Application of Biochar to Soils and Bioretention Media to Reduce Stormwater Volume and Nutrient Concentrations

Paul T. Imhoff[1]

Joseph Brown[1], Wenling Tian[1], Chuck Hegberg[2] Sriya Panta[1], Seyyedaliakbar Nakhli[1], Pei Chiu[1], Jovita Saquing[1], Yudi Yan[1], and Larry Trout[3]

[1]University of Delaware
[2]reGENESIS Consulting Services, LLC
[3]RK&K, Inc.

Supporting Partners: National Fish and Wildlife Foundation, Delaware Dept. of Transportation, Maryland Transportation Authority, City of Charlottesville, VA

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Problem

- DE, DC, MD, NY, PA, VA, and WVA required to meet Chesapeake Bay water quality standards for nutrients and sediments

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Current Solution

- Costly
  - Stream restoration = $73k per impervious acre treated
  - Tree plantings = $100k " " "
  - Retrofits = $92k " " "

- Sometimes impractical
  - Usually requires purchase of private property or right of way
  - Land requirements kill some BMP projects

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Proposed Solution #1: Roadway Soils

- How to reduce costs?
  - ➢ Use existing highway greenway – usually not counted for treatment
    - Too compacted
    - Little infiltration
    - Steep slopes
    - Utilities
  - ➢ Modify
    - Increase infiltration
    - Increase water holding
    - Biological removal of pollutants

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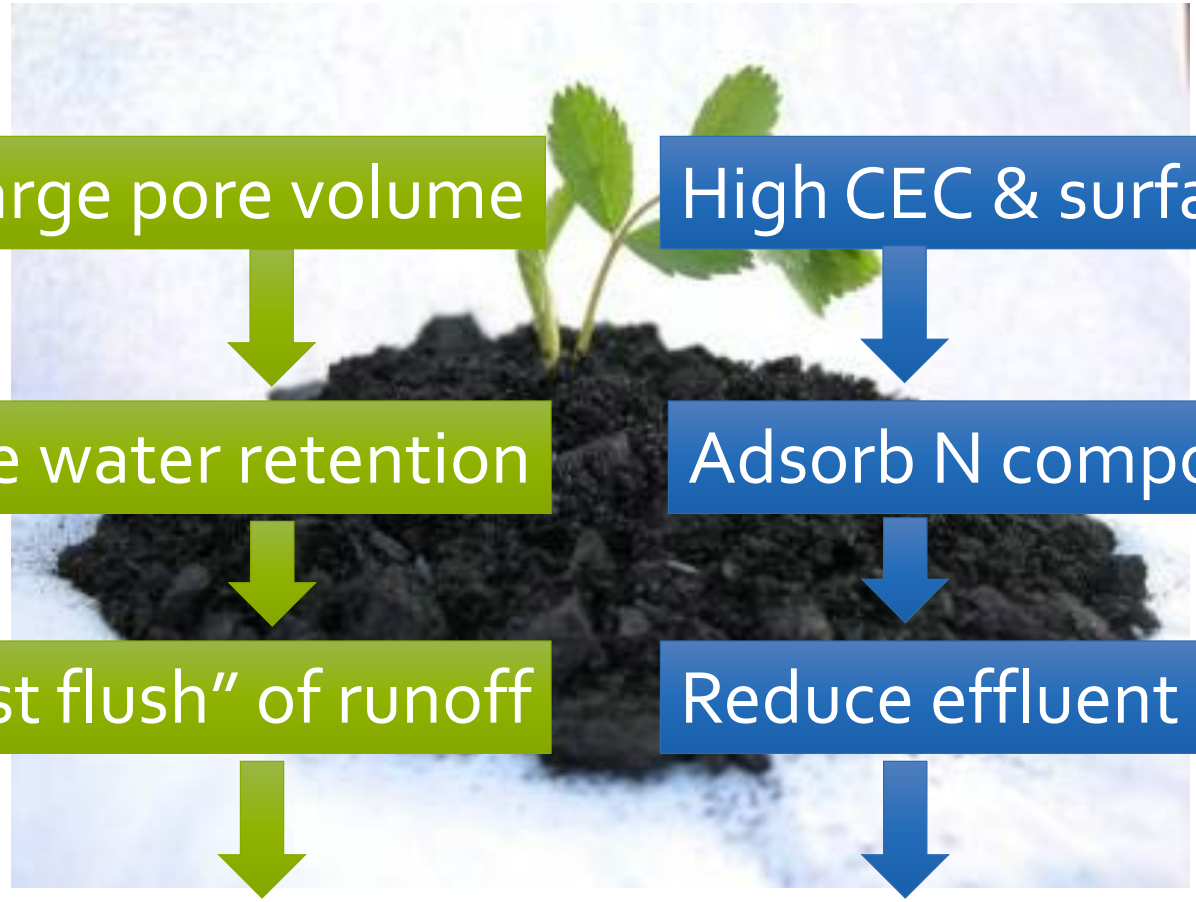
Hypotheses



Large pore volume → Increase water retention → Capture "first flush" of runoff

High CEC & surface area → Adsorb N compounds → Reduce effluent concentration

- Enhance retention of N and water in the soil zone
- Increase rates of infiltration and chemical transformations

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Field Test of Roadway Biochar Amendment

