VANCOUVER PUBLIC LIBRARY GREEN ROOF MONITORING PROJECT

Chris Johnston P.Eng., Kathryn McCreary B.A.Sc., Cheryl Nelms, B.Eng.

Kerr Wood Leidal Associates Ltd. Burnaby, B.C.
Public Works and Government Services Canada

Abstract
In order to quantify stormwater runoff benefits associated with green roofs in the Vancouver, British Columbia, a one-year monitoring program was initiated. Two green roofs were monitored, a 350 mm (14") soil layer plus vegetation at the Vancouver Public Library (VPL) and a 200 mm (4") soil layer plus vegetation at the White Rock Public Works building. At the time of writing, the data from the White Rock Public Works building was not ready. The measured stormwater runoff from the VPL green roof showed a 16% reduction in volume when compared with that estimated for a traditional flat roof. The maximum possible reduction is 33% for natural, pre-development conditions at the VPL site. This represents a 48% reduction in runoff volume. The green roof also reduced peak flows during summer storm events. We expect the results to improve further as the monitoring continues through this spring and summer.

Introduction

Project Background

The Vancouver Public Library's (VPL) Central Branch building and green roof were constructed in 1995. The 2,600 m^2 (28,000 sq.ft.) roof includes an extensive green roof with a gross area of 1850 m^2 (20,000 sq.ft.) and a net area of 1,500 m^2 (16,150 sq.ft). The green roof was designed and completed by architect Moshe Safdie and Landscape Architect Cornelia Hahn Oberlander.

Figure 1 VPL Green Roof – Arial View

The green roof is inaccessible to the general public but can be viewed by occupants in the surrounding residential and commercial towers.

Another similar green roof project was undertaken at the Public Works Building of White Rock. The green roof at the City of White Rock was constructed in 2002. Unfortunately, the results of the White Rock green roof were unavailable to be published at this time.

Project Objective

Public Works and Government Services Canada (PWGS) initiated this study to add to the pool of information on Best Management Practices (BMPs) and Low Impact Development (LID) methods. In June 2003, PWGSC partnered with Kerr Wood Leidal Associates Ltd. (KWL) to conduct a year long monitoring project on the VPL green roof. The purpose of the project is to assess the performance of the green roof during the rainy and dry seasons (saturated and non-saturated conditions). Data on air and runoff water temperature, soil moisture, relative humidity, rainfall, wind speed and direction, gust speed and solar radiation are being collected. With this information a computer model can be developed to assist in predicting stormwater impacts for various soil depths and climatic regions of the Pacific Northwest.

This paper presents the first portion of that work highlighting the ability of the VPL green roof to reduce the total volume of runoff and attenuate peak flows. The focus of this paper is to present stormwater quantity data, observations and findings for a period of eight months.

References

Field research on the performance of green roofs with respect to stormwater quantity in North America is in its infancy. In Canada, two green roof research centers have been established; the National Research Council green roof monitoring facility in Ottawa, Canada and the British Columbia Institute of Technology (BCIT) green roof research center in Vancouver, Canada. Stormwater quantity data was not available at this time from either of these research facilities. Preliminary stormwater quantity data published by Moran et al, 2003 in a North Carolina field study found the green roof retained rainwater and both reduced the peak flow and the time to peak; however, due to a lack of data conclusions were tentative. The New York City Department of Environmental Protection and the Altria Corporation have funded the development of stormwater models to complement the field monitoring results on the Pace University green roof project in order to develop green roof stormwater detention and retention performance with respect to the climatic conditions of New York City (http://www.greenroofs.ca/grhcc/NYEIS_description.html)

