The Water Balance Model (WBM): A Tool for Stormwater Source Control Modeling in a Watershed Context

Proposed Work Plan for WBM Upgrade

Most natural hydrologic phenomena are so complex that they are beyond comprehension, or exact laws governing such phenomena have not been fully discovered. Before such laws can ever be found, complicated hydrologic phenomena (the prototype) can only be approximated by modeling.

—Ven Te Chow

1. Overview of the Model

To support several complementary efforts in the Greater Vancouver Region of British Columbia, CH2M HILL developed a decision support tool for volume-based analysis of stormwater strategies. The tool is named the ***Water Balance Model*** (WBM) and is versatile in meeting educational, watershed planning and site design needs and objectives.

The WBM provides an interactive means for local governments to integrate land use planning with stormwater management, and to evaluate the potential for developing or re-developing *communities that function hydrologically like natural systems.* The tool creates an understanding of *how*, and *how well*, stormwater source control strategies would be expected to achieve watershed protection and / or restoration objectives.

The WBM incorporates algorithms that simulate how runoff is generated at the site level, and has a wide range of application possibilities:

- **Design of volume-based stormwater controls**
- **Site performance assessment**
- **Evaluating opportunities for urban retrofits**
- **Volume-based watershed trading for urban stormwater management**
- **Watershed management optimization**
- **Analysis of global climate change impacts**
- **Public education and outreach**

The hydrologic modeling tools that are commonly used by stormwater practitioners originated in an era when 'flow-based thinking' dominated stormwater management and surface water modeling. Therefore, not one of these models is suitable for modeling water balance volumes at the site level. This gap in modeling technology was the trigger for development of the WBM.

Model Inputs and Outputs

The power of the WBM is in the 'engine' that instantly, interactively, and transparently models hydrologic processes at the site level, including the processes that govern the movement of water through soil and vegetation. This engine provides a continuous simulation of runoff from individual sub-catchments or neighbourhoods (also simulates other hydrologic pathways – infiltration and evapo-transpiration).

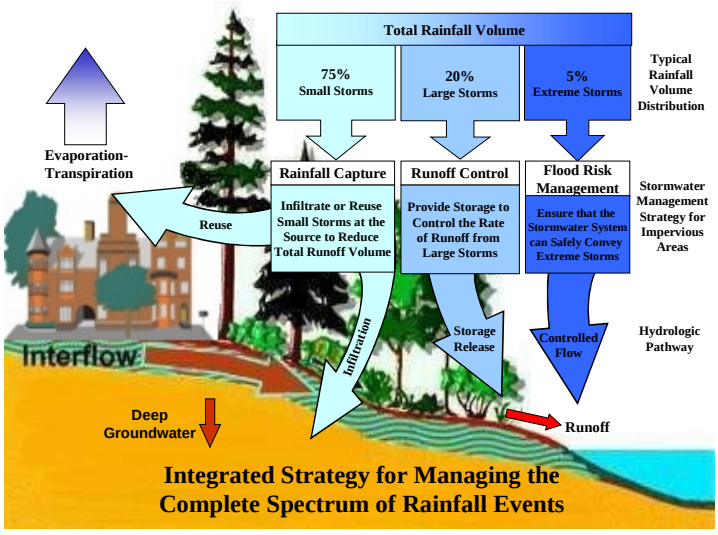
The WBM can be applied to evaluate the hydrologic performance of stormwater source controls (e.g. bioretention, infiltration facilities, rainwater capture and re-use, green roofs) and stormwater detention. It provides a continuous simulation of the runoff from a development (or re-development) area, or from a watershed (or sub-catchment) with multiple land uses, given these inputs:

- **Continuous rainfall data** (any time increment) and **evapotranspiration data**
- **Extent and distribution of land use types**
- **Site design parameters for each land use type (**e.g. road width, rooftop coverage, parking coverage, population density)
- **Soil and groundwater information** (e.g. vegetation rooting depth, porosity, hydraulic conductivity, water table level)
- **Information on stormwater controls** (location and design parameters for stormwater source controls and detention facilities).

The sensitivity of source control performance to any of these model inputs can be tested by comparing modeled scenarios.

