United States Environmental Protection Agency

Some results of EPA Research on Permeable Pavement

Michael Borst
Engineer
U.S. Environmental Protection Agency
Edison, NJ

Site visit from NYC DDC, NYC DOT, and HD Inc.
August 7, 2017

Discussion with municipal and state decision makers emphasized two research needs often lacking in existing data.

- Real-world scale
- Long-term monitoring

EPA has ongoing permeable pavement research at three locations

- Edison, NJ
- Louisville, KY
- Fort Riley, KS

United States Environmental Protection Agency

EDISON, NJ

EPA
United States
Environmental Protection
Agency

To get measurements at the real-world scale, we need to be involved in the design stage.

In 2009, EPA designed and built a 1-acre parking lot for facility staff and visitors that was surfaced with three types of permeable pavement.

EPA Facility Parking Lot
Edison, New Jersey

Overall, construction took about a year.

November 26, 2008

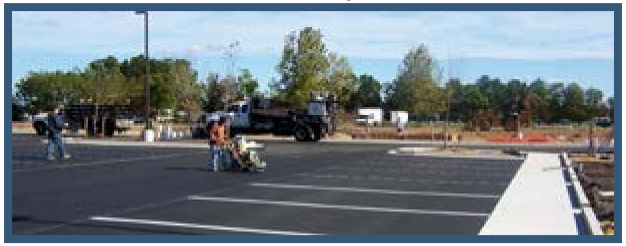
February 26,2009

March 25, 2009

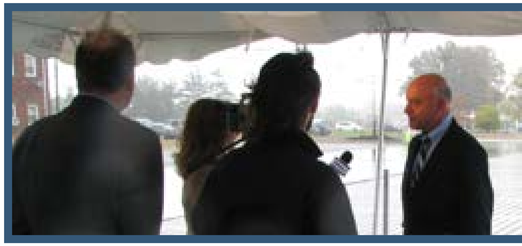
June 1, 2009

August 5, 2009

October 6, 2009

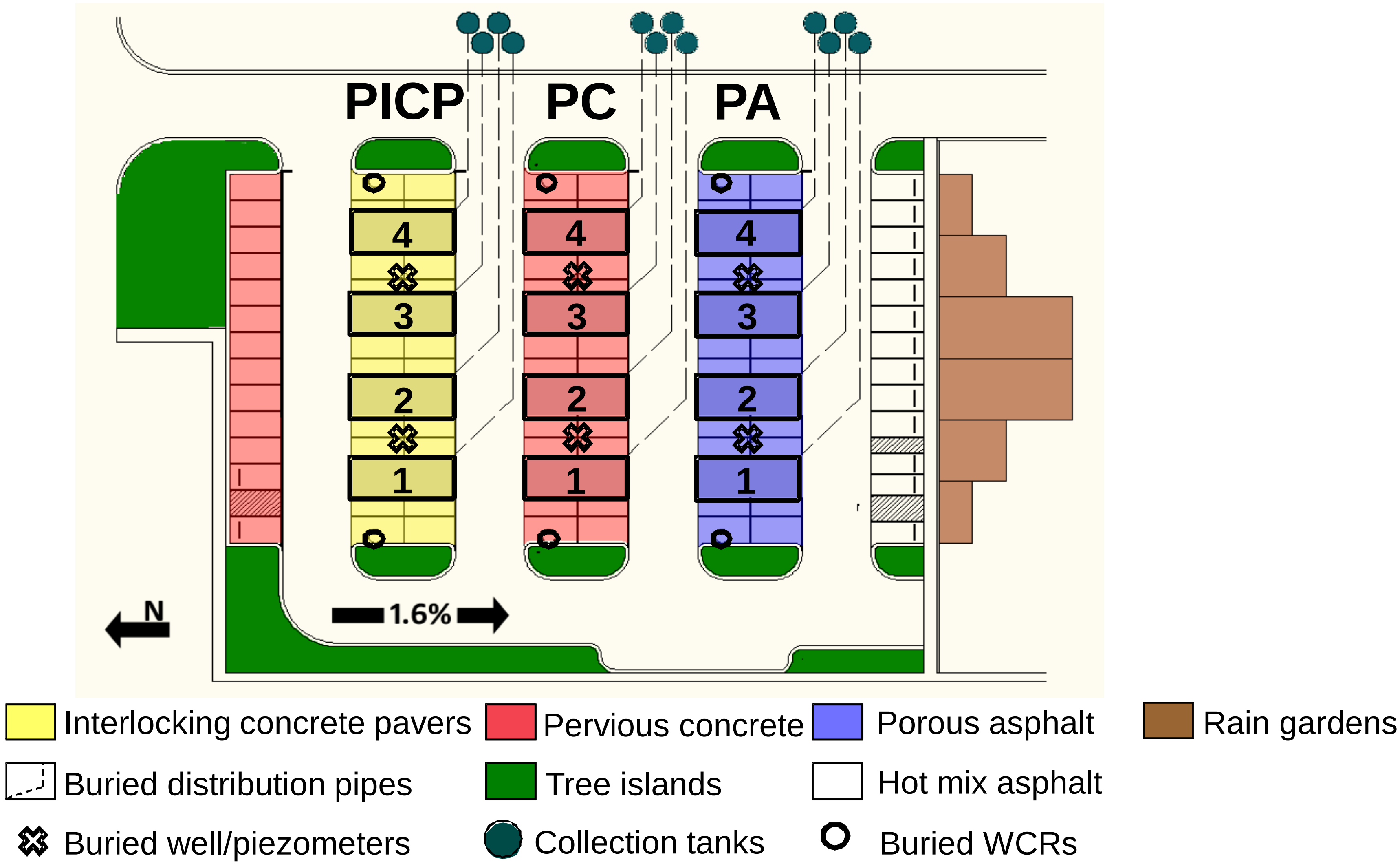


October 8, 2009



October 28, 2009

The design incorporated water quality and hydrologic monitoring capabilities.



Interlocking concrete paver installation took a little more than a week.

EPHenry EcoPavers

East Penn Pavement Company

EPA United States Environmental Protection Agency

The porous concrete pour took two days followed by a week of covered cure time

Weldon Concrete

Nova Crete, Inc.

EPA
United States
Environmental Protection
Agency

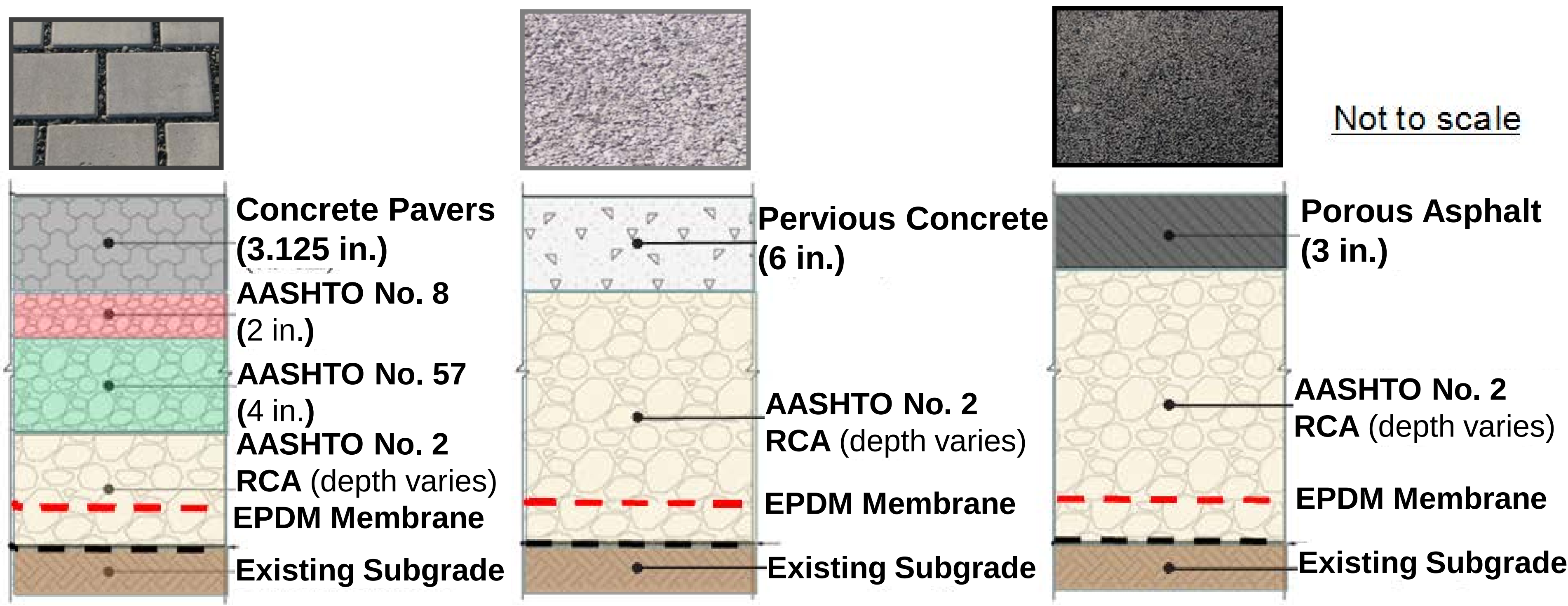
Placing the porous asphalt took two days.

Stavola, Inc.

Stavola, Inc.

United States Environmental Protection Agency

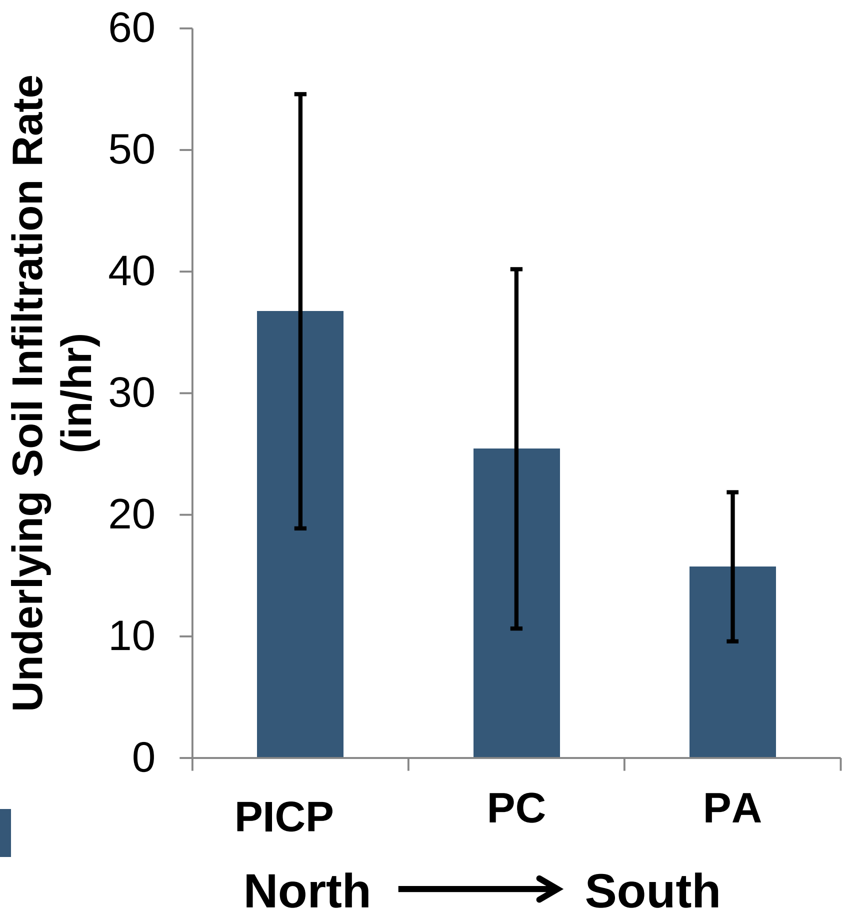
Vertical cross sections of permeable sections varied slightly from material to material.



