



Integrating the Site with the Watershed and the Stream

Primer on Integrated Rainwater and Groundwater Management
for Lands in the Englishman River Watershed and Beyond



April 2012

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Acknowledgments

The federal-provincial Regional Adaptation Collaboratives (RACs) Program provided funding for development of this Primer. The purpose of the RACs Program is to support coordinated action towards advancing regional climate change adaptation decision-making.

- In British Columbia, Natural Resources Canada has partnered with the Ministry of Environment and Fraser Basin Council to work directly with other collaborators, including government and non-government organizations such as the Partnership for Water Sustainability in BC, and the British Columbia Conservation Foundation.
- The vision for the BC Regional Adaptation Collaborative, **Preparing for Climate Change: Securing B.C.'s Water Future**, is to enhance resilience to a changing climate and the anticipated, related impacts on water and aquatic ecosystems. Project activities have led to recommendations and actions for improved policies, practices and plans, as well as tools to support adaptation action.

Collaboration with the City of Parksville created the opportunity to inform the educational process that is part of the City's Official Community Plan Review. In turn, the Parksville experience will inform the **Inter-Regional Education Initiative** that is advancing a consistent approach to rainwater management and water sustainability on Vancouver Island.

This Primer builds on the technical foundation created by the Water Balance Model Partnership; and incorporates the findings of a precedent-setting groundwater research project undertaken by Dr. Gilles Wendling. His research was funded by the Mid Vancouver Island Habitat Enhancement Society.



Integrating the Site with the Watershed and the Stream

Primer for Integrated Rainwater and Groundwater Management

Table of Contents

	page
About This Primer	i
1. Background / Context	1
▪ Companion Documents	
▪ A Call to Action	
▪ Linking Rainfall, the Landscape, Groundwater and Streamflow	
2. Connect Water, Land and People	5
▪ Regional Team Approach	
▪ Living Water Smart, BC's Water Plan	
▪ Living Water Smart Actions & Targets	
▪ Why Protect Stream Health	
▪ Designing with Nature in BC	
▪ Get the Watershed Vision Right	
▪ Englishman River Watershed	
▪ Guiding Principles	
3. Look at Rainfall Differently	15
▪ From Stormwater to Rainwater	
▪ Water Balance Methodology	
4. Protect Stream Health	19
▪ A Road Map for Integrated Rainwater Management	
▪ Changes to the Water Balance	
▪ Stream Health Methodology	
▪ Science of Stream Erosion	
5. Look at Groundwater Differently	29
▪ Characterizing Aquifers	
▪ How Much Groundwater is Discharging into the Englishman River?	
▪ Groundwater and Surface Water: Same Water	
▪ Groundwater and Land: They ARE Connected!	
6. Mimic the Water Balance	35
▪ Doing Business Differently in BC	
▪ Local Government Responsibility	
▪ How to Think Like a Watershed	
▪ Establish Watershed-Specific Performance Targets	
▪ View the Watershed through an Asset Management Lens	
7. Guidance Documents	44

Integrating the Site with the Watershed and the Stream

Primer for Integrated Rainwater and Groundwater Management

List of Figures

	page
1. Inter-Regional Educational Initiative	2
2. Elements of the Water Balance	4
3. Regional Team Approach	6
4. Why Protect Stream Health	8
5. 'Design with Nature' – Objectives and Outcomes	10
6. Englishman River Watershed	12
7. Desired Outcome: Manage Natural Environment and Built Environment as Integrated Components of a Healthy Watershed	14
8. Integrated Strategy for Managing the Rainfall Spectrum	16
9. Rainfall Distribution	18
10. Hydrologic Changes in the Water Balance	18
11. Consequences of Changes to the Water Balance	20
12. Impact of Changes in Hydrology on Watercourse Erosion and Base Flow Relationships	21
13. Impact of Increasing Urbanization on Stream Corridor Ecology	22
14. Stream Erosion	24
15. Five Stream Features that are affected by Urban Development	26
16. Five Major Factors which Collectively Shape Stream Integrity	26
17. Romney Creek (Parksville) – Example of Degraded Conditions	27
18. North Vancouver (Metro Vancouver) – Example of Healthy Functioning Stream	28
19. Shelley Creek (Parksville) – Example of Stream Habitat Preserved	28
20. Shelley Creek (Parksville) – Example of Stream Improvements	28
21. General Groundwater Directions in Overburden Aquifers In Englishman River Lower Watershed	30
22. Estimated Groundwater Flux to Englishman River from Overburden Aquifer	32
23. Groundwater and Surface Water: Same Water	32
24. Geoscape	33
25. Estimated Recharge Zones of Overburden Aquifers contributing to Englishman River	34
26. Local Government Responsibility to Manage Drainage & Protect Stream Health	36
27. Drainage Modelling: From Theory to Interpretation	38
28. View the Watershed through an Asset Management Lens	42

Integrating the Site with the Watershed and the Stream

Primer for Integrated Rainwater and Groundwater Management

About This Primer

Released in 2008, **Living Water Smart, BC's Water Plan** is a call to action to prepare communities for change and do business differently. Living Water Smart has 45 actions and targets:

- These establish expectations vis-à-vis how land will be developed (or redeveloped) and water will be used.
- The desired outcome is that BC communities will embrace 'designing with nature', reduce their water footprints, and protect stream health.

This Primer supports implementation of Living Water Smart in the local government setting. It is written for expert and non-expert audiences. Table 1 presents a section-by-section synopsis of the Primer storyline. Also, the image below serves as a road map. It identifies three elements of the **Water Balance**, namely: rainfall, groundwater and streamflow. The Water Balance is short-circuited when the land surface is hardened and below-ground flowpaths to streams are eliminated, such that:

- Too Much Water:** During wet weather periods, increased runoff volumes over longer durations cause stream erosion and instability.
- Too Little Water:** During dry weather periods, groundwater-fed baseflows are diminished.
- Do Business Differently:** Both conditions have financial implications and sustainability consequences over time.

The Primer introduces the issue of the '**unfunded infrastructure liability**'. Viewing the watershed through an asset management lens provides local governments with a driver to require that development practices mimic the Water Balance.



Kim A. Stephens, MEng, PEng,
Executive Director
Partnership for Water Sustainability in BC
March 2012



Integrating the Site with the Watershed and the Stream

Primer for Integrated Rainwater and Groundwater Management

Table 1 – Synopsis of the Primer Storyline

<p>This lynch-pin position statement on page 43 of “Living Water Smart, British Columbia’s Water Plan” provides context for the Primer:</p> <p><i>“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.”</i></p>		
	Section Title	Content Highlights
1	Background / Context	Draws attention to the Province’s ‘call to action’ to build greener communities. Connects the dots to the ‘how-to-do-it’ <i>Vancouver Island Inter-Regional Educational Initiative</i> . Introduces the water balance way-of-thinking and the factors that impact on watershed and stream health.
2	Connect Water, Land and People	Describes the regulatory and educational drivers behind a collaborative approach to changing the ‘land ethic’ in BC. Highlights the importance of a regional team approach to ‘get the watershed vision right’. Identifies guiding principles for implementing change in the local government setting.
3	Look at Rainfall Differently	Provides historical context for the evolution of the Water Balance Methodology. Describes how this led directly to the <i>Integrated Strategy for Managing the Rainfall Spectrum</i> ; and was the catalyst for a paradigm-shift from past peak flow practice to today’s volume-based practice.
4	Protect Stream Health	Explains how Puget Sound research has provided a road map for integrated rainwater management. Illustrates how ‘changes in hydrology’ impact on diversity and abundance of the fisheries resource. Connects the dots between Water Balance Methodology and the science of stream erosion.
5	Look at Groundwater Differently	Explains how the Englishman River demonstration project was only possible because of community involvement. Introduces the ‘flux’ concept to characterize groundwater movement. Introduces the use of ‘butterfly views’ to create understanding of how groundwater moves to the river.
6	Mimic the Water Balance	Provides guidance for establishing expectations so that champions in the local government setting can then lead change. Describes local government responsibility to protect the water balance. Introduces financial drivers for viewing a watershed through an asset management lens.
7	Guidance Documents	Lists and provides links for downloading.

Integrating the Site with the Watershed and the Stream

Primer for Integrated Rainwater and Groundwater Management

1. Background / Context

This Primer introduces building blocks that can inform 'water-centric' policy development by BC municipalities. Embedding a science-based understanding in an Official Community Plan, for example, can make a difference on the ground. Thus, the Primer objectives are three-fold:

- provide insight into the regulatory and educational context for moving from awareness to action in order to **protect watershed and stream health** in BC;
- explain how introduction of the Rainfall Spectrum concept a decade ago led us to look at rainfall differently in BC;
- foreshadow how pioneer research in the Englishman River watershed can similarly lead us to look at groundwater differently.

The City of Parksville OCP is a demonstration application for the Primer. The learning captured in this Primer will also be shared with other local governments on Vancouver Island. Knowledge-transfer will be facilitated through the current *Inter-Regional Education Initiative*.

Companion Documents

This Primer is the third in the latest series of guidance documents released by the Partnership for Water Sustainability. The first two Primers were released in November 2011:

- Primer on Rainwater Management in an Urban Watershed Context:**
Provides engineers and non-engineers with a common understanding of how a science-based approach to rainwater management has evolved since the mid-1990s.
- Primer on Urban Watershed Modelling to Inform Local Government Decision Processes:**
Provides engineers and non-engineers with guidance in three areas: setting performance targets, defining levels-of-service, and application of screening / scenario tools.

The core concepts presented in these companion documents provide an educational foundation for rainwater management in a watershed context.

A Call to Action

In 2008, the Province put in place a policy framework that is a 'call to action' on the part of local governments (refer to image below). 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 British Columbians can create the future that we all want.

A Call to Action

Living Water Smart, BC's Water Plan
and the **Green Communities Initiative**
provide a vision of what the regions of our province
can look like if local governments.....

- prepare communities for climate change,
- choose to live water smart, and
- strive to build greener communities

Inter-Regional Education Initiative: Figure 1 references regions where watershed-based strategies and programs for integrating the site with the watershed and stream are being advanced. Inter-regional sharing, collaboration, alignment and consistency will accelerate effective implementation of watershed protection objectives within each region. The focus of the *Inter-Regional Educational Initiative* is on the 'how-to' details of integration and implementation.

Everyone needs to agree on expectations and how all the players will work together, and after that each community can reach its goals in its own way

"The 'regional team approach' is founded on partnerships and collaboration; and seeks to align actions at three scales – provincial, regional and local."

Glen Brown, Executive Director
BC Ministry of Community, Sport & Cultural Development
& Deputy Inspector of Municipalities
September 2009

Integrating the Site with the Watershed and the Stream

Primer for Integrated Rainwater and Groundwater Management



Inter-Regional Education Initiative

Figure 1

Explanatory Notes – Provincial Significance

1. The Province intervened in the Comox Valley to both create a new regional district and mandate regional plans. The *Comox Valley Sustainability Strategy* and *Comox Valley Regional Growth Strategy* provide the planning framework for implementing **An Integrated Watershed Approach to Settlement**.
2. The Nanaimo Region's **Drinking Water & Watershed Protection Plan** created a drinking water and watershed protection service area with taxation authority in the region's electoral areas. Because the scope has been expanded to include the member municipalities, this means the plan has more of a regional function.
3. The **Cowichan Basin Water Management Plan** is a provincial case study for watershed governance changes being contemplated as part of *Water Act Modernization*.
4. In the Capital Region, the Bowker Creek Watershed Blueprint and District of Sooke Rainwater Management Plan are demonstration initiatives for **Integrated Watershed Management**. Both are founded on partnerships that have enabled community groups and municipal staffs to coalesce around a shared vision: *What do we want this watershed to look like in 100 years, and what steps will we take to get there?*
5. Metro Vancouver's **Integrated Liquid Waste & Resource Management Plan** established the framework for moving beyond regulatory compliance to transitioning the region to an approach where management of liquid discharges and rainwater resources is planned and implemented within a broader, sustainability framework.

Integrating the Site with the Watershed and the Stream

Primer for Integrated Rainwater and Groundwater Management

Linking Rainfall, the Landscape, Groundwater and Streamflow

The purpose of this Primer is to provide the reader with a *science-based understanding* of factors that impact on watershed and stream health, either for better or worse. Building blocks in a science-based understanding are:

- Rainfall (precipitation);
- the ability of the landscape to absorb rainfall;
- movement of water through the ground; and
- the resulting flow in streams.

As illustrated on Figure 2, these elements are part of a system that we call the Water Balance. Land development short-circuits this system when the land surface is hardened and below-ground flow paths to streams are eliminated. By describing the linkages and connecting dots, the ultimate goal of the Primer is to foster responsible decisions about use and development of land.

What 'Science-Based Understanding' Means:

The foundation document for this Primer is *Stormwater Planning: A Guidebook for British Columbia*, released by the Province in 2002.

The Guidebook describes what "science-based understanding" means in practice. Also, it draws on work completed in 1999 for King County in Washington State as part of the Tri-County response to the listing of Chinook salmon as an endangered species. "A significant finding was that scientists and managers think and operate differently," states the Guidebook.

The Guidebook provides this definition: "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."

Through a science-based understanding of the relationship between hydrology and aquatic ecology, the Guidebook derived watershed protection objectives that provide an over-arching framework for rainwater management. In linking the site to the watershed and the stream, this Primer builds on the Guidebook by integrating stream erosion and groundwater understanding.

Connecting Dots: Looking ahead to the sections that follow this one, a key message is that TIME is a critically important dimension in maintaining the water balance. Another key message is that water is always moving. These considerations underpin a science-based rainwater management strategy. The image below serves as a road map:



This Primer is grounded in an approach that recognizes that engineering is the 'art of applied science'. According to Dr. Peter Coombes of the University of Newcastle and the University of Melbourne in Australia, "Good engineering



practice relies on astute observation and sound deduction. Breakthroughs in practical understanding and application happen when applied scientists ask the right questions:

What are the data telling us?" Dr. Coombes is a recognized leader in Water Sensitive Urban Design in Australia. In September 2006, he was the keynote speaker at the Water in the City Conference, held in Victoria.

