the partnership
for water sustainability in bc

IREI - Inter-Regional Education Initiative

Water Balance Approach on Vancouver Island

January 2018

Note to Reader:

This publication is the 7th in the Partnership's "Watershed Blueprint Case Profile Series".

To download a PDF copy of this Watershed Case Profile, as well as any of the others in the series, visit the Rainwater Management community-of-interest on the waterbucket.ca website at:

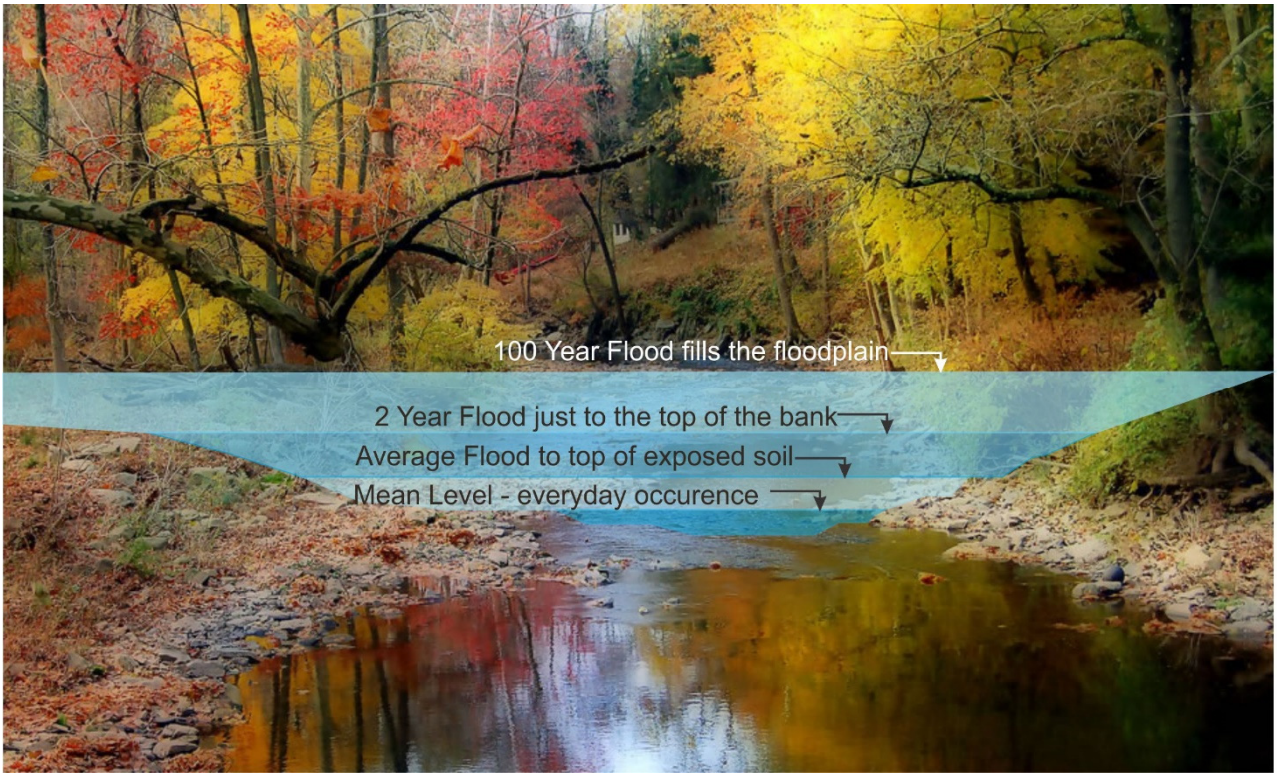
http://waterbucket.ca/rm/category/showcasing-british-columbias-watershed-based-approach/watershed-case-profile-series/

Or go directly to the following link:

http://waterbucket.ca/rm/wp-content/uploads/sites/5/2018/01/Water-Balance-Approach-on-Vancouver-Island_Jan2018.pdf

Water Balance Objectives

Restore Watershed Hydrology, Prevent Stream Erosion, Ensure Fish Survival



About the above image: *Water levels corresponding to various flow conditions are superimposed on the creek image.*

Standard engineering practice is preoccupied with the peak rates of flow for extreme events that happen infrequently. This is the traditional design mindset for flood conveyance and protection.

This engineering objective does not account for the cumulative environmental impacts of all the other rainfall-days in a year. Yet most stream erosion is caused by comparatively small flow rates that happen frequently and usually range between the mean annual flood and the 2-year flood event.

ACKNOWLEDGMENTS: The Partnership for Water Sustainability in BC gratefully acknowledges the financial support of the governments of Canada and British Columbia (through the Clean Water & Wastewater Fund), as well as the support of our regional district partners in the Georgia Basin Inter-Regional Education Initiative (IREI).

The educational goal of the IREI is to build practitioner capacity within local government to implement a whole-system, water balance approach branded as ***Sustainable Watershed Systems, through Asset Management***.

Inter-governmental collaboration and funding enable the Partnership to develop approaches, tools and resources; as well as provide teaching, training and mentoring.

Regional Districts supporting the IREI

About the Partnership for Water Sustainability

The Partnership for Water Sustainability in BC is a legal entity, incorporated in 2010 as a not-for-profit society, and delivers services on behalf of government. It originated as an inter-governmental partnership, formed in 2002 to fund and develop the Water Balance Model as a web-based decision support tool.

When the **Water Sustainability Action Plan for British Columbia** *(Action Plan) was released in 2004, the Water Balance Model for BC was the centrepiece initiative. Action Plan experience informed development of* **Living Water Smart, British Columbia's Water Plan***, released in 2008, as well as the parallel* **Green Communities Initiative***.*

The Partnership for Water Sustainability embraces shared responsibility, is the hub for a "convening for action" network in the local government setting, and is responsible for delivering the Action Plan program through partnerships and collaboration. This program includes the **Georgia Basin Inter-Regional Education Initiative***.*

The Partnership for Water Sustainability plays a bridging role between Province, local government and community; and is the steward for **Stormwater Planning: A Guidebook for British Columbia***, a provincial guidance document released in 2002.*

Water Balance Approach on Vancouver Island:
What the reader will learn from this Case Profile

A watershed is an integrated system – with three types of flows, each with a different time scale. Yet long-standing drainage engineering practices for servicing of land ignore, overlook or eliminate two of the three. Such practices are the root cause of stream and aquatic habitat degradation, with these impacts:

- *more flooding;*
- *more stream erosion; and*
- *less streamflow when needed most.*

Why is this still happening 16 years after the provincial government introduced the Water Balance Methodology, and set a whole-system direction for urban hydrology and drainage engineering in this province, with release of **Stormwater Planning: A Guidebook for British Columbia***?*

The process to adopt, change or evolve standards of practice is slow. Bridging the gap between policy and action (i.e. a new standard of practice) relies on local governments that lead by example and undertake how-to-do-it demonstration applications. On Vancouver Island, applications of the ***Water Balance Methodology*** *have been completed in three regional districts along the east coast of the Island. These have proven out* ***how*** *to:*

- *apply science-based understanding;*
- *establish watershed-based performance targets; and*
- *downscale those targets to the site level.*

This Watershed Case Profile presents capsule summaries of each demonstration application. But it does more than that. It provides an explanation of the problem and the solution. It then closes with an overview of **Sustainable Watershed Systems, through Asset Management.** *The latter foreshadows a potentially powerful regulatory driver for transforming drainage engineering practice at the site scale.*

Kim A. Stephens, MEng, PEng,
Executive Director
Partnership for Water Sustainability in BC
January 2018

A program deliverable for "Sustainable Watershed Systems, through Asset Management" -
An initiative under the umbrella of the Water Sustainability Action Plan for British Columbia

Table of Contents & Storyline

This table is a synopsis. It distils the essence of each section into a succinct statement. These create a storyline. Readers should pause and reflect on the messages before continuing.

To download a PDF copy of **Stormwater Planning: A Guidebook for British Columbia**:
http://waterbucket.ca/rm/sites/wbcrm/documents/media/242.pdf

