Exploring Regenerative Stormwater Conveyances for Tennessee:

Design, Installation, and Performance Evaluation Workshop

THE UNIVERSITY OF TENNESSEE KNOXVILLE

BIG ORANGE. BIG IDEAS.®

Introduction

- Funding: Tennessee Healthy Watershed Initiative
- Workshop Delivery: Tennessee Water Resources Research Center
- Partners: Knox County, City of Knoxville

John Schwartz
Professor and Associate Head

Jessica Thompson
Doctoral Candidate

Jon Hathaway
Assistant Professor

Special Thanks!

- Bill Hunt, NC State University
- Adrienne Cizek, Stormwater Solutions Engineering (Milwaukee, Wisconsin)
- https://stormwater.bae.ncsu.edu/
- (google: ncsu stormwater)
- ASCE Low Impact Development Conference – Houston, TX, 2015

How did we get here?


EXXON

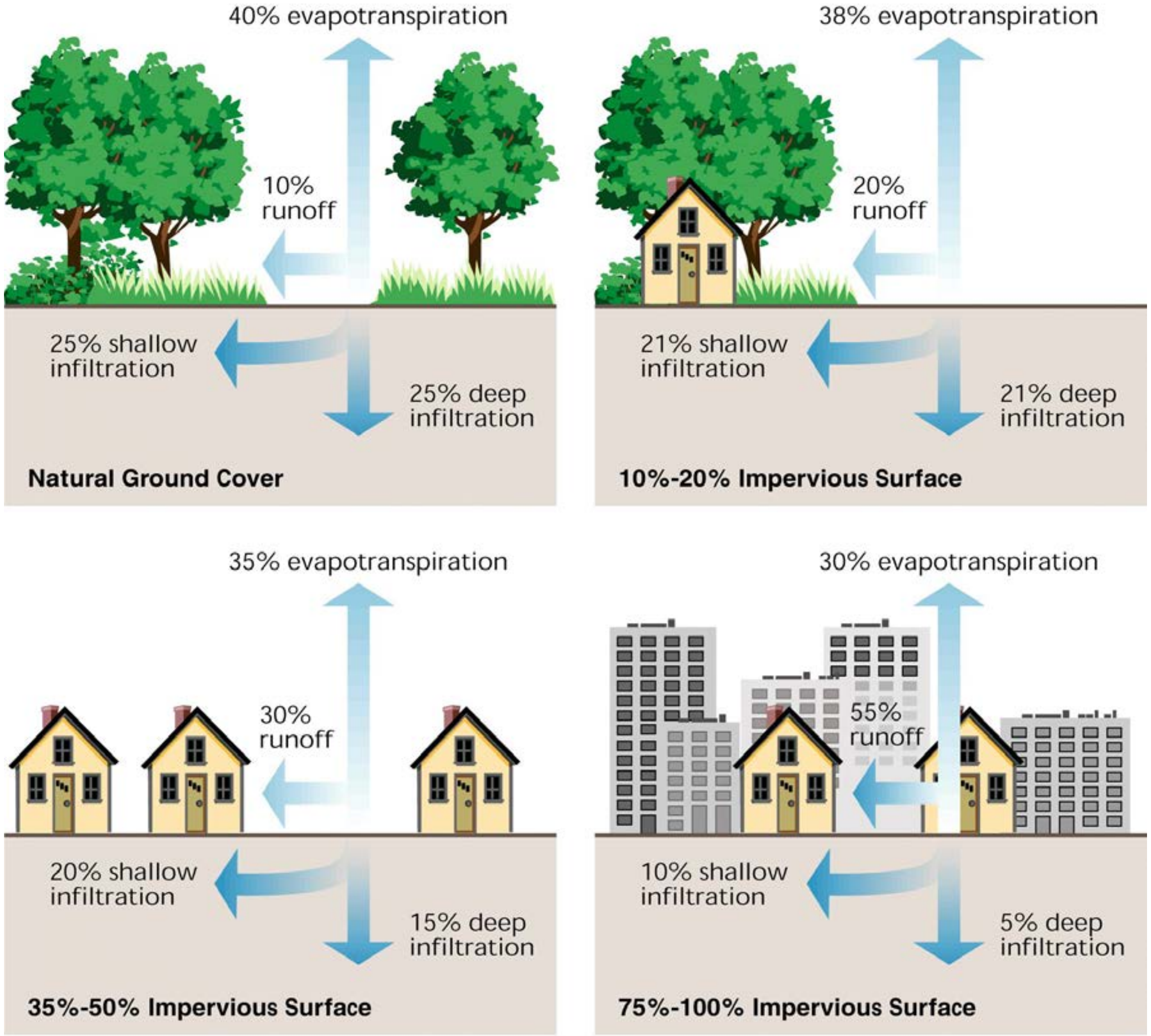


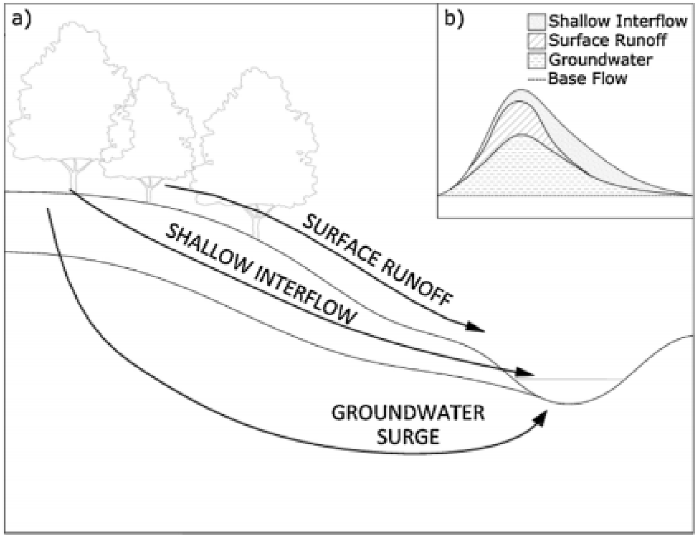
Fig. 3.21 -- Relationship between impervious cover and surface runoff. Impervious cover in a watershed results in increased surface runoff. As little as 10 percent impervious cover in a watershed can result in stream degradation.
In Stream Corridor Restoration: Principles, Processes, and Practices (10/98).
By the Federal Interagency Stream Restoration Working Group (FISRWG) (15 Federal agencies of the U.S.)

Rules and Regulations

- Federal
  - EPA Phase I of NPDES
  - EPA Phase II of NPDES
