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Progression of Clogging in a Permeable Pavement Parking Lot

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July 13 2020

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Outline of Presentation

- Construction of permeable pavement research and demonstration site
- Surface infiltration study and conclusions
- Interlude: high resolution survey and replacement of one permeable surface with another
- Opportunity: new surface infiltration study
- Results

Construction Began in 2008 with Opening in Late October 2009.

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November 26, 2008

December 18, 2008

February 26,2009

March 25, 2009

June 1, 2009

August 5, 2009

October 6, 2009

October 8, 2009

October 28, 2009

Edison Environmental Center Permeable Pavement Research and Demonstration Site

The lot for employee and visitor parking and testing of three permeable surfaces: porous asphalt (**PA**), pervious concrete (**PC**) and permeable interlocking concrete pavers (**PICP**).

Three Permeable Parking Rows

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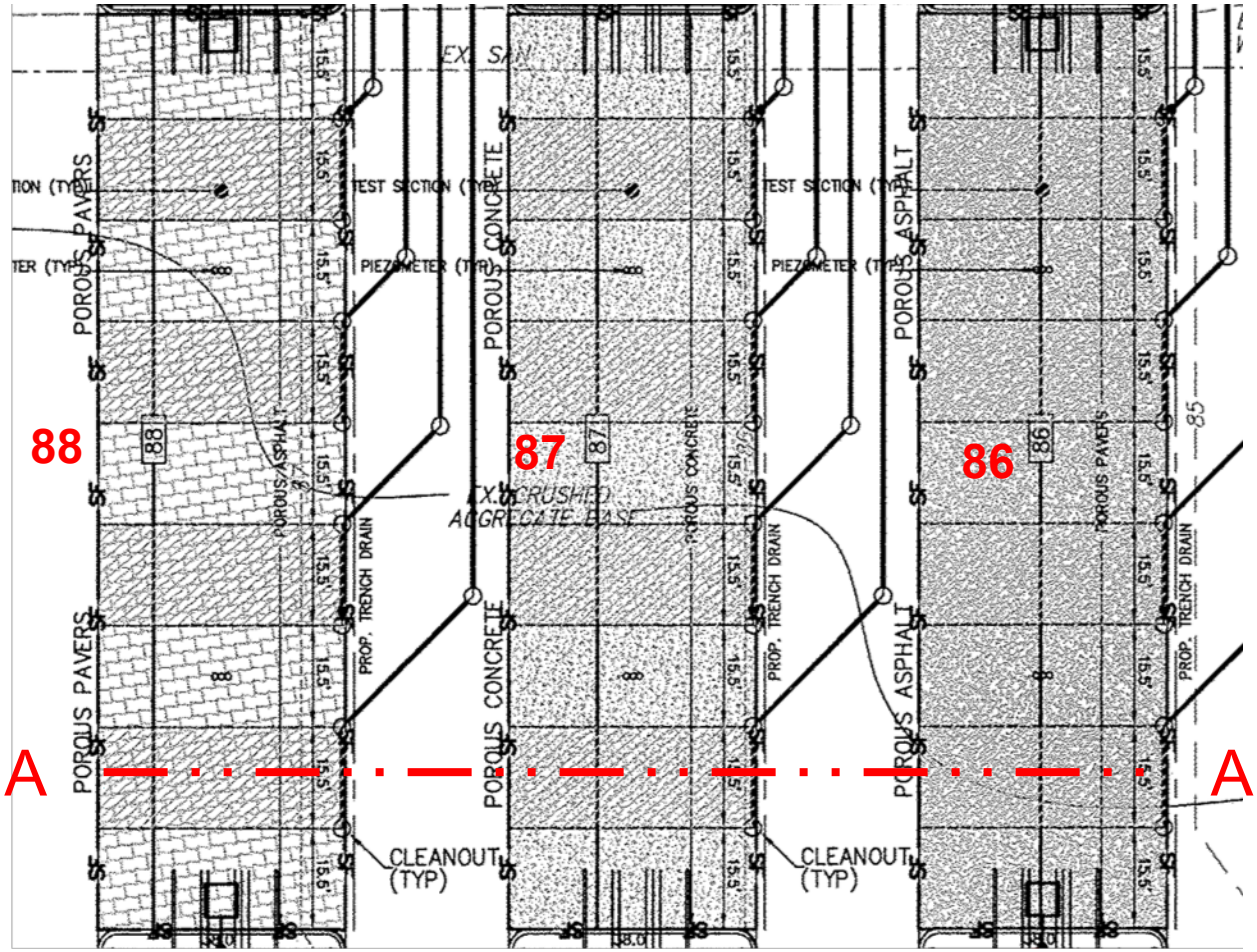
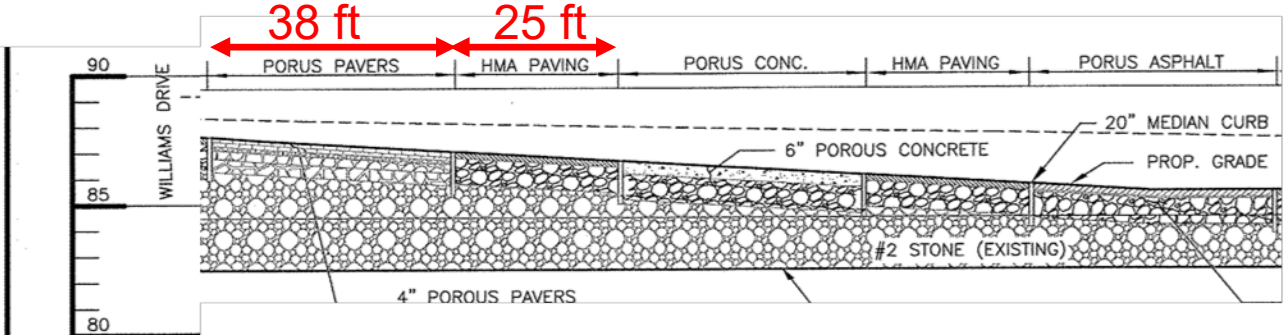
Final design of parking lot elevations from 85 ft to 89 ft above mean sea level (MSL). Section A-A shows slope from north to south of ~1.6%.





Section A-A

Permeable Surfaces during Rain

Driving lanes between parking rows are watershed area for each permeable surface.

Surface Infiltration Study

Monthly infiltration test using *modified* version of ASTM C1701.

Modifications to ASTM C1701 were:

(1) how the seal was achieved between the ring and the surface;
(2) added temperature measurements of surface and water;
(3) if pre-wet test exceeded 30 minutes, result recorded as infiltration rate test.

Surface Infiltration Rates after First Six Months

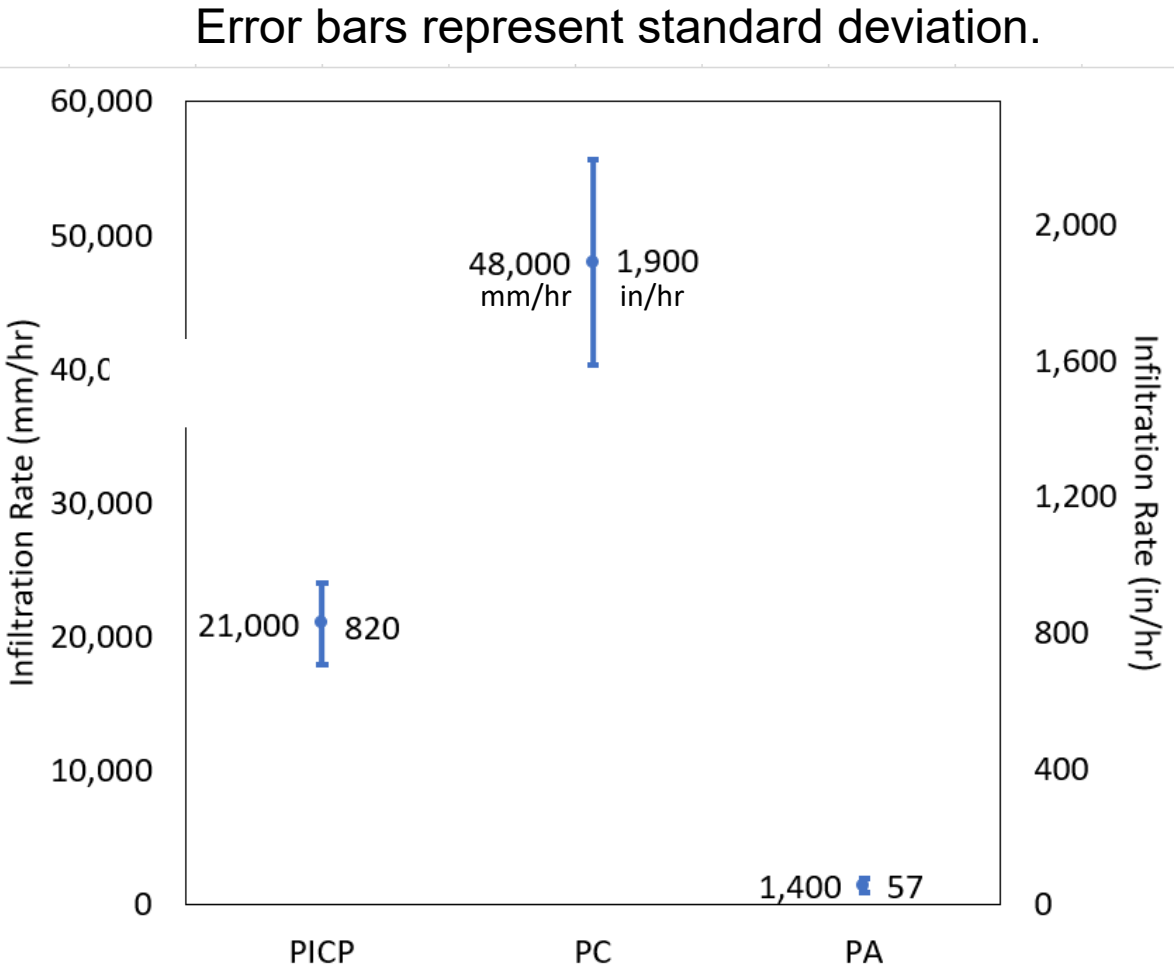
Surface type	Initial surface infiltration rate (mm/hr ± 1SD)	Literature reported infiltration rate (mm/hr)
PICP	24,400 ± 3,050	20,000 (Bean et al., 2007)
PC	42,200 ± 8,760	40,000 (Bean et al., 2007)
PA	1,470 ± 430	4,300 (Ferguson, 2005)

Test from December 2009 through April 2010

Mean Surface Infiltration Rates Exceeded Maximum Expected Direct Rainfall Rates.

