Why Performance Monitoring Matters

Demonstrating accountability, reducing risk and determining life cycle costing for asset management

By

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&
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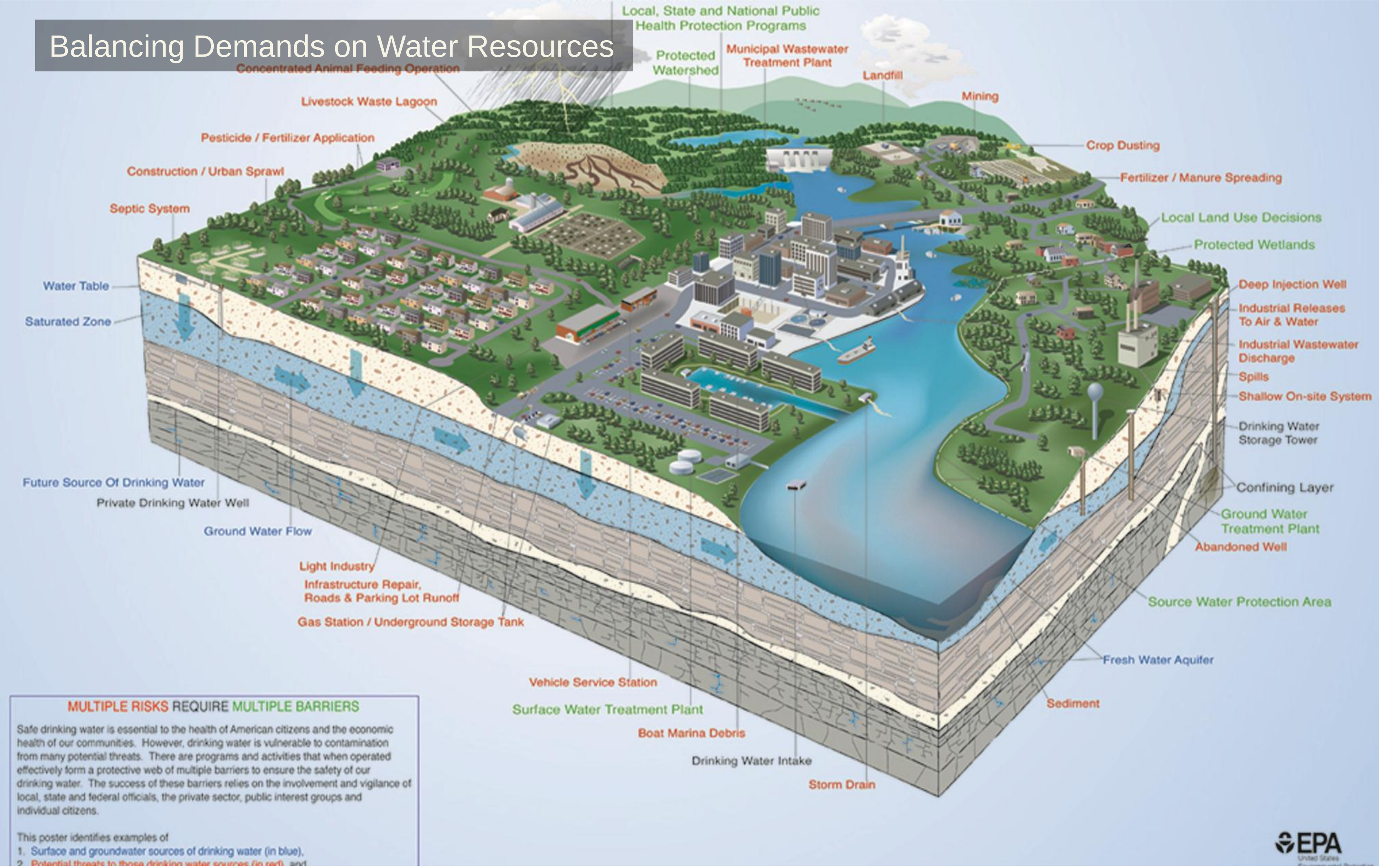
November 4, 2013

