figure 5 shows that the larger of two rainfall events resulted in much less runoff. The

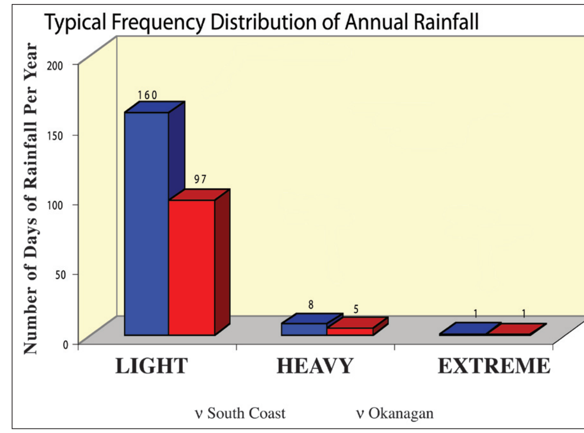

Figure 3. Number of days with rainfall

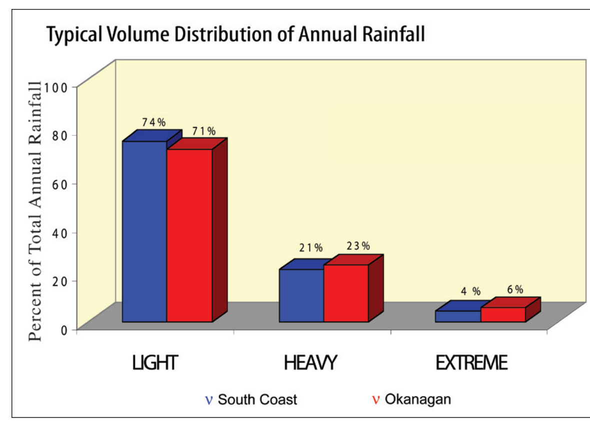

Figure 4. Rainfall volume in storm events

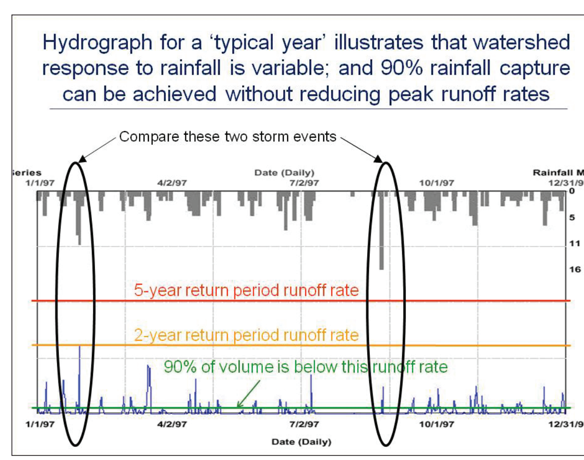

Figure 5. Watershed hydrograph for a typical year

smaller event was preceded by a period of wet weather such that more runoff resulted. The hydrograph also shows that 90% of the total annual runoff volume corresponds to a very small runoff rate. The implication of this finding is that the 90% can easily be managed through rainfall capture measures. For the other 10%, it is a matter of detaining and conveying in accordance with the integrated strategy for managing the complete rainfall spectrum (Figure 2).

Additionally, retaining 90% on site would have little effect on peak runoff rates unless other practices are brought to bear. This implies that retaining 90% of the rainfall is only a part of the requirement for an effective rainwater management system. This underscores the need to manage the complete rainfall spectrum.

Understand the Relationship Between Stream Health and Stream Erosion. Stream health is a function of streamflow duration, and therefore correlates with stream erosion. Flow duration is something that we can measure and verify. We can also assess the potential for erosion or sediment accumulation within a watershed.

Several quantitative indicators can be utilized in assessing the potential for erosion or sediment accumulation within a watershed. The methodology is based upon shear stress as applied to the stream bed and banks over time. This is a measure of the energy available to cause erosion in a stream. Continuous hydrologic simulation is the key to evaluating multiple development scenario comparisons.

Using long-term climate records to calculate stream discharge means that the durations and frequencies of various occurrences within the watershed and stream can be estimated easily. Also, this approach leads us into examining the hydrograph for the entire year, not just one or two big events that may be associated with flooding.

Continuous hydrologic simulations and this methodology have been used as the basis for developing the Water Balance Model (*www.waterbalance.ca*) as part of an ongoing process to advance the science of environmental mitigation.

"The lesson is that the interflow system is an incredibly important and yet fragile component of a watershed. It is critical for maintaining stream health and our fishery resource."

Understand How Water Reaches the Stream. If rainfall is captured to reduce site discharge, how does the water then get to the stream, and what are the processes and timelines? Figure 2 shows the generalized flow patterns of natural and post developed conditions.

