HYDROLOGIC IMPACTS OF RETENTION LAYERS WITHIN EXTENSIVE VEGETATED ROOF ASSEMBLIES

Giuliana Frizzi
Jennifer Drake
Stormwater 2023
May 23, 2023

UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING

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The New Zealand Water & Wastes Association Waiora Aotearoa
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Outline

- Background
- Project Objectives
- Methods
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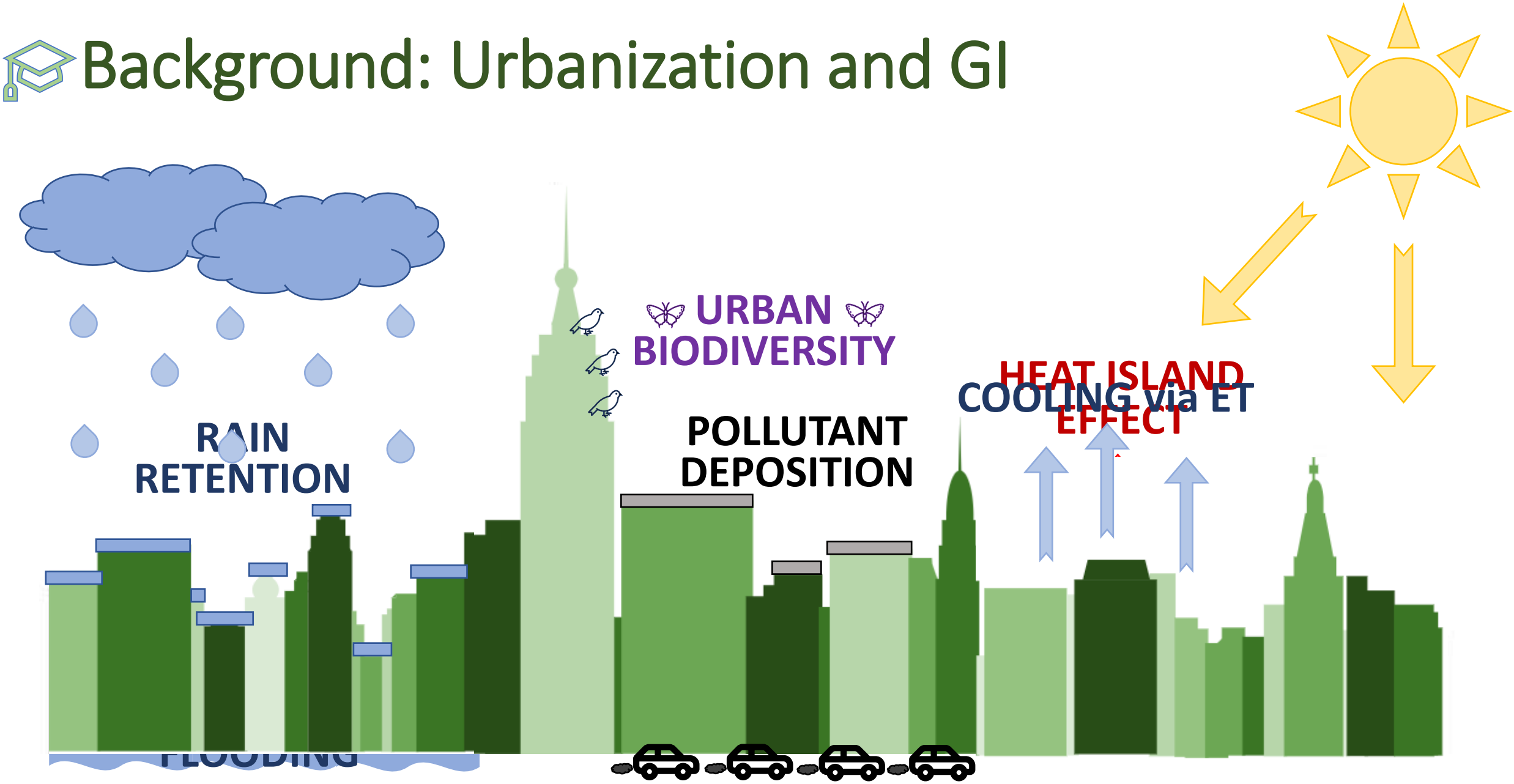
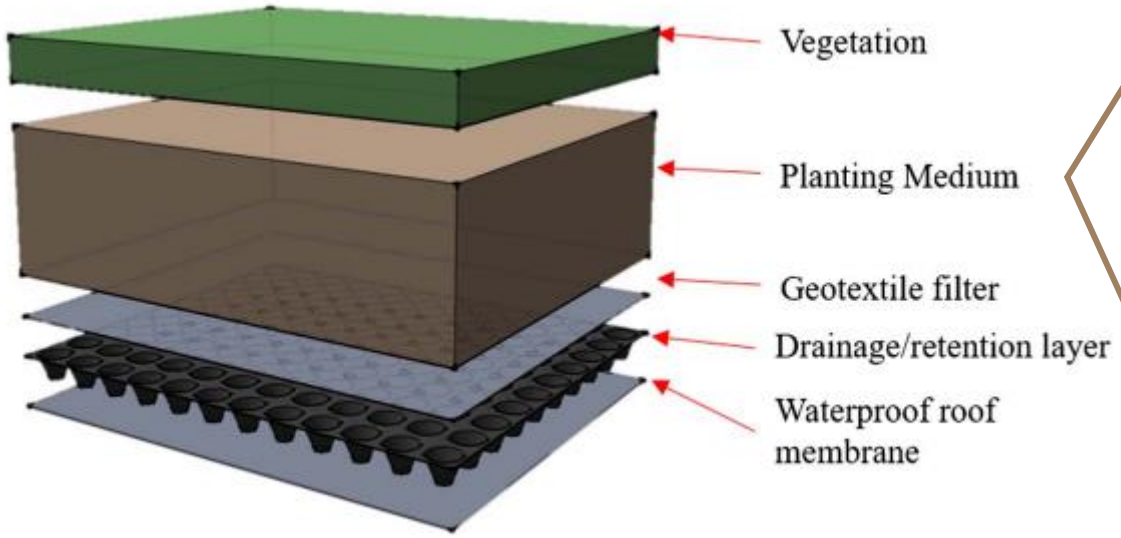
- Conclusion
- Future Steps