Vancouver Island Demonstration Region

Cowichan Valley Regional Water Balance Analysis, 2013

Comox Valley Regional Water Balance Analysis, 2015

Shelly Creek (Nanaimo Region) Water Balance Analysis, 2017

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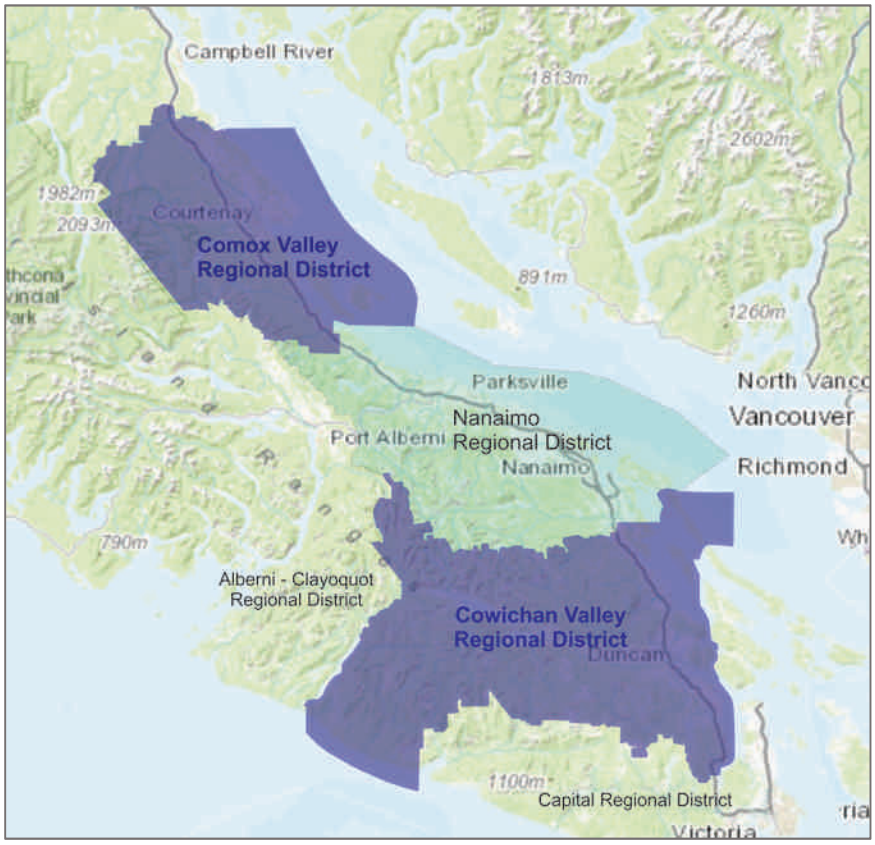
Application of Performance Targets

In 2002, the provincial government released *Stormwater Planning: A Guidebook for British Columbia*. This established a new direction for urban hydrology and drainage engineering. Introduction of the *Water Balance Methodology* enabled the setting of performance targets for rainfall capture, runoff control and groundwater recharge:

> ***If we manage the runoff volume, and if we mimic the natural flow pattern in streams, then we can… prevent increased stream erosion, prevent increased risk of flooding, and protect aquatic habitat.***

The east coast of Vancouver Island is a demonstration region for showcasing how to apply the *Water Balance Methodology* at a regional scale, and then downscale water balance performance targets to the site scale.



Note to Readers:

The capsule summaries presented later on in this Watershed Case Profile provide a high-level picture of the nature of the content in the three Water Balance Analyses. Those reports are comprehensive and detailed.

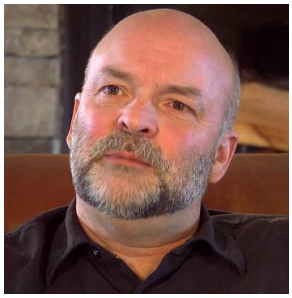
The source documents would provide an understanding of the selection criteria for representative watersheds.

Context for Action

Among land and drainage practitioners, how water gets to a stream and how long it takes, is not well understood. Their failure to grasp the fundamentals is the root cause of degraded urban streams:

> When it rains - there is too much runoff, too fast.
> When there is no rain, there is too little streamflow.
> The consequences are: more flooding; more stream erosion; and less streamflow when needed most.

Why is this still happening 16 years after publication of the Guidebook? In the absence of a regulatory requirement, the process to adopt, change or evolve standards of practice is slow. Entrenched beliefs and a reluctance to change are delaying implementation of the **Water Balance Methodology**.



Andy Reese
Water Resources Engineer, Writer, Speaker & Textbook Author

Voodoo Hydrology!

Andy Reese coined the term Voodoo Hydrology in 2006 to describe drainage engineering and stormwater management practice.

"We have for years relied upon common design methodologies and trusted their results. But, should we?

"It is an inexact science at best. We rely on judgment and guesswork.

"Perhaps, if we make enough estimates of enough factors, the errors will average out to the right answer. This is where voodoo really comes in handy."

Opening Minds is a Challenge: Drainage engineering practice[1] for servicing of land still relies on very simple formulae and methodologies to calculate *peak rates of flow*. Such analyses are empirical, not science-based. Andy Reese coined the term *voodoo hydrology* (see sidebar) to describe this situation.

Standard engineering practice only considers surface runoff in analyses. Yet the flow of rainwater from cloud to stream is comprised of **three water balance pathways:** *surface runoff; shallow interflow*; and *deep groundwater*. The other two pathways are ignored by designers. Time, a critical factor, is also ignored.

There is a growing awareness of what ought to be done differently. But missed opportunities "to get it right" persist. Opening minds to accept changes in practice is a challenge.

[1] To learn more, download the Primer: http://waterbucket.ca/wp-content/uploads/2012/05/4_Primer-on-Land-Development-Process-in-BC_September-2013.pdf

Call to Action

The image below conceptualizes the evolving nature of the educational journey, commencing with release of the Guidebook. In 2018, British Columbia is at a tipping point. How will we bridge the gap between UNDERSTANDING and IMPLEMENTATION?

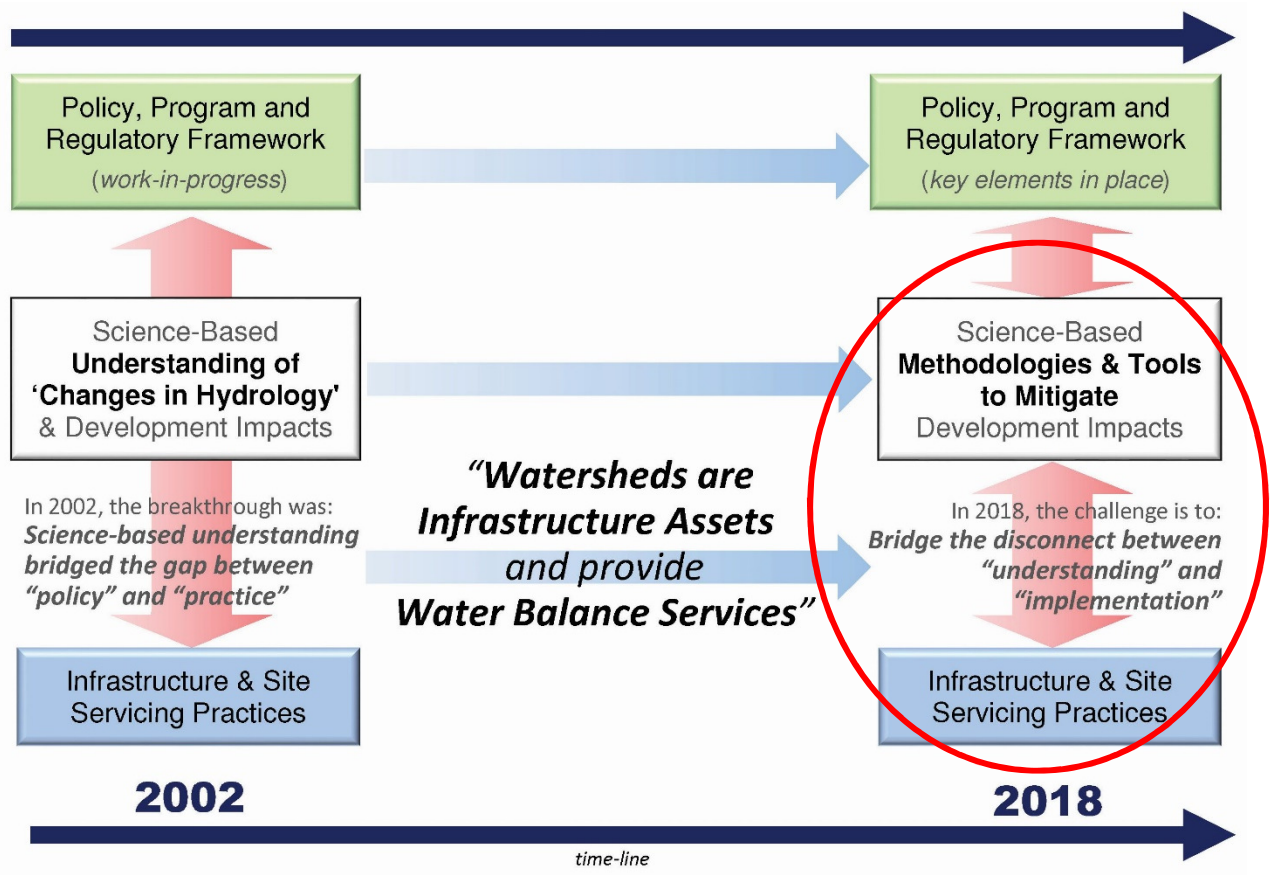
It is one thing to provide practitioners with tools and resources. It is another matter for them to apply the tools, and use them correctly.

Desired policy outcomes for a Water Balance Approach are:

Less flooding, less stream erosion, more streamflow when needed.

Reduce Life-Cycle Costs & Risks: Regulatory objectives linked to *Asset Management for Sustainable Service Delivery: A BC Framework* would make it possible to transform drainage engineering practice at the site scale. The BC Framework sets a strategic direction that refocuses business processes on outcomes that reduce life-cycle costs and risks.

Alignment with the BC Framework would enable and support the **transition of drainage practice from "*voodoo hydrology*" to a water balance approach branded as *"Sustainable Watershed Systems, through Asset Management"*.**



Water Balance Demonstration Applications

Representative Watersheds:

The watersheds which would be most representative of the developed portions along the eastern shore of Vancouver Island would include Dove Creek near Courtenay, Millstone River near Nanaimo, Bings Creek near Duncan, and possibly the Oyster River neat Saratoga Beach. These watersheds have similar stream connectivity, aspect, and elevation.