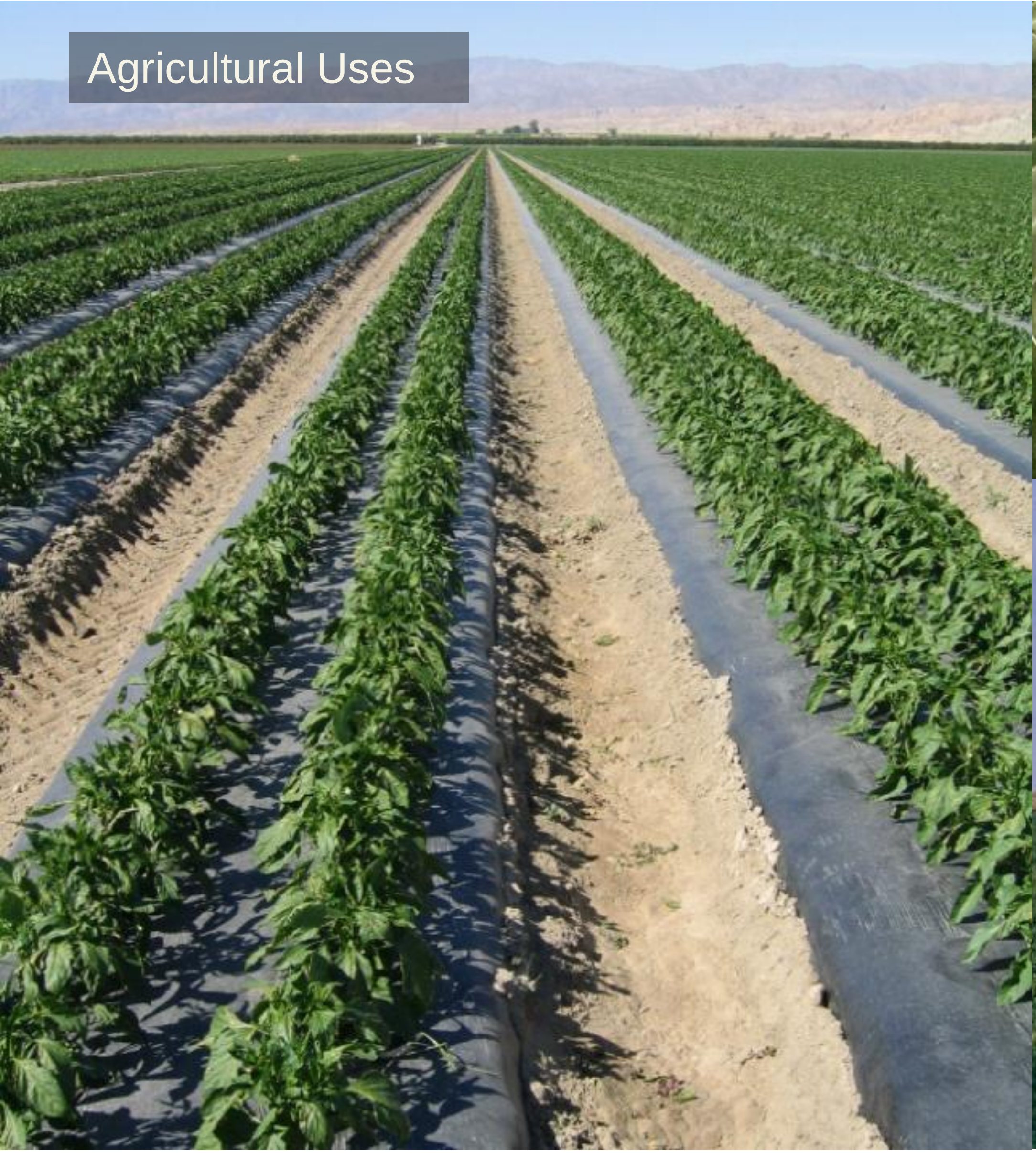
Balancing Demands on Water Resources



Balance Water Quantity, Water Quality, Quality of Life

Conflicts between uses

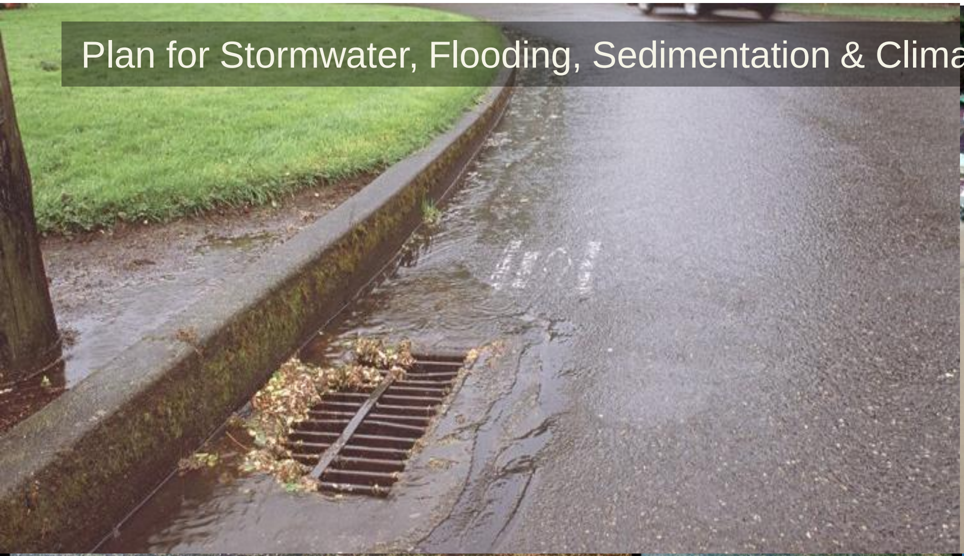
Agricultural Uses

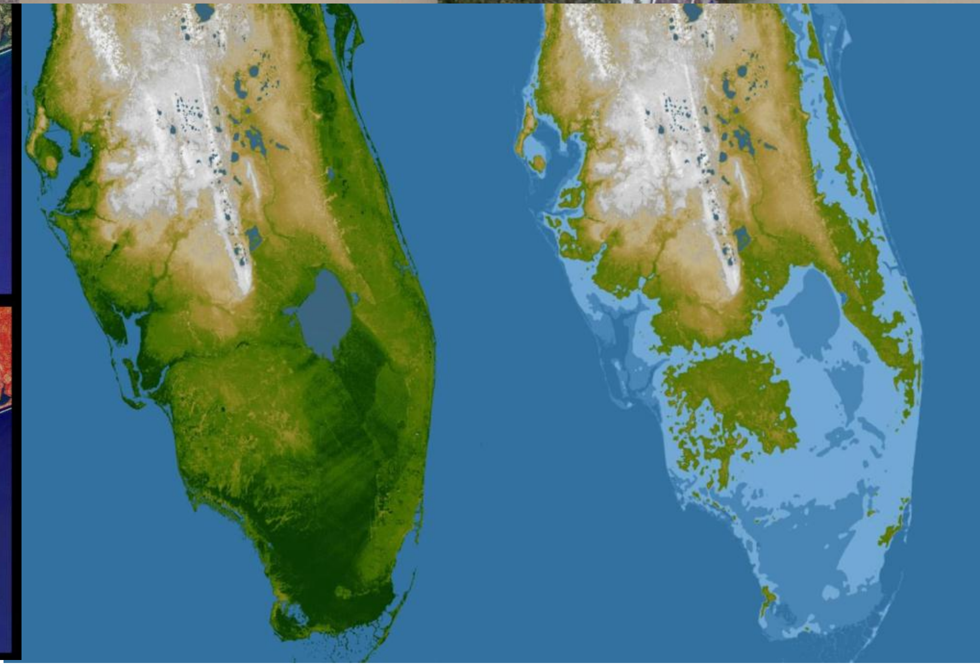


Recreational Uses

Wildlife Habitat

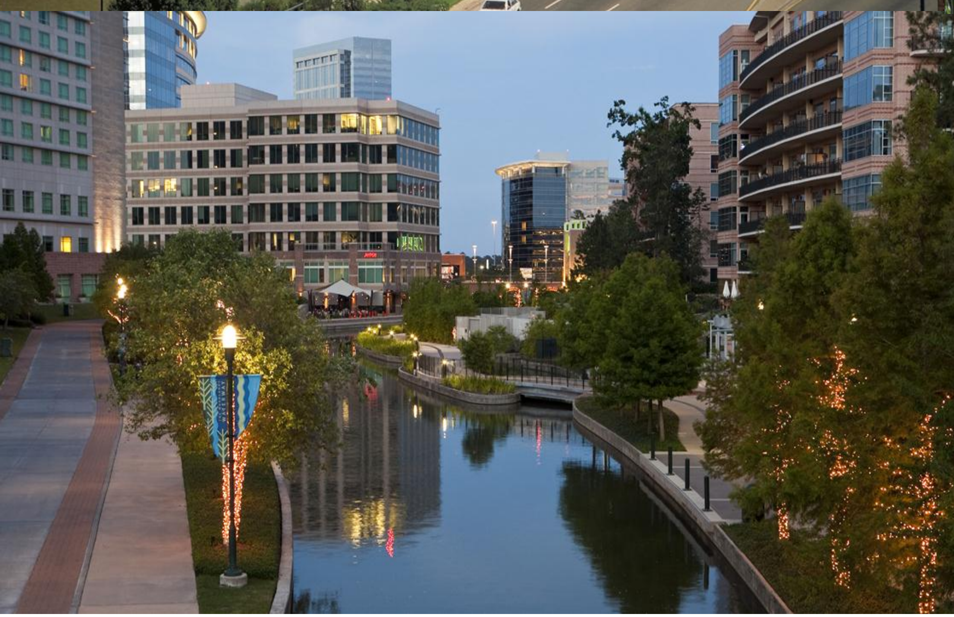
Plan for Stormwater, Flooding, Sedimentation & Climate Change






Urban Sprawl

Integration … Integration … Integration



Why Performance Monitoring Matters

- Stormwater Management is an evolving & regulations are becoming more stringent.

- Finding what works and what does not & determining how to maximize public benefit from stormwater infrastructure is a critical mission of CVC.

- Long-term monitoring data are lacking in Ontario, especially for Low Impact Development (LID) and Green Infrastructure (GI) practices.

Why Performance Monitoring Matters

Why are stormwater controls required?

Are they a good public investment?

Do they work in Ontario? What are maintenance requirements/costs?

Does the public accept them?

How much do they cost?

Are we meeting regulatory requirements?

Presentation Overview: Why Monitor Stormwater

- Demonstrating Regulatory Compliance
  - Are Water Quality Goals Being Achieved?
- Site Characterization and Best Management Practice (BMP) Selection
  - Site Specific Runoff Characterization
  - Assessing Performance for Various BMPs
  - Better Understand BMP Life Cycle Costs
  - Help Evaluate and Develop Standard Design Practices
  - Maintenance Requirements for Long Term Performance

Why Monitor Stormwater: Regulatory Compliance

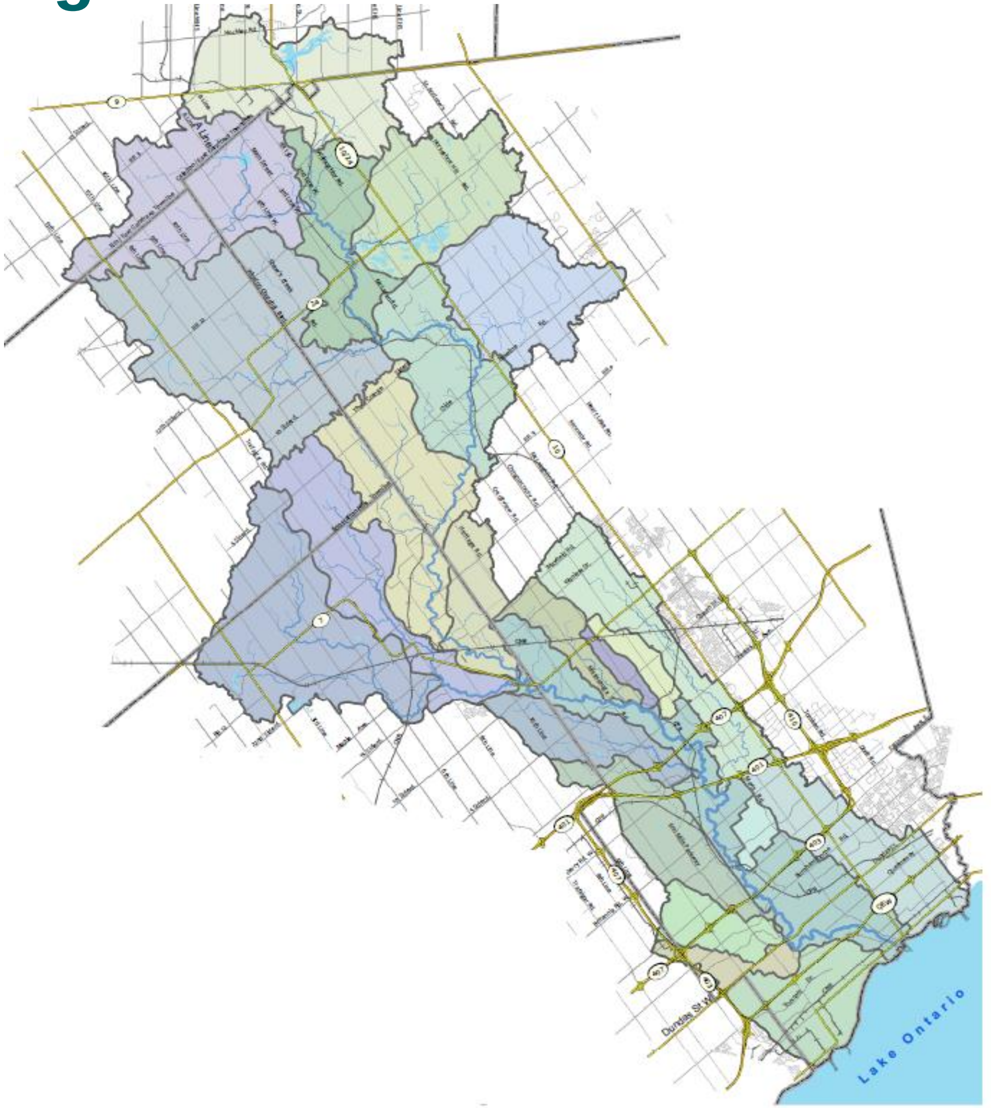
- Inherently supports the Province of Ontario’s Water Opportunities Act.
- Provides data to demonstrate whether Provincial Water Quality Objectives (PWQOs) can be achieved.
- Provides data to support the use of Innovative Best Management Practices (BMPs) in Ontario.
- Can help guide regulatory policy, including design and maintenance requirements.

Why Monitor Stormwater: Regulatory Compliance

- Are conditions in receiving waters protective of beneficial uses?
- What is the extent and magnitude of the current or potential receiving water problems?
- What is the relative urban runoff contribution to the receiving water problem(s)?
- What are the sources to urban runoff that contribute to receiving water problem(s)?

Source: Southern California Coastal Water Research Project (SCCWRP) (paraphrased)

Current CVC Monitoring Program:



Helping to Demonstrate Regulatory Compliance

- Currently collecting water quantity and quality data at 5 sites within the CVC boundary.
- Land uses for the monitoring sites are diverse, range from residential to highly impervious areas (i.e. parking lots, and mixed commercial and residential).
- Collecting water quality data for constituents using the PWQO's as the basis.