The output hydrograph generated by the WBM can become an input to a wide range of hydraulic routing models. WBM hydrographs represent a major improvement over conventional hydrologic simulation.

Model Application



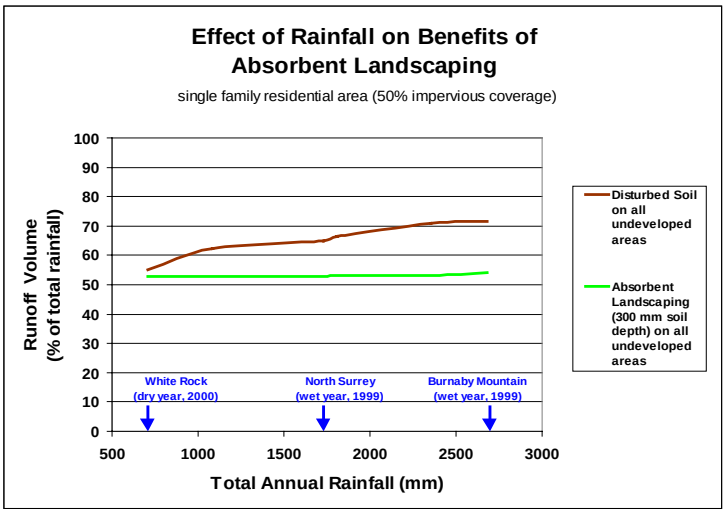
Integrated Strategy for Managing the Complete Spectrum of Rainfall Events

The WBM enables modelling of all three components of the Integrated Strategy for managing the complete rainfall spectrum – that is, *retain* the small frequent events, *detain* the large events, and *convey* the extreme events.

The WBM can be used to evaluate how well alternative strategies (including stormwater source source control and detention) can reduce the runoff from development areas, and how this translates into benefits at the watershed level.

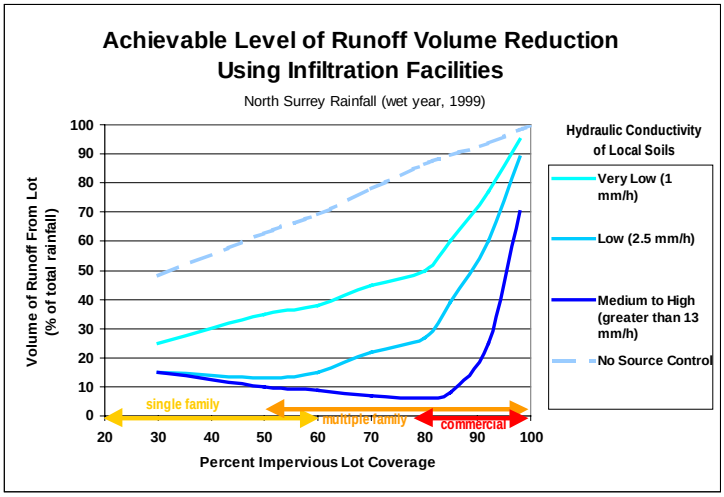
2. Sample Model Output

The following figures illustrate the type of output that the WBM produces:



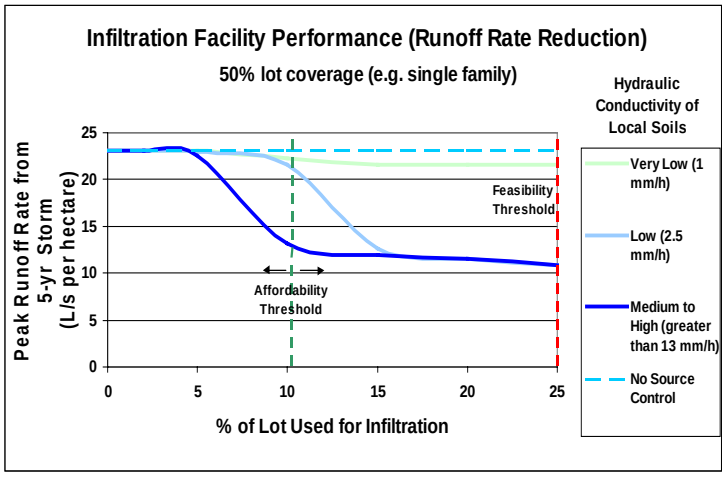
Absorbent landscaping is most beneficial for high rainfall locations, even under conditions where the hydraulic conductivity of the underlying soil is very low.