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

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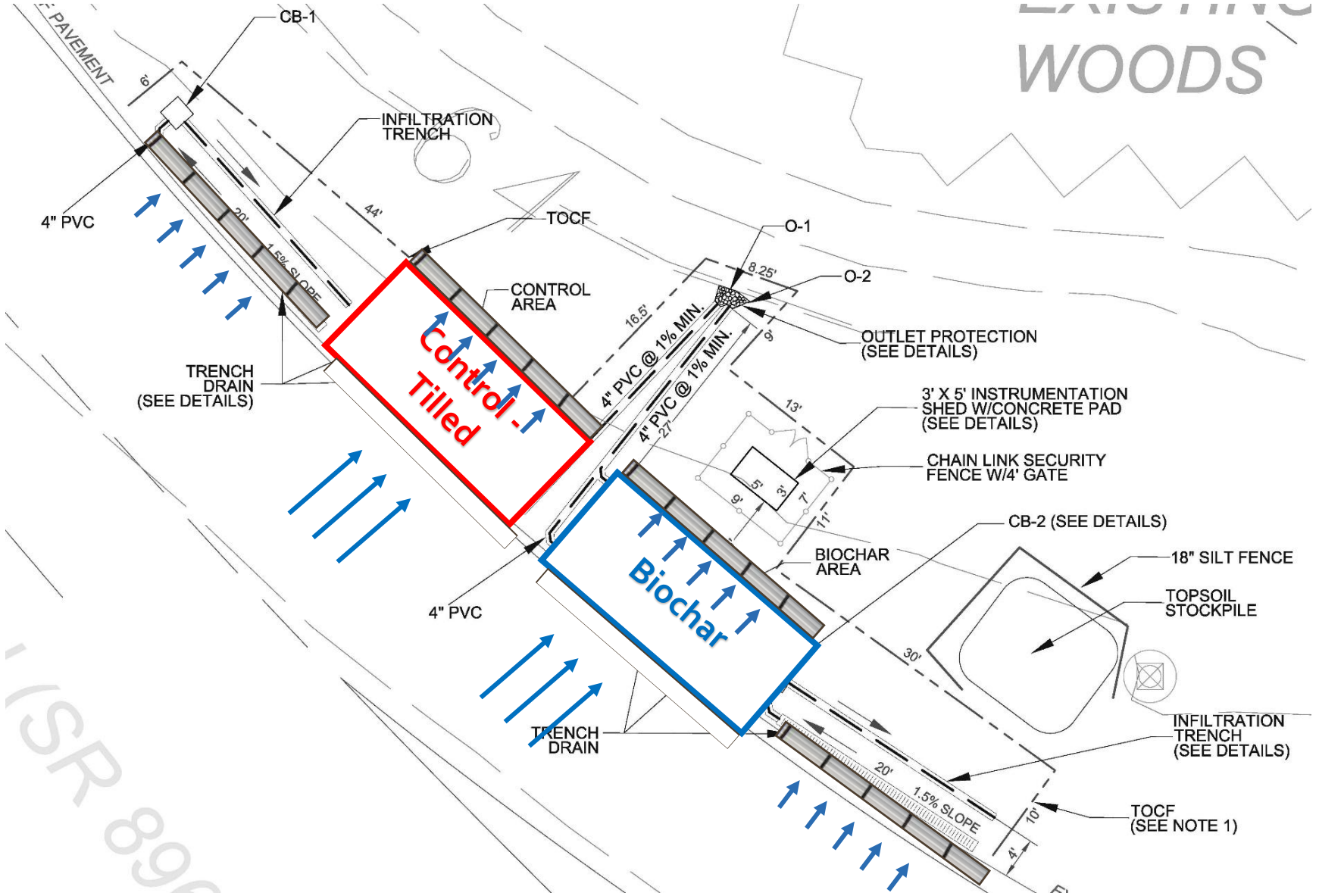
Field Study – Roadway Soils



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Field Test of Roadway Biochar Amendment

Control Strip - Tilled

4% Biochar Strip

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Field Study – Roadway Soils

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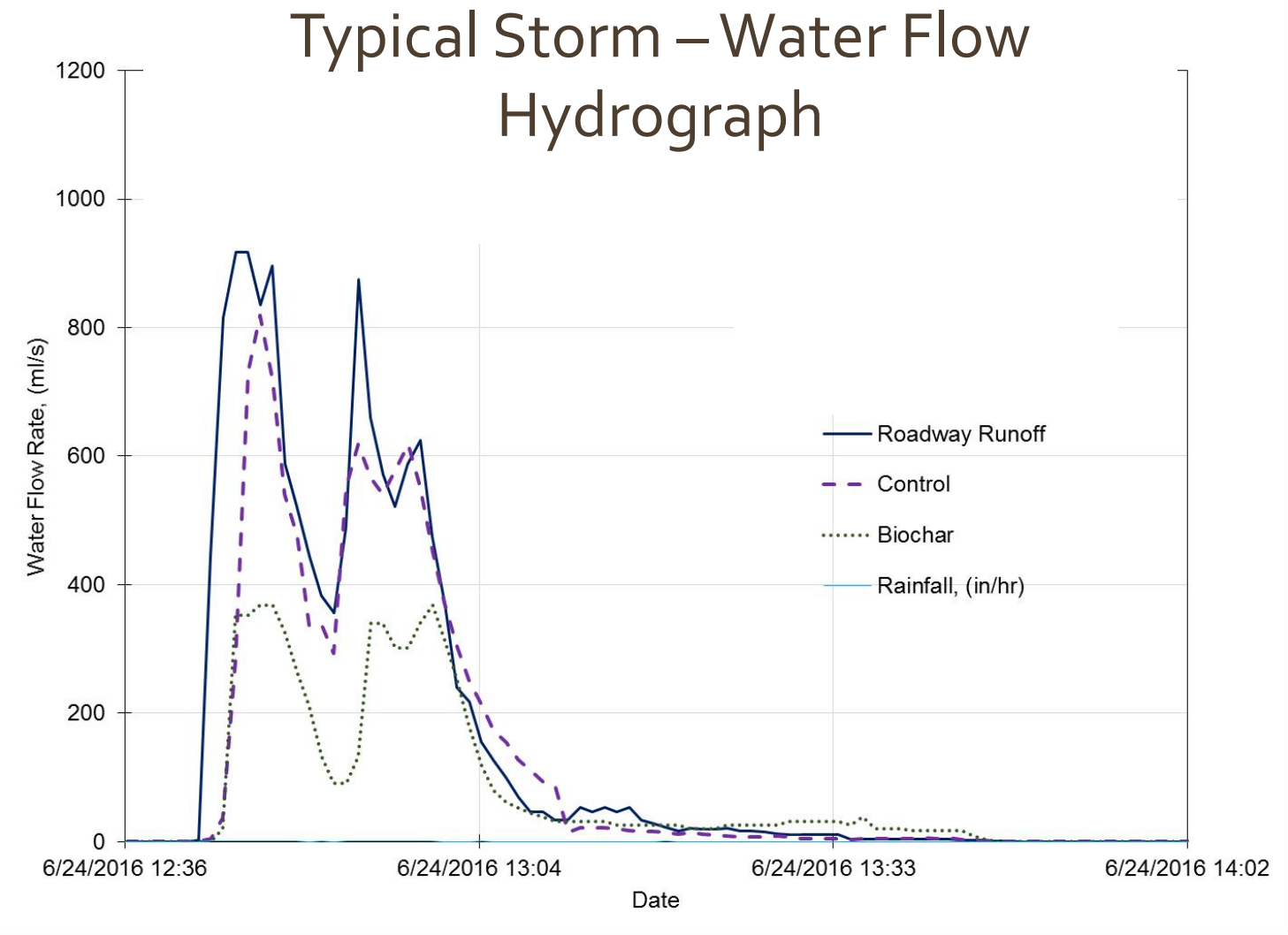
Field Study – Roadway Soils



