Commentary on Effective Municipal Rainwater/Stormwater Management and Green Infrastructure to Achieve Watershed Health

Prepared Jointly By

WATER Balance MODEL Powered By QUALHYMO

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Effective Municipal Rainwater/Stormwater Management that Achieves Watershed Health

The *Local Government Act* vests the responsibility for drainage with municipalities, and 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

Metro Vancouver municipalities are legally obligated to prepare fully integrated rainwater/stormwater management plans by 2014. Municipalities also committed to adopting (or updating) policies or bylaws related to improving rainwater/stormwater management for at least two related issues over the period of the current LWMP agreement (*Reference: Policy C37*). The *Local Government Act* 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 that are established under Integrated Stormwater Management Plan (ISMP) processes.

Currently, Metro Vancouver's Stormwater Inter-agency Liaison Group, comprising member municipalities and regulatory agencies, facilitates improvements in regional approaches to rainwater and stormwater management. Over the past decade, this inter-agency group has provided leadership by either commissioning or sponsoring a series of deliverables, notably: the Water Balance Model software (available at www.waterbalance.ca); ISMP template; rainwater facility design guidelines; and education and showcasing innovation events. As a result, the Metro Vancouver region is now recognized provincially and internationally as a leader in rainwater management and green infrastructure.

The Ministry of Community Services is the lead Ministry for rainwater management and green infrastructure; and has a mandate to leverage the Green Communities Project to advance implementation of green infrastructure province-wide. To influence the greening of the built environment, Ministry policy is that "today's expectations are tomorrow's standards".

Beyond the Guidebook: The New Business As Usual (2007),(available at www.waterbalance.ca), builds on *Stormwater Planning: A Guidebook for British Columbia* (2002) and provides key guidance to the new provincial approach. Technically founded on products flowing from the Stormwater Inter-agency Liaison Group, and validated through Metro Vancouver pilots, *Beyond the Guidebook* advances a performance target methodology for correlating green infrastructure effectiveness in protecting stream health. This initiative incorporates lessons learned over the past six years in order to help municipalities establish what performance targets makes sense at the site, catchment and watershed scales.

Now that prerequisite tools and resources exist, a key to success of ISMPs in meeting the LWMP goal of maintaining or improving watershed health as communities grow and redevelop will be the effective integration of rainwater management techniques and green infrastructure in land use planning, plus follow-through upon ISMP implementation, integrated from the regional down to the site scale.

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Strategies for integrating drainage actions with other policy and actions, to be truly effective, include:

- Identification and protection of natural green infrastructure (green space and Environmental Sensitive Areas) that performs multiple services
- Reduction of watershed load through effective land use planning
- Incorporation and retrofitting of engineered green infrastructure technologies into development plans
- Use of technical modeling software like *Water Balance Model powered by QUALHYMO* to verify plans at the site, catchment and watershed scales
- Adjustment of bylaws and policies to support objectives
- Plan performance monitoring and follow-up to adapt and adjust to lessons learned
- Budgeting that anticipates administrative and operations support

A desired outcome is to create neighbourhoods that integrate good planning and innovative engineering designs, for overall greater environmental, social and economic sustainability.

The methodology embedded in the **Water Balance Model powered by QUALHYMO** enables a watershed target to be established; it also enables the user to assess how to meet the watershed target at the site scale. Accompanying this commentary is a paper titled *Establish Watershed-Specific Runoff Capture Performance Targets* that was released by the Inter-Governmental Partnership at the 2008 Water Balance Model Partners Forum.

Table 3: Adopting new rainwater/stormwater practices for new developments – Decision Point

Action	Level of Commitment
Complete and implement integrated rainwater/stormwater management plans that are **affordable and effective i**n protecting Watershed Health	• Municipalities continue to develop and complete ISMPs by 2014 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.
	• Municipalities 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
	• Municipalities evaluate the acceptability of watershed-specific runoff targets on the basis of an evaluation framed by these three questions: 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?
	▪ Municipalities implement green infrastructure solutions that result in effective rainfall management at the site, catchment and watershed scales.
Embed ISMP strategies in neighbourhood concept plans	• Municipalities develop rainwater/stormwater and land use plans through an inter-departmental process that is collaborative and integrated. • Municipalities provide guidance as to how watershed-specific targets can be met at the development scale.