  - EISA (2007), sec 406
    - Energy Independence and Security Act (2007)
      - – Section 406
    - Requires all Federal Construction Activities > 5,000 sf to use Low Impact Development

Stormwater Practices Today

- Target to mimic predevelopment *conditions* (Cizek and Hunt 2013)
  - Including both hydrology and flow pathways to achieve water quality
  - Examples: bioretention, permeable pavement, and **regenerative stormwater conveyances (RSC)**.



taken from Cizek and Hunt (2013).

RSCs are…

Low Impact Development (LID) alternative to swales, pipes, media filtration and in some cases, retention/detention structures.

Also referred to as

- Biofiltration Conveyance (BFC) *(NC DOT)*
- Step Pool Stormwater Conveyence (SPSC) *(MD DPW)*

Biohabitats

Regenerative Step Pool Storm Conveyance (SPSC) – also known as Coastal Plain Outfalls

Design Guidelines


Home Port Farms - Immediately after


Home Port Farms - One year after construction


Homeport Farms - Six years after construction

ANNE ARUNDEL COUNTY
MARYLAND
County Executive John R. Leopold

DPW
Ron Bowen, P.E.

Original : June 2009
Revision 1: August 2010
Revision 2: November 2010
Revision 3: July 2011
Revision 4: November 2011
Revision 5: December 2012

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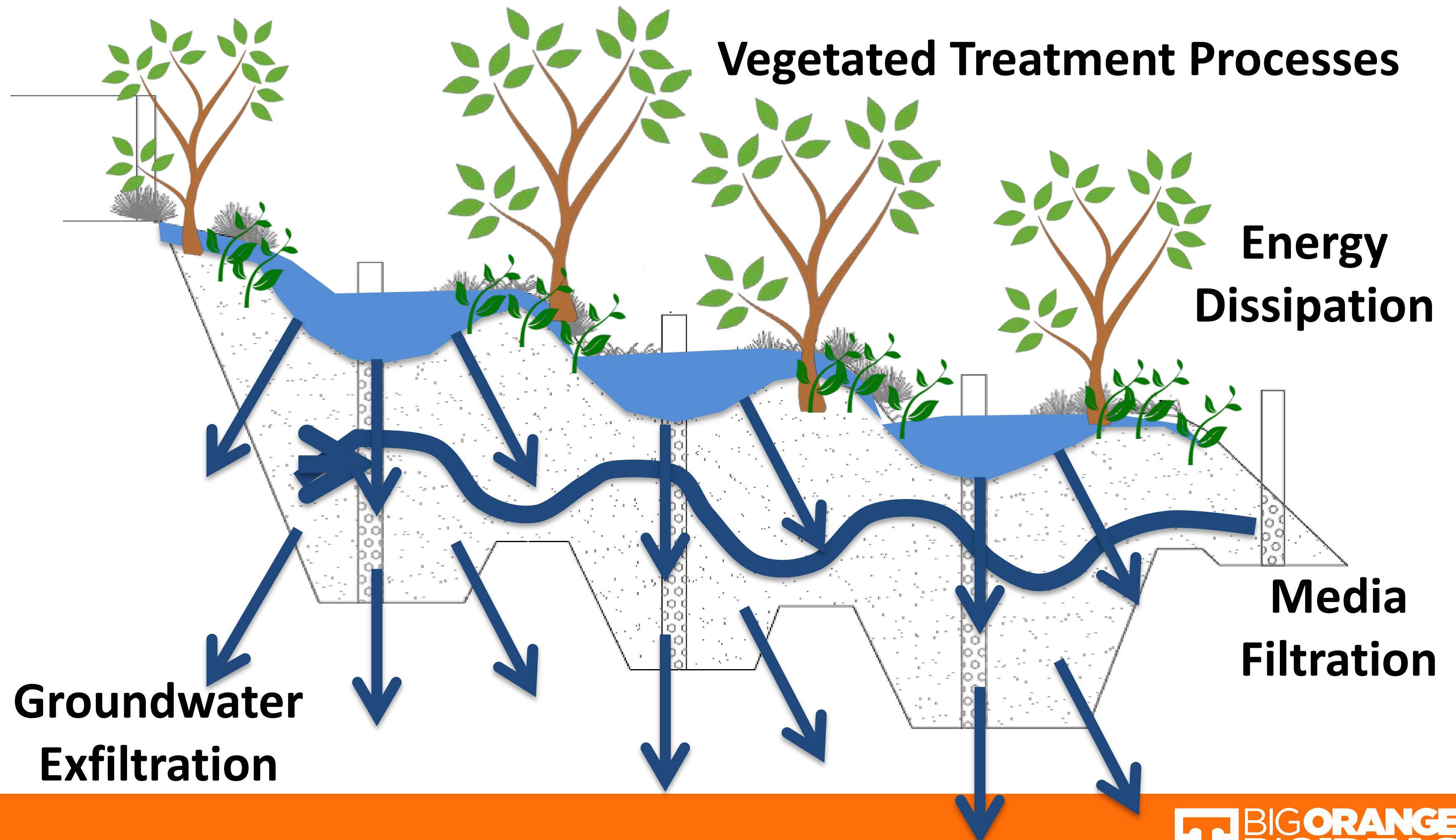
History of RSCs

