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Green Infrastructure Performance and Effectiveness in CSO Basin #130 (Louisville)

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

United States Environmental Protection Agency

Outline

- Project background
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  - Monitoring methods
- Performance of individual controls
  - Surface clogging monitoring
  - Hydrologic processes
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- University of Louisville results
- Q&A

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PROJECT BACKGROUND

Organizational cast of characters

- EPA Office of Research and Development
- EPA Region 4
- KY DOW
- LJCMSD
- URS
- University of Louisville

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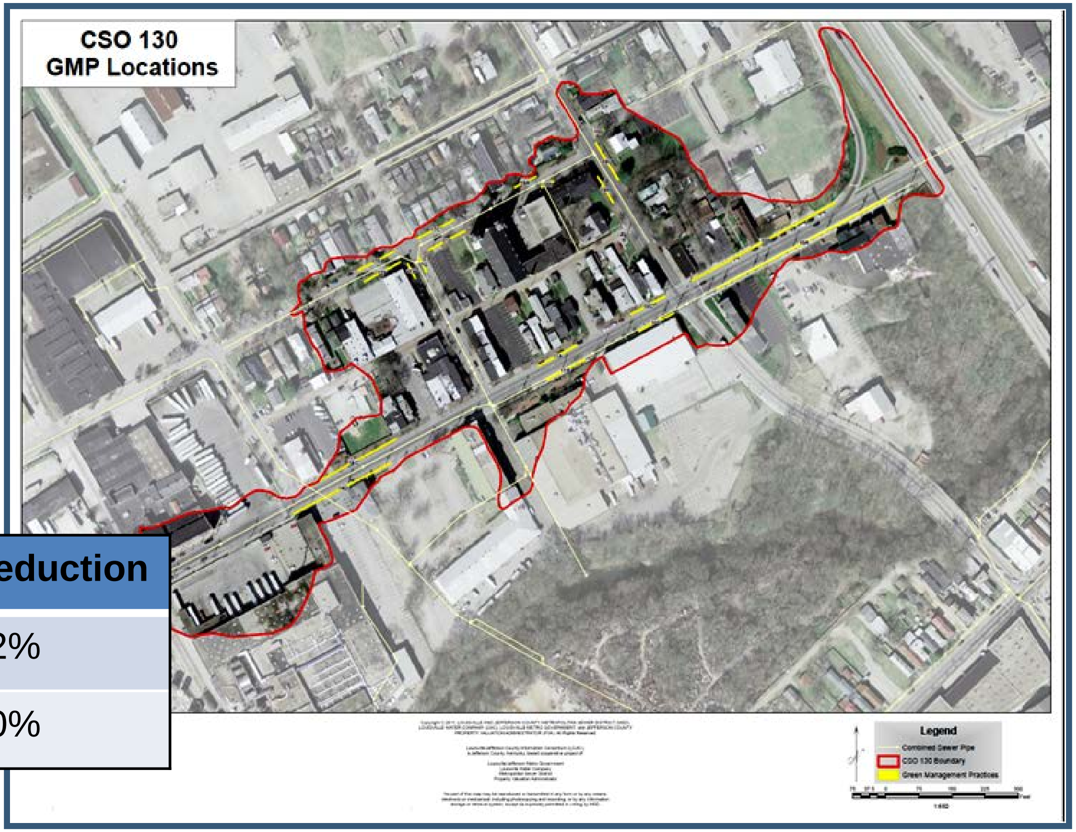
Site description

The test basin is the 17 acre drainage basin CSO130 in the Butchertown section of Louisville.



Work being done under a consent decree.

Metric	Current	Target	Reduction
AAOV (MG/Yr)	1.3	0.67	52%
Overflows	16	8	50%

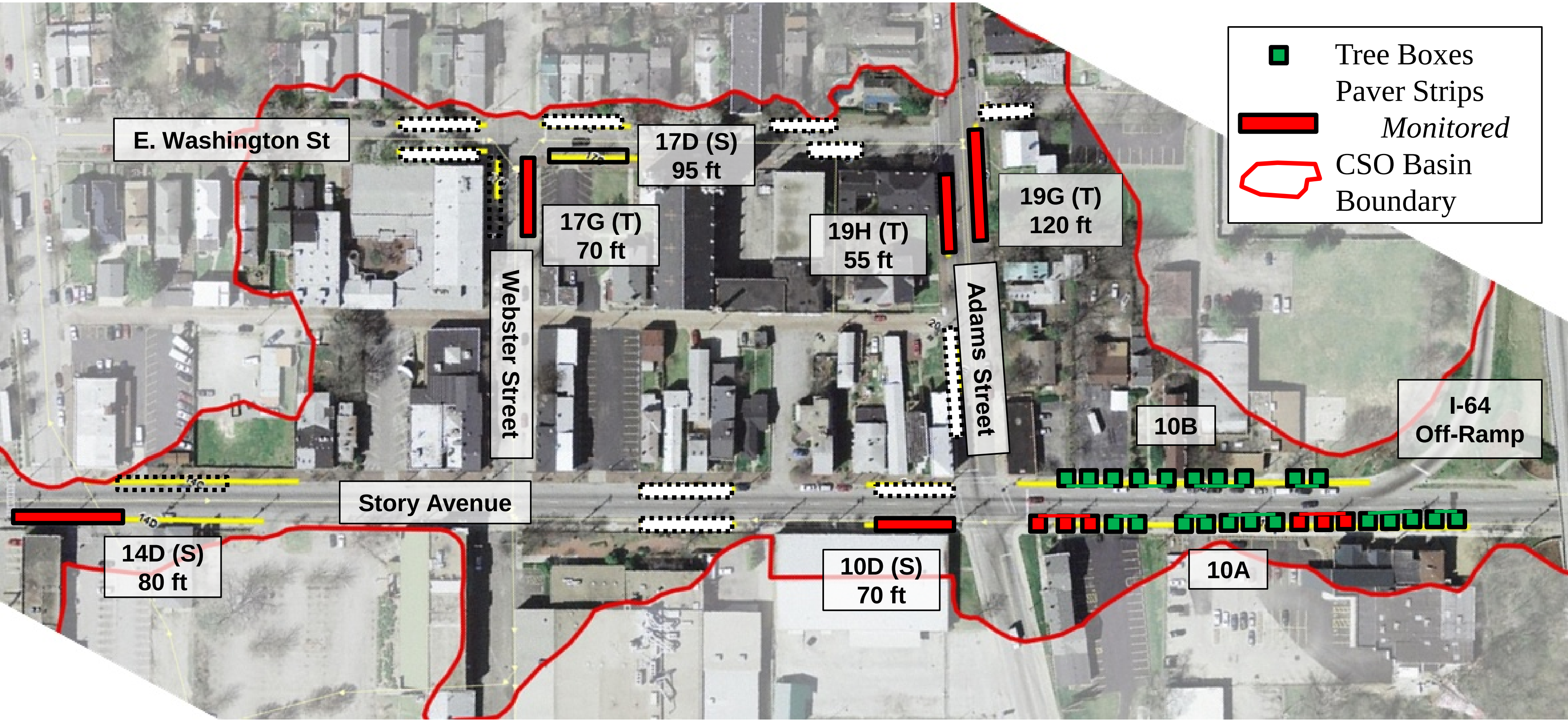
Within CSO 130, MSD decided that the preferred stormwater control is permeable paver strips installed as parking lanes near the catch basins.

MSD made a policy decision to assume responsibility for the ongoing maintenance.

This led them to place the controls on publically-owned property.

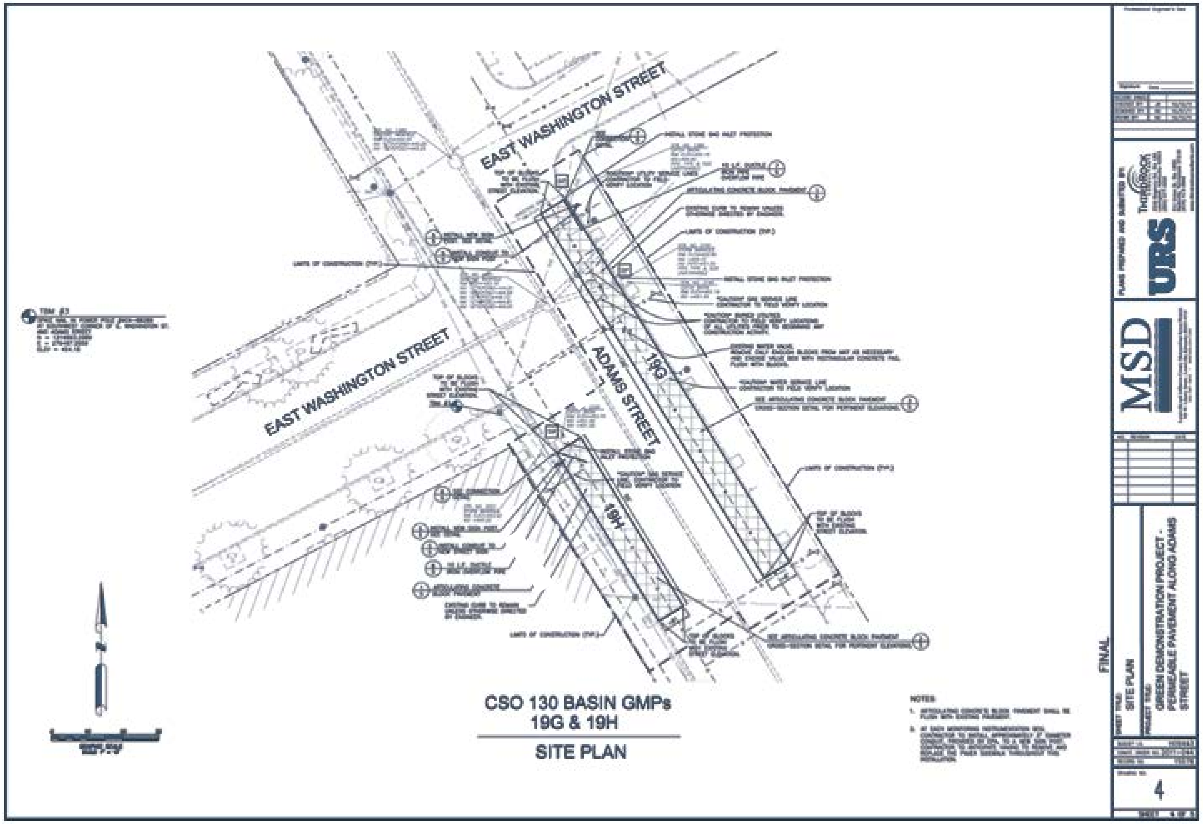
The limited publically-owned property and generally narrow sidewalks forces the controls into the streets.

6 of 18 articulated paver strips and 6 of 28 tree boxes were heavily instrumented.



In Dec. 2011 two articulated paver strips were installed at the corner of East Washington and Adams Streets

ORD did not develop the design of the controls or select locations, but did develop the monitoring program and the experimental design within the constraints.



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The MSD contractor removed existing pavement, excavated the trench and storage gallery before we installed the selected monitoring equipment.

We sampled underlying soil and made in situ measurements during construction.

Sample collection with extended hand auger

"Long pipe" Infiltration testing

LCJMSD's geotechnical survey near these controls reported an infiltration rate of 4.3 cm/hr 4.0 to 4.6 m below grade.

Piezometer location	19G		19H	
	Infiltration rate (cm/hr)	**USDA soil texture classification** (% sand/silt/clay)	**Infiltration rate** (cm/hr)	**USDA soil texture classification** (% sand/silt/clay)
Upgradient	0.114	Sandy Loam (58/34/8)	0.258	Sandy Loam (55/36/9)
Middle	0.108	Loam (50/33/17)	0.780	Silt Loam (35/50/15)
Downgradient	0.012	Silty Clay Loam (18/52/30)	0.096	Sandy Loam (62/25/13)
Average	0.078		0.378	

Most of the articulated paver strips installed in the next phase used shafts instead of trenches.

Photos: Josh Rivard, University of Louisville
Louisville Control 19B
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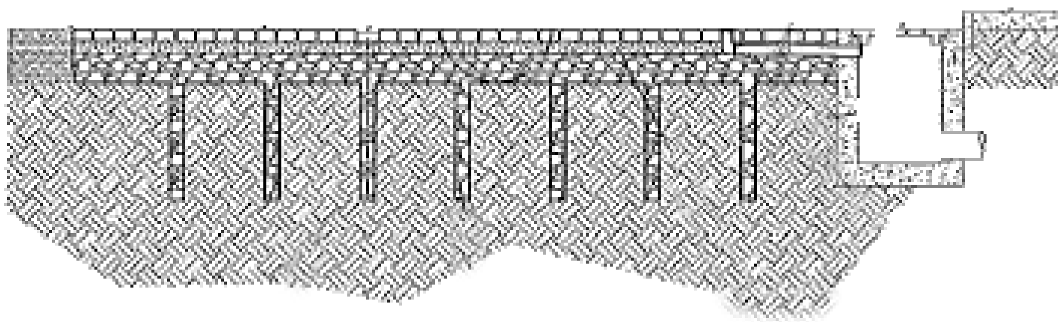
The design change introduced augured shafts to hydraulically connect to soil with large infiltration capacity.



ARTICULATING CONCRETE BLOCK SHAFT STRIP
NOT TO SCALE

The number and depth of shafts varies across the controls.