Stream Gauging Station	
08HB032	Millstone River
08HD011	**Oyster River**
08HB075	**Dove Creek**
08HA016	Bings Creek
08HA003	Koksilah River
08HB089	Tsolum River
08HA001	Chemainus River
08HB074	**Cruickshank River**
08HA010	San Juan River
08HB002	Englishman River
08HB025	**Browns River**
08HB024	**Tsable River**
08HB014	Sarita River
08HA072	Cottonwood Creek
08HA068	Garbage Creek
08HB048	Carnation Creek
08HA070	Harris Creek
08HA069	Renfrew Creek

Regional Water Balance Analyses: The first step in understanding the hydrologic performance of a watershed is to correlate and evaluate concurrent hydrometric data – that is, stream gauging stations (Water Survey of Canada) and climate (precipitation) stations (Environment Canada). The map below identifies 18 streams within the three study areas.

- The characteristics of all watersheds are similar to conditions in the built-up areas within each study area.
- Each stream has 10 years minimum of continuous records, and a recording period which overlaps that for the climate data.
- Within the three study areas, there are no other sources of reliable long-term streamflow records.
- The discharges from the 18 watersheds are unregulated. None contains a large lake which could attenuate peak discharges.

The three demonstration applications together provide a comprehensive picture of the **annual *Water Balance Distributions* characteristic of watersheds** along the east coast of Vancouver Island.

Simulate Flow-Duration to validate targets:

The critical parameter is the number of hours per year of erosion-causing streamflow rates.

Erosion-causing rates occur in the range between the mean annual discharge and 2-yr flood.

*Water balance goal is to **prevent** an increase in the number of hours per year of erosion-causing rates.*

Region-Wide Water Balance Targets: The seasonal time scale associated with the flow of rainwater through the interflow system on its way to a stream requires computer simulation of continuous and concurrent hydrometric data (streamflow and precipitation) to calibrate, verify and evaluate watershed response.

The results of the three sets of regional Water Balance Analyses are consolidated in the table below. These are the combinations necessary to replicate water balance pathways and restore the annual **flow-duration** pattern characteristic of a natural watershed.

Land Use: The development pattern of communities can be readily divided into three groups for hydrologic analysis. The groups are based on the total percentage of impervious (i.e. 'hardened') area:

1. Less than 10% for agricultural and park areas.
2. Between 10% and 50% for low density residential areas.
3. Higher than 50%, or actually upwards of 80%, for commercial, industrial, institutional and high density residential areas.

A threshold for stream impacts is 10%. Below 10%, mitigation would not normally be necessary to maintain stream health.

*The **Retention Volume** is required to limit the flood frequency of discharges, to allow time for infiltration to ground and to provide a volume that augments low stream discharges.*

*The **Base Flow Release Rate** replicates interflow and is equal to the mean annual stream discharge; it allows stored volume to augment low summer flows.*

*The **Infiltration Area**, is the surface contact area required to achieve desired volumes of infiltration to deep groundwater and mimic pre-development water balance.*

*The **Detention Volume** for the 100-year event reduces the risk of downstream flooding.*

Region-Wide Water Balance Targets

	Cowichan Valley		Comox Valley		Nanaimo Region
Performance Targets per hectare of total development area	Impervious Area		Impervious Area		**Shelly Cr Watershed** per hectare of imperv. area
	10% to 50%	>50%	10% to 50%	>50%	
Retention Volume m^3 per hectare	320	365	164	210	150
Base Flow Release Rate Lps per hectare	0.5	0.5	1.0	1.0	1.0
Infiltration Area m^2 per hectare	200	100	100	200	100
Neighbourhood Detention Vol. m^3 per hectare	included above in retention volume	included above in retention volume	420	470	100

Cowichan Valley

The first regional hydrology analysis was in the Cowichan Valley. It was undertaken in parallel with the District of North Vancouver's Hastings Creek Water Balance Analysis. These two case studies established initial precedents for demonstrating HOW to integrate Water Balance Targets in order to achieve three objectives:

- Low summer flows would be sustained because there is an operating interflow system.
- Downstream properties would not be at an increased risk of flooding or flood damage.
- Excess water would not be directed into the ground and this precaution would prevent the occurrence of potentially adverse impacts of excessive groundwater levels and discharges in areas lower in the watershed.

Subsequent regional hydrology analyses have evolved the finer points of how the Water Balance Methodology is applied and the results reported.

Study Area: The focus of the Cowichan Valley demonstration application of the whole-system, water balance approach is on the built-up portions of the Cowichan Valley Regional District (refer to the pink-shaded area on the map below). In general, these areas are the relatively flatter lands of low elevation. Also, they are readily accessible from the transportation network.

Rainwater Management:

"Rainwater management in an urban area must include the goal of mitigating adverse impacts which would result from urban development.

"Achieving this goal involves application of ***standard engineering analysis methodologies*** *combined with* ***typical design techniques*** *in an* ***innovative manner****."*

Executive Summary
Cowichan Valley Water Balance Analysis
October 2013

Multiple Risks resulting from urban development:

Aquatic habitat damage and the loss of fisheries resources.

Increased flood risks in downstream reaches

Increased erosion and property damage

Costs associated with flood damage and repairs to eroded streams.

Comox Valley

The second regional hydrology analysis was in the Comox Valley. It was undertaken to populate the online Water Balance Express with region-specific Water Balance Targets. Widespread use of this tool would advance two desired outcomes:

- Establish a consistent set of mitigation methodologies and calculation results that could be applied across the region, including within the regional district's member municipalities.
- Enable individual landowners to construct rain gardens that would mitigate the off-site impacts of the development footprint; and to do this without the need or cost of engaging engineers or other professionals.

Implementation of the integrated set of Water Balance Targets would ensure interflow connectivity to the stream, maintain or decrease potential flood risks, and mimic infiltration to groundwater.

Study Area: The focus of the Comox Valley demonstration application is on the occupied portions of the Comox Valley Regional District (refer to the shaded area on the map below). The built-up areas comprise residential developments, farms, commercial and industrial areas, and parks.

Development & Soil Disturbance:

"As development proceeds there is drastic disruption to the shallow soils as building foundations and underground infrastructure is constructed....

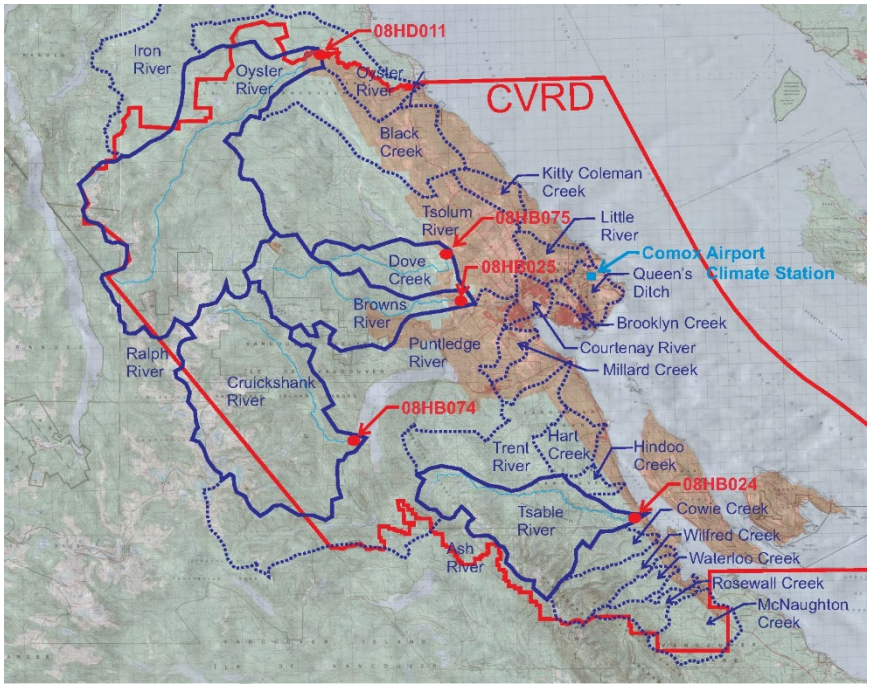
"....with the greatest impacts occurring in the denser developments where the ground disturbances are contiguous."

Executive Summary
Comox Valley Water
Balance Analysis
January 2016

Stream Erosion:

The flow-duration assessment, which is an essential part of the Water Balance Methodology is used to demonstrate that stream erosion can be controlled to pre-development rates.

Or, stream erosion could be reduced if this is deemed to be a desirable outcome when mitigating the impacts of development.



Fisheries Importance:

"The large number of smolts found indicates that Shelly Creek offers spawning and rearing habitat within its lower reach.

"It also indicated that it is heavily used as overwintering habitat during high water by migrating fish in the Englishman River."

Source: 2011 Smolt Trapping Report for DFO

Watershed Assessment:

"Existing standards of practice have resulted in negative impacts to Shelly Creek.

"Continuing to use the accepted standard of practice as applied to design of human activities which include municipal engineering and land development will result in further environmental degradation of the watershed and loss of stream productivity."

