Soil Amendment for Water Quality

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Center for Urban Environmental Research and Education
University of Maryland Baltimore County

National Fish and Wildlife Foundation
Project Spotlight Seminar Series
19 December 2018

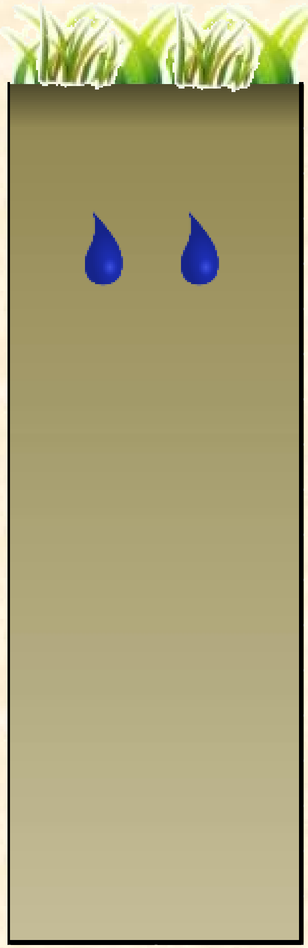
University of Maryland Baltimore County

Center for Urban Environmental Research and Education (CUERE)

Overview

- Standard grading & topsoiling practices disturb and compact healthy urban soils
- Adapt soil decompaction and amendment to restore hydrologic & ecological landscape services
- Technical, commercial, & institutional feasibility
- Produces superior sustainable landscaping by restoring *ecosystem services of soil column*
- Transferable and transformative with appropriate credit, inspection, and maintenance protocols

Bay-Wise Landscapes



Standard Topsoiling

Standard Topsoiling		Suburban Subsoiling
Sparse	**Plant vigor**	Dense
Low	**Infiltration Rate**	High
Limited	**Plant Available water**	High
High	**Bulk Density**	Low
Low	**Organic Matter**	High
Limited	**Plant avail. nutrients**	Abundant, organic
Shallow	**Root depth / density**	Deep, dense
Low	**Bacterial / Fungal Activity**	High / Active

Suburban Subsoiling


Heritage Development Company
Coming
City View Center
Spring 2005
WAL·MART
BED BATH & BEYOND
DICK'S
GIANT EAGLE
JOANN
216-514-510

Root-Limiting Soil Strength (BD)

Dense turf cover growing in thatch layer.

Design Sustainable Chesapeake Bay Landscapes

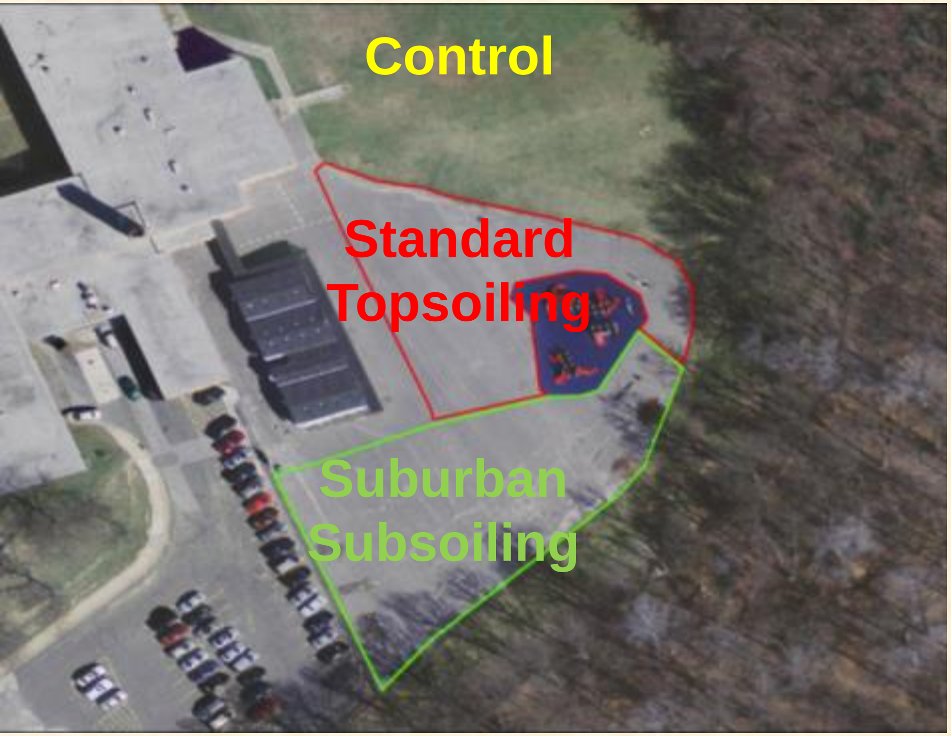
- Avoid disturbance and compaction
  - Limit disturbance and vehicle traffic
- Minimize Disturbance and Compaction
  - Light weight equipment
  - Wide low pressure tires
  - Avoid wet soil conditions
- **Restore Disturbed Compacted Soils**
  - Suburban Subsoiling
  - Complete Cultivation
  - Loose Tipping