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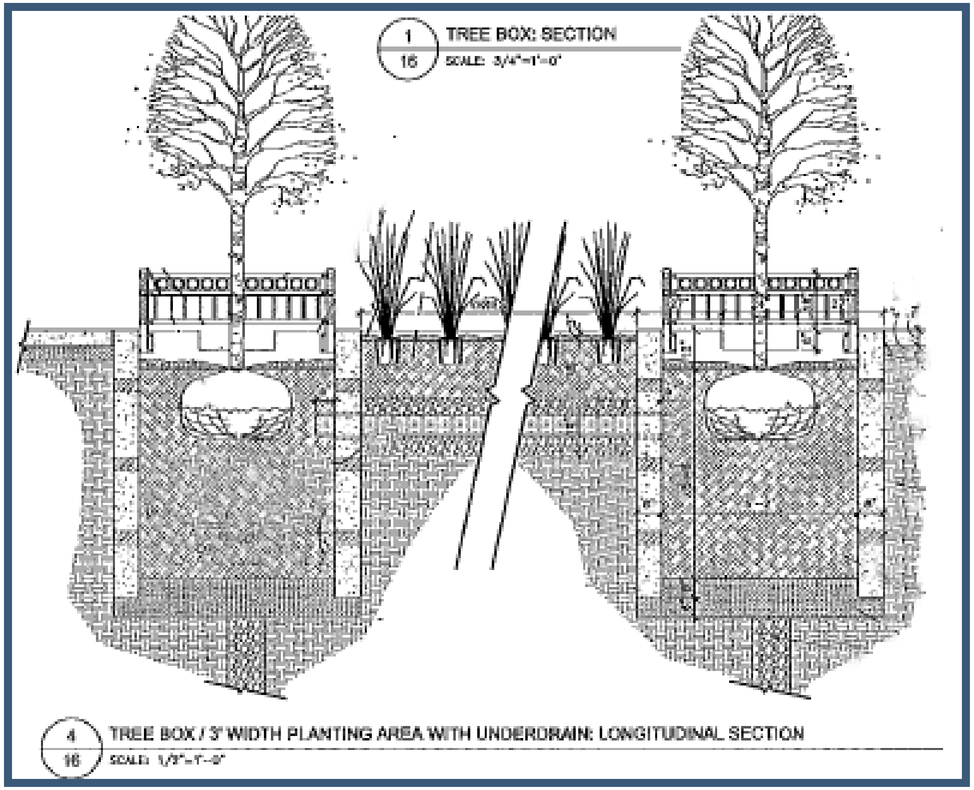
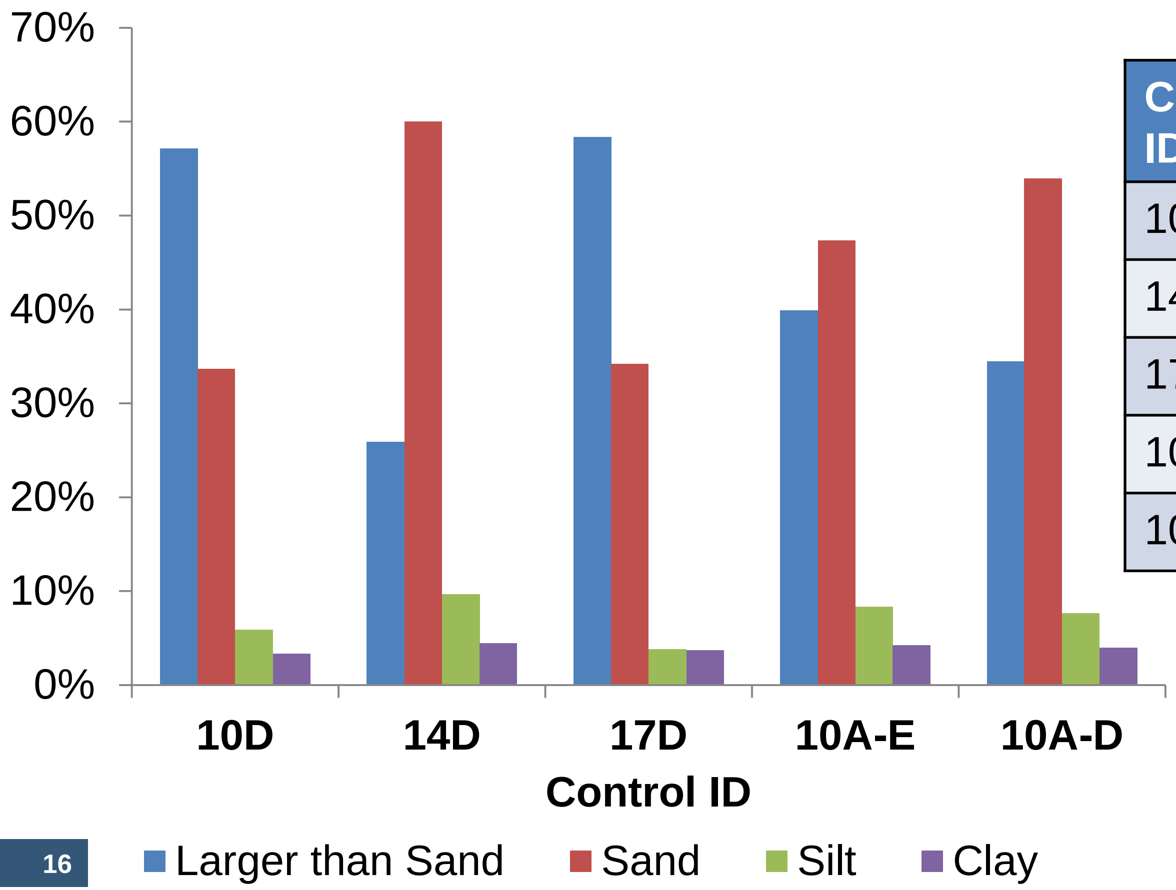
Tree boxes were installed in groups of two or three with a connecting infiltration trench and at locations where no parking lanes were present.



Analysis of soil samples from the bottom of shafts confirmed coarse material.



Control ID	# Shafts	Shaft Depth Range (ft)
10D	5	19.5 – 21.0
14D	7	20.7 – 22.3
17D	10	6.7 – 10.5
10A-E	3	19.5 – 21.9
10A-D	3	18.4 – 19.4

10A-E & 10A-D are tree boxes.

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Monitoring methods

The necessary processes for the individual SCM are straightforward.

1. Allow runoff water to flow to the SCM
2. Allow runoff water to infiltrate into the SCM
3. Allow infiltrated water to exfiltrate from the SCM
4. Repeat

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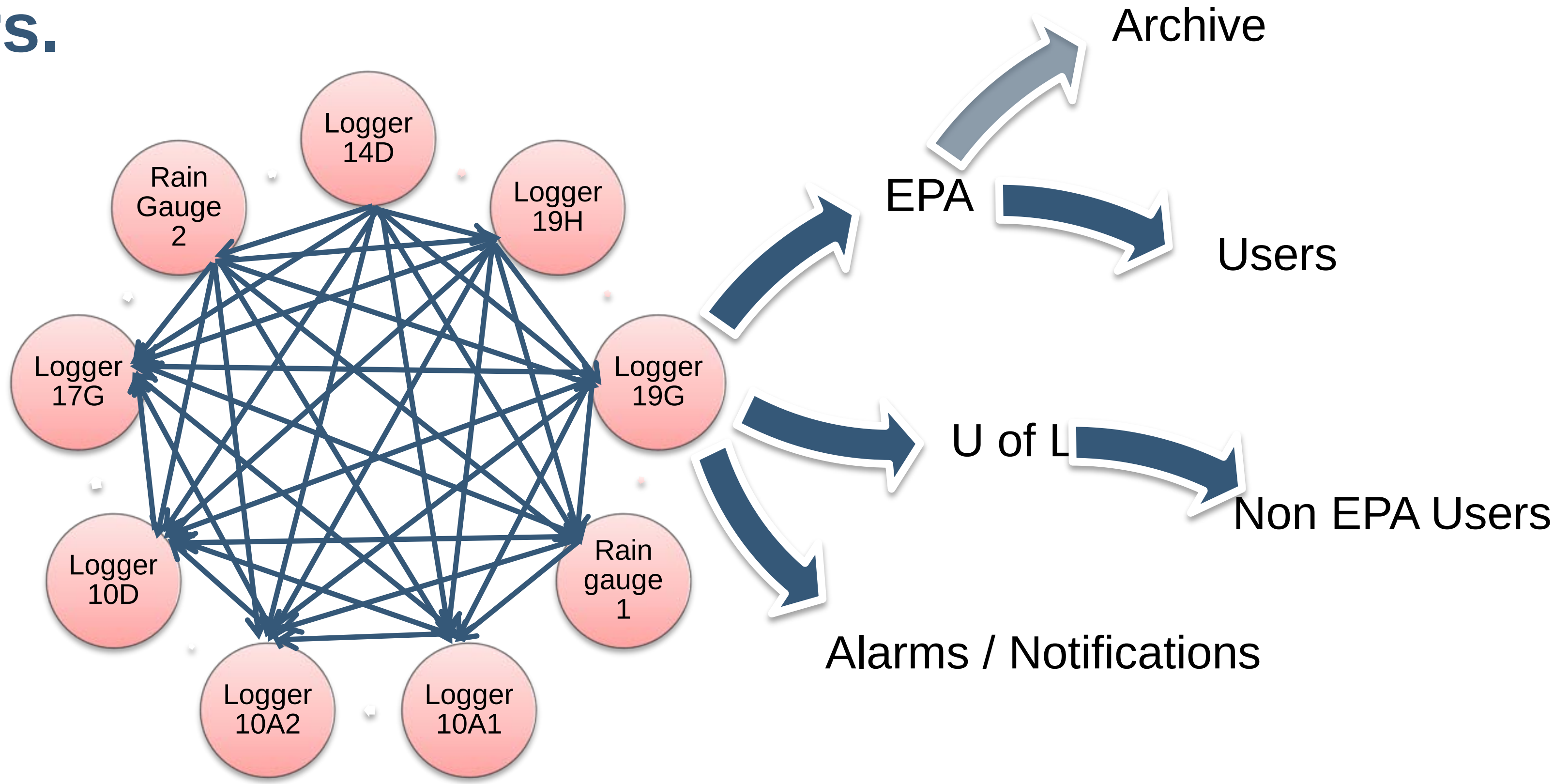
The permanently installed sensors are pressure transducers, time domain reflectometers (TDRs), thermistors, and passive capillary lysimeters.

The instruments in each control are hard wired to the datalogger.

19G

19H

The loggers communicate by radio to accumulate all data at logger 19G for daily transmission to users.



"Best" communication path among loggers is selected by the loggers based on signal strength.(RF-TD polling)

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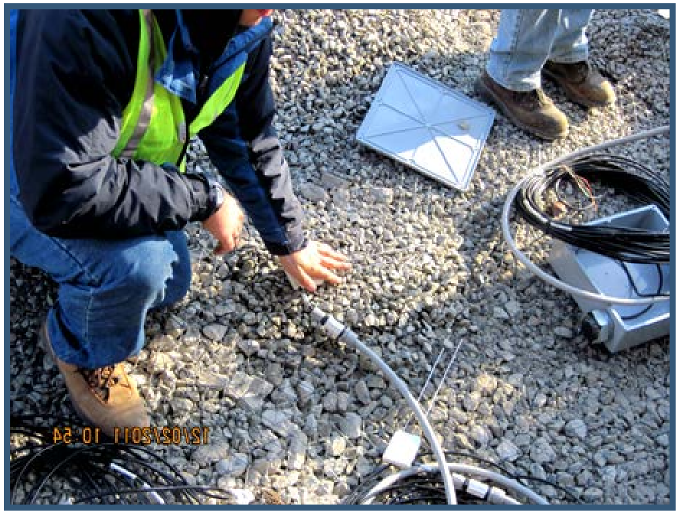
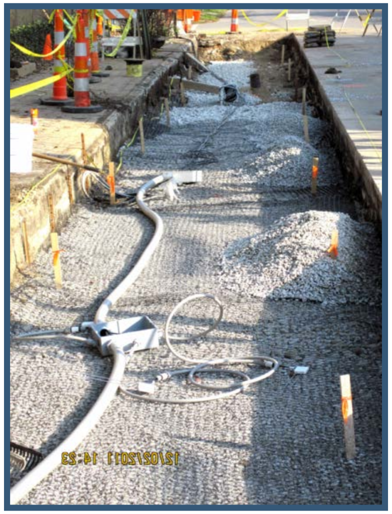
PERFORMANCE

Surface clogging monitoring

Time Domain Reflectometers (TDRs) were installed 40 cm below the paver surface in the aggregate to measure surface clogging progression.

