United States Environmental Protection Agency

Permeable Pavement Research Highlights

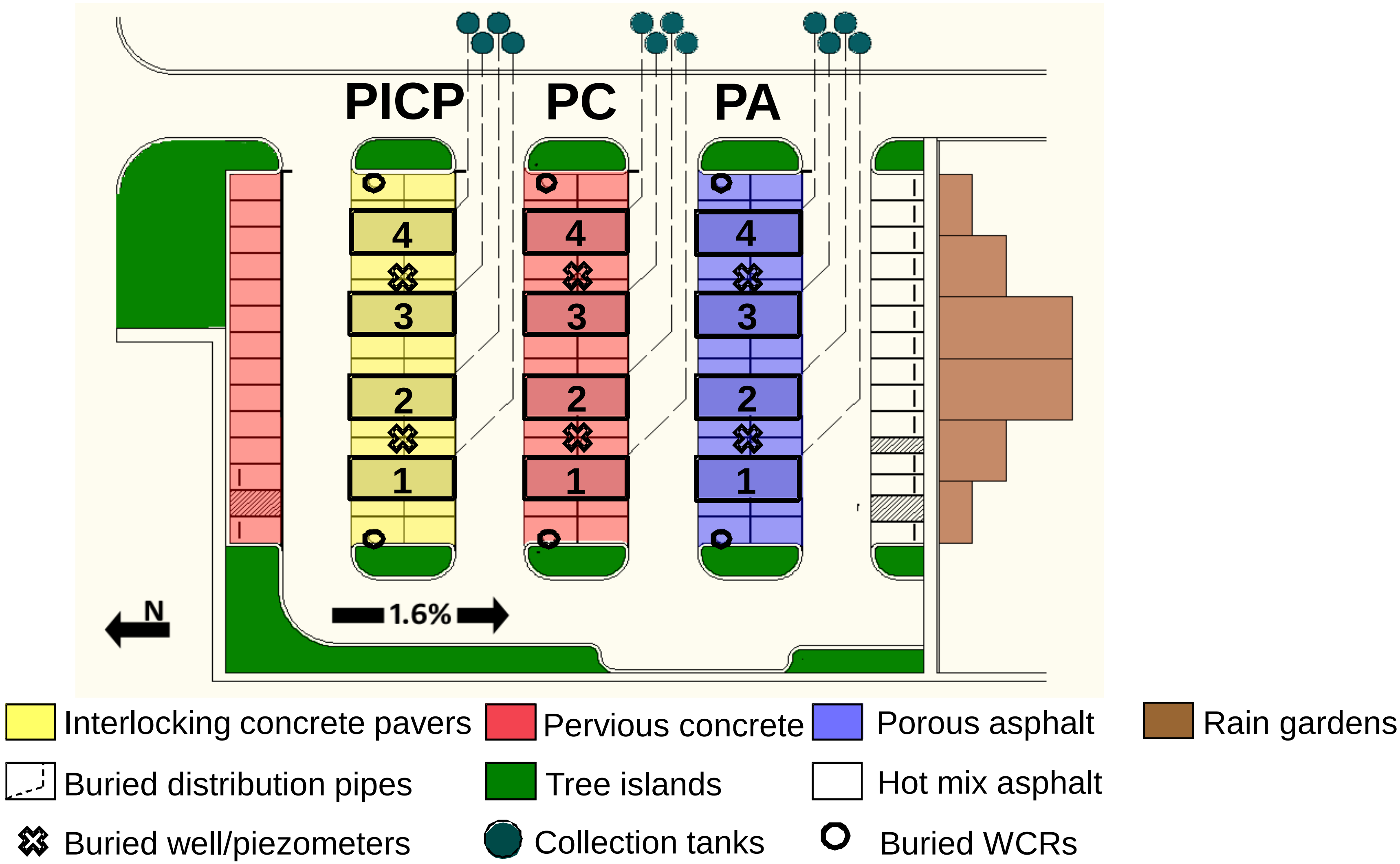
Performance and effectiveness of permeable pavement systems

Edison Environmental Center
Edison, New Jersey

In-Street Application
Louisville, Kentucky

Office of Research and Development
National Risk Management Research Laboratory
Water Supply and Water Resource Division
Urban Watershed Management Branch

The design at the EEC incorporated water quality monitoring capabilities.



The permeable pavement parking lot at the Edison Environmental Center allows evaluation of water quality effects.

- Published or in review
  - Chloride
  - Speciated nitrogen
  - Organic carbon
  - Phosphate
  - pH
  - Eh
- In production
  - SVOCs
  - Metals
- Just starting
  - Microbial indicators

Surface results:

- The three surfaces have very large infiltration rates.
- Clogging progresses from upgradient to downgradient.
- Microtopography partly determines clogging pathway.
- 5 to 7% of the captured water evaporates through the surfaces.