Based on engineering drawings from Morris & Ritchie Associates, Inc. 2009

United States Environmental Protection Agency

Post excavation testing showed large infiltration rates for the underlying soil.



Four equally-sized and spaced lined sections collect infiltrating water from each monitored permeable surface with the balance infiltrating to the underlying soil.

Infiltrate drains from the lined sections to 1,500-gallon tanks on the east side of the parking lot where it can be sampled.

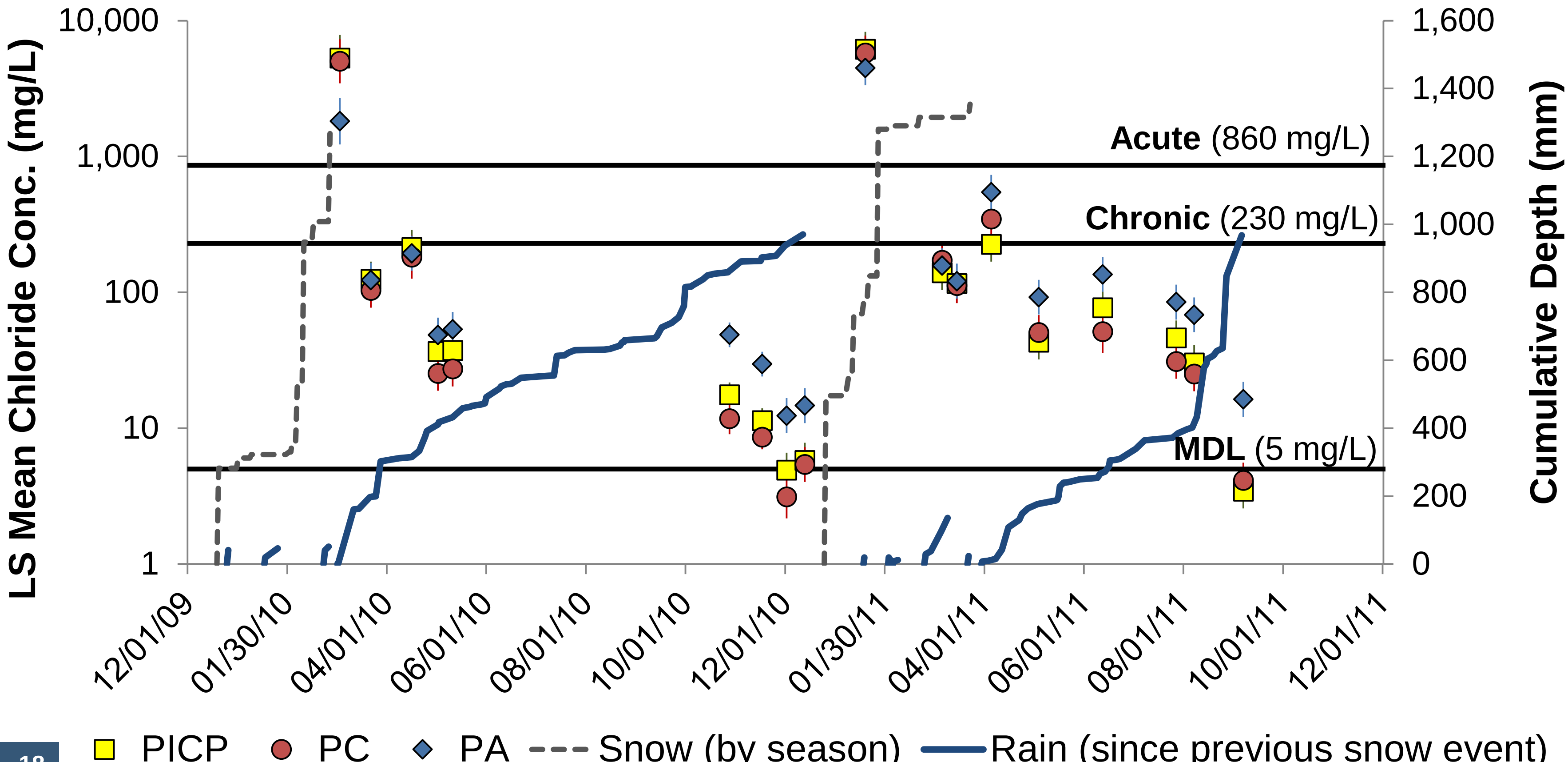
The tanks are designed to collect a 1.5-inch rain event before bypassing.

EPA
United States
Environmental Protection
Agency

We mange snow and ice with calcium chloride (with no sand) and a rubber edged plow blade.

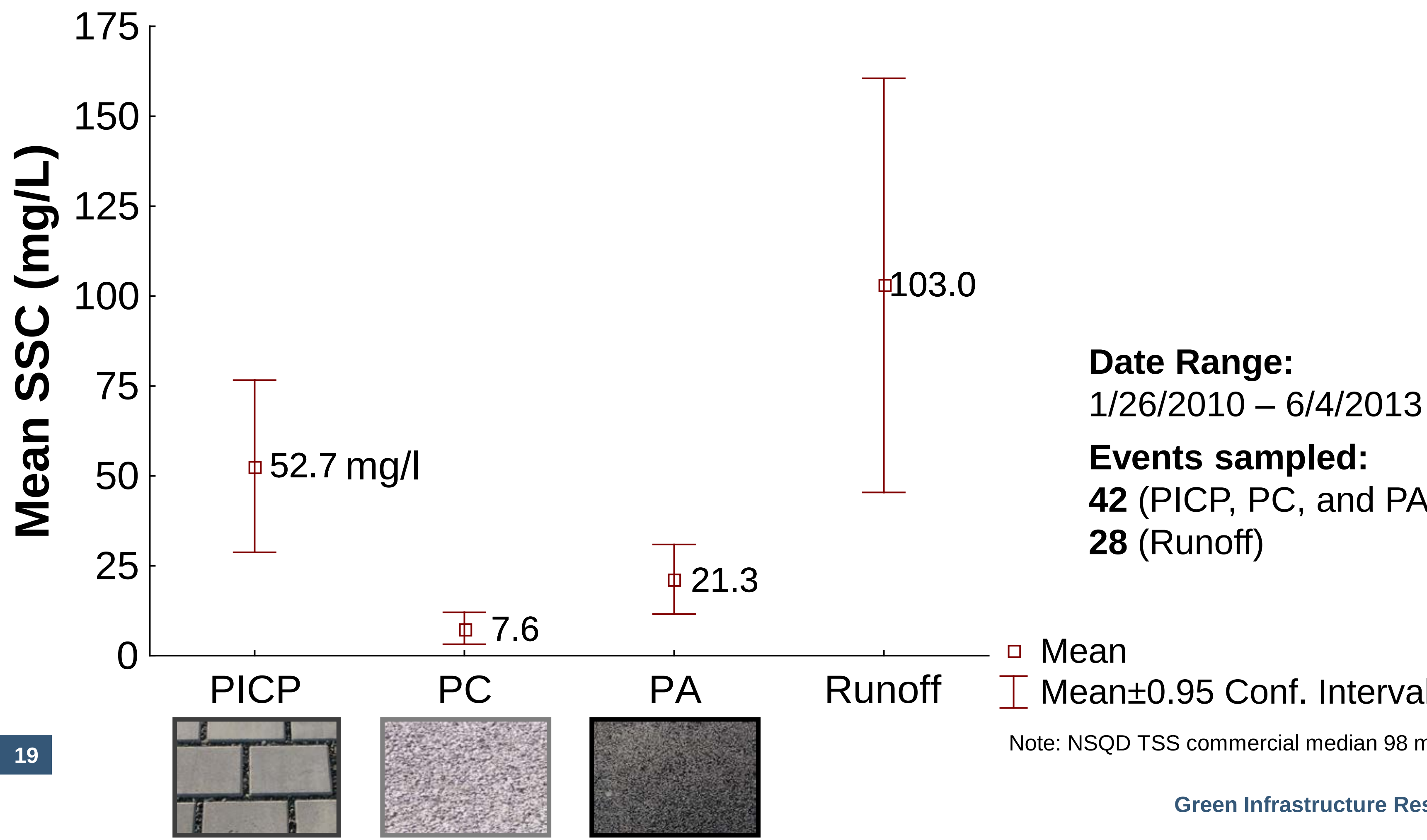
United States Environmental Protection Agency

After winter salt application, chloride concentration decreases throughout the remainder of the year.



Bars represent 95% confidence intervals; snowfall data from NJ State Climatologist.

All permeable surfaces reduced Suspended Solids Concentration (SSC) to different degrees.

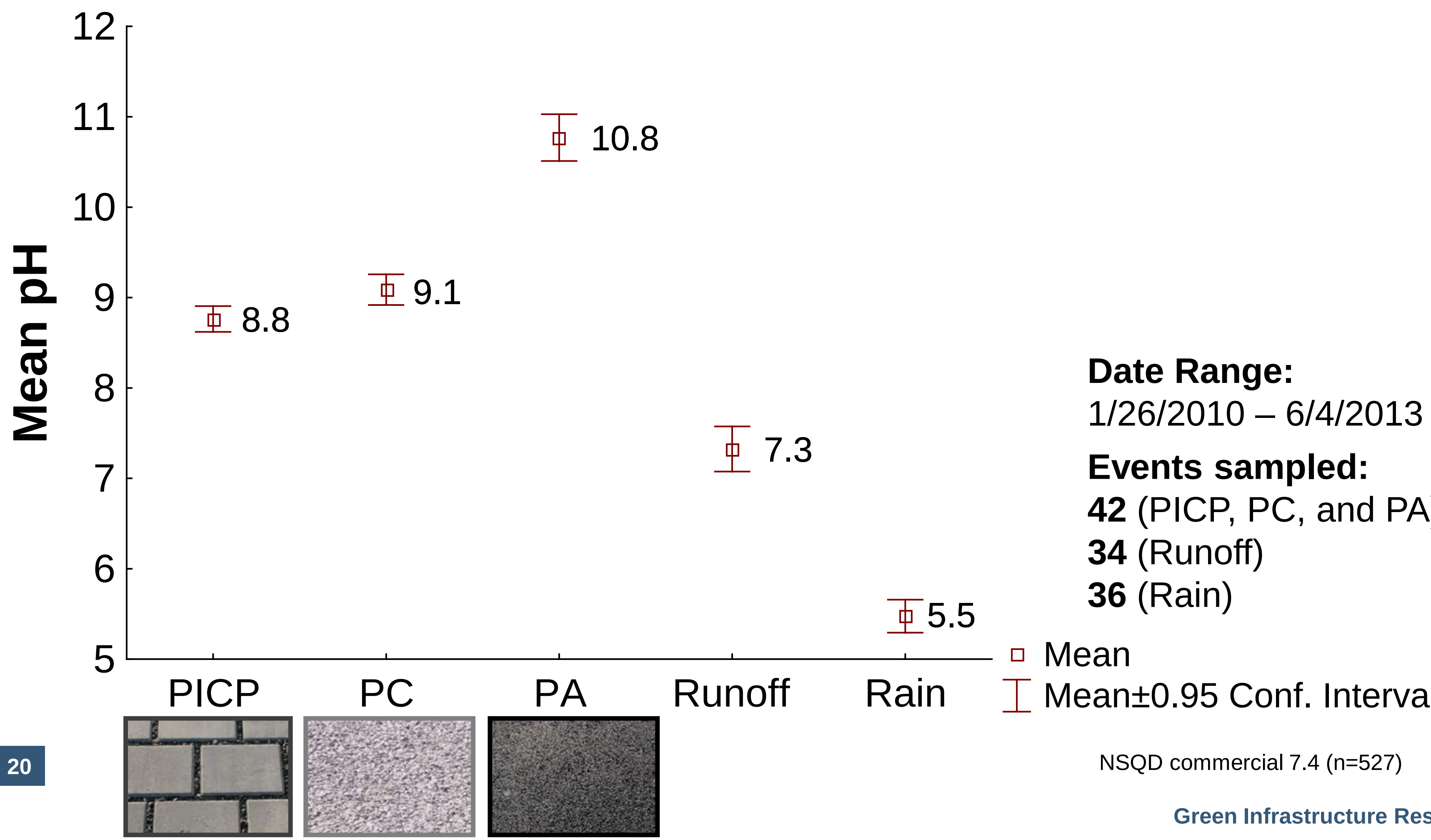


Date Range:
1/26/2010 – 6/4/2013

Events sampled:
42 (PICP, PC, and PA)
28 (Runoff)

Note: NSQD TSS commercial median 98 mg/L

Acidic rainfall is buffered by all pavement surfaces, but the pH of the PA exfiltrate is surprisingly high.