Vegetation

The green roof was designed to replicate the Fraser River and the surrounding lands. Festuca ovina Glauca var. ‘Elijiah Blue’, Blue Fescue, Festuca ovina Glauca var. ‘Solling’, Green Fescue, represent the River, and Arctostaphylos uva ursi, Kinnikinnick represents the higher elevations of the land. Plants were selected in part to due to the low maintenance, water consumption and fertilizer requirements. An irrigation system was installed to aid in the establishment of the plants and is used weekly in the summer months. The initial depth of the light weight growing medium installed was 350mm (14-inches) and had a specified weight of no more than a wet density weight of 1120kg/m^3 (70lbs/ft^3) and a pH of 6.0 to 6.5. The growing medium is composed of 1/3 washed sand with particle size between 0.025 and 0.30mm, 1/3 pumice and 1/3 Humus Builder. Humus Builder is a product based on composted organic materials such as composted food waste from Vancouver restaurants. The waterproofing membrane is a hot applied rubberized asphalt applied by American Hydrotech. The prefabricated drainage layer is a waffled drainage core bonded to a layer of non-woven filter fabric Nilex WD15WP supplied by the Nilex Group.

Flow Monitoring System Design

Introduction

During the wet months, rainwater saturates the soil layer and excess water flows through the soil layer and along the bottom soil layer towards 150 mm (6") diameter steel roof drains. There are eight main drains, with two draining the actual green roof section. Runoff from each side of the green roof drains downward via drain piping to the P1 Parking Level through two large 50 mm (2") positive displacement flow meters. Low flows exit through a smaller 19 mm positive displacement meter that is drained to the buildings sump then pumped back to the storm sewer system, High flows overwhelm the smaller meter and flow by gravity via horizontal pipes to the City's storm sewer system. The main components of the green roof monitoring project are the metered piping system located in the parking garage, and the weather station, located on the roof top.

Piping

The metered piping system, as depicted in Figure 2,

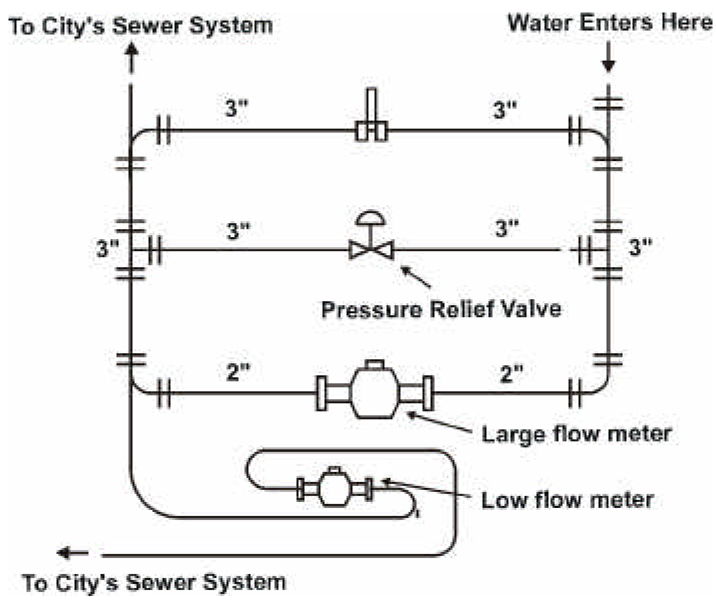
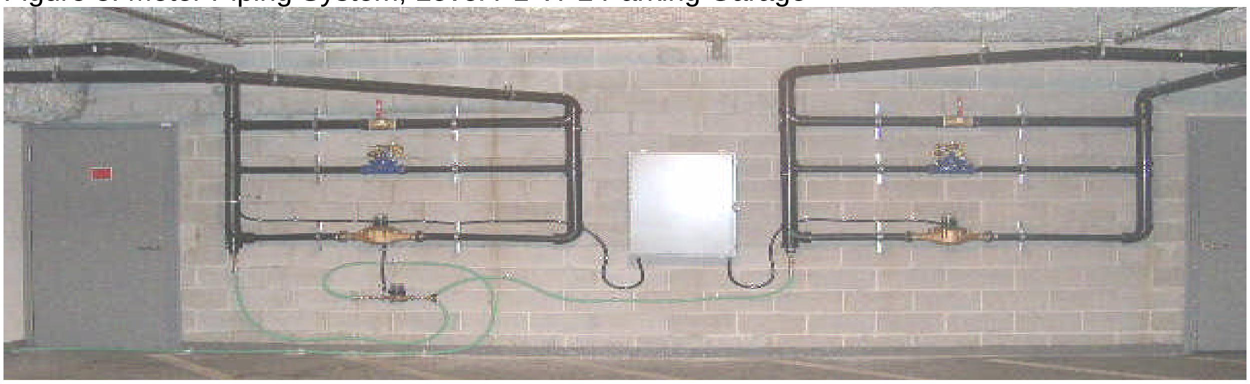