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Beyond the Guidebook: The New Business As Usual
Create Liveable Communities & Protect Stream Health

WATER Balance MODEL Powered By QUALHYMO

Establish Watershed-Specific Runoff Capture Performance Targets

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Establish Watershed-Specific
Runoff Capture Performance Targets

Identify what needs to be done at the site scale to prevent stream erosion and protect stream health

In 2002, **Stormwater Planning: A Guidebook for British Columbia** articulated a principle that performance targets at the watershed scale provide a starting point to guide the actions of local government in the right direction. The objective is to translate those targets into appropriate site design criteria that then provide local government staff and developers with practical guidance for achieving the goal of stream protection.

The methodology embedded in the **Water Balance Model powered by QUALHYMO** enables a watershed target to be established; it also enables the user to assess how to meet the watershed target at the site scale. The critical consideration is that the watershed target be characteristic of conditions in the watershed. When establishing a watershed-specific discharge target, three fundamental questions need to be answered:

1. Could the target be achieved?
2. If it could be achieved, how would it be achieved?
3. Should the target be achieved?

The litmus test for an acceptable **Watershed Target** is that the resulting RAINwater management solutions make sense, are affordable and result in net environmental benefits at a watershed scale. For a performance target to be implemented and effective, it must have feedback loops so that adjustments and course corrections can be made over time.

1. Defining a Target Condition

A physically-based target condition can be established based on an understanding of geomorphology and stream characteristics. In order to be achievable, the target condition must be translated into performance targets that can be applied to RAINwater management practice.

Since changes in Water Balance and hydrology are the primary source of rainwater runoff impacts on stream health, it is especially important to establish performance targets for managing **RUNOFF VOLUME** and **RUNOFF RATE**. In 2002, the Guidebook introduced the Water Balance Methodology for:

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

The Guidebook emphasizes that performance targets and rainwater management practices be optimized over time based on monitoring the performance of demonstration projects; and strategic data collection and modeling. As success in meeting performance targets is evaluated, rainwater management programs can be adjusted because: **We change direction when the science leads us to a better way**.

2. Relationship of Rainfall Spectrum to Watershed Objectives

The Guidebook introduced the concept of **performance targets** to facilitate implementation of the *integrated strategy* for managing the complete rainfall spectrum. To create a mind-map for practitioners, the rainfall spectrum was defined in terms of three tiers, with each tier corresponding to a component of the integrated strategy, namely:

- **Rainfall Capture** - keep rain on site by means of 'rainfall capture' measures such as rain gardens and infiltration soakaways
- **Runoff Control** - delay overflow runoff by means of detention storage ponds which provide 'runoff control'
- **Flood Mitigation** – reduce flooding by providing sufficient hydraulic capacity to 'contain and convey'

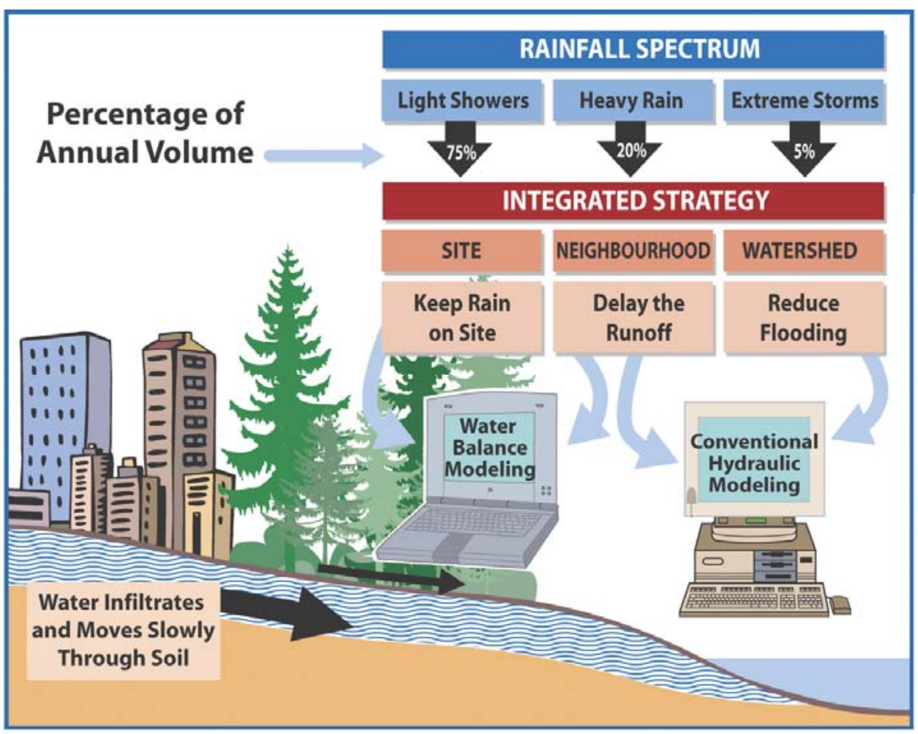
As noted previously in the discussion in the section titled Defining a Runoff Volume Target, the concept of **rainfall tiers** simply enabled a systematic approach to data processing and identification of rainfall patterns, distributions and frequencies.