NSQD commercial 7.4 (n=527)

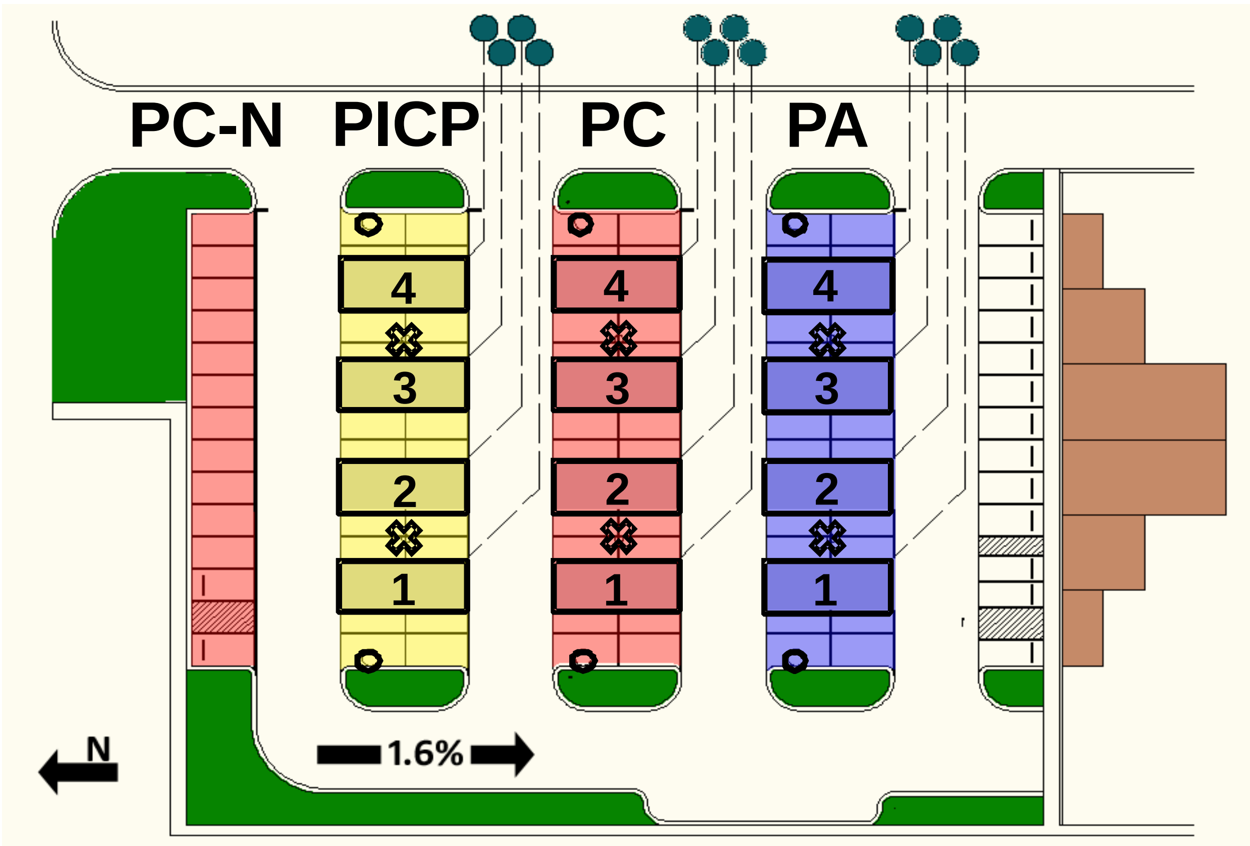
United States Environmental Protection Agency

SURFACE INFILTRATION & SURFACE CLOGGING

We measured surface infiltration rates using a modified version of ASTM C1701 at roughly monthly intervals for about three years.

Modifications were
(1) how the seal was achieved between the ring and the surface
(2) added temperature measurements of surface and water.

We monitored the four permeable sections.



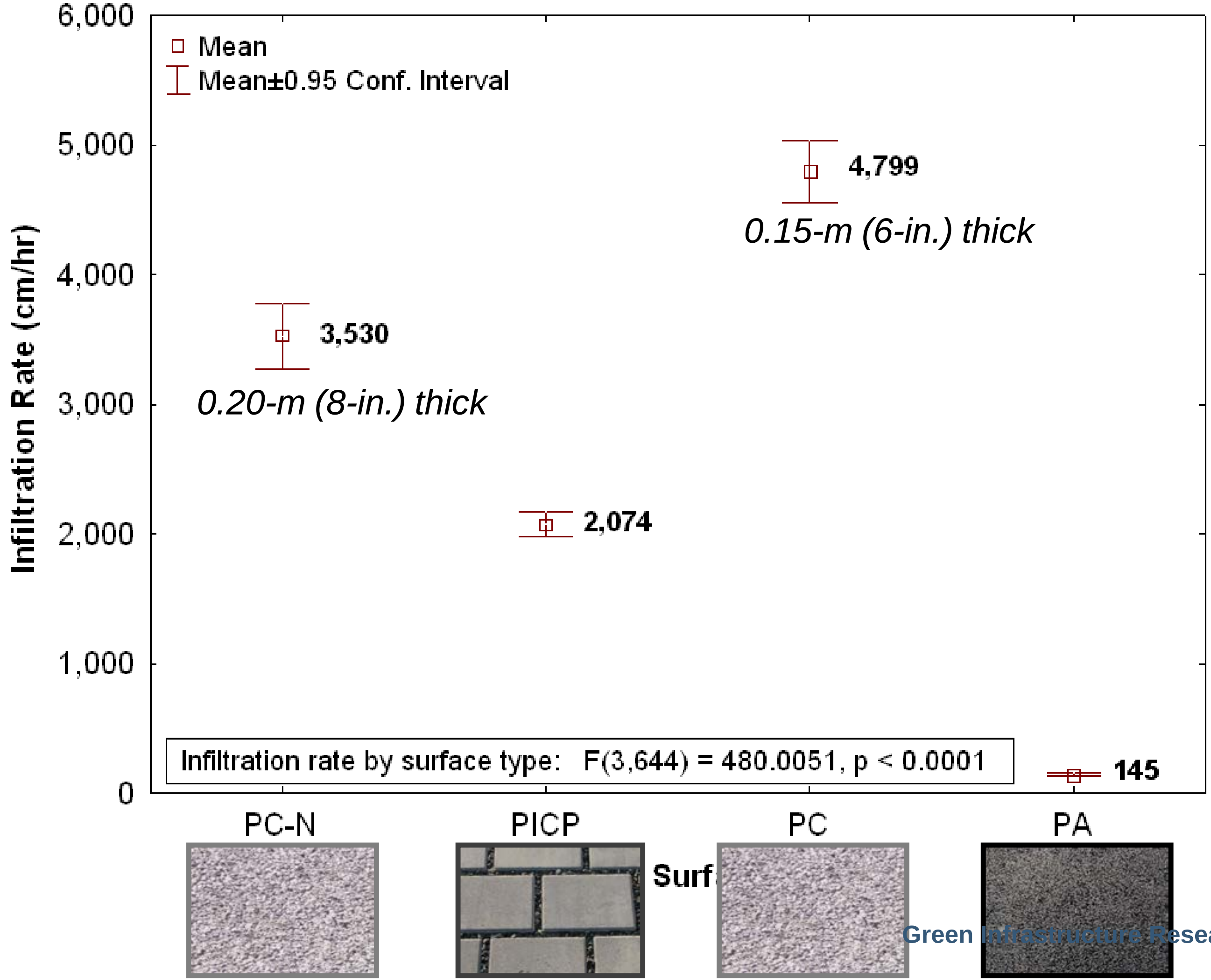
Interlocking concrete pavers | Pervious concrete | Porous asphalt | Rain gardens
Buried distribution pipes | Tree islands | Hot mix asphalt
Buried well/piezometers | Collection tanks | Buried WCRs

The infiltration rate varies among the four tested surfaces, but all surfaces are sufficient to handle maximum expected direct rainfall rates.

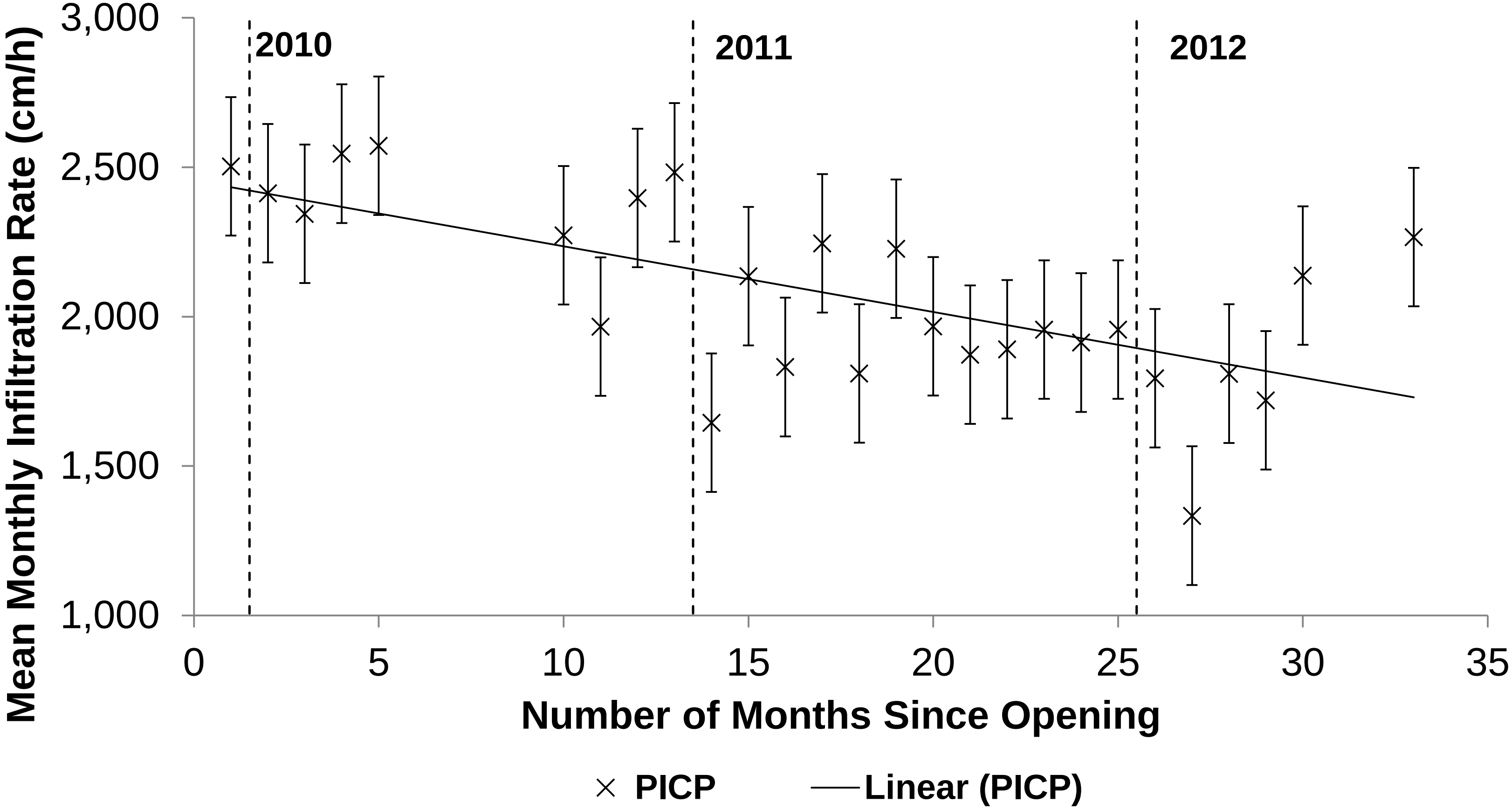
100-year, 5-minute rainfall intensity

- <u>Edison, NJ</u>

20.8 cm/hr (8.2 in/hr)



Infiltration decreased with age for the three surfaces that received run-on from driving lane.