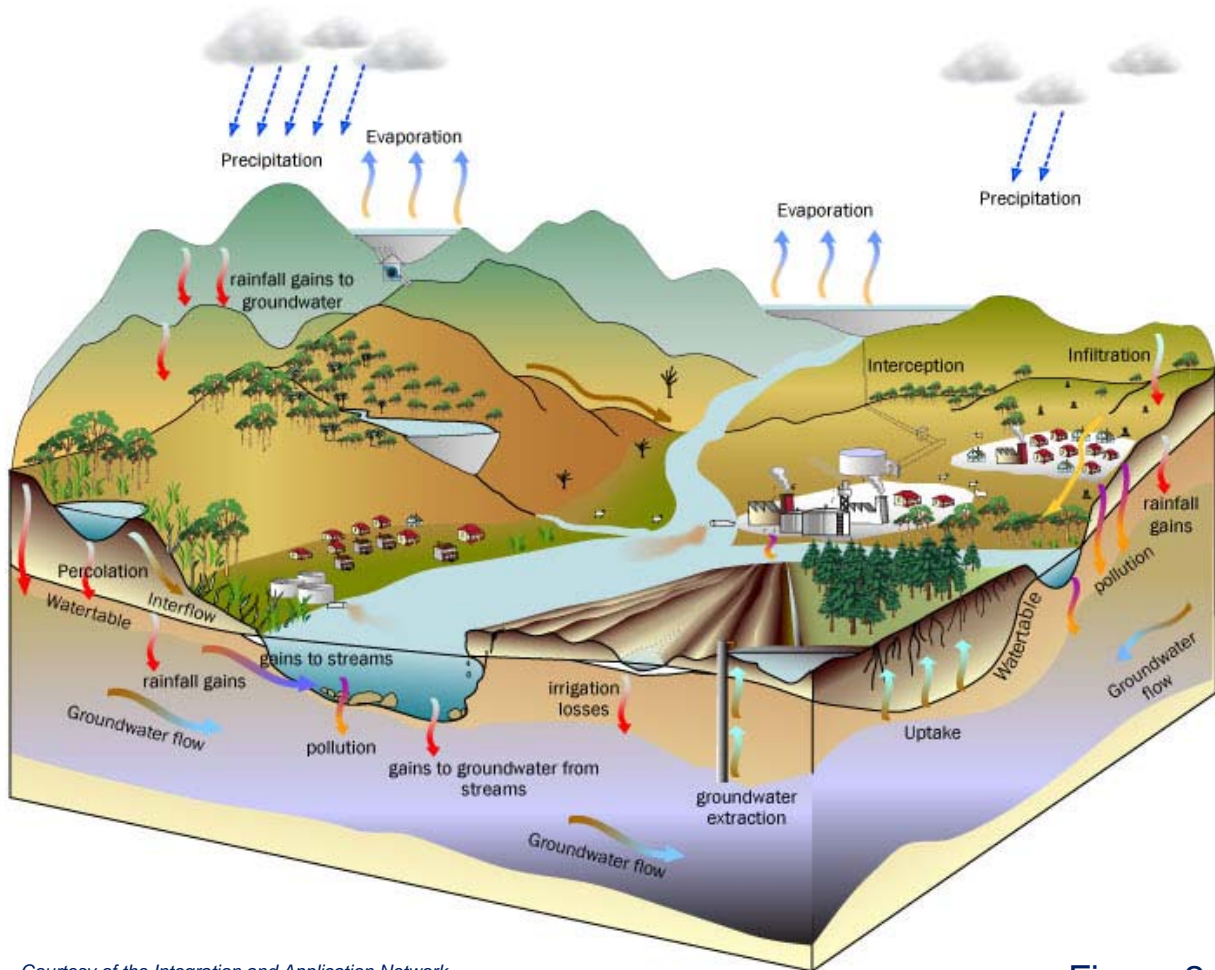
This Primer synthesizes the pioneer work of three BC engineers, namely: Kim A Stephens, Jim Dumont and Dr. Gilles Wendling. Because they looked at rainfall and groundwater differently, they were able to connect dots and develop practical applications of water balance thinking.

Looking at rainfall differently started with the *UniverCity Sustainable Community* on Burnaby Mountain in Metro Vancouver. This project was the genesis for the Water Balance Methodology that links rainfall to stream health protection.



Integrating the Site with the Watershed and the Stream

Primer for Integrated Rainwater and Groundwater Management



Courtesy of the Integration and Application Network,
University of Maryland Center for Environmental Science (ian.umces.edu/symbols/)

Figure 2

Elements of the Water Balance

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Primer for Integrated Rainwater and Groundwater Management

2. Connect Water, Land and People

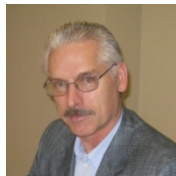
BC local government is among the most autonomous in Canada, and BC is perhaps the least prescriptive province. Historically, the Province has enabled local government by providing policy and legal tools in response to requests from local government. Local government can choose to act, or not.

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.

Regional Team Approach

“BC’s enabling philosophy has become a driver for a regional team approach (see Figure 3) to implementing a new culture for urban watershed protection and restoration in BC,” reports Tim Pringle, President of the *Partnership for Water Sustainability in BC*.

“We are observing that 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.”



“We are also observing that major breakthroughs happen when decision makers in government work with grass-roots visionaries in the community to create the future desired by all. Collaboration grows from a shared vision about the future and the commitment to action. The regional team brings the players together to implement a top-down and bottom-up approach,” adds Eric Bonham, a founding member of the *CAVI-Convening for Action on Vancouver Island* initiative, and a former Director in the Ministries of Environment and Municipal Affairs.



Living Water Smart, BC’s Water Plan

Released in June 2008, Living Water Smart presents government’s vision for sustainable land and water stewardship. The Green Communities Initiative complements Living Water Smart and comprises plans, strategies and enabling tools to achieve the land and water stewardship vision. Together, the two initiatives represent a call to action. Together, they provide the provincial context for a regional team approach.

The 45 actions and targets in Living Water Smart establish expectations vis-à-vis how land will be developed (or redeveloped) and water will be used.

Share a Vision, Create a Legacy: “The ultimate goal of the Living Water Smart and Green Communities initiatives is to establish expectations that, in turn, will influence the form and function of the built environment. If land and water practitioners are then successful in bringing a ‘water for life and livelihoods’ vision to fruition by embracing *shared responsibility*, this will create a legacy for those who follow in our footsteps,” states Lynn Kriwoken, a Director in the Ministry of Environment and the Province’s lead person for development and delivery of Living Water Smart.



Collaborate and Make Green Choices: “At the end of the day, planners and engineers and other disciplines must come together to determine the issues and solutions. While legislative reform is a foundation piece, collaboration takes place outside the legislative framework.”

“This is why we constantly emphasize that Living Water Smart is about motivating and inspiring everyone to embrace *shared responsibility*. Influencing behaviour and attitudes is at the heart of moving from awareness to action.”

“Our immediate objective is to encourage ‘green choices’ that will flow through time, and will be cumulative in creating liveable communities, reducing wasteful water use, and protecting stream health,” concludes Lynn Kriwoken.

Integrating the Site with the Watershed and the Stream

Primer for Integrated Rainwater and Groundwater Management



Source: Water Sustainability Action Plan for British Columbia

Figure 3

Regional Team Approach

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Primer for Integrated Rainwater and Groundwater Management

Living Water Smart Actions & Targets

Three actions / targets in particular serve to establish expectations vis-à-vis how land will be developed and water will be used. A desired outcome is to reduce the **'water footprint'** of BC communities. The three actions / targets are listed below; they are also cross-referenced to the three subject areas and page numbers in the Living Water Smart vision document:

- **Doing Business Differently:** *"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"* (page 43)
- **Preparing Communities for Change:** *"By 2012, new approaches to water management will address the impacts from a changing water cycle, increased drought and risk, and other impacts on water caused by climate change"* (page 61)
- **Choosing To Be Water Smart:** *"By 2020, 50% of new municipal water needs will be acquired through conservation"* (page 75)

The stream health target on p 43 is the lynch-pin for a collaborative and consistent approach that aligns local government policies and actions with provincial and regional goals.

Web-Accessible Tools: "To make it possible to achieve Living Water Smart targets and actions, the Province has developed a suite of tools in partnership with local government," reports Ted van der Gulik, the Senior Engineer in the Ministry of Agriculture, and Chair of the inter-governmental Water Balance Model Partnership.



"These tools are all web-based and are intended to support new approaches to water management. They can be applied on-the-ground by land and water practitioners. Our vision is that they will collectively facilitate informed decision-making with respect to climate change adaptation and stream health."

Why Protect Stream Health

In BC, headwater tributary streams are a predominant feature; and watershed health is very much about protection of aquatic habitat. The critical issue is the damage to and loss of habitat caused by land use change and resulting erosion of the headwater streams.

Figure 4 illustrates typical land development; and can represent either a problem or an opportunity.

Impact of the Salmon Crisis: Looking back, the salmon crisis of the 1990s was the catalyst for action. 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. A generation ago, the ecosystem value of headwater streams was not fully appreciated. The result: streams were being lost as a consequence of rapid population growth and land development.

The 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 in BC.

Science-Based Understanding Informs Policy and Practice: By 2002, as an implementation action resulting from enactment of the Fish Protection Act (1997), the Province released *Stormwater Planning: A Guidebook for British Columbia*. The Guidebook was a joint effort of Environment Canada and two Ministries – Environment and Municipal Affairs. The process produced a science-based framework to guide development of the rainwater (stormwater) component of Liquid Waste Management Plans.

The core premise of the Guidebook is that land development and watershed protection can be compatible. This also suggests that urban watershed restoration is achievable over time. The Guidebook signified a paradigm-shift. This resulted from recognition of HOW a science-based understanding could bridge the gap between high-level policy objectives and site design practices.

Integrating the Site with the Watershed and the Stream

Primer for Integrated Rainwater and Groundwater Management

Stream health depends on
ALL properties in a watershed



If we reduce our 'water footprint', and if we ensure the integrity of groundwater flow, we can then protect stream health

Source: Water Sustainability Action Plan for British Columbia

Figure 4

Why Protect Stream Health

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Primer for Integrated Rainwater and Groundwater Management

Designing with Nature in BC

The *Partnership for Water Sustainability in BC* is helping the Province implement the Living Water Smart and Green Communities initiatives. This is being accomplished through shared responsibility in delivering the *Water Sustainability Action Plan*.

Released in 2004, the Action Plan provides a partnership umbrella for on-the-ground initiatives that advance a *design with nature* way-of-thinking and acting. The phrase is borrowed from the title of a seminal book by the late Ian McHarg, internationally renowned landscape architect and writer on regional planning using natural systems.

Figure 5 identifies the objectives and desired outcomes that brand 'designing with nature'.

Legislative Authority for Integrated Approach: "The 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," states Glen

Brown, the Executive Director of the Province's Local Government Infrastructure and Finance Division and the Deputy Inspector of Municipalities.

"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 through an environmental lens."

Climate Change Adaptation: "Designing with nature captures the essence of climate change adaptation. Adaptation is about responding to the changes that will inevitably occur. Adaptation is at the community level and is therefore about collaboration," adds Raymond Fung, Director of Engineering and Transportation with the District of West Vancouver, and Chair of the Green Infrastructure Partnership.



Get the Watershed Vision Right

The *Inter-Regional Education Initiative* is linking activities in and between four regions so that everyone can benefit from lessons learned. Collaboration between local governments and the stewardship sector has emerged as a critical success factor in "getting the watershed vision right".

Four Regions are Leading by Example: These 'top-down and bottom-up' initiatives demonstrate what can be accomplished by embracing the 'regional team approach':

- **In the Comox Valley:** The *Comox Valley Land Trust* created the vision for *Nature Without Borders*; and this vision is influencing the actions of local government.
- **In the Nanaimo Region:** The champion for undertaking a precedent-setting approach to groundwater research and application in the Englishman River is the *Mid Vancouver Island Habitat Enhancement Society*.
- **In the Cowichan Valley:** The *Cowichan Watershed Board* is the vehicle for bringing together people in order to advance stewardship action.
- **In the Capital Region:** The *Bowker Creek Blueprint* is a 100-Year Action Plan to guide watershed and creek corridor restoration as neighbourhoods redevelop in the urban core of three municipalities.

Looking ahead, Section 5 elaborates on the significance and value of the Englishman River groundwater research, within the City of Parksville and beyond.



Integrating the Site with the Watershed and the Stream

Primer for Integrated Rainwater and Groundwater Management

Collaboration, a 'Design with Nature' approach, and re-use of resources are keys to mitigation of unfunded infrastructure liability and adaptation to climate change

To achieve higher levels of stream, wetland and marine environment protection:

- Protect and restore urban 'green' space
- Strive for a lighter 'water footprint'
- Re-use and recycle water, energy & nutrients from liquid wastes
- Develop compact, complete communities



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Source: Water Sustainability Action Plan for British Columbia

Figure 5

'Design with Nature' - Objectives and Outcomes

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Primer for Integrated Rainwater and Groundwater Management

Living Rivers Initiatives in the Englishman River Watershed

The Englishman River Watershed is a case study demonstration application of what it means to connect water, land and people.

Geographic Context: The Englishman River is located on the mid-east coast of Vancouver Island at Parksville and drains an area of approximately 324 km² (Figure 6). The river's headwaters arise on the eastern slope of Mt. Arrowsmith and Mount Moriarty Ridge and flow easterly for 40km, entering the Strait of Georgia just north of Rath Trevor Beach Provincial Park. The Englishman is a community watershed, with a headwater storage dam on Arrowsmith Lake and water intake and treatment facilities in the City of Parksville, licenced by the Arrowsmith Water Service (AWS).

Land Use: The majority of the Englishman watershed is privately-owned forest lands held by Island Timberlands Limited Partnership and TimberWest Forest Corp. The lower half of the watershed (i.e., downstream of Englishman River Falls Provincial Park) is a mix of protected areas, forestry, agriculture and rural/urban residential areas, with the greatest population (12,000) within the City of Parksville's urban containment boundary.

Fish and Water Sustainability Projects: In 2006, the BC Conservation Foundation (BCCF) received approval from the Living Rivers Trust Fund Advisory Group for a multi-year *Living Rivers – Georgia Basin/Vancouver Island* business plan that focuses on fish and water sustainability projects in high priority Georgia Basin and Vancouver Island watersheds.

Investments from this program in the Englishman Watershed have been substantial to date, including construction of log jam fish rearing structures; side-channel improvements; fish abundance and stream flow monitoring; headwater lake storage feasibility; estuary biophysical inventory and restoration planning; public education about the value of water conservation; and, applied groundwater research.

BC Regional Adaptation Collaborative: In 2009, Natural Resources Canada provided BCCF with multi-year funding for the *Englishman River RAC Case Study* so that BCCF could complete:

1. a water balance study for the watershed;
2. engineering feasibility studies for a proposed Shelton Lake (South Englishman River sub-basin) storage dam; and,
3. a watershed management plan (incorporating climate change adaptation).

"In place of a formal Englishman Watershed Management Plan, however, the *2012 Official Community Plan Review* being undertaken by the City of Parksville opened the door to develop a Primer that will advance *water-centric thinking* in the mid-Island region," reports Craig Wightman, BCCF Senior Fisheries Biologist.



"In addition to informing the Parksville OCP, the Primer will inform the Nanaimo Regional District's *Drinking Water & Watershed Protection Plan*. Our objectives are to assist City and regional staff with incorporation of new scientific knowledge extending surface water hydrology and the health of aquatic ecosystems to inter-connected groundwater resources, a breakthrough recently documented by Dr. Gilles Wendling in his pioneering study of the lower Englishman's aquifer formations.

"By adopting a more holistic urban planning model, one which recognizes that healthy streams and groundwater are inextricably linked and valuable, the City of Parksville can assume a leadership role as it strives for a sustainable future. In practical terms, this means that strong principles of water stewardship will influence the community's growth and development, with enhanced protection of all water sources an overarching goal."

"In so doing, Parksville can ensure improved drought security and natural flood control in the face of climate change, as well as enhanced water quality in support of the native salmon, wildlife and recreational assets valued by so many of its citizens," concludes Craig Wightman.