Historical Context:

For convenience, and to provide a starting point for analysis, the Guidebook referenced the three tiers to a value defined as the **Mean Annual Rainfall** (MAR). As our understanding of what is achievable through 'rainwater management' has grown, we have moved beyond this early concept. Looking back:

- The MAR concept was introduced in part to provide consistency with the *1992 Land Development Guidelines.*
- It established a point of departure that was familiar to practitioners so they would readily make the transition to a new way of thinking.
- In 2002, focussing attention on the MAR facilitated a paradigm-shift in the state-of-the-practice.

The MAR was introduced in order to focus attention upon what could be done at the site level, while assuming there would be benefits to the watershed and streams. Our knowledge is progressing and we now see a need to begin to evaluate the total spectrum of rainfall and resulting runoff that flows into streams from the surrounding watershed.



Of relevance and importance, our current understanding of runoff processes leads us to acknowledge that rainfall does not equal runoff; that the physical processes are complex; and that applying rainfall capture targets may be overly simplistic. A more rigorous, yet simple analytical methodology has been developed to address this issue.

3. Performance Targets

Defining a Runoff Volume Target:

In 2002, the science was explicitly telling us that major biophysical changes occur once the impervious percentage of a watershed reaches about 10%. Beyond this threshold, the change in the Water Balance triggers watercourse erosion, which in turn degrades and /or eliminates aquatic habitat.

In 2002, the science was explicitly telling us that where urban use densities are produced, the focus should be on what needs to be done at the site level to effectively mimic a watershed with only 10% impervious area, and in so doing reduce runoff volume to the same 10% level.

A Starting Point for Early Action:

In 2002, the Guidebook addressed the question of what could be done at the site level to protect watershed health; and presented the following rationale for early action (reference: page 2-11):

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

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

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

Looking ahead, the objectives of most Integrated Stormwater Management Plans (ISMPs) will include trying to maintain or restore the natural Water Balance as development or re-development proceeds. Improved understanding of how to do that will evolve through demonstration projects that test and refine solutions to aquatic habitat and receiving water quality challenges."

Defining What is Achievable:

To provide a starting point for early action, the Guidebook referenced the Water Balance Methodology to a **healthy watershed**, defined as one where the proportion of impervious area is below the 10% threshold for runoff volume. The Guidebook also defined **rainfall tiers** to enable a systematic approach to data processing and identification of rainfall patterns, distributions and frequencies.

A key finding was that the frequently occurring, light to medium rainfalls account for 90% of the total annual rainfall volume. This established that rainfall capture is achievable. This finding provided the initial basis for establishing a Rainfall Capture Target to prevent surface runoff from the *impervious* portions of a development site; however, the Guidebook also cautions that (reference: page 6-20):