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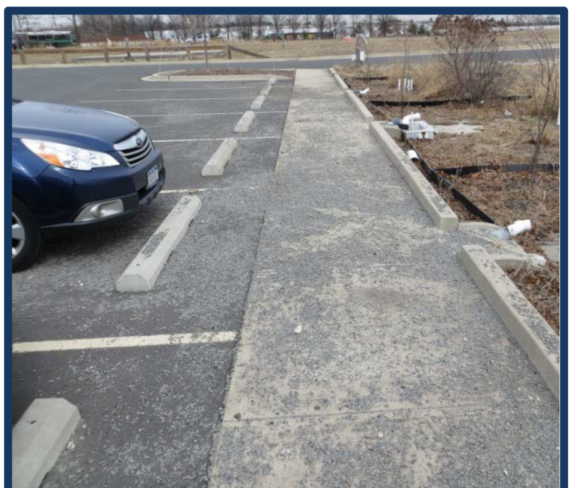
Large portions of the pervious concrete disaggregated.

The problem first became apparent about 18 months after pouring concrete. It was repaired by the contractor in May 2011, but has recurred.



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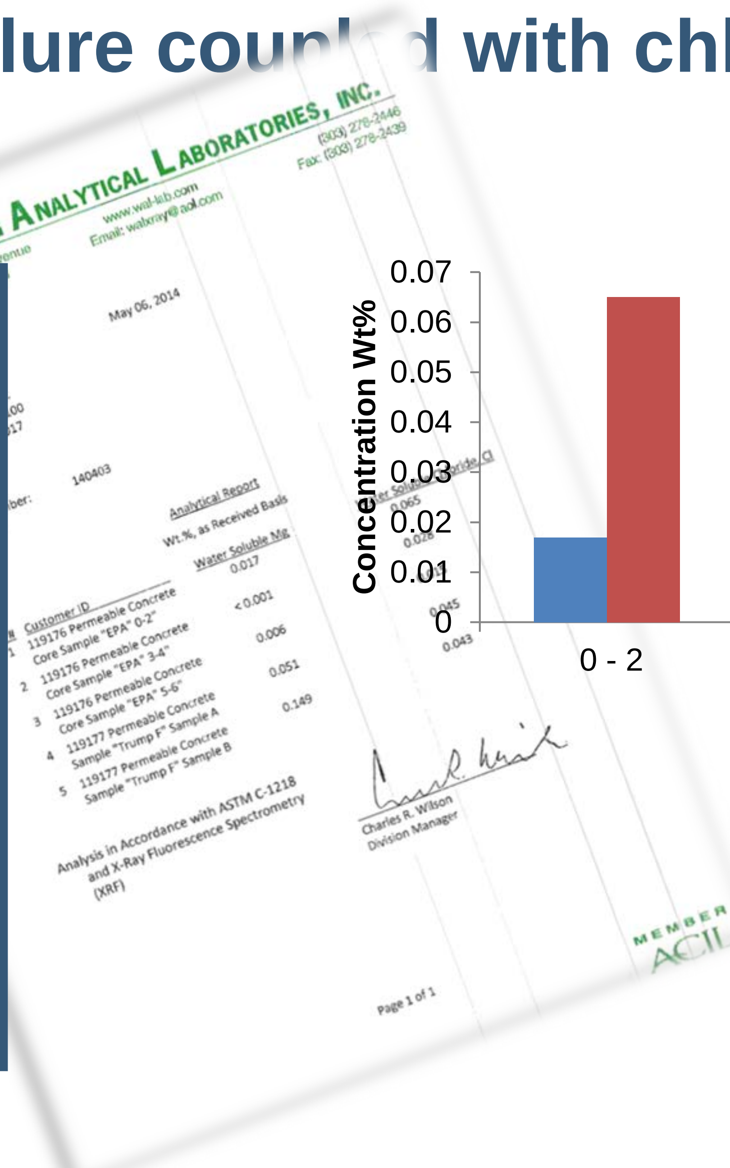
Is structural failure coupled with chloride?


Wyoming Analytical Laboratories, Inc.
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May 06, 2014
140403
Analytical Report
Wt.%, as Received Basis

	Customer ID	Water Soluble Mg	Water Soluble Chloride, Cl
1	119176 Permeable Concrete Core Sample "EPA" 0-2"	0.017	0.065
2	119176 Permeable Concrete Core Sample "EPA" 3-4"	< 0.001	0.028
3	119176 Permeable Concrete Core Sample "EPA" 5-6"	0.006	[illegible]
4	119177 Permeable Concrete Sample "Trump F" Sample A	0.051	0.045
5	119177 Permeable Concrete Sample "Trump F" Sample B	0.149	0.043

Analysis in Accordance with ASTM C-1218 and X-Ray Fluorescence Spectrometry (XRF)

Charles R. Wilson
Division Manager

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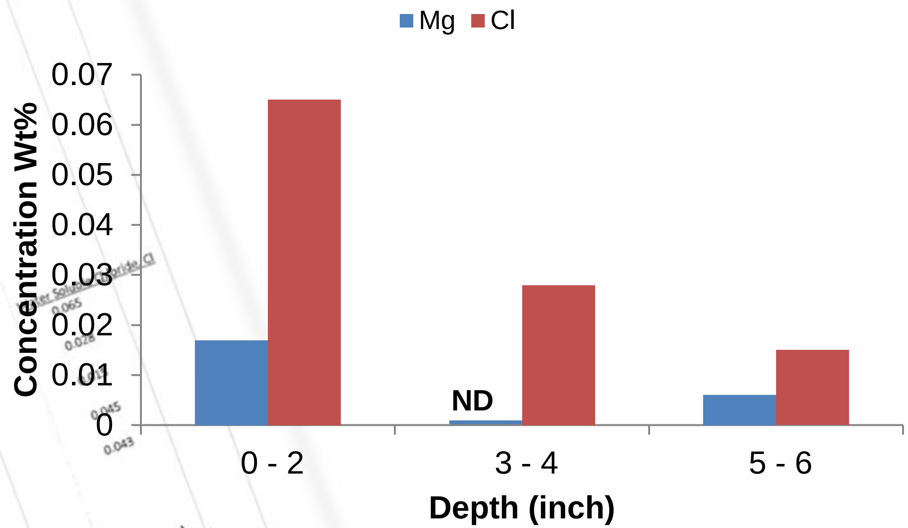
MEMBER ACIL