"Rainwater management has developed far beyond the simplistic assumptions that created the detention ponds of the 1980s. It is now time to take another leap forward, albeit by moving sideways, and recognize near surface lateral water flow, otherwise known as 'interflow'," states Alan Jonsson, habitat engineer with Fisheries and Oceans Canada.

"Interflow is often the dominant drainage path in glaciated landscapes of British Columbia. Even undeveloped sites that are founded on till and bedrock rarely show overland flow because of interflow pathways. Interflow has been traced flowing at velocities that are 1/200th as fast as channel flows on a similar gradient. It is not hard to imagine the beneficial effect that this has in prolonging flows from rainfall to first-order streams.

"Unlike deeper aquifer fed groundwater, interflow water is often rich in dissolved organic carbon and other nutrients. It is this flow that feeds hundreds of small ephemeral streams throughout the Lower Mainland (in the southwest corner of British Columbia) where more than half the population resides. Such streams provide important salmonid food supply and rearing habitat. In some cases, they may even support Coho spawning.

"When we acknowledge the role of interflow and its incredible ability to absorb and slowly discharge precipitation, we are led to the realization: a watershed's hydrology can be severely degraded without any increase in impervious area. All that is required is a loss of functional soil layer and/or the addition of ditches or perforated pipes and presto, one 'urbanized' watershed. Conventional watershed health metrics such as total impervious area can under estimate impacts where interflow dominates.

"Unfortunately, it is a rare thing to find a rainwater management practitioner that ever 'thinks sideways.' How many times have we all heard 'There's no infiltration on this site'? The challenge for engineers is to determine the influence of interflow on a site and then design and implement techniques that replace or restore it. Our present patterns of land development often seem perfectly suited to ensuring the elimination of interflow. Utility trenches, basements, discontinuous soil, and highly compacted soils all work together to deprive small streams of water. Without a significant change in development practices and standards, based on watershed-specific understandings, we cannot maintain stream health and productivity.

"The lesson is that the interflow system is an incredibly important and yet fragile component of a watershed. It is critical for maintaining stream health and our fishery resource. Where the system is still operating it must be protected; where human activity will cause an alteration to its function, then replacement systems must be created that will mimic its operation to prevent any additional impacts to the stream and our resource," concludes Jonsson.

These observations further emphasizes the need to evaluate the impacts of diverting 90% of rainfall by infiltration into deep groundwater. Such prac-

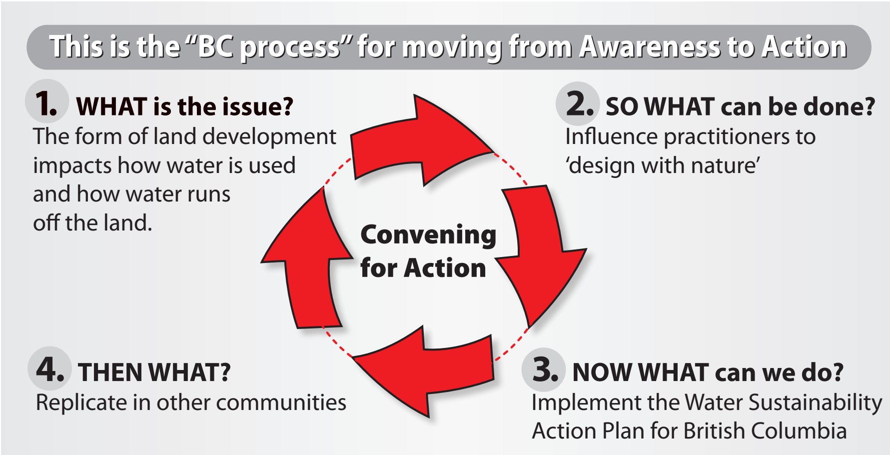

Figure 6. The British Columbia process

tices could eliminate base flows in the headwater streams and result in even greater unanticipated and unwanted environmental impacts.

Synopsis of What We Have Learned. We have distilled the foregoing technical discussion into a set of seven conclusions:

1. Impacts to the headwater streams of the Pacific Northwest are evidenced by erosion and habitat loss well before water quality becomes an issue.
2. Traditional engineering approaches may not result in impact mitigation—for example, discharge rate control may not result in the expected benefits.
3. Evaluation of the rainfall spectrum allows us to see new connections.
4. Simply capturing and deeply infiltrating rainwater may not be the best solution for a stream.
5. Simply capturing 90% of rainfall may not be beneficial to the stream.
6. Introduction of stream energy provides us with an additional tool to evaluate and mitigate stream impacts.
7. Updates to our scientific knowledge allow us to establish and implement more effective environmental mitigation as part of an ongoing adaptive management process.

These conclusions can be applied as guiding principles for designing with nature to achieve this goal: protect stream health and create liveable communities.