Integrating the Site with the Watershed and the Stream

Primer for Integrated Rainwater and Groundwater Management

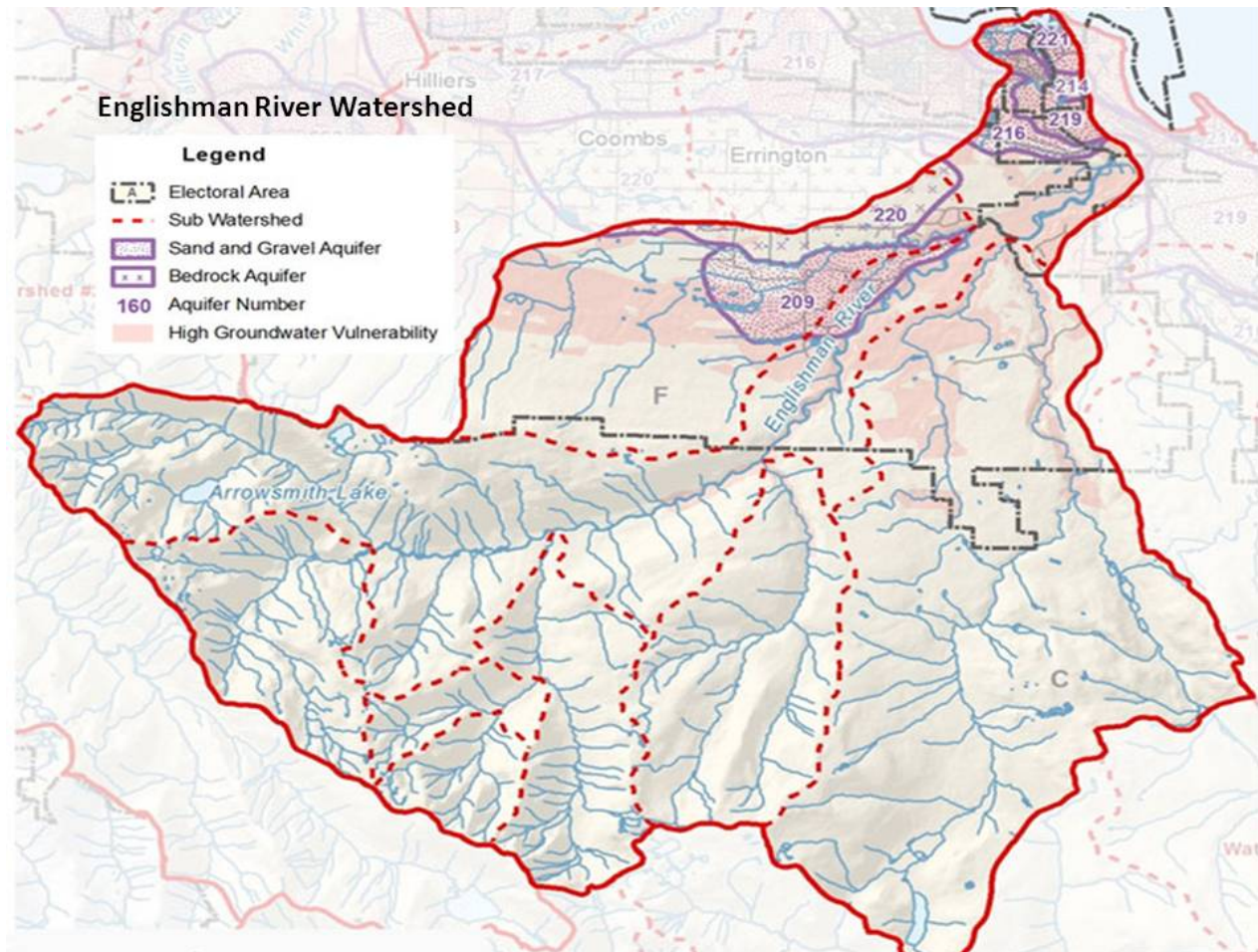


Figure 6

Englishman River Watershed

Integrating the Site with the Watershed and the Stream

Primer for Integrated Rainwater and Groundwater Management

Guiding Principles

The core concepts introduced in preceding pages provide the philosophical foundation for an integrated approach to use and conservation of land and water. Next, these core concepts are synthesized into a set of guiding principles.

Connecting Water, Land and People: Lessons learned by those who are leading change can help those who want to move to a design with nature strategy. Guiding principles are:

1. Choose to be enabled.
2. Establish high expectations.
3. Embrace a shared vision.
4. Collaborate as a 'regional team'.
5. Align and integrate efforts.
6. Celebrate innovation.
7. Connect with community advocates.
8. Develop local government talent (i.e. *Inter-Regional Education Initiative*)
9. Promote shared responsibility.
10. Change the land ethic for the better.

Systemic change is possible, even in the complicated sphere of planning for use and conservation of land. It requires understanding and pursuit of holistic outcomes.

Connecting Natural and Built Environments:

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 rainwater runoff quantity and quality can trigger progressive loss of biodiversity and abundance of aquatic species within the corridor.

Integrated, or watershed-based, rainwater 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 7.

Creating Change on the Ground: Practical research and new tools are now enabling engineers, planners and other disciplines to do business differently. Case study experience demonstrates that creating change on the ground revolves around four basic ingredients:

1. Start with a unifying concept that makes sense (e.g. 'design with nature' goal);
2. Develop a science-based and pragmatic methodology for undertaking technical analyses (e.g. mimic water balance);
3. Create a web-based calculation tool that has a user-friendly interface and is accessible to anyone (e.g. *Water Balance Model*); and
4. Implement a multi-audience outreach and professional development program that is defined by consistent messaging.

The practitioner and community culture in BC is changing as an outcome of collaboration, partnerships and alignment. Changing the culture requires a process. This takes time to complete. There is no short-cut.

Integrated Rainwater Management: In the past, drainage practices concentrated on peak flow rates and overlooked the importance of volume management. Integrated solutions manage both volume and flow rates.

Next, the spotlight shifts to the science behind an integrated and holistic approach to rainwater and groundwater management:

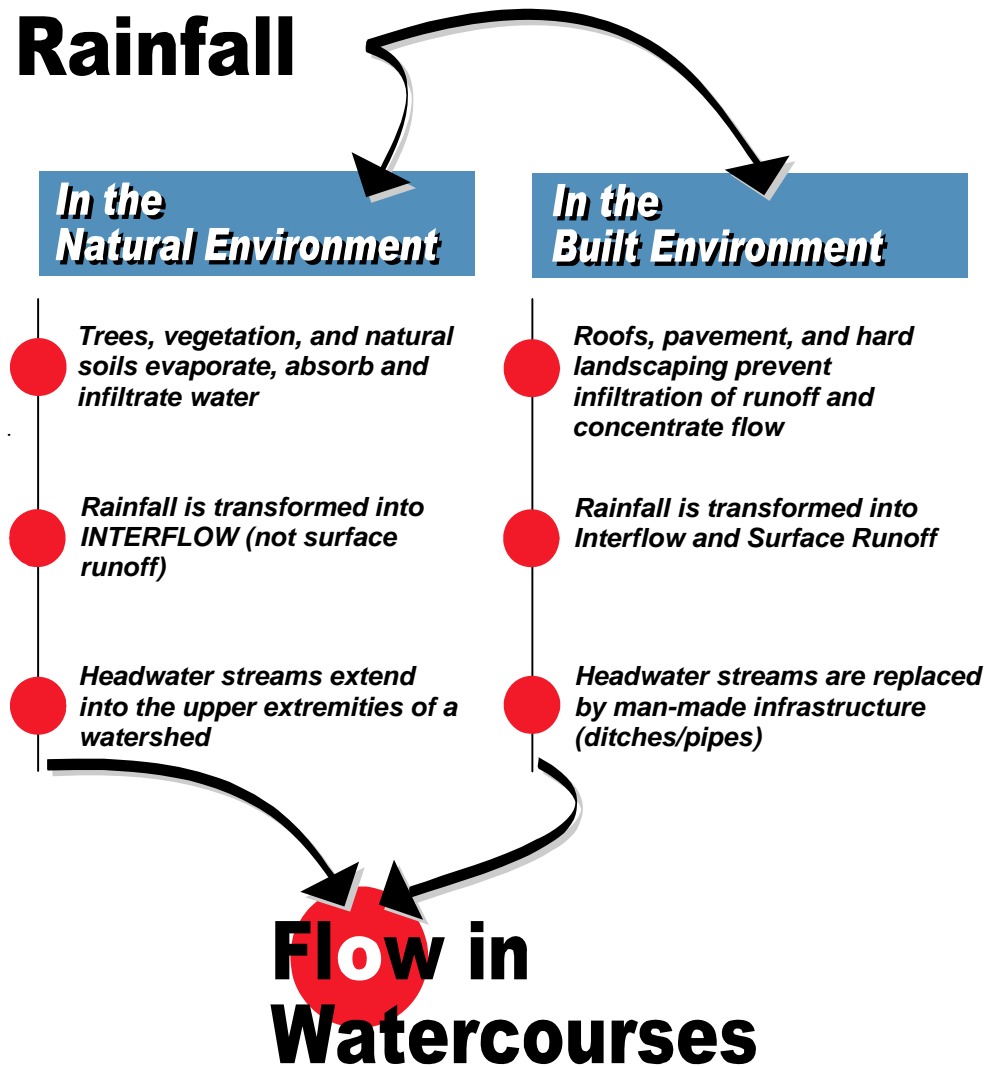
- First, Section 3 introduces the Water Balance Methodology that underpins an understanding of how to protect stream health.
- Then, Section 4 explains how 'changes in hydrology' impact on diversity and abundance of the fisheries resource.
- After that, Section 5 synthesizes what is important to know about the Englishman River groundwater demonstration project.
- Finally, Section 6 provides guidance so that local government can move from awareness to implementation.

Looking ahead, the next four sections provide the foundation for an approach keyed to establishing watershed-specific performance targets.

Integrating the Site with the Watershed and the Stream

Primer for Integrated Rainwater and Groundwater Management

Rainfall



Source: Chapter 3, *Stormwater Planning: A Guidebook for British Columbia*, 2002

Figure 7

Desired Outcome: Manage Natural Environment and Built Environment as Integrated Components of a Healthy Watershed

Integrating the Site with the Watershed and the Stream

Primer for Integrated Rainwater and Groundwater Management

3. Look at Rainfall Differently

A decade ago, looking at rainfall differently led the Province of BC to develop the *Water Balance Methodology*, and initiate a paradigm-shift in the way rainwater is managed. The Province:

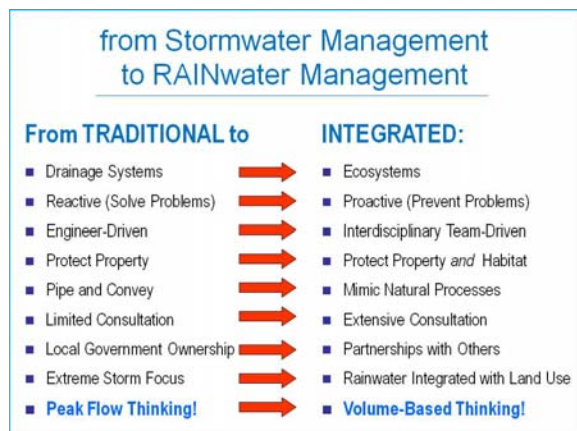
- Formalized the performance target methodology in *Stormwater Planning: A Guidebook for British Columbia*, a provincial guidance document released in 2002.
- Translated science-based understanding so that local governments could establish achievable and affordable performance targets for rainfall capture and runoff control.

BC was the first provincial or state government in North America to implement the Water Balance Methodology.

From Stormwater to Rainwater

The Guidebook was the catalyst for moving from the extreme storm view embodied in conventional 'Stormwater Management' to the integrated, holistic and landscape-based perspective that is embodied in 'Rainwater Management'. In 2002, the Guidebook also set the stage for defining *water sustainability* as an outcome of *green infrastructure* policies and practices. This followed four years later in 2006.

The comparison below captures the evolution of drainage planning in BC between 1970 and 2002. The move to volume-based practice was made possible by the Water Balance Methodology.



The Integrated Strategy: The Water Balance Methodology is founded on the concept known as the *Rainfall Spectrum*: the methodology accounts for all the rainfall-days in a year; and links rain that falls on a site...to the runoff leaving the site...to the flow in a stream.

Reproduced from the Guidebook, Figure 8 illustrates the elements comprising the *Integrated Strategy for Managing the Rainfall Spectrum*. Water gets to a stream in one of three ways: surface runoff, shallow groundwater (interflow), and deep groundwater. Figure 8 shows that each way has a materially different time horizon.

The Rainfall Spectrum is a universal relationship. In other words, the number of rainfall-days and the total rainfall volume per year may vary by region, but the distribution of that volume has a consistent pattern.

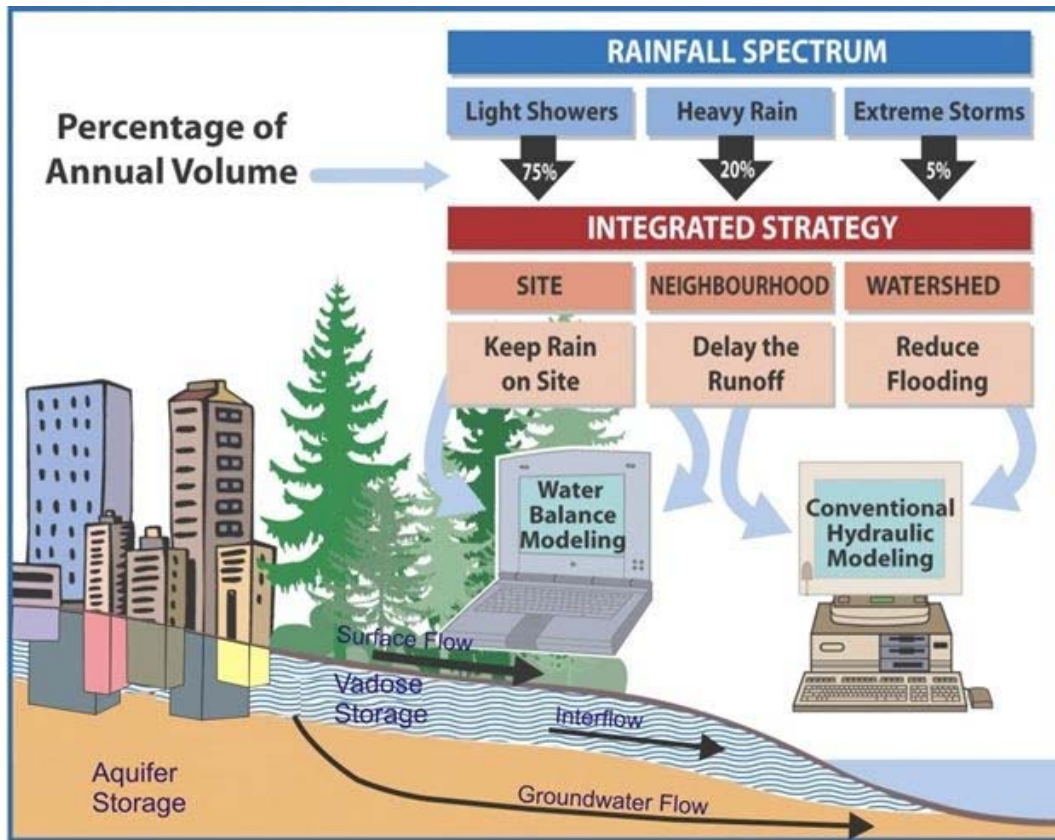
Evolution of the Methodology: The Water Balance Methodology is dynamic; and it is being enhanced over time to incorporate fresh insights resulting from science-based understanding. A key goal is to improve the technical basis for local government decisions. Three milestones in the evolutionary process are introduced below:

- First, in 2002, the Guidebook integrated hydrology and aquatic ecology. This built on Washington State research findings about the four factors limiting stream health. These are introduced in Section 4.
- Then, in 2007, the 'Beyond the Guidebook' initiative added geomorphology to the mix. This addressed the relationship between volume control and resulting flow rates in streams; and correlated stream health with stream erosion.
- Now, in 2012, the understanding yielded by the Englishman River research has added a groundwater dimension to stream health.

The Water Balance Methodology is a foundation block for those tasked with developing a Master Drainage Plan, an Integrated Stormwater Management Plan (ISMP), the Rainwater Management Component of a Liquid Waste Management Plan, or a Watershed Blueprint.

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Source: Stormwater Planning: A Guidebook for British Columbia, 2002

Figure 8

Integrated Strategy for Managing the Rainfall Spectrum

Explanatory Notes – Key Messages:

Urban development reduces the 'vadose storage' and interflow. Therefore, restore these capabilities by means of green infrastructure solutions.

Basements and underground structures will lower groundwater levels to the footing level. The ground above this then becomes part of the vadose zone and can be used for vadose storage. When designed properly, this zone can form part of the green infrastructure solution.