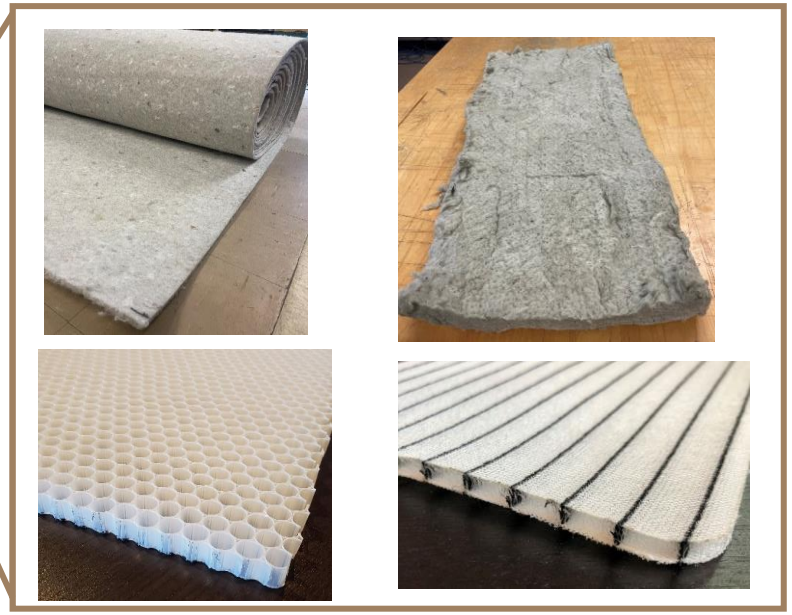
Background: Urbanization and GI



Background: Vegetated Roof Assemblies

Extensive Green Roofs:



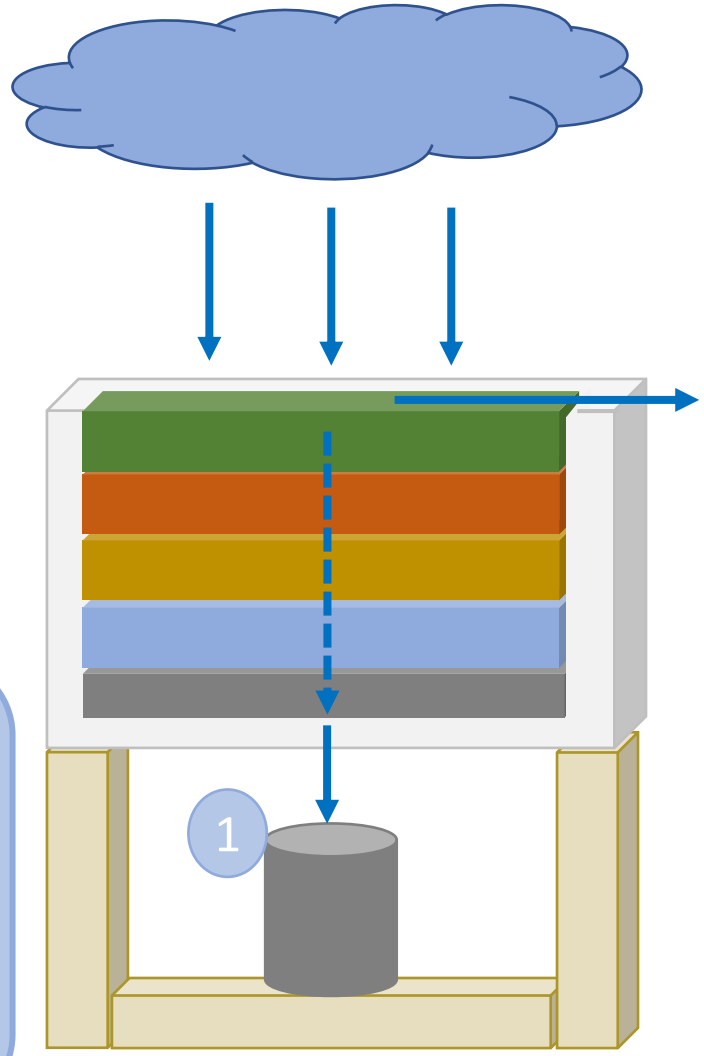


Research Aim: Evaluates the hydrologic performance of various vegetated roof assemblies (VRAs) that use ultra-lightweight and soilless retention/detention materials over the course of the growing season under the natural rainfall conditions to see which is most suited for the Toronto, Ontario climate.