NRMCA revised O&M guidance (2015)

"Deicing chemicals should not be used on any type of concrete in the first year."

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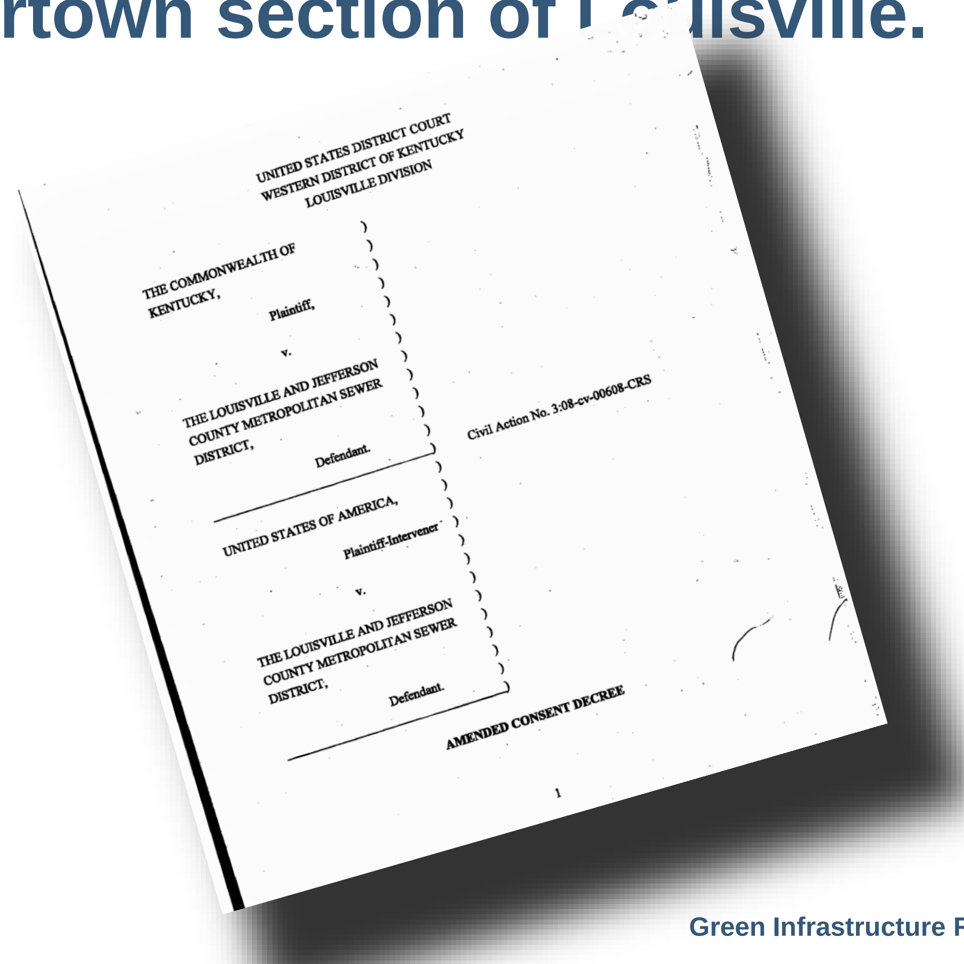
In 2011, Louisville MSD installed permeable pavement strips in parking lanes near the catch basins in the Butchertown section of Louisville.

In-Street Application

Louisville, Kentucky



UNITED STATES DISTRICT COURT
WESTERN DISTRICT OF KENTUCKY
LOUISVILLE DIVISION

THE COMMONWEALTH OF KENTUCKY,
Plaintiff,
v.
THE LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT,
Defendant.

UNITED STATES OF AMERICA,
Plaintiff-Intervener
v.
THE LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT,
Defendant.