A 300-mm absorbent soil depth can virtually eliminate surface runoff from undeveloped areas, even in the wettest conditions.



Where soils have medium or better hydraulic conductivity, runoff volume could be reduced to about 10% of total rainfall for all but the highest coverage land uses.

Significant levels of runoff volume reduction can also be achieved in soils with poor conductivity.



Reductions in runoff rates using infiltration facilities depend on the hydraulic conductivity of local soils and the amount of area provided for infiltration.

Affordability thresholds govern infiltration facility sizes for lower coverage land uses, and feasibility thresholds govern for higher coverage land uses.

3. Need for Model Upgrade

The WBM was initially developed as an spreadsheet application but the number of modules has outgrown this format. At the most basic level, portability is an issue due to the size of the Excel file: over 50 MB. In addition, needed enhancements that would allow the WBM to model multiple land uses and multi-year continuous simulations are simply not possible under the current platform.

The purpose of this document is to establish a vision for the evolution of the WBM and to develop an estimate of the effort require to move the WBM to a more practical version.

4. Vision for the Enhanced WBM

The application will have the 'look and feel' of a web environment. Users will interact with the WBM using a web browser (Internet Explorer or Netscape) much like they would do in a website, except that they would not be connected to the internet.

Information will be supplied through forms and options will be invoked through hyperlinks and buttons. Reports will be delivered in webpages either within the same browser window or in a new window. The data will be stored in Microsoft Access, which is factory-installed in many personal computers.

The new platform will allow for more efficient data storage procedures, faster performance, increased portability, more flexible output options and easier technical enhancement as the state-of-the-science evolves.

5. Proposed General Work Plan

The effort to upgrade the WBM consists of three main steps:

- **Step 1 - Definition of Software Requirements:** This step will establish what users desire from the software and how to fulfill their needs. Much of this work was already done by CH2M HILL in developing the current version of the software. Through the demonstrations of the WBM, a wealth of information has become available from potential users and some of it has been incorporated in the spreadsheet version. This step will formalize remaining issues that need to be addressed in the new version of the WBM.

- **Step 2 - Software Design and Specifications Document:** In this step, a blueprint of the software will be developed. This blueprint will define the way the user interacts with the software, software architecture, system requirements, computations to be performed, input/output options, and any other features needed for the programming team to produce the software. The final product of this step is a document that clearly establishes what functions the WBM needs to execute and how to go about programming those functions. Specific elements of this step are further defined in the attached Proposed Detailed Work Plan.

- **Step 3 - Software Development:** This step will involve the programming effort, testing of the software, final development, preparation of a user's manual and online help, and training. This is the main part of the project consisting of producing and testing the software. Work will be guided by the detailed specifications resulting from Step 2. Software testing will proceed at several stages in the process by the development team and the user community. At a point of substantial completion a "beta" version of the software will be released for field-testing. Software documentation and online help will be prepared once the final version of the software has been defined as a result of testing.

6. Proposed Detailed Work Plan

The accompanying Table 1 outlines the proposed actions, with associated timelines and costs, required to complete the WBM upgrade. The table includes both administrative and technical action items. Administrative actions are listed in green and technical actions are listed in blue. All timelines and costs are tentative.

Step 1 could officially begin as soon as sufficient funding is secured. Steps 1 and 2 could be completed within three months of the start date. The target date for completion of Step 3 is February 1st, 2003.

The total estimated cost is $140,000 (Canadian dollars). Note that the budget for Step 3, software development, will only be known with certainty once Step 2, the *Software Design and Specifications Document* is completed. Costs provided for Step 3 are for planning purposes only at this initial stage.

The vision for the WBM is that of a tool that can implement the latest thinking in stormwater management in the United States and Canada. Funding sources are from an international partnership that includes jurisdictions in British Columbia, Environment Canada, and potentially the United States Environmental Protection Agency as well as jurisdictions in Washington State and Oregon.