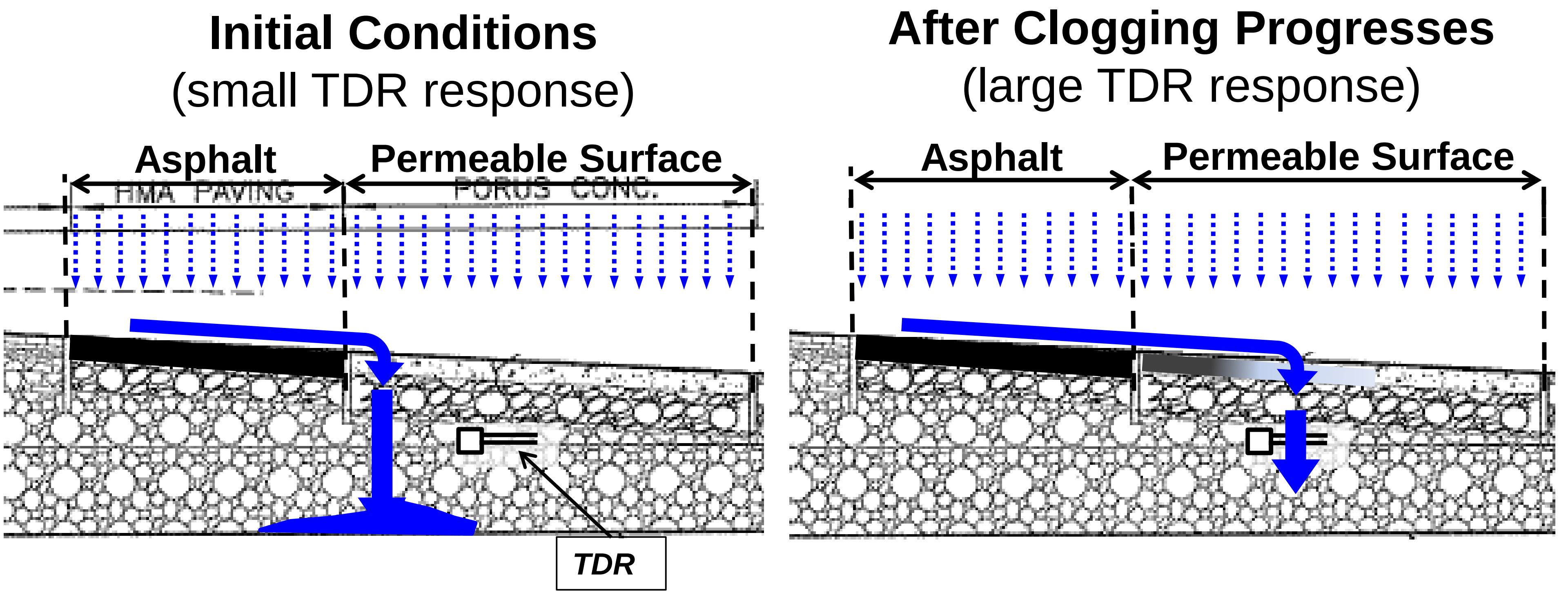




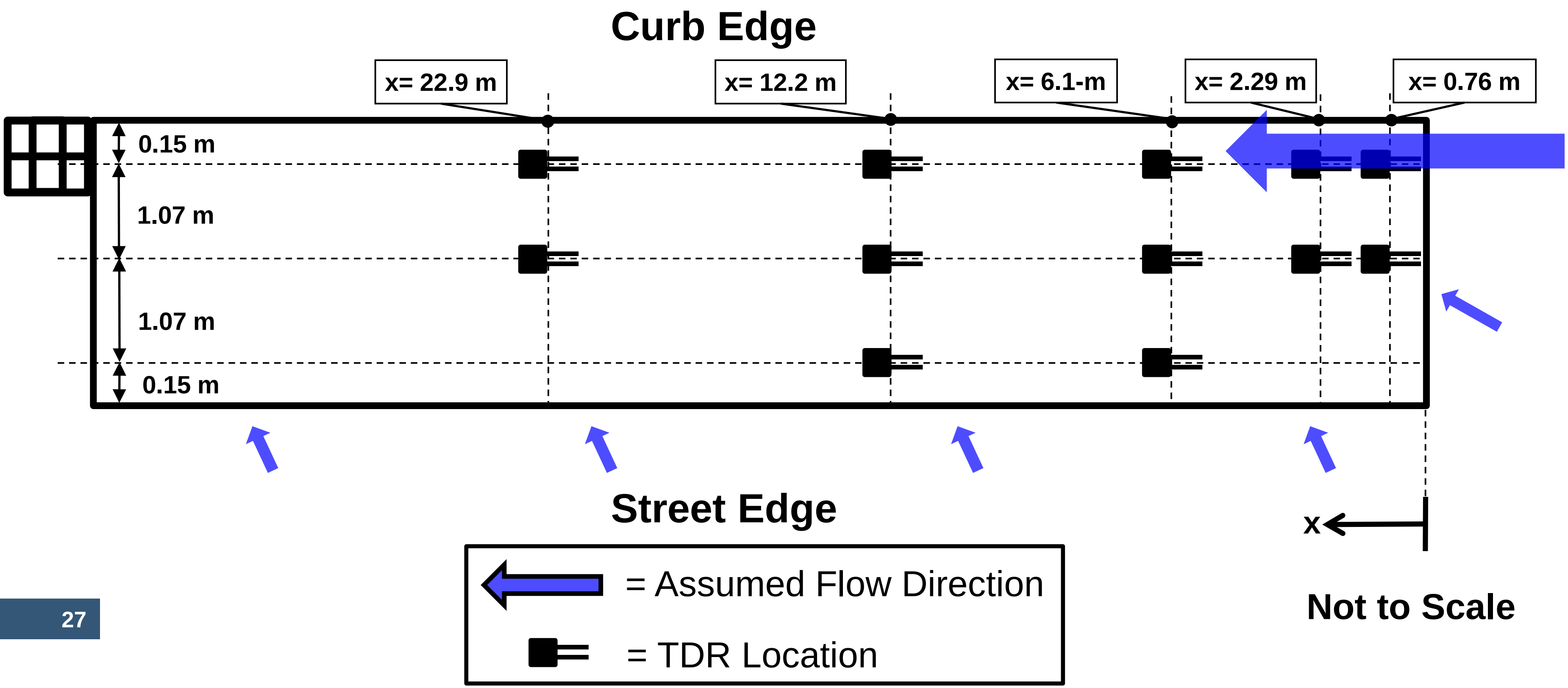
The foundational research[1] linking the TDR response to moisture content was done in mineral soils, not gravel so the output value is the "Relative Volumetric Water Content" (RVWC).

1 Topp, G. C., Davis, J. L., and Annan, A. P. (1980). "Electromagnetic determination of soil water content: Measurements in coaxial transmission lines." *Water Resources Research*, 16, 574-582.

Magnitude of response is consistent with relative amount of water infiltrating through the surface.



We expect flow to concentrate along the curb with much smaller flows from the road crown and direct rainfall entering elsewhere.



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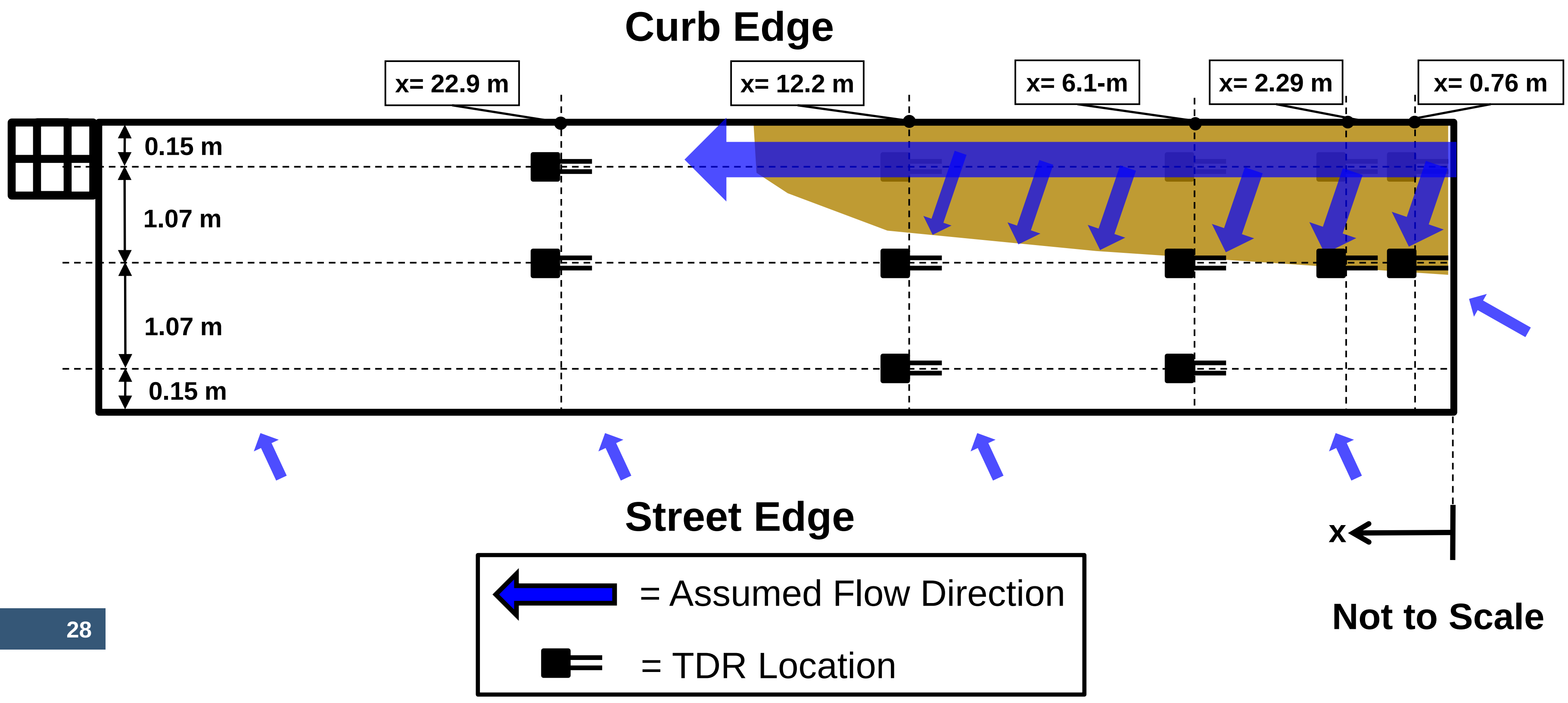
We expect the concentrated flow to transport and deposit sediment from the drainage area.



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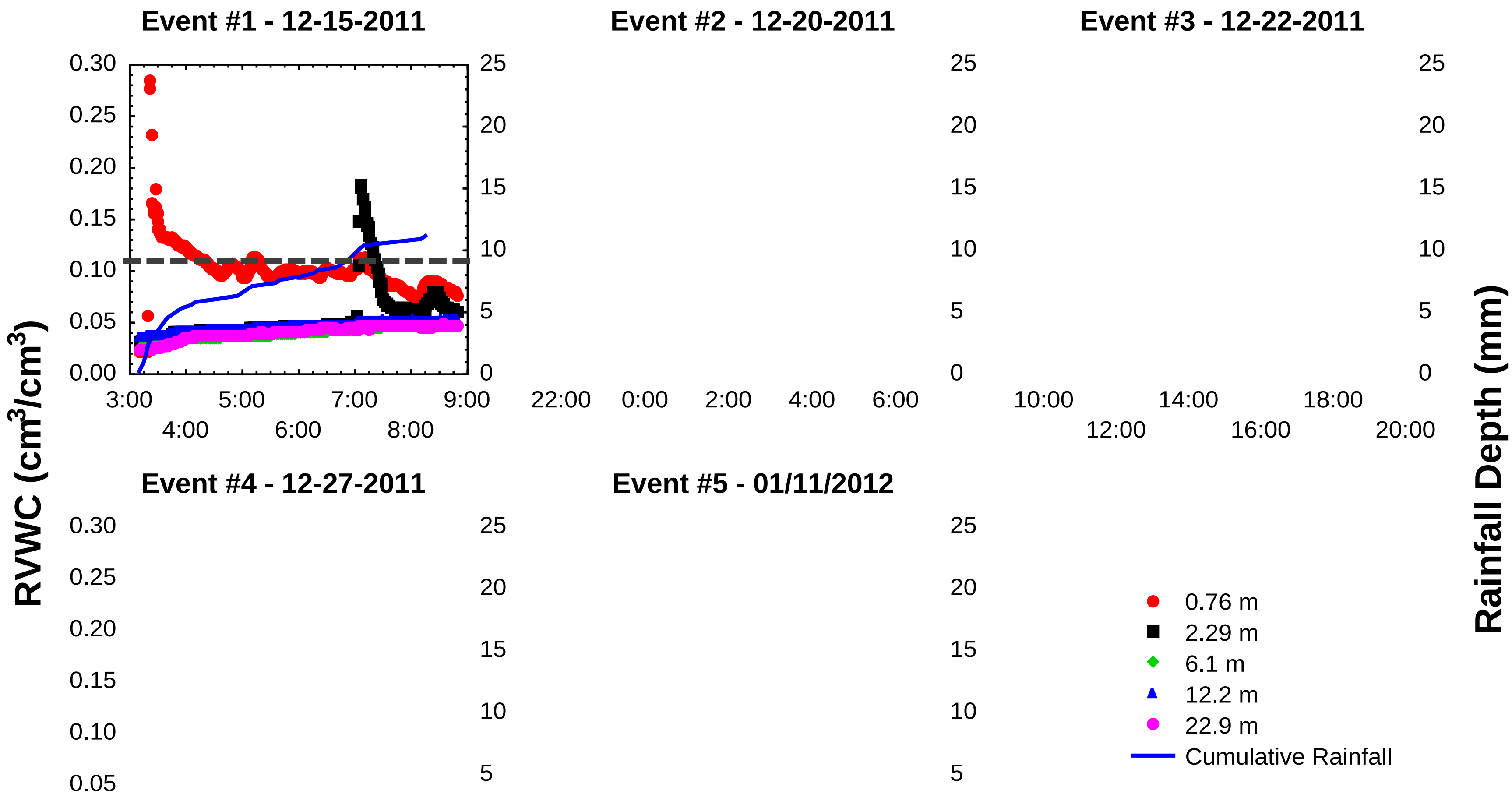
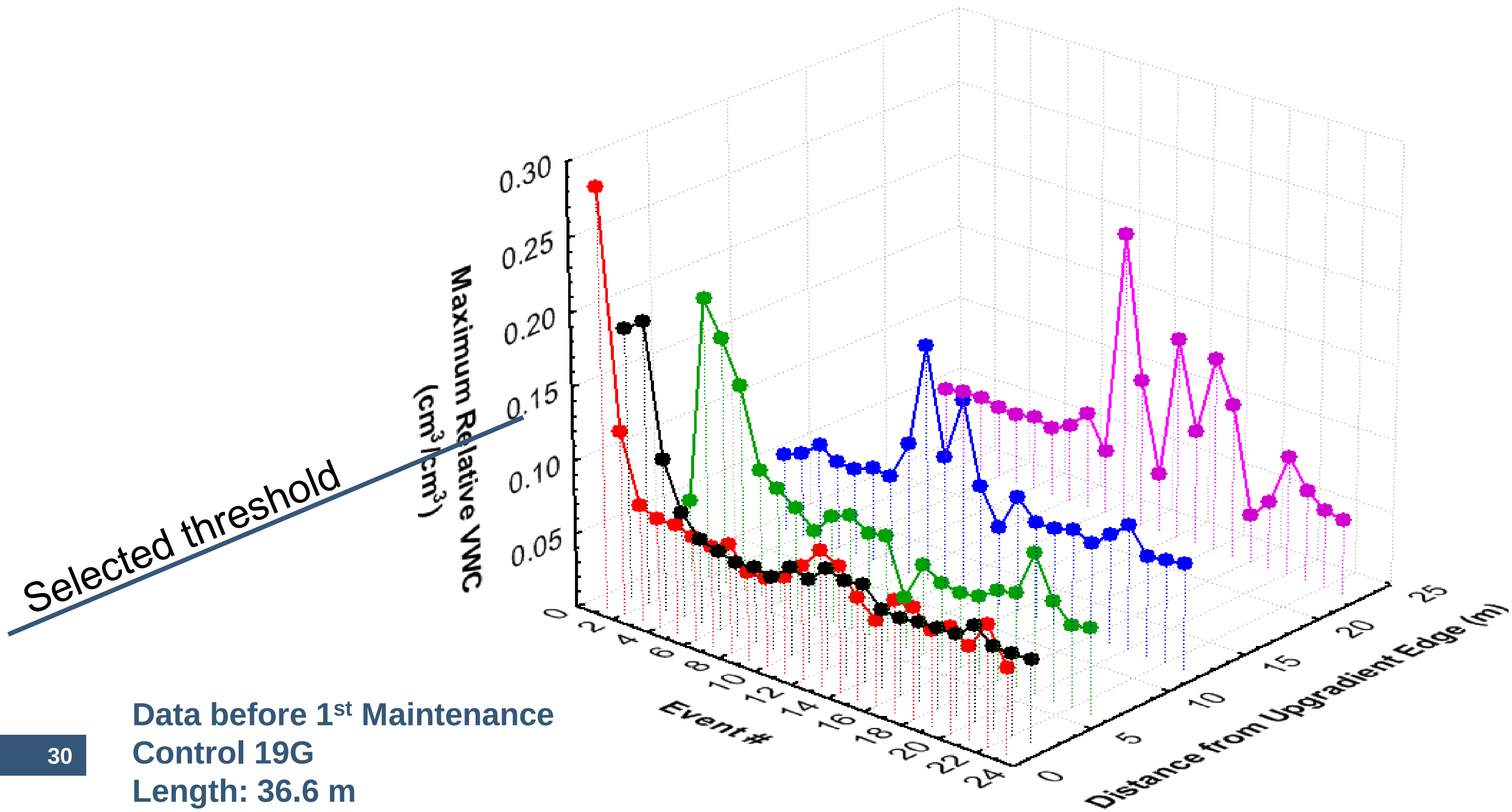
Using the TDRs nearest the curb edge, we can monitor the progression of surface clogging.