Definitions: 'Aquifer Storage' refers to the saturated zone where all void spaces are filled with (ground)water. 'Vadose Storage' refers to the unsaturated zone where void spaces are filled with air AND water.

How Does Water Get to a Stream?

Surface Runoff

- minutes to hours

Shallow Groundwater

- days to seasons

Deep Groundwater

- years to centuries

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Water Balance Methodology

At the turn of the century, the *UniverCity Sustainability Community* atop Burnaby Mountain in Metro Vancouver was the genesis and first case study demonstration for the Water Balance Methodology. By 2002, the Province's decision to embed the Water Balance Methodology in the Stormwater Guidebook defined a turning point in the regulatory vision for drainage planning, from reactive to proactive.

Historical Context: In the mid to late 1990s, widespread changes in thinking about rainwater and stormwater impacts reflected new insights. Historical context is provided as follows:


- **In 1973:** A glimmer of understanding when Thomas Hammer publishes his research findings on the relationship between land use changes and stream erosion.
- **By 1996:** A year of breakthroughs by a number of pioneers results in a 'roadmap' for integrated rainwater management.
- **By 2000:** A mandate to re-invent urban hydrology in order to protect tributary stream health in the Brunette River urban watershed in Metro Vancouver leads to development of the Water Balance Methodology.
- **In 2002:** Province releases the Guidebook.
- **By 2007:** Beyond the Guidebook brings together all the pieces to link the site to the watershed to the stream.

The Water Balance Model, a web-based scenario comparison tool, was developed as an extension of the Guidebook. It enables assessment of how to meet performance targets for rainfall capture.



Launched in 2003, the web-based Water Balance Model was the outcome of a 'building block process' during the 2000 - 2002 period:

- Stormwater Planning: A Guidebook for British Columbia
- Metro Vancouver Report on Stormwater Source Control Evaluation
- Chilliwack Policy & Design Manual for Surface Water Management
- UniverCity:* The Sustainable Community at the top of Burnaby Mountain



Rainfall Distribution: Figure 9 shows that 'light showers' account for most of the annual rainfall volume. When the Guidebook was rolled out in 2002, the images shown as Figure 9 proved to be a powerful education tool because they:

- helped to change the way drainage practitioners and others view rainfall;
- focussed attention on the distinction between *rainfall capture* and *runoff control*; and
- promoted understanding of why infiltration is achievable for much of the year.

Circa 2000, there was fear and doubt that anything could be done to prevent rainwater runoff. The images presented as Figure 8 were among the keys to changing the core beliefs of drainage practitioners.

Hydrologic Changes: Figure 10 illustrates how the proportions of the water balance change as the percentage of hard surface increases: runoff goes up; infiltration and surface evaporation both go down. It too is an important educational tool

"Evaporation is critical and typically gets overlooked in conventional drainage modelling. The role of the tree canopy, for example, in intercepting rainfall has not been fully understood or appreciated," states Jim Dumont, Engineering Applications Authority for the Water Balance Model Partnership. "To maintain the mass balance would require more and more infiltration as development intensifies, but is that a good or bad thing. Too much infiltration can cause significant problems."

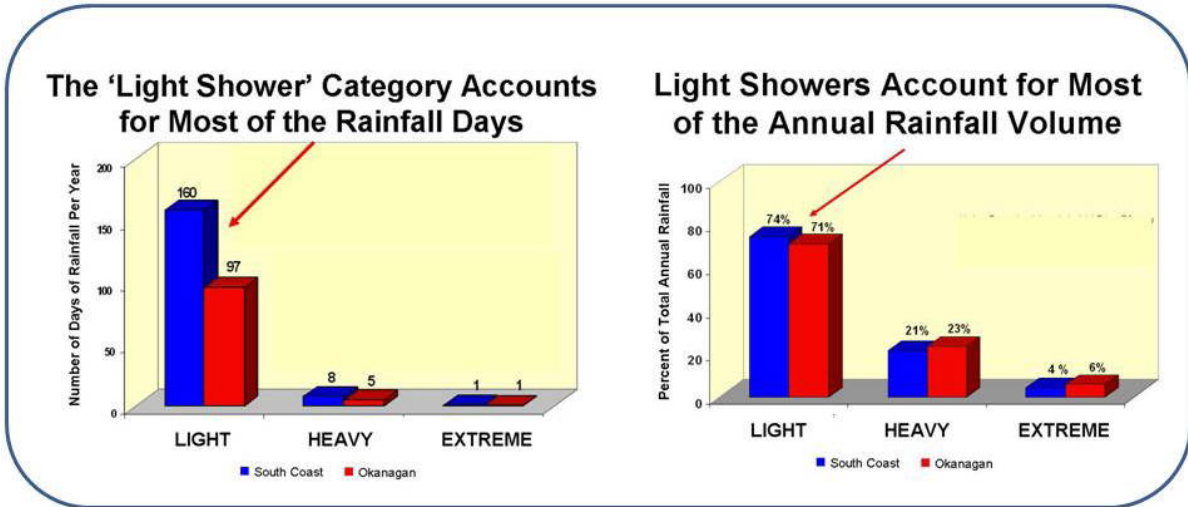


Figure 10 is a foundation piece for managing the *Rainfall Spectrum* (Figure 8). It helps provide an understanding of the pragmatic considerations driving the paradigm-shift from past **peak flow** practice to today's **volume-based** practice.

"What most people overlook is that evaporation is almost equal to infiltration. This means there is increasingly more volume to manage as the landscape is built over. This also means we need to implement landscape-type solutions that mimic the water balance," concludes Jim Dumont.

Integrating the Site with the Watershed and the Stream

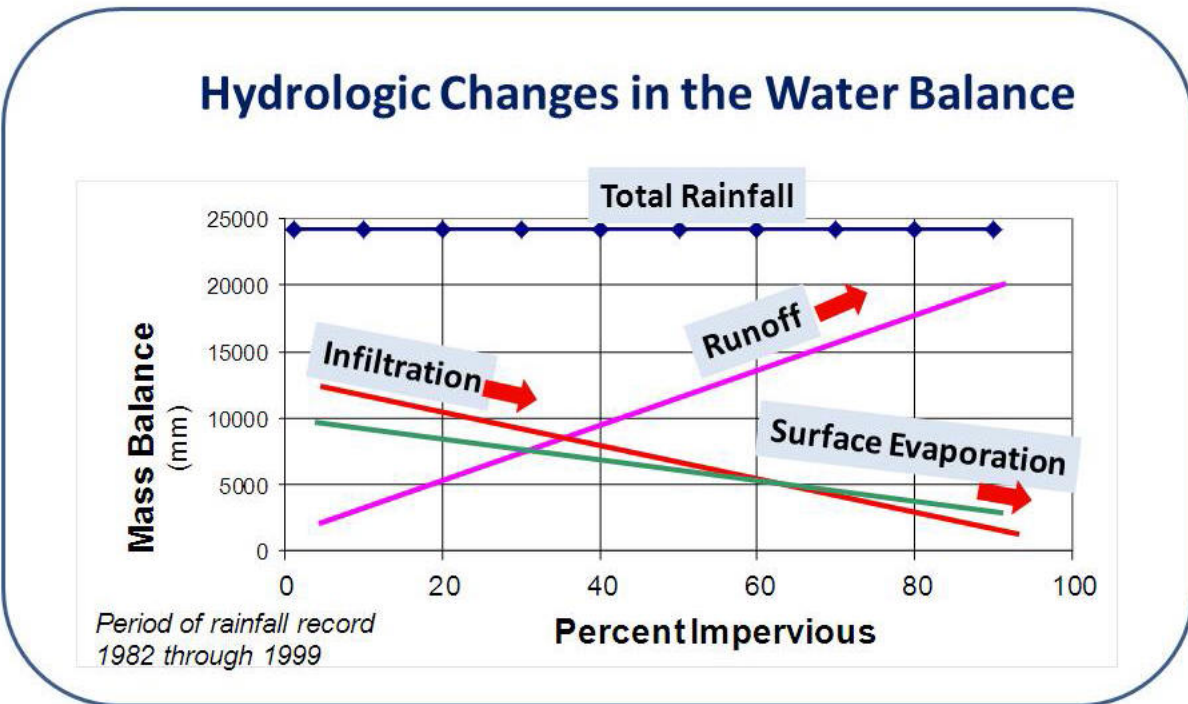
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Source: Chapter 6, *Stormwater Planning: A Guidebook for British Columbia*, 2002

Rainfall Distribution

Figure 9



Source: *Water Balance Model Partnership*

Figure 10

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4. Protect Stream Health

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 State's Puget Sound and British Columbia's Georgia Basin together comprise the Salish Sea. In terms of how rainwater management in a watershed context has evolved, there is a history of cross-border sharing and collaboration.

A Road Map for Integrated Rainwater Management

In 1996, the Center For Urban Water Resources Management at the University of Washington (in Seattle) published a seminal paper by Richard Horner and Chris May. They synthesized a decade of Puget Sound research to identify the factors that degrade urban streams and negatively influence aquatic productivity and fish survival. They demonstrated that the four factors limiting stream health are, in order-of-priority:

1. **Changes in Hydrology** – Greater volume and rate of surface runoff caused by increased impervious area and road network densification.
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'.
4. **Deterioration of Water Quality** - Increased sediment load due to more runoff volume causing channel erosion. Pollutant wash-off from land uses, deliberate and accidental waste discharges.

The limiting factors and order-of-priority identified by Richard Horner and Chris May provided a 'road map' for integrated rainwater management. In BC, the Horner and May findings provided a springboard from which to reinvent urban hydrology and develop the Guidebook.

Changes to the Water Balance

Figures 11, 12 and 13 illustrate the progressive changes in hydrology and resulting impacts on stream health when land use change alters the Water Balance.

Same Rainfall, Different Runoff Pattern: Figure 12 illustrates 'changes in hydrology' as impervious area increases. A critical parameter for erosion is the number of runoff events per year that equal or exceed the magnitude and duration of the natural channel-forming event – before urbanization altered the Water Balance.

Impacts on Stream Corridor Ecology: Figure 12 is a schematic representation of the Horner and May findings, and 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 (i.e. last two rows).

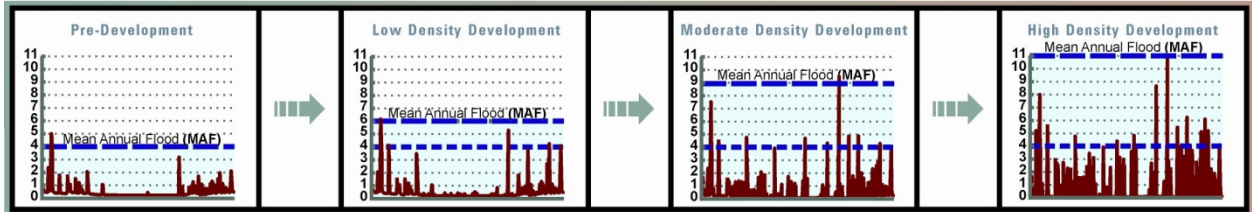
Eroded material creates turbidity, or dirty water, that can irritate fish gills and make it difficult for fish to find their food. Eroded sediments can cover spawning beds, smothering fish eggs in the gravel and possibly blocking access to spawning areas for the next generation.

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.

Integrating the Site with the Watershed and the Stream

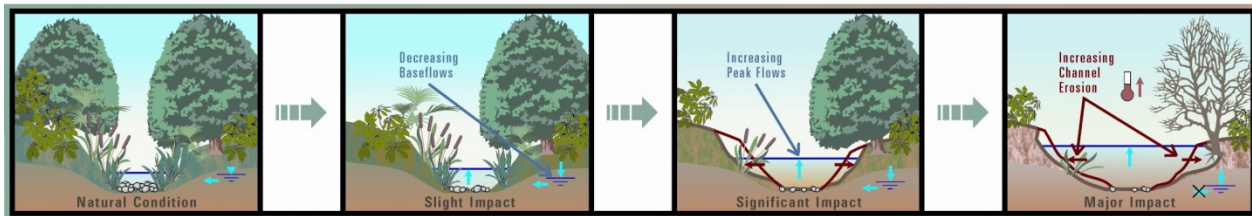
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EFFECT ON TYPICAL YEAR HYDROGRAPH



Same Rainfall, Different Runoff Pattern

EFFECT ON WATERCOURSE EROSION



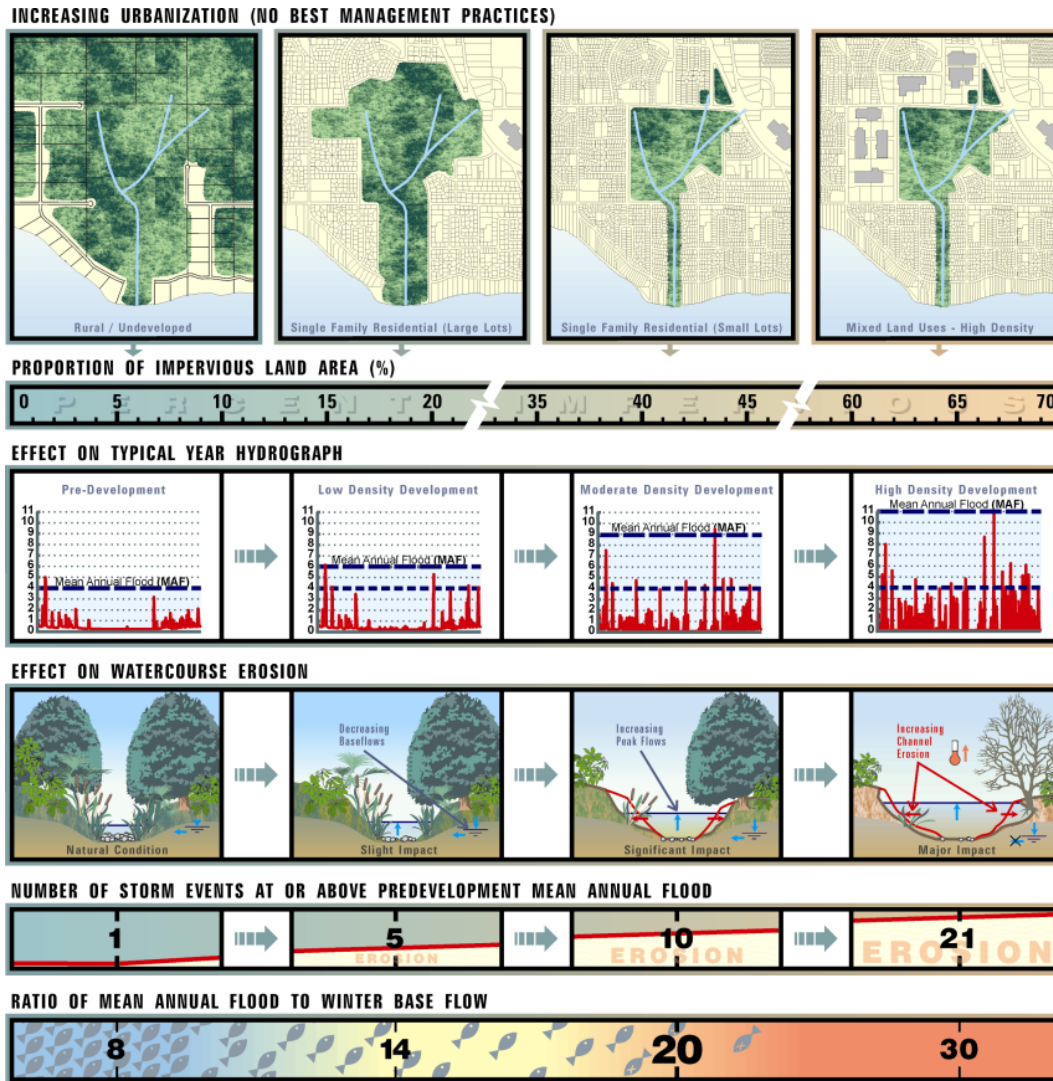
Increasing Volume + Longer Duration = More Stream Erosion + Loss of Stream Habitat