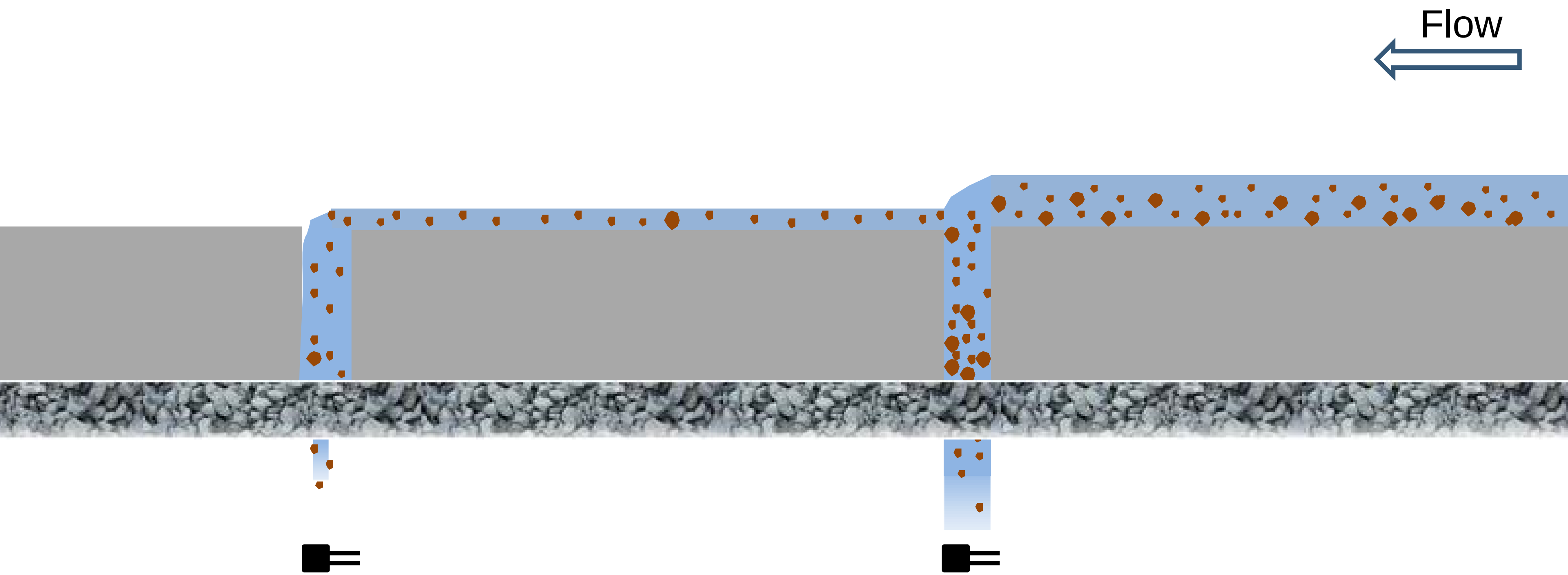


$y = -21.97x + 2455$
$R^2 = 0.4194$
$p = 0.0003$

Bars represent standard error.

EPA United States Environmental Protection Agency

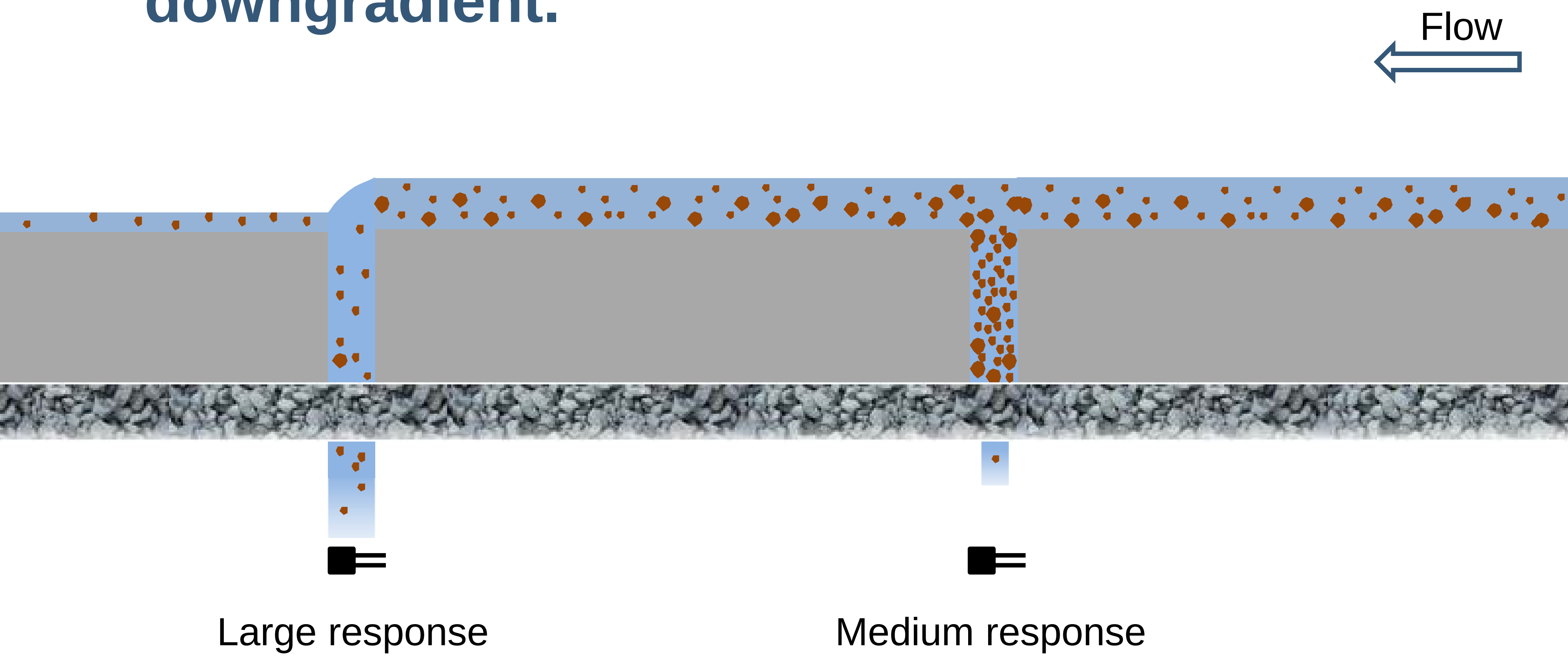
We developed a working hypothesis of the mechanics of the infiltration processes.



Small response

Large response

As gaps fill with sediment, the location of the primary infiltration area moved downgradient.



United States
Environmental Protection
Agency

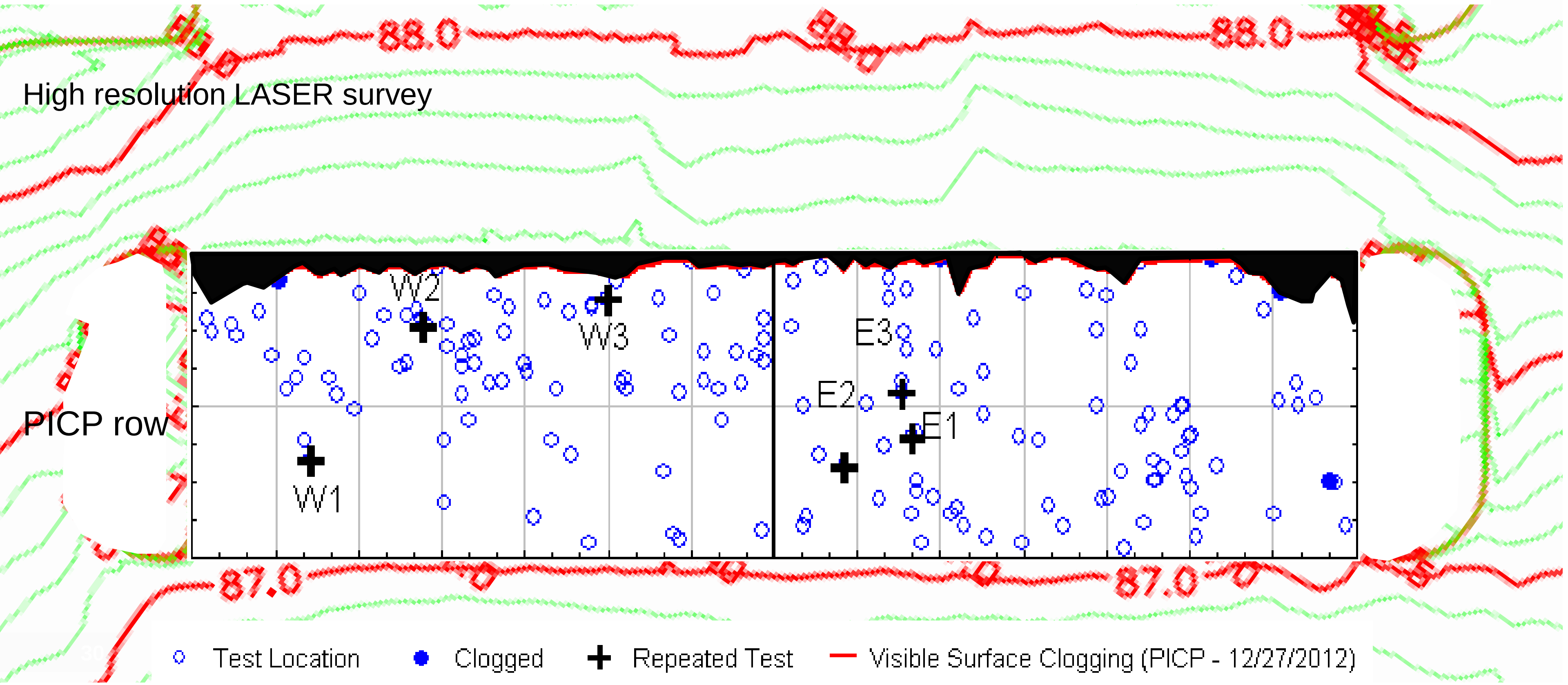
Inspection supports the proposed mechanism.

The progressive accumulation was also visible in the PICP section.