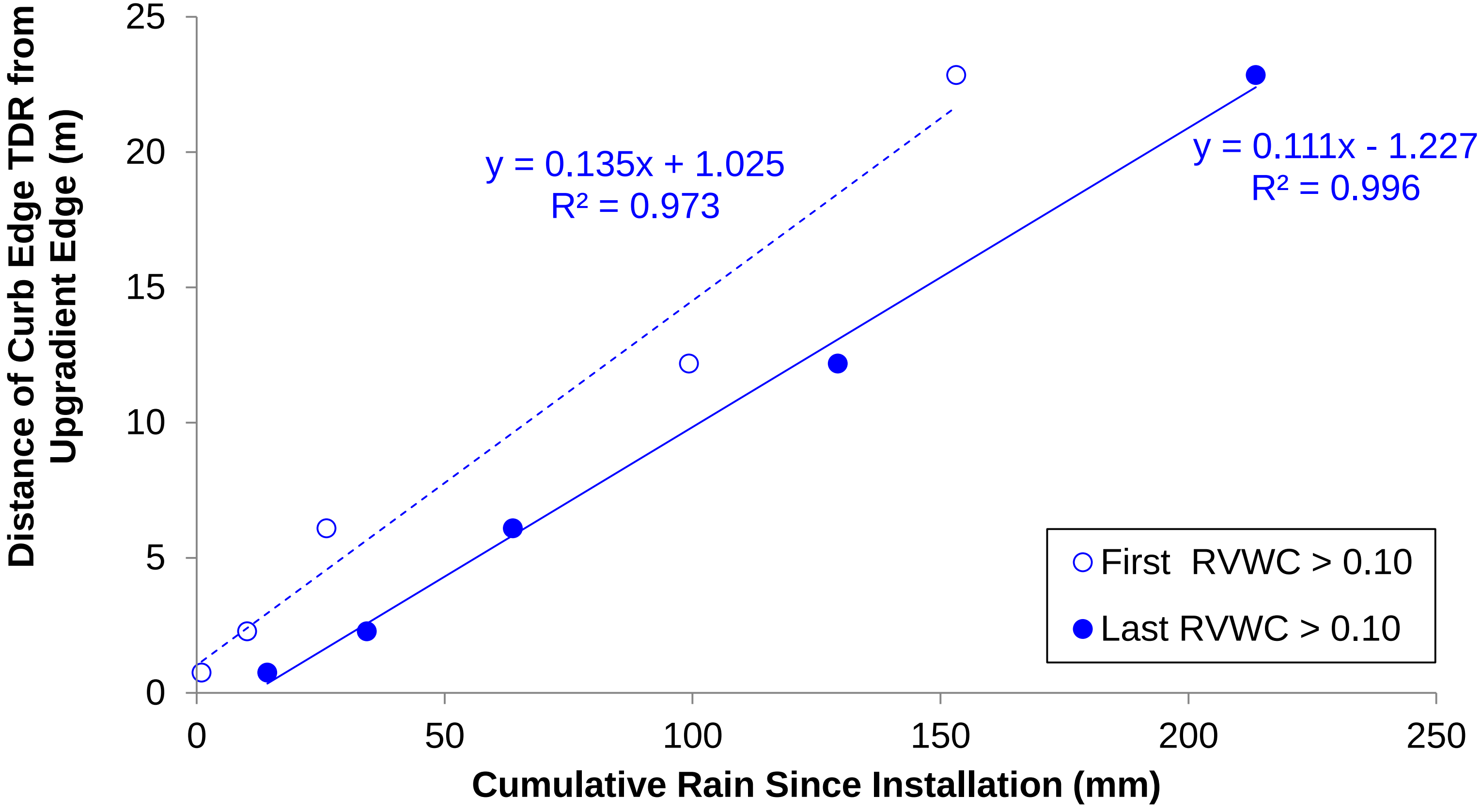
Louisville Control 19G
TDR data at 1-minute intervals
Rainfall data at 5-minute intervals MSD rain gauge TR05

The curb edge TDR responses support the predicted clogging progression.



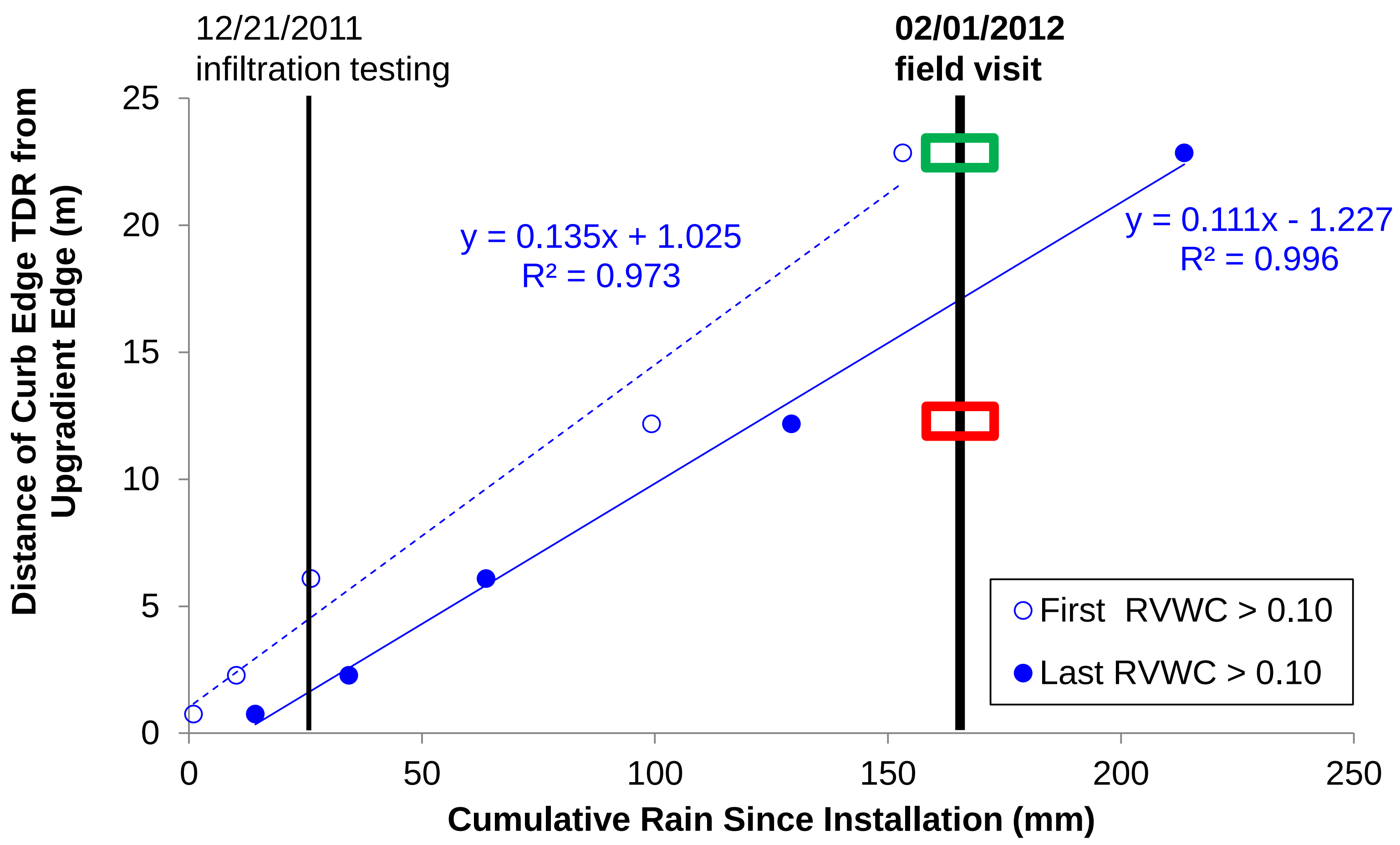
Data before 1st Maintenance
Control 19G
Length: 36.6 m

The TDR response can be used to determine the control's longitudinal clogging rate as a function of rainfall.



Control Louisville 19G
Response threshold 0.10 RVWC
The initial clogging rate was about 0.123 m per mm (10 ft per inch) of rain.

Infiltration tests and field visits were used to support the threshold selection.



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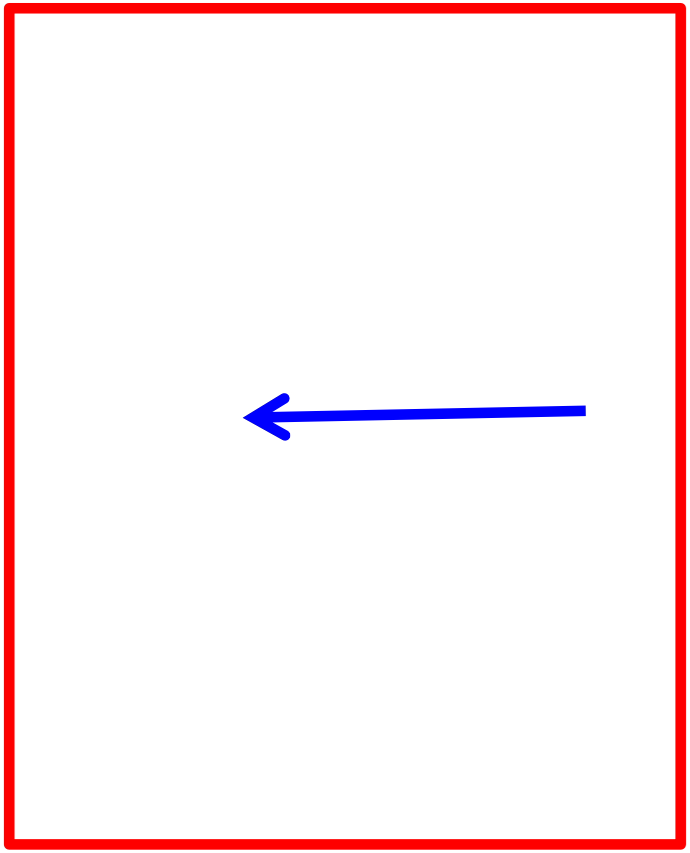
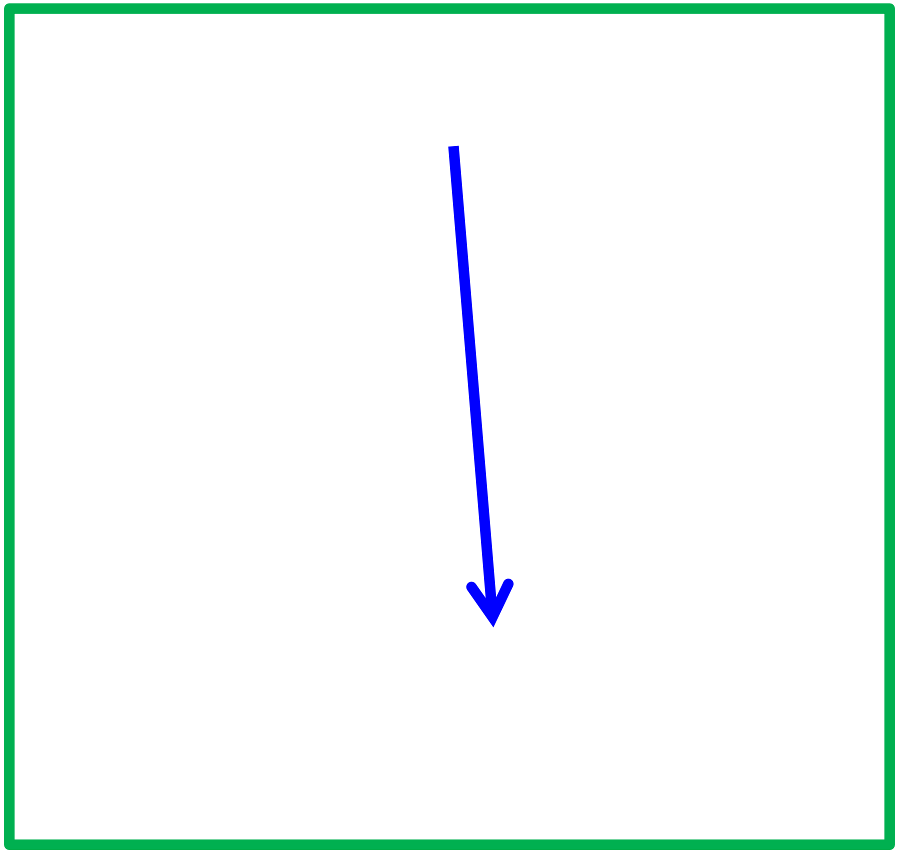
Visual inspection on February 1, 2012 confirmed where a surface was clogged.