Project Objectives

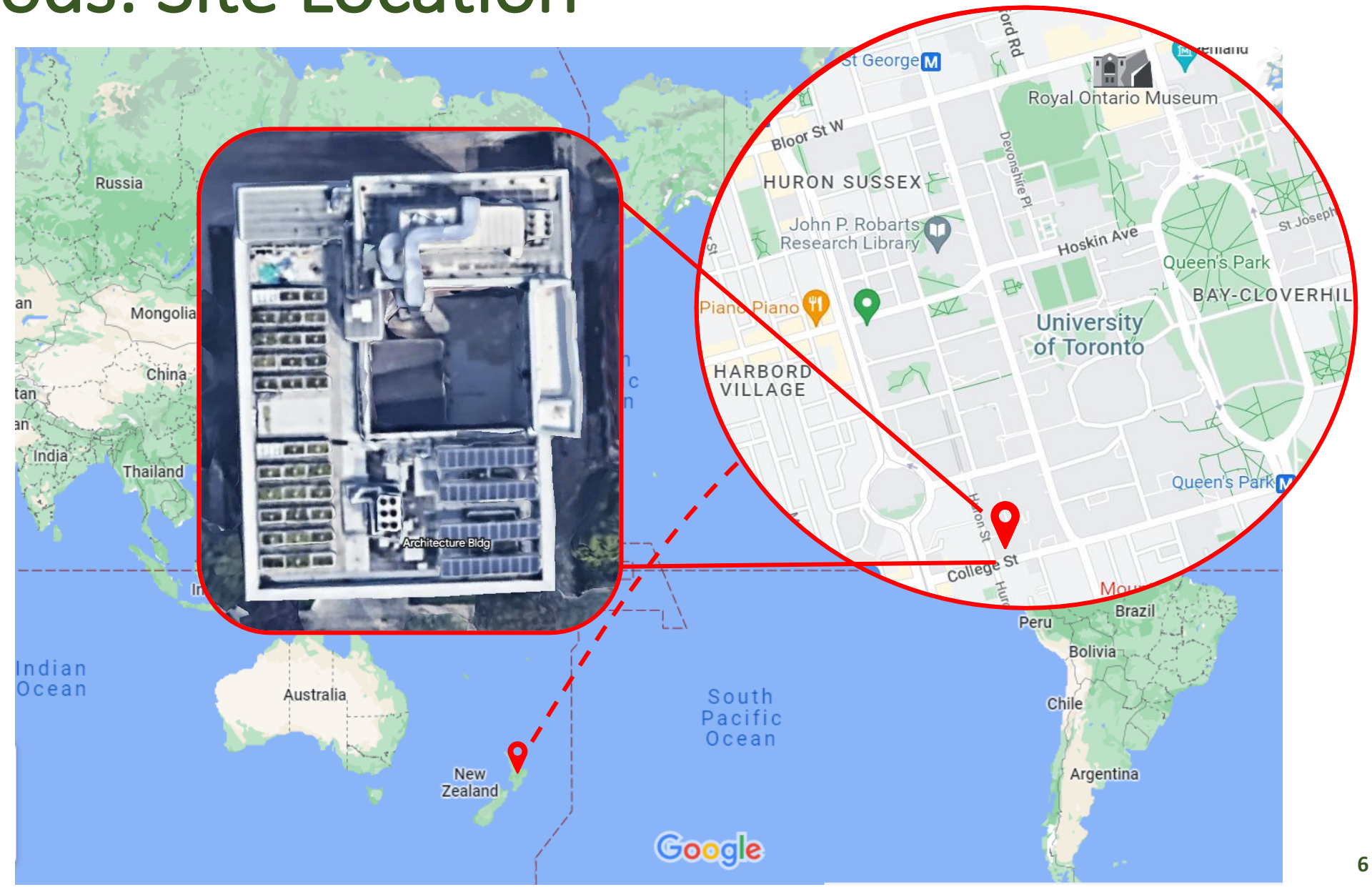
- Retention (%)
- Peak Flow Attenuation (%)
- Discharge Duration
- Discharge Delay

1. Quantify the stormwater benefits of ultra-lightweight mat and soilless retention/detention materials for extensive green roofs.



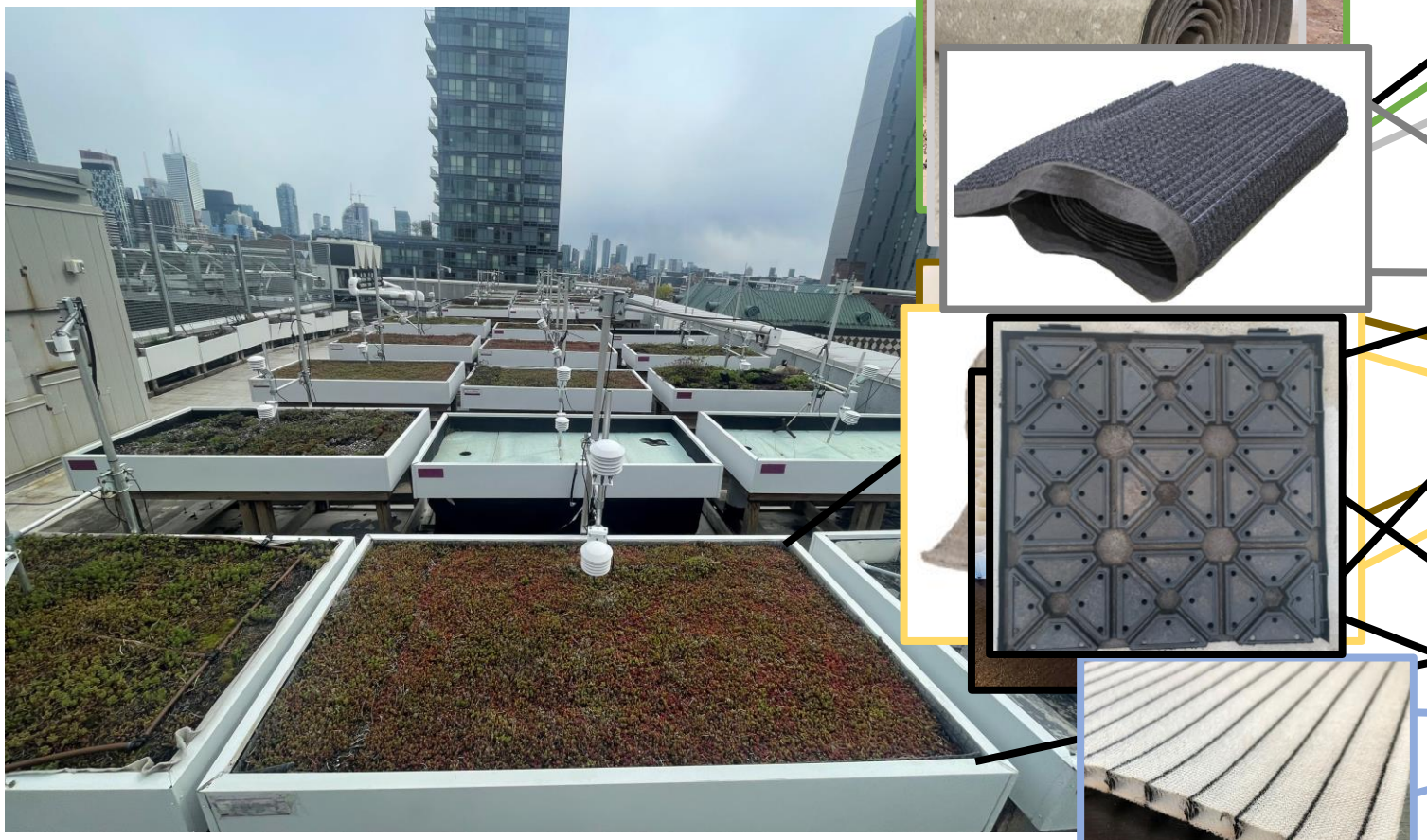
2. Develop runoff coefficients and curve numbers for ultra-lightweight green roof and hybrid green-blue roof systems in Toronto, Ontario.