Suburban Subsoiling

adapting agricultural subsoiling practices to the urban landscape

Yorkwood Elementary School

Baltimore City impervious area removal project

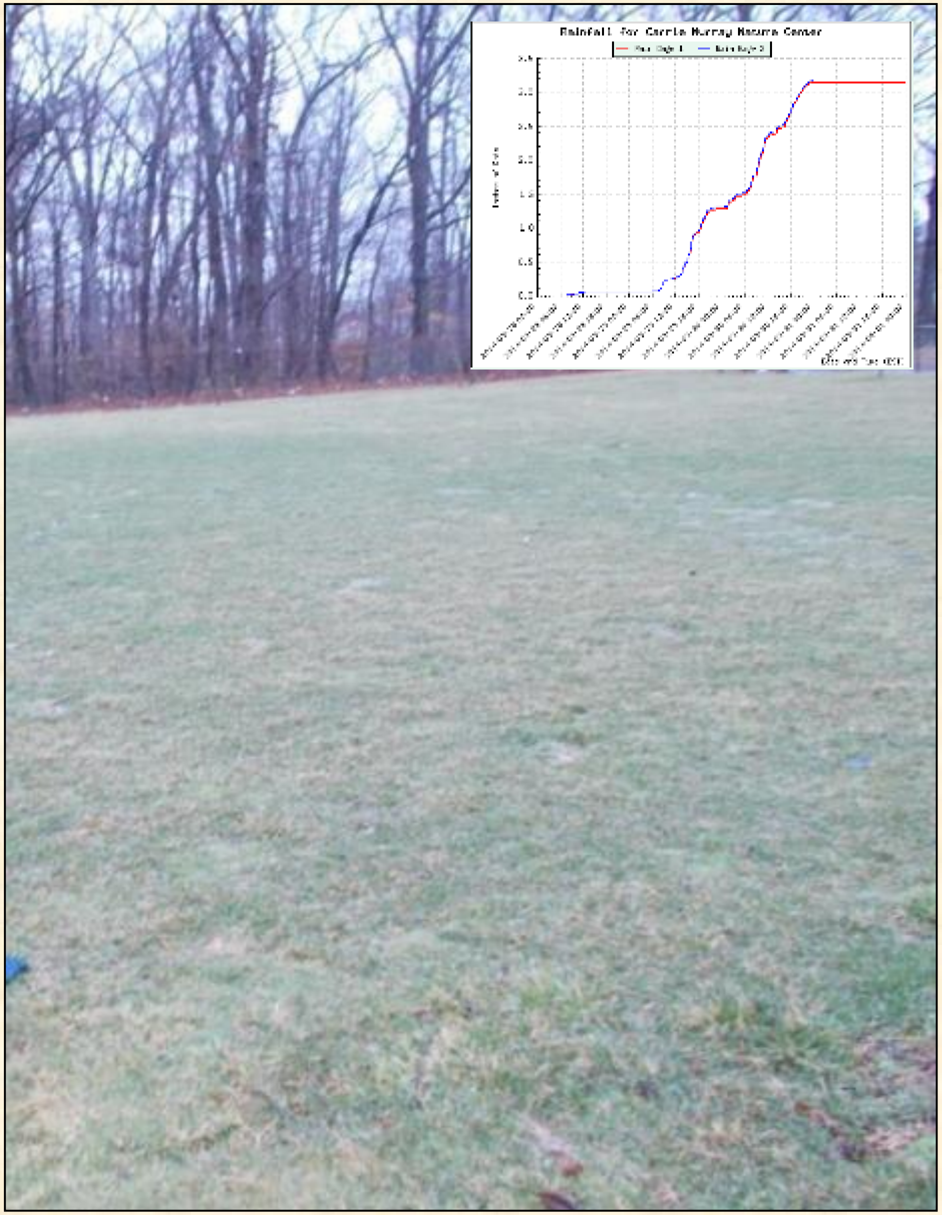


Suburban Subsoiling

- Deep ripping
- Compost amendment

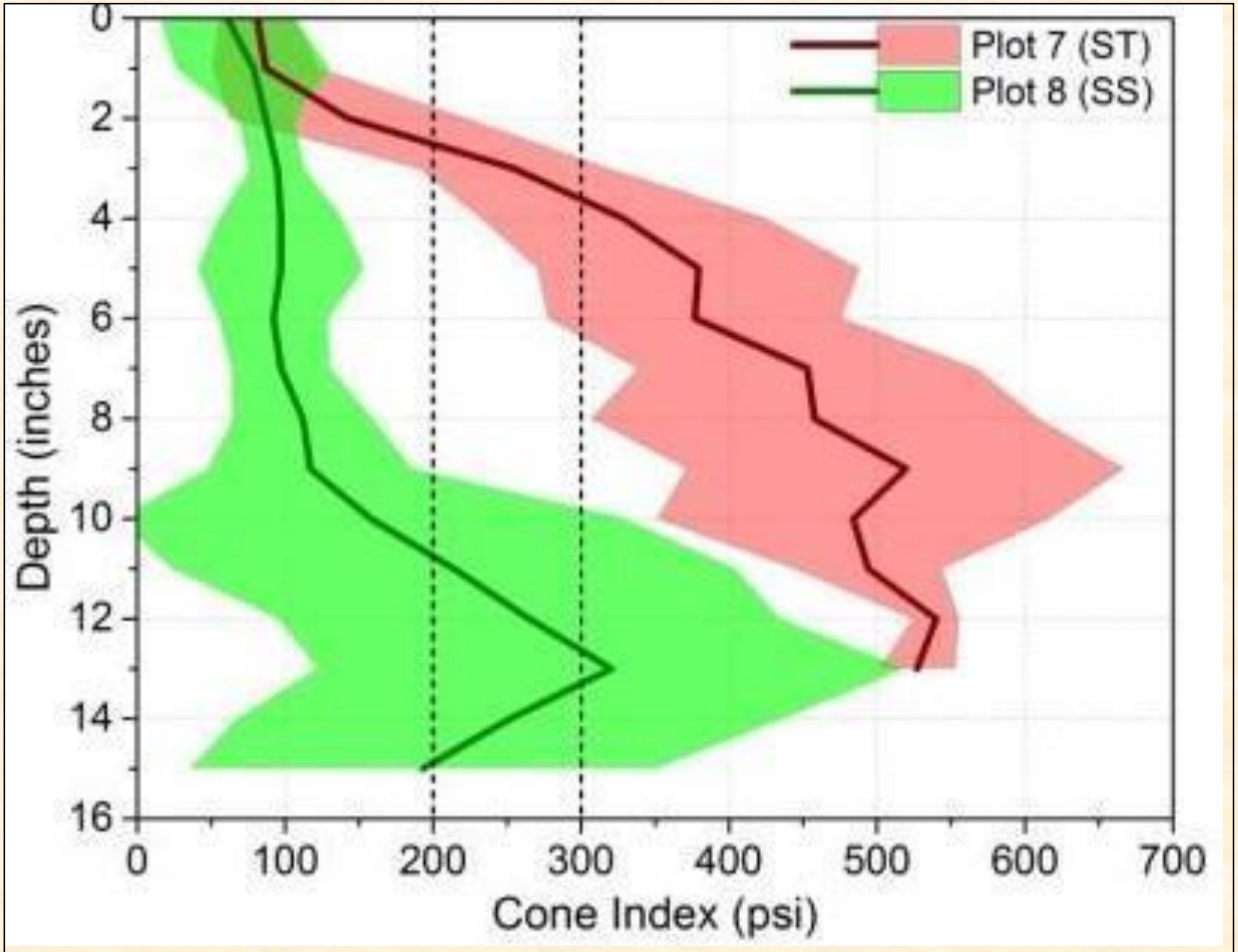

Standard topsoiling
Suburban subsoiling

Sunday 30 March 2014



Decompact & Amend **Soil Profile** – *not just soil surface*!

MD-SHA Taneytown, MD



ICC Mitigation project with Montgomery Parks

Complete Cultivation –
Adapted From Open Pit Mine Reclamation

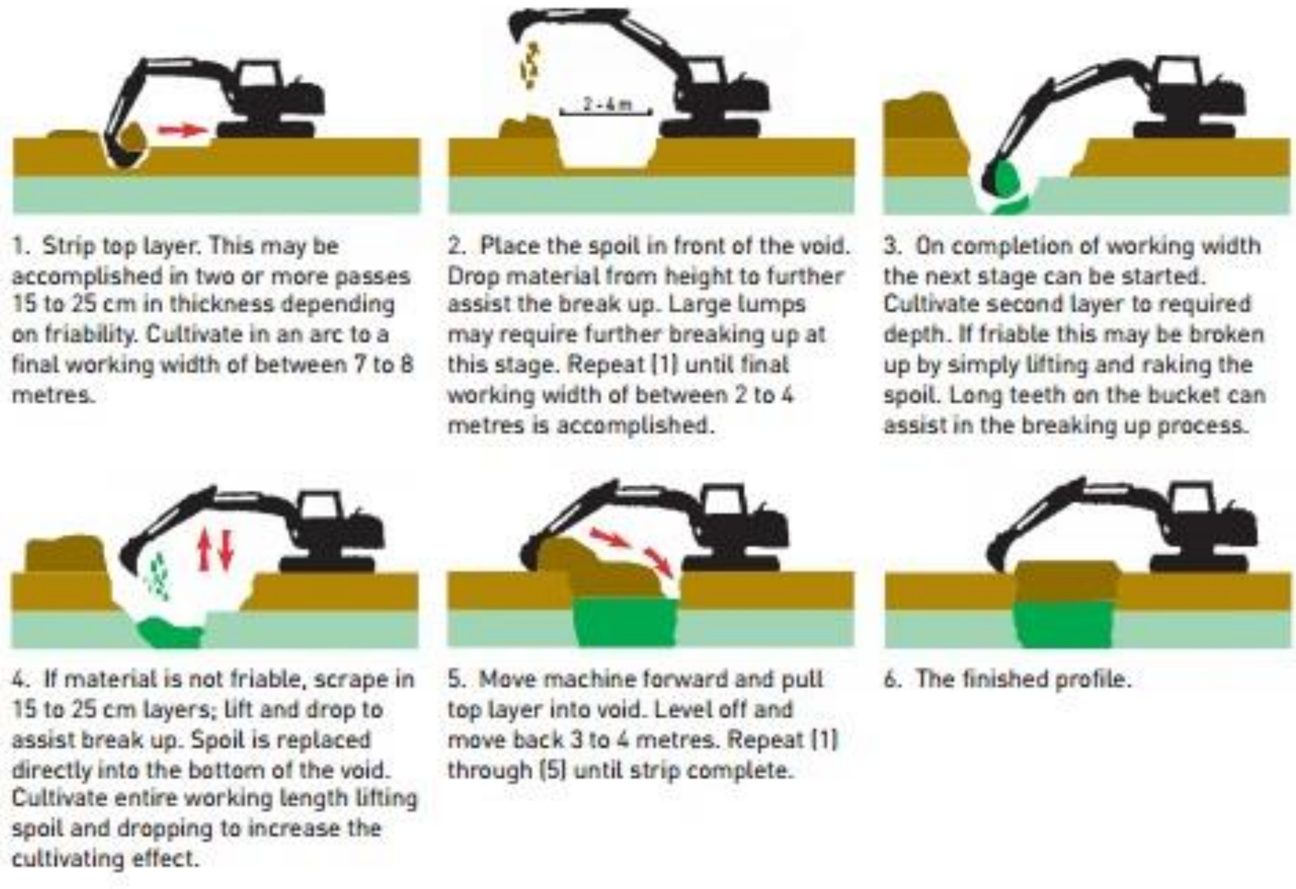


Figure 2 Profile strip method (from Reynolds, 1999).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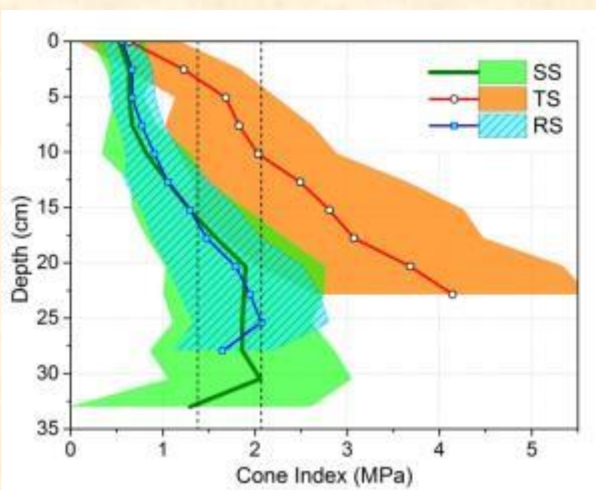
Complete Cultivation + Compost
04/26/2015 16:08


Standard Treatment: Rototill + fertilizer
04/26/2015 16:08

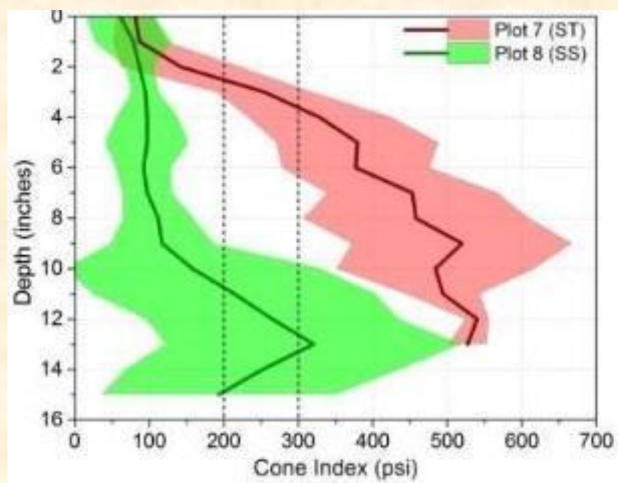
Yorkwood Taneytown TVCC

		Yorkwood Elementary		SHA Taneytown		Turf Valley Country Club	
		SS	ST	SS	ST	SS	ST
Infiltration (in/hr)	**4.87 vs 0.05**	3.25	0.13	7.55	0.006	3.8	0.02
Bulk Density (g/cc)	**1.20** vs **1.61**	1.25	1.71	1.11	1.56	1.25	1.57
Organic Matter (%)	**8.3** vs **3.4**	9.39%	3.09%	6.4%	3.5%	9.04%	3.6%

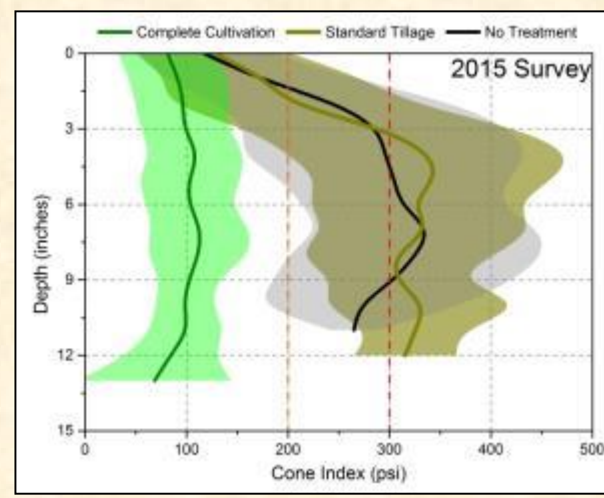
Yorkwood



Taneytown



Turf Valley Country Club



Findings & Lessons Learned

- Means and Methods Matter!

  (Not your father's rototiller!)

- Restore porous permeable organic soil profile – not just a planting bed!