No sediment

Sediment

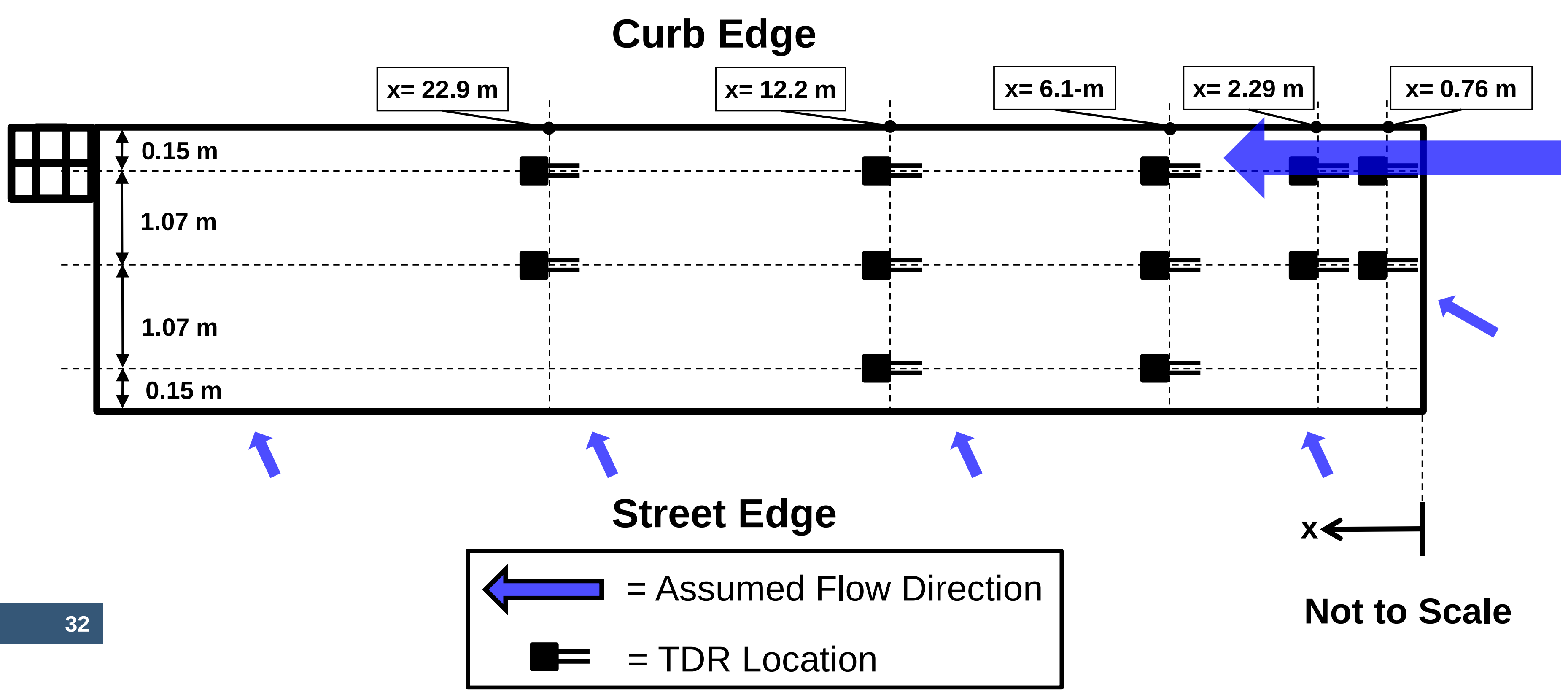
The surface clogging progression has varied slightly because of microtopography.



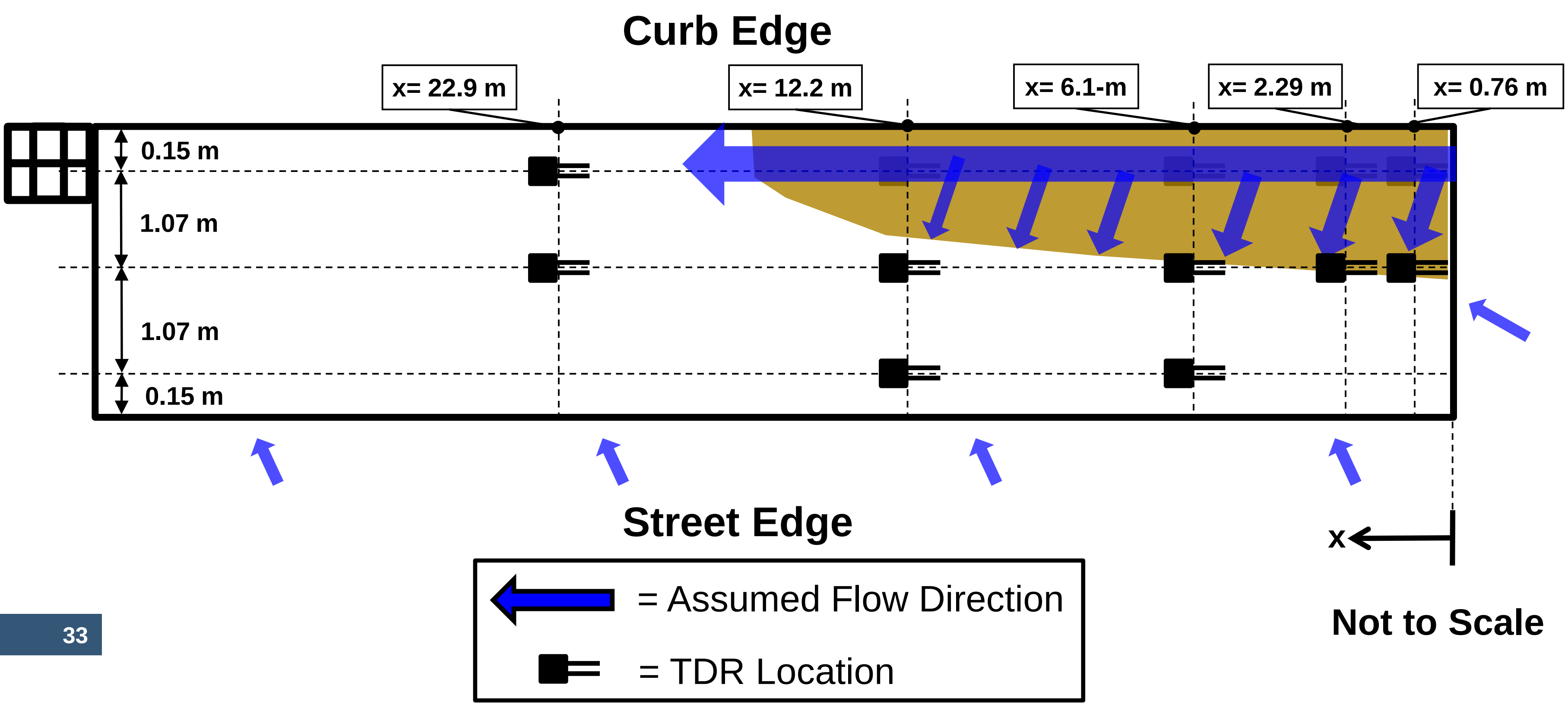
LOUISVILLE, KY

United States Environmental Protection Agency

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

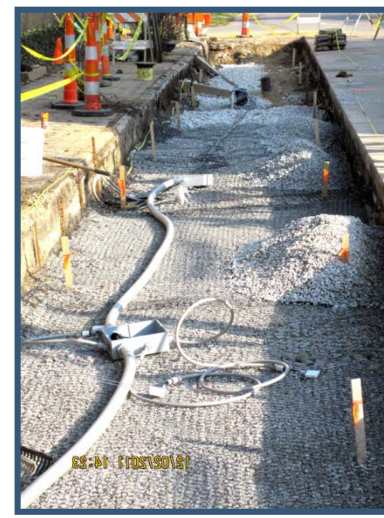


We expect the concentrated flow to transport and deposit sediment from the drainage area.



United States Environmental Protection Agency

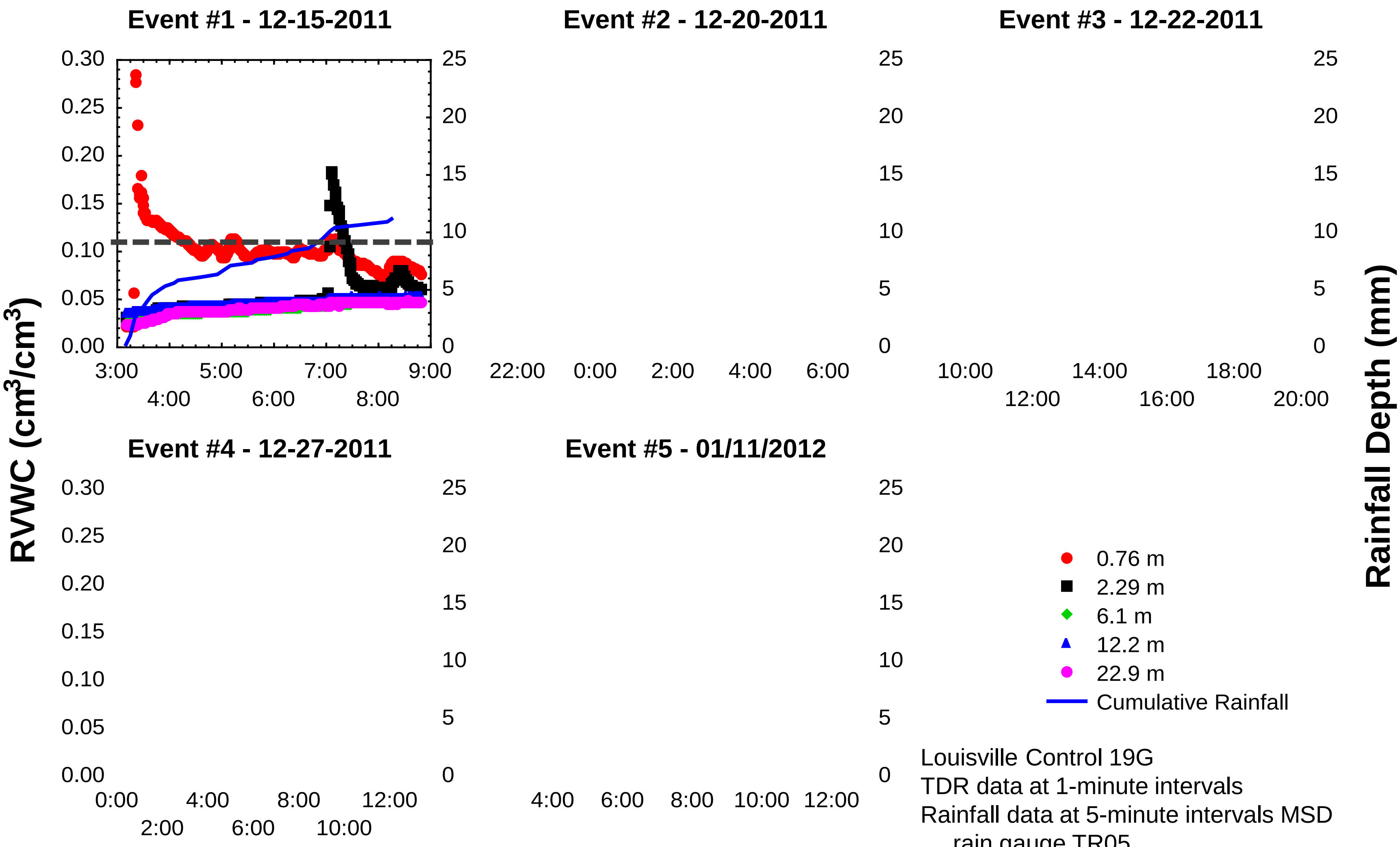
Time Domain Reflectometers (TDRs) were installed 40 cm below the paver surface in the aggregate to measure surface clogging progression.



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).