Civil Action No. 3:08-cv-00608-CRS

AMENDED CONSENT DECREE

1

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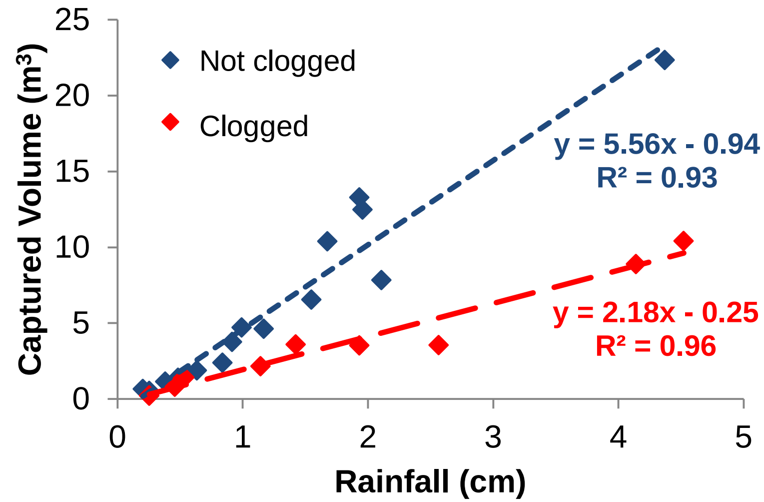
Findings:



- There are very large variations in soil hydraulic conductivity at small spatial scales.
- Clogged does not mean sealed.
- We can use embedded instruments to monitor the clogging progression.
- Clogging distance is proportional to rainfall depth and not time.
- Static volumetric design may cause oversized stormwater controls.

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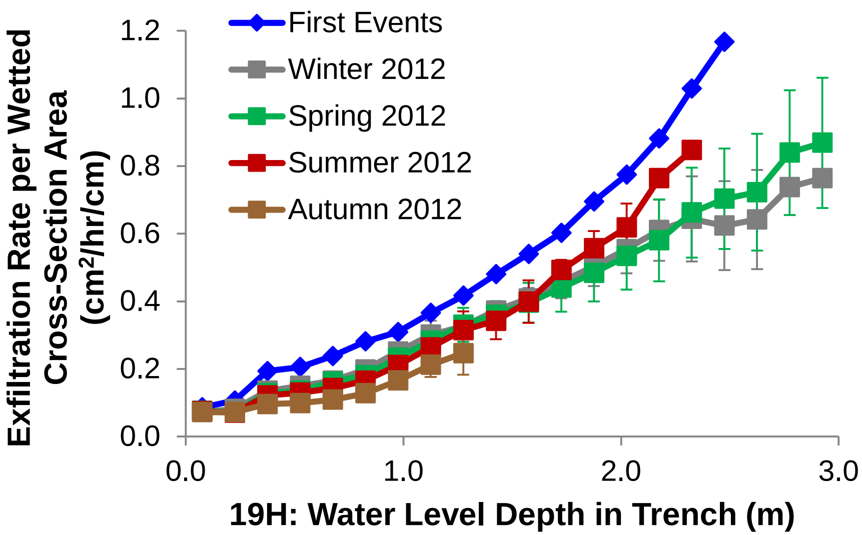
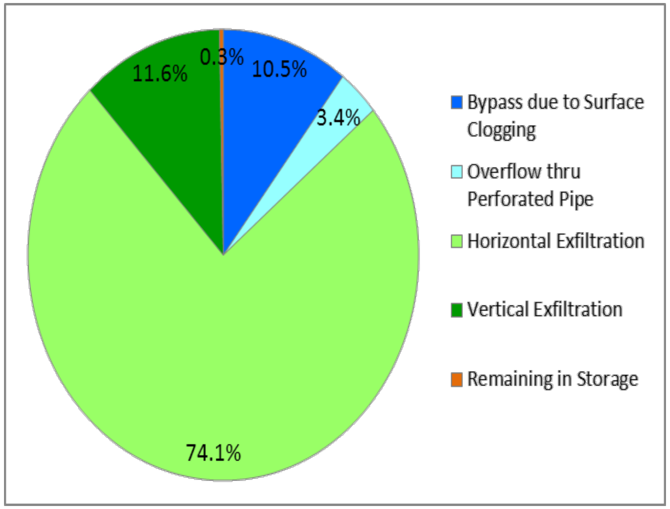
Findings:

- Exfiltration rates vary with age.
- Exfiltration rates vary with water depth and constant hydraulic flux is not representative of exfiltration processes.
- Much of the exfiltration occurs through the sides.
- SCM geometry is important.





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Maintenance:

- Multiple techniques were implemented.
- Each technique increased surface infiltration capacity, but did not always restore baseline conditions.
- Longevity of the restored infiltration capacity varied.
- Results are probably product specific.

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Construction costs have been essentially proportional to volume.

Item	Quantity	Unit Cost ($)	Extended Cost ($)	Fraction (%)
No. 57 Aggregate	52 CY	0.61	3,172	6.6
Geogrid	1,400 SF	4.00	5,600	11.6
Pavers	1,400 SF	14.00	19,600	40.6
Earthwork	235 CY	35.00	8,225	17.1
No. 3 Aggregate	181 CY	40.00	7,240	15.0
Asphalt removal	1,400 SF	0.75	1,050	2.2
Overflow pipe	LS		1,200	2.5
Traffic control	LS		600	1.2
Survey & stake	LS		200	0.4
Erosion / sediment control	LS		200	0.4
Bonding	LS		650	1.3
Mobilization / Demobilization	LS		500	1.0
Total			$48,237	100.0

$126/sq yd

Semi-fixed costs 4.5% of total

$310/sq yd

Costs: November 2011 Louisville, KY Two paver strips. Excludes monitoring costs and change orders

EFFECTIVENESS

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Ideally, we wanted a Before-After Control-Impact (BACI) Study.