Biochar amended soil attenuates peak flow ~ 77%

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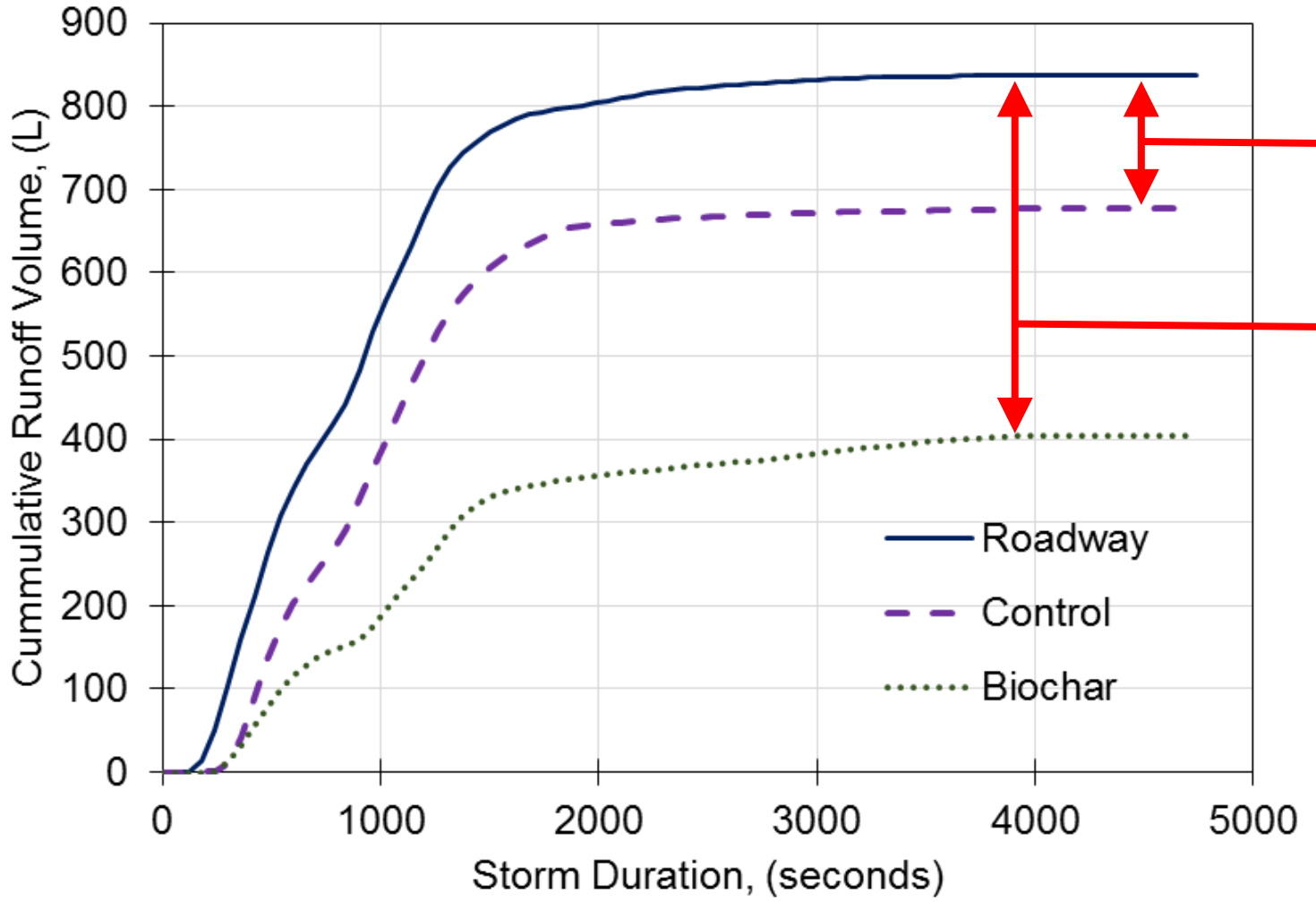
Field Study – Roadway Soils

Typical Storm – Water Flow



Tillage attenuates runoff volume by ~ 20%

Biochar amendment attenuates runoff volume by ~ 53%

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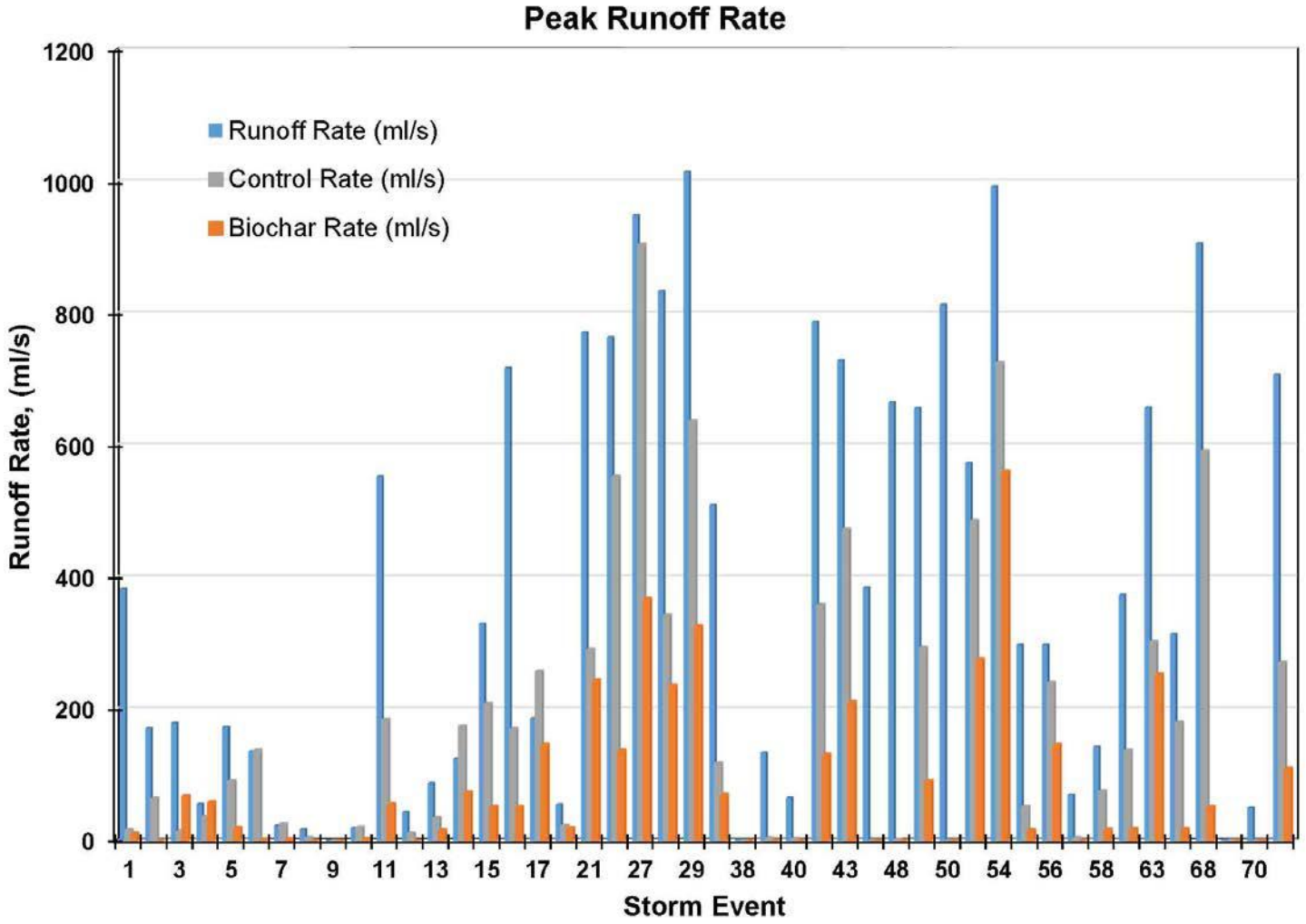
Field Studies – Roadway Soils