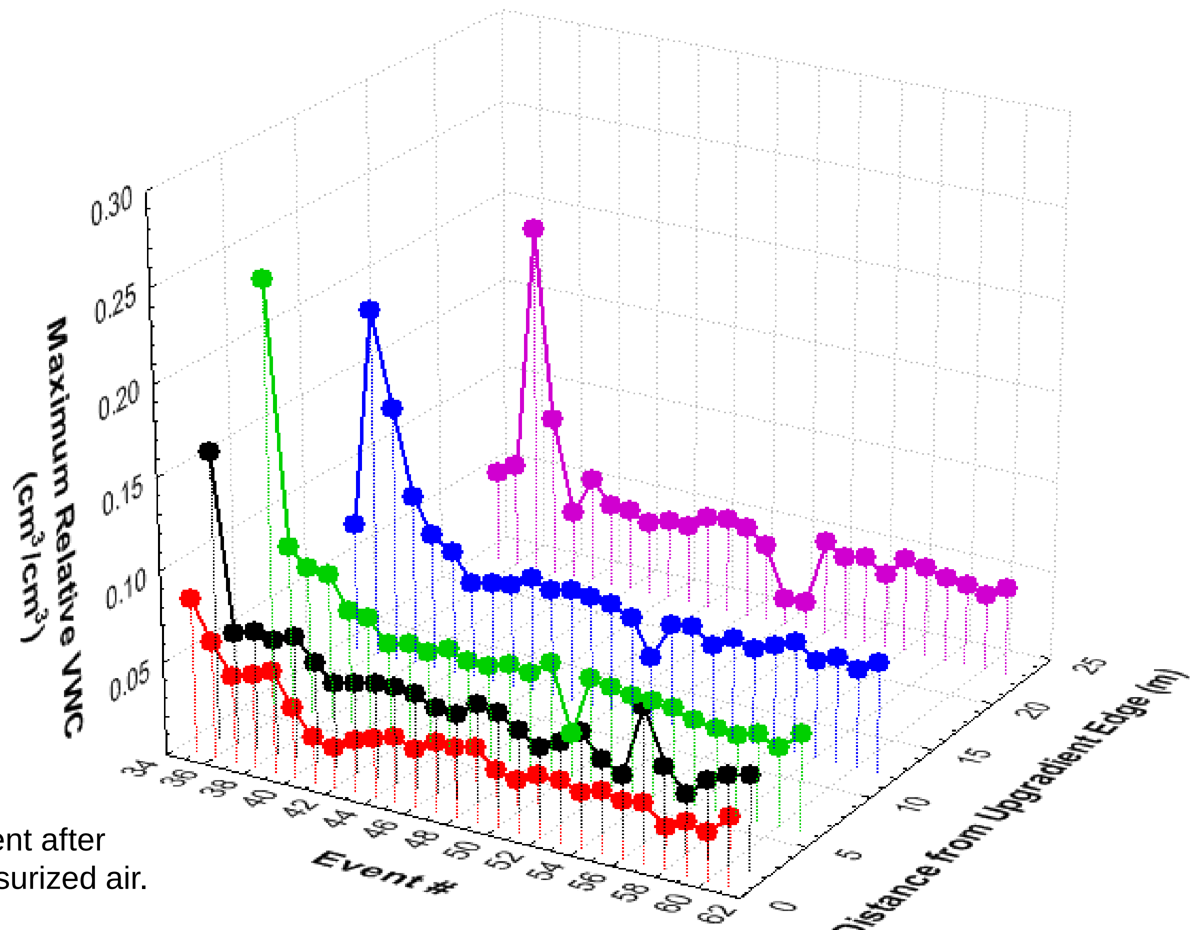
Control 19G
Length: 12.2 m



Control 19G
Length: 22.9 m

Photo: Josh Rivard
University of Louisville

TDR responses after maintenance could be used to evaluate effectiveness.



infiltration capacity was not restored

Event #35 was first event after maintenance with pressurized air.

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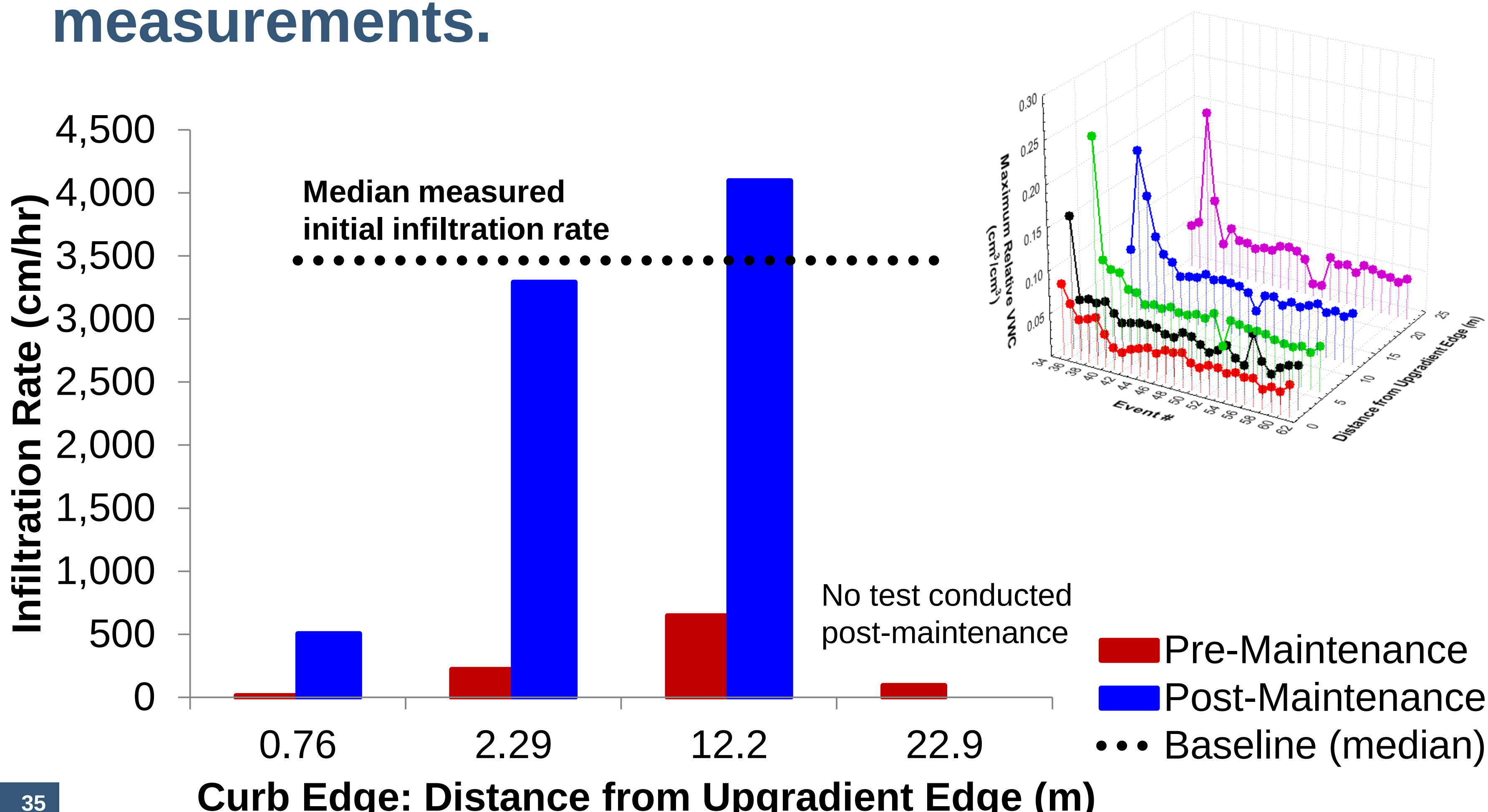
Manual infiltration tests supported electronic measurements.



Manual measurements made using ASTM C1701
Data source: University of Louisville.

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Hydrologic processes

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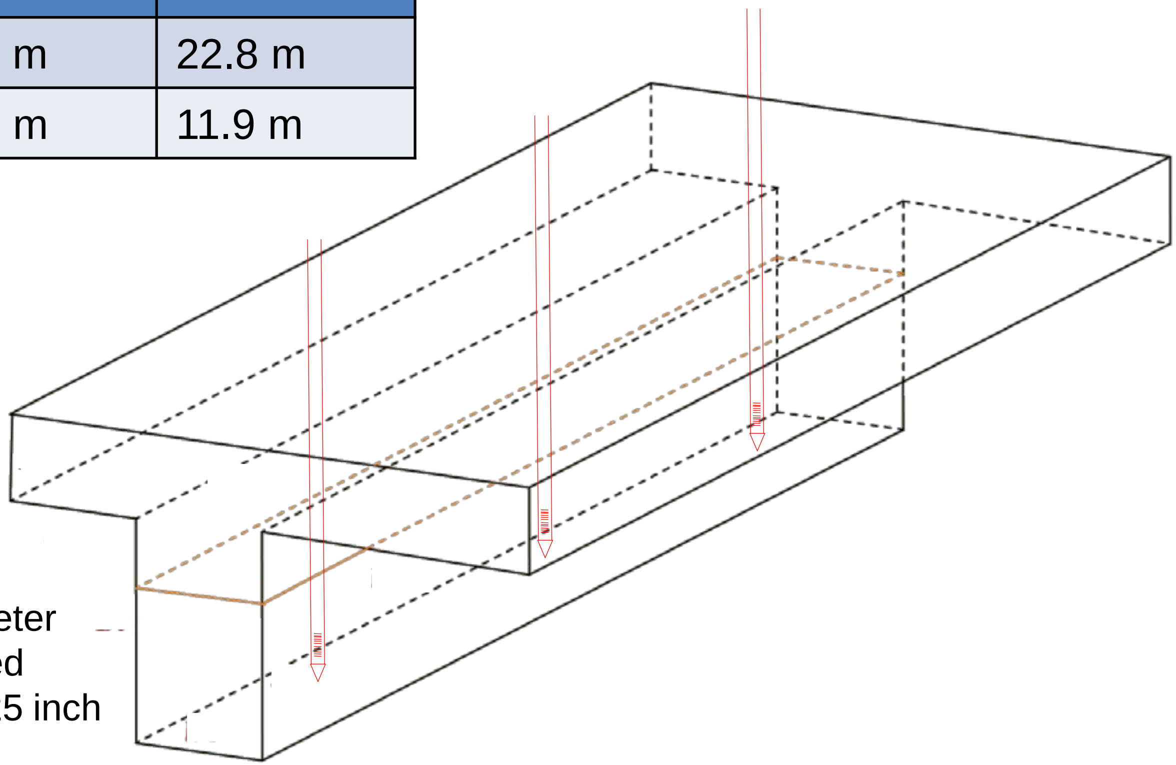
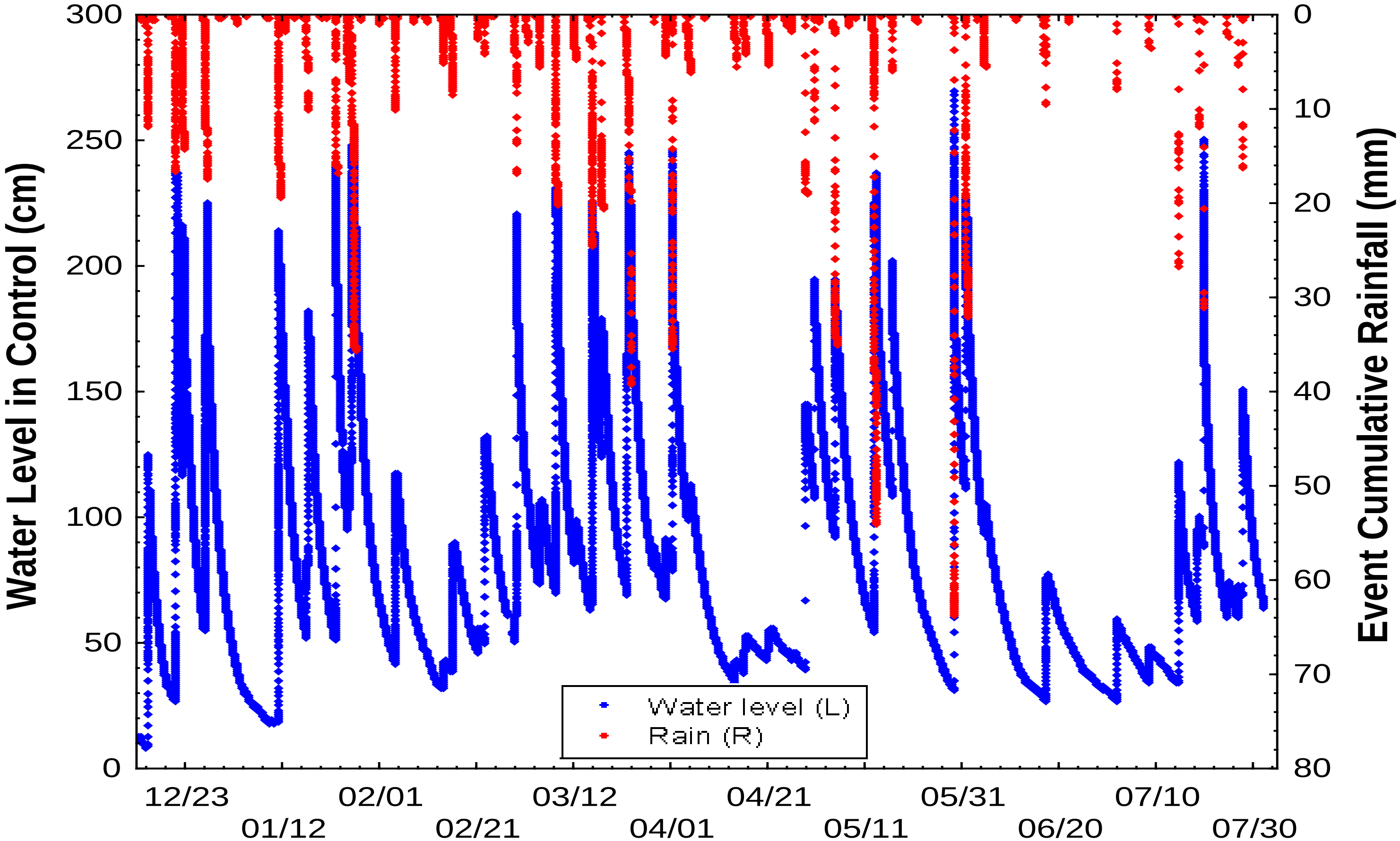
A set of three pressure transducers in piezometers measure the water level rise and fall.