100-year, 5-minute rainfall intensity 208 mm/hr (8.2 in/hr)

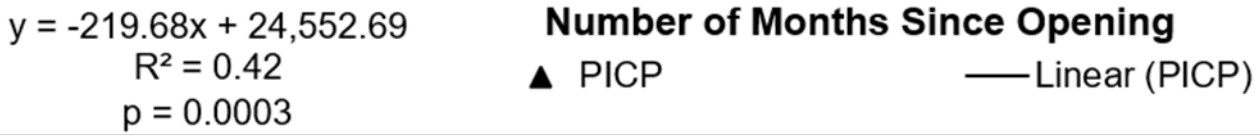
Results December 2010 through August 2012



Infiltration Rate Decrease with Time

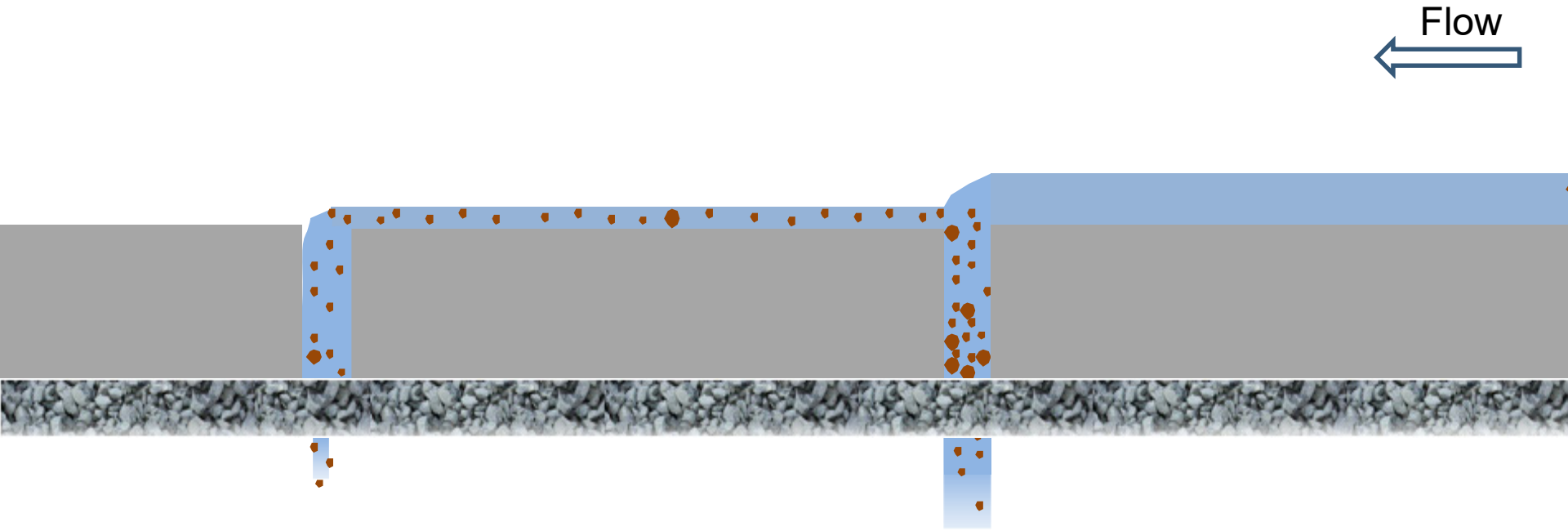
R^2 low – poor explanatory power for regression scatter.

Potentially due to nature of using randomly chosen locations for infiltration testing.



Error bars represent standard error.

Hypothesis of Clogging Process



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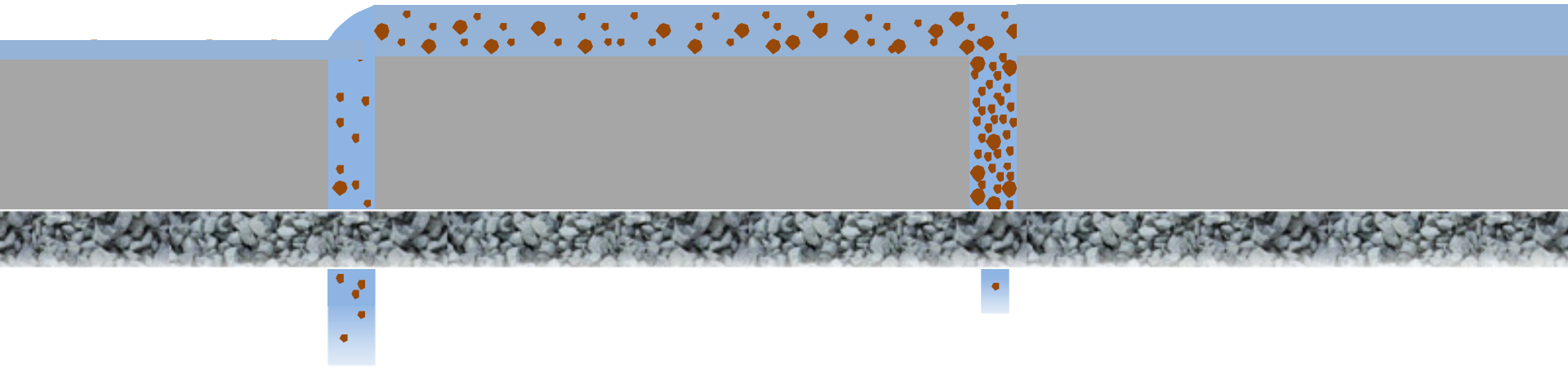
As gaps fill with sediment, up gradient locations clog and downgradient infiltration rates remain high.



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Sediment accumulates (*and clogging progresses*) from the upgradient edge.

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Conclusions of Infiltration Study

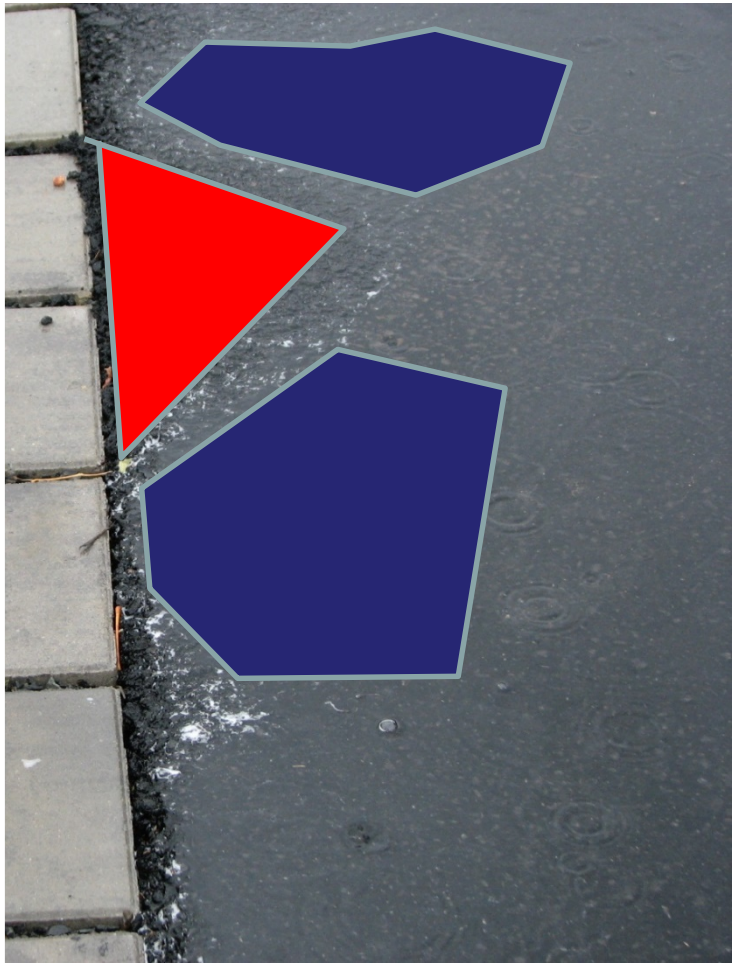
- Clogging not random – clogging from upgradient slope
- Clogging slowly – need for cleaning maintenance projected to take decades
- Small contributing area compared to other applications
  - ratio watershed to permeable area = 0.66
  - other applications larger ratios, i.e., 1:1, 2:1, 5:1
- Clogging not uniform

Observation of Micro-topography and Concentrated Flow

Red – high spot prevents runoff from reaching permeable surfaces.