Convening for Action in British Columbia

Released in June 2010, *Beyond the Guidebook 2010: Implementing a New Culture for Urban Watershed Protection and Restoration in British Columbia* describes how a "convening for action" philosophy has taken root in British Columbia. Bringing together local government practitioners in neutral forums has enabled implementers to collaborate as regional teams. Their action-oriented focus has resulted in "how to do it" examples that help decision-makers visualize what "design with nature" policy goals look like on the ground.

Figure 6 illustrates the process for moving from awareness to action in British Columbia. "Convening for action is our branding. When we gather, it is for a purpose. There must be an outcome," states Mike Tanner, chair of the WaterBucket Website Partnership. "*www.waterbucket.ca* is the communication vehicle for the *Water Sustainability Action Plan for British Columbia.* It draws attention to the champions in local government who are leading by example. waterbucket.ca provides the 'convening for action' partners with a way to ensure consistent messaging, establish expectations, and record our history as we create it."

Move from Awareness to Action. A decade ago, the province of British Columbia decided to follow an educational rather than prescriptive path to change the way that land is developed and water is used. The provincial government has provided a "design with nature" policy framework that enables local governments to build and/or rebuild communities in balance with ecology. Desired outcomes are to create liveable communities and protect stream health. They go hand in hand.

"Our guiding philosophy is that the future desired by all will be created through alignment of federal, provincial, regional, and local policies and actions. Getting there relies on collaboration, partnerships, and a change in mind-set," states Glen Brown, the executive director of the province's Local Government Infrastructure and Finance Division and the deputy inspector of municipalities.

"British Columbia local governments are among the most autonomous in Canada, and British Columbia is perhaps the least prescriptive province. Historically, the province has put in place enabling policy and legal tools in response to requests from local government. Local government can choose to act, or not. In general, the enabling approach means the onus is on local government to take the initiative. The province recognizes that communities are in the best position to develop solutions, which meet their own unique needs and local conditions.

"This enabling philosophy is a driver for what we are branding as a *regional team approach* to implementing a new culture for urban stream/watershed protection and restoration. To make the regional team approach effective, everyone needs to agree on expectations and how all the players will work together. After that, each community can reach its goals in its own way.

"It has taken patience and consistent messaging over the past decade to incrementally build consensus, facilitate a culture change, and start implementing a new way of doing business. British Columbia communities now have the tools and the case study experience to 'design with nature,'" concludes Brown.

Connect Language to Outcomes. For more than a decade, the language used by drainage practitioners around the world has been changing to reflect the evolving objectives in doing business differently. Consider these terms:

> *"Communities are working together to develop sustainable community-based short- and long-term solutions to preserving watershed and values."*

stormwater management, low-impact development (United States), sustainable drainage, green infrastructure, rainwater management, design with nature, water-sensitive urban design (Australia), innovative stormwater management, sustainable urban drainage systems (United Kingdom). What is an appropriate and relevant term to use?

"When you think about it, the way we see the world is shaped by our vocabulary," states Robert Hicks, senior engineer with the Metro Vancouver regional government in British Columbia. "It is important to use terminology and descriptions which are linked closely with the objectives and ideas. Ideally, the right choice of wording will frame the concepts clearly, and provide the terminology with some longevity. Clarity will help with uptake.

"Other languages like French and German often use more exact terms than English for 'stormwater' and 'wastewater,' for example, and this changes how relationships and worth are perceived. With English, there is a tendency to build jargon. In British Columbia, we are adapting the European approach, which is to focus on function and solution—site level, rainwater, green, integrated, infrastructure, etc."

Create a Vision of the Desired Watershed Condition. British Columbia's Water Balance Model (*www.waterbalance.ca*) bridges planning and engineering, links development sites to the stream and watershed, and enables science-based performance targets to be established. This unique scenario comparison and decision support tool differs from other drainage modelling tools in three fundamental ways:

- It is Web-based;
- Development is driven by the community of users; and
- It can help create a vision of the future watershed.

"Developed as an extension of the Guidebook, the Water Balance Model demonstrates how to achieve a lighter 'water footprint.' This helps planners and designers wrap their minds around how to implement 'design with nature' solutions on the ground. The stream health methodology embedded in the Water Balance Model enables a watershed target to be established. It also enables the user to assess how to meet the watershed target at the site scale," explains Ted van der Gulik, senior engineer in the BC Ministry of Agriculture and chair of the Water Balance Model Partnership.

"A key message is that the Water Balance Model is a 'scenario comparison tool.' Because there is no restriction on the scenarios, this allows users to create an understanding of the past and present and compare it to many possible futures. This capability allows communities to assess how watersheds can be altered, for good or bad. Then they can create a vision of where they would like to go, and how the watersheds can meet their vision," says van der Gulik.