- Developed in Anne Arundel County, Maryland to help restore Chesapeake Bay Watershed

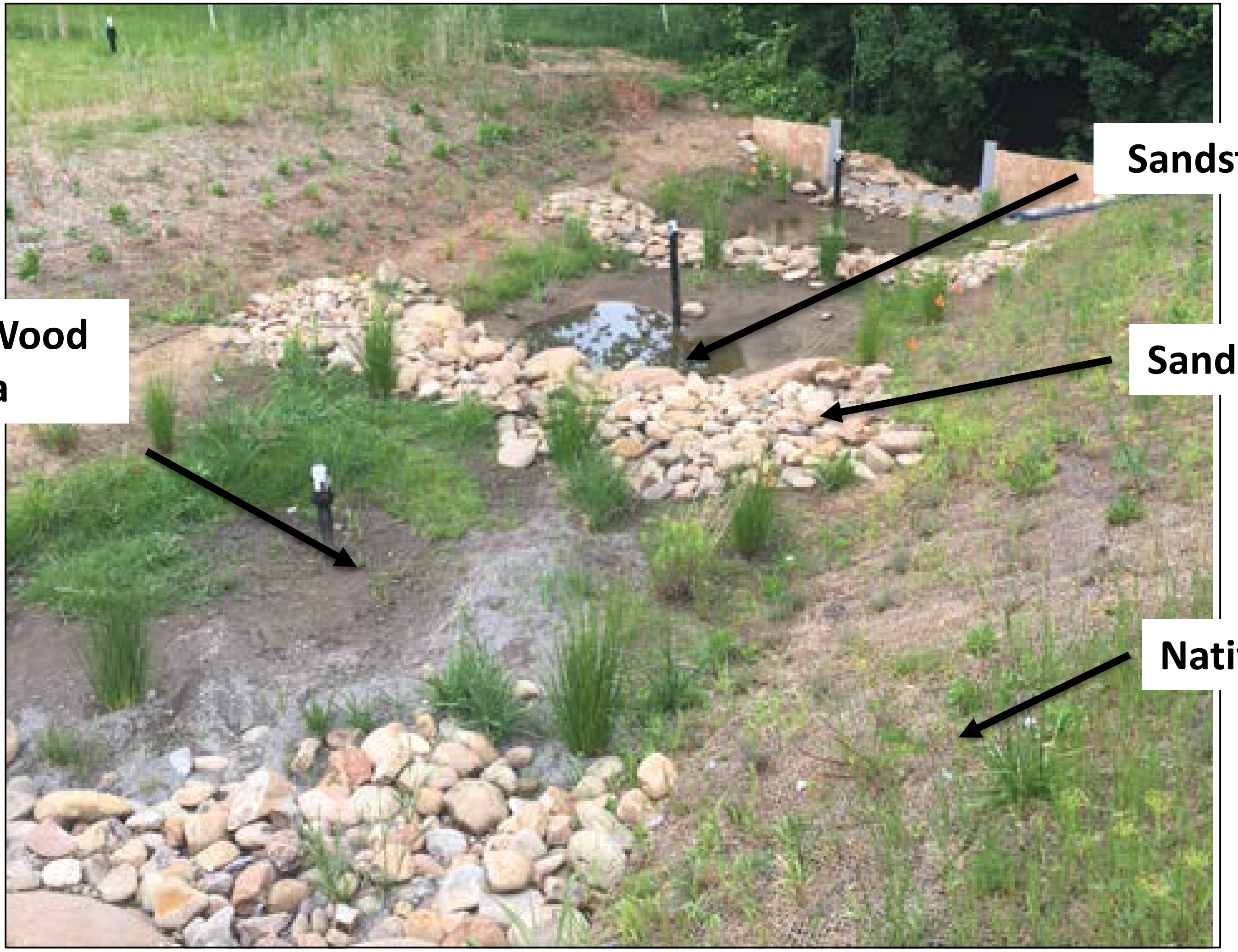
- Wet or dry channel options (Berg et al. 2013)
  - **Wet** - located in a perennial stream, promote floodplain connectivity, and are considered a stream restoration practice
  - **Dry** - restoration of ephemeral streams or eroding gullies and are considered a stormwater retrofit practice