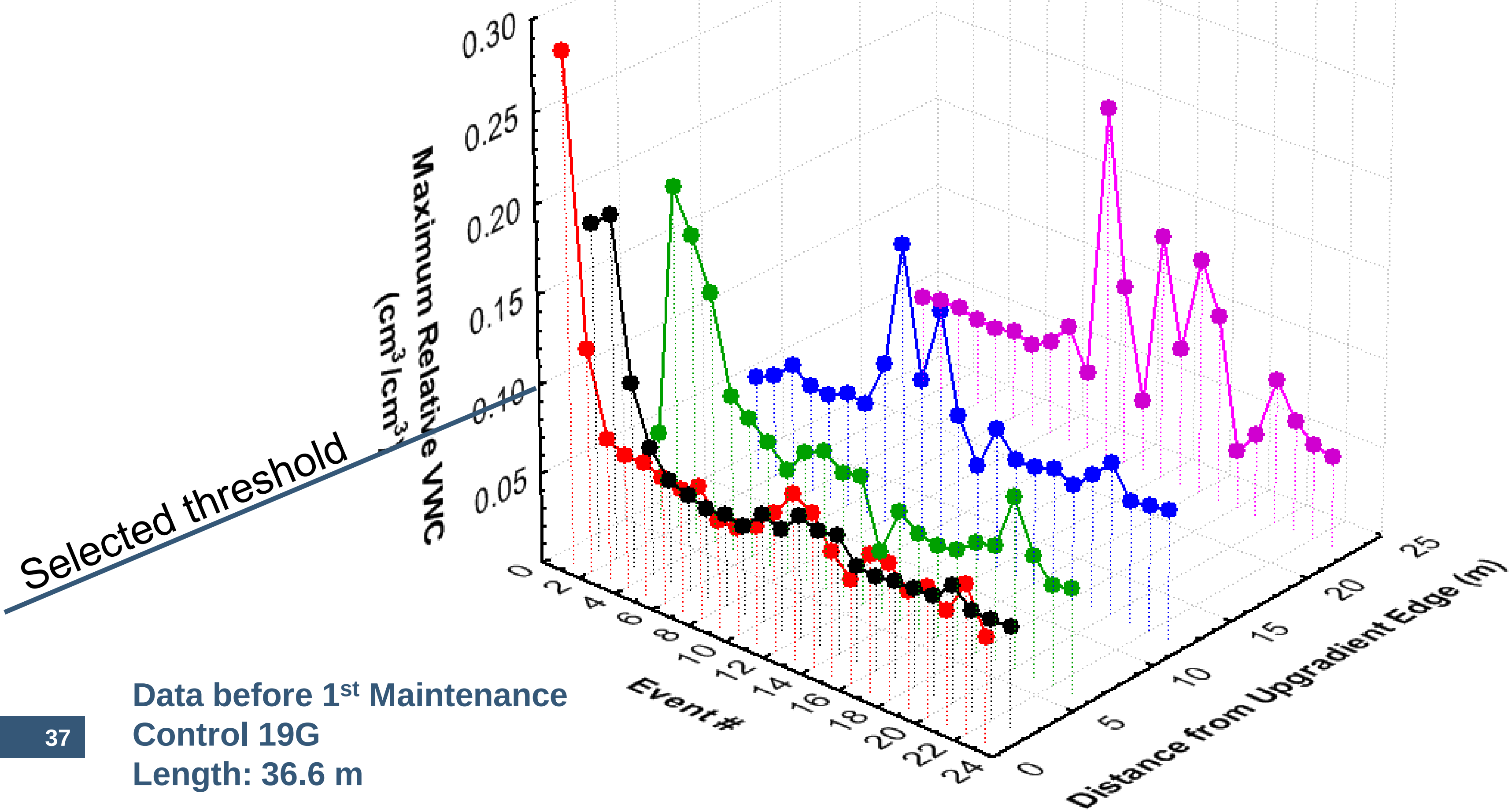
1 Topp, G. C., Davis, J. L., and Annan, A. P. (1980). “Electromagnetic determination of soil water content: Measurements in coaxial transmission lines.” *Water Resources Research*, 16, 574-582.

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



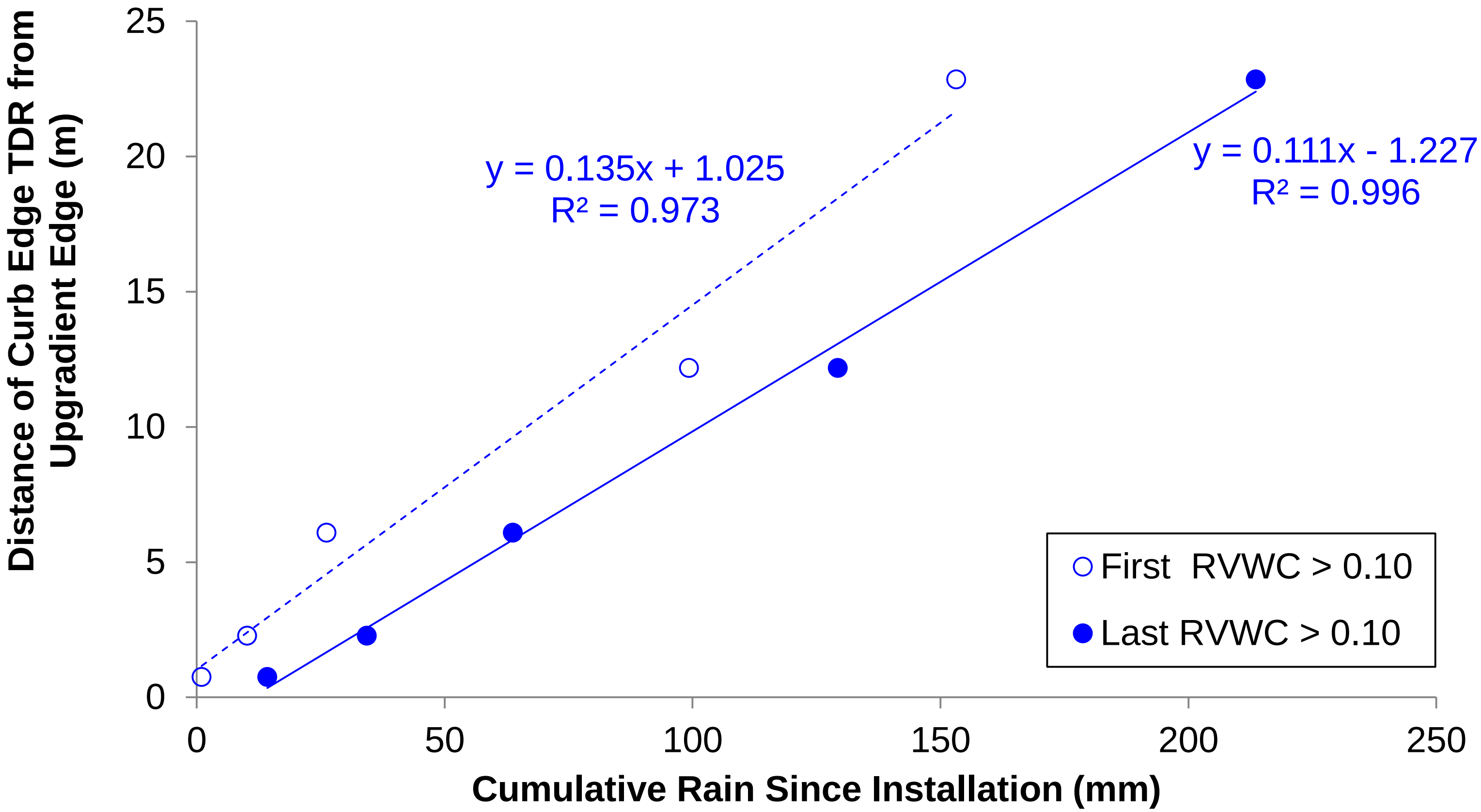
United States Environmental Protection Agency

The curb edge TDR responses support the predicted clogging progression.



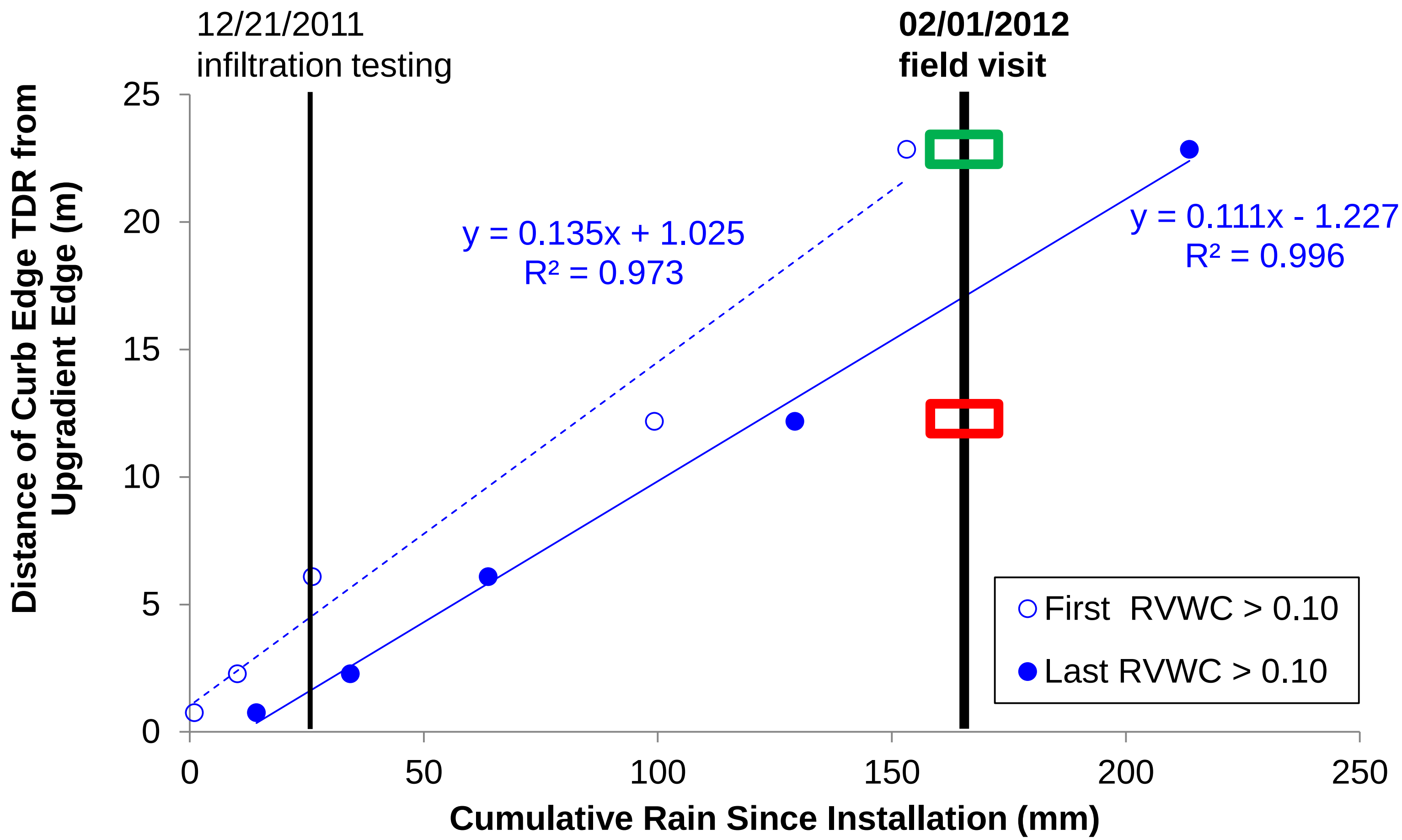
Data before 1st Maintenance
Control 19G
Length: 36.6 m

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

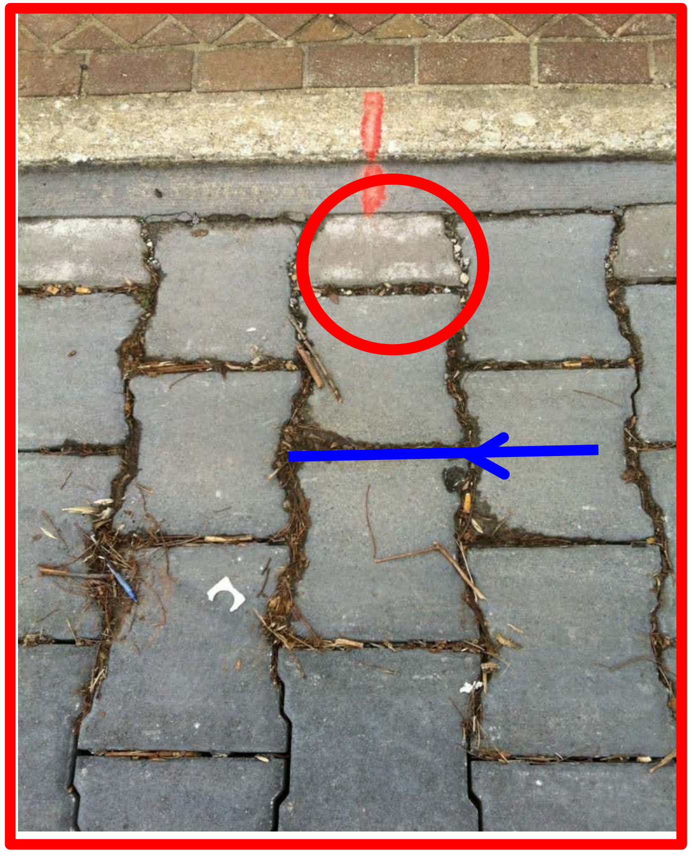


Control Louisville 19G
Response threshold 0.10 RVWC
The initial clogging rate was about 0.123 m per mm (10 ft per inch) of rain.