Blue – low spots concentrate flow.

The concentrated runoff is more likely to carry particles that clog permeable surfaces.



High Resolution Survey

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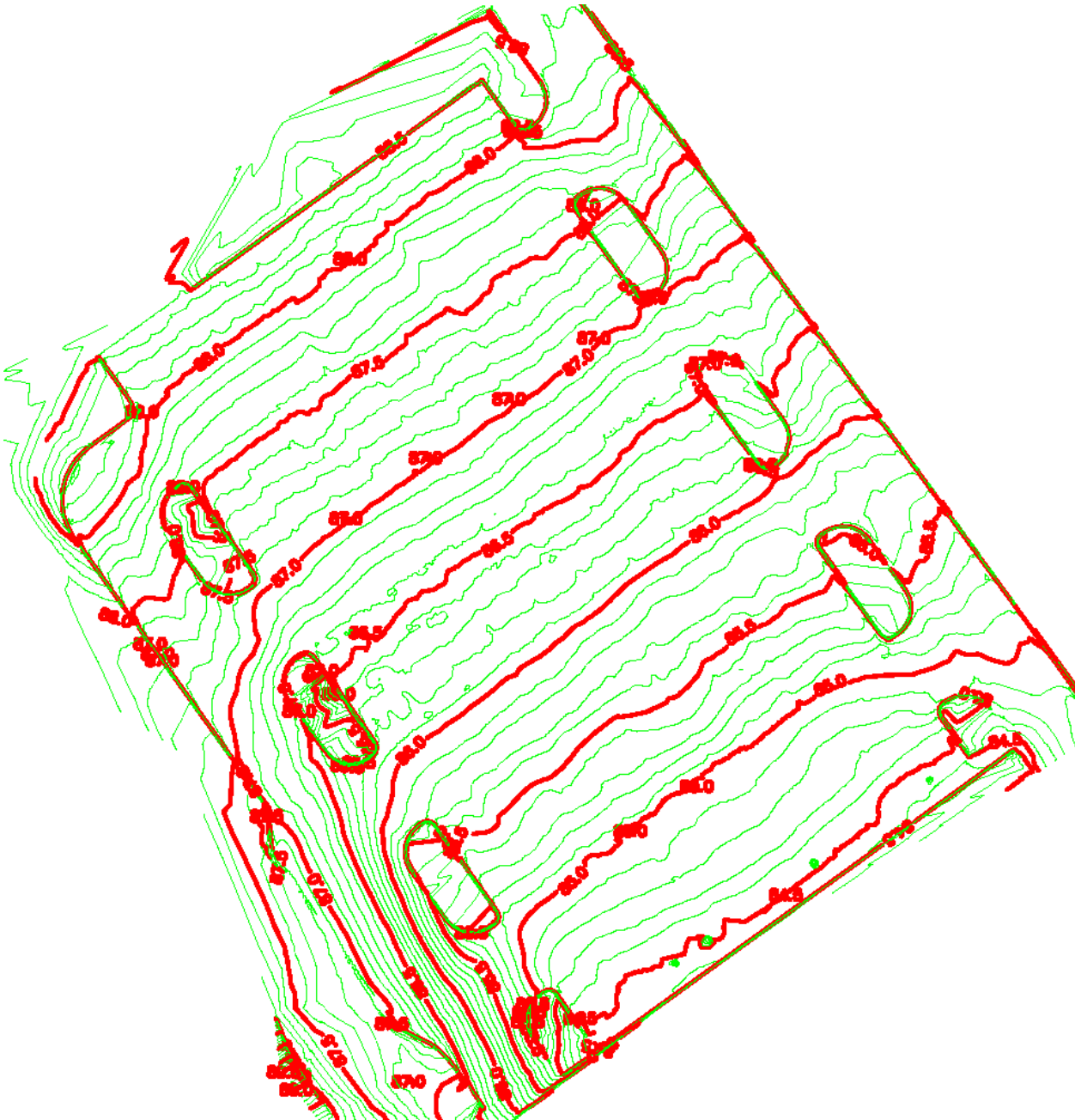
- Conducted by Johnson, Miriam and Thompson (JMT) on December 28, 2014.
- JMT provided survey elevations (ft) above MSL and contours.
- Contour lines generally parallel but evidence of microtopography.



Disaggregation of Pervious Concrete

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 recurred more extensively in 2014.

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Replacement Surface (2016): New Pavers

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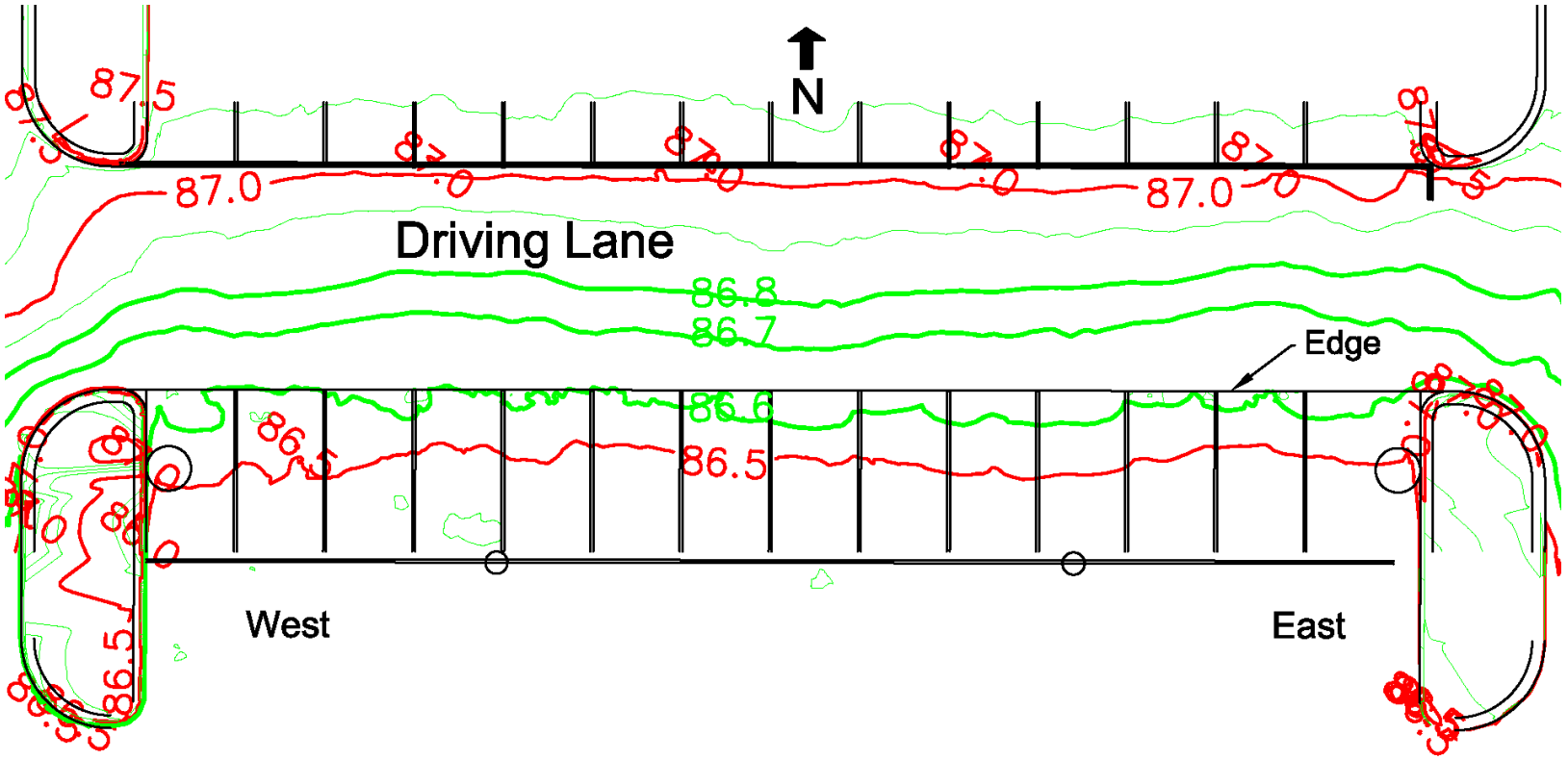
Opportunity: New Infiltration Study

- Parking on new pavers, nominally began on 8/1/16
- Use results of high resolution survey to predict where clogging will and will not occur for new PICP installation
- Same infiltration test - modified version of ASTM C1701
- Infiltration testing on new PICP began 4/27/17 (270 days after installation)
- Quarterly testing from upgradient edge - not random
- Not always able to obtain desired location due to parked vehicles
- Results inclusive to 3/13/19 (954 days after installation)

Identifying Clogging and Non-clogging Locations

- High resolution survey of parking lot in 2014 included damaged pervious concrete.
- After removal of pervious concrete and replacement by new PICP in 2016, 86.6 ft contour line is only predictive if in driving lane.
- To help predict other areas of clogging (low spots) and non-clogging (high spots), 86.7 ft contour line is used.

High Resolution Survey Elevations Overlay on Parking Lot Drawing



West side is closer to building.
Elevation (ft) measured above mean sea level (MSL).