Source:
Shelly Creek Water Balance and Sediment Reduction Plan – Technical Summary, June 2017

Nanaimo Region

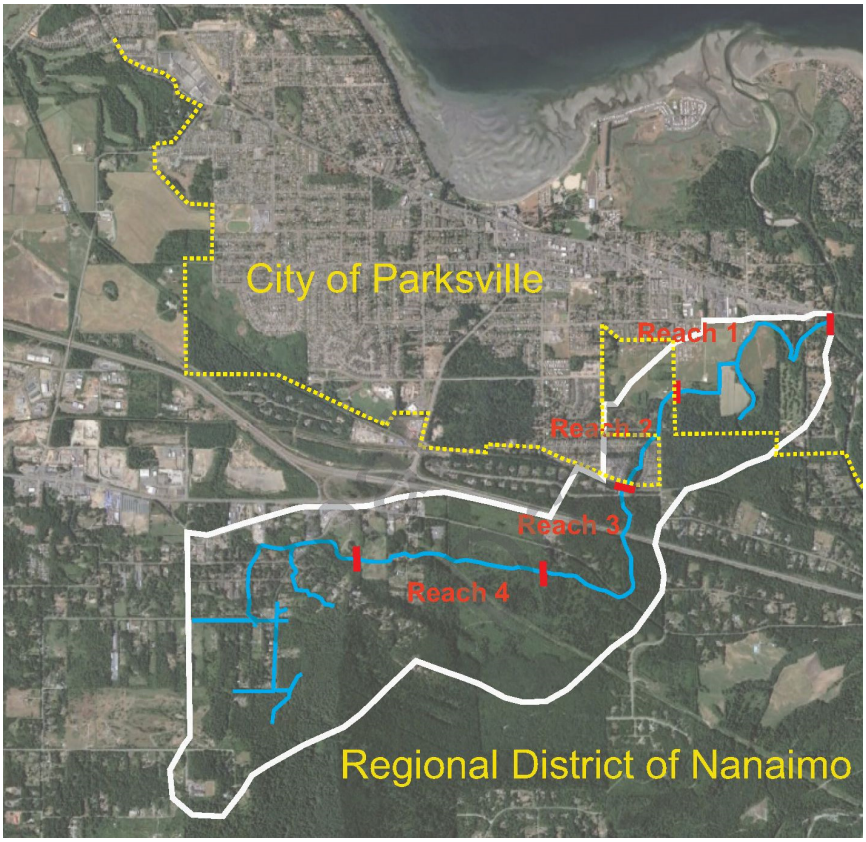
The third regional hydrology analysis was undertaken for the Shelly Creek watershed in the Regional District of Nanaimo, and on behalf of the Mid Vancouver Island Habitat Enhancement Society.

Shelly Creek is a fish-bearing creek and stewardship volunteers have been active over the past six years. The Water Balance Analysis drills down to tackle two questions that define the issues in any watershed undergoing development:

- What is causing the stream channel to fill with sediment?
- How can community action restore the stream's health?

This case study created an opportunity to make this distinction: without **restoration** of the hydrology of the watershed, channel **remediation** measures by themselves are not likely to be successful in restoring the fisheries productivity of Shelly Creek.

Study Area: Over the past 80 years, land alterations have included clearing and ditching for farming, ditching for road development and land subdivision, logging, linear developments (highway, railway, hydro transmission), and residential and industrial developments.



The Water Balance & Importance of Interflow

Interflow Explained:

The interflow system is very shallow, typically less than 1 meter from the ground surface.

Although the interflow system is a critical flow path within a watershed, it is not well understood.

It is fragile and vulnerable, and subject to unintended damage – for example, flow within the interflow system is readily intercepted by simply building a road or digging a ditch to improve the drainage of a land parcel.

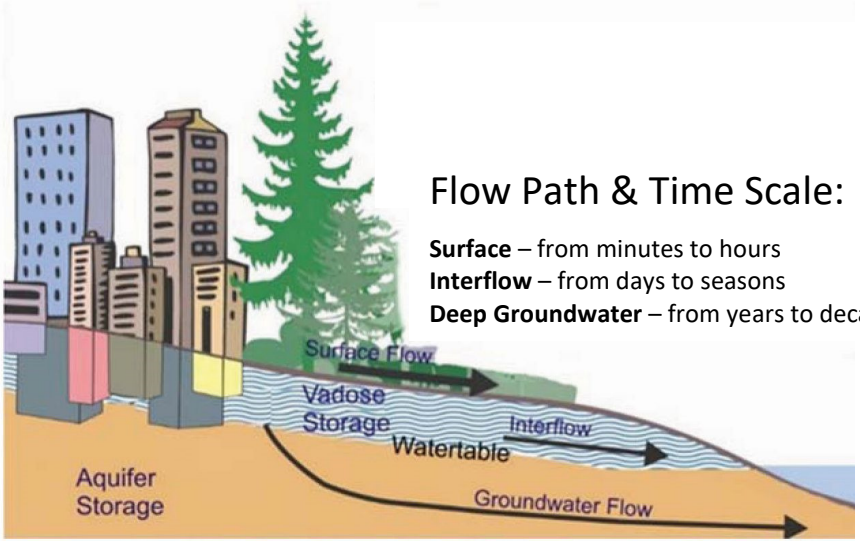
Once intercepted, the interflow would be collected and conveyed to a stream much quicker than would happen naturally, within days rather than over a season.

While this interception of flow would not increase the peak discharge to the stream, it would reduce the discharge within a few days of dry weather as the land dries out.

The Basics

Watershed protection starts with an understanding of how water gets to a stream, and how long it takes (refer to illustration below). Of the three pathways, interflow is vitally important (see sidebar to learn why). In coastal British Columbia, **interflow is the primary pathway in an undeveloped watershed**.

When interflow is eliminated, there is more surface runoff volume. Then, flow in streams is at higher rates over longer periods of time. The net effect is that streams erode.



Flow Path & Time Scale:

Surface – from minutes to hours
Interflow – from days to seasons
Deep Groundwater – from years to decades

Protect the Surface Sponge: In everyday language, interflow is defined as the shallow horizontal movement of water through the surface soil 'sponge'. Historically, the community development and infrastructure servicing process has overlooked, ignored or eliminated interflow. Instead, the thrust of drainage engineering standard practice is single-purpose: *contain, control and convey surface runoff as quickly as possible*.

Get it right. Think like a system. Understand where the water goes naturally when it rains. Preserve the natural pathways by which water reaches streams. Slow, spread and absorb runoff. Mimic natural flows in streams. **Benefits would include less flooding, less stream erosion, more streamflow when needed most.**

Whole-System, Water Balance Approach:

1. *Understand where the water goes naturally and reproduce those conditions.*
2. *Restore sub-surface **interflow** to maintain hydrologic integrity.*
3. *Maintain the proportion of rainwater entering a stream via each of 3 water balance pathways!*
4. *Replicate the streamflow-duration pattern to mimic the Water Balance*

Richard Horner
Professor Emeritus

University of Washington
Seattle

*"Unless and until land development practices mimic the natural water balance, communities cannot expect to restore the biological communities within streams. Simply put, **hydrology hits first and hardest.**"*

Water Balance Distribution: The table below is included to provide the reader with context and a "feel for the numbers". The percentages are derived from long-term hydrometric data for gauged watersheds.

The table shows how the water balance proportions versus flow path vary by region across Canada. It also underscores the relative magnitude and importance of the interflow component of a properly functioning watershed system in coastal British Columbia.

	Annual Water Balance by Region				
Flow Paths	Coastal BC	Alberta - Edmonton	Ontario - Ottawa	Nova Scotia	Maryland
Precipitation	**100%**	**100%**	**100%**	**100%**	**100%**
Evaporation	20%	92%	40%	28%	40%
Streamflow	**80%**	**8%**	**60%**	**72%**	**60%**
▪ *Surface Runoff*	10%	4%	10%	10%	10%
▪ *Interflow*	**60%**	3%	25%	52%	25%
▪ *Aquifer Flow*	10%	1%	25%	10%	25%

Water Balance Methodology: Land development changes the water balance proportions. Simply put, interflow is transformed into surface runoff. This has consequences for stream health.

The Water Balance Methodology[2] addresses the alterations to the land surface and its land use while providing solutions that would maintain stream health within a developed watershed.

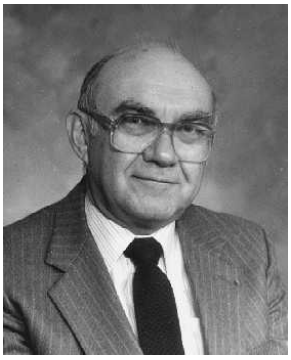
The Water Balance Methodology also recognizes the potential change in the paths followed by rainwater in the hydrologic cycle and establishes the methodologies required to protect stream and watershed.

The Water Balance Methodology uses the understanding of the watershed hydrologic cycle, combined with its physical characteristics, in a series of calculation processes and computer models to **quantitatively arrive at mitigation solutions**.

[2] To learn more, download the Primer: http://waterbucket.ca/wp-content/uploads/2012/05/Primer-on-Water-Balance-Methodology-for-Protecting-Watershed-Health_February-2014.pdf

A call to action because...

Drainage engineering practice is lagging behind real-world hydrology and, as a consequence, streams are eroding.



Robert L. Smith
(1923-1995)

Presidential Science Advisor for Water Resources

In 1990, he wrote:

"Hydrology remains a hybrid between the art and the science.

"Good practice of the art is dependent on understanding the theory of the science; not the reverse.