Elm Drive – Bioretention and Permeable Pavers

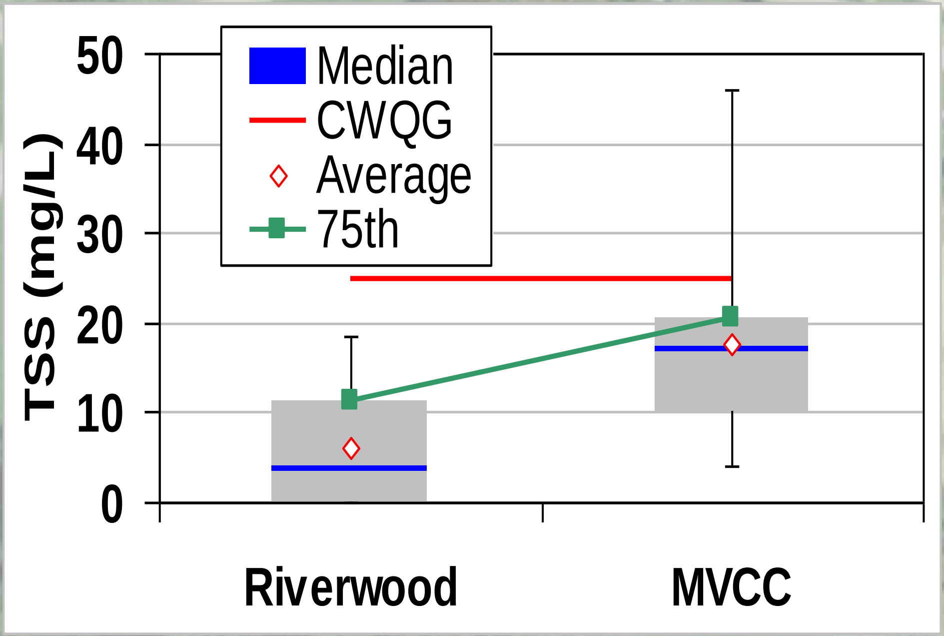
- The combined effect of Filtration and Volume Reduction exceeds expectations

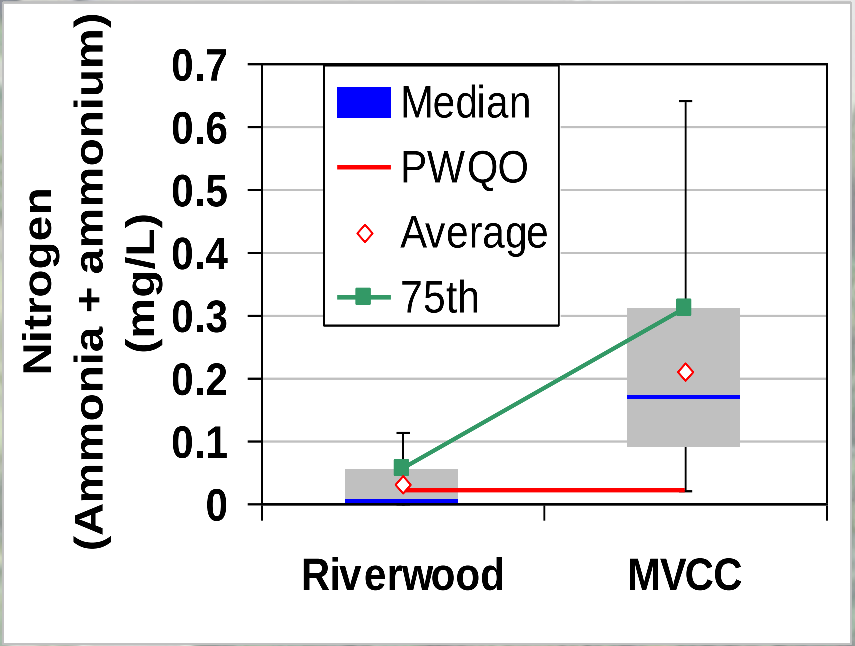
Parameter	Median Effluent EMC	75th Percentile	In Stream Objective PWQO CCME	Typical Residential uncontrolled NSQD	Typical Bioretention control BMPDB	Typical Pond BMPDB	Estimated Load Reduction W. Volume reductions
Cd µg/L	0.09	0.1	0.2	0.25	0.789	0.18	94.3 %
Pb µg/L	0.92	1.32	5	6	1.98	2.0	99.1 %
TKN mg/L	0.7	1.25	1	1.29	0.64	1.2	93.6 %
TP mg/L	0.065	0.125	0.03	0.27	0.142	0.1	98.1 %
TSS mg/L	**14**	**20.5**	**25**	**61**	**8.42**	**12**	**99.1 %**

- Volume Reduction = Loading reduction

Riverwood – Bioretention Parking Lot

- Bioretention cells treat water before discharge to wetland.
- Discharge is compared to MVCC; a conventional parking lot.





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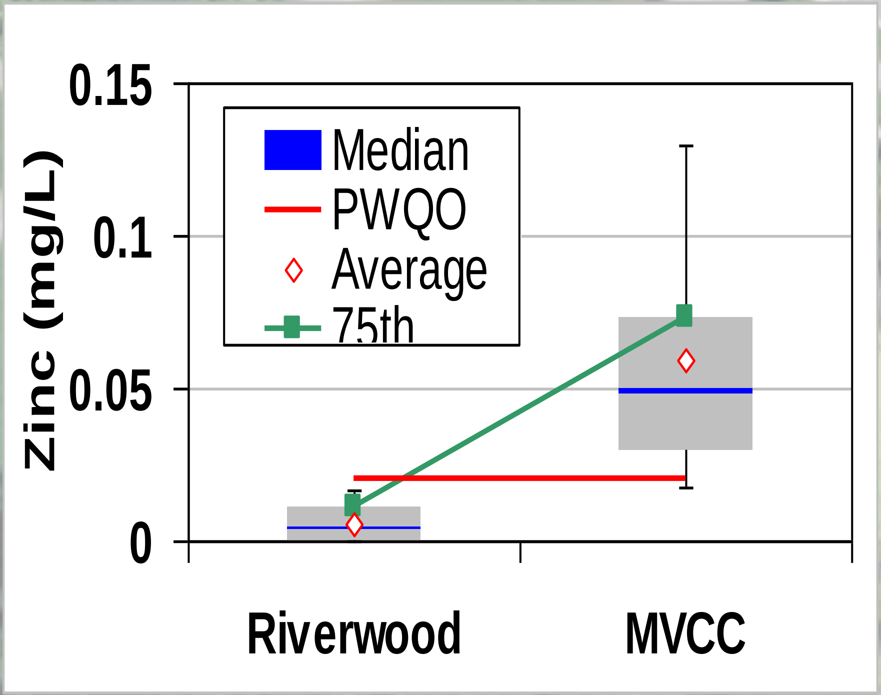
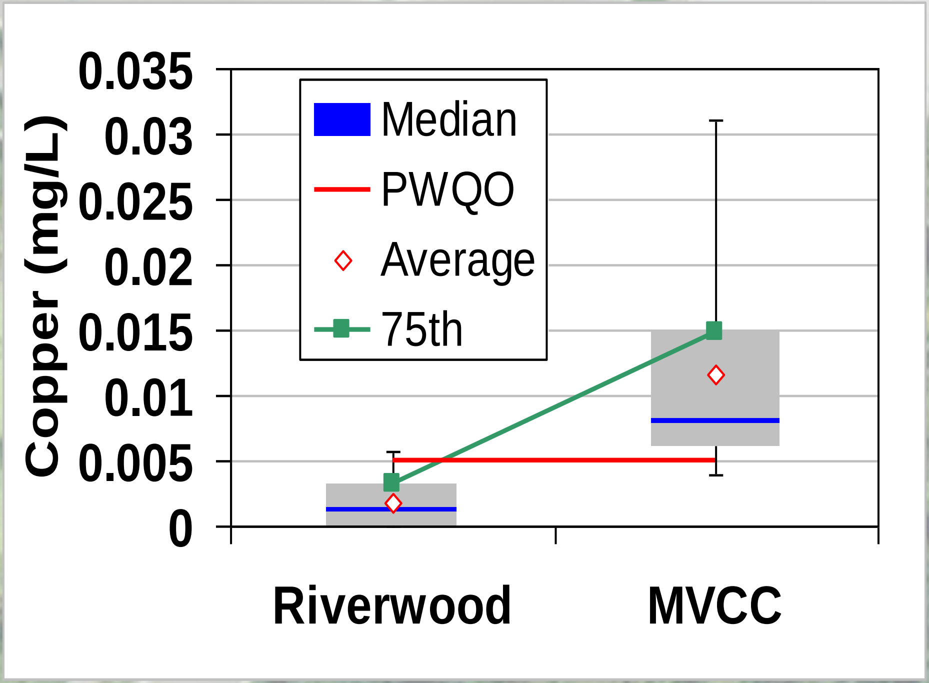
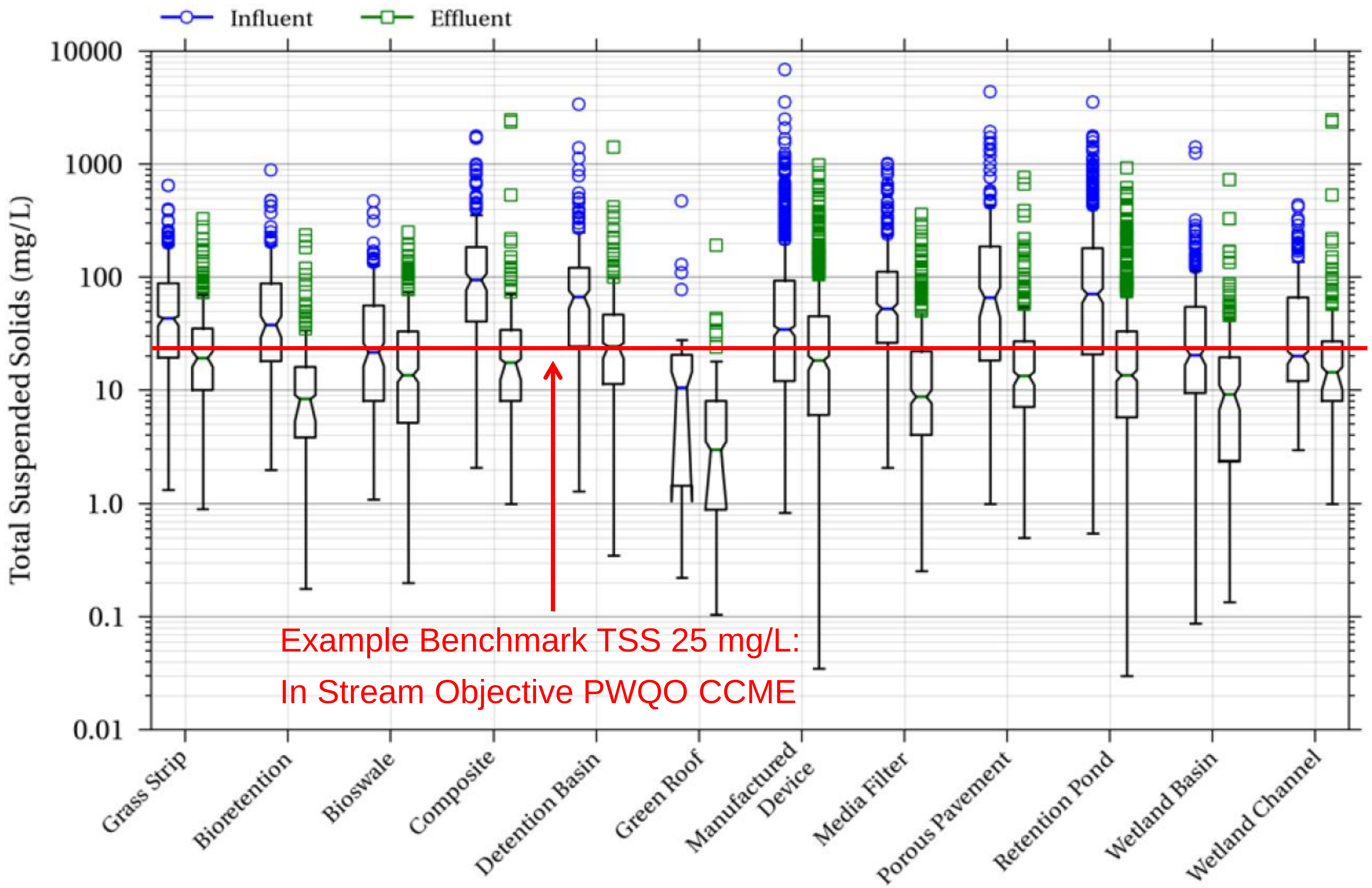