Control	Location 1	Location 2	Location 3
19G	0.7 m	12.2 m	22.8 m
19H	1.3 m	6.1 m	11.9 m



Piezometers are 1 ½ inch diameter schd 40 PVC with 12 inch slotted length (0.02-inch slots with 0.125 inch spacing) covered by well sock.

Water in the trench would typically be mostly drained before the next rain event.



Level : 1-minute data from 12/13/2011 through 07/31/2012
Rainfall: Average of 3 pixel NEXRAD data from MSD

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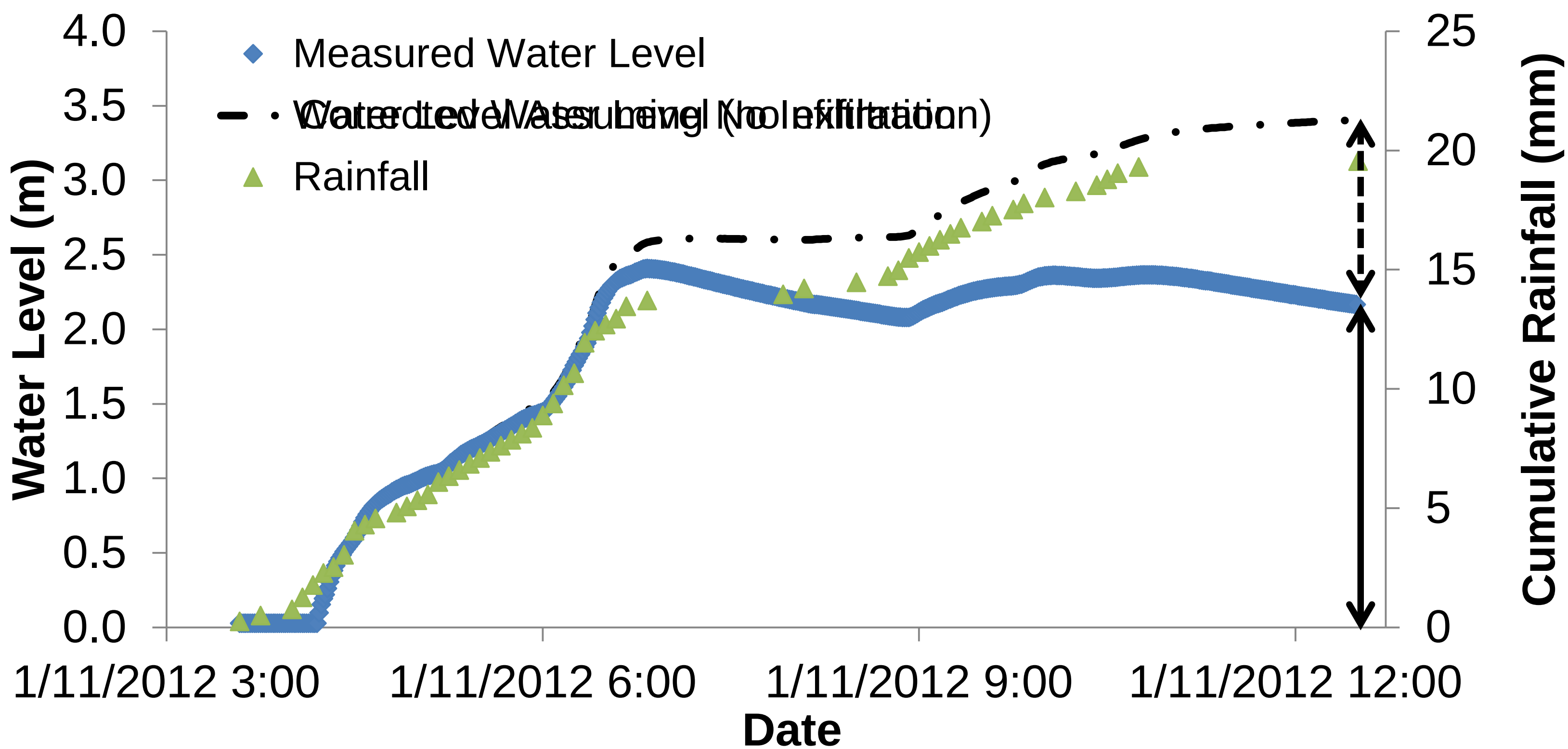
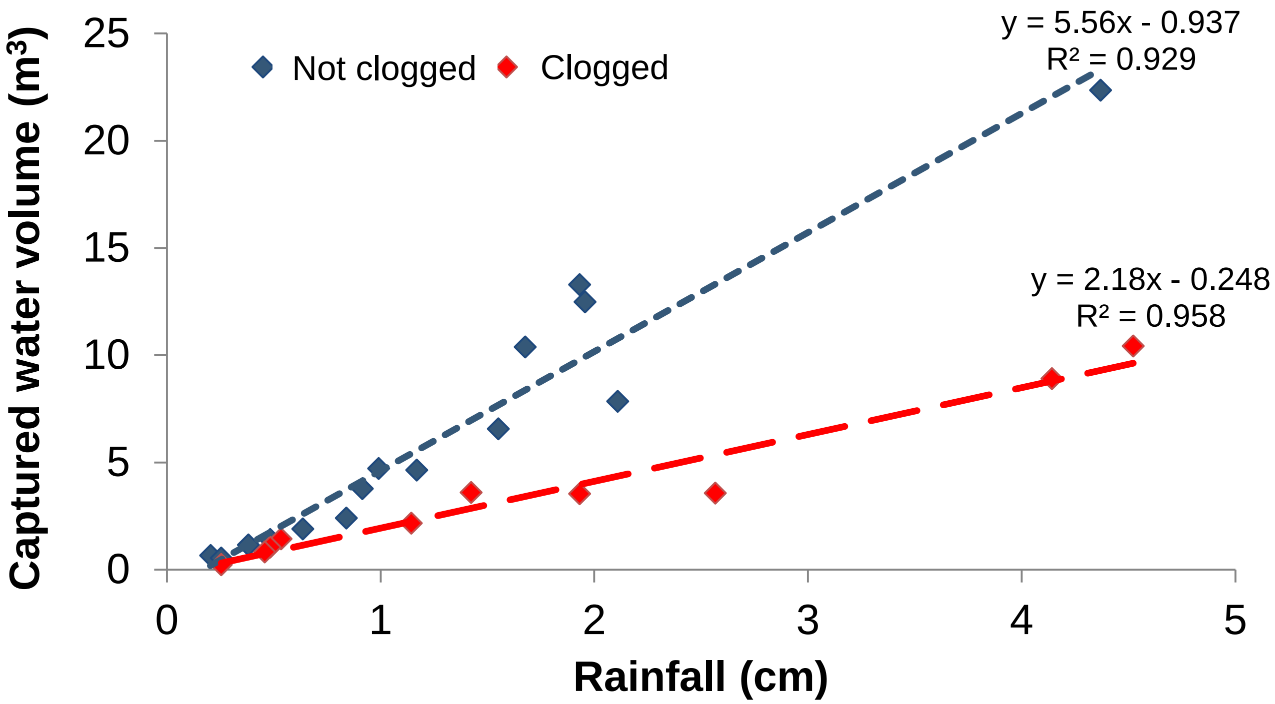
Water level was adjusted for intra-event exfiltration to calculate volume captured.



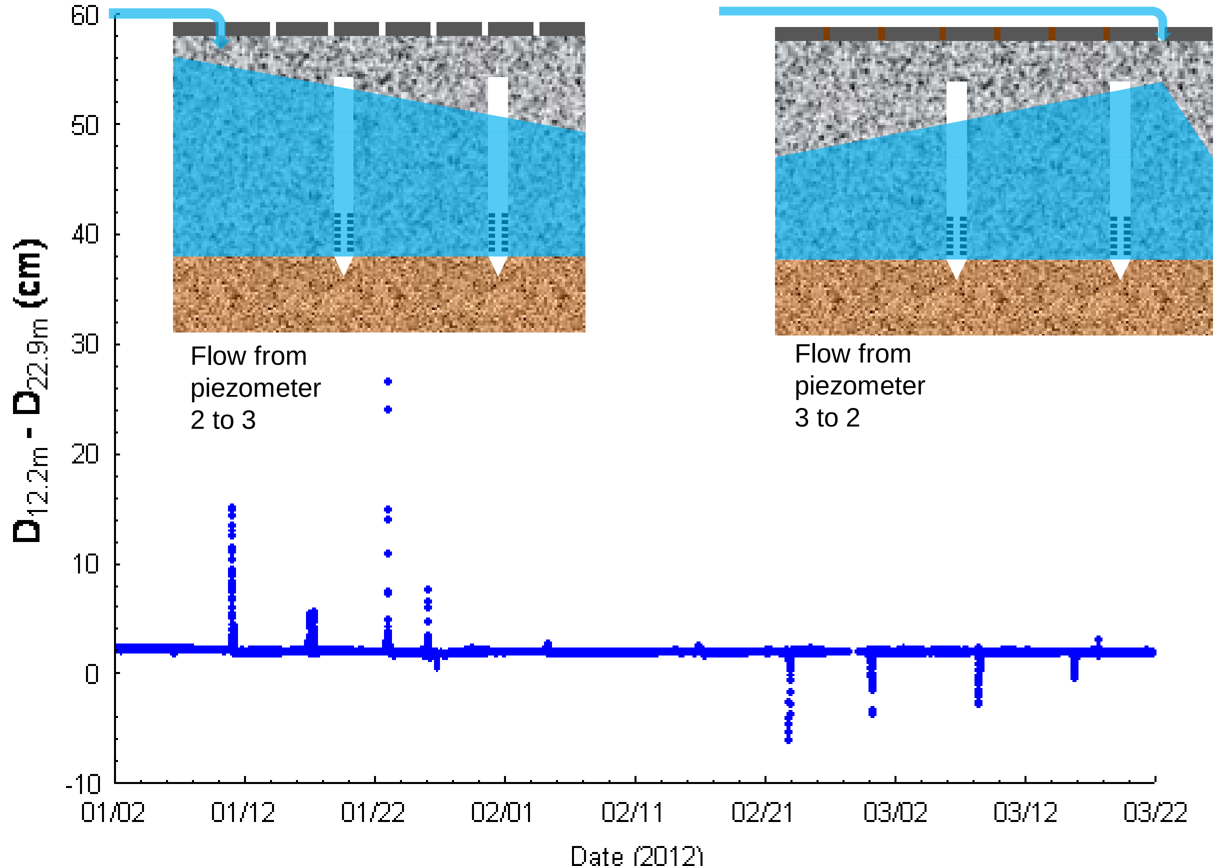
The data fall into two groups “not clogged” and “clogged.”