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

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

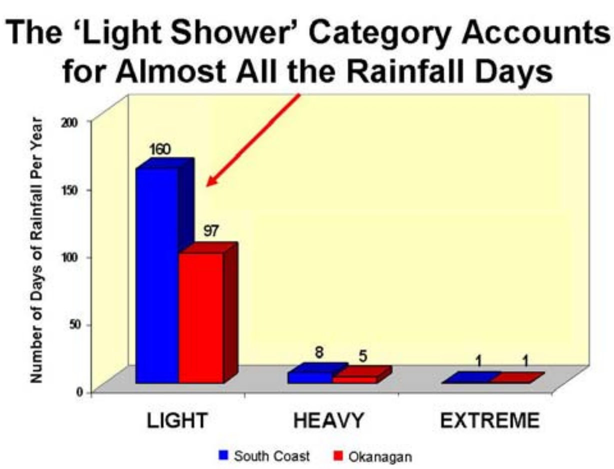
Defining a Runoff Rate Target:

The Guidebook emphasizes that a combination of Runoff Capture and Rate Control is necessary to mimic the rate of interflow in a naturally vegetated watershed. Interflow is defined as the portion of rainfall that soaks into shallow ground and moves slowly through soils to streams. To provide a starting point for early action in achieving runoff control, the Guidebook identified the goal of **maintaining the natural Mean Annual Flood** as the runoff rate target.

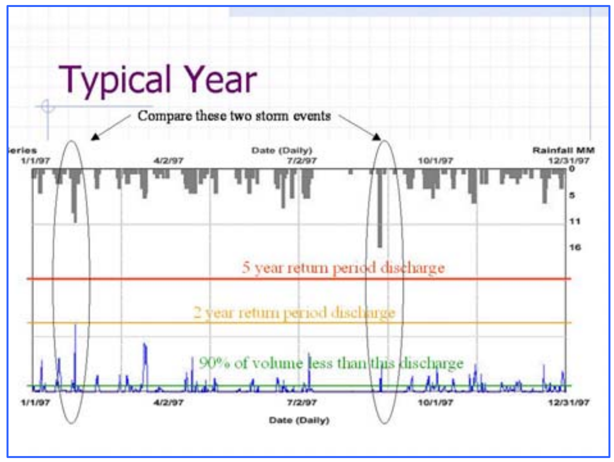
The Mean Annual Flood (MAF) is defined as the channel-forming event; as the MAF increases with development, stream channels erode to expand their cross-section, thereby degrading aquatic habitat. Therefore, the Guidebook states that an appropriate runoff rate target is to ensure that streamflow rates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

Building on the Guidebook Foundation:

It is in addressing the inter-relationship between Runoff Capture and Rate Control that **Beyond the Guidebook** picks up where the Guidebook left off in 2002. Looking back, the Guidebook focused attention upon the site level while assuming there would be benefits to the watershed and streams. Our knowledge is progressing and we now see a need to begin to evaluate the total spectrum of rainfall and the flows entering the streams from the watershed.



A simple chart of rainfall and stream flow for a typical year follows and shows some of the complex processes involved in the watershed between the time rain falls and when it reaches the stream. This leap in our knowledge plus the development of the tools available to assess these relationships allows us to go **Beyond the Guidebook** in establishing reasonable and achievable performance targets. The next step in advancing our knowledge allows us to focus upon the stream, the critical item that is so important to the environment.



This hydrograph for a 'typical year' illustrate the variable response of a watershed to rainfall. Two events are highlighted in the graphic. The larger of the two rainfall events resulted in much less runoff. As can be seen from the hydrograph, the smaller of the two rainfall events was preceded by a period of wet weather such that more runoff resulted.

The hydrograph also shows that 90%of the total annual runoff volume corresponds to a very small runoff rate. The implication of this finding is that it we can easily manage 90% through rainfall capture measures. For the other 10%, it is a matter of detaining and conveying in accordance with the integrated strategy for managing the complete rainfall spectrum. Further, that retaining 90% on site would have little effect on peak runoff rates unless other practices are brought to bear. This implies that retaining 90% of the rainfall is only a part of the requirement for an effective rainwater management system.

Runoff-Based Approach:

Over the past five years, experience has shown that landscape-based measures for rainfall capture are typically low risk, especially when they reflect an understanding of how to employ soil depth and planting coverage to best advantage. This experience has set the stage for the next leap forward – which is to apply a 'runoff-based approach' to rainwater management at a watershed scale.