Storms in 2016



Tillage reduced peak runoff rate by ~ 51%

Biochar amendment reduced peak runoff rate by ~ 77%

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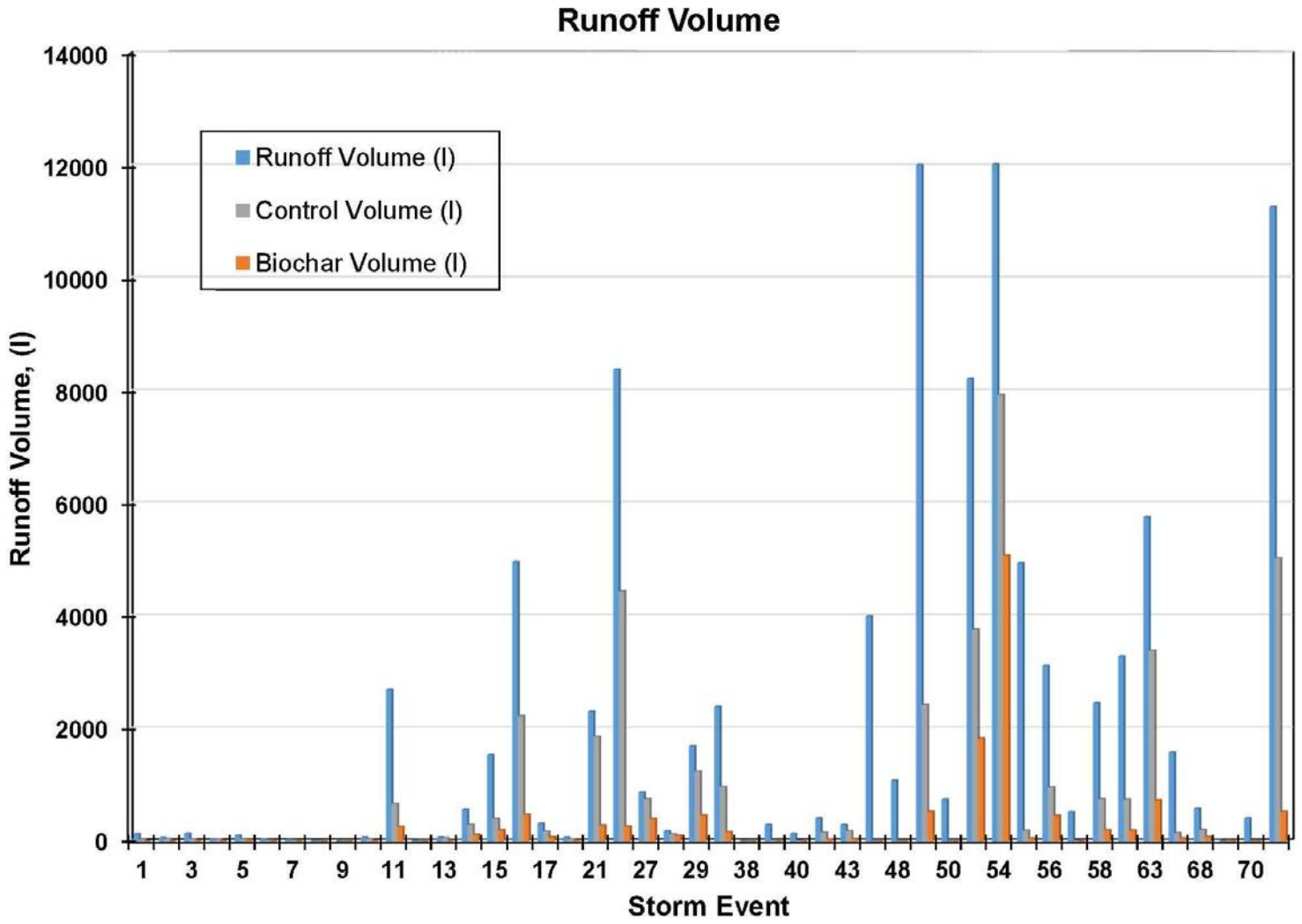
Field Studies – Roadway Soils

Storms in 2016



Tillage reduced runoff volume by ~ 54%

Biochar amendment reduced runoff volume by ~ 83%

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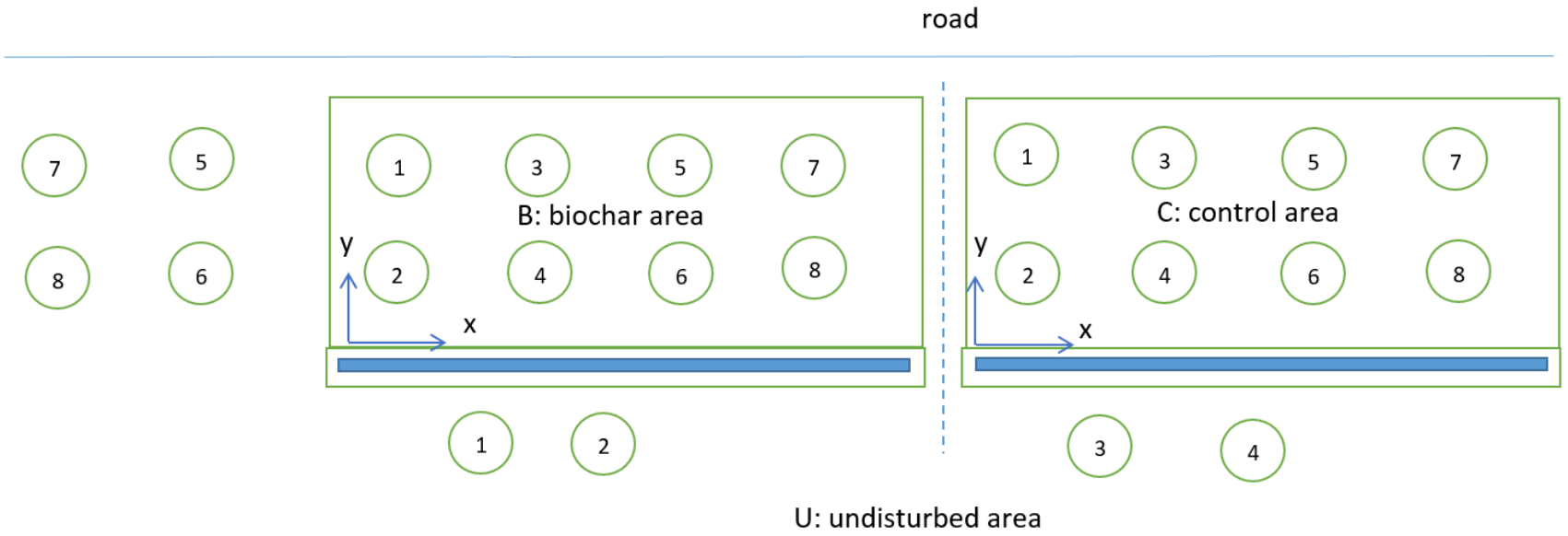
Why Reduction in Runoff?