- Rapid Vegetative Stabilization – essential for SEC, but *<u>not sufficient</u>*

- Yields ***Superior Sustainable Landscaping***

- Quantify hydrologic services by Rv or ECN

  Journal of Hydrology 543:770-781

Findings & Lessons Learned

- Feasible with incremental changes in current practice
- Reduced Irrigation & Fertilizer = Short pay-back period
- Cost-effective when properly staged
- Life-Cycle costs superior now for long-term institutional land owners
  (e.g. transportation ROW, DOT, DOD, etc.)
- Revised compost specifications (maturity) for soil husbandry vs. fertilization

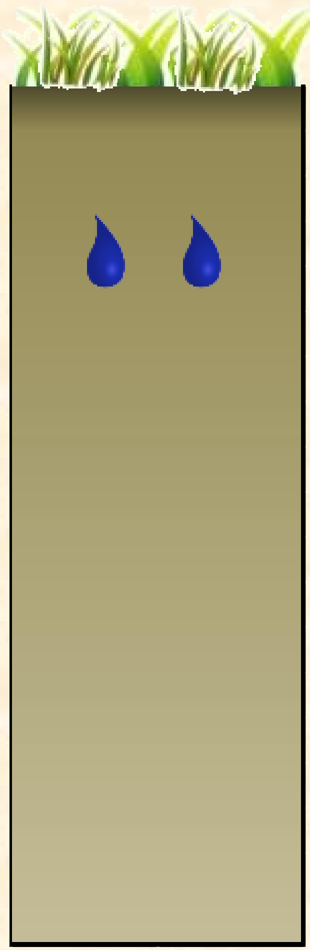
Next Steps (Institutional Feasibility)

- Consistent Site-Specific Credit
  - Rv or Effective Curve Number (ECN) for Sustainable Sites initiative (SSI)
- Inspection and Maintenance Protocols
  - *just like every other BMP!*
  - *deep tyne hollow core aeration & topdressing*

Conclusion

- Hydrologically Impoverished Pervious landscapes are ubiquitous in the urban environment - *by design*
- Urban Soil Husbandry can restore hydrologic function
- Superior Sustainable Landscaping & Hydrologic Services
- Transferable and transformative with appropriate credit, inspection, and maintenance protocols

Bay-Wise Landscapes



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Standard Topsoiling

Suburban Subsoiling

Thanks!

Questions?

Reducing Stormwater Volume and Nutrients with Biochar

University of Delaware Faculty and Students

- Paul Imhoff, Pei Chiu and Julie Maresca
- Joseph Brown and Sriya Pant

Collaborators

- Chuck Hegberg, reGENSIS Consulting Services, LLC
- Larry Trout, RK&K, Inc.

Supporting Partners

- Delaware Department of Transportation
- Maryland Transportation Authority
- City of Charlottesville, VA

Dare to be first.

University of Delaware

NFWF

Chesapeake Bay Program
Science. Restoration. Partnership.

Chesapeake Bay Stewardship Fund

Historical Data

- Biochar addition to Terra Preta soils of Amazon Basin

Without Biochar

With Biochar

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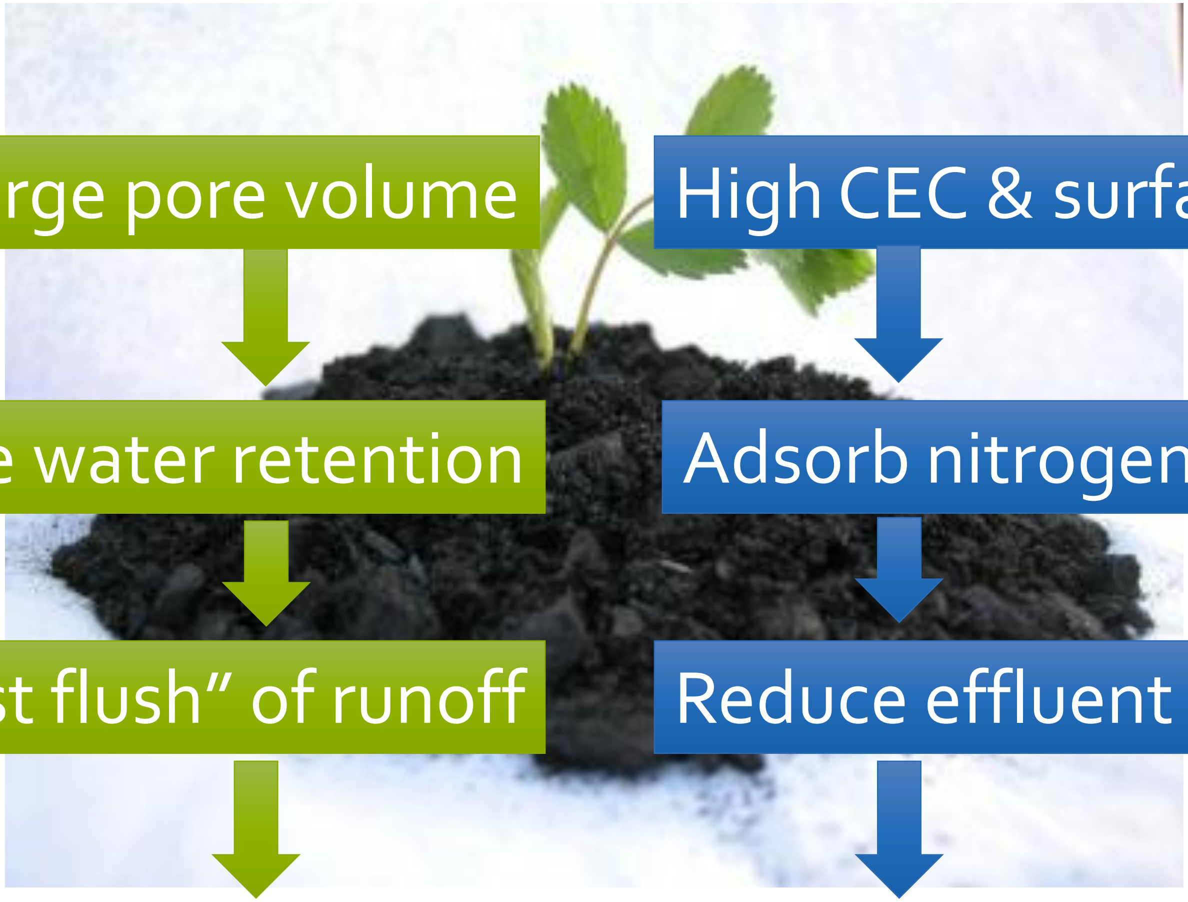
Hypothesis



Large pore volume

Increase water retention

Capture "first flush" of runoff

High CEC & surface area

Adsorb nitrogen compounds

Reduce effluent concentration

- <u>Enhance retention</u> of nitrogen and water in the soil zone
- <u>Increase rates</u> of infiltration and chemical transformations

University of Delaware Research

- Laboratory studies – biochar's influence on
  - Soil hydraulic properties – NFWF study
  - Nitrogen fate
- Field studies – biochar's influence on
  - Bioretention media
    - Water retention
    - Nitrogen removal
  - Roadway soils – NFWF study
    - Reduction in runoff volume and peak flows
    - Nitrogen removal

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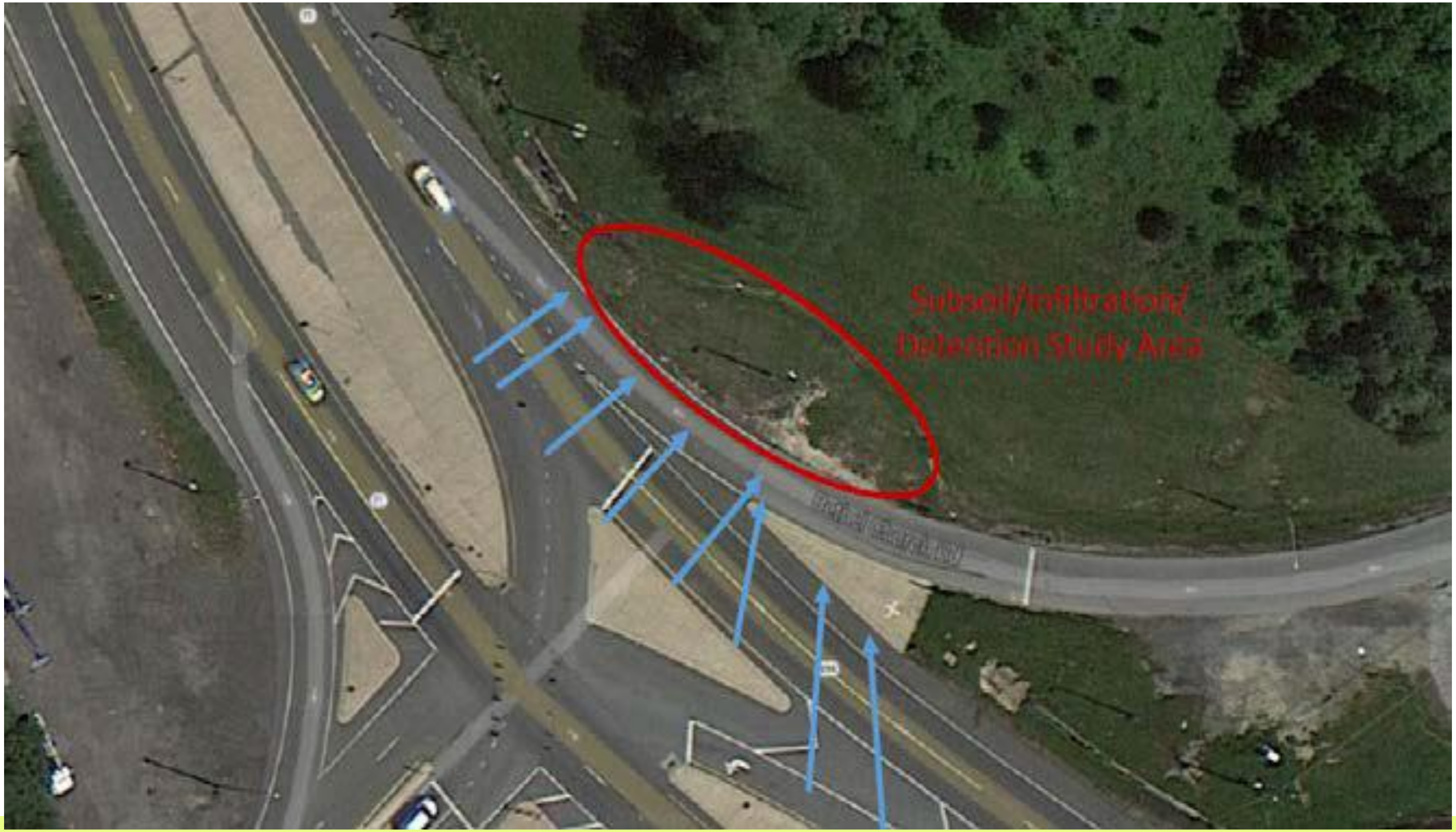
Design