Preliminary Budget

The anticipated budget is summarized below:

STEP	DESCRIPTION	BUDGET
1	Definition of Software Requirements	$22,000
2	Software Design and Specifications Document	$45,000
3	Software Development	$73,000
TOTAL		$140,000

Preliminary Schedule

Subject to funding being in place, the target date for project completion is February 28th 2003. The objective is to complete Steps 1 and 2 within the first three months.

STEP	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
1									
2									
3									

7. Contact Information

For information about the proposed WBM upgrade, please contact

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TABLE 1 - DETAILED WORK PLAN

Action	Lead	Timeline	Expected Cost ($ Canadian)
PHASE I			
Project Initiation Meeting	WBM Inter-Governmental Partnership	Mar '02	$0
Define and secure minimum level of funding required to proceed with WBM enhancement	WBM Inter-Governmental Partnership	May '02	$0
Arrange for third party to manage funds and contracting	WBM Inter-Governmental Partnership	May '02	$0
Meet with WBM Steering Committee to define project scope and deliverables	WBM Inter-Governmental Partnership	Jul '02	$0
Incorporate deliverables into contract	WBM Inter-Governmental Partnership	Jul '02	$0
Resolve WBM ownership and intellectual property issues and write into contract	WBM Inter-Governmental Partnership	Jul '02	$0
Step 1 - Definition of Software Requirements			
Develop scope of upgrade program	CH2M Hill		$4,000
Define software requirements	CH2M Hill		$12,000
Finalize software requirements	CH2M Hill	Jul '02	$6,000
Step 2 - Software Design and Specifications Document			
Establish sources and format of input data	CH2M Hill	Aug '02	$2,000
Define data structures and management procedures	CH2M Hill	Aug '02	$3,000
Select Graphical User Interface (GUI) platform (HMTL, ASP, Flash , or Director-based navigation)	CH2M Hill	Aug '02	$3,000
Define issues of access, passwords, ownership and privacy	CH2M Hill	Aug '02	$2,000

Action	Lead	Timeline	Expected Cost ($ Canadian)
Design GUI screens and prepare prototypes in the selected platform	CH2M Hill	Aug '02	$12,000
Develop prototype model for "walk through" purposes	CH2M Hill	Aug '02	$2,000
Prepare sample data set	CH2M Hill	Aug '02	$2,000
Define software testing and quality control procedures	CH2M Hill	Aug '02	$2,000
Specify documentation requirements re: user's manual, online help, technical reference manuals, and software administration, support and maintenance	CH2M Hill	Aug '02	$12,000
Prepare accurate cost estimate and schedule for Step 3 - Software Development	CH2M Hill	Aug '02	$2,000
Hold interim progress meeting with Inter-Governmental Partnership	CH2M Hill	Sep '02	$3,000
Step 3 - Software Development			
Program WBM according to specifications from Step 2	Lanarc	Oct '02	$31,000
Conduct software testing	Lanarc	Dec '02	$6,000
Complete final software development	Lanarc	Jan '03	$8,000
Pilot with local government users ("beta" testing)	Lanarc	Jan '03	$6,000
Make final adjustments as required	Lanarc	Jan '03	$5,000
Build instructions for use into user interface, or develop user manual	Lanarc	Feb '03	$14,000

Action	Lead	Timeline	Expected Cost ($ Canadian)
Present enhanced WBM to Inter-Governmental Partnership and / or GVRD Stormwater Interagency Liaison Group	CH2M Hill	Feb '03	$3,000
Decide on how to distribute / provide access to enhanced WBM	WBM Inter-Governmental Partnership	Mar '03	to be determined
Hold training workshops for specific user groups	CH2M Hill	Mar '03	to be determined
Clarify provisions for providing ongoing technical support	WBM Inter-Governmental Partnership	Mar '03	to be determined
TOTAL ESTIMATED COST (*Phase I*)			**$140,000**
PHASE II			
Develop plan to validate and calibrate model outputs against field data		to be determined	to be determined
Develop internet capability		to be determined	to be determined
Incorporate WBM into the GVRD's ISMP Template		to be determined	to be determined