Methods: Site Location



Methods: Site Setup

Location: Green Roof Innovation Testing Laboratory #1 (GRITLab1)

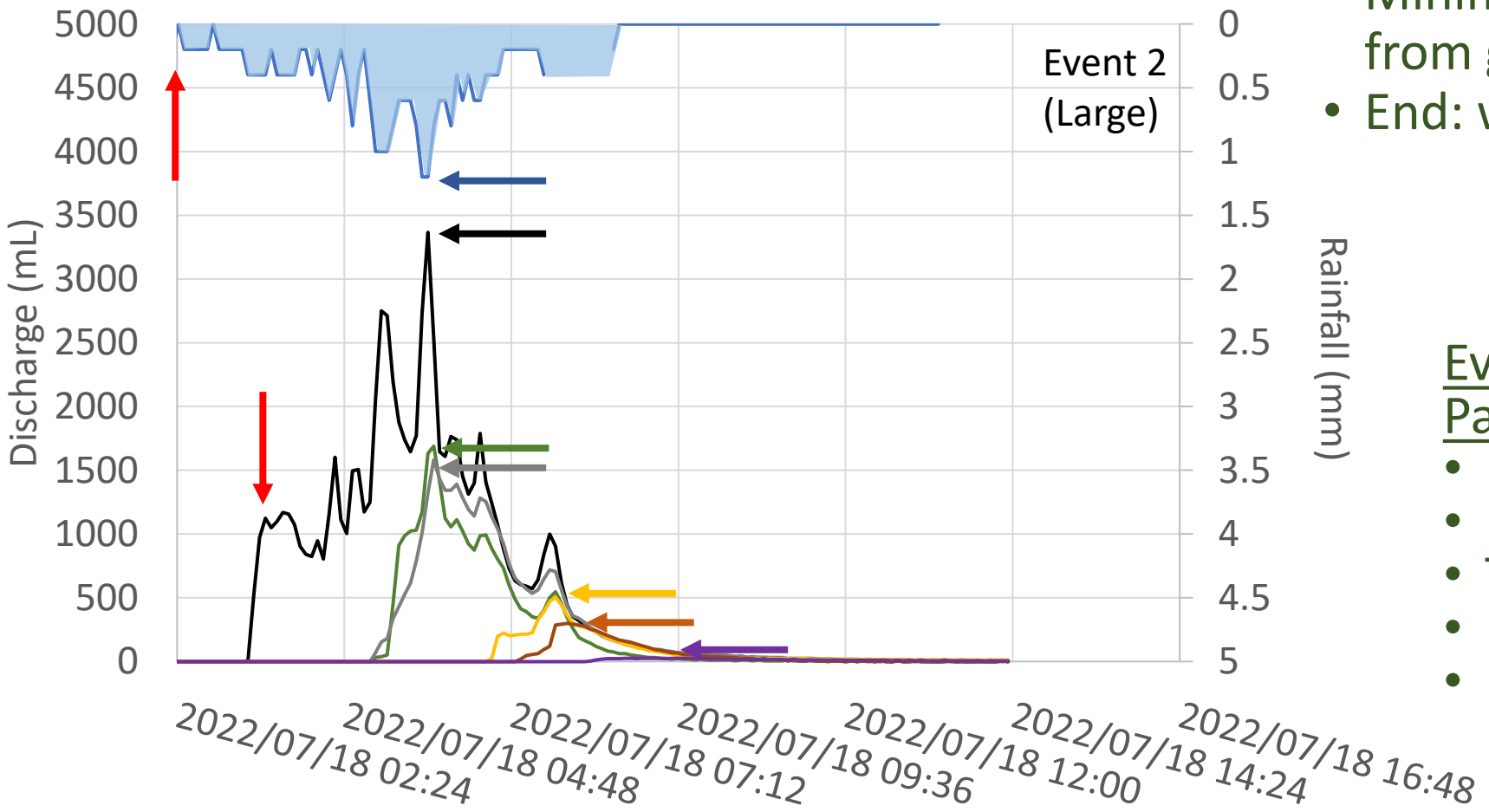


	Layer	Material	Depth [mm]
Grey	Stone	¾" Stone	50
GRC	Vegetation	Sedum Mat	30
	Growing Media	Extensive-Mix	130
	Drainage	Fabric+Plastic	11.43
	Drain/Retain	Plastic	38.1
FLEECE	Vegetation	Sedum Mat	30
	Retention	Fleece	8.5
	Retention	Fleece	8.5
	Drainage	Fabric+Plastic	11.43
	Drain/Retain	Plastic	38.1
MW-oGM	Vegetation	Sedum Mat	30
	Retention	Mineral Wool	26
	Drainage	Fabric+Plastic	11.43
	Drain/Retain	Plastic	38.1
MW-GM	Vegetation	Sedum Mat	30
	Growing Media	Extensive-Mix	75
	Retention	Mineral Wool	26
	Drainage	Fabric+Plastic	11.43
	Drain/Retain	Plastic	38.1
RD	Vegetation	Sedum Mat	30
	Growing Media	Extensive-Mix	75
	Retention	Mineral Wool	26
	Storage	Honeycomb	25
	Detention	Polyester Fabric	5
	Drainage	Fabric+Plastic	11.43
	Drain/Retain	Plastic	38.1

Methods: Data Collection

- Weather station records 5-min intervals of air temperature (°C) and rainfall (mm) via Campbell Scientific datalogger
- Additional QA/QC with rain gauge at GL2 (260m NW) and ECCC ‘Toronto City’ Station (950m N)
- Frequency of tips recorded at 5-min intervals via HOBOware loggers
- Tipping bucket with 6.28 mL tip capacity