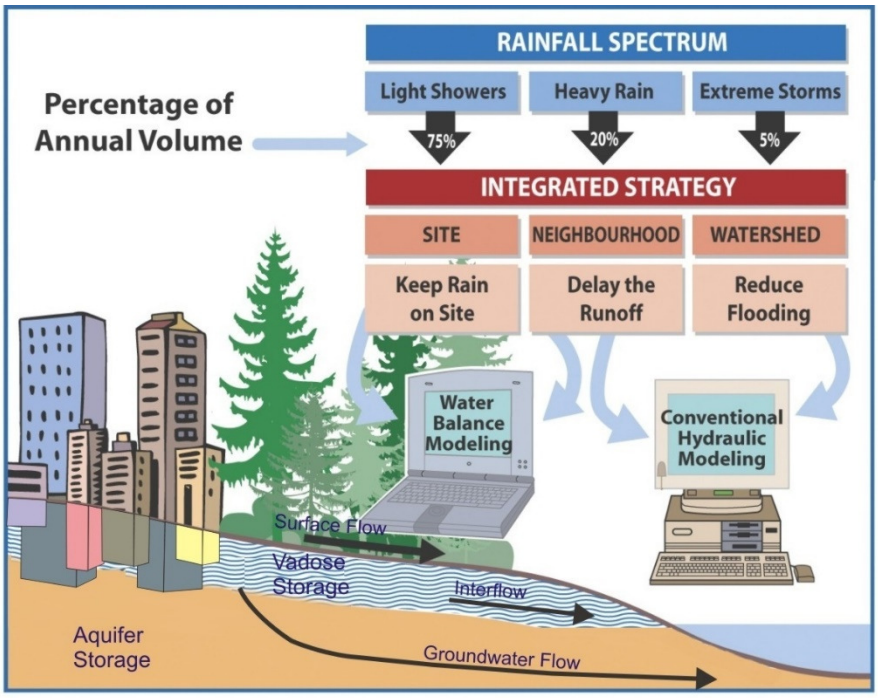
"Become fundamentally sound in the theory, and your ability to accept and adjust for uncertainty in boundary conditions will reflect good judgement."

Look at Rainfall Differently

In 2002, the Guidebook established a new direction for drainage engineering in British Columbia with introduction of the **Integrated Strategy** for managing the complete spectrum of rainfall events (see image below). The Integrated Strategy expands the scope and responsibility of drainage practice to include stream health. The Guidebook looked at rainfall differently. Its innovation included:

- Translated "science-based" understanding.
- Introduced the "retain-detain-convey" strategy.
- Formalized the performance target approach.
- Established an adaptive management precedent.
- Initiated the paradigm-shift to rainwater management.

Sustainable Watershed Systems: Vancouver Island is a demonstration region for the whole-system, water balance approach. This means that the insights gained from case study experience would inform what communities must do in order to move from POLICY to IMPLEMENTATION.



Water Balance Performance Targets

"Integrated Strategy for Managing the Rainfall Spectrum" has 3 objectives:

1) Mimic the proportion of water infiltrated to groundwater under natural watershed conditions; 2) provide interflow connectivity to the stream; and 3) maintain or decrease potential flood risks.

The Guidebook centrepiece is the Water Balance Methodology (WBM). It is applied to set performance targets that would prevent flooding and protect stream health. The **flow-duration** relationship is the cornerstone of the WBM. As understanding has grown, the methodology has evolved (see chronology below).

Managing urban watersheds as an integrated Water Balance system - **three flows, each with a different time scale** - requires that performance targets be determined by means of **verifiable calculations**. Only then can mitigation measures be analyzed and optimized for cost and effectiveness.

Case Study Experience: Vancouver Island demonstration applications have shown how to downscale performance targets that, over time, would restore the natural flow-duration pattern in a stream situated within an urbanized or urbanizing area. Real-world success would be defined as reduced stream erosion during wet weather, and sustained 'environmental flows' during dry weather.

Linking Rainfall, the Landscape, Streamflow, Groundwater and Sustainable Service Delivery has been a building blocks process

Evolution of Water Balance Methodology

2002 – How to reduce runoff volume
("Stormwater Guidebook: A Guidebook for BC)

2007 – How to mimic flow-duration
(City of Surrey - Fergus Creek Watershed Plan)

2012 – How to sustain deep infiltration
("Primer on Integrated Rainwater & Groundwater Mgmt")

2013 – How to integrate performance targets
(Cowichan Valley & North Vancouver - case studies)

2014 – How to downscale targets to a site level
("Primer on Water Balance Methodology")

2015 – How to view water balance pathways as infrastructure assets providing services
("Beyond the Guidebook 2015: Sustainable Watershed Systems, through Asset Management")

2017 – How to apply water balance targets to prevent erosion and restore stream health
("Shelley Creek Water Balance & Sediment Reduction Plan")

Ray Linsley
(1917-1990)

Professor at Stanford University, author, innovator & pioneer modeller

Pioneered development of continuous hydrologic simulation as the foundation for water balance modelling

"To be useful...the simulation model must be physically based and deterministic, and it must be designed to simulate the entire hydrological cycle...hence it must be a water balance model."

Jim Dumont
Engineering Applications Authority

Partnership for Water Sustainability in BC

"Issue #1 is widespread lack of understanding of the relationship between flow-duration and stream (watershed) health"

Verifiable Calculations: The Water Balance Methodology has evolved since 2002 such that it is now a **synthesis of watershed hydrology and stream dynamics**. The methodology is built on the respective analytical foundations developed a generation ago by several notable water resource pioneers, namely: Ray Linsley (United States); and Ivan Lorant and Craig MacRae (Canada).

The ongoing work of Jim Dumont (British Columbia) has made the synthesis possible. His innovation is in HOW he has **integrated proven scientific and engineering principles.** Over time, he has developed a logical and straightforward way to produce verifiable calculations. The Water Balance Methodology provides drainage engineers with the capability to quantify impacts on watershed hydrology and the benefits of replicating water balance pathways.

Flow-Duration Relationship: Interweaving of watershed hydrology and stream dynamics boils complexity down to this measure: ***how many hours is the discharge larger than a specific flow rate***.

A flow-duration image is included on the next page for illustrative purposes. It presents the total picture for Shelly Creek, which is the demonstration application for the Nanaimo region. The results of flow-duration analyses for a range of four scenarios tell us that:

- The *mean discharge* for the natural hydrology condition of the Shelly Creek watershed is approximately 1 litre per second per hectare (Lps/ha); and this rate was exceeded for 6,900 hours during the 21 year period of analysis.
- The *2-year return period* natural flood discharge of 7.9 Lps/ha was exceeded for just 10 hours during the 21 year period. Thus, this cannot be the rate of discharge causing stream erosion.
- Using 5.2 Lps/ha as an illustrative example, the graph shows that continued alteration of the watershed landscape due to land development would ultimately result in a possible **14-fold increase in the duration** of erosion-causing discharge rates, that is: from 58 hours under natural conditions, to 312 hours for existing conditions, to 782 hours in future.

Conclusion: The vast majority of stream erosion is caused by discharge rates between the *mean annual discharge* and the 5-year return period flood event.

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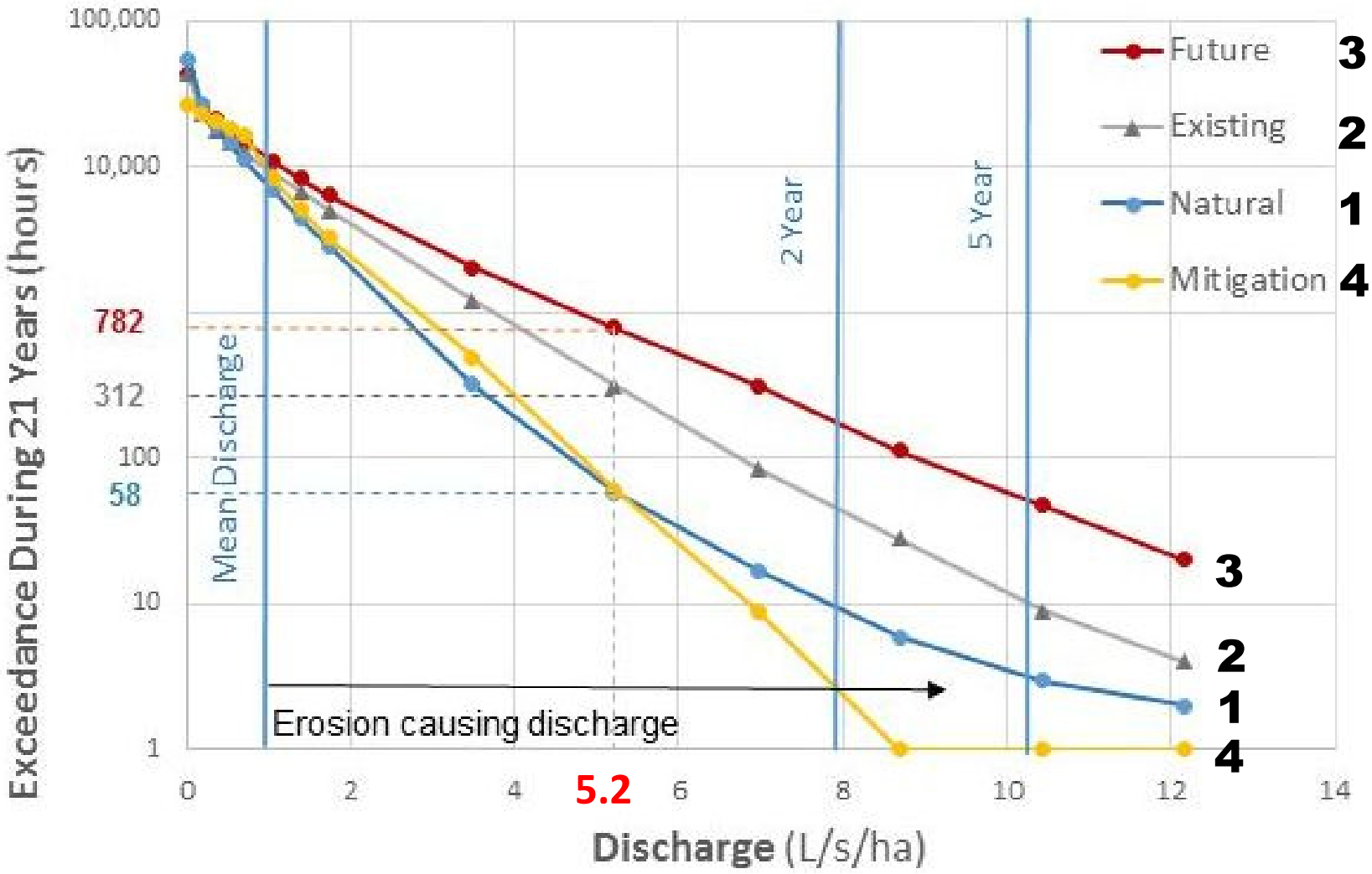
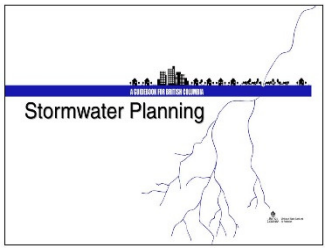
Shelly Creek in the Nanaimo Region: Flow-Duration Relationships for a Range of Scenarios