Figure 2: Metered Piping System Schematic (South Side)

There are two drain pipes that collect runoff from both sides of the roof. Due to the design of the VPL building, it is not possible to combine the two drains, therefore there are two identical metered piping systems, located side by side, in the parking garage. Figure 3 shows the position of each of the meter piping system in relation to each other.

Figure 3: Meter Piping System, Level P1 VPL Parking Garage



A pressure relief valve was installed in parallel with the water meter, and will open if the meter becomes fouled. A bypass valve was also installed as an additional redundant measure. To date, both the bypass valve and pressure relief valve have not been used. However, debris does accumulate on the meter strainers. The 50mm strainers are cleaned every three months and the 19mm strainer every 2 weeks.

Water Meter

There are two types of water meters on the system, one for measuring large flow and the other for measuring low flow. The large flow meter (see Figure 4) is a 2” T-10 Meter comprised of three main parts: a register, an EnviroBrass® 11 maincase, and a nutating disc measuring chamber. The TRICON®/S Register mounts on the meter maincase. The maincase resists internal pressure stresses and external damage, protecting the nutating chamber inside. The water flows into the nutating disc measuring chamber causing the disk to nutate in a circular motion so that the fluid discharges from the meter. A pin on the plate measures the number of rotations of the plate; calibrated to 10 litres/pulse sent to the data-logger. Water flowing at low flow will not rotate the nutating disk, and will pass through the large meter and into the low flow meter (see Figure 5). The low flow meter is a 5/8” T-10 NSF61 Meter which has been calibrated to register 1 litre/pulse. The water flows through the meter via shut off valve into garden hose, attached to the main meter piping system, and out through a nearby drain.

Figure 4: 2’’ T-10 Meter
(for large Flow)

Figure 5: Low Flow Meter

Monitoring Equipment

Data logger

The data logger is a Telog based system (Figure 6) that logs the flow information from the water meters and runoff water temperature using a temperature probe inserted through the PVC pipe.