Influent
Effluent
Total Suspended Solids (mg/L)
10000
1000
100
10
1.0
0.1
0.01
Grass Strip
Bioretention
Bioswale
Composite
Detention Basin
Green Roof
Manufactured Device
Media Filter
Porous Pavement
Retention Pond
Wetland Basin
Wetland Channel
Example Benchmark TSS 25 mg/L:
In Stream Objective PWQO CCME

Why Monitor Stormwater: Site Characterization

- History of Issues with Stormwater Monitoring in the United States (1994 and now, but its getting better).
- Widespread use of BMPs without sufficient understanding of performance and factors leading to performance.
- Inconsistent data reporting methods limit scientific comparison/evaluation of studies.
- Differences in monitoring strategies and data evaluation methods result in wide range of reported “effectiveness” (e.g. – to + percent removals).

Why Monitor Stormwater: Site Characterization

Example BMP Factors:

- **Design**
  - Proper sizing
  - Media selection
- **Construction**
  - Constructed as designed?
  - Damaged during development?
- **Maintenance**
  - Access
  - Frequency

Example Site Factors:

- Soil type
- Depth to groundwater
- Depth to bedrock
- Hydrology (e.g., water source for wetlands)
- Space constraints
- Community acceptance or tampering

A robust BMP monitoring program seeks to document these factors, in addition to providing performance information.

Why Monitor Stormwater: Site Characterization

- Site specific pollutant and loading characterization for various land uses (i.e. Residential Area vs. Industrial Area).
- Evaluate the relationship between rainfall and runoff response for various land uses and soil types.
- Evaluate the relationship between runoff and receiving waters.
- Provides a basis for selecting and recommending particular BMPs for specific land uses and the regional climate.

Why Monitor Stormwater: Site Characterization

- What degree of pollution control and effluent quality does the BMP provide under “normal” conditions?
- How does BMP efficiency vary from pollutant to pollutant?
- How does “normal” efficiency vary with large or small storm events?
- How does “normal” efficiency vary with rainfall intensity?

Why Monitor Stormwater: Site Characterization

- How does “normal” efficiency vary with different operational and/or maintenance approaches?
- Does efficiency improve, decay or stay stable over time?
- How does BMP efficiency compare with the efficiency of other BMPs?

International Stormwater BMP Database

www.bmpdatabase.org

Home | Get Data | Submit Data | Documents | Guidance | About

I-95 Plaza Bioretention Cell, Delaware DOT

Welcome! The International Stormwater Best Management Practices (BMP) Database project website features a database of over 530 BMP studies, performance analysis results, tools for use in BMP performance studies, monitoring guidance and other study-related publications.
New to the site? **Start Here**

News

- National Stormwater Quality Database Has A New Home
- 2013 BMP Database Release
- 2012 BMP Performance Summaries

Related Databases & Research

- National Stormwater Quality Database
- Agricultural BMP Database
- Construction BMP Database
- Chesapeake Bay Research Portal

Urban Stormwater Research Reports

- 2012 BMP Performance Summaries
- 2012 Statistical Appendices
- 2012 Manufactured Device Performance Analysis Summary
- 2012 Volume Reduction in Bioretention
- 2012 Database Overview
- 2012 Chesapeake Bay BMP Performance Summary

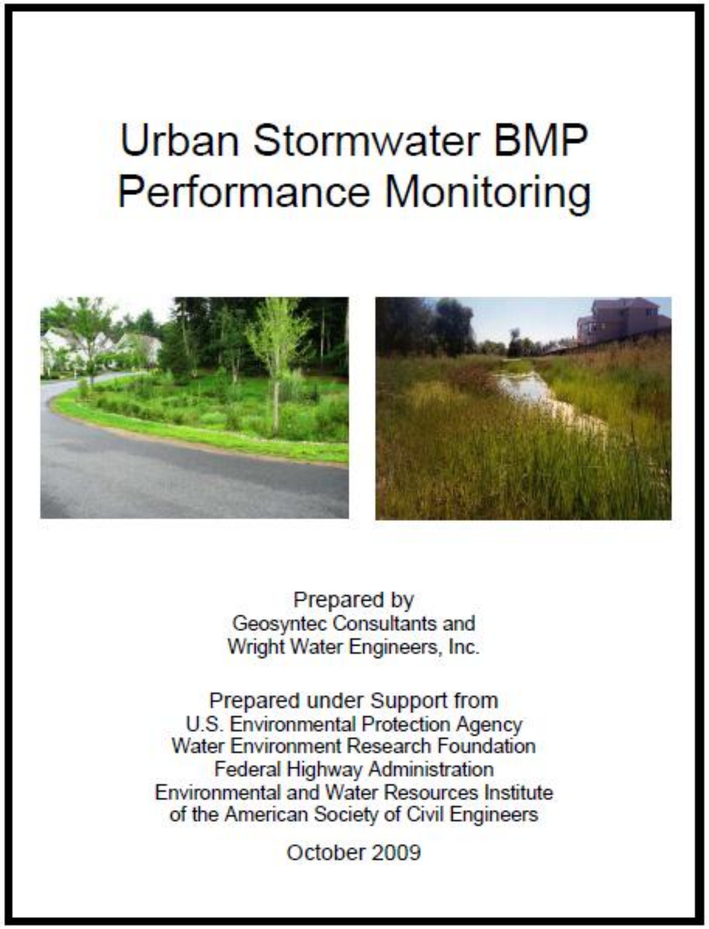
Retrieve Urban Stormwater BMP Performance

- BMP Study Retrieval Tool
- BMP Map Tool
- BMP Category Reports
- Online Statistical Analysis Tool
- Download Access Database

Why Monitor Stormwater: Site Characterization

BMP Database: Quick Overview as of 2012

- New Data Sets: 500 BMP Milestone
- Performance Summaries Updates:
  - TSS, Nutrients, Metals, Bacteria
  - Expanded Volume Reduction for Bioretention
  - Expanded statistical analyses
  - Manufactured Device Unit Process
- New On-line Tools
  - Map Interface
  - Custom Statistical Summaries (Beta)



Urban Stormwater BMP
Performance Monitoring

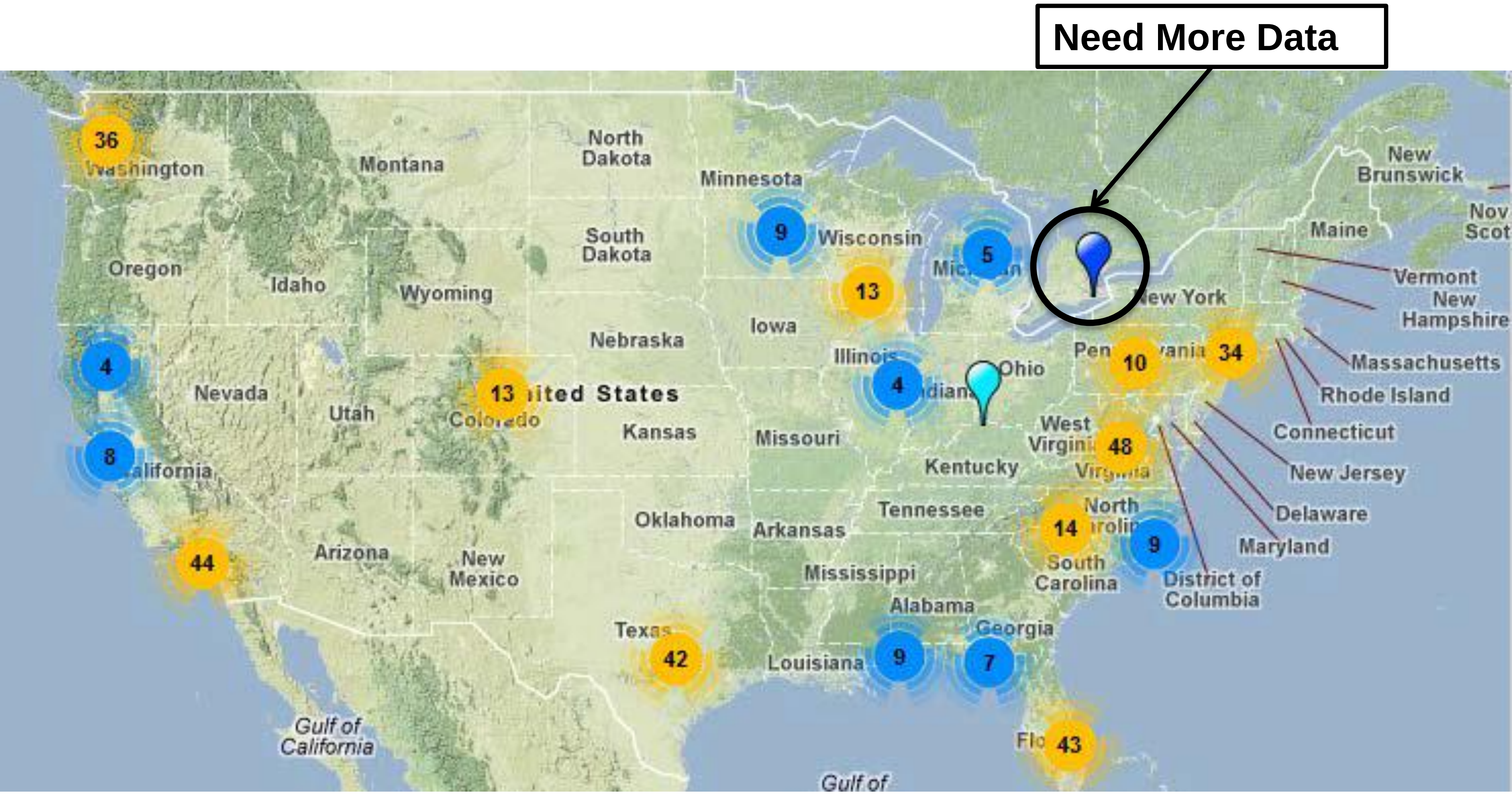
Prepared by
Geosyntec Consultants and
Wright Water Engineers, Inc.