Downscale Water Balance Performance Targets



"Performance targets provide the foundation for implementing common sense solutions that eliminate the source of rainwater-related problems."

- *from the Guidebook, page 6-1*

East Coast of Vancouver Island

Demonstration applications of the Water Balance Methodology in three regional districts – Cowichan Valley, Comox Valley and Nanaimo – have shown how to apply an understanding of regional hydrology to establish verifiable targets for site design.

Downscale Targets to Design at the Site Level: The Water Balance Methodology accounts for all three flow paths. Each flow path is associated with one of these three design parameters: volume, area and flow rate.

The objective in setting targets is to keep the three flow paths in balance – by not infiltrating too much, while allowing interflow to occur and to discharge the water to the stream within a season.

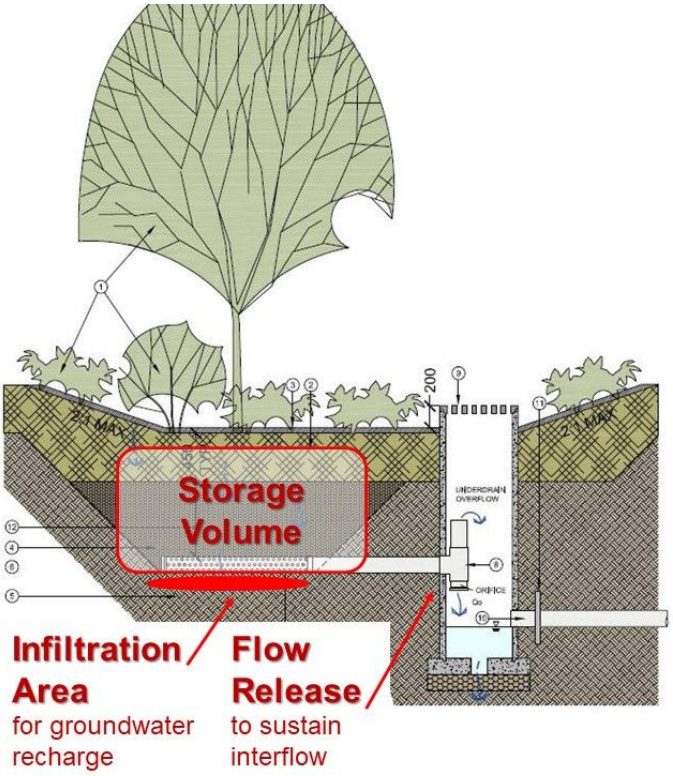
An easy way to visualize the application of performance targets is to consider this typical cross-section view for a properly designed rain garden:

What the Guidebook also says about Performance Targets:

"For a performance target to be implemented and effective, it must be quantifiable.

"It must also have a feedback loop so that adjustments and course corrections can be made over time.

"To be understood and accepted, a performance target needs to synthesize complexity into a single number that is simple to understand and achieve, yet is comprehensive in scope."



Why the Express?

Spur changes in site practice, accrue cumulative benefits, restore watershed hydrology over time.

Julie Wilson
Academic Coordinator & Instructor

Master of Land & Water Systems Program, UBC

"The Express is an example of how science can be translated into a meaningful form to help inform non-scientists on how to contribute to positive change.

"The video tutorial is helpful in demonstrating how the addition of the 'Lego blocks' can improve the stream health score."

Slow, Sink and Spread Rainwater

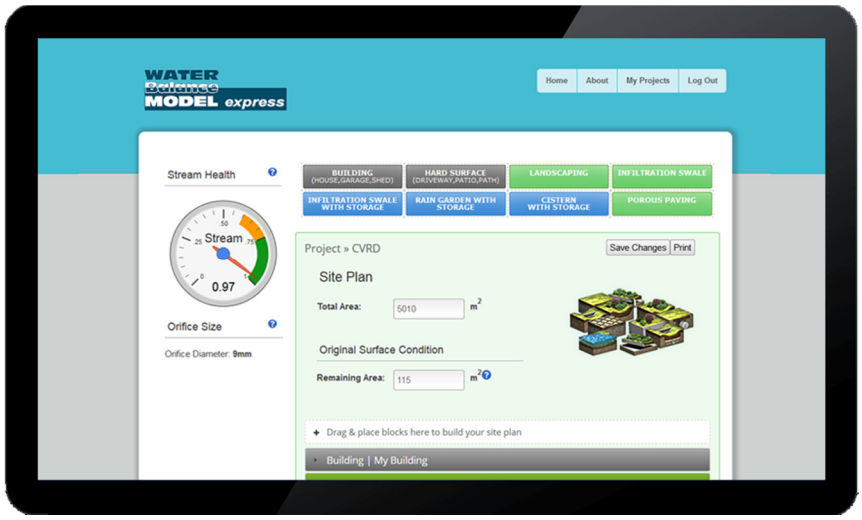
The end-goal in carrying out regional Water Balance Analyses is to populate the *Water Balance Express for Homeowners* with pre-set performance targets for retention volume, base flow release rate, and infiltration area. The Express is built and is functional for each of the Cowichan Valley and Comox Valley regional districts.

Engage the Homeowner: The Express is an online tool. Funded by government under a climate adaptation program, it is designed to support homeowner action at the site scale. It would help them conceptualize how easily they can implement soil-based measures to slow, sink and spread rainwater after it drains from roofs and paved surfaces.

The Express is integrated with Google Maps / Earth and land use zoning. An online video[3] tutorial, created at the University of British Columbia provides step-by-step guidance on Express use.

Using the Express, homeowners can locate their property on a map, recreate their current house and yard, and then like Lego, add building blocks of different rainwater management features to the property, to reduce their property's runoff and infiltrate more water into the soil.

Ideally, the Express would be linked to a regulatory tool to facilitate effective implementation. Each local government would need to customize its own approach.



http://cvrd.waterbalance-express.ca/
http://comox.waterbalance-express.ca/

[3] https://vimeo.com/159415594

The Journey from Policy to Implementation

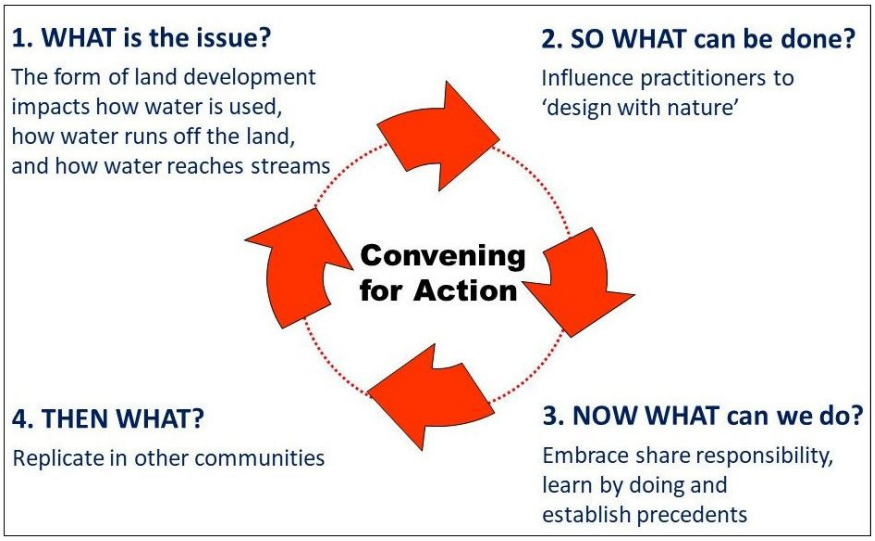
Capacity-Building Challenge

A watershed is an integrated system – with three types of flows, each with a different time scale. Yet drainage engineering practices for servicing of land continue to ignore, overlook or eliminate two of the three. Why is this still happening 16 years after the provincial government introduced the Water Balance Methodology?