- Selection of field site – intersection of DE 896 and Bethel Church Road



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Design

- Roadway soil amendment
  - Amend top 30 cm with 4% by mass wood-based biochar
  - Measure runoff volume and quality

- Bioswale amendment
  - Amend top 30 cm with 4% by mass wood-based biochar (base)
  - Amend top 30 cm with 4% by mass wood-based biochar (side slopes)
  - Measure in situ water volume and quality

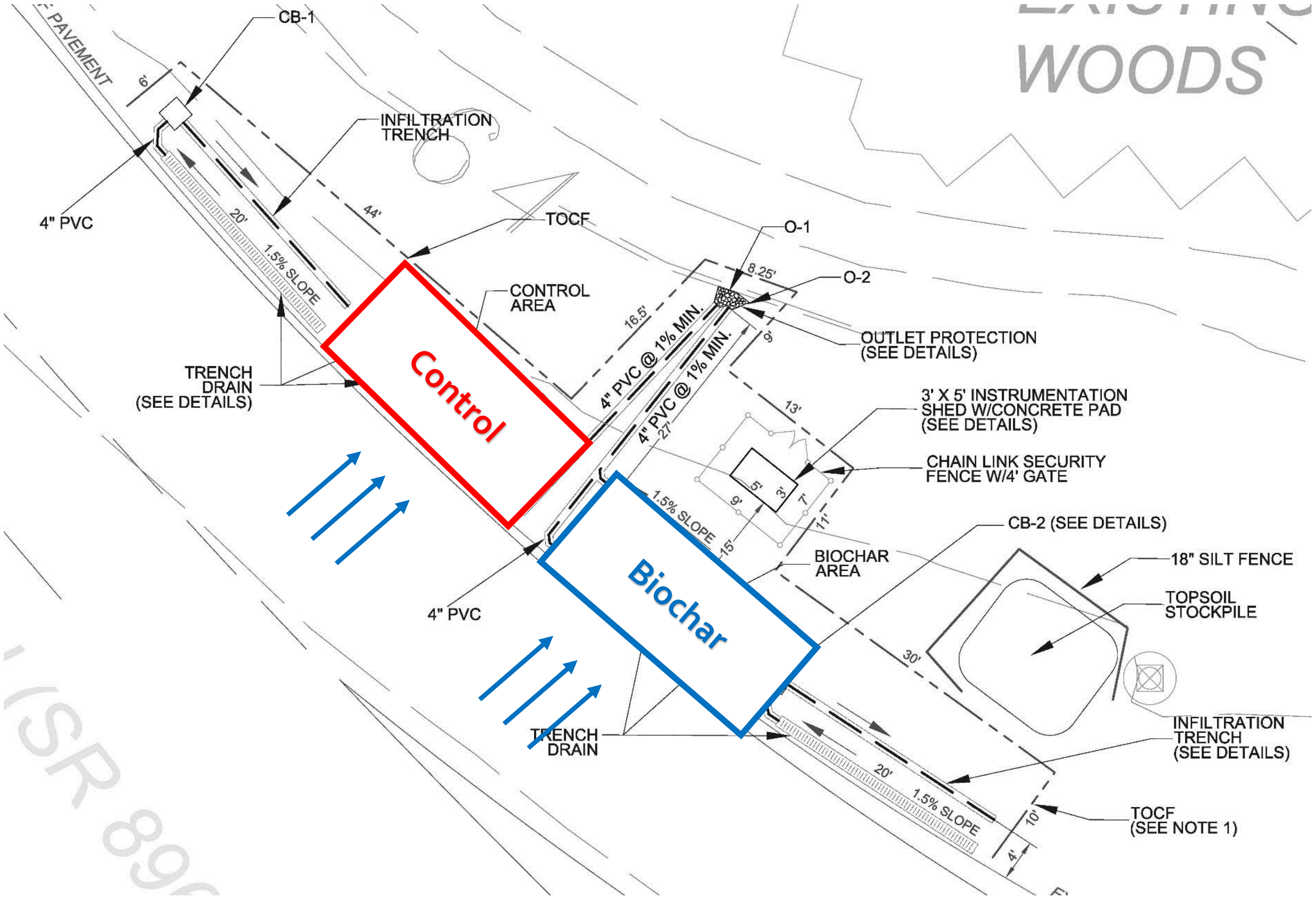
- 1.3 acres treated region

Roadway Soil Amendment

- Biochar reduces runoff volume and peak flows
- Side-by-side comparison if biochar-amended and un-amended roadway soils

Roadway site in Delaware also in Chesapeake Bay Watershed

Field Study – Roadway Soils



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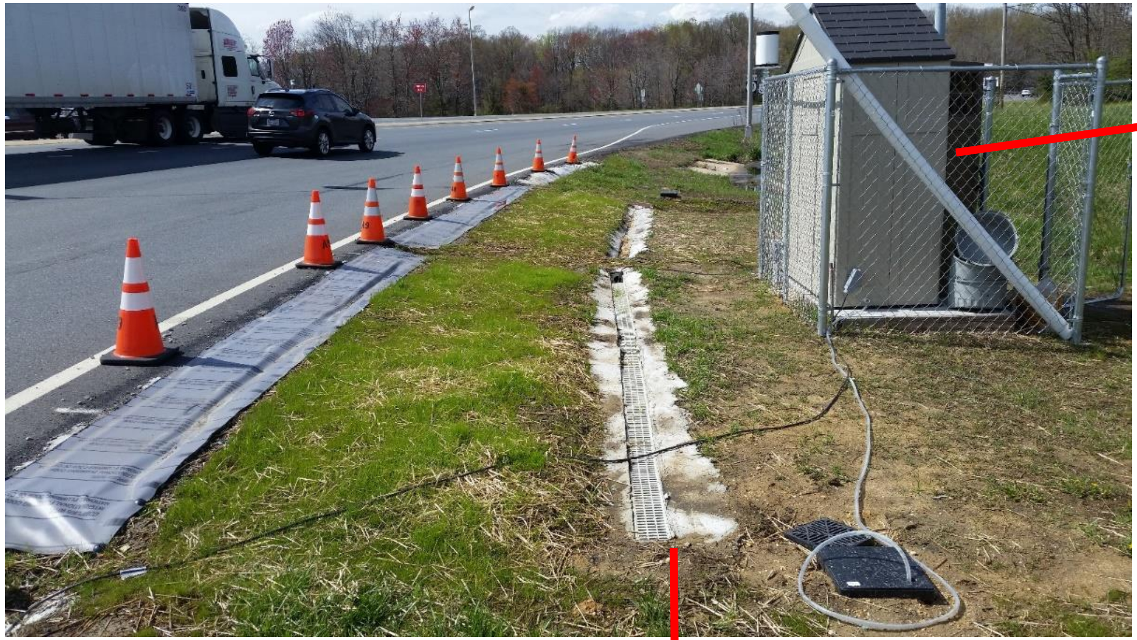
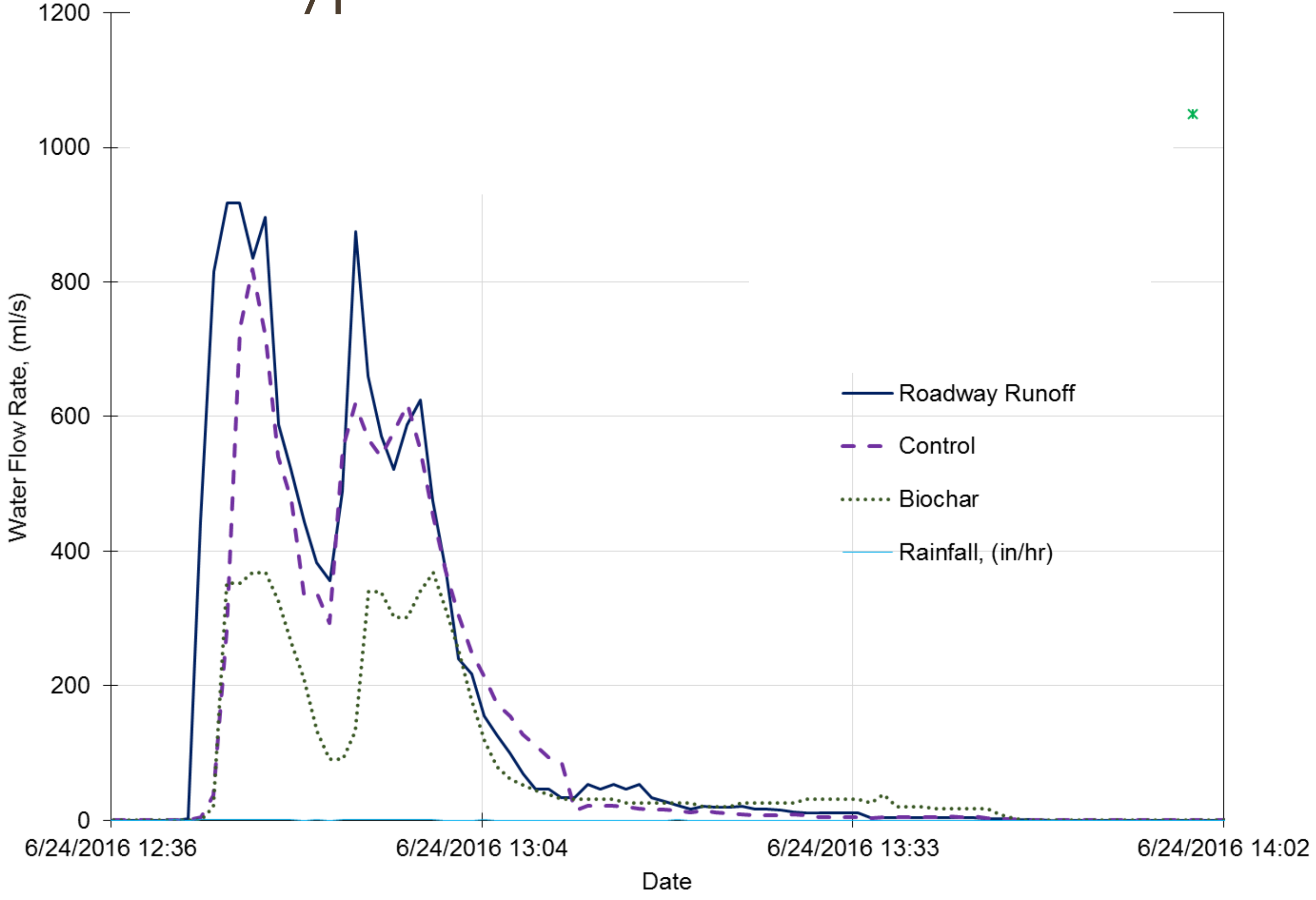
Field Study – Roadway Soils