Figure 11

Consequences of Changes to the Water Balance

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

(WITHOUT BEST MANAGEMENT PRACTICES)

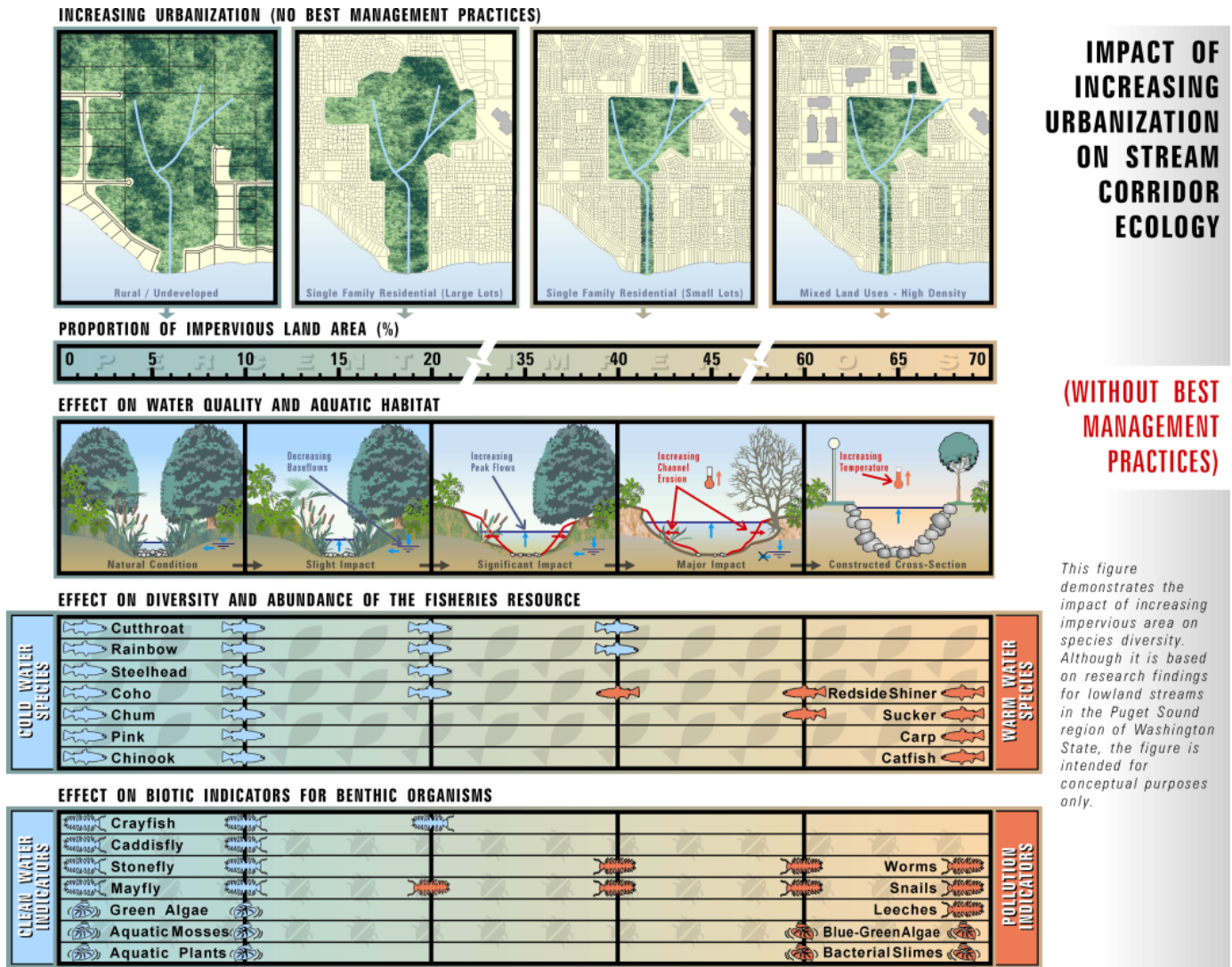
This figure demonstrates the impact of increasing impervious area on the number of erosion-causing events, and increased peak flow impacts on channel stability. Although it is

Source: Stormwater Planning: A Guidebook for British Columbia, 2002

Figure 12

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Source: Stormwater Planning: A Guidebook for British Columbia, 2002

Figure 13

Integrating the Site with the Watershed and the Stream

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Stream Health Methodology

Land development produces increased volumes of stream discharge combined with increased duration of discharge. The result is increased stream erosion following development. So, mitigation of the stream impacts must include controlling the combination of discharge rate and the time over which it occurs.

Integrating the site with the watershed and the stream requires integration and synthesis of hydrology, aquatic ecology and geomorphology. In *Beyond the Guidebook*, the outcome is called the *Stream Health Methodology*.

Many advances in science-based understanding occurred in the mid-1990s. Yet engineering practice generally did not incorporate this understanding. The water balance methodology driving the *Beyond the Guidebook* initiative addresses this historical oversight.

Understand What Causes Stream Erosion: In hindsight, what did not happen in the 1990s was a comprehensive bringing together or synthesis of engineering and biophysical understanding. At the time, neither discipline had a clear understanding of the processes involved or of the wide ranging impacts that they were trying to mitigate. Yet the way forward is foreshadowed in this quote from Larry Roesner (of Colorado State University), proceedings editor for a 1996 ASCE



conference: "What is required is the development of soft engineering that simultaneously achieves the scientists' criteria for ecosystem protection or restoration, and looks and acts like a natural environment".

What Erosion Looks Like: Channel discharge and width increase as a consequence of urbanization. The photo included as Figure 14 is representative of conditions often experienced in urban streams. It illustrates the impact of down-cutting and/or bank-undermining over time. The cause-and-effect relationship boils down to this sound-bite: *more volume equals more erosion*.

Science of Stream Erosion

The Stream Health 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. The methodology also relies on a **continuous simulation** of watershed response (i.e. stream discharge) to rainfall over a period of record, which would typically be several decades.

The quantitative indicators for stream erosion analysis are *Tractive Force* and *Total Impulse*.

Estimate the Tractive Force: "The methodology is founded on the concept of quantity of energy available to cause stream erosion. The approach also recognizes that some stream erosion is essential; and uses estimates of tractive force applied over time to establish the energy available to cause stream erosion and to provide a balance between pre- and post-development conditions," explains Jim Dumont.

"While the use of tractive force as a single measure is interesting, it only provides a snapshot of conditions within a stream and the energies associated with flow."

Estimate the Total Impulse: "When we introduce the additional dimension of time and examine the tractive force applied to the stream cross section, we can then convert the measure of force into a measurement of the amount of energy being applied to a stream cross section," Jim Dumont further explains.

"Application of this formula is particularly simple because the continuous simulation of watershed response to rainfall will provide both the discharge and depth of flow at each hour of the simulation throughout the period of simulation."

"The flow conditions that would not result in movement of bed and bank material can be eliminated. This leaves only the **Impulse**, or total energy that would result in stream erosion. The effect of development and different mitigation schemes can be tested numerically," concludes Jim Dumont.

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Photo Credit: Richard Boase, District of North Vancouver

Tractive Force Equation	Impulse Equation
<ul style="list-style-type: none"><input type="checkbox"/> Simple equation<ul style="list-style-type: none">✓ Applicable for a wide, open channels✓ Product of unit weight of water, hydraulic radius of flow, and slope of channel<input type="checkbox"/> Include banks for narrow channels<ul style="list-style-type: none">✓ Banks are often the critical part	<ul style="list-style-type: none"><input type="checkbox"/> A measure of <u>energy applied to the stream</u> cross-section in the form of friction<input type="checkbox"/> Use duration of flow to estimate total Impulse for a range of flow depths<input type="checkbox"/> Can exclude non-erosive tractive force<input type="checkbox"/> Easy to include in continuous modelling

Figure 14

Stream Erosion

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Effects of Urbanization on Small Stream Health

The previous pages and figures have provided background on the evolution of an engineering methodology to protect stream health. Next, this Primer elaborates on the aquatic biology perspective. Examples of Parksville streams are also introduced to provide local context.

Commit to Water Stewardship: “Urbanization is a collective term describing a series of land and water uses which can dramatically affect small streams and their biological resources (Figure 15). In many cases, the effects of urbanization accumulate over time (sometimes decades), reflecting a continuum of decisions and actions that incrementally degrade streams and reduce their biological productivity and resilience,” observes Craig Wightman.

“Historically, many small watercourses deemed to be ‘in the way’ of development have been ditched, straightened or placed in culverts, denuded of riparian vegetation, and impacted by more intense storm runoff and droughts (the latter a result of greatly increased impervious surfaces in the basins). They are also impacted by water-borne pollutants and changes in thermal regimes, typically becoming much warmer in summer following loss of riparian canopy.”

“To attempt to reverse decades of impacts can be costly and high risk. Hence, it makes sense to commit to water stewardship at the outset of urban development, with early planning taking into account the environmental needs of watercourses, fish and wildlife species, and their intrinsic natural heritage values to a community’s present and future generations.”

“While initially protecting aquatic health is always a ‘water smart’ decision, several BC communities have also elected to restore damaged streams as demonstrations of hope and collective action. Burnaby’s Guichon Creek in the City of Burnaby (Metro Vancouver) and Bowker Creek in Victoria-Saanich-Oak Bay (Capital Region) are two ‘good news’ stories attesting to the power of vision, partnership and innovation to reverse past effects of neglect and mistreatment.”

What is a Healthy Urban Stream?

“There are many elements that, in total, shape the health of urban streams. These include natural stream flows, suitable water chemistry, energy (e.g., sunlight, organic matter) and physical structure (including riparian corridors) that generate diverse habitats for native species of flora and fauna (Figure 16),” continues Craig Wightman.

Protect Riparian Corridors: “The concept of water resource health, or integrity, is reflected by the ‘ecological goods and services’ commonly associated with healthy functioning watersheds. In terms of importance to humans, aquatic ‘goods and services’ are most commonly tied to clean and safe drinking water, safe consumption of fish, assimilation of wastewater and healthy and diverse communities of aquatic plants, fish and other wildlife.”

“Functioning, intact riparian corridors along urban streams also provide greenways that directly enhance local conservation, recreation and property values. And, as we are now fully appreciating, surface and groundwater are rarely mutually exclusive; but are joined through complex hydro-geological pathways that are seasonally co-dependent for recharge.”

“Riparian set-backs on salmonid-bearing streams in the Nanaimo Regional District (and in all member municipalities) were mandated by the provincial government through passage of the Fish Protection Act (1997), followed by enactment of the Riparian Area Regulation (RAR) in 2004,” reports Craig Wightman.

“RAR requires local governments to protect riparian areas during residential, commercial, and industrial development. RAR is intended to protect ‘features, functions and conditions that are vital in the natural maintenance of stream health and productivity’.”

“These include sources of large organic debris; areas for stream channel migration; vegetative cover; provision of food, nutrients and organic matter; stream bank stabilization; and, buffers from excessive silt and surface runoff pollution.”

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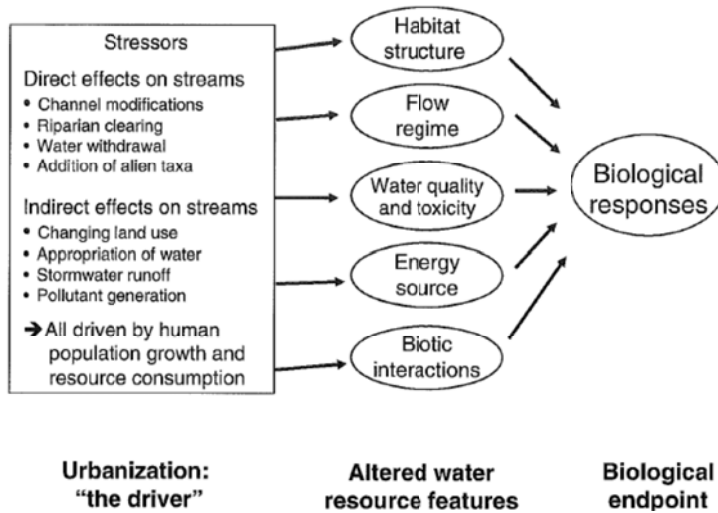


Figure 15

Five Stream Factors that are affected by Urban Development

(modified from Karr 1991 and Karr and Yoder 2004)

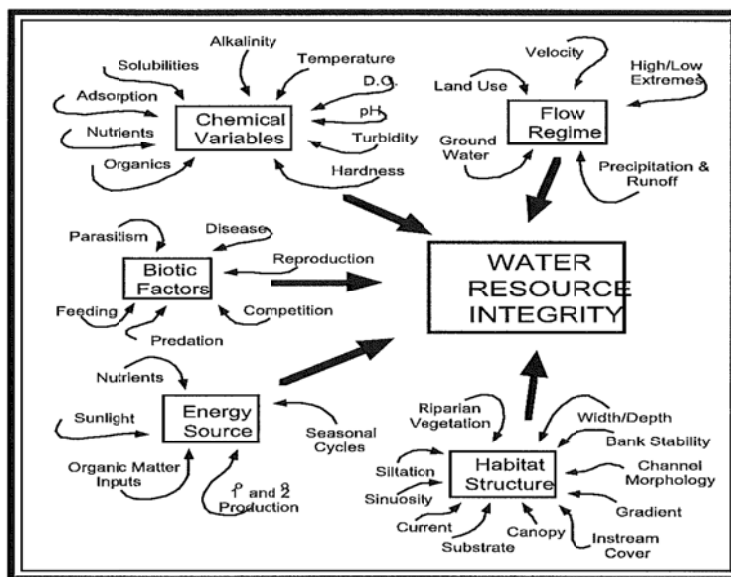


Figure 16

Five Major Factors which Collectively Shape Stream Integrity

(modified after Karr *et. al.* 1986)

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What a Healthy Stream Looks Like

"In assessing the health of urban streams, the presence, condition and number of fish, insects, algae, plants and other aquatic life provide a reliable barometer. These are called biological indicators and, in aggregate, are the best and most accurate measures of health for streams, lakes and wetlands," explains Craig Wightman.

"Secondary measures, such as water quality and habitat – including spawning and rearing conditions for salmon and trout - are also informative. These metrics, and their underlying scientific methods, can be used by experienced practitioners in diagnosing stream conditions or limiting factors, and prescribing protection and remedial actions."

Illustrative Examples: The contrast between 'degraded' and 'healthy' stream conditions is illustrated by Figure 17 (photos of Romney Creek near the Parksville Springwood Pump Station) and Figure 18. The latter is the cover photo from the District of North Vancouver's "Quick Guide" to Streamside Protection Development Permit Areas.

"Sections of Romney Creek have been ditched; and its original riparian cover largely removed and replaced by grass and ornamental shrubs along the pump station's perimeter fence. Three-spined stickleback is reportedly the only native fish species still occupying the stream at this location," reports Craig Wightman.

"Sticklebacks often display environmental plasticity in the face of conditions too harsh to support cold water species, like Coastal Cutthroat trout. Hence, if trout were once present in upper Romney Creek, they may have been lost as a product of expanding urbanization over time."

"In contrast, the small North Vancouver stream (Figure 18) remains in its original course, well-shaded by riparian tree and shrubs, and with a predominant substrate of mixed boulders, cobbles and gravels. Coarse substrates provide high quality habitat for larval forms of aquatic insects and safe hiding and foraging sites for juvenile salmon and trout. From a fish habitat perspective, the photo conveys an impression of stream stability, diversity and values worth preserving! The District of North Vancouver has ensured preservation of these natural amenities through its Streamside Protection requirements, passed as a bylaw in 2008."