Infiltration and Clogging Definition Rates

- **Infiltrating -** no impact, infiltration rate 5,920 mm/hr (233 in/hr) or more
- **Clogging -** impacted, infiltration rate 5,920 mm/hr (233 in/hr) or less
- **Clogged -** impacted, infiltration rate 99 mm/hr (3.9 in/hr) or less
- Cease testing **Clogged** locations, start next test 0.3 m (1ft) from edge; *however*, two **Clogged** test locations were repeated.

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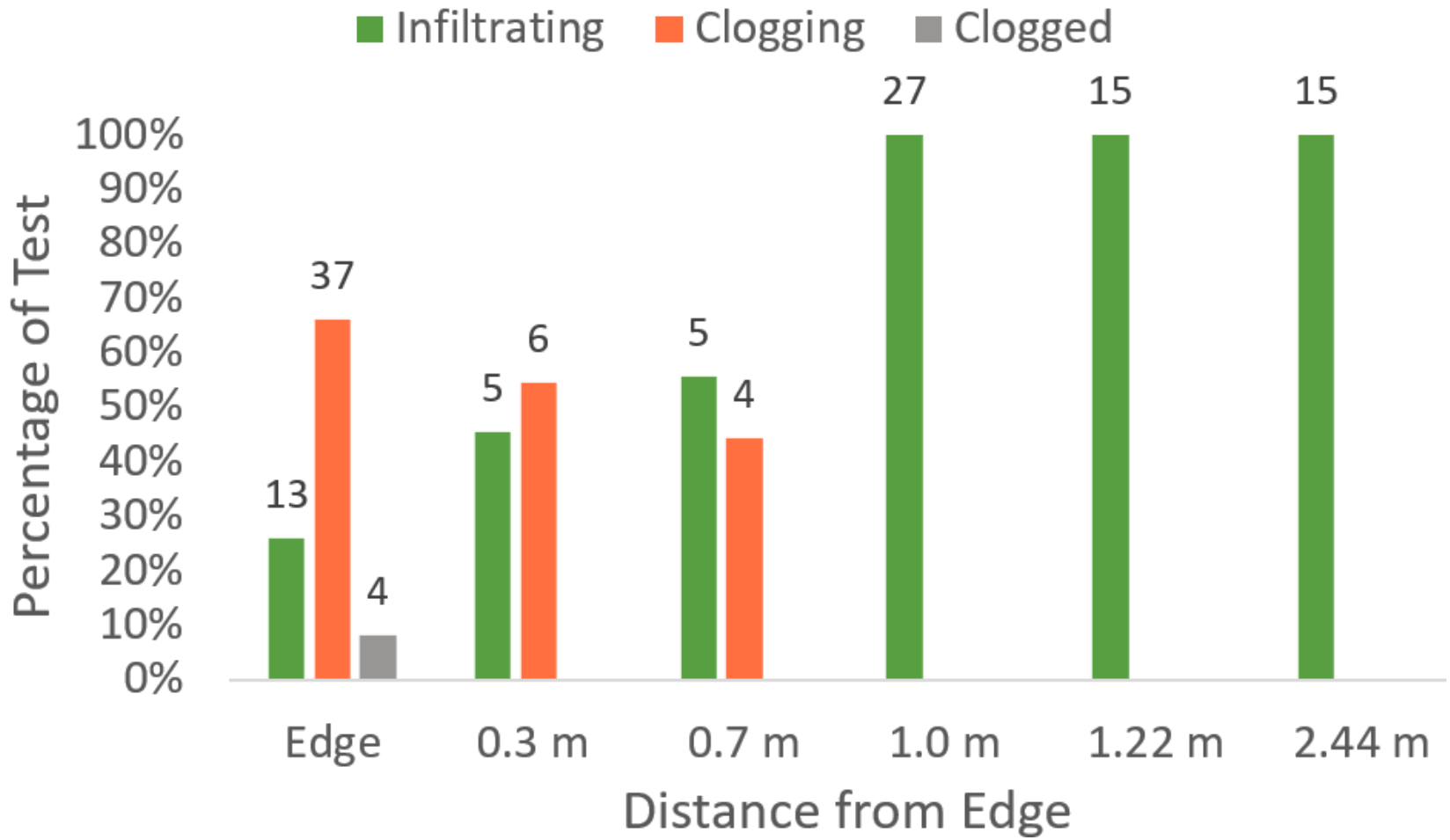
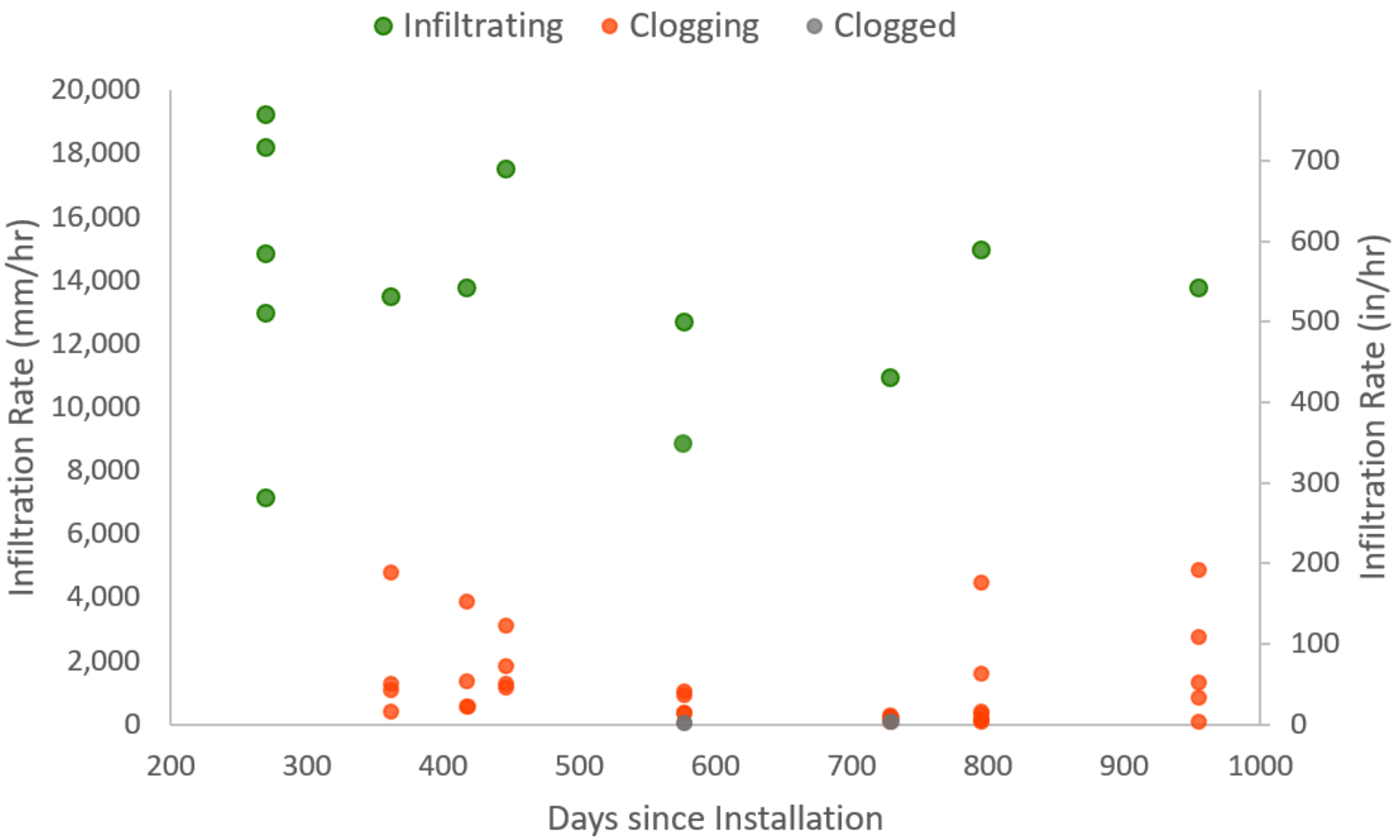
Results: Distance from Edge Primary Factor for Clogging