Control | **Impact**

Before

After

Plan "B" created a virtual comparison sewershed for comparison.

Modeled (InfoWorks) | **Measured**

Before

After

The statistics allow determination of whether the “impact” had a measurable effect after adjusting for all other factors.

	Control	Impact
Before	• $X_{1,1}, X_{1,2}, X_{1,3} \ldots$	• $X_{2,1}, X_{2,2}, X_{2,3} \ldots$
After	• $X_{3,1}, X_{3,2}, X_{3,3} \ldots$	• $X_{4,1}, X_{4,2}, X_{4,3} \ldots$

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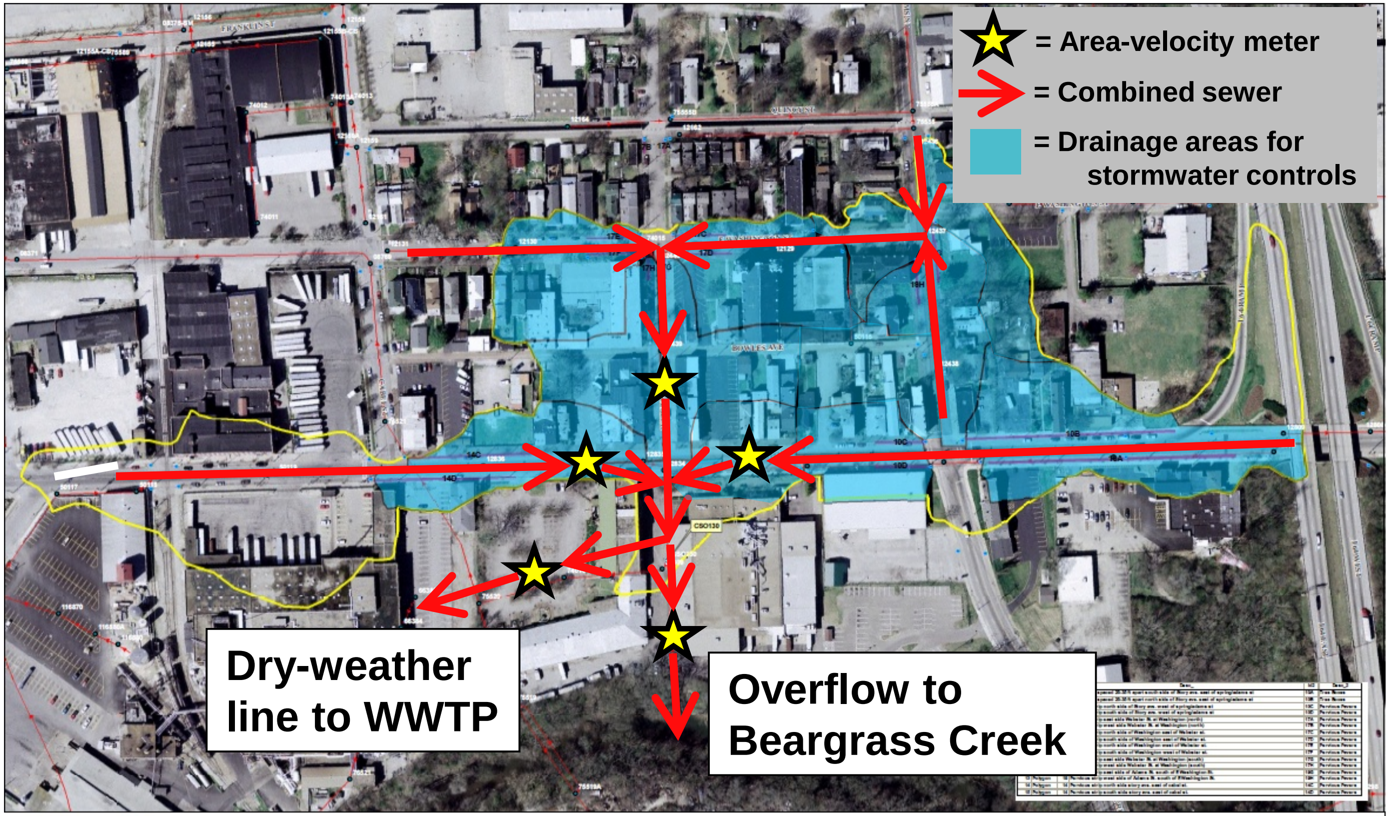
In-sewer flows were measured at 5 locations for at least 1 year before construction to develop the preconstruction condition model using InfoWorks (Innovyze).

Sigma 920 area-velocity flow meters (later FloWav) were installed and managed by LJCMSD.

The flow meters separated the basin into 4 catchments, and catch basins were used to define 29 subcatchments.

Drainage areas were defined using 6-inch LIDAR data and refined with on-site observations.