- Also referred to as coastal plain outfalls, regenerative step-pool storm conveyances, and biofiltration conveyances

RSCs are… a series of pools and riffles designed to convey, manage, and treat stormwater runoff



RSC Design Components



Credit: Biohabitats, Inc

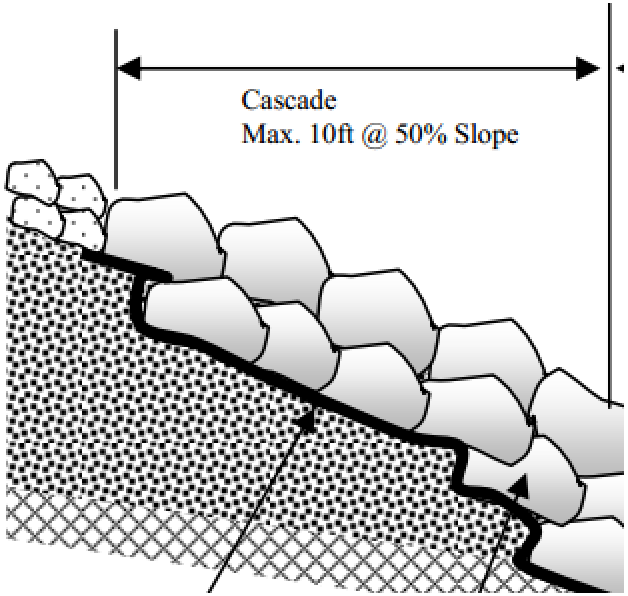
Credit: Anacostia Watershed Society

Credit: Fairfax County, Virginia

Credit: City of Columbia, Missouri

Benefits over other SCMs

- Commonly used where other practices have failed
  - Steep slopes
  - Massive head cutting
- Applicable on steep slopes
  - 5% when used for WQ
  - 10% without cascade
  - 50% with cascade
- Provides predevelopment flow paths
  - Surface flow
  - Shallow interflow
  - Exfiltration




Longevity Graphics
And Printing
Prestwick Ridge Way
Prestwick Ridge Way
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Vista Glen Way
Vista Glen Way
Vista Glen Way
Vista Glen Way
Vista Glen Way
Sutherland Park
Apartments
Sutherland View
Apartments
AAA Cooper
Transportation
Cate Ave
Pilkay Rd NW
Google
3D

Previous RSC Research

Wet Channel	Dry Channel
Brown (2010)*	Cizek (2014)
Browning (2008)	Koryto (2017)
Cook et al. (2014)	Cizek et al. (2017)*
Filoso and Palmer (2011)*	
Palmer et al. (2014)*	
*peer reviewed publication	

Previous RSC Research

- Originally, RSCs were developed as a tool to repair massive head cutting in existing stormwater conveyances or streams

- More recently, they have been implemented in areas with more dense soils
    - Piedmont region of North Carolina (Cizek 2014, Koryto 2016)
    - Ridge and Valley region of Tennessee (this research)

- Previous research has yielded mixed results for water quality and hydrologic performance