Measurements of Hydraulic Conductivity with Disc Infiltrometer



Measurements for:
biochar, tilled and undisturbed regions

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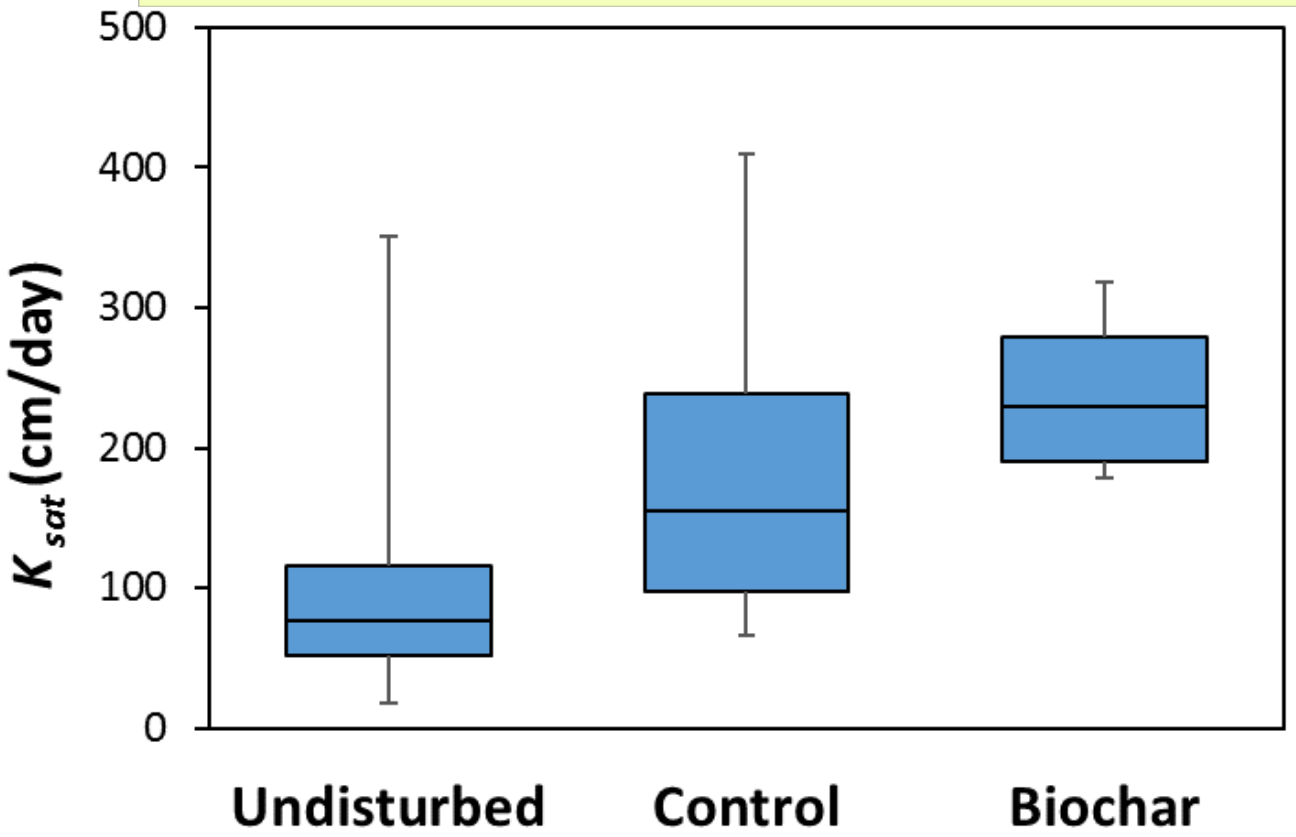
Why Reduction in Runoff?



- Biochar increased geometric mean K_{sat} by ~ 50% over control (tilled)
- Consistent with 47% reduction in runoff peak flow rate over control (tilled)

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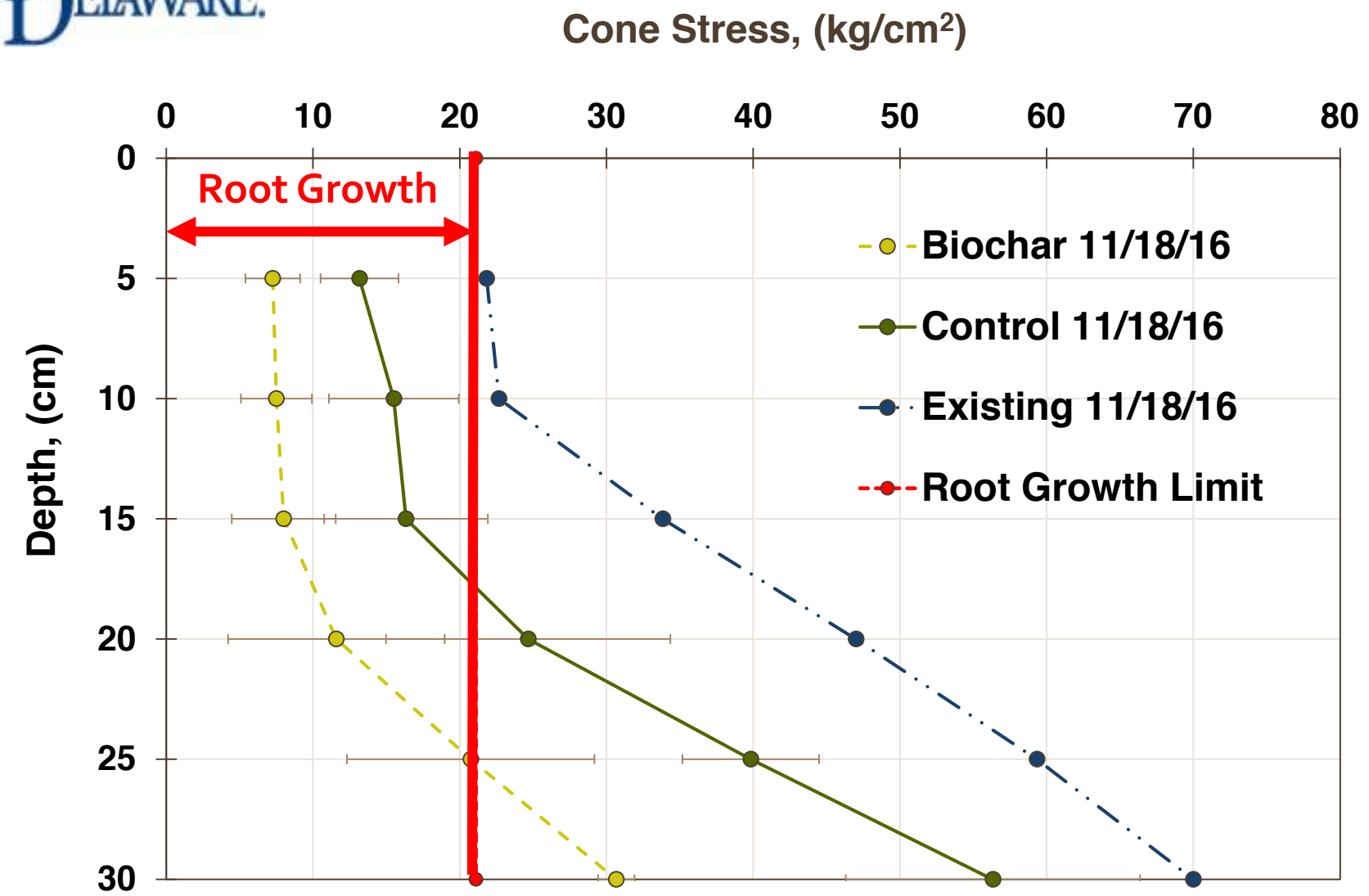
Other Benefits – Decreased Compaction