Infiltration Rate along Edge Only



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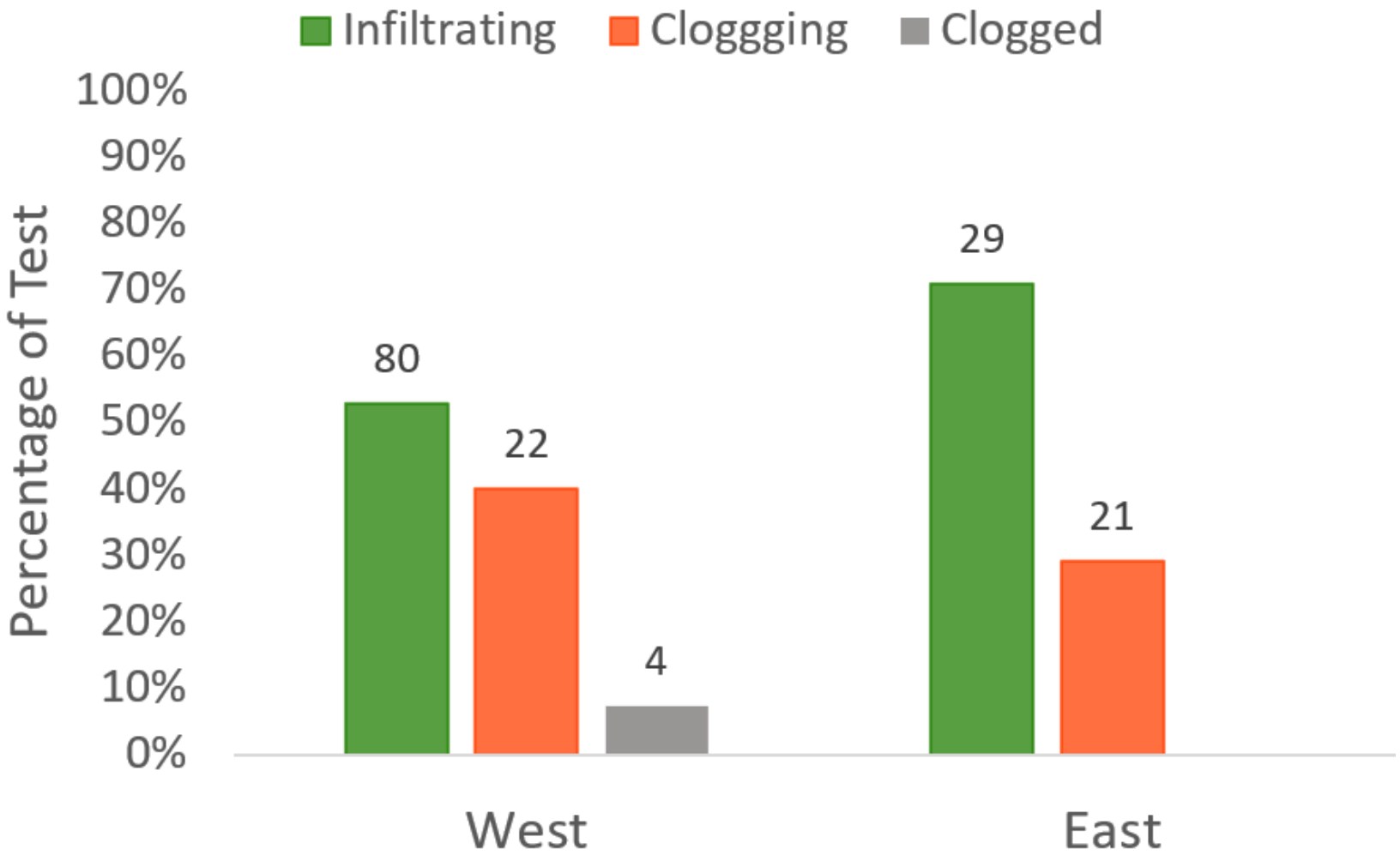
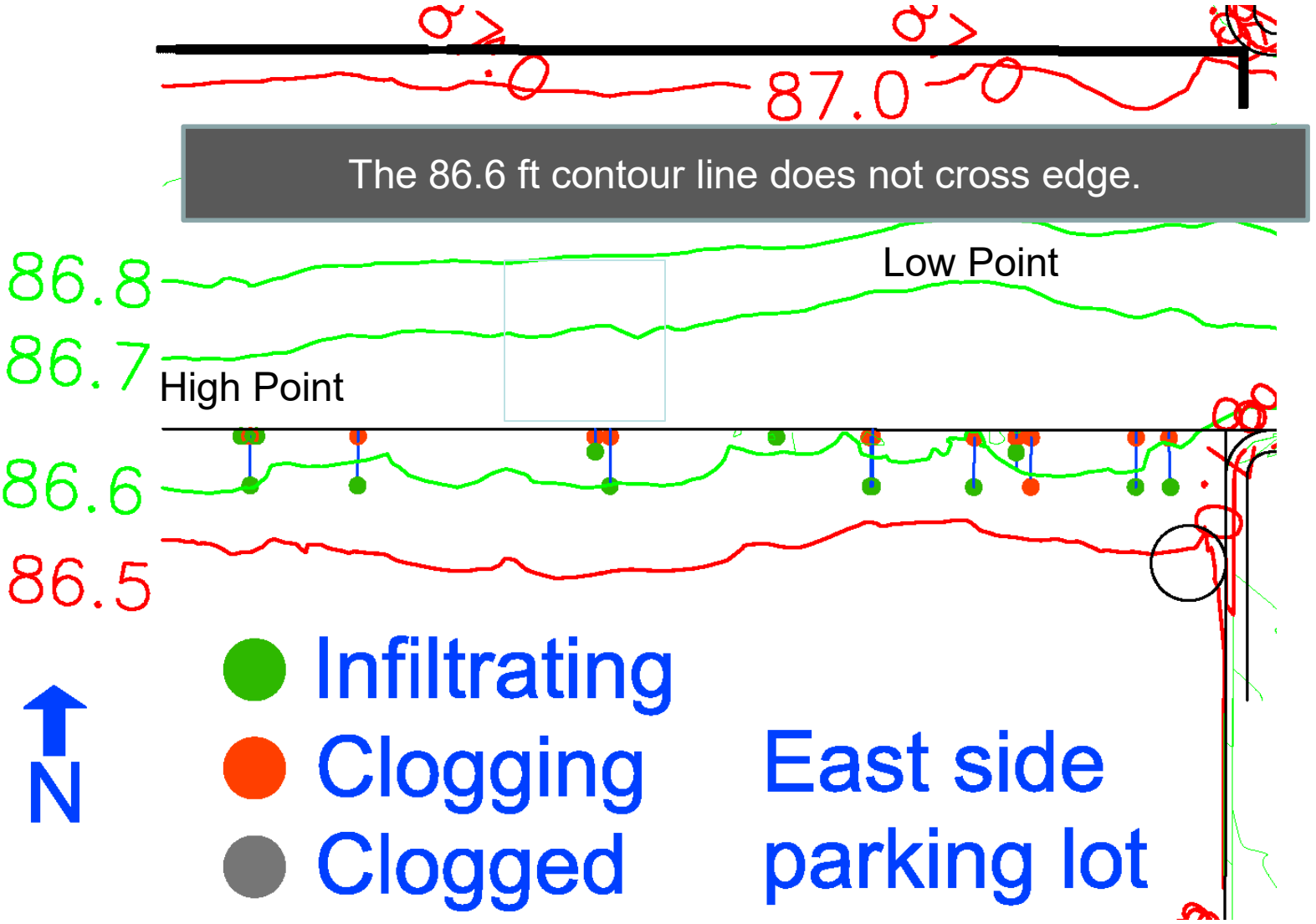
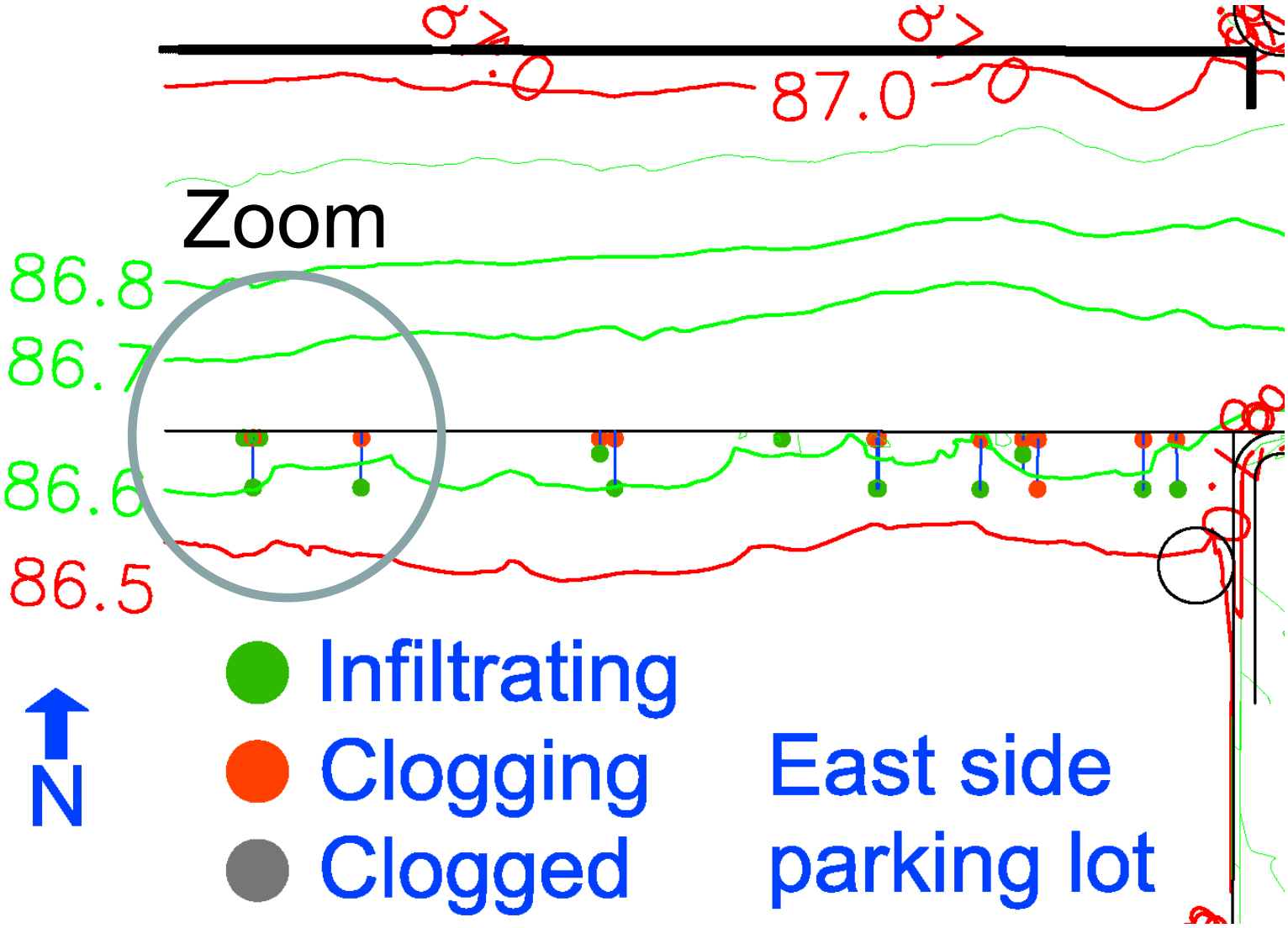
More Clogging Test Locations on West Side