Prepared under Support from
U.S. Environmental Protection Agency
Water Environment Research Foundation
Federal Highway Administration
Environmental and Water Resources Institute
of the American Society of Civil Engineers

October 2009

Credit Valley Conservation

Why Monitor Stormwater: Site Characterization



Total Phosphorus

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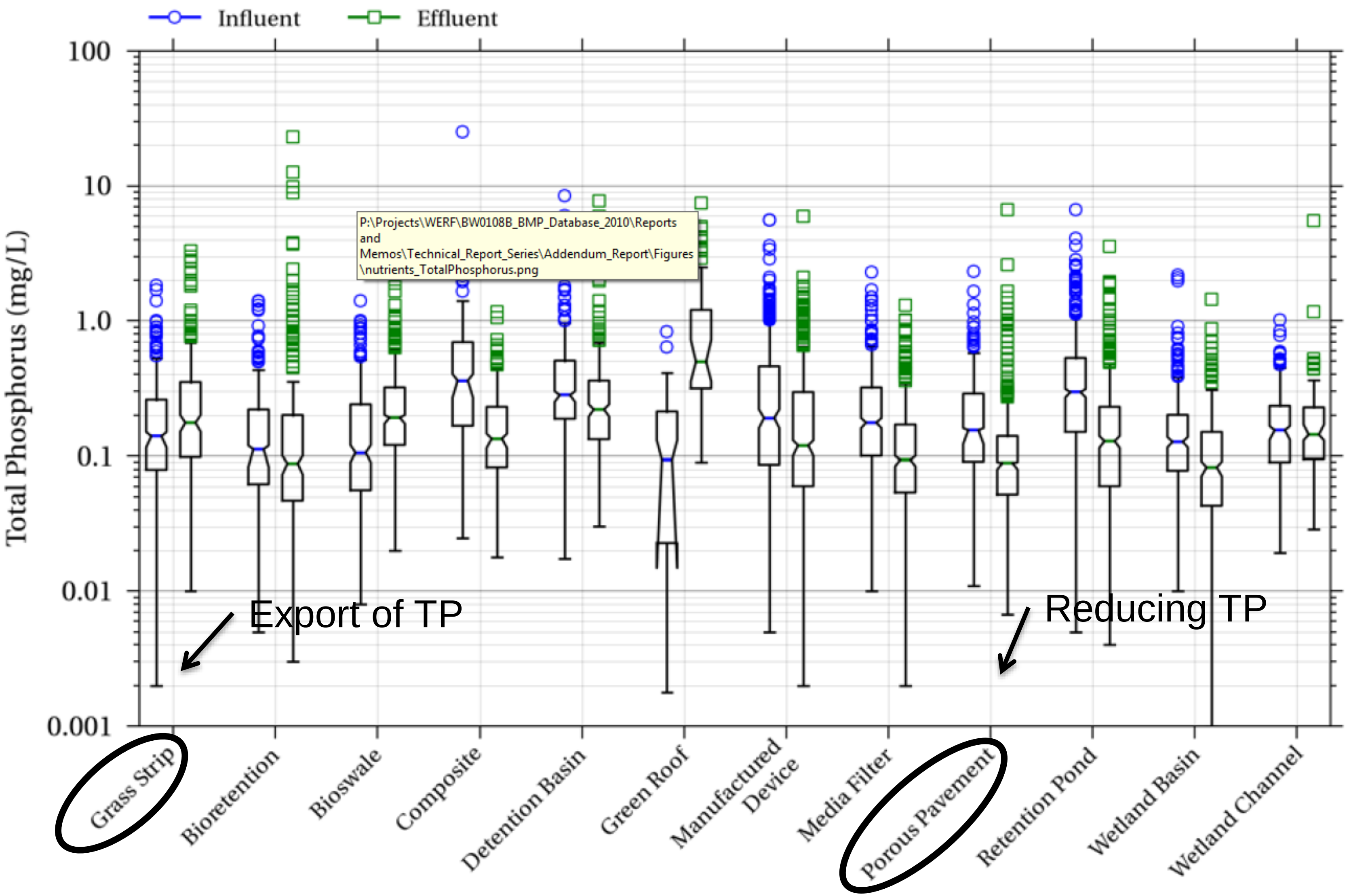

E. coli

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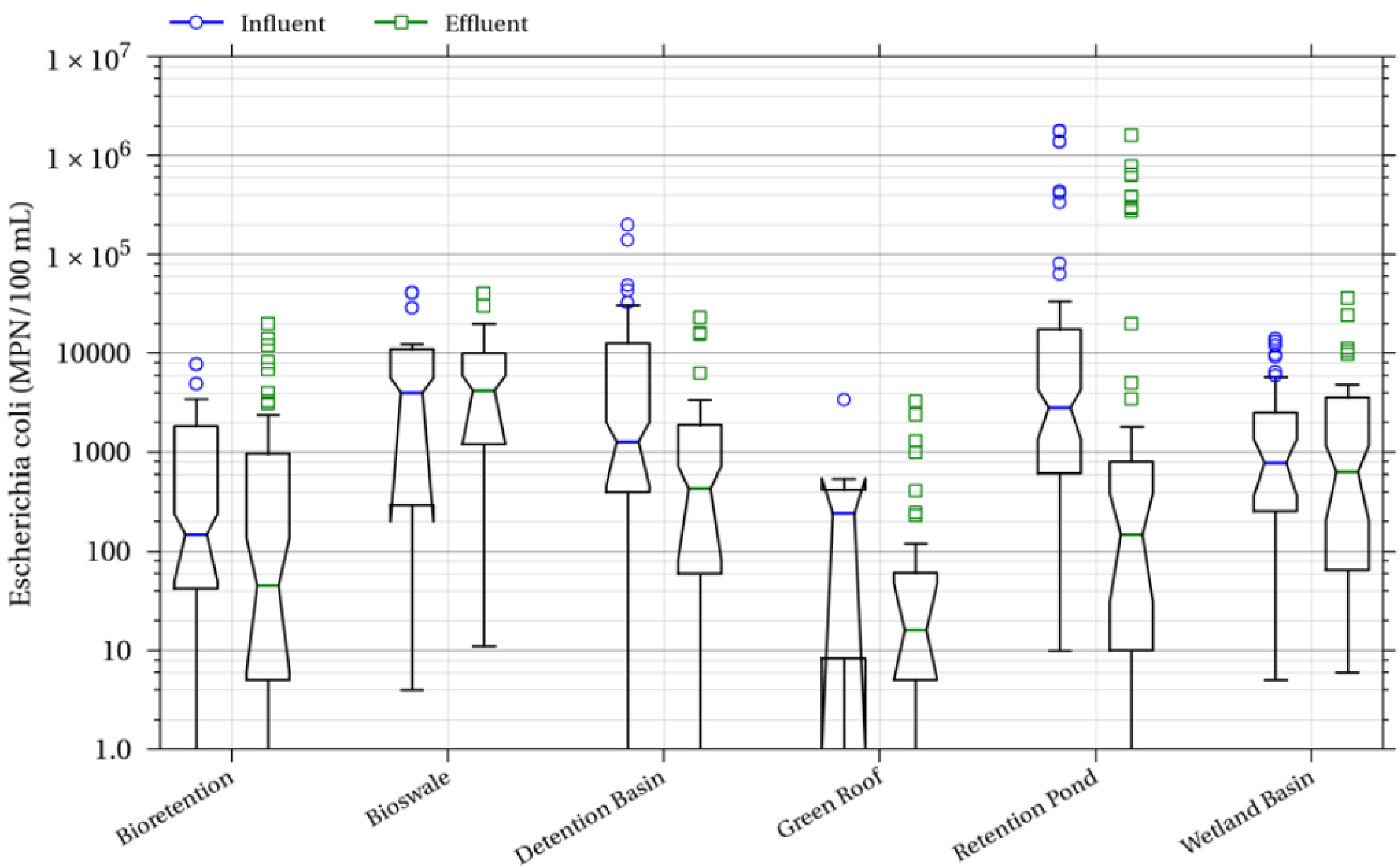

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Why Monitor Stormwater: Design Considerations

High P Index Soils

Bioretention

Phosphorus as P, Total (mg/L)

BASIC STATISTICS

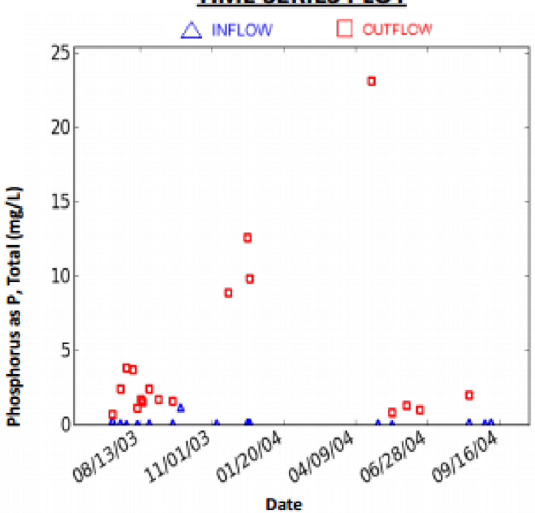
PERFORMANCE METRIC	INFLOW	OUTFLOW	COMPARISON
Number of EMCs:	15	18	--
Percent Non-Detects:	0%	0%	--
Median:	0.13	1.85	Increased*
Mean:	0.21	4.45	Increased
Standard Deviation:	0.27	5.63	--
25th Percentile:	0.11	1.35	Increased
75th Percentile:	0.19	3.77	Increased
Well-fit to normal distribution?	No	No	--
Well-fit to lognormal distribution?	Yes	Yes	--