Field Study – Roadway Soils

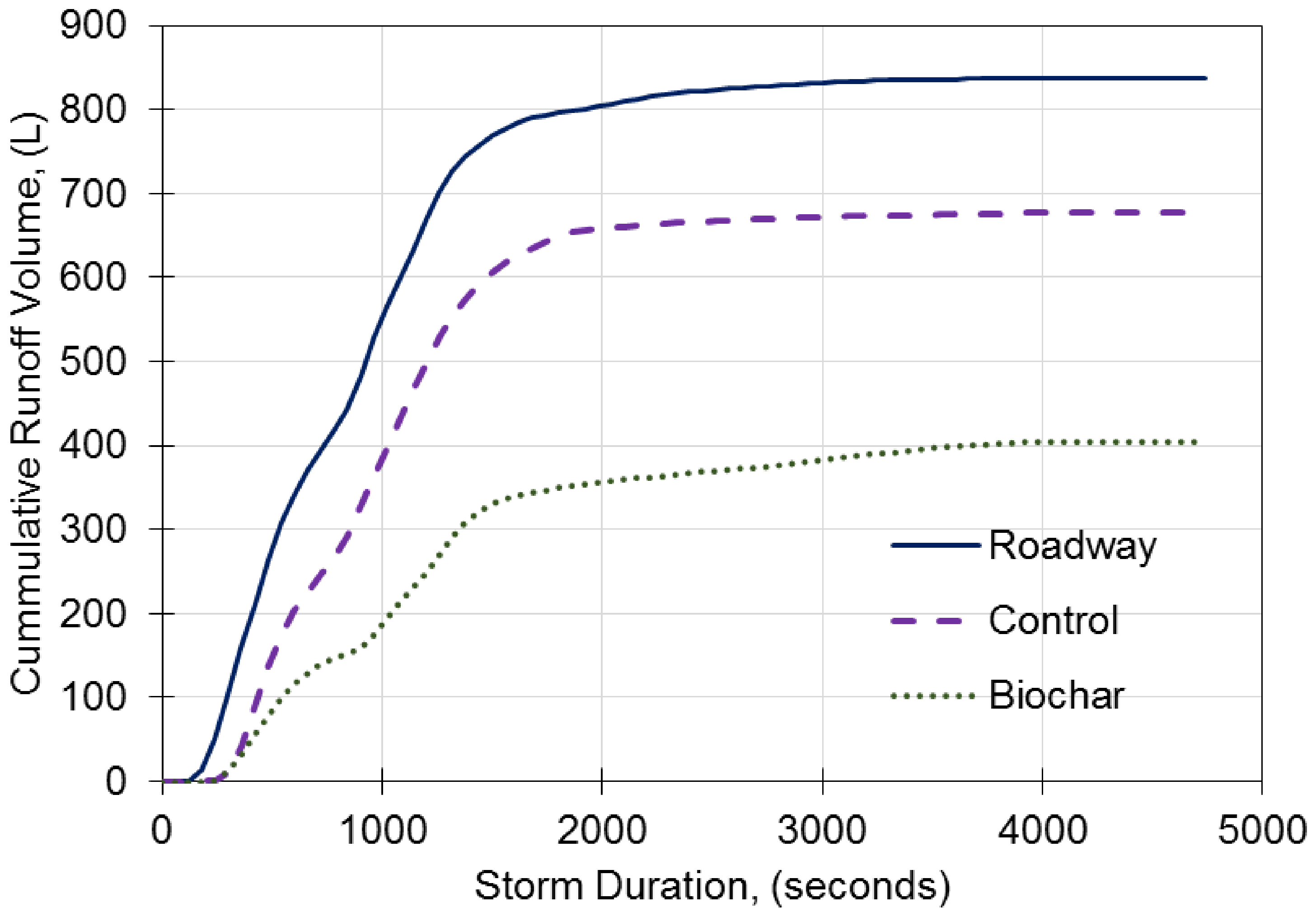
Typical Storm – Water Flow



Biochar amended soil attenuates peak flow ~ 50-60%

Field Study – Roadway Soils

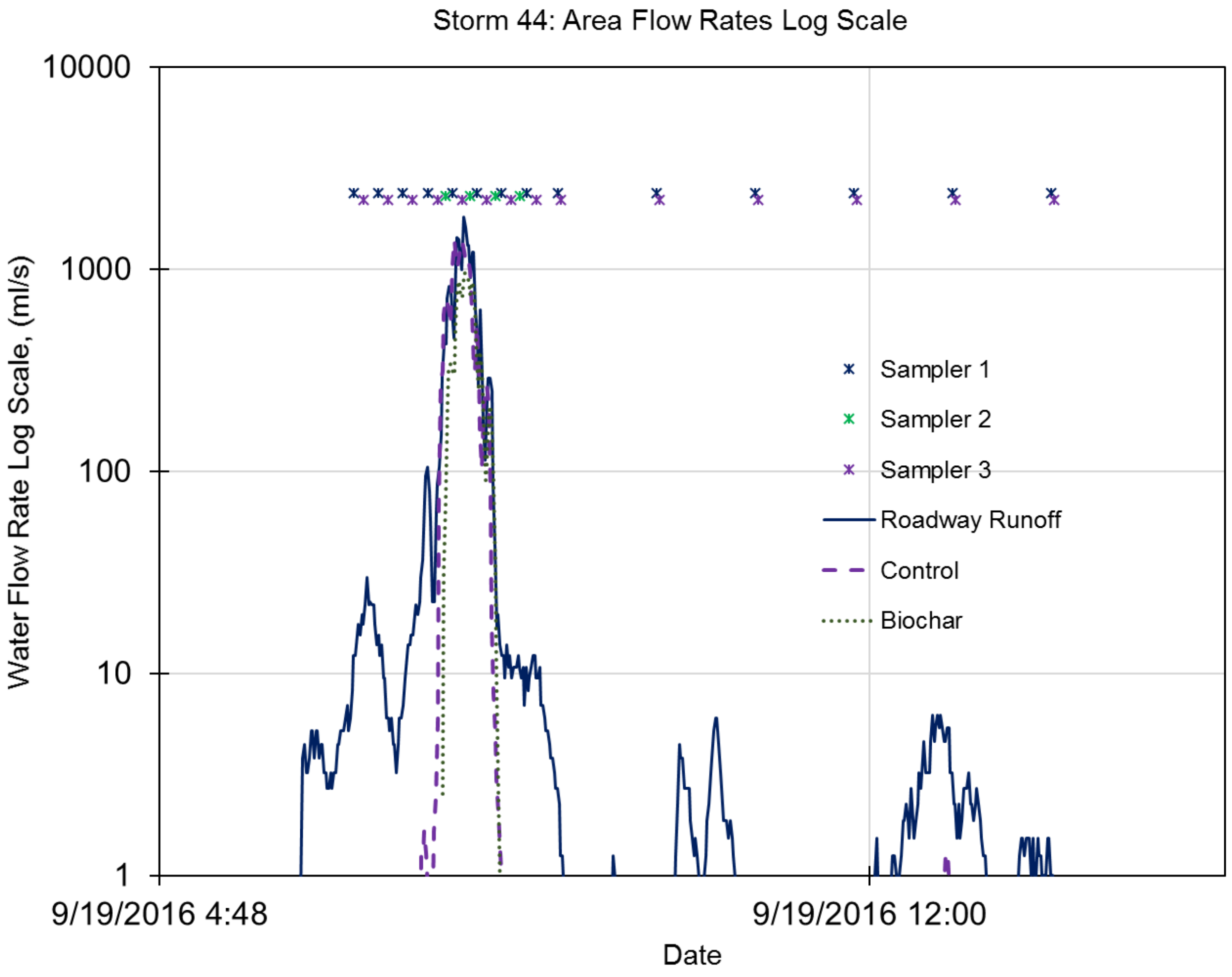
Typical Storm – Water Flow



Biochar amended soil attenuates runoff volume by ~ 70%

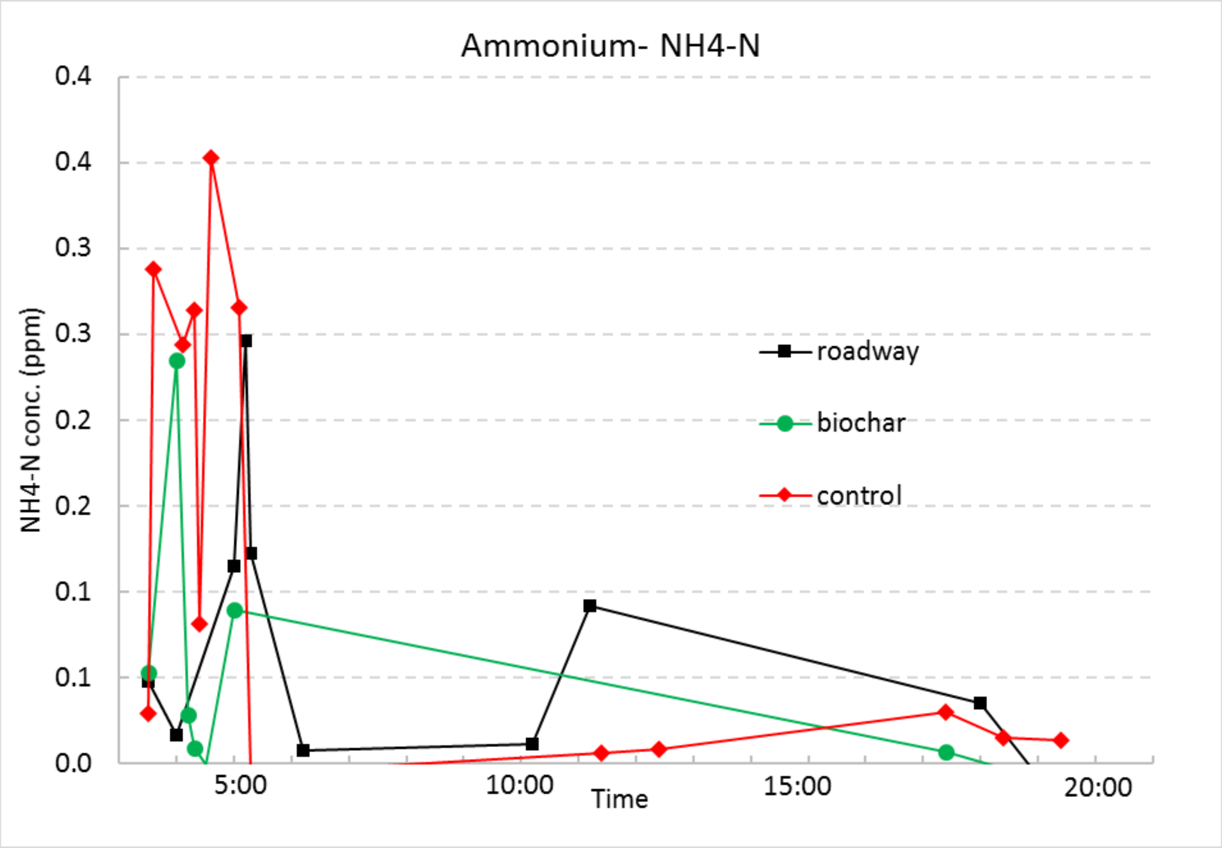