A concern is that the long, drawn out nature of the capacity-building journey creates additional risks due to the cumulative impact of missed opportunities to "get it right" regarding land drainage.

Call to Action: British Columbia is at a tipping point. A provincial policy, program and regulatory framework is in place to help local governments bridge the gap between policy and action (i.e. a new standard of practice). But there is a leadership vacuum, and provincial government coordination is essential if we are to "get it right" vis-à-vis servicing of land from a water balance perspective.

The first step is to acknowledge that there is a problem with standard practice, and recognize that immediate action is required to remedy the problem. Then embrace the *BC Process* (as conceptualized below) for moving from awareness to action. After that, institutionalize use of the **Water Balance Methodology** to provide a technical starting point.



From Awareness to Action means:

"We recognize that there is a problem."

"This is what we will do about it."

Dale Wall
Deputy Minister (retired)
Ministry of Community Development

"The 'convening for action' initiative is the best example of peer driven innovation that I have ever seem. It has led to nothing less than a quiet revolution in how we approach the design and construction of human settlements in BC.

"I firmly believe that that this ability to creatively innovate in support of sustainable practices will enable us to meet a host of future challenges."

- *from Beyond the Guidebook 2015 , p. 54*

Game-Changers

On transitioning from Stop-Gap to Long-Term:

A goal is to "get it right" in the stream channel.

The challenge in "getting it right" is to move from stop-gap remediation of problems to long-term restoration of a properly functioning watershed.

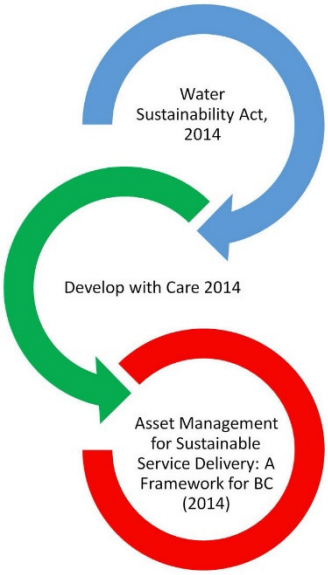
The provincial government has long recognized that communities are in the best position to develop solutions which meet their own unique needs and local conditions.

This is the reason BC's regulatory environment for urban watershed protection is outcome-based and relies on collaborative processes to implement changes in practice.

However, implementing changes in practice in a timely fashion requires that a "top-down & bottom-up" process be in play to align provincial, regional and local actions.

Otherwise, the process to adopt, change or evolve standards of practice and apply tools such as the Water Balance Express may be painfully slow, might not happen, or could simply peter out due to indifference or neglect.

Moving from Understanding to Implementation: Three landmark provincial initiatives came to fruition in 2014. Together they provide a platform for integrated and coordinated actions:



- **WHAT** – The *Water Sustainability Act* connects land and water, and makes the link to desired water balance outcomes (that would be achieved by integrating watershed systems thinking into asset management).
- **SO WHAT** – *Develop with Care 2014: Environmental Guidelines for Urban and Rural Land Development in British Columbia* makes the link between environmental function and resilience as communities grow.
- **THEN WHAT** – *Asset Management for Sustainable Service Delivery: A BC Framework* ("the BC Framework") makes the link between local government services, the infrastructure that supports the delivery of those services, and watershed health.

Elements of all three would be embodied in the **transition of drainage practice from "*voodoo hydrology*" to a water balance approach branded as *"Sustainable Watershed Systems, through Asset Management"*.** The BC Framework is the lynch-pin because it goes to the heart of what local government does on an everyday basis.

Moving towards a Water-Resilient Future....

The capacity-building program for "Sustainable Watershed Systems, through Asset Management" is aligned with the vision for

Asset Management for Sustainable Service Delivery: A BC Framework

The New Paradigm: Watersheds as Infrastructure Assets

A watershed is an integrated system.

Three pathways by which rainfall reaches streams are "infrastructure assets".

The pathways provide "water balance services".

Ecological Accounting Process:

EAP assesses an entire watershed at a creekshed scale. The EAP focus is on ecological services supported by hydrological realities.

EAP recognizes the worth of the natural assets and the services (uses) that they provide in a community.

Towards Sustainable Watershed Systems

Funded by the governments of Canada and BC, the capacity-building program branded as *Sustainable Watershed Systems, through Asset Management* is designed to inform and educate local governments about the whole-system, water balance approach.

A guiding principle is that regulatory objectives linked to the *BC Framework* would be the catalyst to transform drainage engineering practice at the site scale. To inform and accelerate change, demonstration applications in the Cowichan and Comox valleys will build on the water balance analyses to showcase a unique approach known as the **Ecological Accounting Process** (EAP).

Asset Management Continuum: Asset management has traditionally been about hard engineered assets such as waterlines, sanitary and storm sewers, and roads. Yet, watershed systems are also "infrastructure assets". More specifically, trees, soil, green spaces and Water Balance pathways contribute to a municipal service function. These assets provide *hydrologic integrity* for a healthy watershed system. This is a driver for protecting and managing nature's services in the same way that engineered assets (and the services they provide) are managed.

A way was needed to conceptualize this process diagrammatically, and thus communicate what the journey by a local government to a *Water-Resilient Future* would look like. This led to the concept of a continuum of steps (as conceptualized opposite on page 20):

- Step One – embrace the BC Framework
- Step Two – implement Sustainable Service Delivery
- Step Three – apply the Ecological Accounting Process

The goal: build local government capacity to transition to Step Three. The outcome would be Sustainable Watershed Systems.

Community Benefits: Implementation of a whole-system, water balance approach would result in these desired outcomes:

- **AVOID** an unfunded liability (by limiting stream erosion, preventing flooding, improving water quality);
- **ADAPT** to a changing climate; and
- **REDUCE** life-cycle costs for drainage infrastructure.

About the Journey from Policy to Implementation:

Asset management for sustainable service delivery occurs alongside associated evolution in community thinking. It is a continuous quality-improvement process, and incremental. A local government would experience the asset management process for sustainable service delivery as a continuum leading to a water-resilient future. ***Sustainable Watershed Systems*** *would be the outcome in Step Three.*

In Step Three, the principal focus of the ***Ecological Accounting Process*** *is on the investment of resources already made by many stakeholders, as well as their aspirations concerning the management (prevention of degradation to and work on enhancement) of ecological services in the creekshed.*

Logo for

'Asset Management for Sustainable Service Delivery: A BC Framework'

Asset Management Continuum for Sustainable Service Delivery

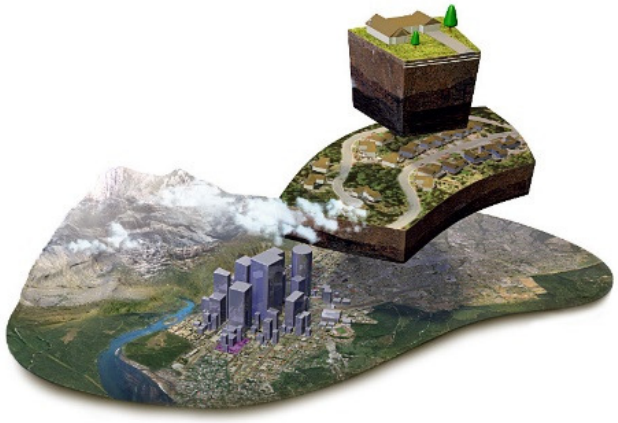
GROUND ZERO: There is no **Asset Management Plan**.
There is an 'unfunded infrastructure liability'.

STEP ONE: Embrace the BC Framework. Focus on engineered assets. Develop **Asset Management Strategy / Plan / Program**.

STEP TWO: Think holistically. Implement life-cycle approach. **Sustainable Service Delivery** is standard practice.

STEP THREE: Account for Water Balance Services. Integrate climate adaptation into asset management. Apply the **Ecological Accounting Process**. Calculate *opportunity cost* of balancing ecological services with drainage infrastructure.

As understanding grows, local governments progress incrementally along the **Continuum**



THE OUTCOME?

A Sustainable Watershed System!

Never forget that a watershed is an integrated system – with three flows, each with a different time scale

Optimizing of Risk, Complexity and Cost

Any hydrologic analysis - whether for flood relief, drainage, or mitigation of urban impacts - is done at a cost. To arrive at an optimal solution at an *acceptable level* of cost (i.e. what is it worth to decision makers), the analytical process underpinning the application of sound engineering judgement and practice would take into account the interplay of these three principles:

1. The cost of the analysis rises as detail is increased.
2. The risk of an inaccurate solution is reduced with more detail.
3. There will be a balance point between risk and cost.

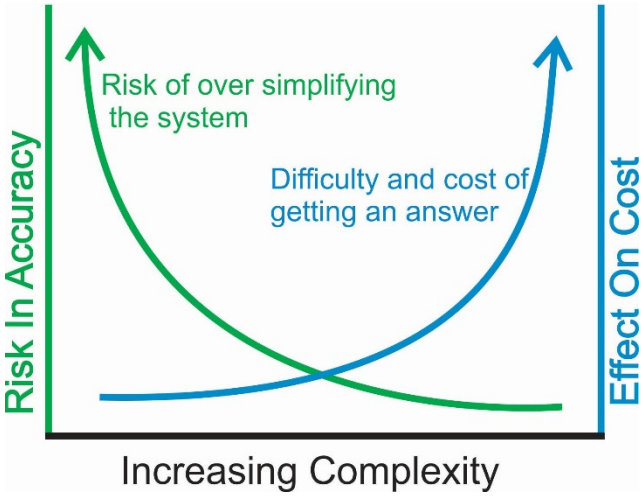
Making Choices:

The goal of Sustainable Watershed Systems...