Methods: Data Analysis



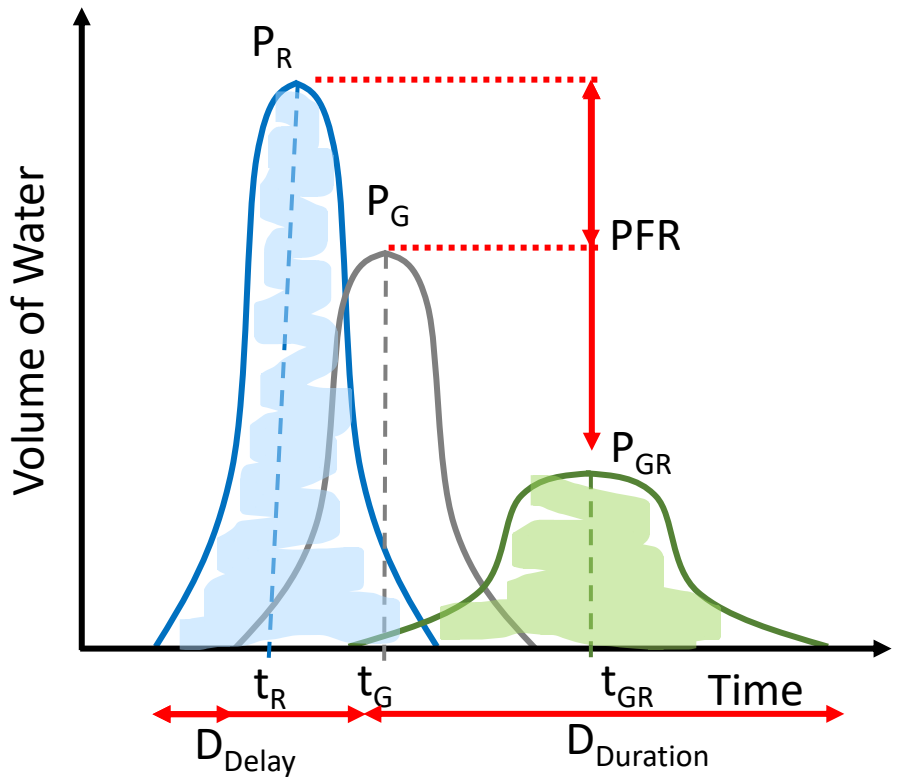
Rain Event Creation

- Start: >1 tip (0.2mm) recorded
- Minimum parameter: discharge from grey bed
- End: when >1 hr between tips

Event-Based Analysis Parameters

- Rainfall depth (mm)
- Peak rainfall (mm/min) (L/min)
- Total rainfall volume (L)
- Bed discharge volume (L)
- Peak bed discharge (L/min)

Methods: Data Analysis



Retention (%)

$$= \frac{Rainfall\ (L) - Testbed\ Discharge\ (L)}{Rainfall\ (L)}$$

Curve Number (NRCS)

$$Q = \frac{(P\ - 0.2S)^2}{(P + 0.8S)} \rightarrow \mathrm{CN} = \frac{25400}{254 + S}$$

Runoff Coefficient

$$C_{vol} = {\sum Q}/{\sum P}$$

Q = discharge depth (mm)
P = precipitation depth (mm)
S = storage (mm)

Detention

- Peak Flow Reduction (%)
- Discharge Delay (min)
- Discharge Duration (min)