Louisville control 19H
Level data at 1-minute intervals
Rainfall data at 5-minute intervals MSD gauge TR05

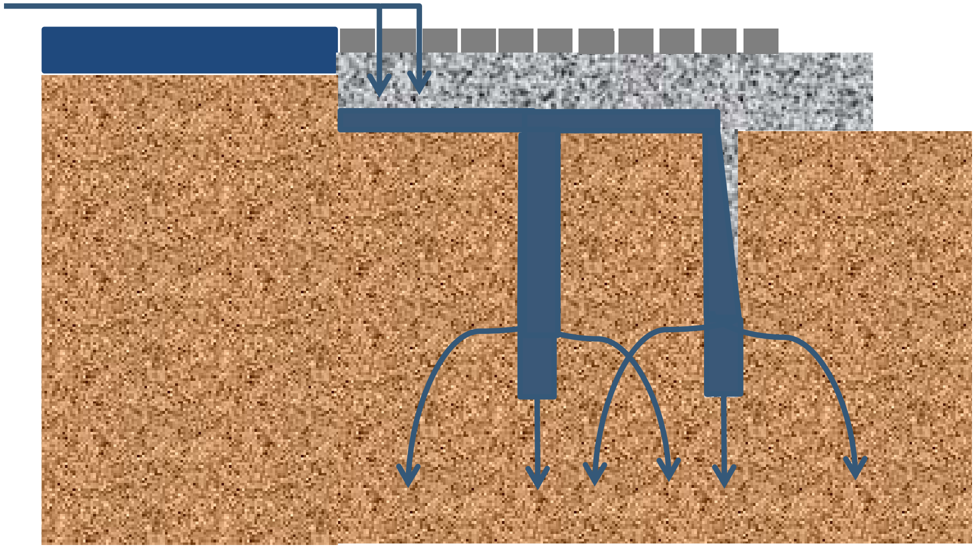
The gradient between the second and third piezometer reversed as clogging progressed.

Piezometer 2 is at 12.2 m and piezometer 3 is at 22.9 m from upgradient edge.



Louisville Control 19G
Level measurements at 1-minute intervals

Accumulated runoff enters the storage gallery and drains into the first available shaft.



Shafts were drilled until encountering a sand layer.

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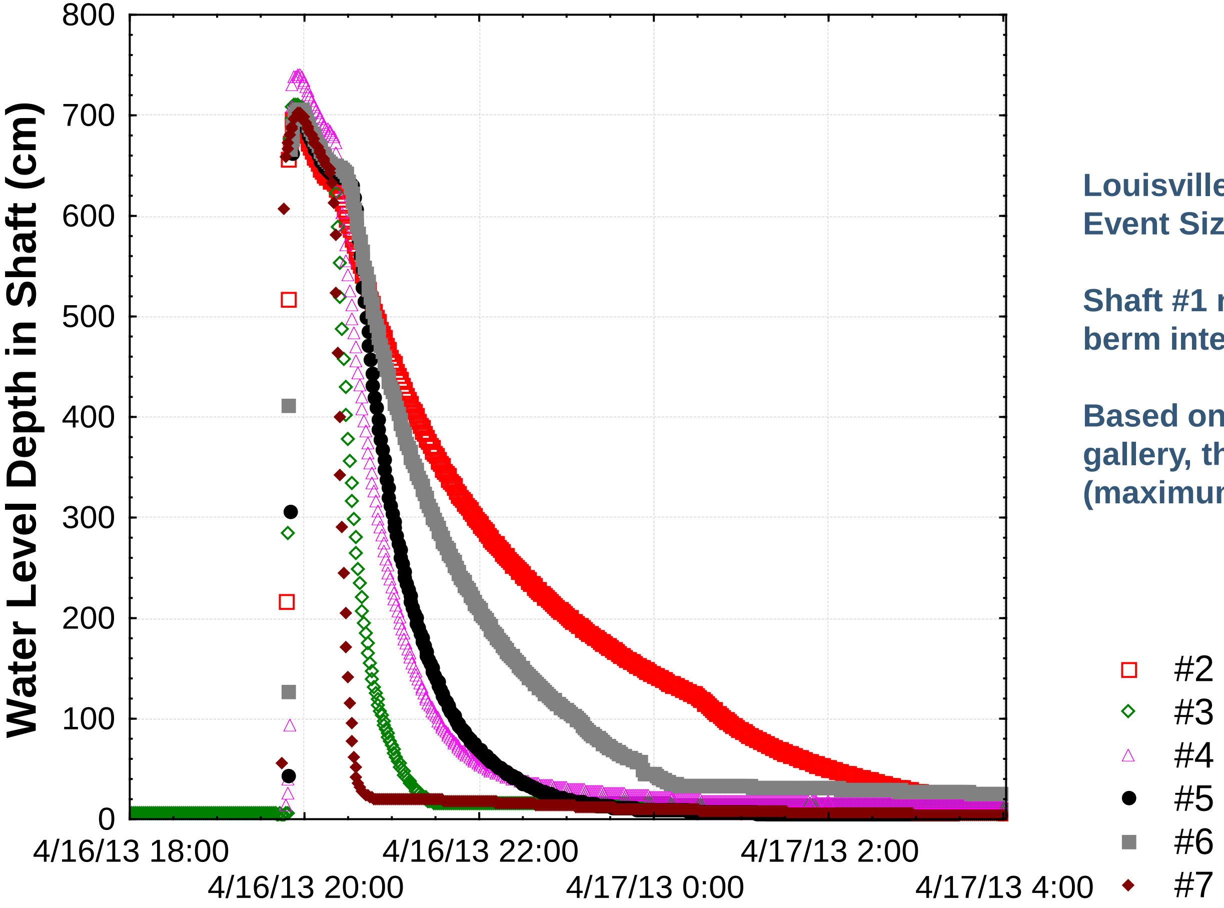
When full, the 21–22 ft deep shafts in 14D can drain completely within 30 minutes to 5 hours.



Louisville Control 14D
Event Size: 18.6 mm (0.73 in.)

Shaft #1 not depicted because internal berm interfered with shaft filling.

Based on water level measured in storage gallery, this entire event infiltrated (maximum water level was 47 cm).

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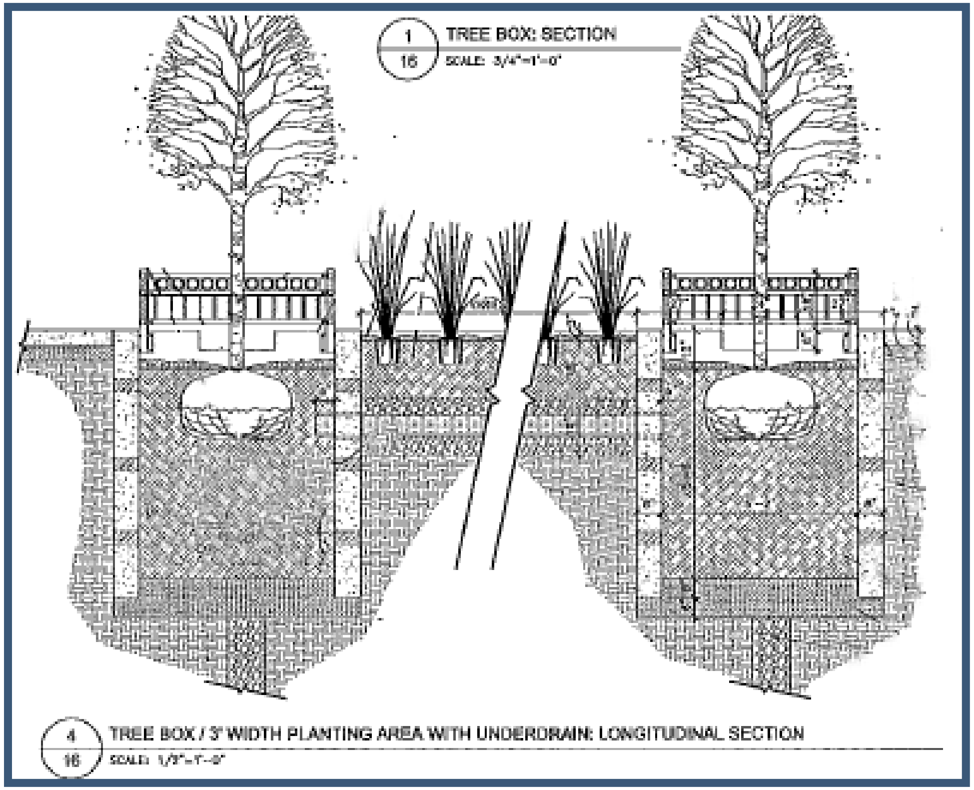
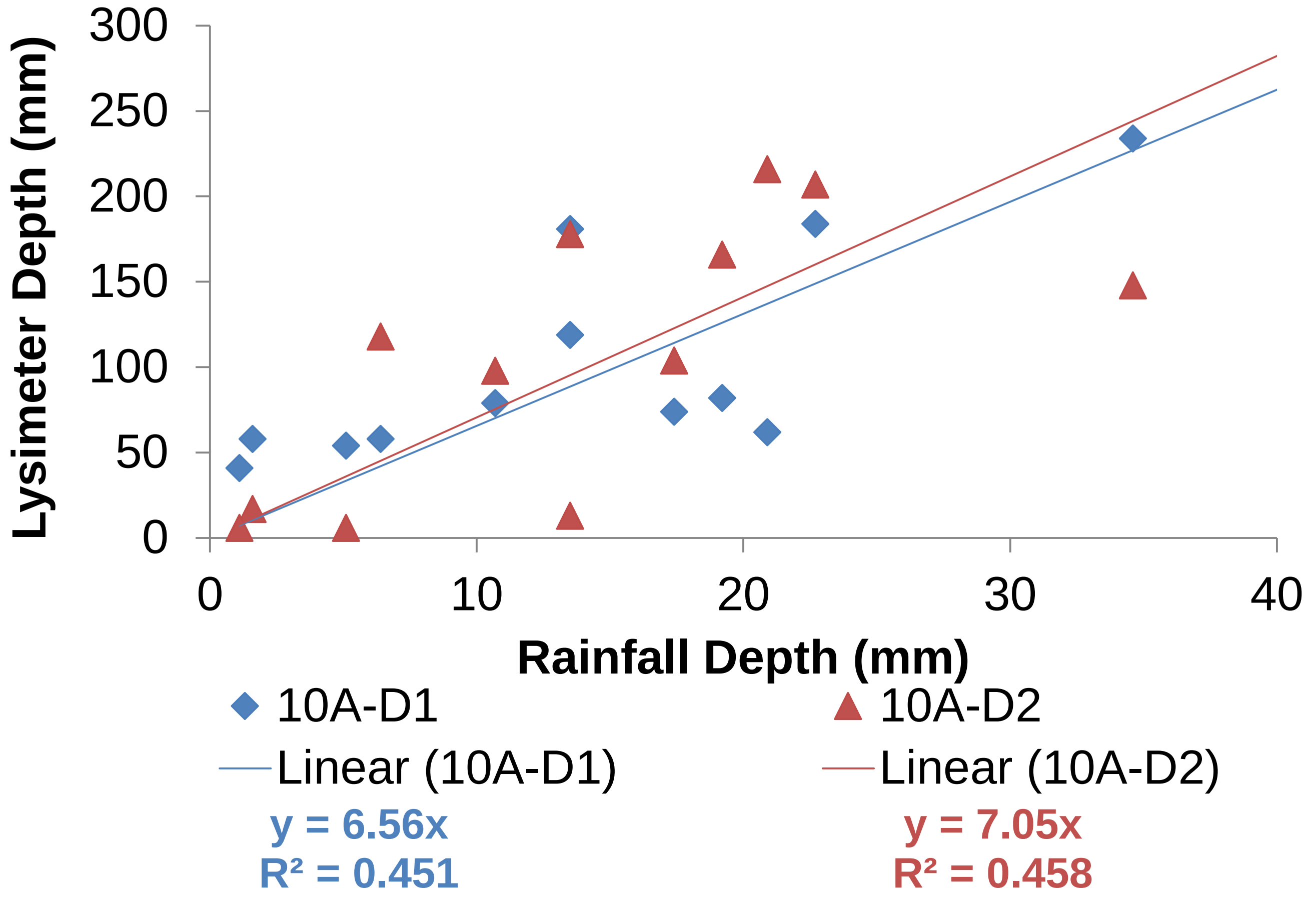
We instrumented two sets of three tree boxes that were installed in groups of two or three with a connecting infiltration trench.



The passive capillary lysimeter measured the hydraulic loading ratio of infiltrating runoff into the tree box media.



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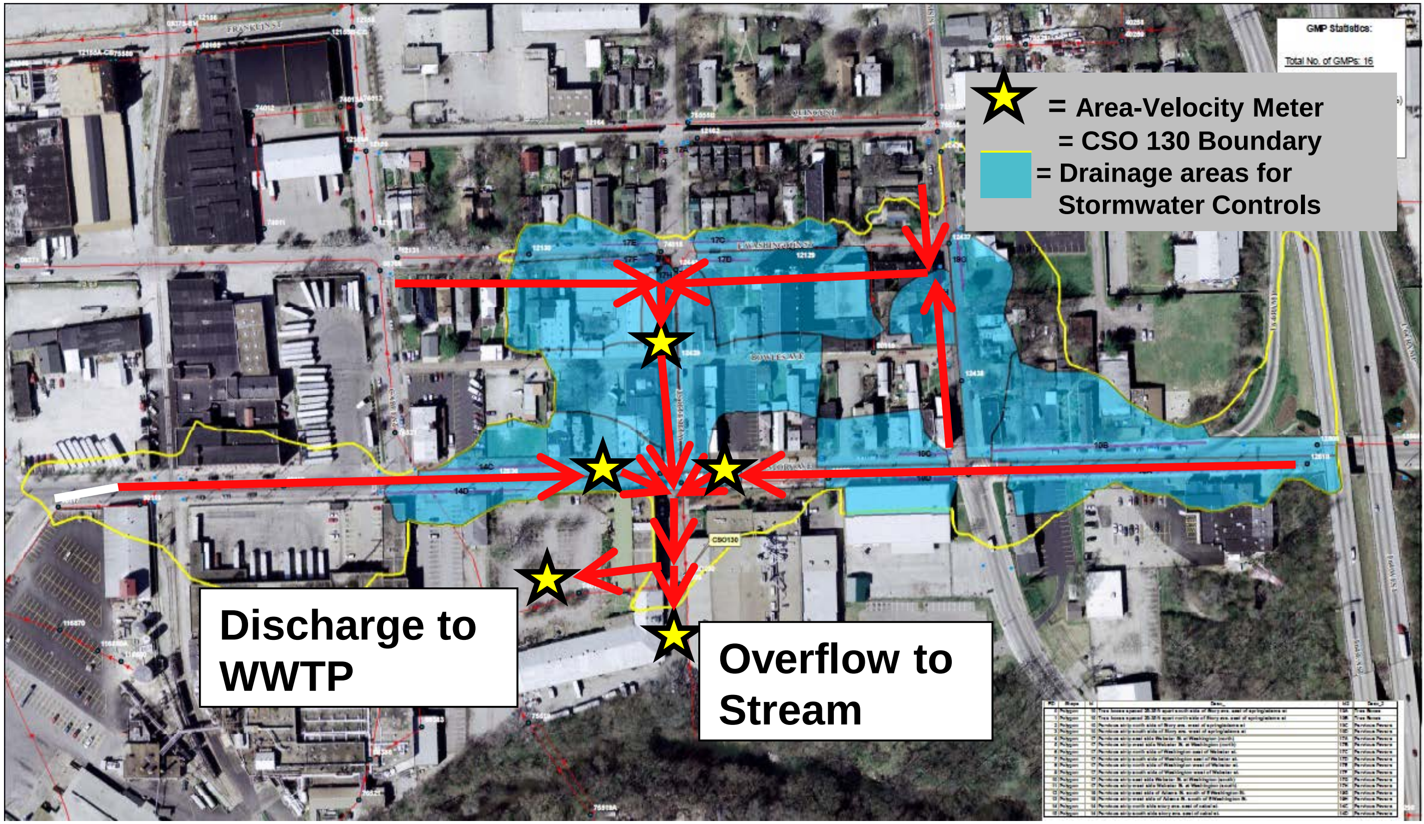
EFFECTIVENESS