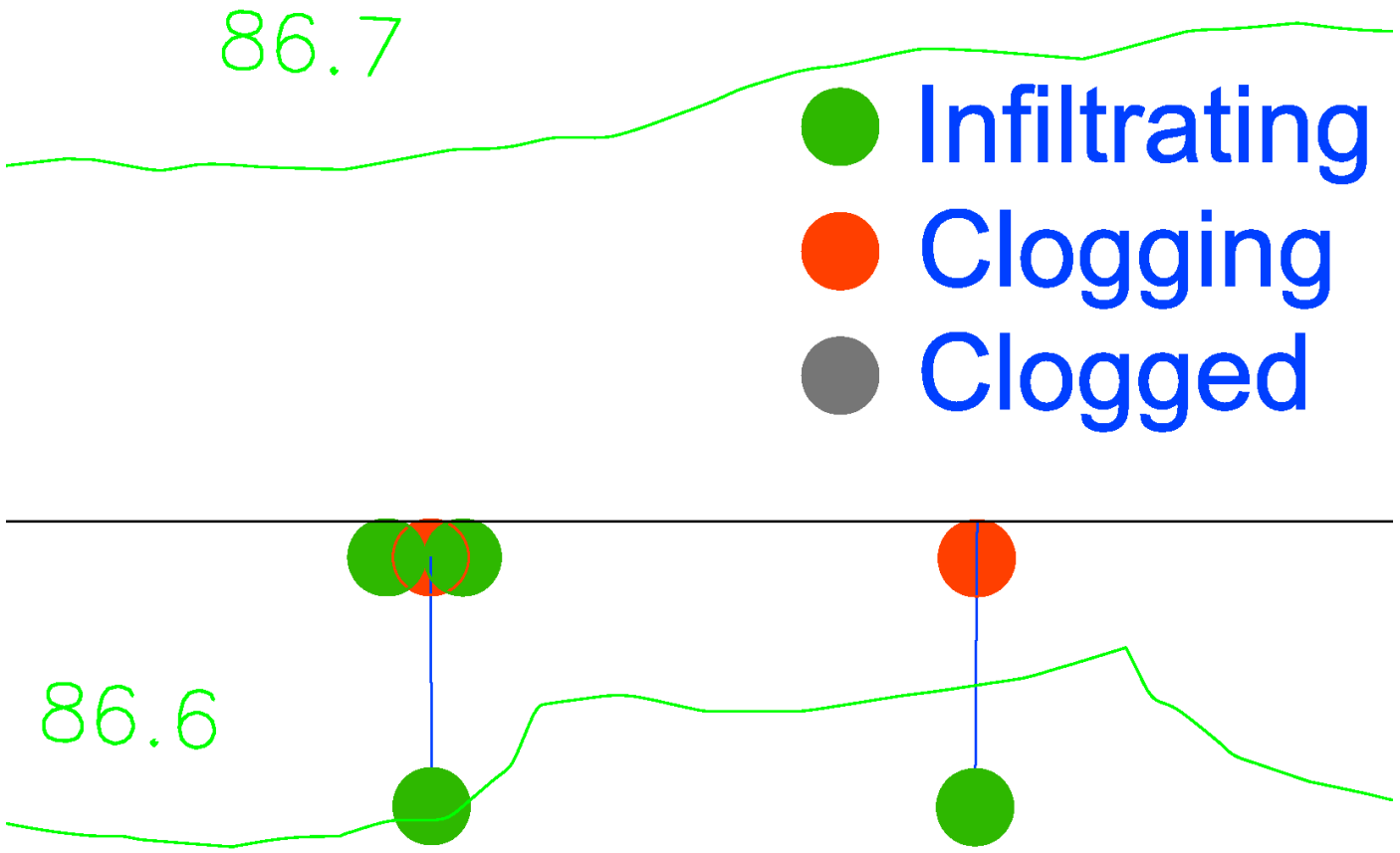
On East Side 86.7 Foot Contour Line Controls Clogging.



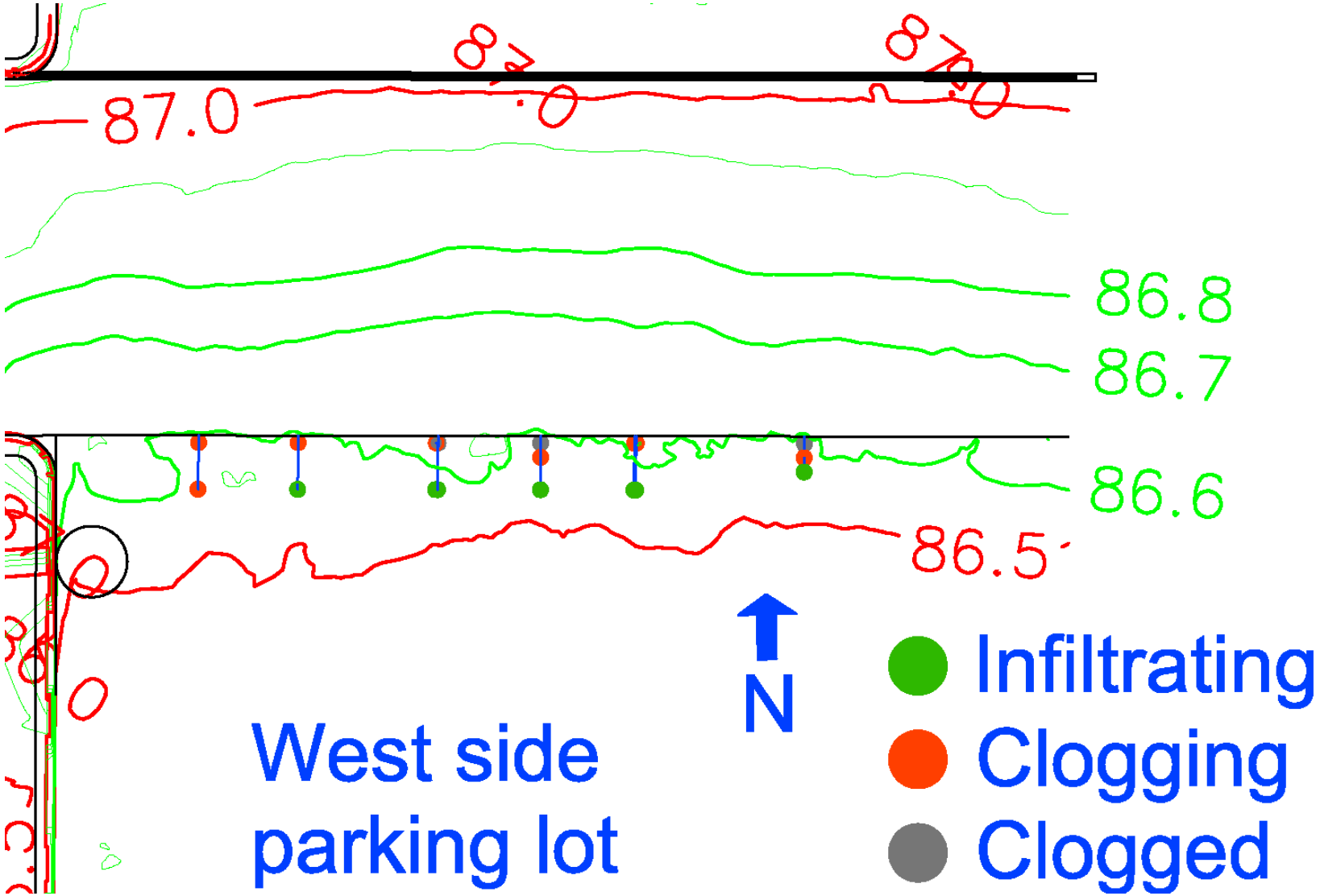
No Locations Clogged on East Side of Parking Lot