Brunswick County

Adrienne Cizek and Bill Hunt

ASCE Low Impact Development
Conference – Houston, TX, 2015

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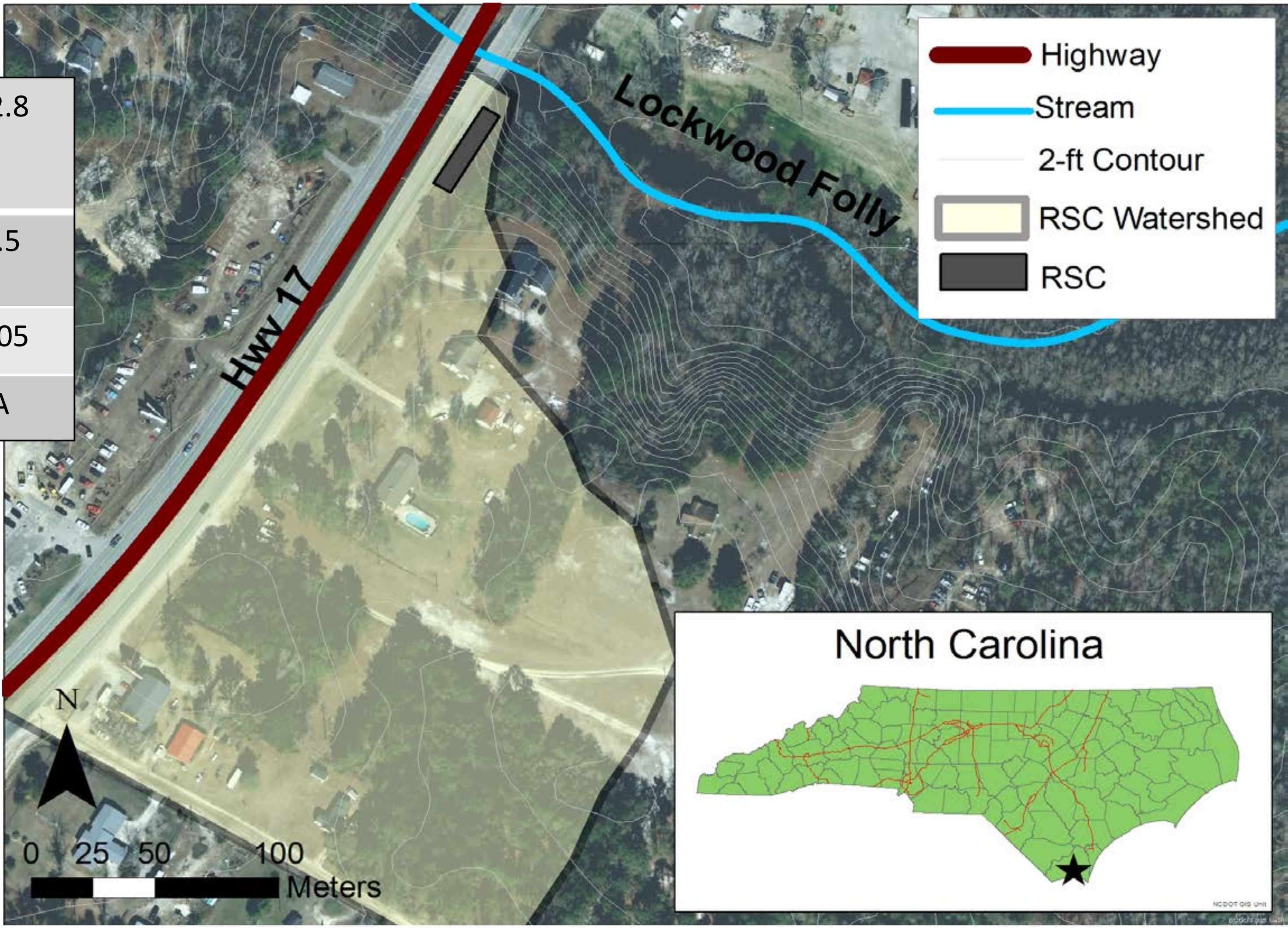
Site Description

Contributing Watershed Area (acres)	12.8
Impervious Area (acres)	1.5
DCIA (acres)	0.05
HSG	A



Monitoring (inlet and outlet of each cell)