"In other small basins, the City of Parksville has recognized stream values and provided riparian setbacks, including upper Shelly Creek in vicinity of Hamilton Avenue (Figure 19). This setback has succeeded in preserving some stream habitats, although erosion and sedimentation are persistent in the same reach. This may be partially due to subdivision construction practices of the past, and also to headwater private land logging beyond the municipal boundary. In spite of less than ideal habitat conditions, stream-resident Coastal Cutthroat trout were captured here in September 2011."



ROMNEY CREEK: Note ditch-like appearance and concrete sill near where it "disappears" under Despard Avenue and a neighbouring sub-division.

Figure 17

Integrating the Site with the Watershed and the Stream

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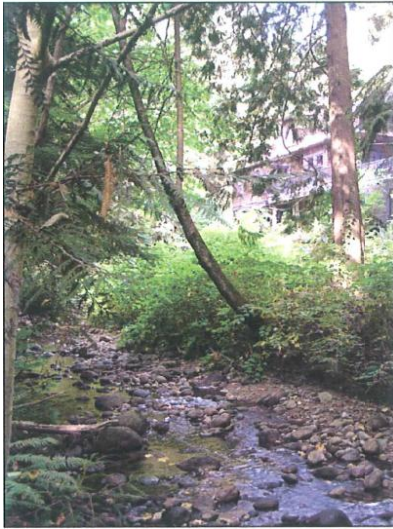


Figure 18

“Other positive signs in the upper Shelly catchment include installation of fish passage baffles in a new culvert under Wildgreen Way, and a sediment retention pond adjacent to the same road (Figure 20).”

“These collective measures represent a milestone in the City’s development planning around small fish-bearing streams. They are an important step in accepting responsibility for the impacts of urban development at spatial scales ranging from backyards to entire drainage basins. To demonstrate commitment and ensure this progressive approach is sustained, it would help if Parksville formally endorsed the tenets of BC’s Living Water Smart Plan (2008), which pledges to educate all land and water managers about the fundamental requirements of stream health. In turn, this will help promote a more holistic approach to conserving surface and groundwater resources for the community’s future,” concludes Craig Wightman.



SHELLY CREEK: Adjacent to Hamilton Avenue subdivision - alder dominated riparian zone, rip-rapped left bank and riffle habitat; resident Coastal Cutthroat trout sampled in September 2011

Figure 19



SHELLY CREEK: Baffled culvert and sediment retention pond installed under and adjacent to Wildgreen Way, respectively. Important steps in preserving healthy streams and fish populations.

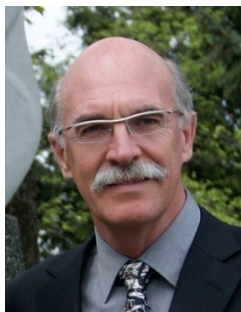
Figure 20

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5. Look at Groundwater Differently

This section synthesizes the pioneer work of Dr. Gilles Wendling, and presents it in his own words. Because he looked at groundwater differently in the Englishman River, Gilles Wendling has advanced the science and he has developed a practical application of water balance thinking. His contributions to science-based understanding extend beyond the technical and into the communication and education realm. His work provides a bridge between rainfall (Section 3) and stream health (Section 4).



Dr. Wendling emphasizes that time is a critically important dimension in maintaining the water balance (refer to Figure 8). Also, that water is always moving. These are fundamental concepts, yet are not always well understood.

Characterizing Aquifers

“Characterizing aquifers is a complex and costly exercise because you need wells in order to reach aquifers and to monitor the depth and fluctuation of the level of the water table,” states Dr. Wendling.

“The cost of drilling a well is typically between \$5,000 and \$10,000, and several wells per aquifer are needed to get the required information to define the movement of groundwater in an aquifer. Then you need to install monitoring equipment, to collect the data, and to store and process it. The final cost is in the hundreds of thousands of dollars if you want to do a proper assessment over a watershed containing several aquifers.”

“The approach that we took with the Mid Vancouver Island Habitat Enhancement Society (MVIHES) in the Englishman River Watershed was to involve the community.”

Involve the Community: Dr. Wendling explains that the benefits of community involvement were two-fold:

“First, we saved the large cost of having to install new wells. We used existing wells that owners volunteered for monitoring.”

“Secondly, we believe that the long-term health of watersheds depends upon the stewardship of the people who live in the watersheds. By getting them involved in its study, the community connects to its watershed, its complexity and how it works.”

“Community members will then be able to more willingly modify their behaviour and management of the land, after they appreciate the direct connection between what happens at surface and what happens in the subsurface, on their property, the property of their neighbours and their local environment,” concludes Dr. Wendling.

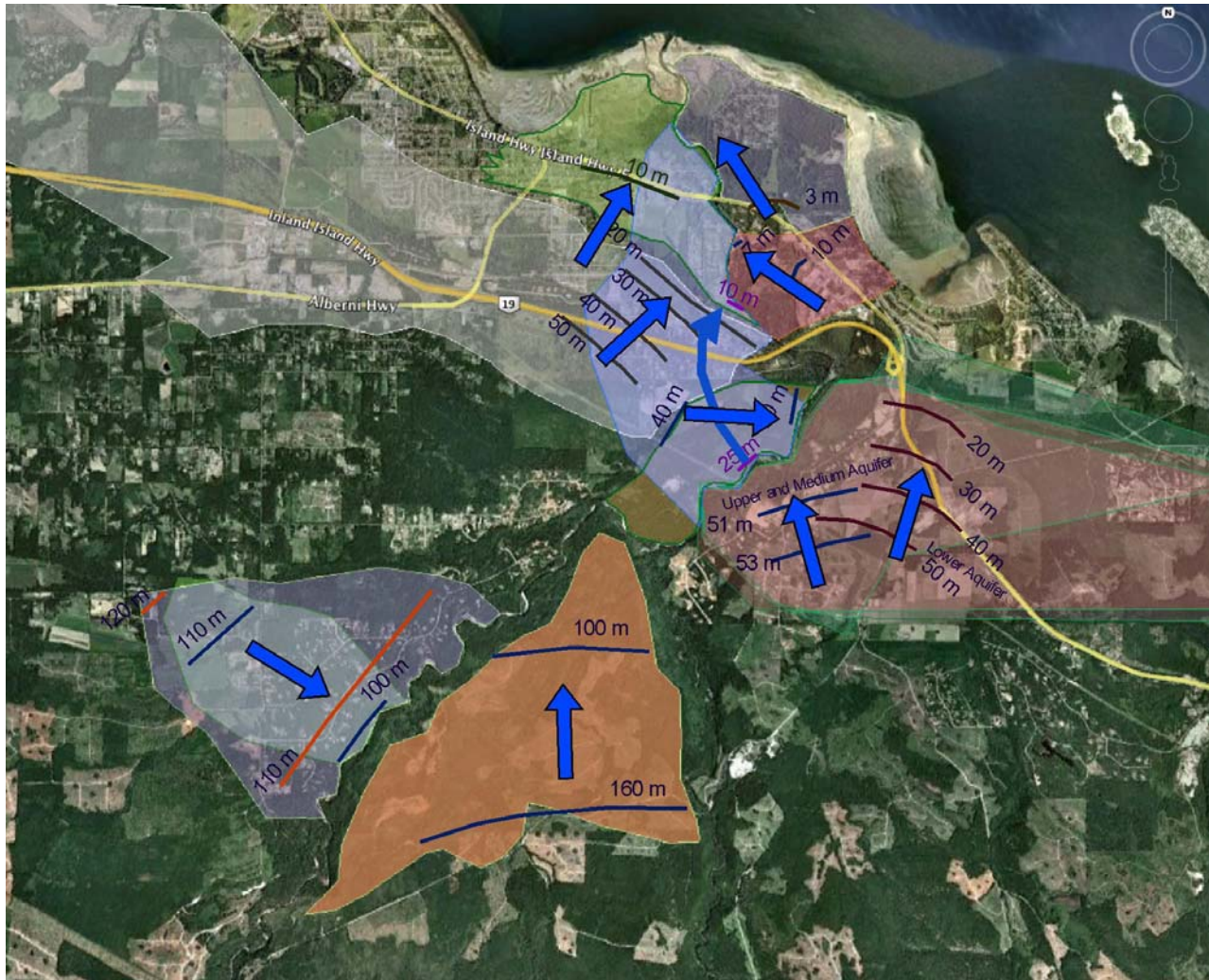
So where are the aquifers and in which direction is the groundwater moving: “Through the review of numerous well logs, the drafting of cross sections, field observations, water level monitoring in water wells, and inspection of the riverbanks, a map was produced showing the estimated footprint of the aquifers in contact with the Englishman River (refer to Figure 21),” continues Dr. Wendling.

“In addition, the depth to water measured in the wells has given us the information to estimate the slope of the water table. So we can now estimate the direction of the water (*shown with the blue arrows on Figure 21*), and the slope of the water table.” The latter is indicated by the water table elevation lines on Figure 21.

“It was important for us to characterize the flux under both high and low water table conditions, particularly to assess if there were sections of the Englishman River where there was a reversal of the flux between the river and the aquifers due to the seasonal fluctuation of the water table. And generally it does not happen. **The aquifers keep providing groundwater to the river, all year long,**” concludes Dr. Wendling.

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General Groundwater Directions in Overburden Aquifers in Englishman River Lower Watershed

Figure 21

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How Much Groundwater is Discharging to the Englishman River?

“In order to visualize the flux between the aquifers and the Englishman River under low summer flow conditions, we created a series of images,” states Dr. Wendling.

“In the accompanying image (refer to Figure 22), you are traveling down the Englishman River, between 10 km and 5 km up from its estuary. On your left you see the face of the left bank, and on your right the right bank. The picture of the land, on both sides allows you to position yourself in the watershed.”

“The blue line represents the elevation of the river. The coloured shapes represent the sections where the aquifers intersect both banks. And the arrows express the flux of groundwater discharging into the river.”

“The estimate of the flux is summarized in the boxes, in litres per second (l/s) and cubic metres per day (m³/day). The ratio between the flux from the aquifers and the summer river lowest flow rate is expressed as a percentage, to show how much the aquifers participate in providing water to the Englishman River during its period of low flows.”

Flux Defined: Flux is a core technical concept, and one that Dr. Wendling stresses when making presentations.

“The groundwater flux is the quantity of water traveling through and aquifer (in the voids between the grains of sand or the pieces of gravel) per section area (typically per m² of the section of the aquifer it is traveling through) and per unit of time (e.g., per second, minute, day, year),” explains Dr. Wendling.

“In my experience, it is important to both remind and emphasize that an aquifer is NOT an underground lake. This fact is not necessarily understood by everyone. So we need to be clear that an aquifer simply consists of saturated layers of sand and gravel in the subsurface. The water is always moving.”

Groundwater and Surface Water: Same water

The ability of Dr. Wendling to make groundwater concepts real to an audience is illustrated by the story that he tells about a puddle on farmland in the Englishman River watershed.

Figure 23 is a collage of four pictures that illustrate the “story of the puddle”. It is a big puddle, approximately 1 metre in diameter.

The Story of a Puddle: “This puddle is not just a puddle. When I walked by it, on July 21, 2010 at 2:31 pm (Figure 23B), on a sunny day, I observed fry; a dozen of them. They were all concentrated at a specific spot. Why there? Because it is where groundwater was discharging to this little puddle,” reports Dr. Wendling.

“They were looking for cooler and fresher water, possibly containing more oxygen than the warm, silty and algae rich water of the puddle.”

“Where was that puddle? At the end of a drainage ditch, upland at the corner of a field (refer to Figure 23C and note the yellow circle). These fry had swum almost 2 km from the Englishman River up small tributaries to the local headwaters.”

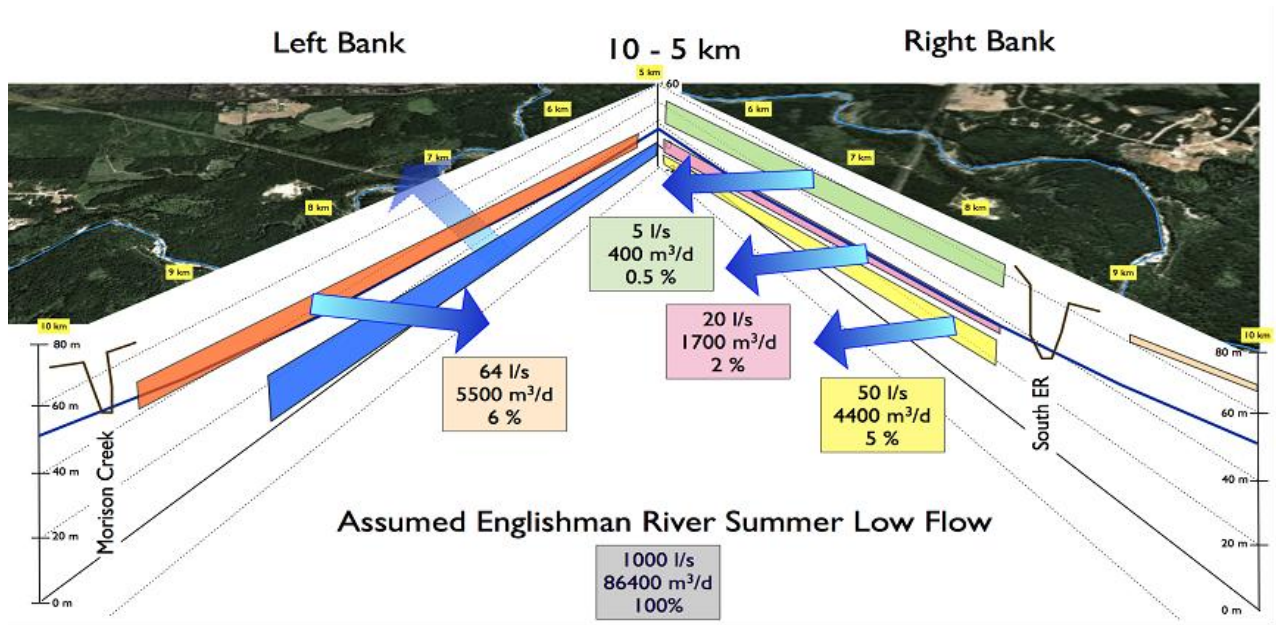
“Our study has shown that in this area, which is an important spawning and rearing ground for salmon, there is an important flux of groundwater towards the Englishman river, both under high and low water table conditions.”

“When I walked by the puddle 2 hours later (Figure 23D), I was very saddened by what I saw. All the fry had died because the water conditions had passed the tipping point that allowed them to survive.”

“This simple observation really confirmed to me that surface water and groundwater are closely connected. They are one, as shown by image (refer to Figure 24) that illustrates how the groundwater from aquifers feeds both the wetlands and the streams. We have to be very careful with what we do with the land and how it affects water tables,” concludes Dr. Wendling.