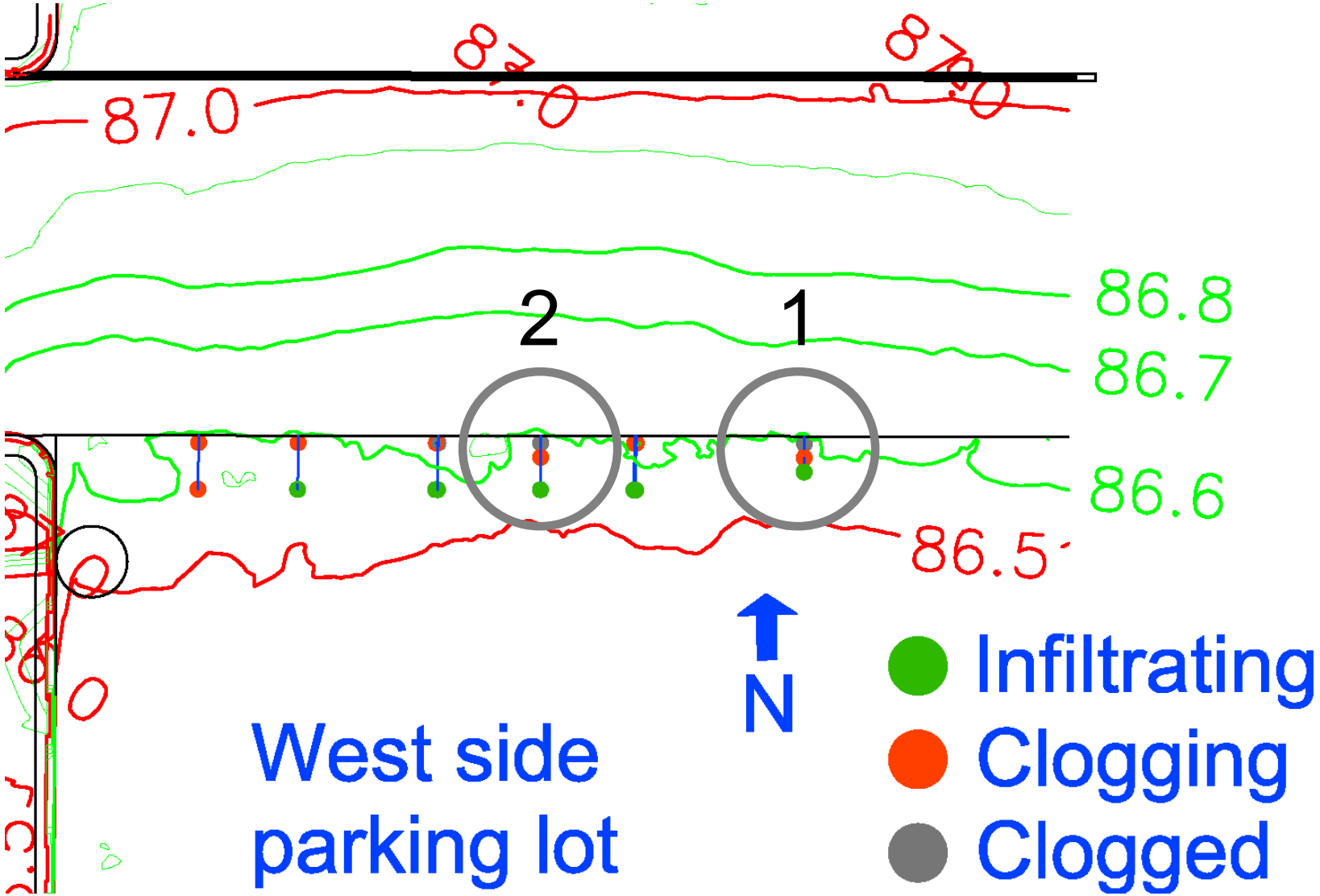
Zoom of High Spot on 86.7 Foot Contour Line



Three Locations Clogged on West Side of Parking Lot



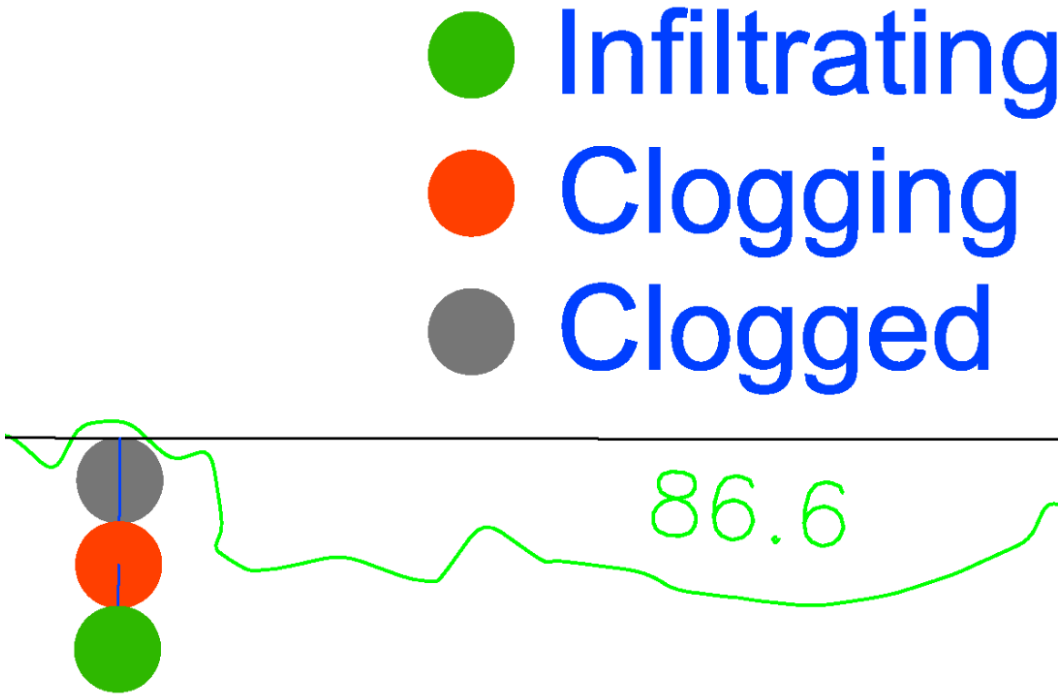
Zooms of First Two Clogged Locations



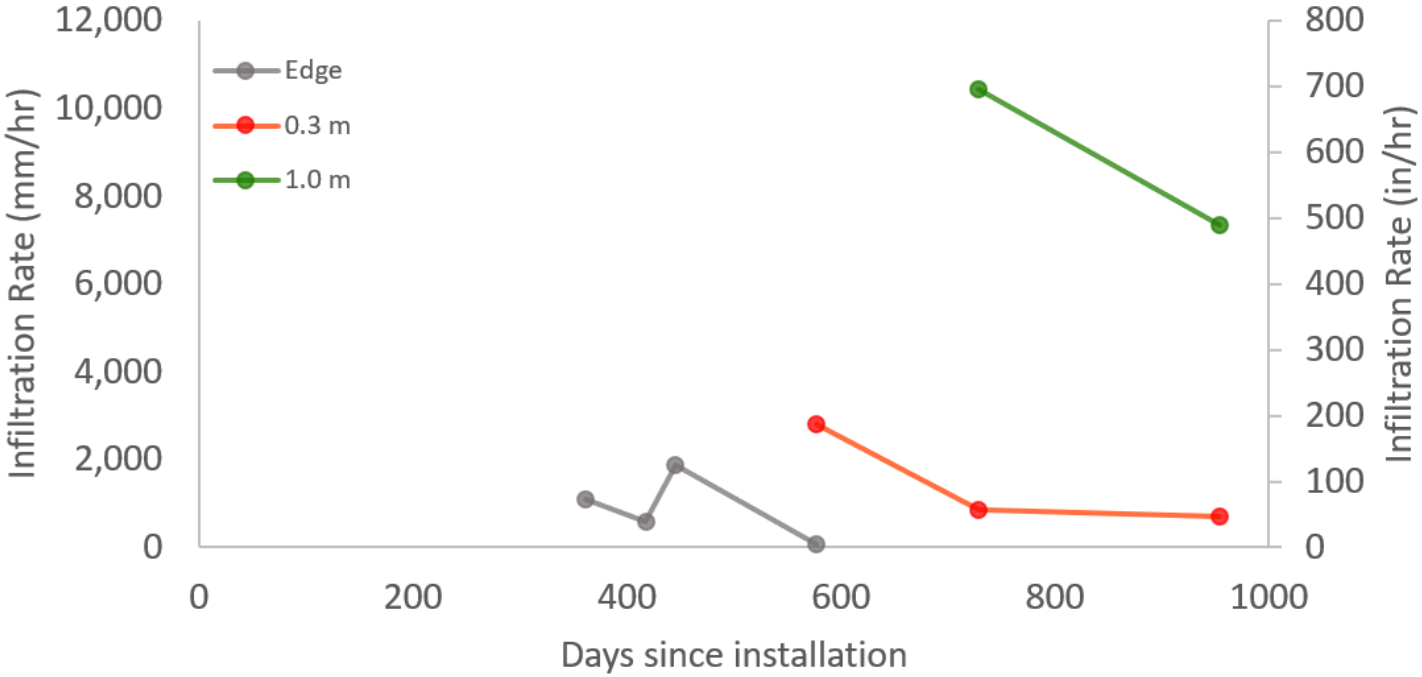
Zoom of First Clogged Location

Clogged condition occurred 577 days after installation.

The 86.6 ft contour line crosses into driving lane.