Field Studies – Roadway Soils

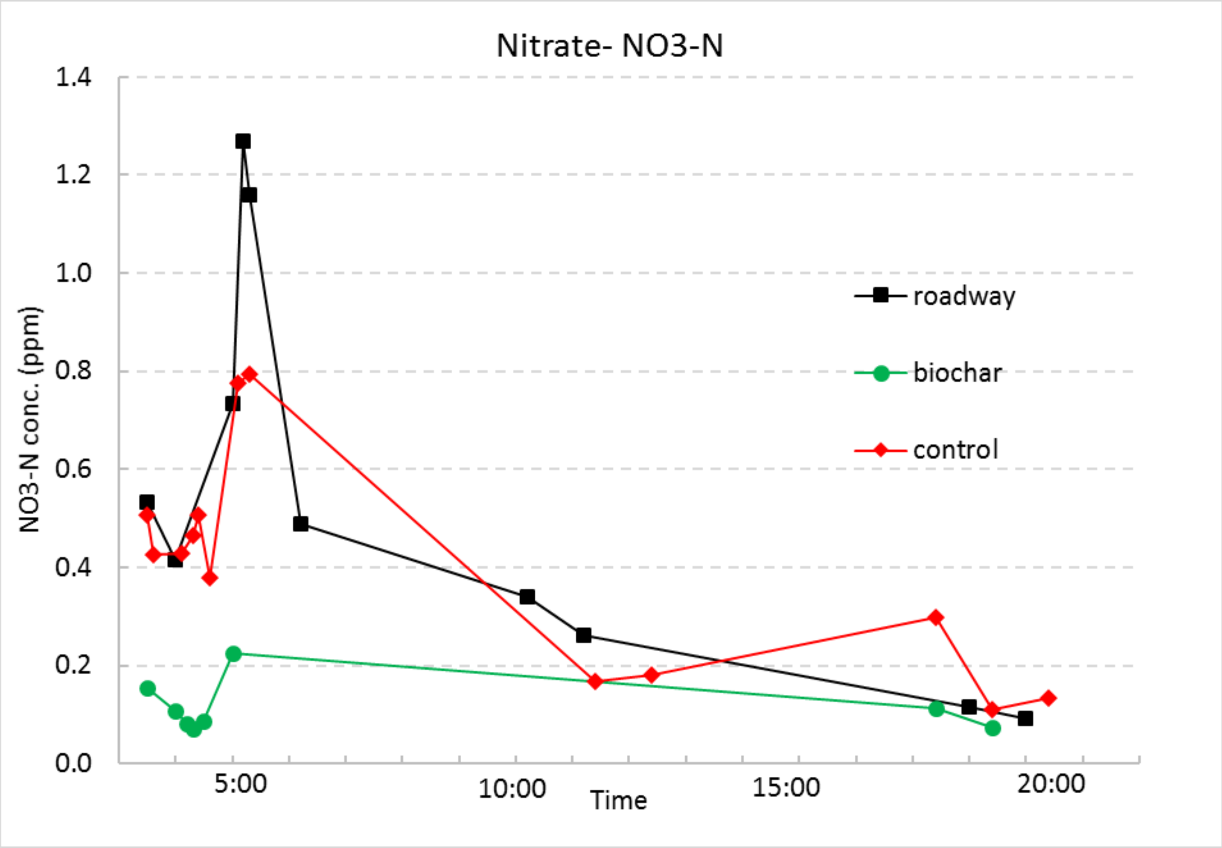
Typical Storm – Water Quality



Field Studies – Roadway Soils

Typical Storm – Water Quality





Biochar unexpectedly reduced nitrate concentrations

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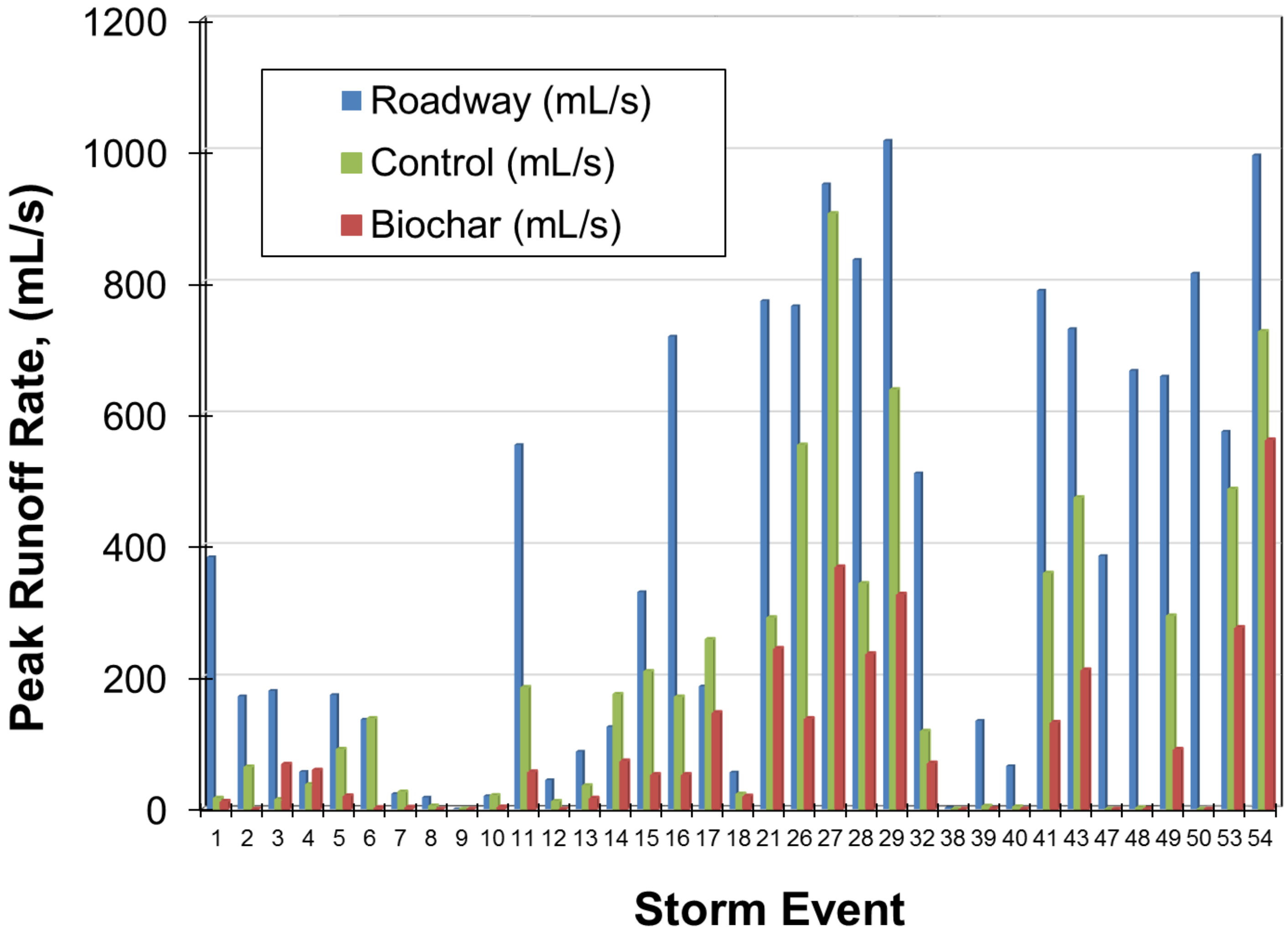
Field Studies – Roadway Soils