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Estimated Groundwater Flux to Englishman River from Overburden Aquifers

Figure 22



Figure 23

Groundwater and Surface Water: Same Water

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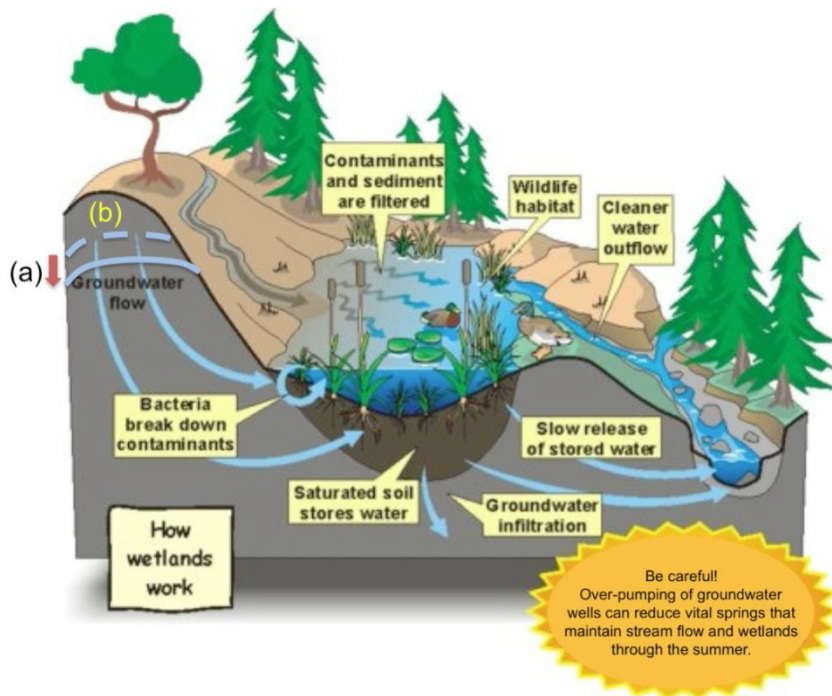


Figure 24

nrcan - geoscape Gulf Islands

Groundwater and Land: They ARE Connected!

"One of the objectives of our project was to delineate the land where aquifers connect to the Englishman River and are being recharged. We have created 'butterfly' views for this purpose," explains Dr. Wendling.

Butterfly Views: "We have used the views of both the right bank and the left bank of the river showing where the aquifers are in contact with the river (refer to Figure 22) and have added the footprint of these aquifers, using color coding."

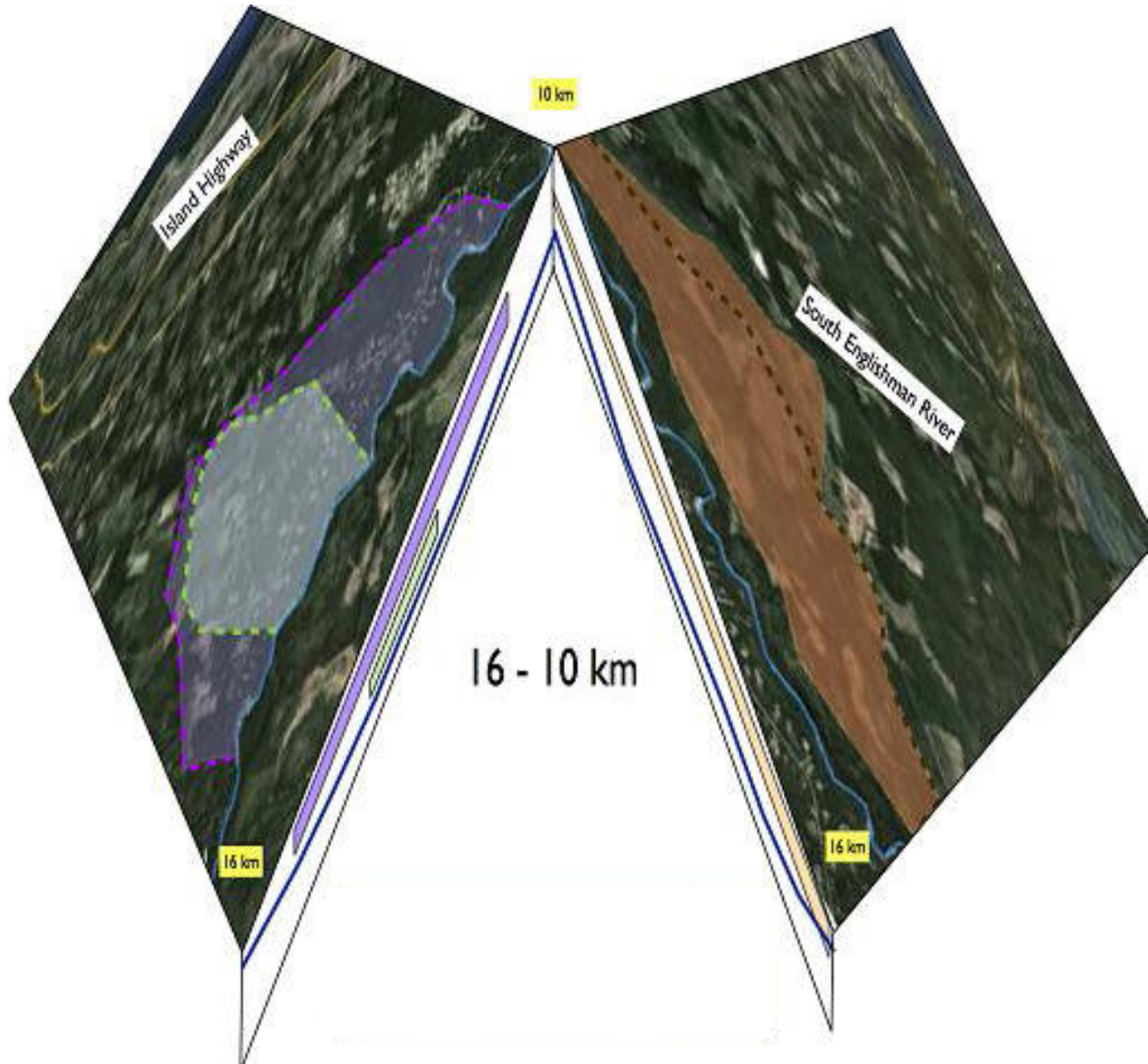
"For example (and with reference to Figure 25), we have a shallow aquifer in purple on the left bank. The purple shaded area shows its footprint. The thick dash line delineates the boundary of the estimated recharge area. This is the area where precipitation will generate infiltration that will reach the aquifer and will continue its travel as groundwater discharging into the river."

"On the right bank, the boundary of the recharge area does not correspond to the footprint of the aquifer, because there is a groundwater divide. Water droplets falling left of the divide (dashed line) will end up in the Englishman River. The ones falling on the right side will end up discharging into the South Englishman River."

Need for an Integrated Approach: "Decisions made about land development therefore have to take into account how both runoff and infiltration are going to be modified due to the change in land topography, cover, permeability, etc.," concludes Dr. Wendling.

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Estimated Recharge Zones of Overburden Aquifers contributing to Englishman River

Figure 25

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6. Mimic the Water Balance

The first five sections of this Primer have established the context for a science-based, integrated and holistic approach to rainwater and groundwater management. This context allows local governments to establish expectations:

This is what we want to collectively and incrementally achieve over time, and this is how we will work together to get there.

To close the loop, this section provides guidance so that champions in the local government setting will be informed and can then lead the move from awareness to action.

Doing Business Differently in BC

Creating desirable communities and protecting stream health are mutually reinforcing outcomes:

- Living Water Smart is the provincial **VISION** for sustainable land and water stewardship;
- **TOP-DOWN & BOTTOM-UP** collaboration between local governments and the stewardship sector is a critical success factor for “getting the local watershed vision right”;
- an over-arching **WATERSHED GOAL** is to manage the natural environment and built environment as integrated components of a healthy watershed;
- the watershed goal can be achieved by making ‘green choices’ and **DESIGNING WITH NATURE** to protect the water balance;
- inter-regional **KNOWLEDGE-SHARING**, collaboration, alignment and consistency will allow everyone to go farther, more efficiently and effectively, with implementation; and
- achieving the desired outcome is contingent on regulators, planners, developers, designers and others embracing **SHARED RESPONSIBILITY** and aligning their efforts.

If local governments and others are to be effective over time in creating liveable and desirable communities that also protect stream health, it follows that land development practices must strive to mimic the Water Balance.

Local Government Responsibility

The image below is included one more time to remind the reader of key elements of the Water Balance. The Water Balance Methodology links rainfall to stream health protection. Land use activities short-circuit the movement of water, thereby altering the natural water balance. This has stream erosion consequences. Thus, the purpose of ‘water-centric’ regulation of land development practices is to prevent or mitigate flow short-circuiting.



Think Like a Watershed: Figure 26 provides a high-level overview of local government responsibility to protect the water balance. The *Community Charter* empowers municipalities with extensive and very specific tools to achieve watershed goals and objectives. The *Local Government Act* provides regional districts with similar enabling powers.

"We need to understand the sub-systems that are in play between the time that rainfall is received at the top of the tree canopy and the time that it actually gets to the stream. That's the key to the whole systems approach," states Will Marsh, author of **Landscape Planning: Environmental Applications**, a classic textbook.



He retired to BC from the University of Michigan-Flint where he was Chairman of the Department of Earth and Resource Sciences and a Director of the Laboratory for Land and Water Management.

"We too often jump too quickly to the engineering computations about this method or that method....when what we really need is a basic understanding of the land and its functions. In other words, think like a watershed," Will Marsh emphasizes.

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Primer for Integrated Rainwater and Groundwater Management

Local Government Responsibility to Manage Drainage & Protect Stream Health

The term 'urban watershed' is a metaphor for those watersheds, or parts of watersheds, over which local governments exert control through regulation of land use. The distinction is important because:

- In Metro Vancouver and in the Capital Regional District, for example, the majority of municipalities completely encompass their watershed areas (or else share them with adjoining municipalities).
- Outside the major metropolitan regions, on the other hand, municipalities tend to be located at the bottom end of wilderness watersheds that are subject to provincial regulation.



In British Columbia, the term 'local government' encompasses municipalities and regional districts. The distinction is noteworthy because municipalities and regional districts are governed by the *Community Charter* and *Local Government Act*, respectively.

The *Community Charter* empowers municipalities with extensive and very specific tools to proactively manage the complete spectrum of rainfall events. These tools enable them to achieve watershed goals and objectives. Although the *Local Government Act* provides regional districts with similar enabling powers to establish a drainage function within a service area boundary, regional districts that do not have such a service do not have the same regulatory powers as municipalities. The Ministry of Transportation and Infrastructure has historically regulated drainage in electoral areas.

British Columbia case law makes clear the responsibility of municipalities to manage runoff volume to prevent downstream impacts. An increasingly important corollary to that responsibility is the need to work from the regional down to the site scale, to maintain and advance watershed health to ensure that both water quantity and quality will be sustained to meet both ecosystem and human health needs.

While a municipality has control over HOW rainwater runoff is generated and managed within its residential, commercial and industrial land uses, it does not have the same ability to regulate watershed activities that are taking place outside its municipal boundaries.

In summary, in this Primer '**urban watershed**' refers to drainage tributary areas within which zoning and land use are under the jurisdiction of municipalities or areas for which a regional district has established a drainage service.

Source: *Beyond the Guidebook 2010: Implementing a New Culture for Urban Watershed Protection and Restoration in British Columbia, 2010*

Figure 26

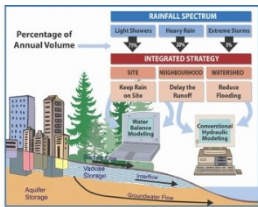
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Primer for Integrated Rainwater and Groundwater Management

How to Think Like a Watershed

Introduced in Section 3, the Water Balance Model (WBM) helps water resource practitioners ‘think like a watershed’. It also promotes an understanding of how to re-establish the connection to the stream after land is developed.

Storage and Interflow: The reader will recall that Figure 6 shows the generalized flow patterns of natural and post developed conditions. Urban development reduces the ‘vadose storage’ and ‘interflow’. Hence, the purpose of green infrastructure solutions is to capture rain where it falls, and to restore vadose storage and interflow.



The WBM was originally developed to quantify and assess the *hydrologic effectiveness* of green infrastructure to meet performance targets for rainfall capture and runoff control. The systems that are simulated in the WBM strive to mimic the interflow system by providing storage, and by providing the baseflow discharges.

WBM is Unique: The WBM is a scenario comparison tool that bridges planning and engineering; links development sites to the stream and watershed; and enables science-based performance targets to be established. Powered by the QUALHYMO calculation engine, the WBM 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.

“All three are powerful in their own rights. There is no other comparable web-based tool,” states Dr. Charles Rowney, WBM Scientific Authority. In the 1980s, he developed the QUALHYMO calculation engine for the Ontario Ministry of Environment.



WBM Outreach and Training: Launched by an inter-governmental partnership in 2003, the WBM has been rebuilt on a new platform. It is quicker and easier to use; and it now has launch buttons at three scales of investigation: SITE, NEIGHBOURHOOD and WATERSHED. In conjunction with the rebuild, the WBM Partnership is implementing an outreach, and training program to advance Sustainable Rainwater Management. In March 2012, the Okanagan Basin Water Board hosted the first training workshop in the 2012-2013 Series.

“I can see how the graphical results would allow me to communicate relevant information to my public and private-sector clients about the effectiveness of rainwater capture and runoff control options – not with complicated tables and calculations, but with relevant, easy-to-understand visual comparisons of the incremental benefits and costs. What a great tool,” reports workshop participant Michelle Sorensen, a professional engineer with a consulting firm based in Kelowna, BC.



Uncertainty Cascade: Figure 27 is a synthesis that comprises eleven steps that cascade down from a theory to interpretation of results. Developed by Dr. Rowney, he has coined this the *Uncertainty Cascade*.

“There is a preoccupation with theory, but the heavy lifting takes place in the last four steps. We need to keep our focus on SOLUTIONS on the ground,” emphasizes Dr. Rowney. “As we have been working on the WBM, we have been orienting it to THE SOLUTION. We are keeping it as simple as possible, but no simpler. The tool has to be consistent, inexpensive, and workable with limited data. It has to fit the local context, and it has to evolve as we learn.”

“We have ample horsepower to pick just about any theory we want and put it inside the WBM. But what we really need to focus on is: *what are the solutions that are really necessary*. An outcome that we are pushing for is the ability to interpret results, and the ability to represent the cases that we are actually trying to solve.”