Second Clogged Location



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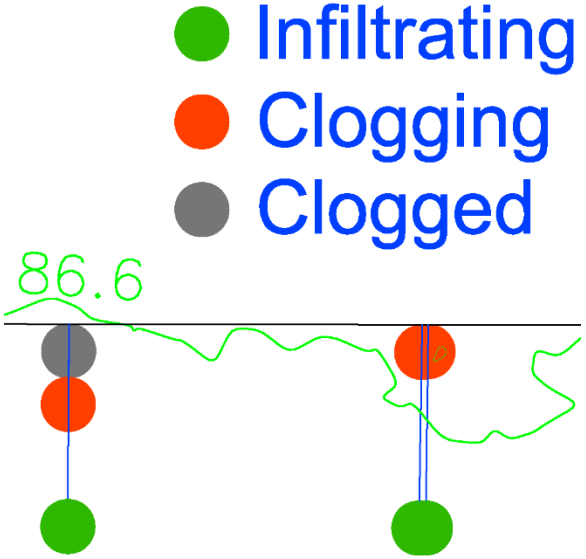
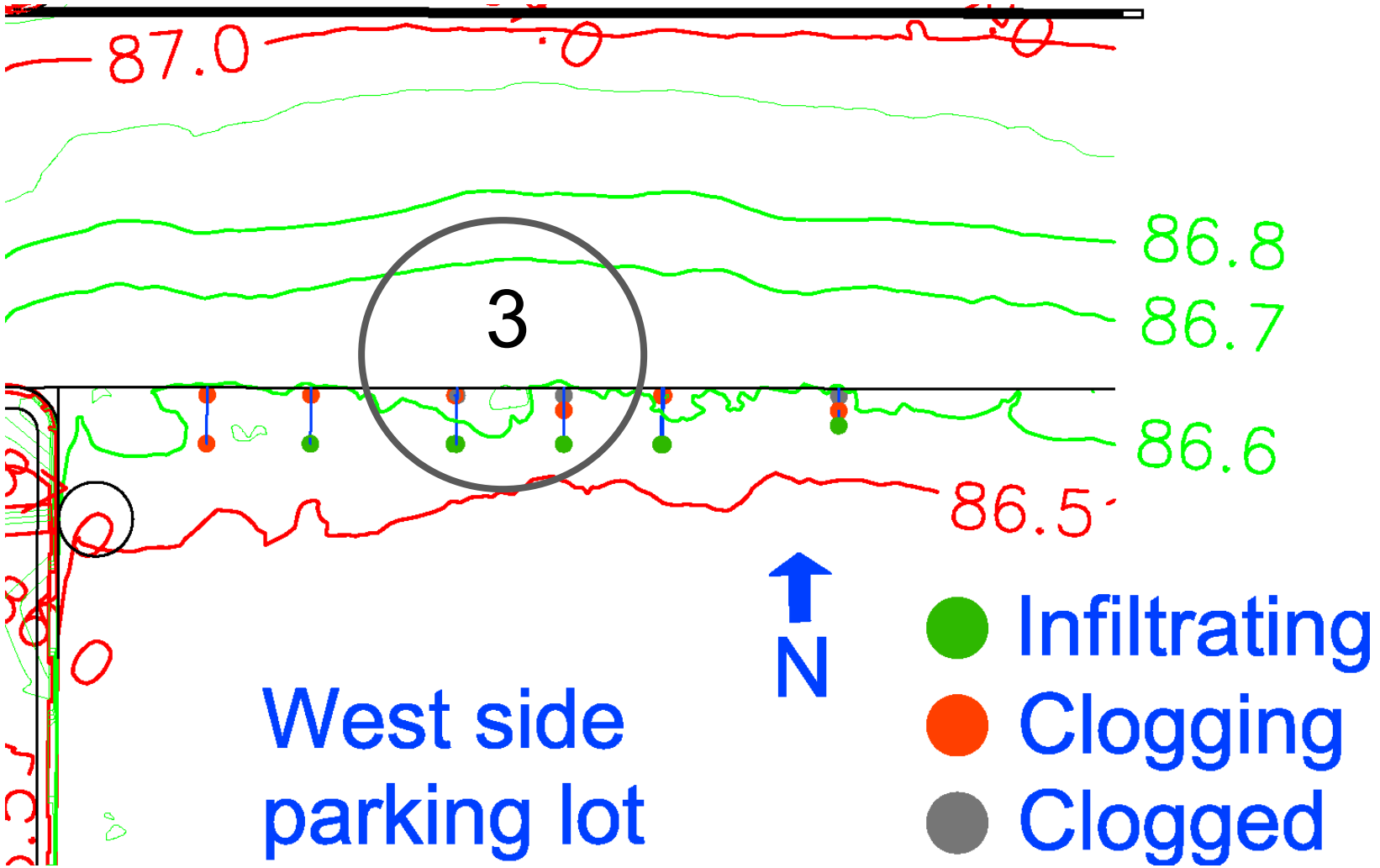


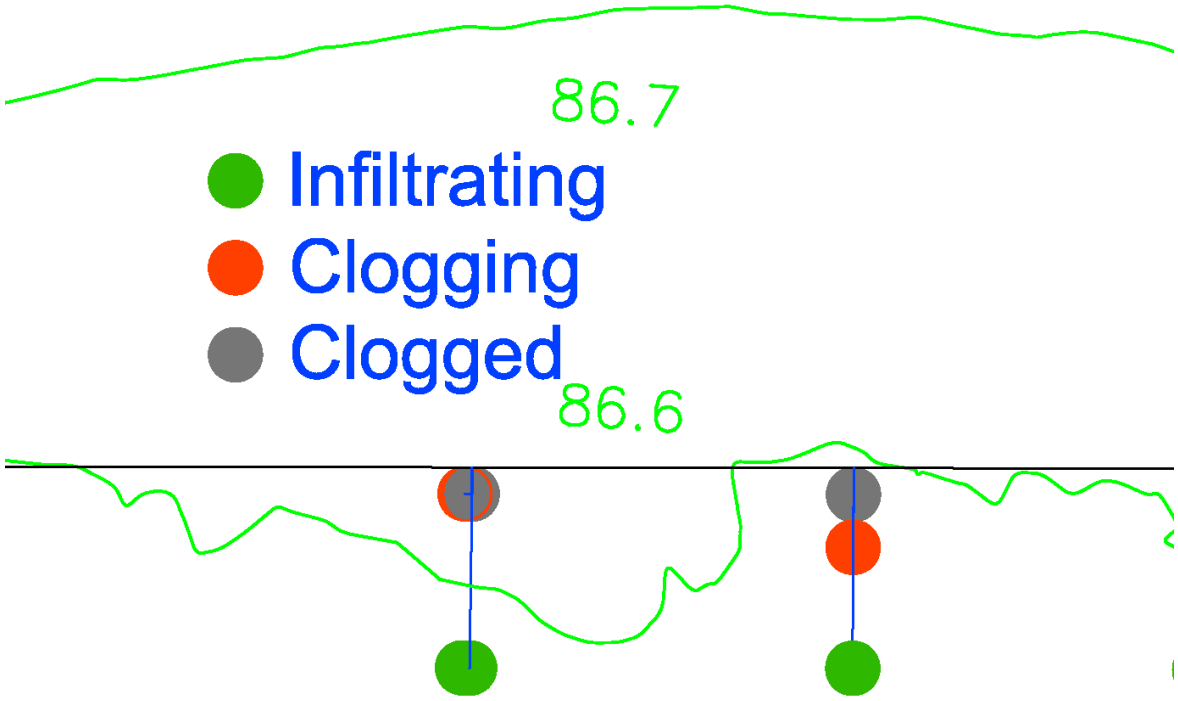
Zoom of Third Clogged Location and Predictive 86.7 Foot Contour Line



Zoom for Third Clogged Location

Third location is **Clogged** 728 days after installation.

The 86.6 ft contour line not predictive while 86.7 ft contour line is.



Small Changes in Testing Location Affect Results

Clogged 728 days after installation; however, slightly west (0.13m) 954 days after installation only **Clogging**.

Conclusions

- Small changes in elevation can lead to:
  - concentrating flow carrying solids to low points resulting in clogging;
  - high points receiving less runoff and clogging slower.
- Small changes from east to west of infiltration testing location can lead to varying results, especially if predictive contour elevation line is removed from edge.
- High resolution survey may result in more frequent spot maintenance rather than less frequent area-wide maintenance.
- High resolution survey may be applicable to other stormwater control measures with unplanned concentrated flow.

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Journal Articles

- E. Stander, A. A. Rowe, M. Borst and T. P. O'Connor (2013). “Novel Use of Time Domain Reflectometry in Infiltration-Based Low Impact Development Practices.” Journal of Irrigation and Drainage Engineering (JIDE), Vol 139, No. 8, pp. 625–634 (http://dx.doi.org/10.1061/(ASCE)IR.1943-4774.0000595).
- Brown, R. and Borst, M. (2013). “Assessment of Clogging Dynamics in Permeable Pavement Systems with Time Domain Reflectometers.” J. Environ. Eng., 139(10), 1255–1265. (http://ascelibrary.org/doi/abs/10.1061/(ASCE)EE.1943-7870.0000734)
- Brown, R.A., and M. Borst. (2014). “Evaluation of surface infiltration testing procedures in permeable pavement systems.” J. Environ. Eng., , 140(3), 04014001. (http://ascelibrary.org/doi/abs/10.1061/(ASCE)EE.1943-7870.0000808)

EPA Reports

- EPA (2010) “Surface Infiltration Rates of Permeable Surfaces: Six Month Update (November 2009 through April 2010)” U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, Ohio, Report No. EPA/600/R-10/083, June, 2010. (http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P1008CH4.txt)

Questions?

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The USEPA, through its Office of Research and Development, funded and managed the research described herein. It has been subjected to the Agency's peer and administrative review and has been approved for external publication. Any opinions expressed in this paper are those of the authors and do not necessarily reflect the views of the Agency, therefore, no official endorsement should be inferred. Any mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Infiltration Rate along Edge Only