Dry Bulk Density:

Undisturbed: 1.63 g/cm^3

Control: 1.46 g/cm^3

Biochar: 1.22 g/cm^3

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Analysis of Biochar Amendment

- For 1 year of testing, biochar reduces runoff volume 83%
- 0.12 acre biochar amendment "treated" 1-acre impervious, removing 83% of nutrients and sediments
- $32k to treat 1-acre impervious
  - Cost similar to urban grass buffer - $27k per acre, but much less land: 0.12 (biochar) versus 3.7 (urban grass buffer)
  - **Much less than average $144k per acre for Maryland SHA BMPs (recent estimate)**

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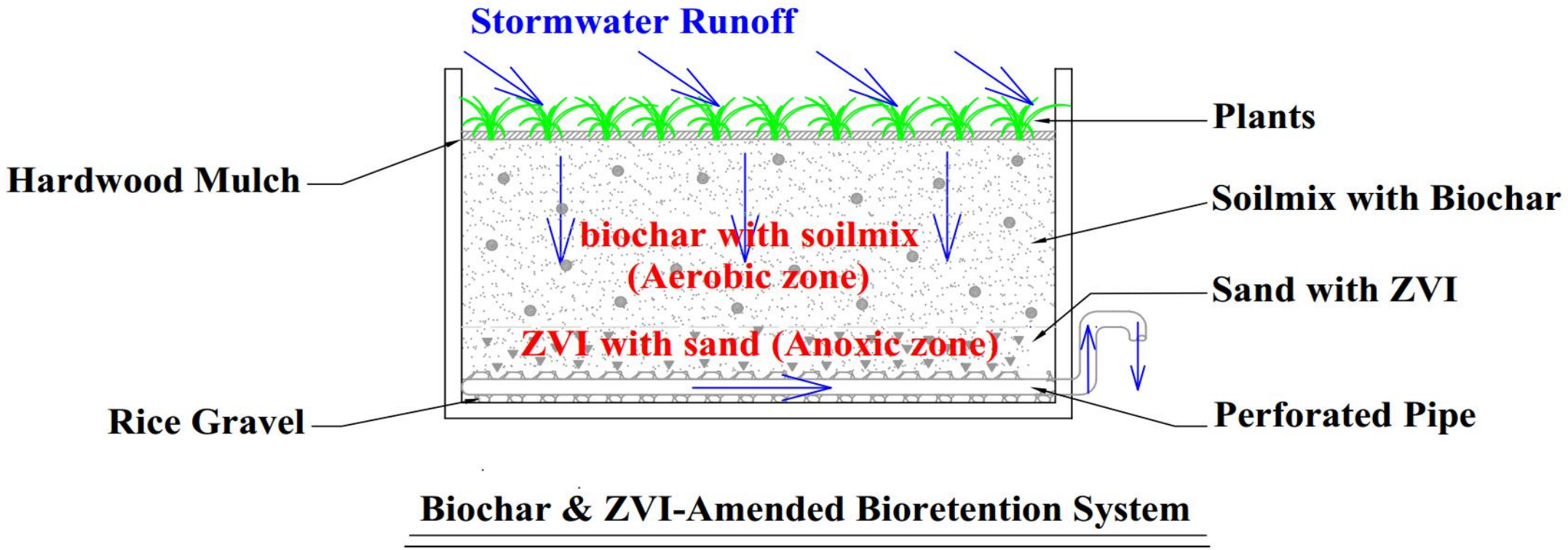
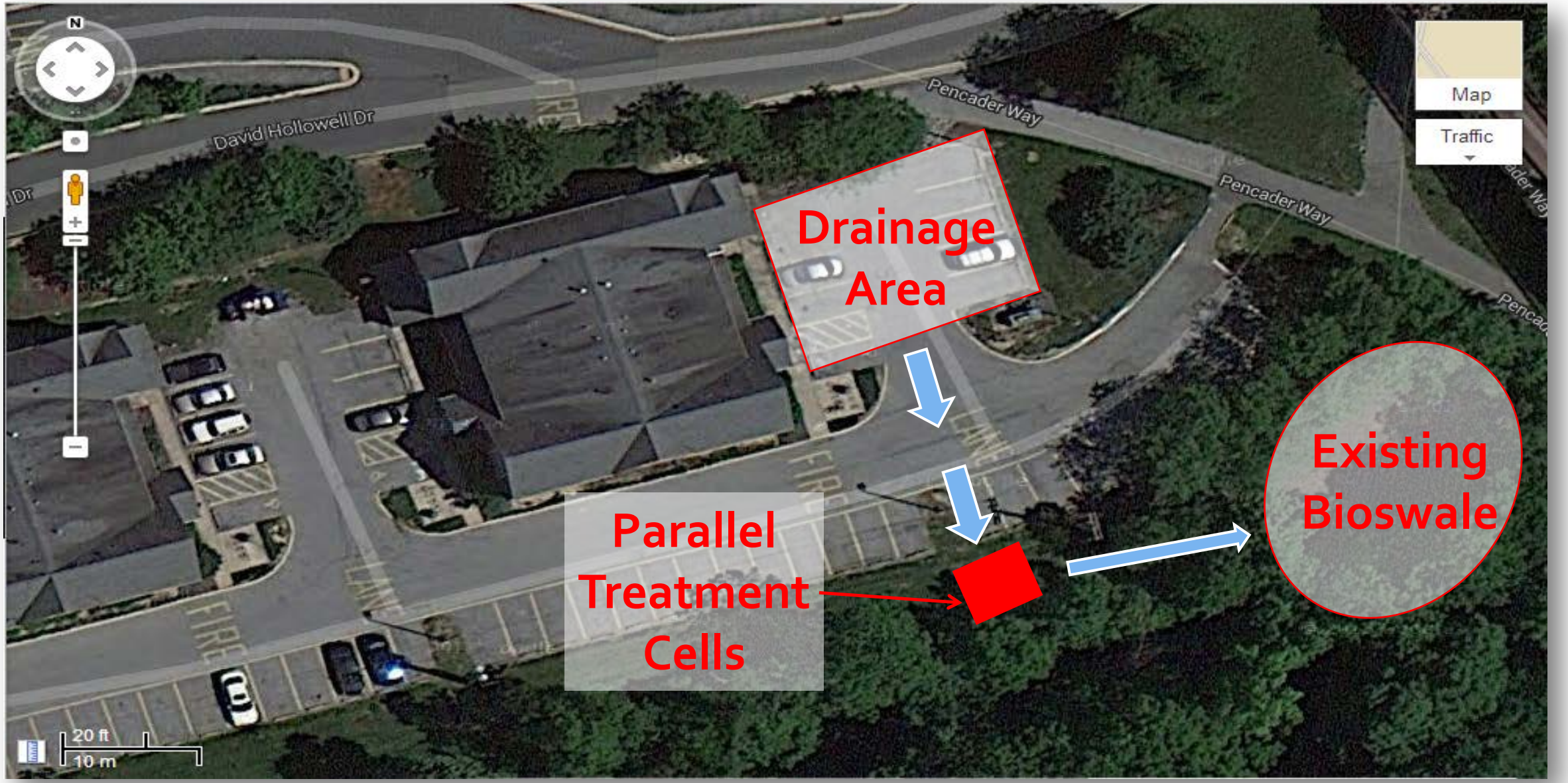
Proposed Solution #2: Bioretention