Figure 6: Telog Logger

Figure 7: Weather Station

Climate Parameters

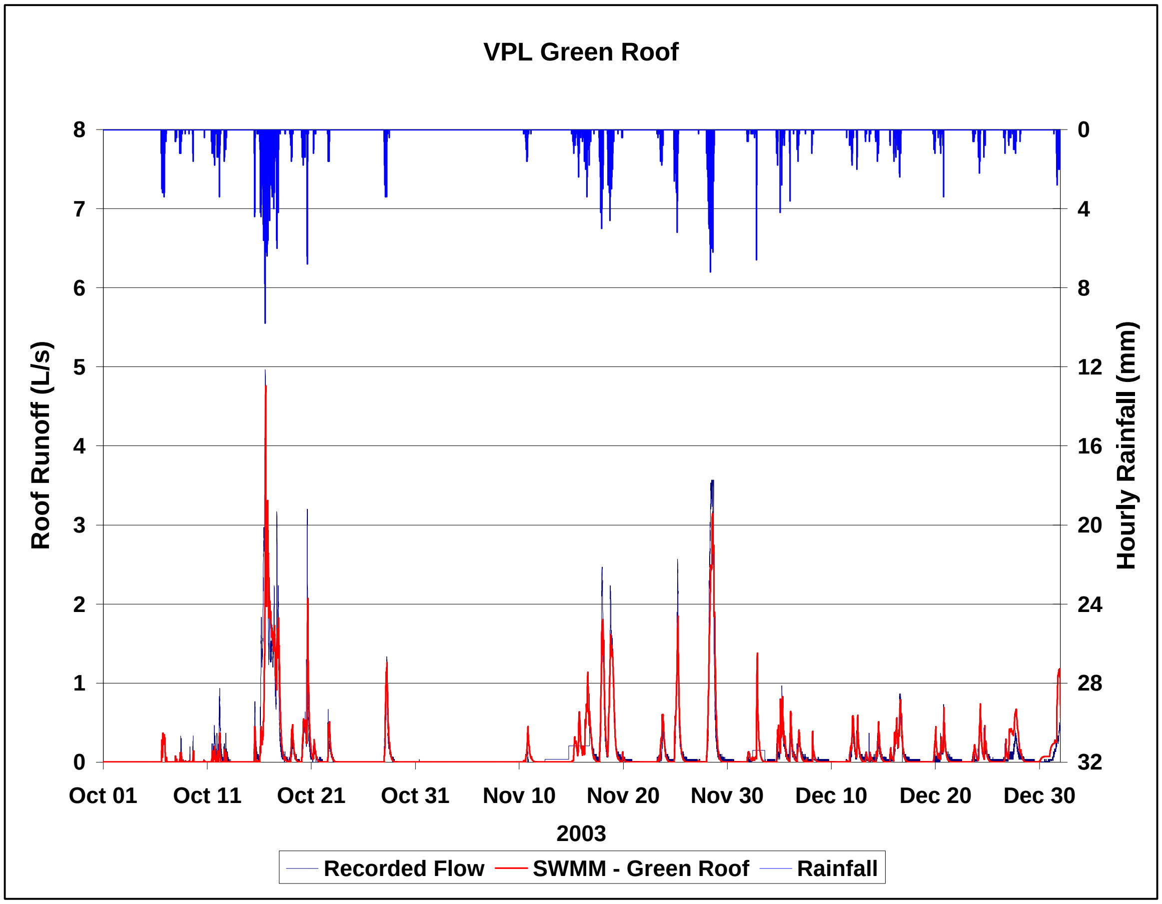
The HOBO Weather Station, seen in Figure 7, was installed in June 2003 to monitor and record parameters on rainfall, humidity, wind speed/direction, gust speed, soil moisture, temperature and solar radiation. It was placed on the southeast corner of the building where it would receive the most direct form of rain and wind. It was also considered to be a location that would provide the most averaged data across the roof top. The weather station is grounded for lightning with a copper wire driven into the soil.

The HOBO Weather Station sensory components relay information to the data logger. All data was logged in five-minute intervals.

Runoff Model

In order to put the monitoring results into context, a computer model was developed to predict the flow response of other roof surfaces. An XP-SWMM model was created to simulate the natural (pre-development) condition, a traditional torch on membrane surface roof, and the current green roof with 350 mm of growing medium. Groundwater parameters in the green roof model were adjusted to calibrate the model with the recorded flow data for both peak flows and total volumes. Figure 8 shows the recorded versus modeled flows for a three month period.

Figure 8: VPL Green Roof Runoff Model Calibration



To create the traditional roof model, the calibrated model impervious area was increased to 100% to simulate a torch-on style roof. The natural condition's model was developed using calibrated parameters for undisturbed, forested areas based on previous work.

Results

The green roof will be monitoring for a period of one year. As of the writing of this paper, the results from July 3003 through February 2004 are available for analysis.

Rainfall

The rainfall received in 2003 is very close to the average annual total for Vancouver according to the Canadian Climate Normals 1961 – 1990. As shown in Table 1 the total annual rain average is 1,117.2 mm (44 inches) and the 2003 total average is 1,106.1 mm (43.5 inches). There is however some variation in monthly rainfall averages. The summer was drier than normal and most of October's above average rain fell over 4 days.