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



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



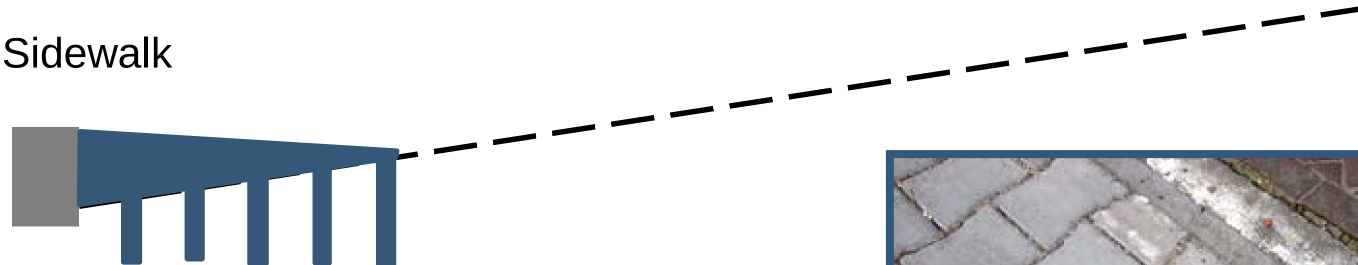
Control 19G
Length: 12.2 m

Photo: Josh Rivard
University of Louisville

Control 19G
Length: 22.9 m

United States Environmental Protection Agency

Street slopes (longitudinal and transverse) and curbs (height and condition) are important considerations when placing the controls in a curb and gutter system.



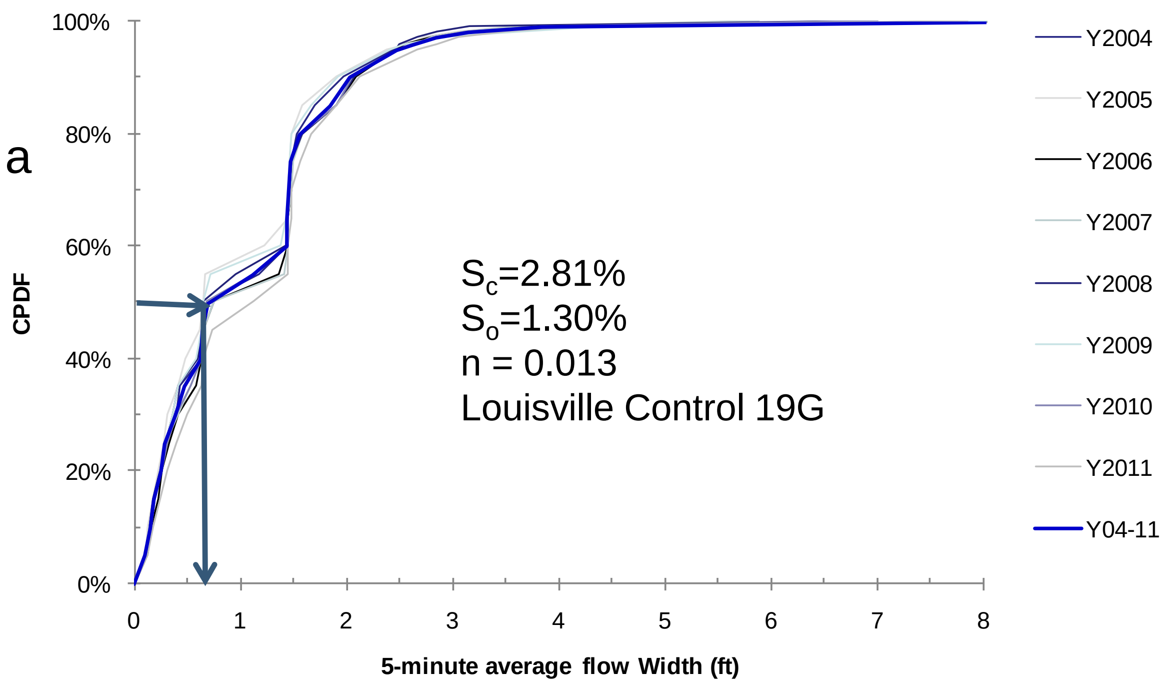
Short curbs by design (or resulting from multiple resurfacing without milling) will limit the working flow width of the control.

Steeper slopes concentrate flow and use less surface area.

The important consideration is working surface area, not surface area.

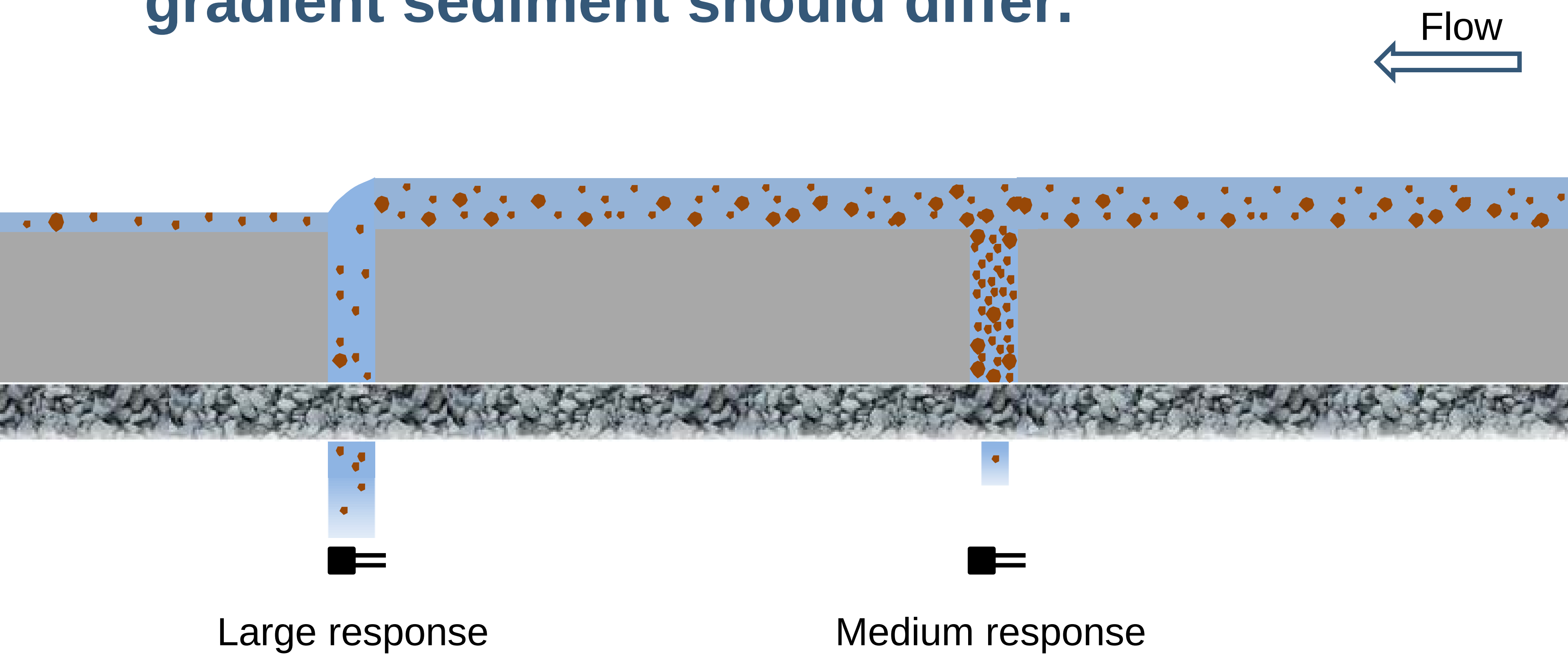
It is not obvious what to use as a working width (e.g., mean / median calculated 5-minute average flow width).

The current ICPI guidance is a ratio of control area to drainage area.



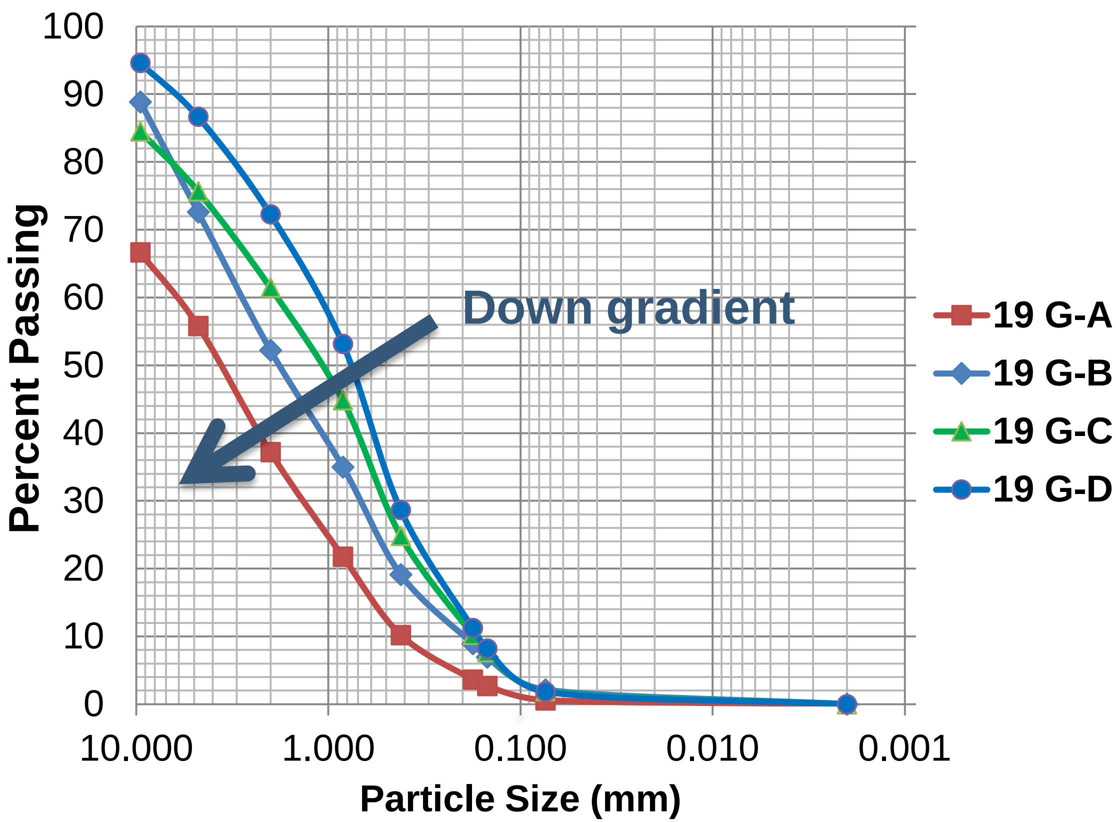
50% of 5-minute average flow widths (excluding infiltration) are 0.75 ft or less