"...will be influenced by willingness to pay, level of protection versus expenditures, ability to raise revenue, and the level of investment versus risk reduction... Underlying the issue of risk is the question of liability and due diligence."

- *from the Guidebook, page 10-2*

Trade-offs in Computer Modelling: The interplay of the concepts of 'risk in accuracy', 'effect on cost', and 'complexity of analysis' is illustrated by the graphic below.



Finding the Balance Point:

"A fundamental principle is that the level and/or detail of modeling should reflect the information needed by decision makers to make an informed decision."

- *from the Guidebook, page 9-15*

Application to Stream Analysis: There is an additional consideration when undertaking the analysis for urban mitigation, and that is the level of detail required to obtain an accurate result.

A great many prescriptive mitigation practices do not include the stream in any form of analysis. As a result, this omission should be seen as increasing the risk of having a solution that does not meet the required accuracy in achieving the desired benefits to a stream.

In contrast, the **Water Balance Methodology** provides an appropriate level of detail that can be increased as time, information, and budgets become available.

A Look Ahead….

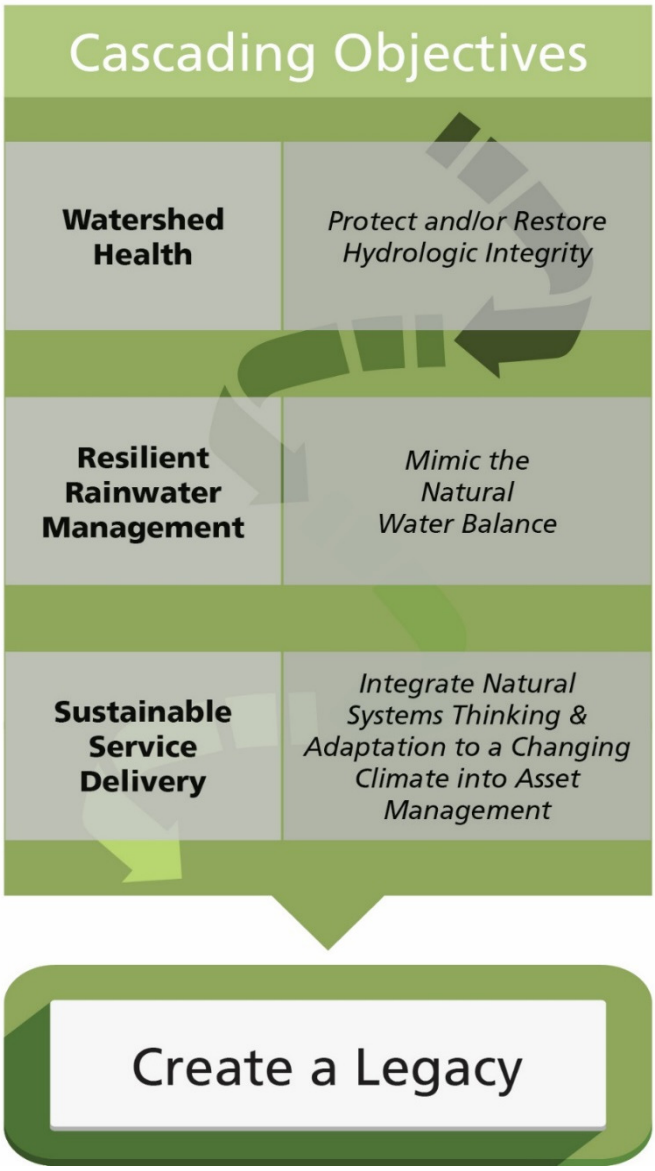
"The rate of progress in implementing new ideas or standards of practice generally depends on the willingness of individual champions in local government to push the envelope in applying new approaches. The number of water sustainability champions throughout British Columbia is growing, and they are collaborating.

*"**Asset Management for Sustainable Service Delivery: A BC Framework** is a game-changer. It signifies the dawn of a new era for local governments in terms of how communities service urbanizing and redeveloping areas, and define how infrastructure is planned, financed, implemented and maintained. Watershed systems are infrastructure assets.*

*"British Columbia local governments are sharing and learning from each other. The province is at a tipping point. Water balance tools and case study experience are in place. It is within the grasp of local governments to move beyond traditional infrastructure asset management. They can account for nature's services by implementing **Sustainable Watershed Systems, through Asset Management**.*

"Over the (coming) years, the IREI program would progressively inform and educate an expanding network of practitioners (inside and outside local government) on how to integrate watershed systems thinking and climate change adaptation into asset management (to achieve hydrologic integrity and hence avoid expensive fixes)."

- *from Beyond the Guidebook 2015 , page 157*



TURN THE CLOCK BACK: *Influence the form and function of the Built Environment. Replicate a desired watershed condition. Shift the ecological baseline upwards.*

This will take time, commitment and perseverance

About the Watershed Blueprint Case Profile Series:

The Waterahed Case Profile Series is unique.

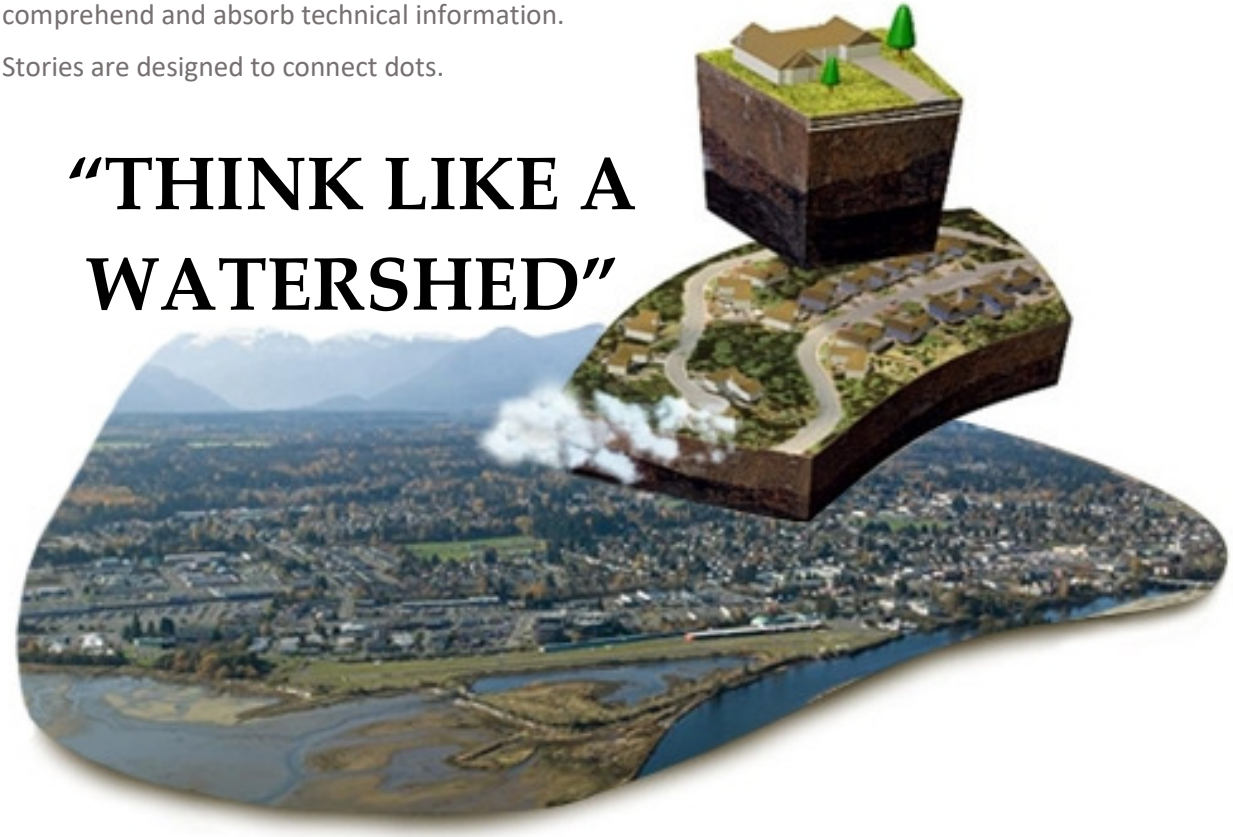
The series showcases and celebrates successes and long-term 'good work' in the local government setting in British Columbia. Our spotlight is on champions in communities which are breaking new ground and establishing replicable precedents.

Storylines touch lightly on technical matters, yet are grounded in a technical foundation.

The objective in 'telling a story' is to engage, inform and educate multiple audiences – whether elected, administrative, technical or stewardship.

Stories in the series are presented in a magazine style to make it easier to read, comprehend and absorb technical information.

Stories are designed to connect dots.



A watershed is an integrated system:

The need to protect headwater streams and groundwater resources in BC requires that communities expand their view - from one that looks at a site in isolation - to one that considers HOW all sites, the watershed landscape, streams and foreshores, groundwater aquifers…and PEOPLE….function as a **whole system**.

the partnership
for water sustainability in bc