All Models: The Uncertainty Cascade

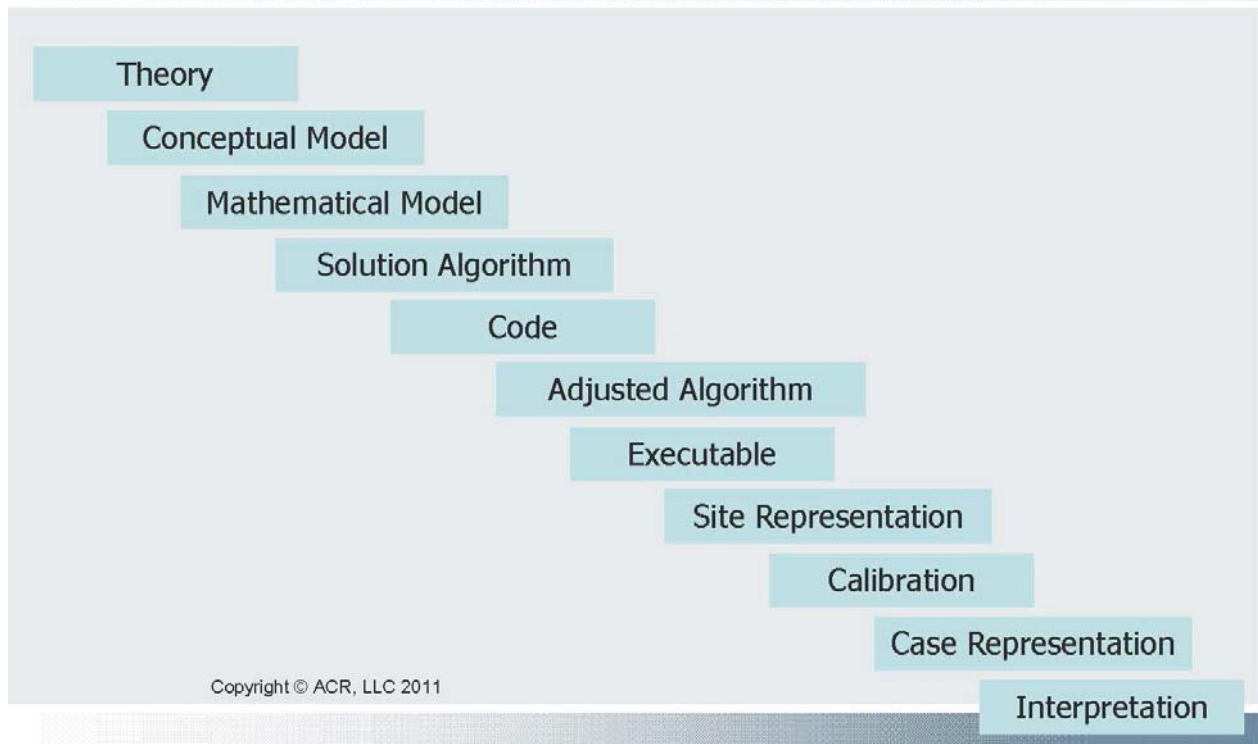


Figure 27

Drainage Modelling: From Theory to Interpretation

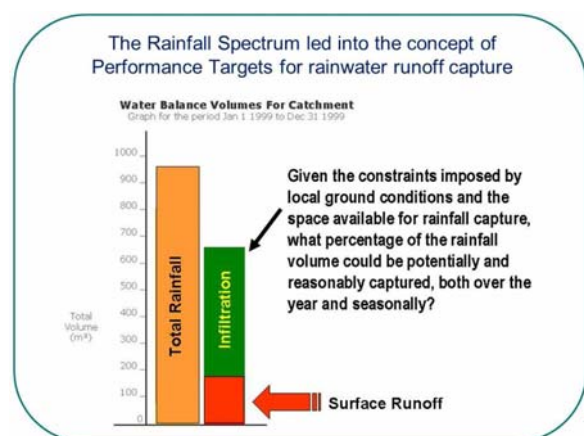
Integrating the Site with the Watershed and the Stream

Primer for Integrated Rainwater and Groundwater Management

Establish Watershed-Specific Performance Targets

In 2002, the Guidebook demonstrated how to bridge the gap between policy and site design, with emphasis on volume control at the site scale. By advancing a performance target approach, the Guidebook initiated a drainage paradigm-shift. In 2007, *Beyond the Guidebook* addressed the relationship between volume control and resulting flow rates in streams. This connected the dots to stream health.

Developed as an extension to the Guidebook, the Water Balance Model enables the user to evaluate and establish performance targets for rainfall capture and runoff control at the site, neighbourhood and watershed scales.



Translate Water Balance Targets into Design Criteria: 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 Guidebook articulated a guiding principle that “performance targets at the watershed scale provide a starting point to guide the actions of local government in the right direction”. A decade ago, this set the stage for translating targets into appropriate site design criteria that would then provide local government staff and developers with practical guidance for achieving the goal of stream health protection.

A Framework for Moving from Planning to Action: Table 2 from *Beyond the Guidebook 2010* identifies what local governments will need to do to protect or restore stream health. Originally released in 2008, it presents a conceptual framework for setting watershed-specific performance targets and then implementing them at the development scale. There must be clear linkages between the targets and development approval processes.

The framework presented in Table 2 envisions a level-of-service approach to setting watershed-specific runoff targets. It identifies questions that need to be asked when evaluating the acceptability of targets. Level-of-service is the integrator for everything that local governments do. Everyone will have to make level-of-service choices. Everyone needs to be thinking in terms of life-cycle costs, especially the future recapitalization of an infrastructure investment.

“The process of establishing an acceptable **‘Level-of-Service’** will require local governments to review, examine, and justify the existing standards and how to transition into the future where costs must be balanced against public needs and expectations,” states Jim Dumont, WBM Engineering Applications Authority.

Transition into the Future: Table 2 may also be viewed as a road map to a destination. In one page, it summarizes what needs to be done. Some local governments are progressing along the road map, yet work remains to be done to bring Table 2 to life for all local governments:

- On the one hand, methodologies and tools to establish appropriate watershed-specific targets exist.
- On the other hand, case study examples to demonstrate what integration looks like at multiple scales are still works-in-progress.

“Performance targets should be customized for individual watersheds and catchments, based on what is effective and affordable in the context of watershed-specific conditions,” emphasizes the Guidebook. “Continuous Water Balance modeling can be applied to determine what is effective and affordable.”

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Primer for Integrated Rainwater and Groundwater Management

Table 2 (brought forward from Chapter 7 in 'Beyond the Guidebook 2010')

Developing Outcome-Oriented Watershed Plans: Framework for Moving from Planning to Action

Action	Level of Commitment
<p>Complete and implement integrated rainwater/stormwater management plans that are affordable and effective in protecting or restoring Watershed Health</p>	<ul style="list-style-type: none"> ▪ Local governments, in collaboration with senior governments, develop Integrated Plans that enable implementation of integrated strategies for greening the built environment; and include establishing watershed-specific runoff targets (for managing the complete rainfall spectrum) that make sense, meet multiple objectives, are affordable, and result in net environmental benefits at a watershed scale. <p><i>(Note: To date, "integrated drainage plans" have typically been called "ISMPs" pursuant to the nomenclature established in Chapter 9 of the 2002 Guidebook. The time has come to describe truly integrated plans as "Watershed Blueprints" to capture the paradigm-shift from pipe-and-convey 'stormwater management' to landscape-based 'rainwater management' that restores watershed function over time)</i></p>
	<ul style="list-style-type: none"> ▪ Local governments, in collaboration with senior governments, establish watershed targets that are characteristic of actual conditions in watersheds, recognizing that there will be different strategies for already developed versus partially developed watersheds.
	<ul style="list-style-type: none"> ▪ Local governments, in collaboration with senior governments, evaluate the acceptability of watershed-specific runoff targets on the basis of an evaluation framed by these three questions: <ol style="list-style-type: none"> 1. What target will achieve the watershed health objective? 2. What needs to be done to make the target achievable? 3. Do the solutions meet the test of affordability and multiple objectives?
	<ul style="list-style-type: none"> ▪ Local governments, in collaboration with senior governments, implement green infrastructure solutions that result in effective rainfall management at the site, catchment and watershed scales.
<p>Embed landscape-based strategies in neighbourhood concept plans</p>	<ul style="list-style-type: none"> ▪ Local governments develop rainwater/stormwater and land use plans through an inter-departmental process that is collaborative and integrated. ▪ Local governments provide guidance as to how watershed-specific targets can be met at the development scale.

Source: **Commentary on Effective Municipal Rainwater/Stormwater Management and Green Infrastructure to Achieve Watershed Health**, April 2008

Released jointly by the Green Infrastructure Partnership and the Inter-Governmental Water Partnership in conjunction with the consultation process for Metro Vancouver's *Integrated Liquid Waste & Resource Management Plan*

The Commentary is accompanied by a paper titled *Beyond the Guidebook: Establish Watershed-Specific Runoff Capture Performance Targets*, released at the 2008 Water Balance Model Partners Forum.

Integrating the Site with the Watershed and the Stream

Primer for Integrated Rainwater and Groundwater Management

View the Watershed through an Asset Management Lens

The linkages between the natural Water Balance, watershed and stream health, and infrastructure liability have emerged as important pieces in ensuring 'sustainable drainage infrastructure', both fiscally and ecologically.

An Incentive to Do Business Differently: Local governments in British Columbia are faced with this financial challenge: the initial capital cost of 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. This fiscal reality creates the incentive to prevent additional financial impacts.

While developers and new home purchasers pay the initial capital cost of municipal infrastructure, it is local government that assumes responsibility for the long-term cost associated with operation, maintenance and replacement of infrastructure assets. Often this is not adequately funded through property taxation and utility charges, as various political priorities compete for limited tax dollars. In addition, local governments bear the entire financial burden to stabilize and restore watercourses impacted by increased rainwater runoff volume AFTER land is developed.

Sustainable Service Delivery: Tackling the unfunded infrastructure liability has led to a life-cycle way of thinking about infrastructure needs, in particular how to pay for those needs over time. The Province's branding for this holistic approach is *Sustainable Service Delivery*. Refer to Figure 28 for a definition.

Asset management usually commences after something is built. The challenge is to think about what asset management entails BEFORE the asset is built. This paradigm-shift starts with land use and watershed-based planning, to determine what services can be provided sustainably. Viewing the watershed through an asset management lens highlights why 'cost-avoidance' is a driver for local governments to require that development practices mimic the Water Balance.

Design with Nature and Protect the Water Balance:

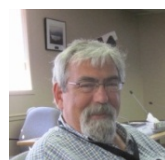
The costs and environmental impacts associated with 'pipe-and-convey' infrastructure contrast with the benefits of 'green' infrastructure at a watershed scale: *natural landscape-based assets reduce runoff volumes, have lower life-cycle costs, decrease stresses applied to creeks, and enhance urban liveability.*

The Brooklyn Creek Case Study (Figure 28) in the Comox Valley illustrates the financial impact when the Water Balance is short-circuited.

"Our Brooklyn Creek experience provides a graphic illustration of an infrastructure liability that is the consequence of NOT designing with nature," reports Glenn Westendorp, Public Works Superintendent with the Town of Comox. "The unforeseen \$1.8 million price tag to stabilize and restore the creek became the driver for doing business differently in Comox. This was the cost to the Town of not protecting the Water Balance."



"The Brooklyn Creek experience epitomizes how stripping away the water storage capacity of the watershed landscape impacts on stream health in two ways: loss of baseflow...that is, too little water in dry weather; and channel instability and erosion...that is, too much water for too long during wet weather," observes Jack Minard, Executive Director of the Comox Valley Land Trust.

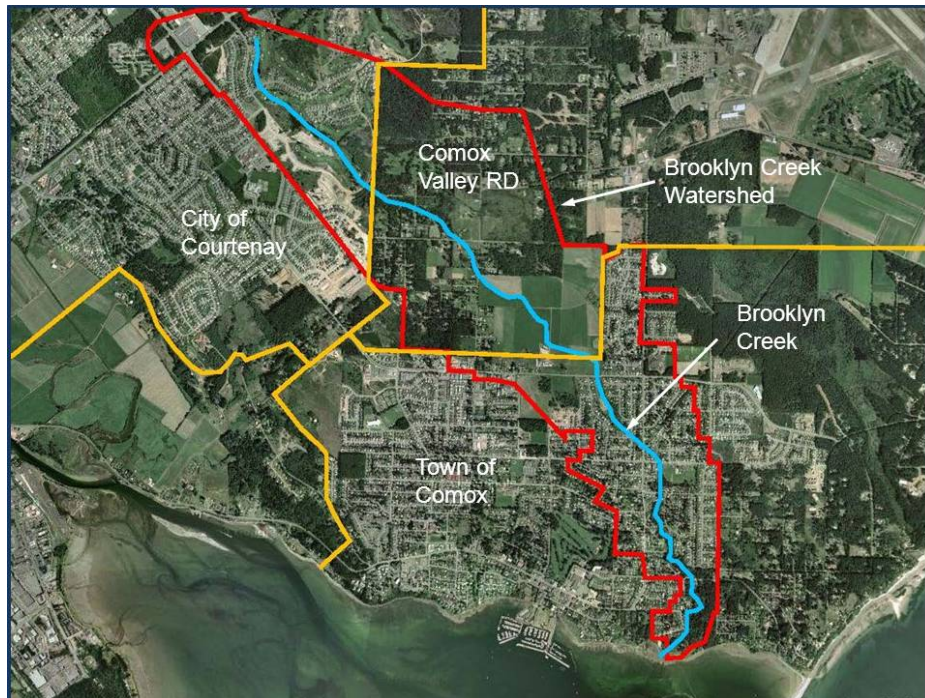


"A drainage system is more than just storm sewer pipes in roadways and culvert pipes at creek crossings. It also includes the ditches, volume control systems, and the receiving streams all the way to something that will not be affected by the discharge," continues Jim Dumont. "As a profession, we engineers have been very good at generating plans to install pipes and build ponds. But we have overlooked the stream. As the Brooklyn Creek experience shows, this is the unforeseen cost that shows up years later. It is the unfunded infrastructure liability."



Integrating the Site with the Watershed and the Stream

Primer for Integrated Rainwater and Groundwater Management



So What is Sustainable Service Delivery?

- It integrates all the principles of Asset Management
- It understands the value of land-use planning
 - And it understands the impacts land-use planning has on service delivery
- It integrates the 'Design with Nature' philosophy
 - Nature is a valuable asset that must be 'maintained' in order to 'operate' effectively
 - Nature's assets often appreciate rather than depreciate – What can we do to leverage this?
 - Nature provides multiple 'services' – some similar to traditional community services – i.e. Rainwater Management
 - Nature, and many of the resources it provides, are finite

Figure 28

View the Watershed through an Asset Management Lens

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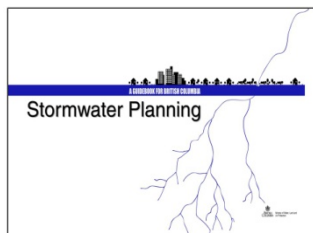
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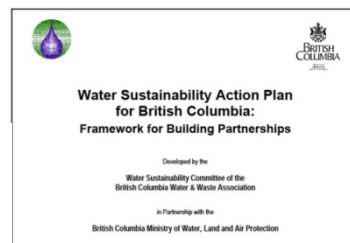
Integrating the Site with the Watershed and the Stream

Primer for Integrated Rainwater and Groundwater Management

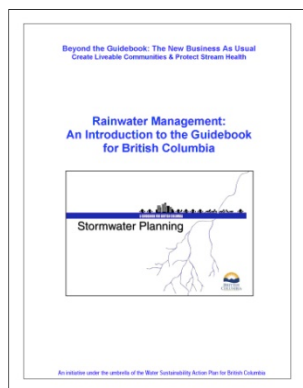
7. Guidance Documents



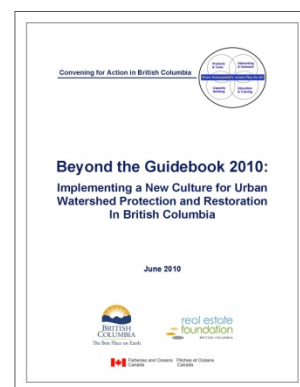
Stormwater Planning: A Guidebook for British Columbia (2002) --- Catalyst for action to establish performance targets for watershed protection and restoration
<http://www.env.gov.bc.ca/epd/mun-waste/waste-liquid/stormwater/index.htm>



Water Sustainability Action Plan for British Columbia: Framework for Building Partnerships (2004) --- Goal: encourage province-wide implementation of fully integrated water sustainability policies, plans and programs
<http://www.waterbucket.ca/cfa/sites/wbccfa/documents/media/81.pdf>



Rainwater Management: An Introduction to the Guidebook for British Columbia (2008) --- Provides a broad-brush picture of what is in the Guidebook; written for expert and non-expert audiences
<http://www.waterbucket.ca/gi/sites/wbcgi/documents/media/197.pdf>



Beyond the Guidebook 2010: Implementing a New Culture for Urban Watershed Protection and Restoration in British Columbia (2010) --- Provides guidance for aligning local actions with provincial and regional goals to 'design with nature'
<http://www.waterbucket.ca/cfa/sites/wbccfa/documents/media/403.pdf>



Primer on Rainwater Management in an Urban Watershed Context (2011) -- Provides engineers and non-engineers with a common understanding of how a science-based approach to rainwater management has evolved since the mid-1990s.
<http://www.waterbucket.ca/rm/sites/wbcmr/documents/media/239.pdf>



Primer on Urban Watershed Modelling to Inform Local Government Decision Processes (2011) --- Provides engineers and non-engineers with guidance in three areas: setting performance targets, defining levels-of-service, and application of screening / scenario tools.
<http://www.waterbucket.ca/rm/sites/wbcmr/documents/media/243.pdf>