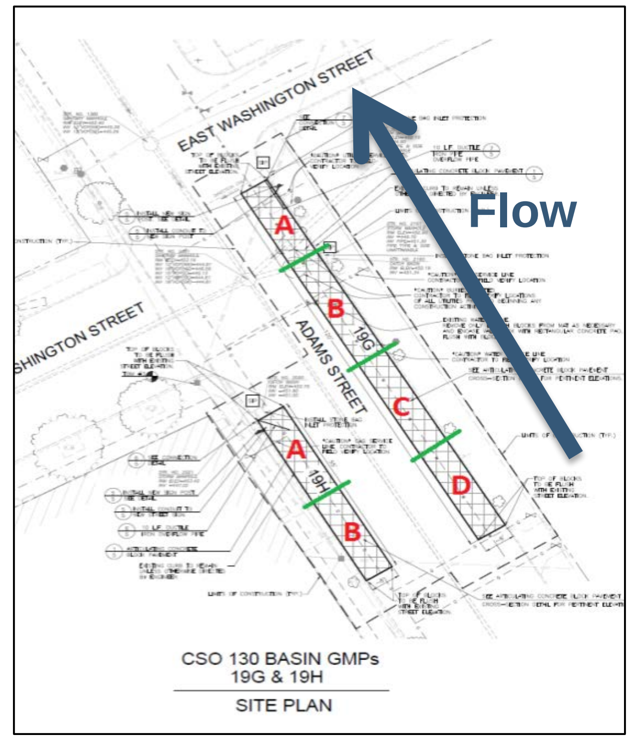
If this model is accurate, the particle size distribution of up gradient and down gradient sediment should differ.



United States
Environmental Protection
Agency

Particle size distribution of the clogging sediment collected from a control in Louisville.

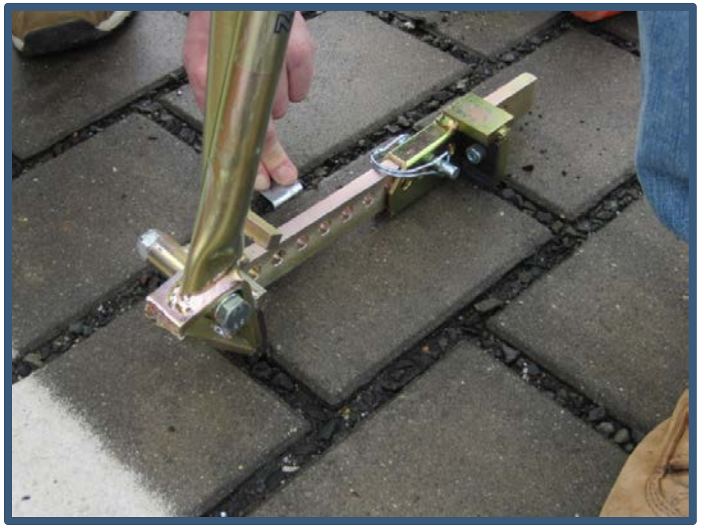




Based in Research by Amir Ehsaei, University of Louisville

United States Environmental Protection Agency

Removing pavers at selected locations shows how clogging advances with gaps filled and small debris loading.



With aggregate between the pavers, most of the fines are trapped in the top 20 mm.

United States Environmental Protection Agency

When pavers are installed without interstitial gravel, sediment progresses the full depth of the paver.

United States Environmental Protection Agency

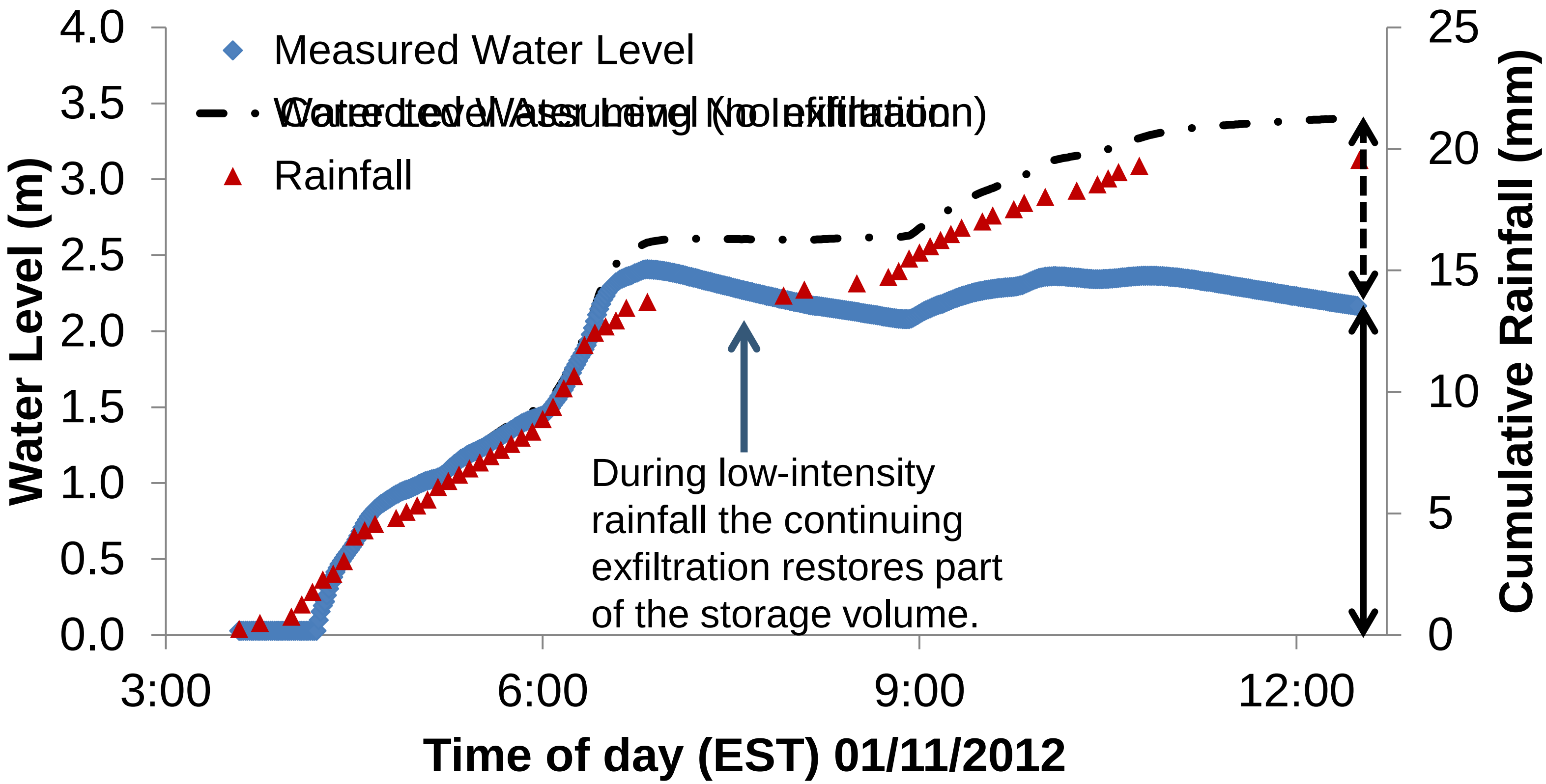
OTHER STUFF

EPA
United States
Environmental Prot
Agency

As part of the research in Louisville we looked at three maintenance techniques.

Kazemi, H., et al., 2017, Assessment of Surface Infiltration Performance and Maintenance of Two Permeable Pavement Systems in Louisville, Kentucky. Journal of Sustainable Water in the Built Environment 3(4) https://doi.org/10.1061/JSWBAY.0000830

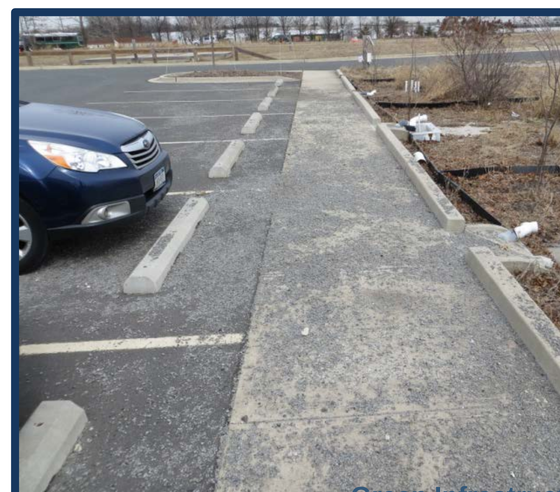
Intra-event exfiltration can be significant part of the collected water volume for long duration events



Level data at 1-minute intervals
Rainfall data from MSD gauge TR05 at 5-minute intervals

Large portions of the pervious concrete at the Edison site disaggregated.

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



The raveling did not penetrate the full depth of the porous concrete.

Is structural failure coupled with chloride?

WYOMING ANALYTICAL LABORATORIES, INC.

www.wal-lab.com
Email: walxray@aol.com
(303) 278-2446
Fax: (303) 278-2439

May 06, 2014

140403

Analytical Report
Wt.%, as Received Basis

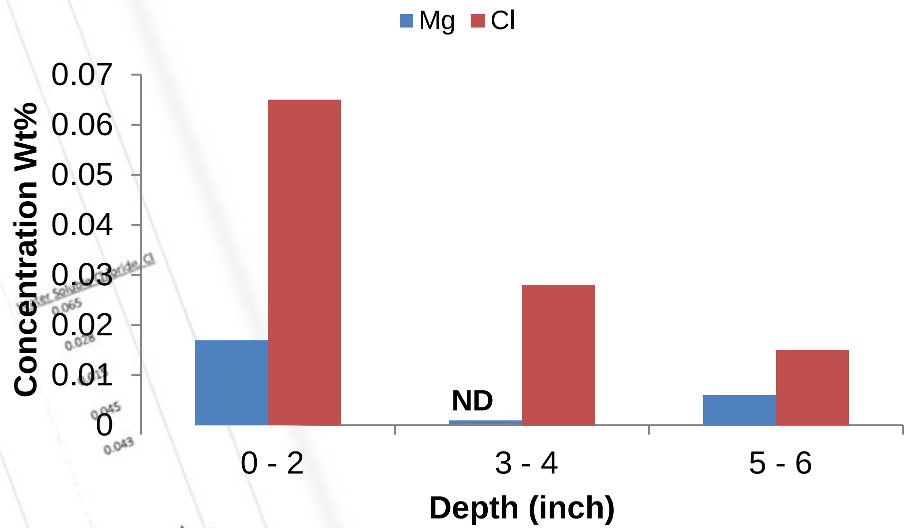
#	Customer ID	Water Soluble Mg	Water Soluble Chloride, Cl
1	119176 Permeable Concrete Core Sample "EPA" 0-2"	0.017	0.065
2	119176 Permeable Concrete Core Sample "EPA" 3-4"	< 0.001	0.028
3	119176 Permeable Concrete Core Sample "EPA" 5-6"	0.006	[illegible]
4	119177 Permeable Concrete Sample "Trump F" Sample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

MEMBER ACIL

Page 1 of 1



NRMCA revised O&M guidance (2015)

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

United States
Environmental Protection
Agency

Michael Borst

borst.mike@epa.gov