*Statistically Significant Difference in Median?	YES

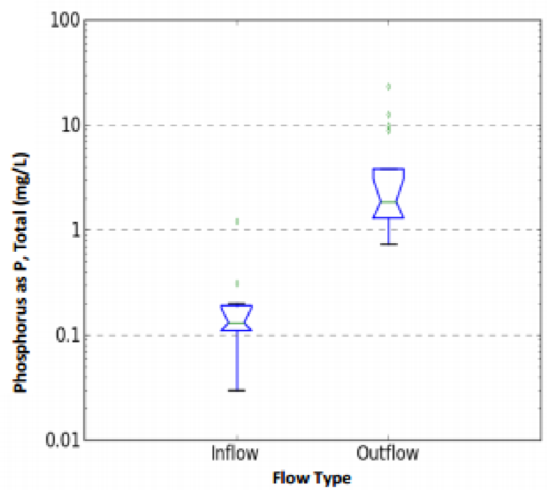
HYPOTHESIS TESTING:

STATISTICAL TEST	DATA	NULL HYPOTHESIS	p-value	Reject Null Hypothesis?	
				α=0.05	α=0.10
Mann-Whitney:	Raw	The inflow and outflow median EMCs are equal.	0	YES	YES
t-Test: (Assume Equal Variance)	Raw	The inflow and outflow mean EMCs are equal.	0.008	YES	YES
	Log	The inflow and outflow mean EMCs are equal.	0	YES	YES
t-Test: (Assume Unequal Variance)	Raw	The inflow and outflow mean EMCs are equal.	0.006	YES	YES
	Log	The inflow and outflow mean EMCs are equal.	0	YES	YES
Levene (Raw Data):	Raw	The two variances are equal.	0.039	YES	YES
	Log	The two variances are equal.	0.333	NO	NO

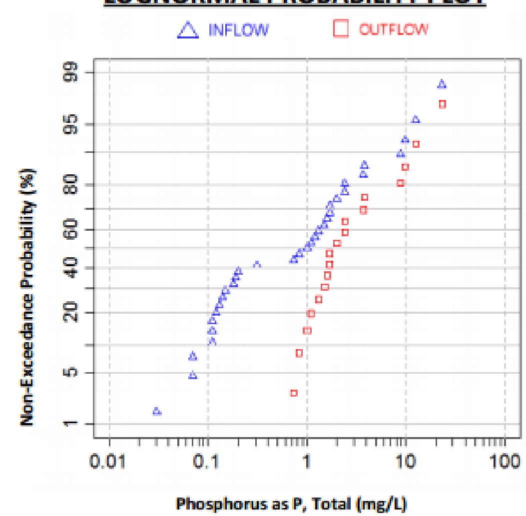
TIME SERIES PLOT



NOTCHED BOX-AND-WHISKER PLOT



LOGNORMAL PROBABILITY PLOT



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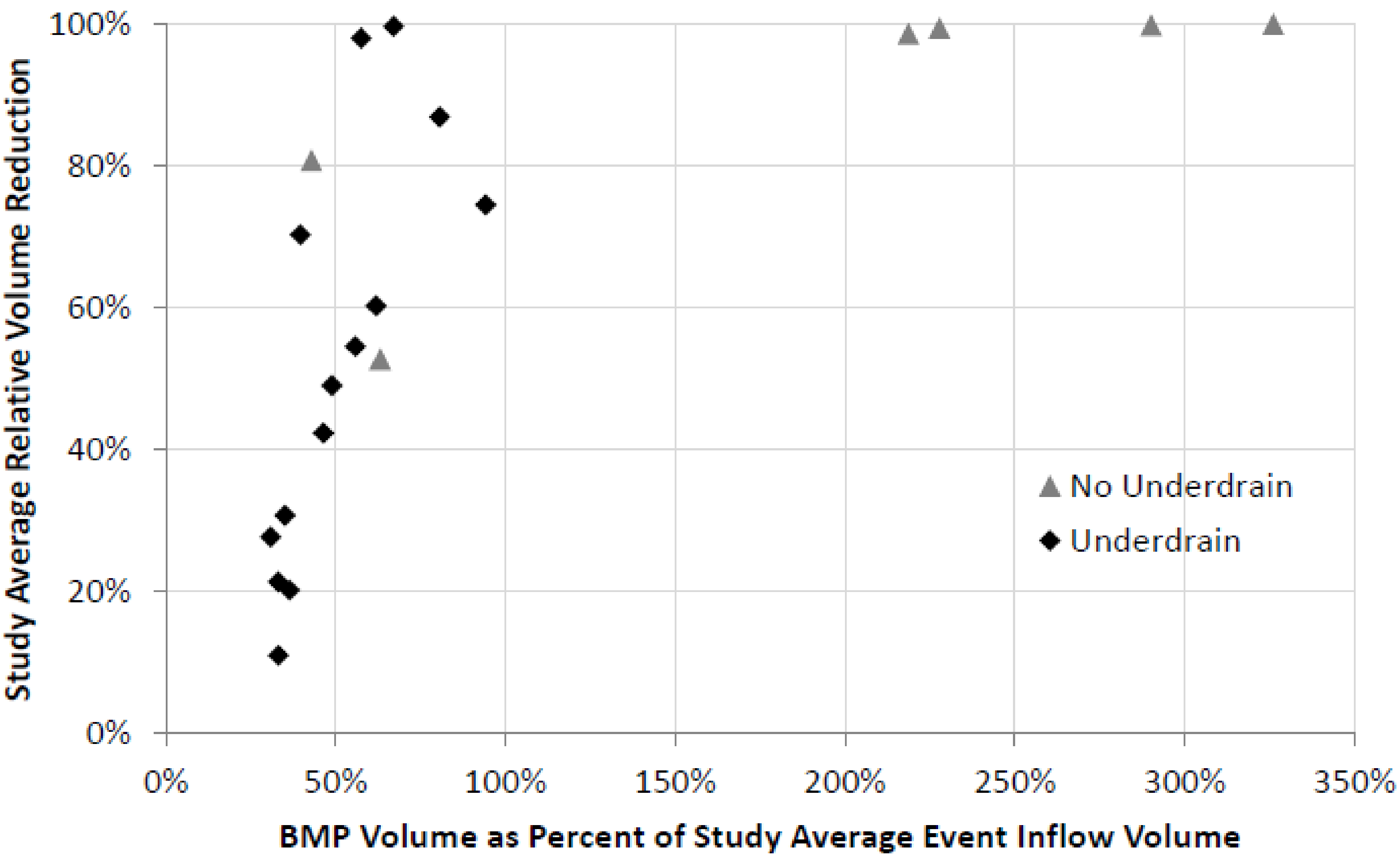
Volume Reduction



Lakeview – Bioretention Residential Street

- Monitoring has revealed installation issues otherwise overlooked.
- Grading at inlets needs to be lowered to capture runoff.
- Recommended changes requiring minor labour are expected to significantly increase the benefit of this facility to downstream infrastructure.

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Why Monitor Stormwater: To Meet Your Objectives!

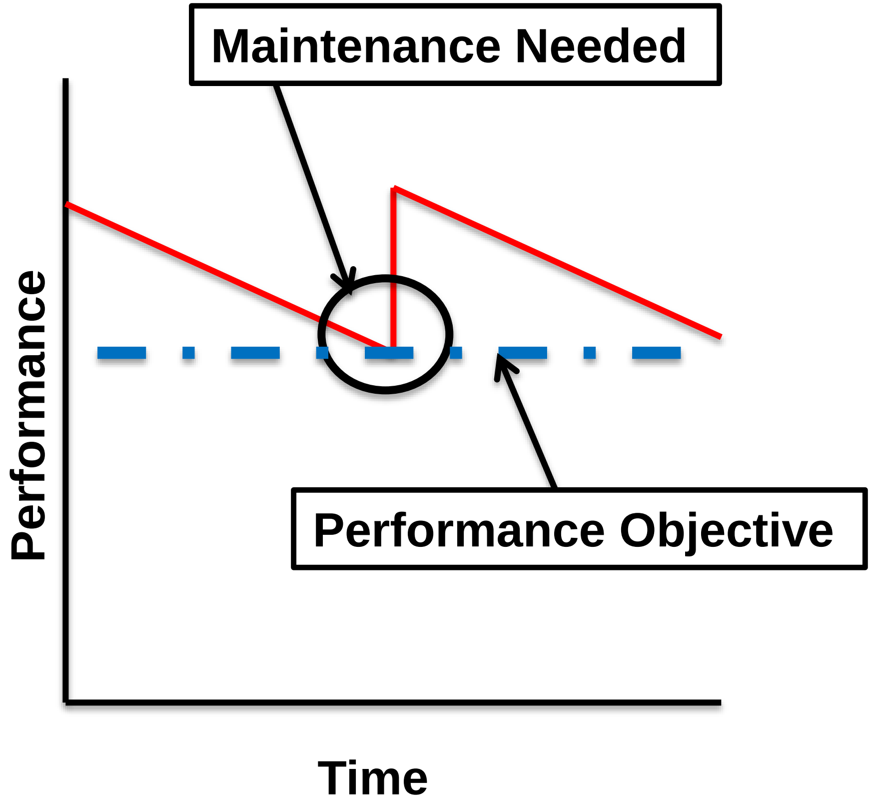
Results of a CVC Survey Filled Out by Project Stakeholders Indicated the 3 Most Important Objectives for CVC’s Stormwater Monitoring:

1. Evaluate long-term maintenance needs and maintenance programs and the impact of maintenance on performance.
2. Determine the life cycle costs for LID practices
3. Assess the water quality and quantity performance of LID designs in clay or low infiltration soils and those that do not use infiltration

Why Monitor Stormwater: Understanding Long Term Performance

1. **Evaluate long-term maintenance needs and maintenance programs and the impact of maintenance on performance**

- Long term data needed – most monitoring studies are 1 to 3 years maximum
- Long term performance monitoring to establish timeline for minor and major maintenance recommendations
- Documentation of maintenance activities
- May vary by land use, BMP type, and climate