Surface Flow

– Compound weirs with Hobo™ water level loggers

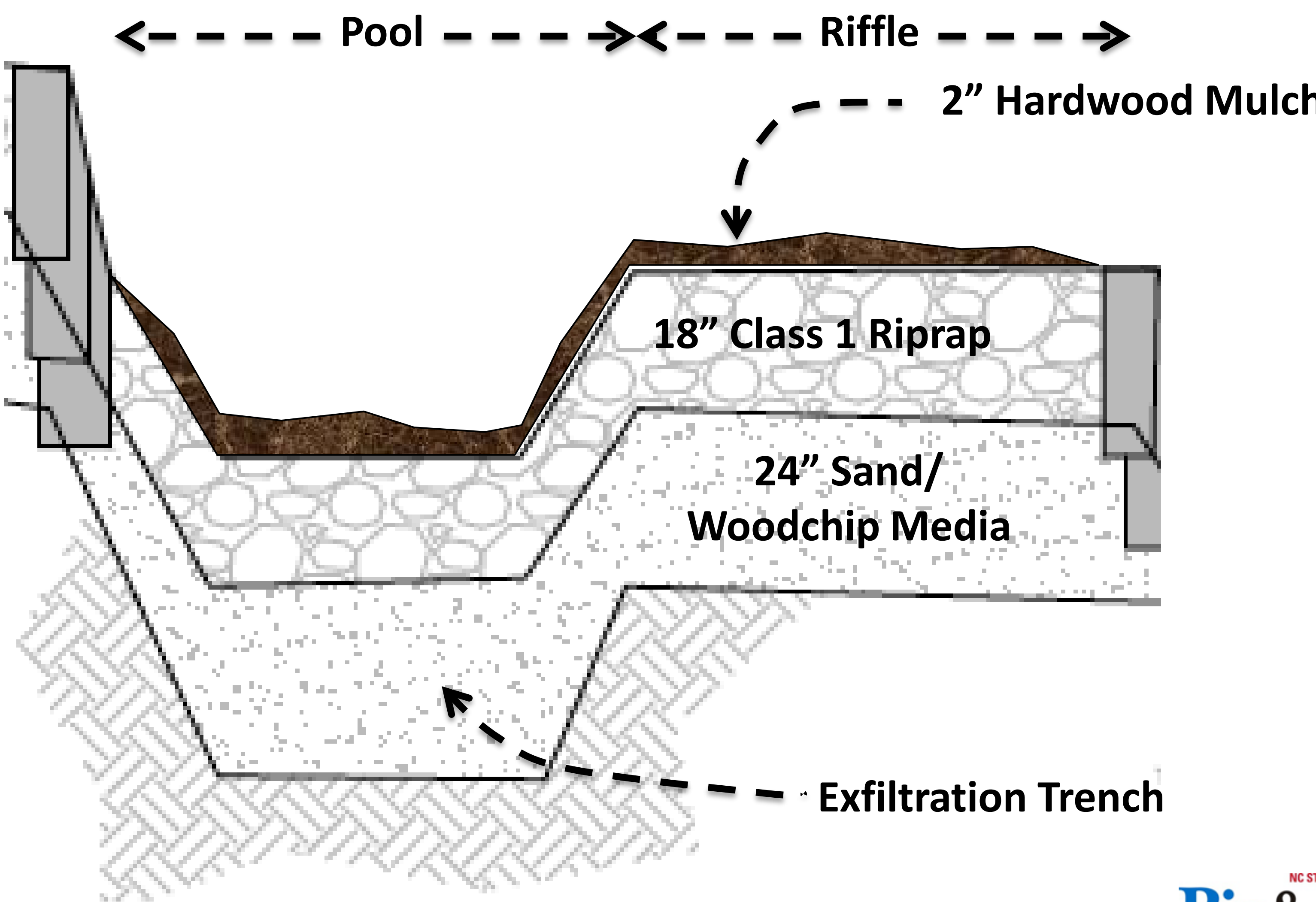
Sub-surface Flow

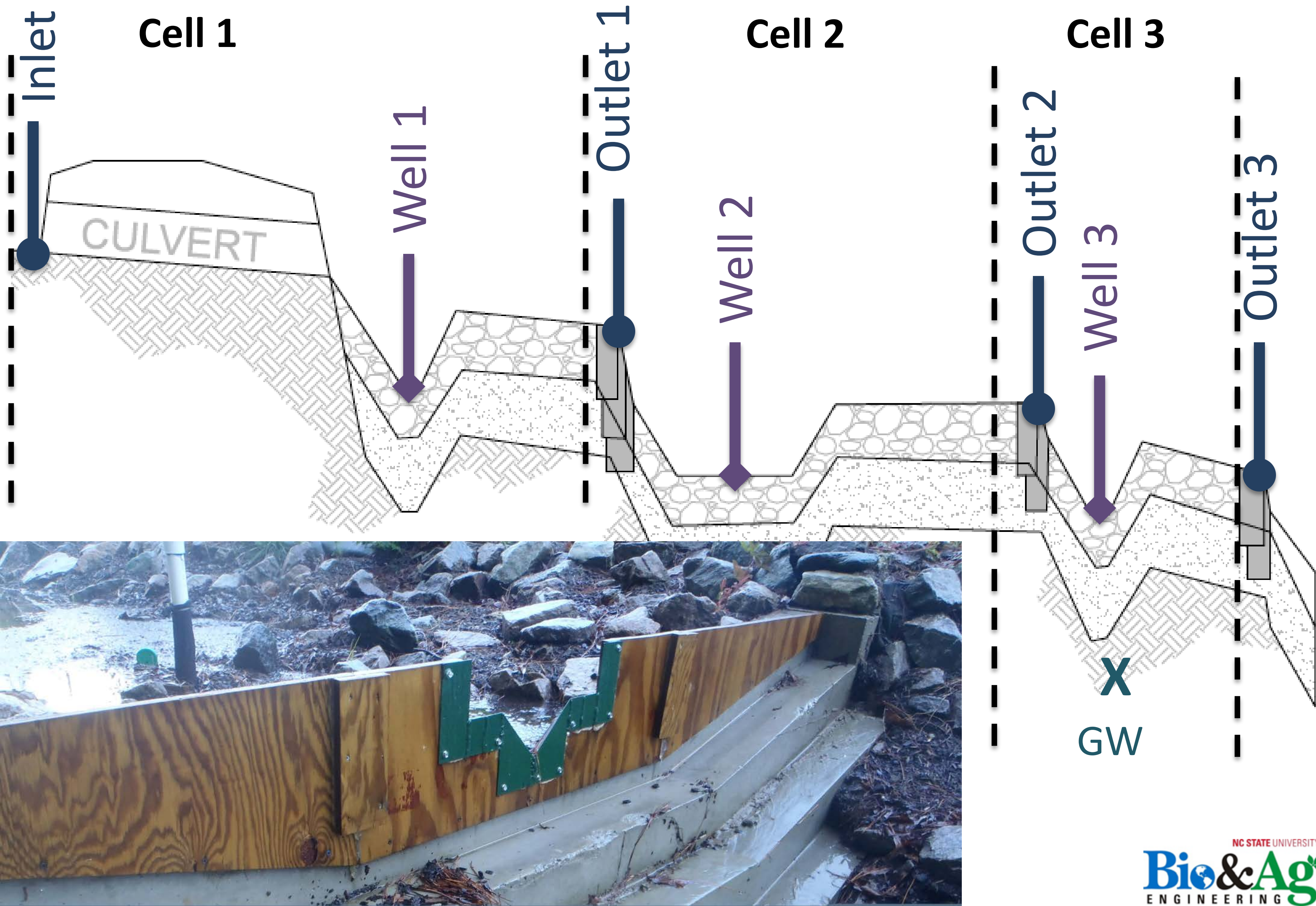
– Sampling wells, Hobo™ water level loggers