Biochar & ZVI-Amended Bioretention System


Drainage Area
Parallel Treatment Cells
Existing Bioswale
David Hollowell Dr
Pencader Way
Pencader Way
Map
Traffic
20 ft
10 m

area
sq.m

existing
bioswale

nderdrainage pipe

16"

shed

fence

control cell

biochar & ZVI
amended cell

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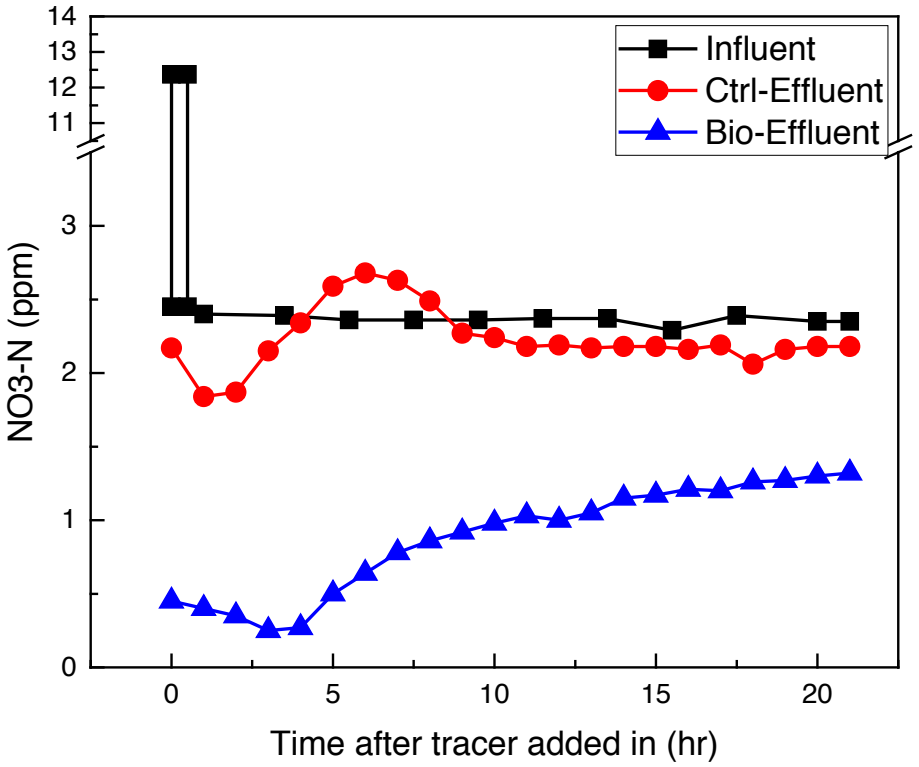
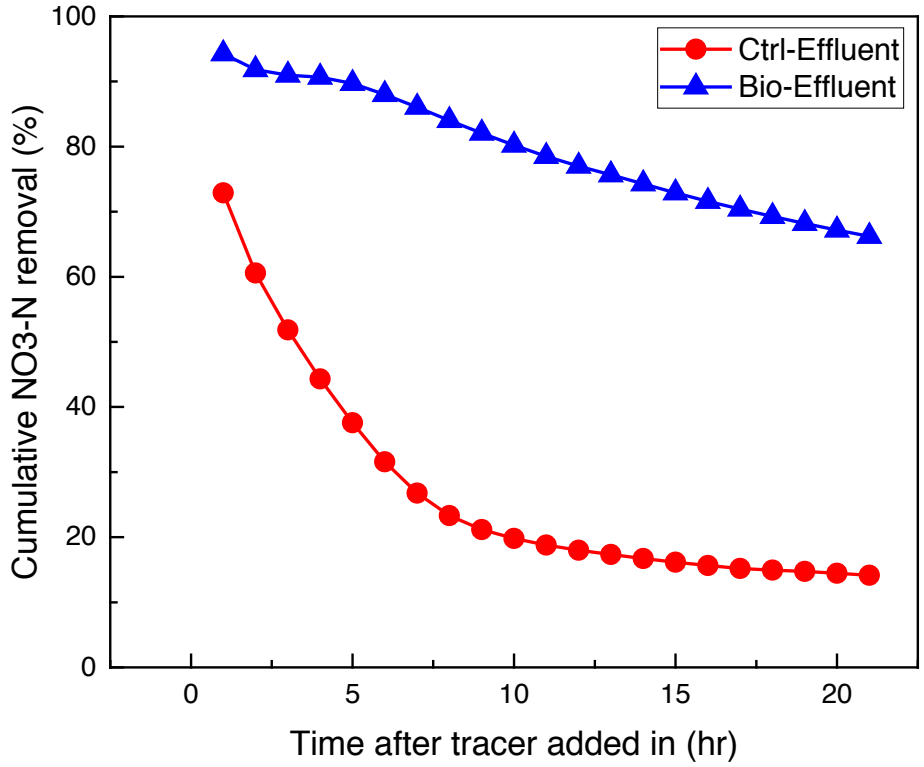
NO_3-N Removal – Example Field Test