Why Monitor Stormwater: Life Cycle Costs

2. **Determine the Life Cycle Costs for LID Practices**

- Long term data needed – most monitoring studies are 1 to 3 years maximum
- Establish a record of maintenance costs for a variety of BMPs
- Performance monitoring to evaluate when replacement or major maintenance is needed (i.e. replacement of bioretention media)
- Long term maintenance costs and associated performance data will give insight into life-cycle costs and help assess risk for failure

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BMP-REALCOST

Best Management Practices – Rational Estimation of Actual Likely Costs of Stormwater Treatment

A SPREADSHEET TOOL FOR EVALUATING BMP EFFECTIVENESS AND LIFE CYCLE COSTS

User's Manual and Documentation

Version 1.21

August 2013

BMP - REALCOST

Version 1.21 - Released July 2013
Urban Drainage Flood Control District
Urban Watersheds Research Institutue
Colorado Stormwater Council
&
Colorado State University

Purpose:	This model serves as an aid for BMP planning in an urban environment
Functions:	Estimates life cycle costs (construction, maintenance, administration) of structural BMPs
	Estimates annual pollutant loading to receiving waters with and without BMPs implemented
	Estimates annual runoff volume to receiving waters with and without BMPs implemented
	Allows for BMP implementation as site controls or regional controls

Release Information

Content:	**The following worksheets are included in the model.**
InputParameters	User-defined inputs describing watershed characteristics and BMP implementation are entered here (**User-Defined**)
Report	Summarizes the outputs from the model in tabular and graphical forms (**Read-only**)
RunoffMitigation	Contains information used for determining how BMPs affect runoff volume and peak flow (**Default and/or User-Defined Values**)
WaterQuality	Contains event mean concentrations used for estimating pollutant loadings (**Default and/or User-Defined Values**)
CGP	Contains cost information for concrete grid pavers (**Default and/or User-Defined Values**)
CWB	Contains cost information for constructed wetland basins (**Default and/or User-Defined Values**)
CWC	Contains cost information for constructed wetland channel (**Default and/or User-Defined Values**)
EDB	Contains cost information for extended detention basins (**Default and/or User-Defined Values**)
HS	Contains cost information for hydrodynamic separators (**Default and/or User-Defined Values**)
II	Contains cost information for inlet inserts (**Default and/or User-Defined Values**)
MFV	Contains cost information for media filter vaults (**Default and/or User-Defined Values**)
PCP	Contains cost information for porous concrete pavement (**Default and/or User-Defined Values**)
PGP	Contains cost information for porous gravel pavement (**Default and/or User-Defined Values**)
PICP	Contains cost information for permeable interlocking concrete pavers (**Default and/or User-Defined Values**)
PLD	Contains cost information for porous landscape detention (**Default and/or User-Defined Values**)
RGP	Contains cost information for reinforced grass pavements (**Default and/or User-Defined Values**)
RP	Contains cost information for retention (wet) ponds (**Default and/or User-Defined Values**)
SFB	Contains cost information for sand filter basins (**Default and/or User-Defined Values**)

Information | InputParameters | Report | RunoffMitigation | WaterQuality | LandCosts | CGP | CWB | CWC | EDB(WQCV) | EDB(EURV) | HS

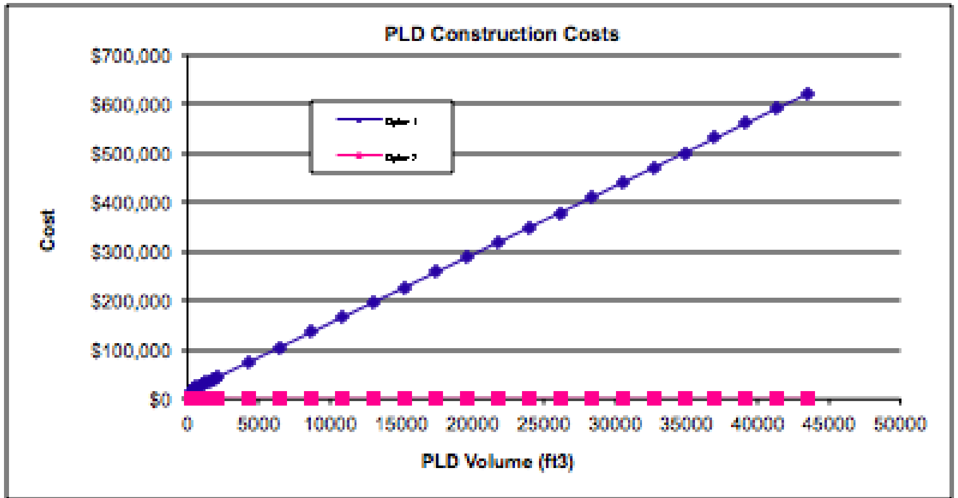
CAPITAL COSTS
Select option button to use appropriate method for estimating costs

Capital Costs - Option 1 (default) — Selected

Option 1

	Default	User	Input
Base Cost (C) =	$10,729.00		$10,729.00
Unit Cost (X) =	$9.93		$9.93
Economy of Scale (α) =	1		1
Cont/Eng/Admin (CEA) =	40.00%		40.00%
Land Consumption (CLC)	0.000023		0.000023
Units (U) =	total volume (ft^3)		

BMP Lifecycle Cost Tool



Construction Costs

Contributing Area (IA)	Option 1	Option 2	PLD Volume (CF)
0.1	$18,048	$0	217.8
0.2	$21,076	$0	435.6
0.3	$24,104	$0	653.4
0.4	[illegible]	[illegible]	871.2
0.5	$30,160	$0	1089
0.6	$33,188	$0	1306.8
0.7	$36,216	$0	1524.6
0.8	$39,243	$0	1742.4
0.9	$42,271	$0	1960.2
1	$45,299	$0	2178
2	$75,578	$0	4356
3	$105,856	$0	6534
4	$136,135	$0	8712
5	$166,413	$0	10890
6	$196,692	$0	13068
7	$226,970	$0	15246
8	$257,249	$0	17424
9	$287,528	$0	19602
10	$317,806	$0	21780
11	$348,085	$0	23958
12	$378,363	$0	26136
13	$408,642	$0	28314
14	$438,920	$0	30492
15	$469,199	$0	32670
16	$499,477	$0	34848
17	$529,756	$0	37026

Horizontal (Value) Axis

BMP Lifecycle Cost Tool

REHABILITATION/REPLACEMENT COSTS		
Cost as a percentage of initial capital costs	30.0%	
Frequency of Rehabilitation/Replacement	10	years

Notes:

The key to making this work is good local cost data from monitoring!

...STS

																%)	Equip...
Activity																Input	Default
Compliance I...																100%	$10.15
																0%	
																0%	
				0			0			0			$0.00			0%	
				0			0			0			$0.00			0%	
				0			0			0			$0.00			0%	
				0			0			0			$0.00			0%	
				0			0			0			$0.00			0%	
				0			0			0			$0.00			0%	
The activities listed below a function of the BMP size																	
Annual Cleanup	CF	1		1	2		2	1		1	$23.31		$23.31	100%		100%	$10.15
Annual Planting	CF	1		1	2		2	2		2	$23.31		$23.31	100%		100%	$10.15
				0			0			0			$0.00			0%	
				0			0			0			$0.00			0%	
				0			0			0			$0.00			0%	
				0			0			0			$0.00			0%	
				0			0			0			$0.00			0%	

(1) - Compliance Inspection is added as an administrative cost

OR

Annual maintenance costs as percentage of capital costs	

Construction Techniques

Bioretention—Installation & Maintenance

- Do not put a filter sock on the underdrain. This is not necessary and can cause the BMP to clog.
- The best surface cover for a rain garden is full vegetation:
  - Do not use rock mulch within the rain garden because sediment build-up on rock mulch tends to inhibit infiltration
  - Wood mulch floats and may clog the overflow, bury plants or flow downstream.
- Consider all potential maintenance requirements such as mowing (if applicable) and replacement of the growing medium.
- Provide pre-treatment when it will reduce the extent and frequency of maintenance.
- Make the rain garden as shallow as possible.

Bioretention—Installation & Maintenance

- Protect area from excessive sediment loading during construction.
- Avoid over compaction of the area to preserve infiltration rates (for partial and full infiltration sections).
- Provide construction observation to ensure compliance with design specifications. Improper installation, particularly related to facility dim… pro…
- Wh… to allow for backfill, compaction, and settling without tearing the liner.
- Provide necessary QA/QC when constructing an impermeable geomembrane liner system.
- Provide adequate construction staking to ensure that the site properly drains into the facility, particularly with respect to surface drainage away from adjacent buildings.

These are lessons learned from experience and monitoring!

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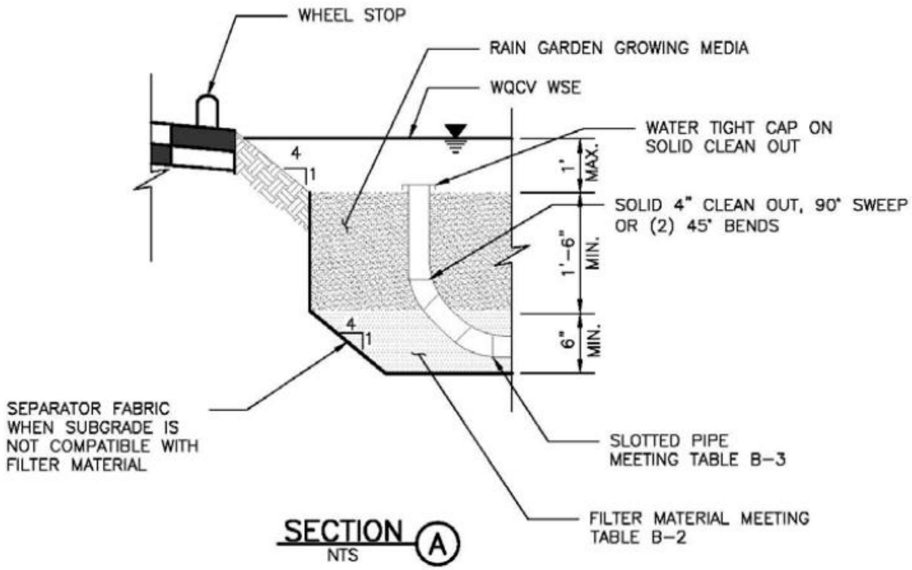
Why Monitor Stormwater: Design Considerations