* Significance Testing using Tukey HSD provided by R-coding software

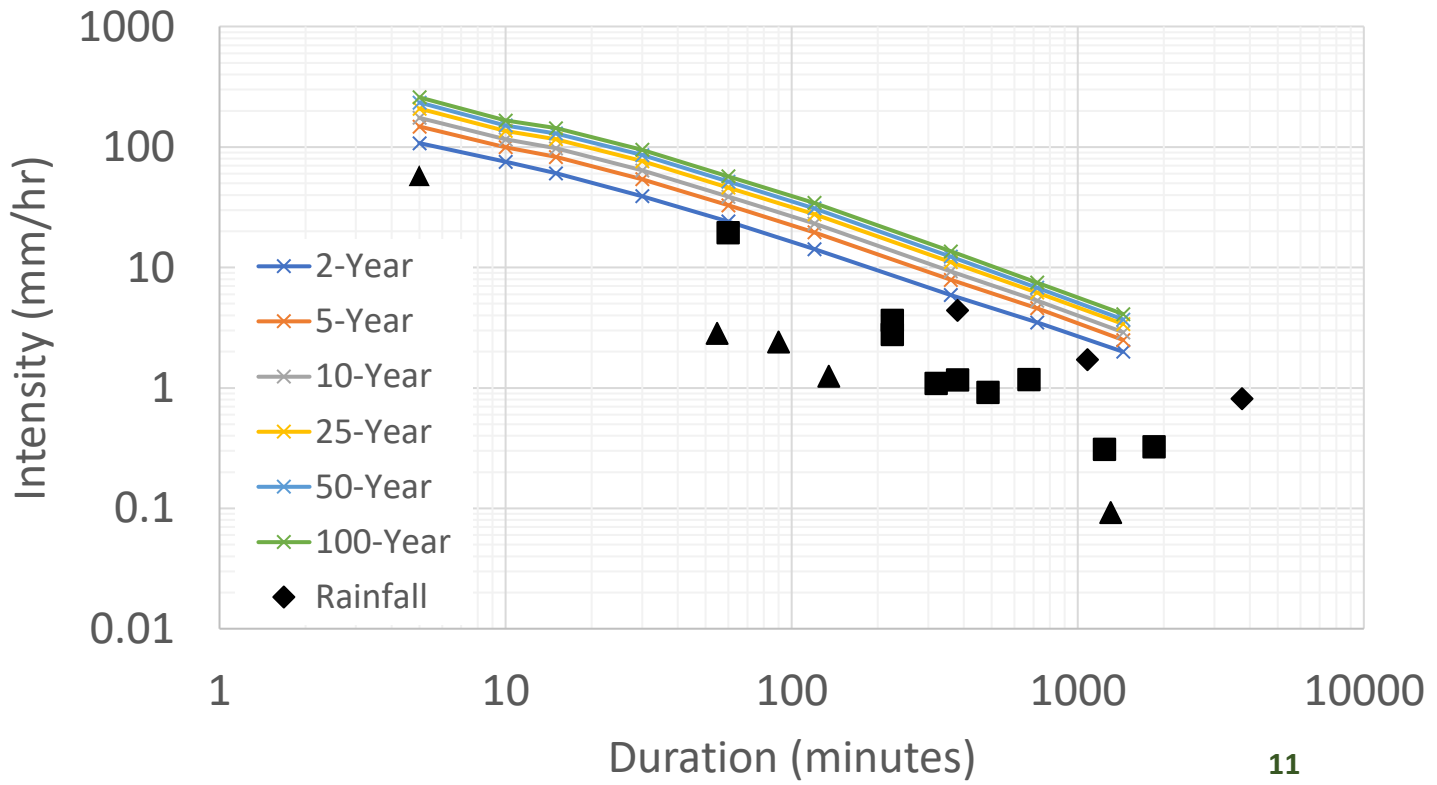
Results: Weather Conditions

- Study Period: July-Nov. 2022
- Total No. Events: 17 events
- Cumulative Rainfall: 220mm

Event Class	Range (mm)	Frequency	Avg Size (mm)
▲ Small	0.2-4.8	5	3.2
■ Medium	5-20	9	10.4
◆ Large	> 20	3	36.6

Discharge Frequency

- Fleece = 44%
- MWwGM = 41%
- GRC = 35%
- CRD = 35%
- MWwoGM = 26%



Results: Retention

Rainfall ranged from 2.0 – 50.8 mm

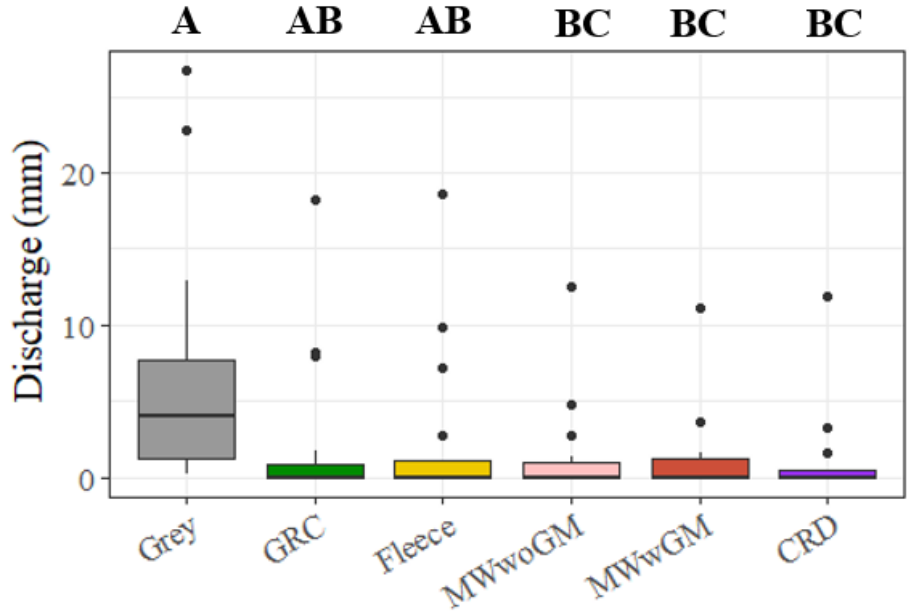
- Grey = 48%
- Fleece = 92%
- GRC = 94%

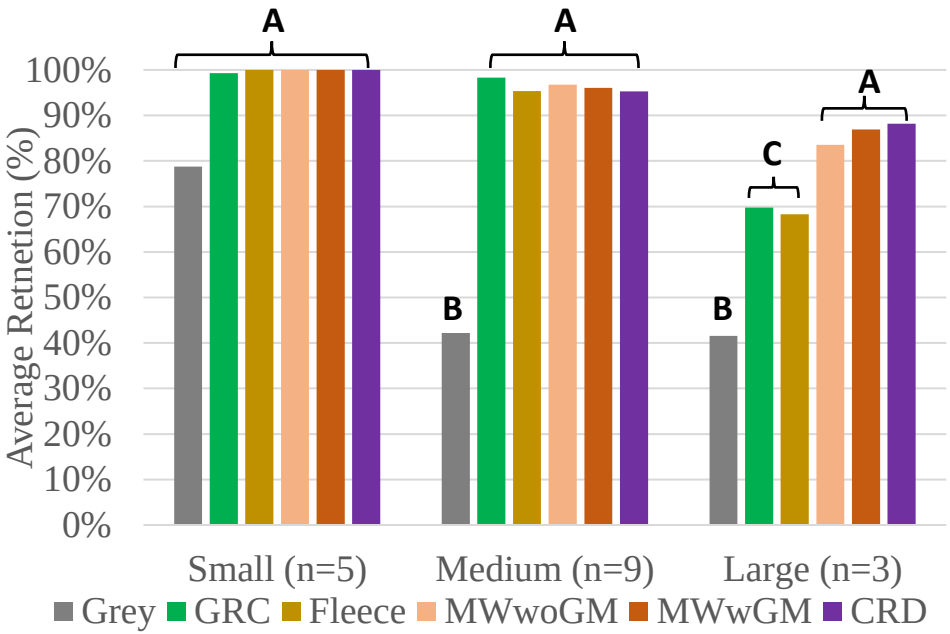
} without Mineral Wool (*p < 0.1)

- MWwoGM = 95%
- MWwGM = 95%
- CRD = 95%

} with Mineral Wool (*p < 0.05)

- VRA completely retain small events and majority of medium events
- Large events is where difference is seen