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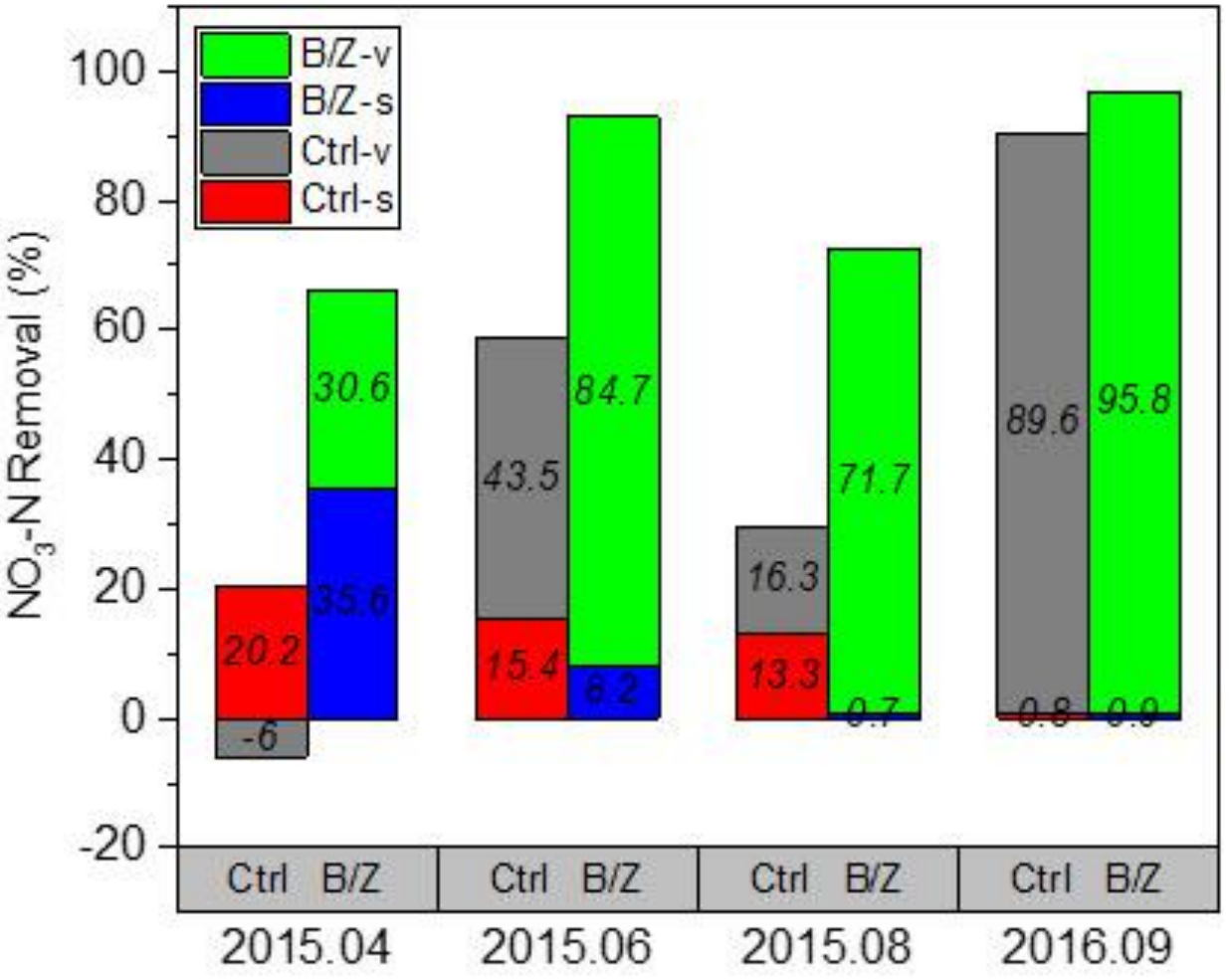
NO_3-N Removal – All Field Tests



Key

B/Z-v – vadose zone of biochar cell
B/Z-s – saturated zone of biochar cell
Ctrl-v – vadose zone of control cell
Ctrl-s – saturated zone of control cell

- Removal better in warm months
- Biochar/amended region outperforms standard mix
- System hydraulics important

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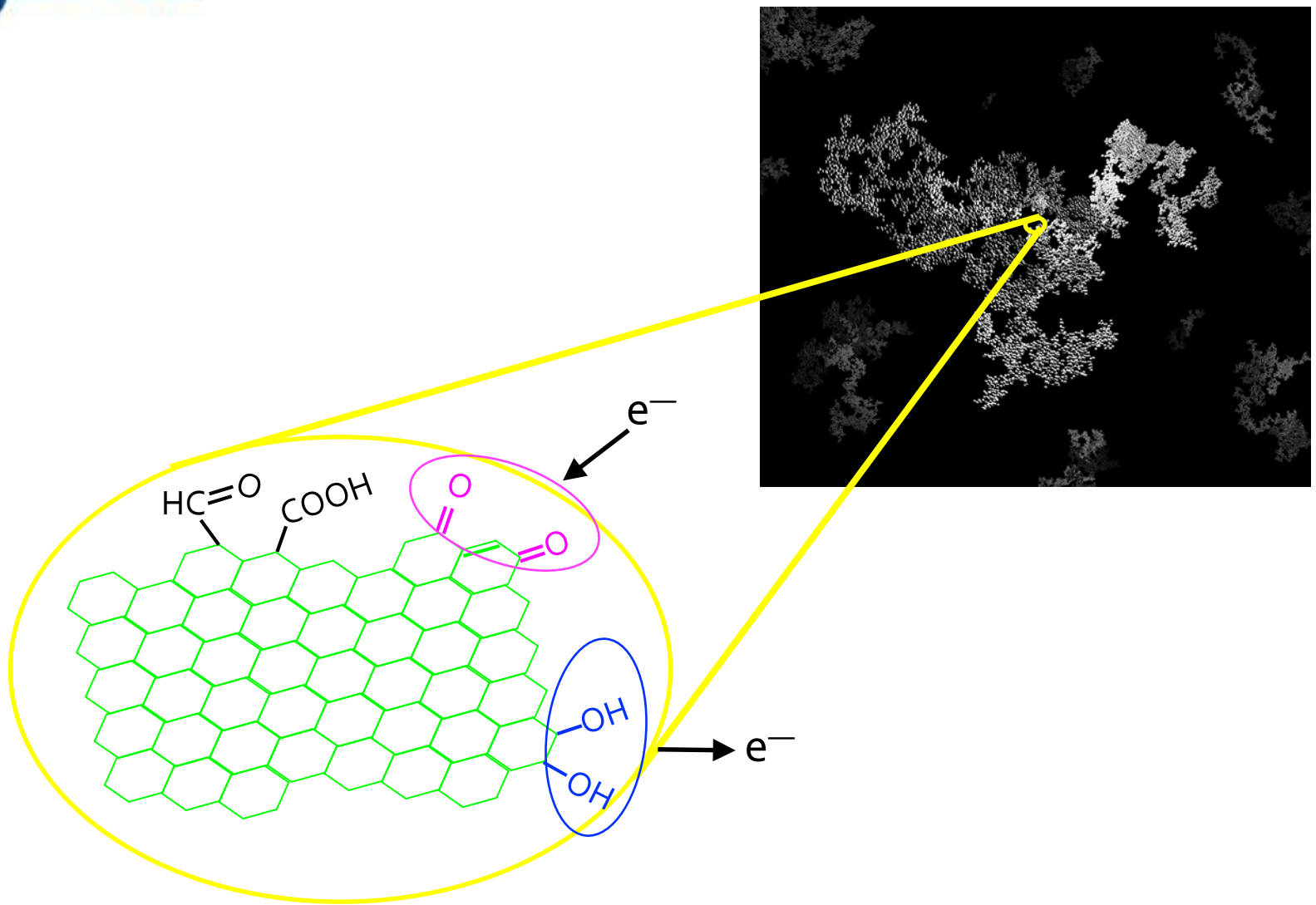
Why Enhanced Denitrification?



Enhanced Denitrification

Electron storage capacity of biochar is bioavailable (up to 0.87 mmol e^-/g) and supports nitrate reduction[1]

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

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Conclusions

- Biochar amendment to roadway soil
  - ➢ Converts compacted soil into useful stormwater treatment BMP
  - ➢ Cost ~ 400% less than most BMPs implemented by MD SHA
  - ➢ Projected cost savings significant for large-scale implementation
- Biochar amendment to bioretention media
  - ➢ Consistently improved removal of nitrate
  - ➢ Improves hydraulics and redox conditions
  - ➢ Removes organic nitrogen, nitrate, and ammonia