Runoff Basis

- ❑ Flow duration for habitat availability
- ❑ Tractive force to measure potential erosion
- ❑ Sediment washoff to evaluate water quality
- ❑ Optimize systems to manage the impacts of the altered hydrologic cycle
- ❑ **Test** mitigation works **prior** to construction

The runoff-based approach provides the analytical foundation for the **Water Balance Model powered by QUALHYMO**. A primary benefit of this approach is the use of continuous simulation using long-term records to calculate runoff means that the frequencies and durations of various watershed conditions can be estimated easily.

Stream Health Methodology:

The strength of QUALHYMO resides in the flow exceedance analysis. This capability leads directly into the **Stream Health Methodology** which is a function of flow duration, and hence stream erosion. (Refer to the adjacent images.)

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

QUALHYMO can simulate water and can add sediments and first order constituents to the analysis process. Because we can calculate how much energy is available in a stream, we can then compare scenarios to determine the most effective combination of rainfall capture measures on development sites.

Duration of Discharge

- ❑ Critical to aquatic health
  - Discharge is linked to stream health
- ❑ It can be measured and verified
- ❑ Computer simulations for duration of:
  - Flood discharges
  - Base flows
  - Fish habitat availability (depth vs duration)

Stream Erosion

- ❑ Calculate stream power
- ❑ Estimate potential erosion
- ❑ Identify critical stream reaches for protection and enhancement
- ❑ Create watershed / stream specific plans

4. The Need for Flexibility in Setting Performance Targets

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

The runoff volume and rate targets presented in **Chapter 6 of the Guidebook** provide a reference point that is based on the Water Balance and hydrology of a healthy watershed. To determine whether these targets are realistic or achievable for a given watershed (reference: page 6-8), the Guidebook states that an Integrated Stormwater Management Plan (ISMP) must answer the following questions:

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

The Guidebook emphasizes the need for flexibility in setting performance targets (page 6-8):

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

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

Continuous Water Balance modeling can be applied to determine what is effective and affordable."

To be understood and effective, a performance target needs to synthesize complexity into a single number that is simple to understand and achieve, yet is comprehensive in scope. A **runoff volume-based** performance target for rainfall capture and rate control fulfills these criteria.

Further information regarding the runoff volume characteristics of the watershed must be determined. There are many documented instances where the runoff is in excess or 10%. If the natural runoff volume exceeds 10% then the post development condition must also exceed 10%.

Achieving the Target Condition at the Site Level:

The Guidebook states that (reference: page 6-5):

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

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

5. Use Performance Targets to Quantify Watershed Objectives

The Guidebook states that, in general, a watershed planning process must address the following fundamental question (reference: page 9-1):

- "How can the ecological values of stream corridors and receiving waters be protected and/or enhanced, and drainage-related problems prevented, while at the same time facilitating land development and/or redevelopment?"

As discussed in the Guidebook, performance targets provide a quantifiable way of measuring success in protecting (or restoring) a watershed, and for identifying what needs to be done to achieve a given environmental protection objective.

- Desired protection objectives for significant stream reaches can be translated into performance targets for reducing runoff volume from the catchments draining into those reaches.
- For catchments upstream of chronic flooding locations, a more appropriate performance target may be to reduce peak runoff rates from large rainfall events.
- Other performance targets relating to the preservation/restoration of significant natural features, measurement of stream health, protection/improvement of water quality, or in-stream enhancements can also be established.

In conclusion, a key principle is to establish performance targets that relate directly to the watershed objectives.

Modeling Alternative Scenarios:

Scenario modeling is used to assess a range of performance targets, and evaluate options for achieving these targets. Furthermore, scenario modeling involves consideration of the complete spectrum of rainfall events that typically occur in a year. The Guidebook states that (reference page 9-14):

"The balance between the above three components depends on the watershed objectives.

- Stream protection/restoration objectives would likely govern scenarios that emphasize source control (e.g. infiltration, rainwater re-use), along with other possible options, such as riparian corridor protection.
- Flood management objectives would likely govern scenarios that place more emphasis on detention and conveyance.

The key is to determine which scenario or blend of scenarios has the best 'fit' to address a range of watershed objectives.

A key aspect of scenario development will be to consider what can be done at the site level to retain the small events, given constraints such as soil conditions, hydrogeology, topography and land use. Further data collection may be required to assess the feasibility of achieving performance targets."