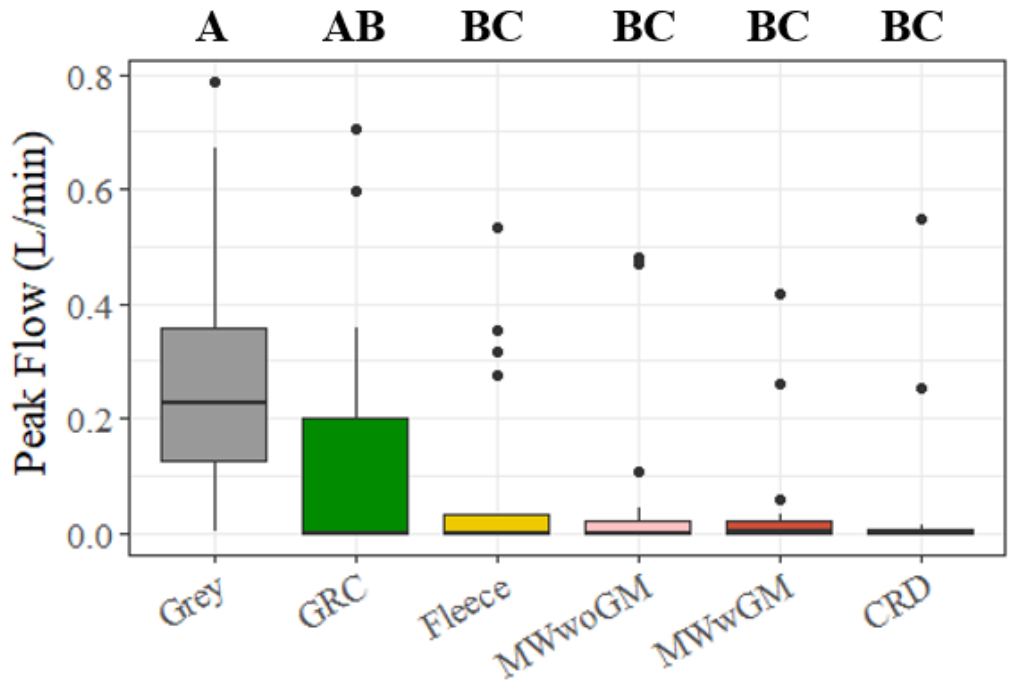
Results: Detention

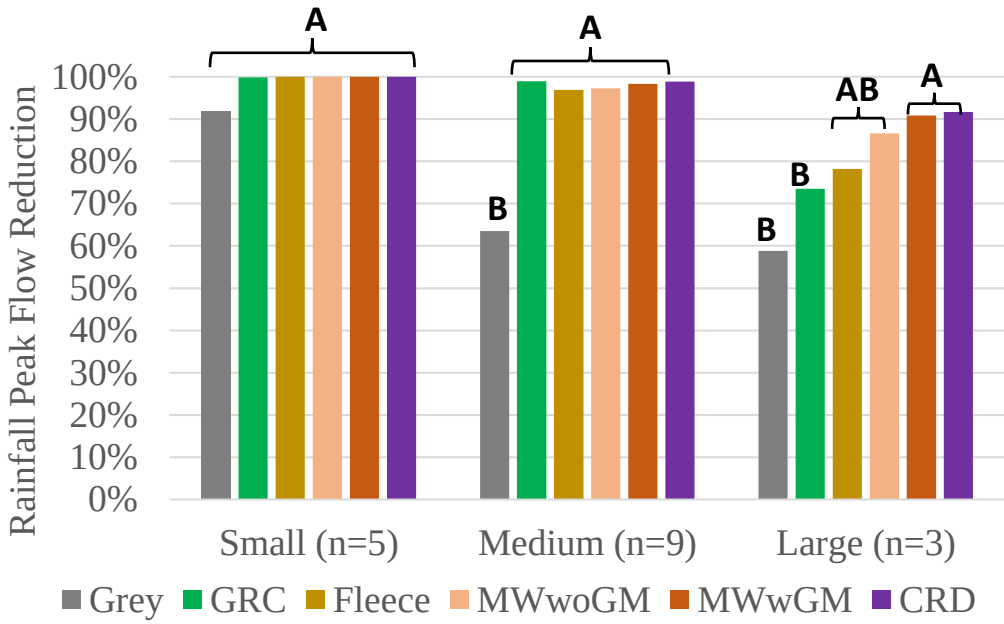
Rainfall peak flow ranged from 0.15 – 5.95 L/min

Rainfall Peak Reduction (%)