Table 1: Vancouver Monthly Rainfall Totals (Vancouver International Airport)

Month	2003 Monthly Average (mm)	Typical Year Monthly Average (mm)
January	150.5	131.6
February	27.1	115.6
March	133.7	105.4
April	139.8	74.9
May	49.3	61.7
June	12.8	45.7
July	19.8	36.1
August	4.1	38.1
September	40.2	64.4
October	248.2	115.3
November	167.4	167.2
December	113.2	161.2
Annual Total	**1,106.1**	**1,117.2**
Month	2004 Monthly Average (mm)	Typical Year Monthly Average (mm)
January	161.4	131.6
February	83.4	115.6

(shaded months indicate duration of flow monitoring program)

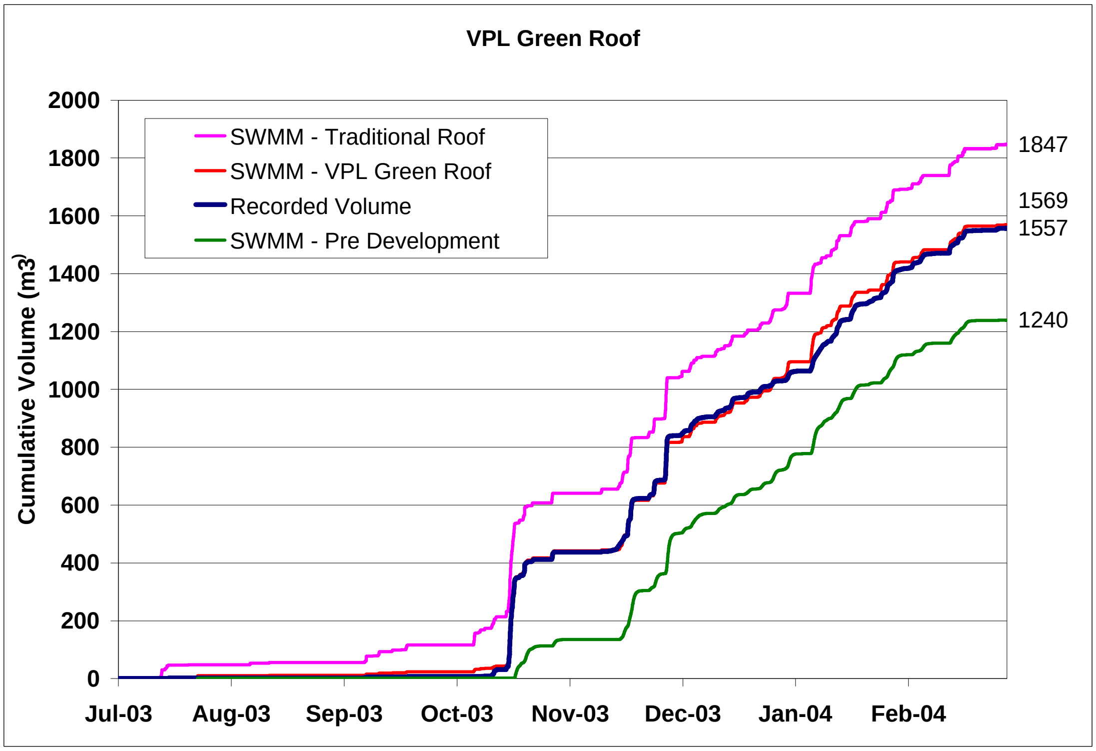
Stormwater Flow Volume Reduction

The volume of runoff from the site was totaled from July 2003 to the end of February. Figure 9 shows the cumulative runoff volume from the four scenarios: pre-development, traditional roof with torch-on membrane, computer model with 350mm of growing medium, and the actual VPL green roof flow results. The measured stormwater runoff from the VPL green roof showed a 16% reduction in volume when compared with that estimated for a traditional flat roof. The maximum possible reduction is 33% for natural, pre-development conditions at the VPL site. This represents a 48% reduction in available runoff volume. This is a very significant reduction, as 20% of the roof is not covered with the growing medium. In other words, assuming 100% green roof coverage, the reduction in runoff would be nearly 70%. Table 2 summarizes the volume runoff from the different scenarios.