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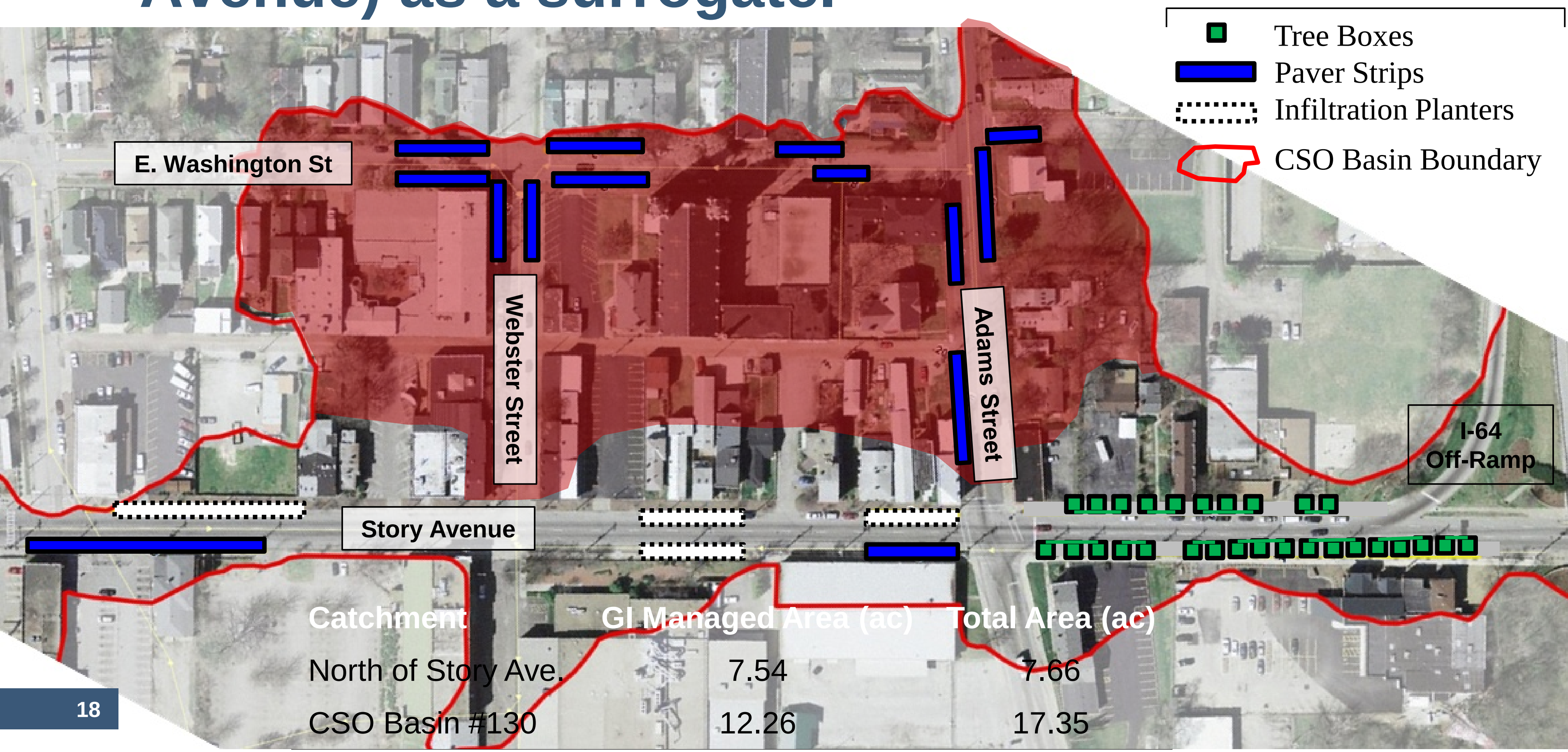
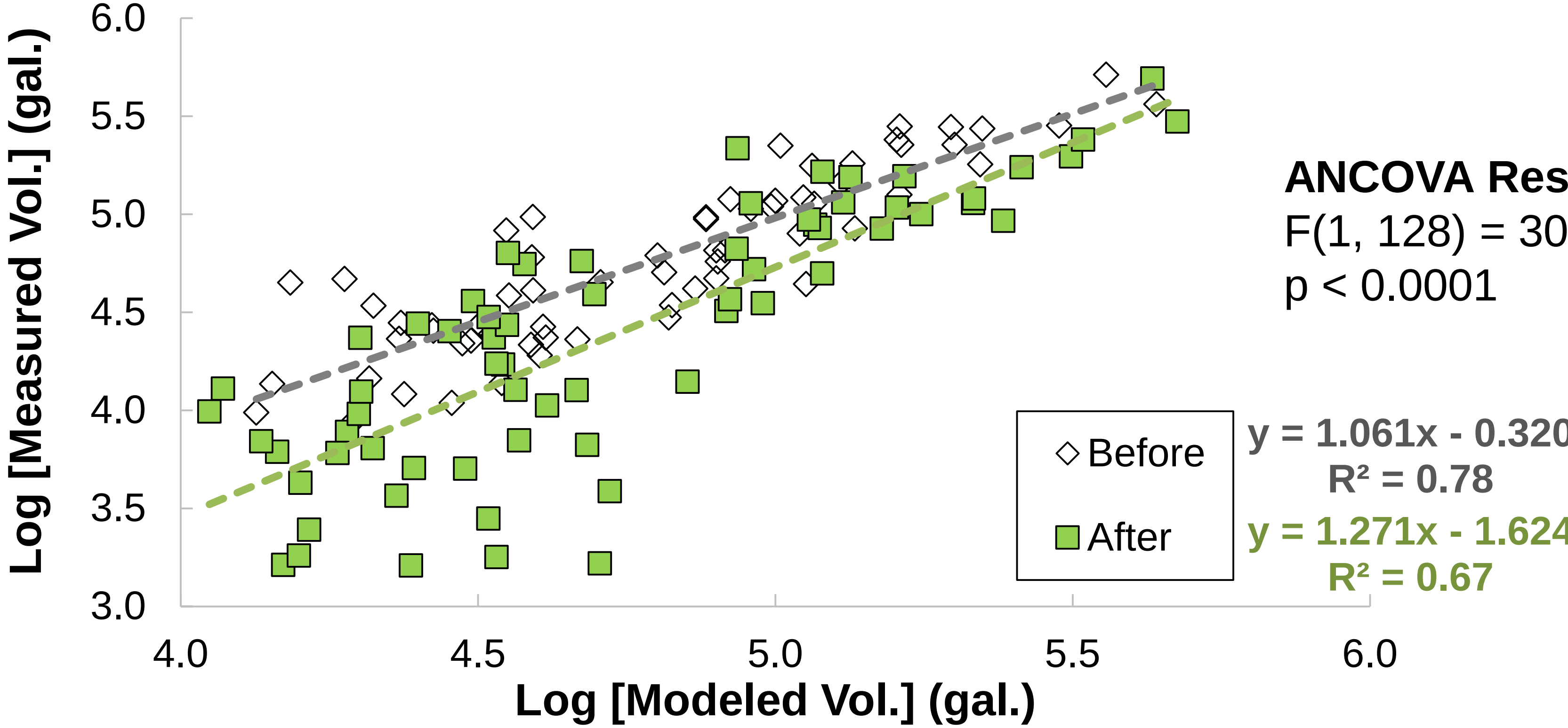
We selected the largest subsewershed area to evaluate the effectiveness (north of Story Avenue) as a surrogate.