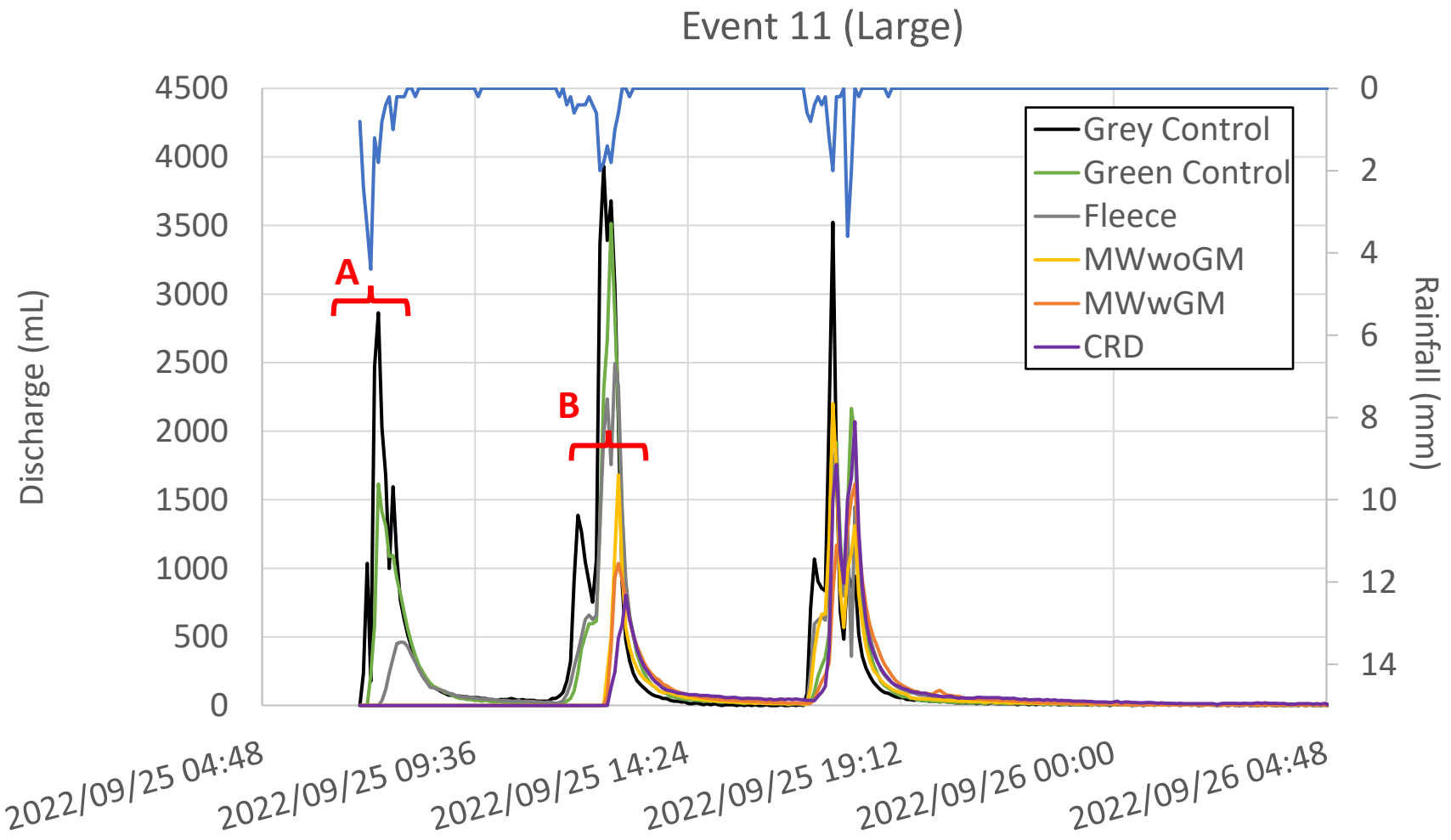
Bed	PF Avg	PFR Avg	PFR Range	Sig Level
Grey	0.28	71	17-99	---
GRC	0.13	95	58-100	---
Fleece	0.09	95	61-100	$p < 0.1$
MWwoGM	0.07	96	84-100	$p < 0.05$
MWwGM	0.05	98	84-100	
CRD	0.05	98	82-100	

- VRA completely reduced small events and majority of medium events
- Large events is where difference is seen





Results: Detention



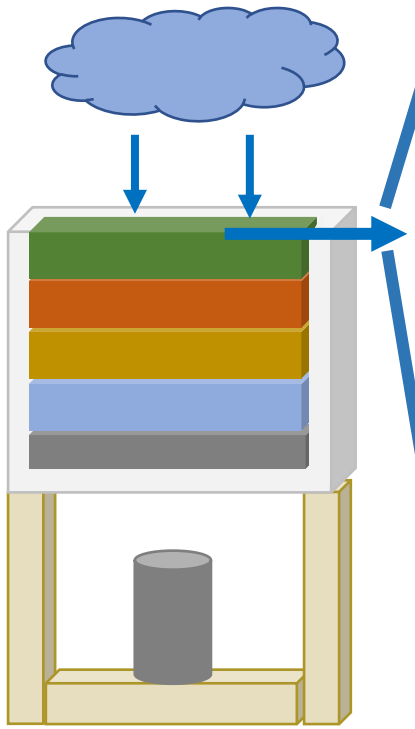
Discharge Delay (hours)

- GRC = 2.4
- Fleece = 5.7
- MWwoGM = 8.7
- MWwGM = 6.5
- CRD = 9.6

Discharge Duration (hours)

- GRC = 12.4
- Fleece = 11.8
- MWwoGM = 10.3
- MWwGM = 8.8
- CRD = 14.7

Results: Curve Number and Runoff Coefficient



Event Breakdown	Curve Number					
	Grey	Green	Fleece	MWwoGM	MWwGM	CRD
n Discharge Events	17	6	8	5	7	6
All Discharge Producing Events	96	84	87	81	77	82
Small (n = 5)	98	94	ND	ND	ND	ND
Medium (n = 9)	96	77	87	93	83	90
Large (n = 3)	93	86	86	75	69	74
	Runoff Coefficient, C_{vol}					
All Discharge Producing Events	0.5	0.2	0.2	0.2	0.1	0.1
Small (n = 5)	0.2	0.04	ND	ND	ND	ND
Medium (n = 9)	0.6	0.1	0.1	0.2	0.1	0.1
Large (n = 3)	0.6	0.3	0.3	0.2	0.1	0.1

* ND = no discharge

Conclusion

	GRC	Fleece	MWwoGM	MWwGM	CRD
Retention	2	3	1	1	1
Peak Flow Reduction	3	3	2	1	1
Discharge Delay	5	4	2	3	1
Discharge Duration	2	3	4	5	1
Curve Number	2	2	1	1	1
Runoff Coefficient	2	2	2	1	1
	18	17	12	12	6

Due to the additional reservoir detention layer, the CRD system hydrologically performed the best with one of the greatest retention levels and the greatest discharge delay and peak flow reduction.

Conclusion

	GRC	Fleece	MWwoGM	MWwGM	CRD
Cost	1	2	2	3	4
Installation	1	1	1	2	4
Maintenance	1	1	2	2	2
Life Cycle	1	2	2	2	3
Building Load Stress	3	1	1	2	3
	7	7	8	11	16

The VRAs with manufactured retention/detention layers preformed better than the natural system hydrologically, but raise the concern of cost, labor, durability and imbedded pollutants.

As a designer, product selection is critical.

Future Steps

Winter Collection

Data will be collected over the winter period and another growing season to identify their seasonal performance

Additional Beds

Bare roof membrane testbed.
New manufactured retention/detention mats to be tested.

Acknowledgements:

Thank you to all the members of Professor Jennifer Drake's research group that aided with the bed construction, data collection and analysis.
Virinder Sidhu, Wenxi Liao, Jad Saade, Hafsa Momin

Partners:

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FACULTY OF APPLIED SCIENCE & ENGINEERING

Giuliana Frizzi
E.I.T., LEED GA

giuliana.frizzi@mail.utoronto.ca
(973)856-9017

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