Collaborate and Align Efforts. Beginning in 2005, "convening for action" programs have been underway in the three regions of British Columbia where most of the population is located: Vancouver Island, Okanagan Valley (in the interior), and Metro Vancouver. Each regional initiative has its own vision and roadmap. However, the regions are learning from each other and collaborating to develop tools and resources. A commonality is a desire for a regional team approach founded on partnerships and collaboration.

The term *regional team approach* is resonating. Insertion of the word *team* in "regional approach" has had a profound impact on how practitioners view their world. *Team* implies there is personal commitment; it also suggests there is a game plan and a coachable context. The regional team approach is proving to be a powerful motivator.

"The old-school approach to stormwater management was really death-by-a-thousand-cuts to stream health. Old-school solutions of bigger pipes and pumps can't save the day, or even keep up with peak flows from climate change. The beauty is that small solutions—distributed infiltration, roof gardens, and all manner of green infrastructure—are actually an effective, cost-conscious approach to nonpoint pollution. In British Columbia, each region has different limitations and different strategies, but by sharing ideas and information we are rapidly spreading these new-school best practices," reflects Dr. Anna Warwick Sears, executive director of the Okanagan Basin Water Board.

"In the Okanagan, we are working on a two-pronged communication strategy, reaching out to homeowners as well as city planners and engineers. Some of our materials are homegrown, adapted to our dry climate, but by borrowing from communities on Vancouver Island, the Metro Vancouver area, and elsewhere in British Columbia, we can deliver great tools at minimal effort," concludes Sears.

Links to Resources

Stormwater Planning: A Guidebook for British Columbia: *www.env.gov.bc.ca/epd/epdpa/mpp/stormwater/stormwater.html*

Beyond the Guidebook: *www.waterbucket.ca/rm/sites/wbcrm/documents/media/37.pdf*

Beyond the Guidebook 2010: *www.waterbucket.ca/cfa/sites/wbccfa/documents/media/403.pdf*

Living Water Smart: British Columbia's Water Plan: *www.livingwatersmart.ca*

British Columbia's Green Communities initiative: *www.cscd.gov.bc.ca/lgd/pathfinder-greencommunities.htm*

For related articles:
www.stormh2o.com/watershed-projects

"Communities are working together to develop sustainable community-based short- and long-term solutions to preserving watershed and values. In the City of Surrey, we have been proactive in going beyond the engineering boundaries to foster a change for the better in the community's 'land and water ethic.' The city's efforts to engage the broader community encompass homeowner outreach initiatives and educational programs in schools," adds Carrie Baron.

"The Province has given us enabling tools to address the needs of our communities and work with the communities on watershed based issues. So, what we are seeing is more communities working together on watershed visions and their implementation. We are not just 'greening' urban drainage, we are facilitating a stewardship ethic through ongoing celebration of innovation. Slowly we are changing the mindset. This is a long-term commitment."

What Next in British Columbia?

"A decade ago, we realized that changing the way we develop land depends on establishing higher expectations and challenging land and water professionals to embrace share responsibility. We knew it would take time to change the culture. We believe that British Columbia is now at a tipping point. Implementation of a new culture for urban watershed protection and restoration is within our grasp," emphasizes Ted van der Gulik.

Achieve More With Less. The approach to rainwater management and green infrastructure in British Columbia is rooted in an underlying environmental ethic. Now, the impact of the new fiscal reality is providing an additional driver for designing with nature: *The initial capital cost of municipal infrastructure is about 20% of the life-cycle cost; the other 80% largely represents a future unfunded liability.*

Each year, the funding shortfall grows. As infrastructure ages and fails, local governments cannot keep up with renewal and/or replacement. Thus, fiscal constraints provide a powerful impetus for doing business differently. Green infrastructure is part of a holistic approach to achieve more with less, especially since local governments bear the entire financial burden to stabilize and restore watercourses impacted by the cumulative impacts of increased rainwater runoff volume.

Sustainable Service Delivery. "Sustainable Service Delivery is the Province of British Columbia's branding for a lifecycle way of thinking about infrastructure needs and how to pay for them over time. The approach is holistic. We are challenging local governments to think about what asset management entails *before* the asset is built. The paradigm shift starts with land-use planning and determining what services can be provided sustainably, both fiscally and ecologically," summarizes the province's Glen Brown.

"The legislative authority for integration of land use planning and asset management, including financial management, already exists. Local governments can develop a truly integrated asset management strategy that views the watershed though an environmental lens.

"The province's Living Water Smart and Green Communities initiatives are catalysts for designing with nature: *Start with effective green infrastructure and protect environmental values.* Get the watershed vision right. Then create a blueprint to implement green infrastructure," concludes Brown.

Kim A. Stephens *is executive director of Partnership for Water Sustainability in British Columbia.* ***Jim Dumont*** *is the engineering applications authority for the Water Balance Model Partnership.*