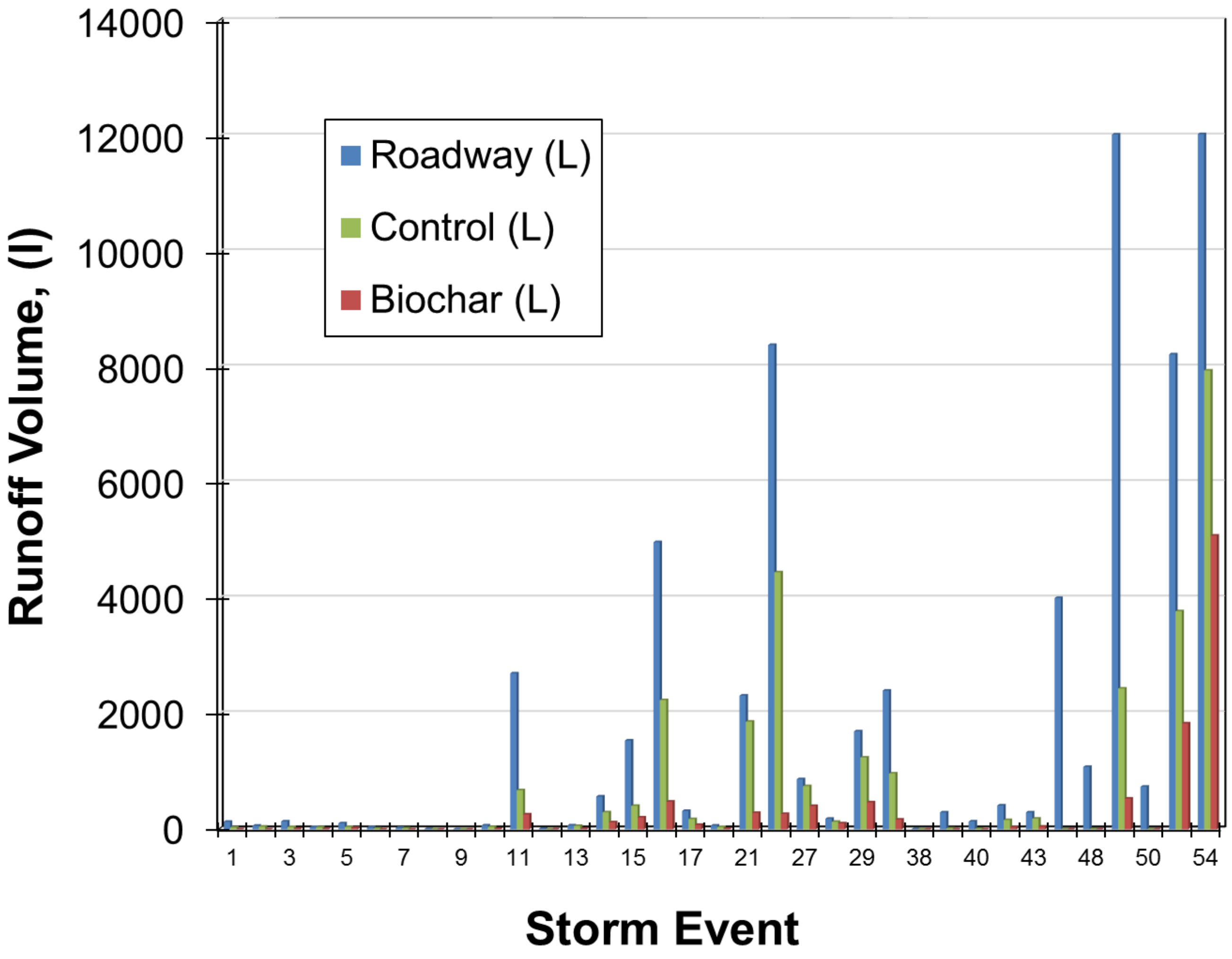
Storms in 2016



4% wood biochar addition reduced peak runoff rate by ~ 48%

Field Studies – Roadway Soils

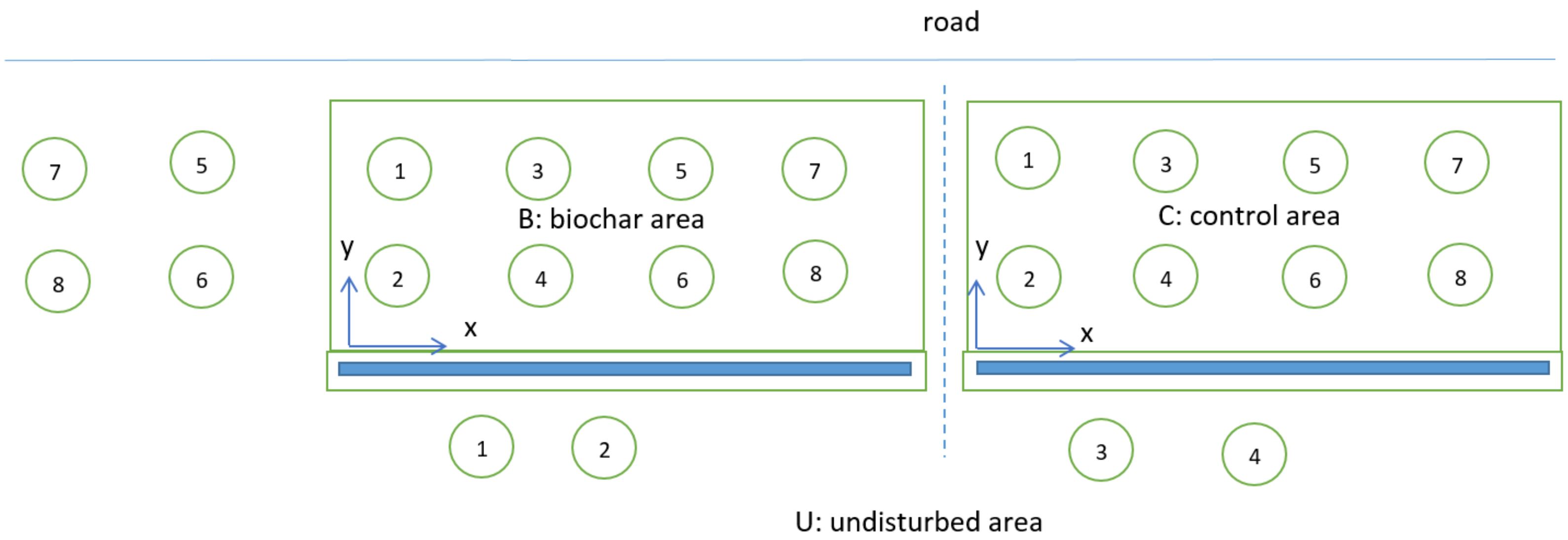
Storms in 2016



4% wood biochar addition reduced runoff volume by ~ 75%

Why Reduction in Runoff?

Measurements of Hydraulic Conductivity with Disc Infiltrometer



Measurements for: biochar, control and undisturbed regions

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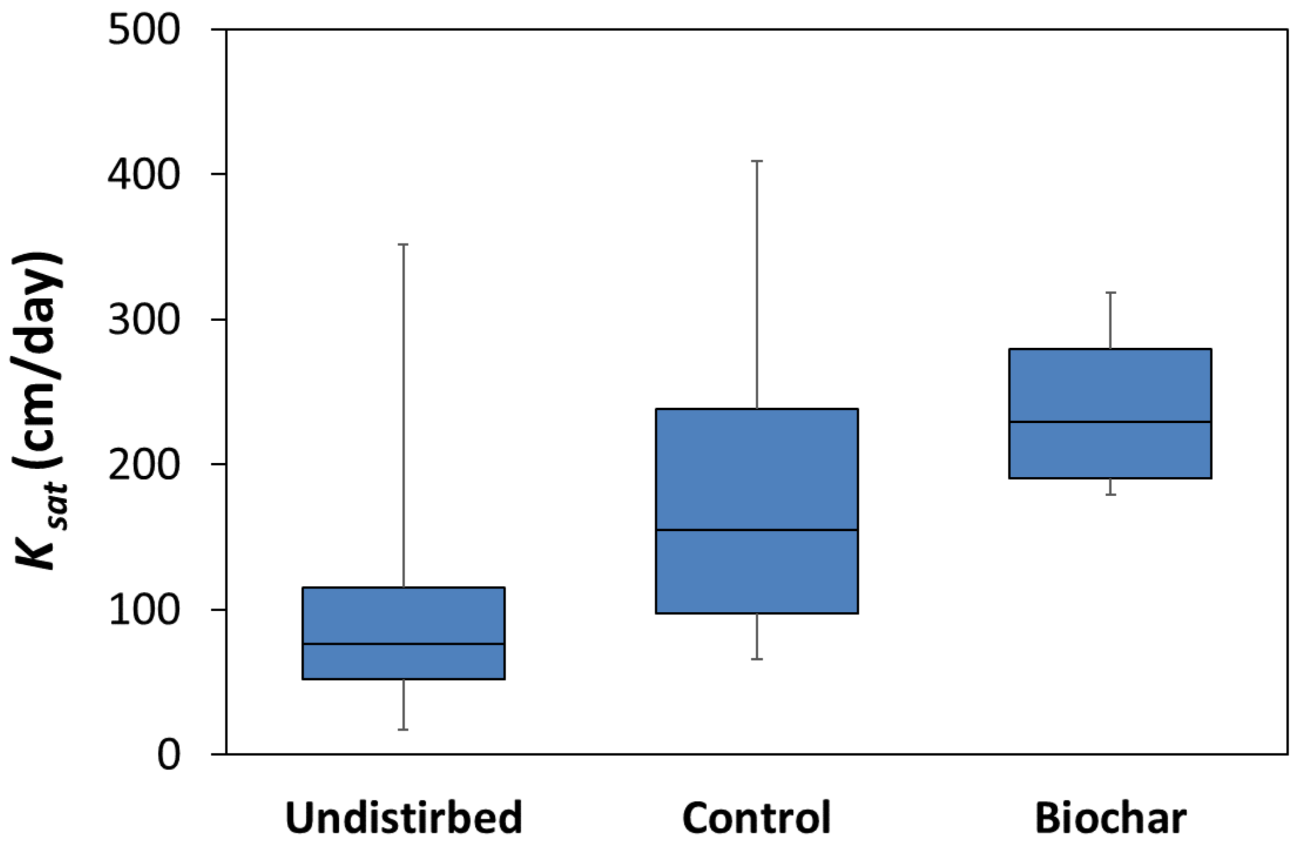
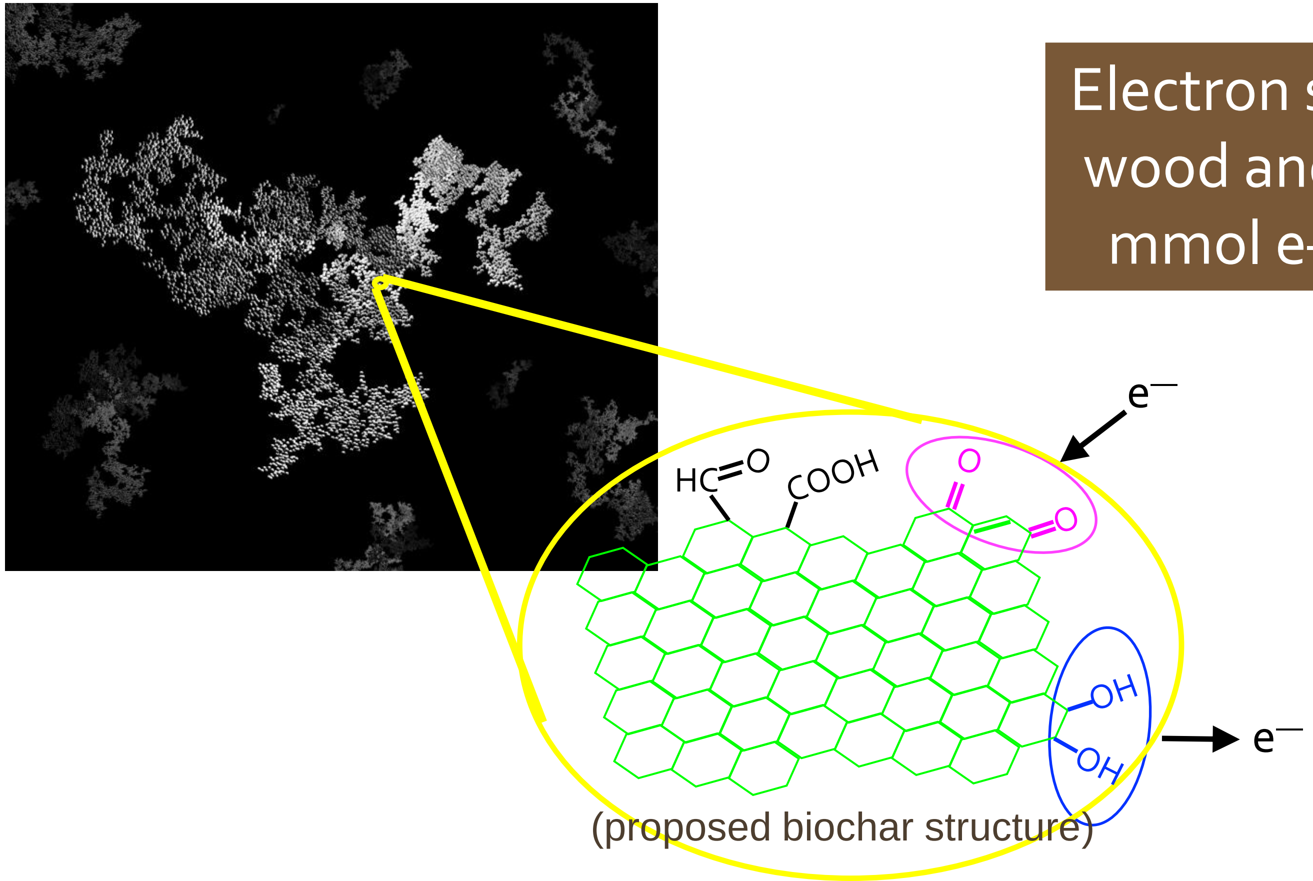
Why Reduction in Runoff?