3. Assess performance of LID designs in clay or low infiltration soils

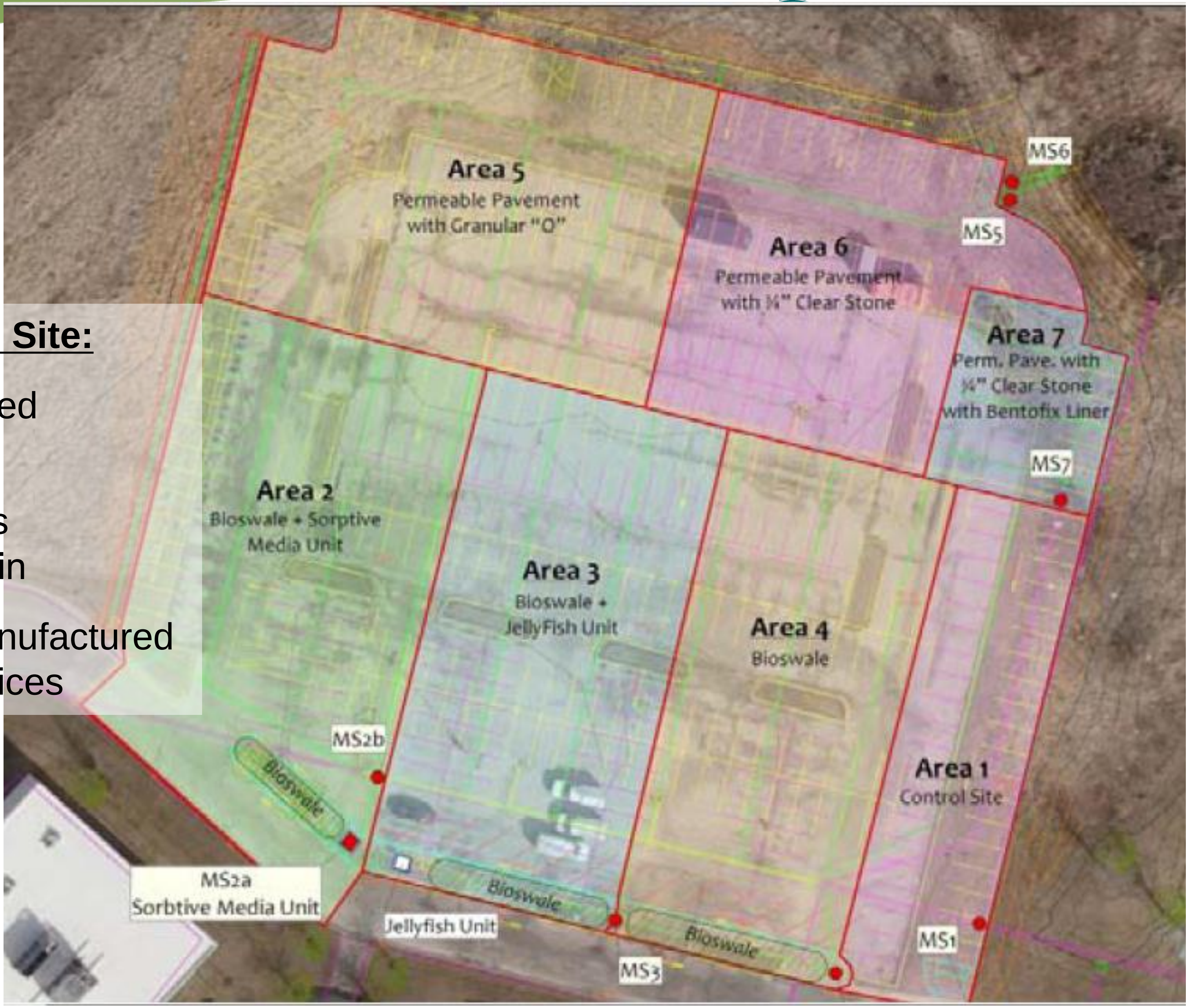
- Monitoring of BMPs in high vs. low infiltration soils will allow for performance comparison.
- Provide insight into design considerations for various soil types.
- Which BMPs work best for groundwater sensitive areas.



Partial Infiltration Section

IMAX Monitoring Site:

- Lined vs. Unlined Performance
- BMPs In Series "Treatment Train
- Proprietary Manufactured Treatment Devices



Poor construction/ detailing

Slide courtesy of Wenk Associates

Poor plant selection / no plan for sediment removal

Slide courtesy of Wenk Associates

Credit Valley Conservation

Poor plant selection/ high level of pollutants

Credit Valley Conservation

Appropriate planting/ but lacking an underdrain

Slide courtesy of Wenk Associates

Slide courtesy of Wenk Associates

Credit Valley Conservation

Why Monitor Stormwater: Measuring Sustainability

LEED-NC

LEED-NC Version 2.2 Registered Project Checklist

<< enter project name >>

<< enter city, state, other details >>

Yes	?	No	Sustainable Sites		14 Points
Y			Prereq 1	**Construction Activity Pollution Prevention**	Required
			Credit 1	**Site Selection**	1
			Credit 2	**Development Density & Community Connectivity**	1
			Credit 3	**Brownfield Redevelopment**	1
			Credit 4.1	**Alternative Transportation**, Public Transportation Access	1
			Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms	1
			Credit 4.3	**Alternative Transportation**, Low-Emitting and Fuel-Efficient Vehicles	1
			Credit 4.4	**Alternative Transportation**, Parking Capacity	1
			Credit 5.1	**Site Development,** Protect of Restore Habitat	1
			Credit 5.2	**Site Development,** Maximize Open Space	1
			Credit 6.1	**Stormwater Design,** Quantity Control	1
			Credit 6.2	**Stormwater Design,** Quality Control	1
			Credit 7.1	**Heat Island Effect,** Non-Roof	1
			Credit 7.2	**Heat Island Effect,** Roof	1
			Credit 8	**Light Pollution Reduction**	1

United States
Environmental Protection
Agency

EPA 231B09001 | October 2009 | http://www.epa.gov

Water Quality Scorecard

Incorporating Green Infrastructure Practices at the Municipal, Neighborhood, and Site Scales

2 Promote Efficient, Compact Development Patterns and Infill

2.A Support Infill and Redevelopment

2.A.1

QUESTION: Are policy incentives in place to direct development to previously developed areas?

GOAL: Municipalities implement a range of policies and tools to direct development to specific areas.

WHY: Municipalities can realize a significant reduction in regional runoff if they take advantage of underused properties, such as infill, brownfield, or greyfield sites. Redeveloping already degraded sites such as abandoned shopping centers or underutilized parking lots rather than paving greenfield sites for new development can dramatically reduce total impervious area while allowing communities to experience the benefits and opportunities associated with growth.

Implementation Tools and Policies	Pts. Avail.	Pts. Rec. or N/A	Notes and Local References
ADOPT PLANS/EDUCATE:			
Local plans identify potential brownfield and greyfield sites, and support their redevelopment.	1		
Capital improvement plans include infrastructure improvements (water, sewer, road, sidewalk, etc. upgrades) for identified brownfield and greyfield sites.	1		
Educate lending and financial institutions about benefits and local priorities of directing development to existing areas.	1		
Conduct outreach to the community to ensure support for local forms and patterns of development.	1		
REMOVE BARRIERS:			
Establish a brownfields program to remove uncertainty regarding cleanup and liability issues.	1		
ADOPT INCENTIVES:			
Provide incentives such as density bonuses and accelerated permitting for brownfield and greyfield sites.	1		
Adopt funding mechanisms for remediating/redeveloping brownfield and greyfield sites.	1		
Streamline permitting procedures to facilitate infill and brownfield redevelopment plan review.	1		
Establish tax increment financing (TIF) districts to encourage redevelopment.	1		
ENACT REGULATIONS:			
In local codes, ordinances, and policies, the municipality differentiates between greenfield and infill development.	1		
		PAGE TOTAL	◄ CARRY THIS SUBTOTAL TO NEXT PAGE = ________

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Credit Valley Conservation

Enduring natural human economic Systems

Natural
Air
Water
Climate

Economic
Jobs
Property values
Equity

Human
Wellness/health
Sense of community
Recreation/leisure

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Measuring Sustainability

Low performance

High performance

Water Quality Treatment

Slide courtesy of Wenk Associates

Credit Valley Conservation

Measuring Sustainability

Low performance

High-performance

Slide courtesy of Wenk Associates

Measuring Sustainability

Low performance

High performance

Questions and Comments?

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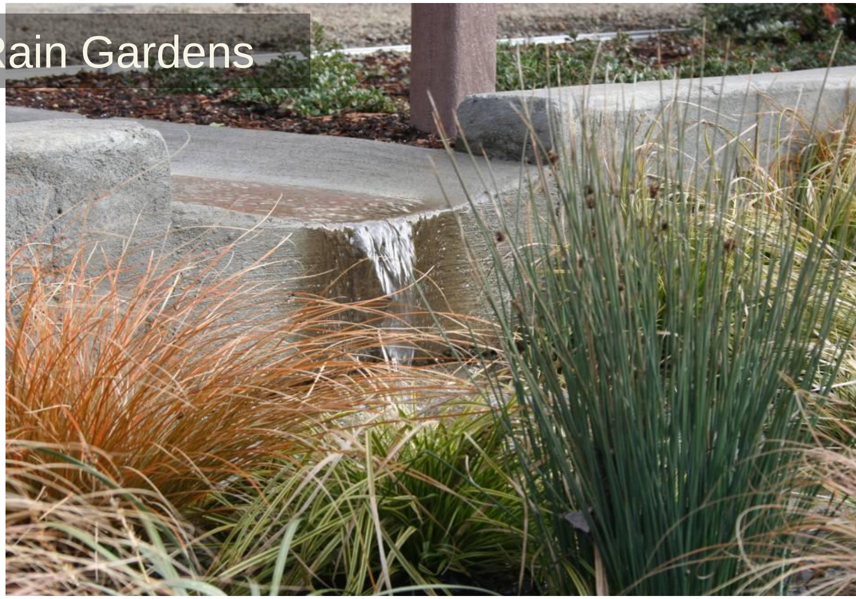
Rain Gardens



Bioretention Basins

Downspout Disconnection