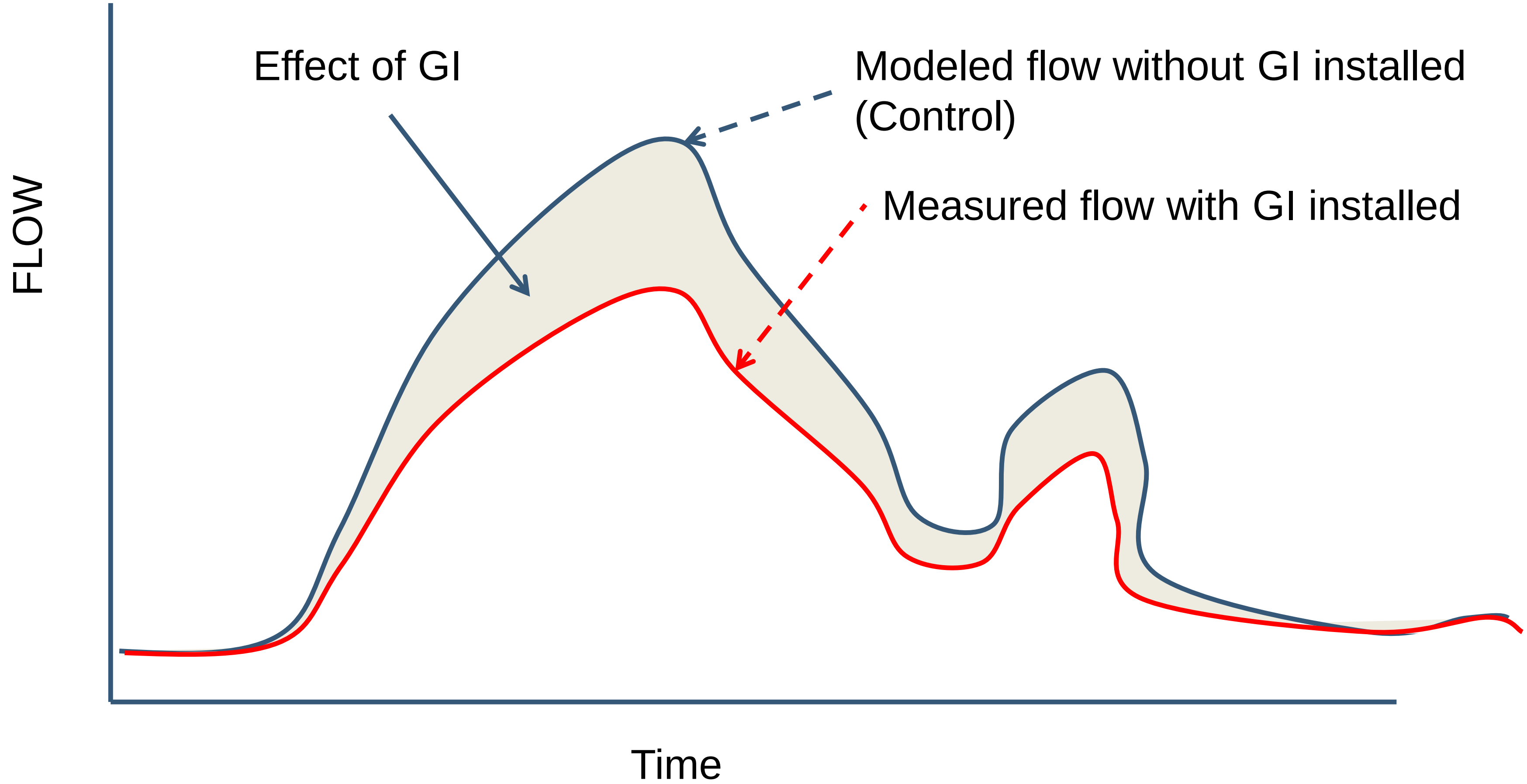
A collection of five flow meters were installed to evaluate effectiveness of groups of controls.

Meters were installed one year before planned construction for this effort and to get design information.

Later data to be used for post construction monitoring needs.



Our plan is to compare modeled flow without GI installed to measured flow after GI has been installed.



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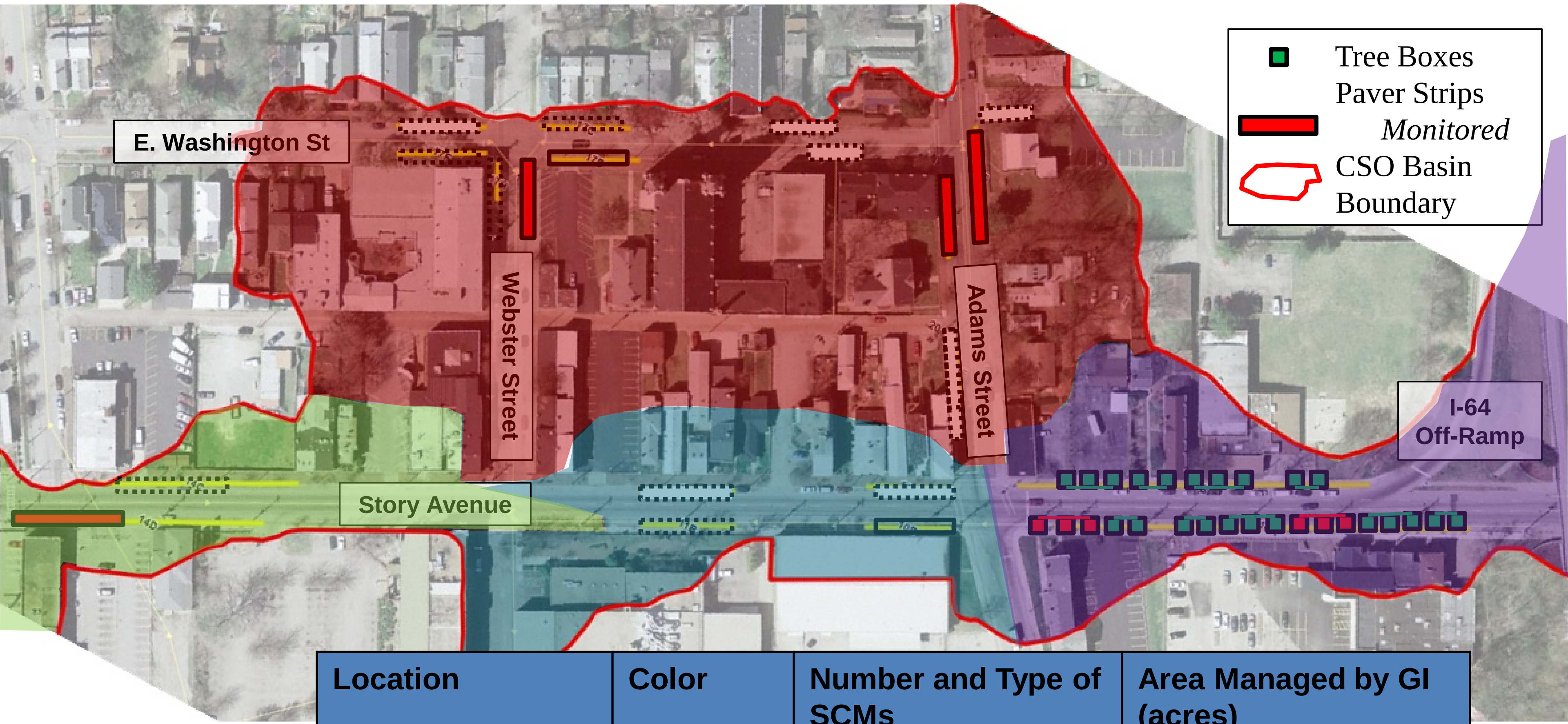
The flow meters allow separate analysis of effectiveness of different types of GI.

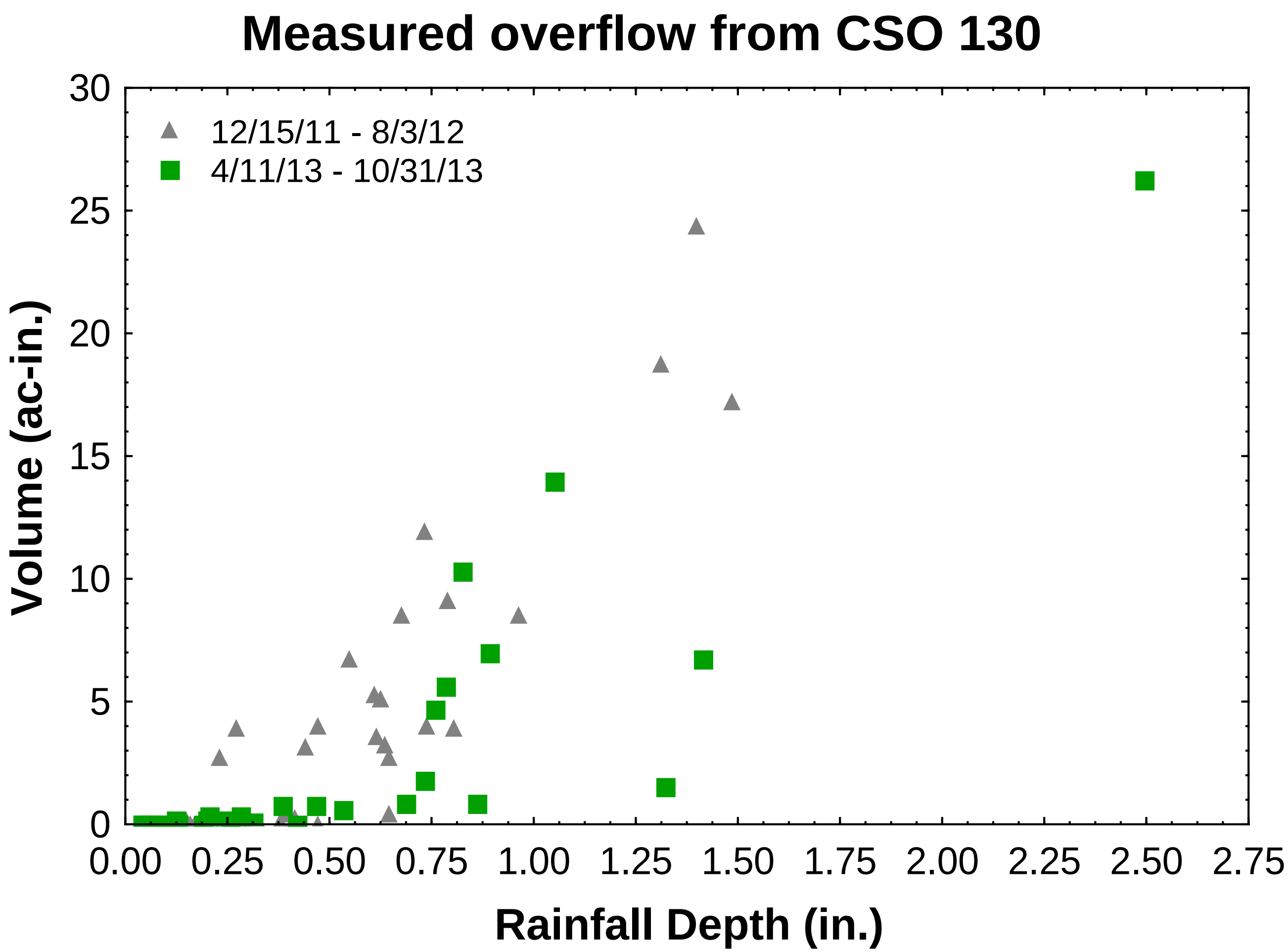


Location	Color	Number and Type of SCMs	Area Managed by GI (acres)
North of Story Ave.	Red	12 Paver Strips	7.54
West Story Ave.	Green	2 Paver Strips	1.29
Central Story Ave.	Blue	4 Paver Strips	1.44
East Story Ave.	Purple	28 Tree Boxes	2.08

So far, GI appears to manage all rain events through about 0.7 inches in this basin.

The target for this basin is to eliminate CSO from all rain events less than 1.09 inches.
(1.09 inch is the 9th largest rain event in the negotiated rain year.)

<u>Note</u>:
There is still ongoing work to disconnect rooftops from the CSS. Some GI practices came on line after April 2013.



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