- Biochar increased mean K_{sat} by approximately 30%, similar to increase observed in lab data
- Mean K_{sat} in field approximately 3 times larger than lab measurements (identical bulk densities).

Why Reduction in Nitrate?

Biochar facilitates denitrification through electron storage



(proposed biochar structure)

Electron storage capacity (ESC) of wood and grass biochar is up to 2 mmol e–/g (Klüpfel et al., 2014)

Saquing, et al., “Wood-Derived Black Carbon (Biochar) as a Microbial Electron Donor and Acceptor,” *Environmental Science & Technology Letters*, 2016.

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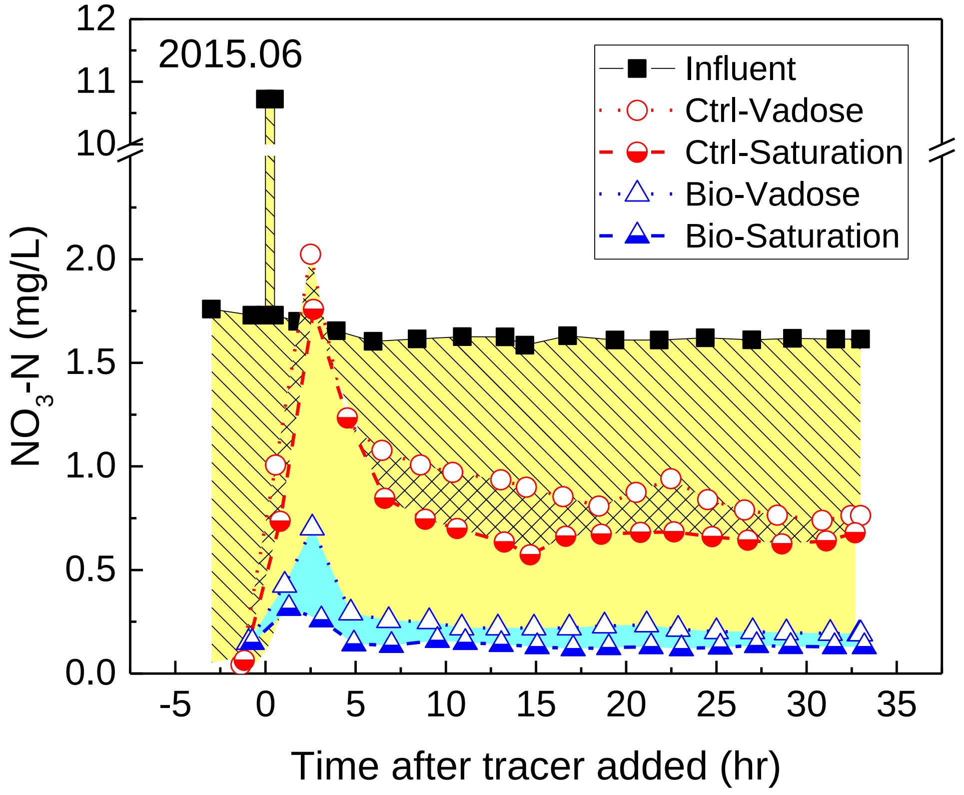
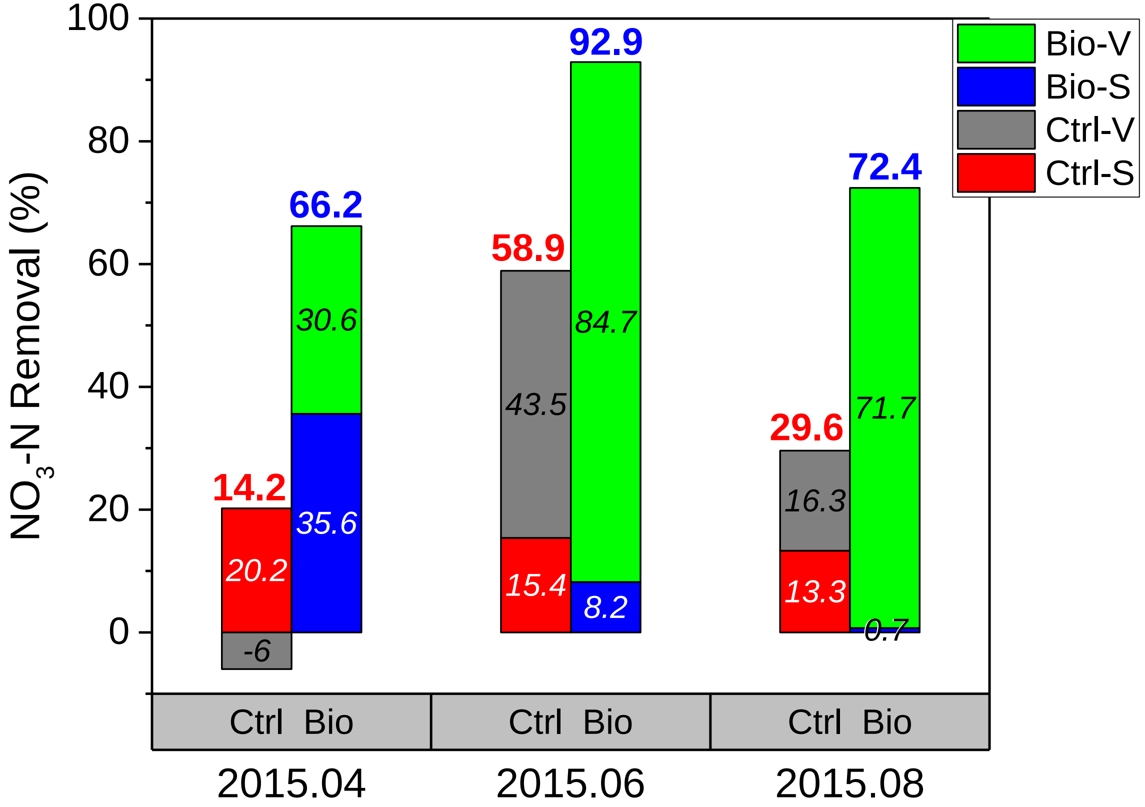
Results from Bioretetion Study





(cross-hatch)	NO_3-N removed by control vadose zone
(double hatch)	NO_3-N removed by control saturation zone
(yellow)	NO_3-N removed by vadose zone with biochar
(cyan)	NO_3-N removed by saturation zone with ZVI

- Biochar increased nitrate removal by between 60 and 370% over the standard bioretention media, depending on season.

Lessons Learned

- Construction design longer than anticipated
- Difficulty with soil heterogeneity – removal of cobbles required
- Dry soil conditions – delayed biochar addition
- Training in use of samplers/analysis equipment longer than anticipated
  - In-house analysis of ammonium, nitrate, nitrate, total nitrogen, total organic carbon, and total suspended solids

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Conclusions

- Biochar amendments can significantly improve hydraulic properties for SOME soils
- Reductions in runoff volume and peak flow consistent with increases in saturated hydraulic conductivity
- Reductions in nutrient concentrations in stormwater unexpected – ongoing data collection
- Future work must evaluate longevity and cost-effectiveness of treatment

Thank You

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