Table 2: Volume Reduction Summary

Scenario	July 2003 – Feb 2004 Cumulative Volume (m^3)	Difference From Predevelopment (m^3)	Max. Reduction Compared to Traditional Roof
Predevelopment	1,240	0	100%
Traditional Roof	1,847	607	0%
Green Roof (Modeled)	1,569	329	46%
Green Roof VPL (Flow Monitoring)	1,557	317	48%

Figure 9: VPL Green Roof Runoff Volume Comparison



The results would indicate that the green roof at the VPL is significantly reducing the volume of runoff from when compared to a traditional torch-on membrane style roof.

The traditional roof runoff volume represents nearly all of the total rainfall volume (1913 m^3). Only 2% of the total rainfall would be evaporated from a traditional membrane roof.

Eliminating sprinkling in the summertime could further enhance green roof performance as the soil moisture gauge showed that the roof never really dried out prior to the fall rains.

Stormwater Peak Flow Reduction

A number of events were analyzed to determine the reduction in peak flow provided by a green roof versus a traditional roof. The green roof runoff, both recorded and modeled, exhibited significant reductions peak flows. During the summer time when the roof is dryer and the rainfall events typically smaller, peak flows were reduced in excess of 80%. During the winter events, the reduction in peak flow decreased with the size of the storm event. The green roof reduced the runoff by approximately 30% during the smaller winter events and by less than 5% for the larger more severe events (i.e. greater then Mean Annual Rainfall (MAR)), This is to be expected as these types of Low Impact Development (LID) techniques are designed to reduce flows during smaller events. Table 3 summarizes the events that were examined and the associated peak runoff rate reductions.

Table 3: Peak Flow Reduction Summary

Event Date	Peak Outflow (L/s)				% Reduction (Recorded vs. Traditional Model)
	Recorded	Green Roof Model	Traditional Roof Model	Natural Condition Model	
7/12/2003 (s)	n/a	0.583	2.910	0.000	n/a
8/6/2003 (s)	0.200	0.254	1.270	0.000	84%
9/7/2003 (s)	0.207	0.672	3.370	0.000	94%
10/16/2003 (l)	4.970	5.090	5.150	0.541	3%
11/28/2003 (l)	3.530	3.140	3.610	1.64	2%
12/5/2003 (w)	0.967	0.826	1.340	0.267	28%
1/29/2004 (w)	1.330	1.260	1.750	0.440	24%
2/14/2004 (w)	1.270	1.330	2.360	0.297	46%

(s) = summer event; (l) = large storm event (greater then MAR); (w) = typical winter event

The natural condition peak flows are also presented in Table 3. The peak runoff from the site in its natural condition, which includes the groundwater flow and interflow draining offsite, is lower than the green roof peak runoff. The site under natural conditions would have a greater soil depth, is 100% pervious, and a portion of the rain would be caught by a tree canopy.

Conclusions

The green roof installation at the Vancouver Public Library was shown to provide a benefit in terms of total flow volume reduction through evaporation over a traditional impervious membrane roof. The measured stormwater runoff from the VPL green roof showed a 16% reduction in volume when compared with that estimated for a traditional flat roof. The maximum possible reduction is 33% for natural, pre-development conditions at the VPL site. This represents a 48% reduction in available runoff volume. Considering that 20% of the roof is still impervious, it means that the actual reduction would be closer to 70%.

The VPL green roof was also able to attenuate the summer peak flows to a great extent (>80 %) and the small winter peak flows by approximately 30%. However, it was unable to attenuate the peak flows from large events (i.e. greater than a 2-year storm) like those that occurred in mid-October and near the end of November 2003.

Since the ultimate stormwater objective is to build cities to mimic natural hydrologic conditions, green roofs appear to go a long way to achieving this. Further, we expect that the even greater benefits will be seen in the months to come as the monitoring program records more small and medium sized rainfall events and evaporation is dries the soil more rapidly.

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