Catchment	GI Managed Area (ac)	Total Area (ac)
North of Story Ave.	7.54	7.66
CSO Basin #130	12.26	17.35

Using the BACI approach, GI significantly reduced in-sewer flow volume per event.

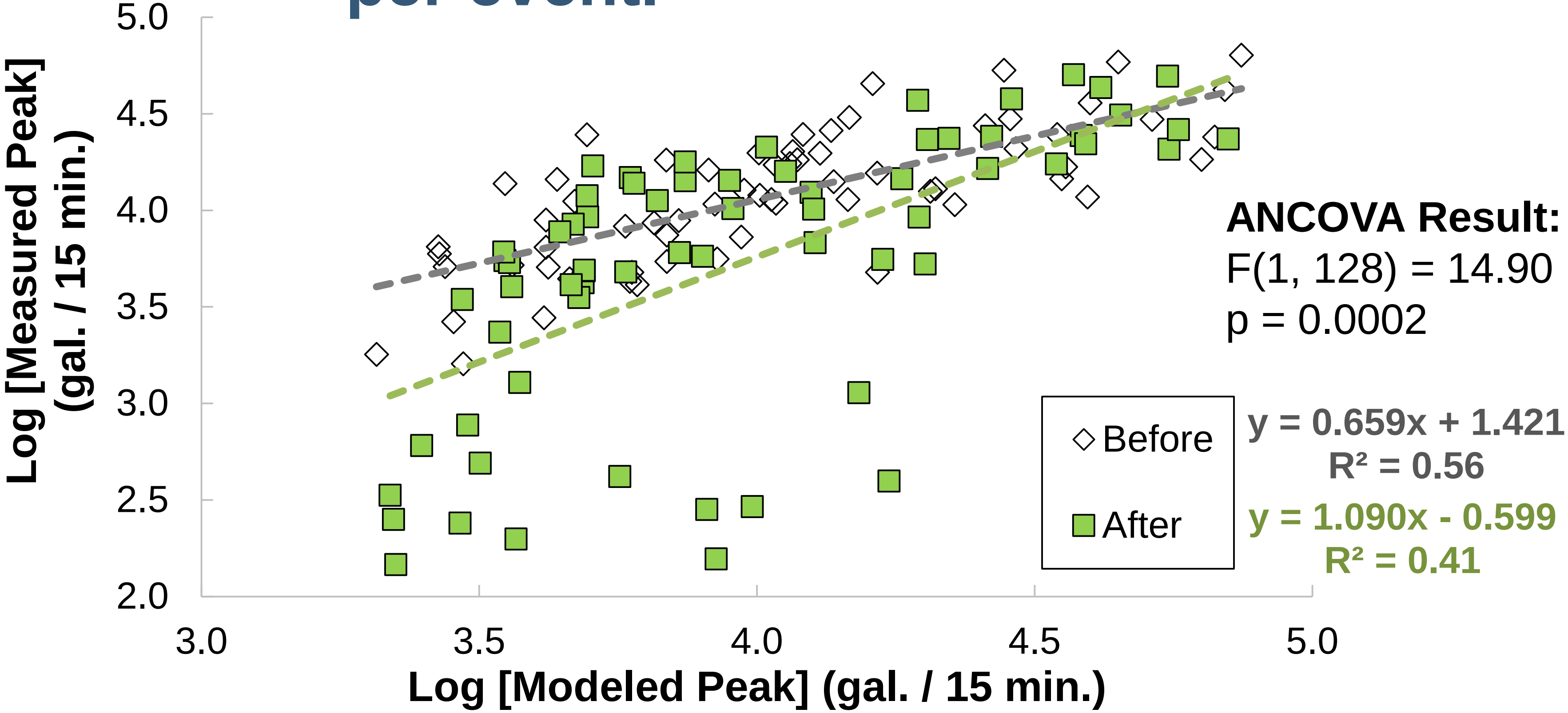


ANCOVA Result:
$F(1, 128) = 30.84$
$p < 0.0001$

Period	**Control** Mean (gal)	**Impact [GI]** Mean (gal)	**Predicted [GI]** (gal)	**% Change**
Before	63,509	59,319		
After	54,108	**24,623**	**50,053**	**– 51%**

North of Story Avenue Catchment

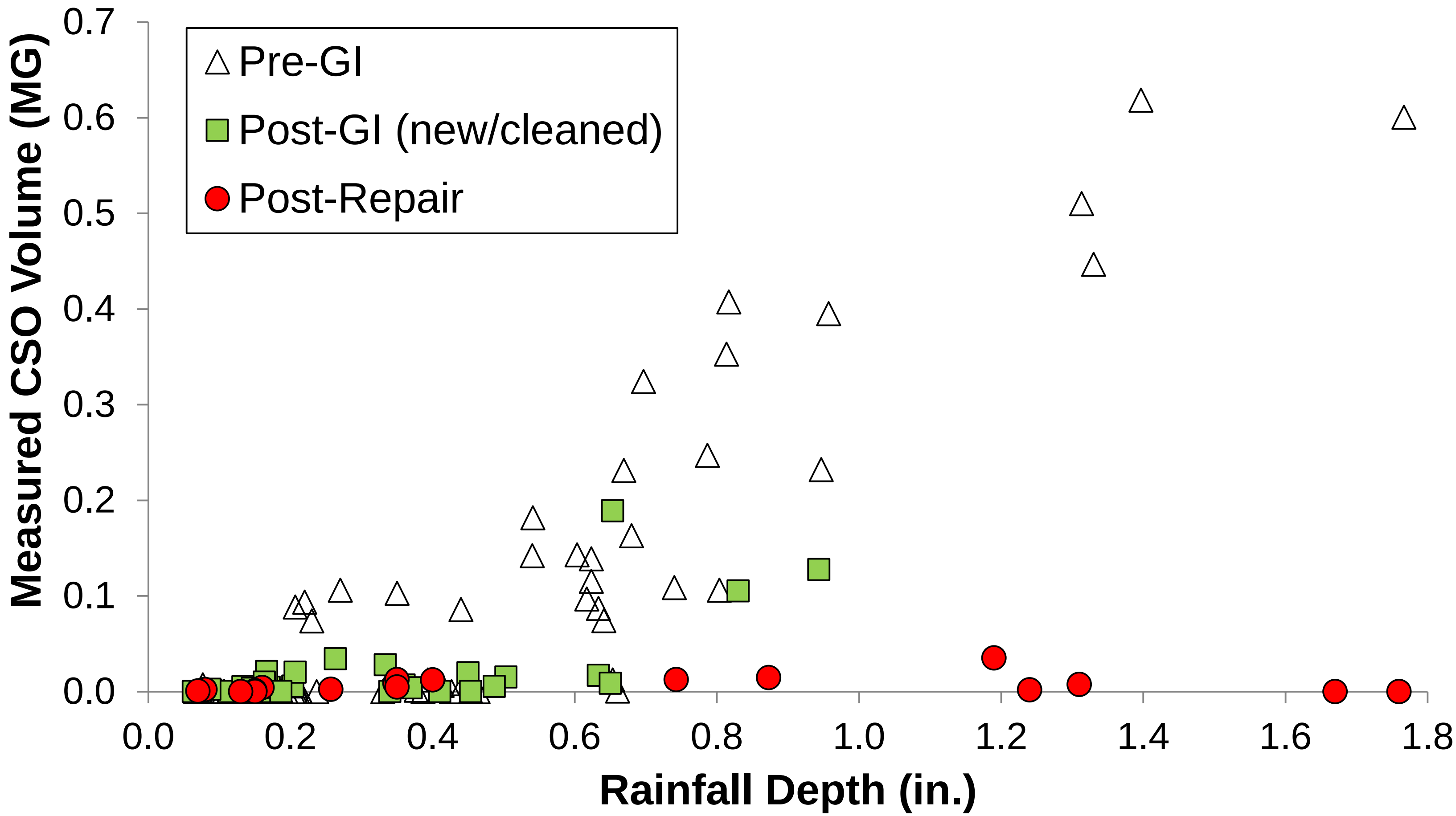
Using the BACI approach, GI also significantly reduced peak flow rates per event.



Period	Control (gal. / 15 min.)	Impact [GI] (gal. / 15 min.)	Predicted [GI] (gal. / 15 min.)	% Change
Before	11,051	12,122		
After	9,308	**5,313**	**10,826**	**– 51%**

North of Story Avenue Catchment

Results after replacing the dry-weather line are promising for meeting basin AAOV targets.



Repairs completed 11/06/2014)

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Green Infrastructure Research