Groundwater Level

– Groundwater well

A **“Cell”** includes one ***pool*** and one ***riffle***…





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Storm Summary

27 inflow producing rainfall events between Oct 2012 and Mar 2014

- 2 outflow producing events

Max Rainfall Depth = 2.9 in over 48 hours

- Inflow = 777 ft^3, peak flow = 195 gpm
- Outflow Volume = 42 ft^3, peak flow = 17 gpm

95% Volume Reduction
90% Peak Flow Reduction

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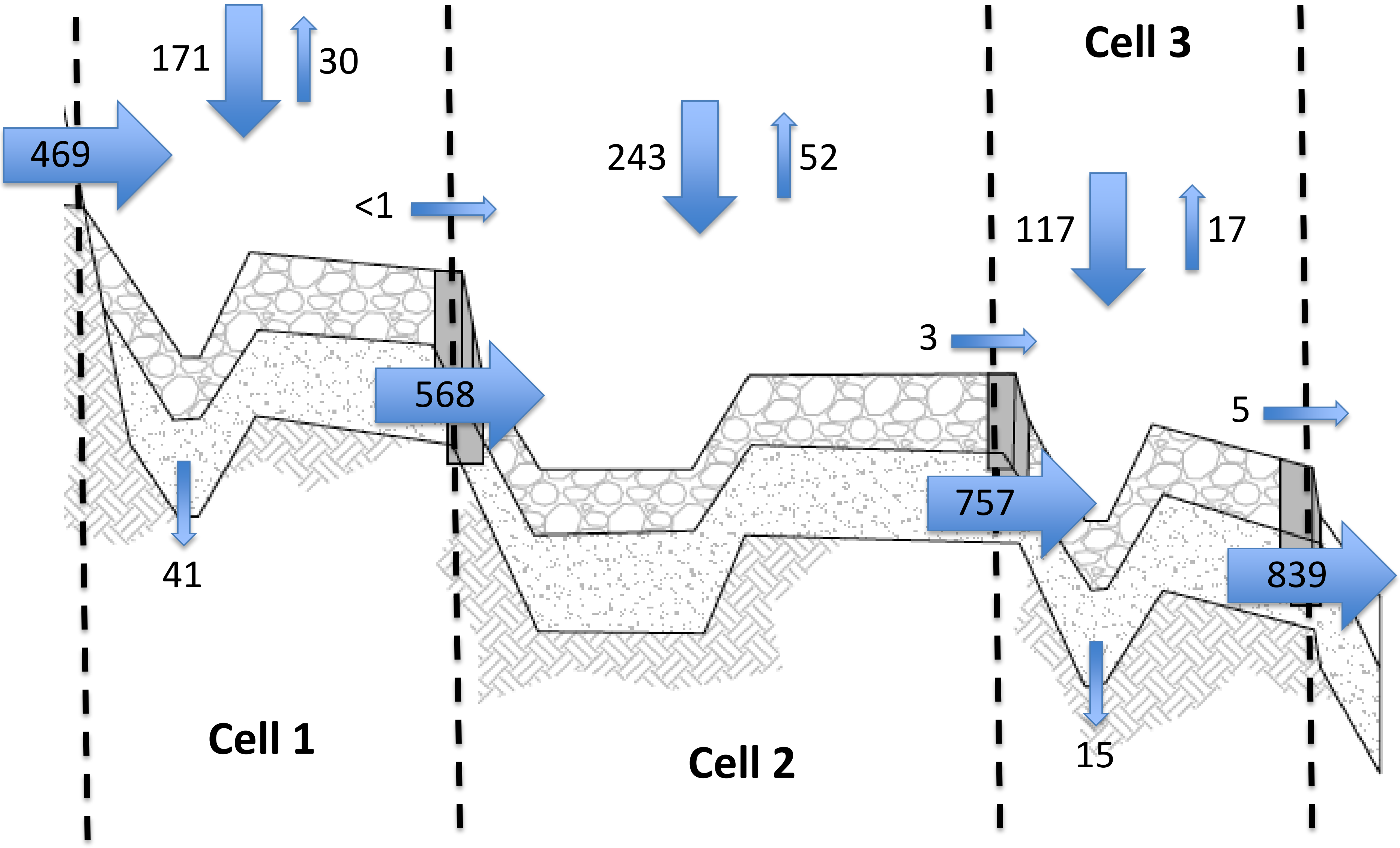
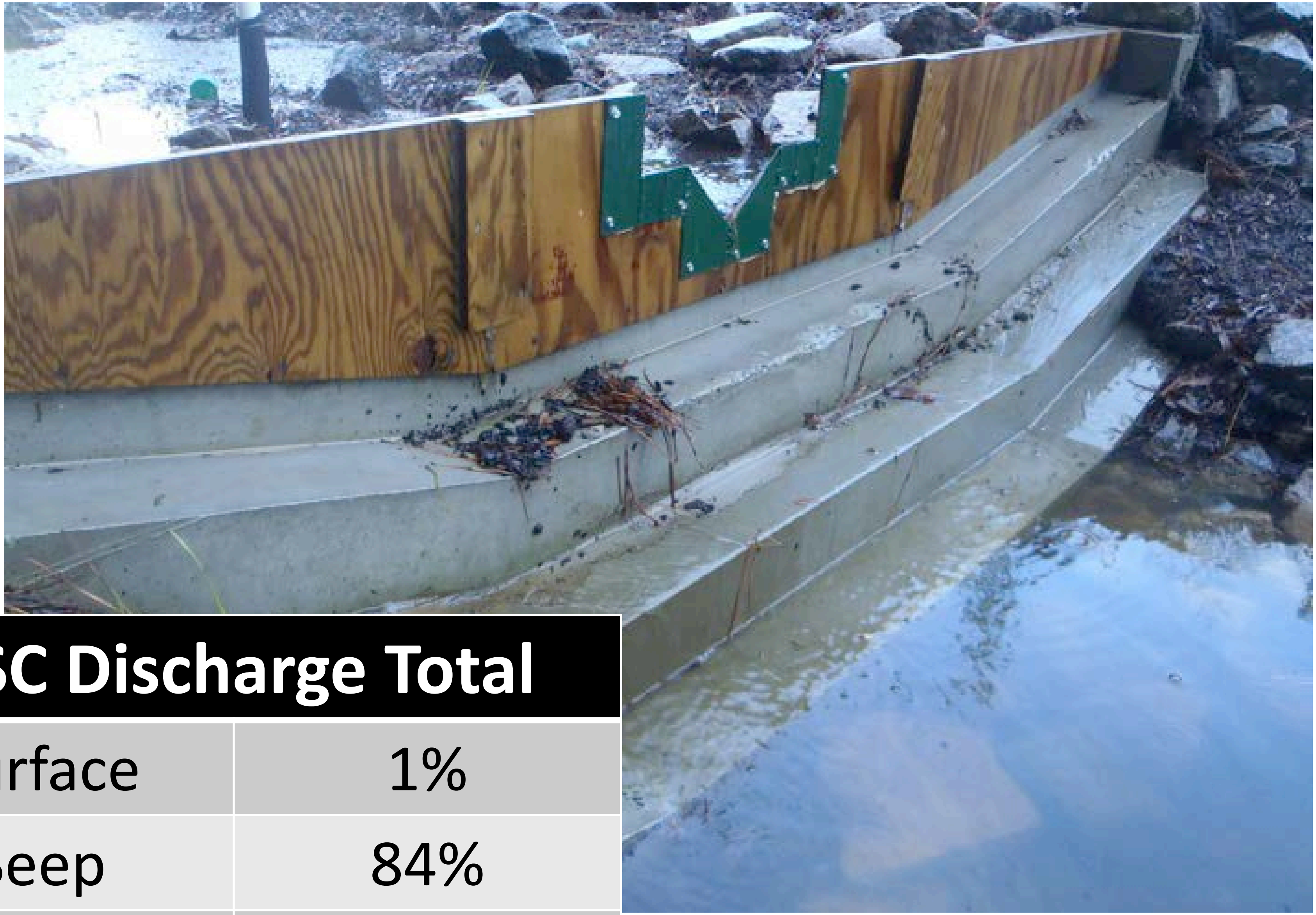
Overall Water Balance (L per 1000 L)





RSC Discharge Total	
Surface	1%
Seep	84%
Exfiltration	6%
Evaporation	10%

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Alamance County

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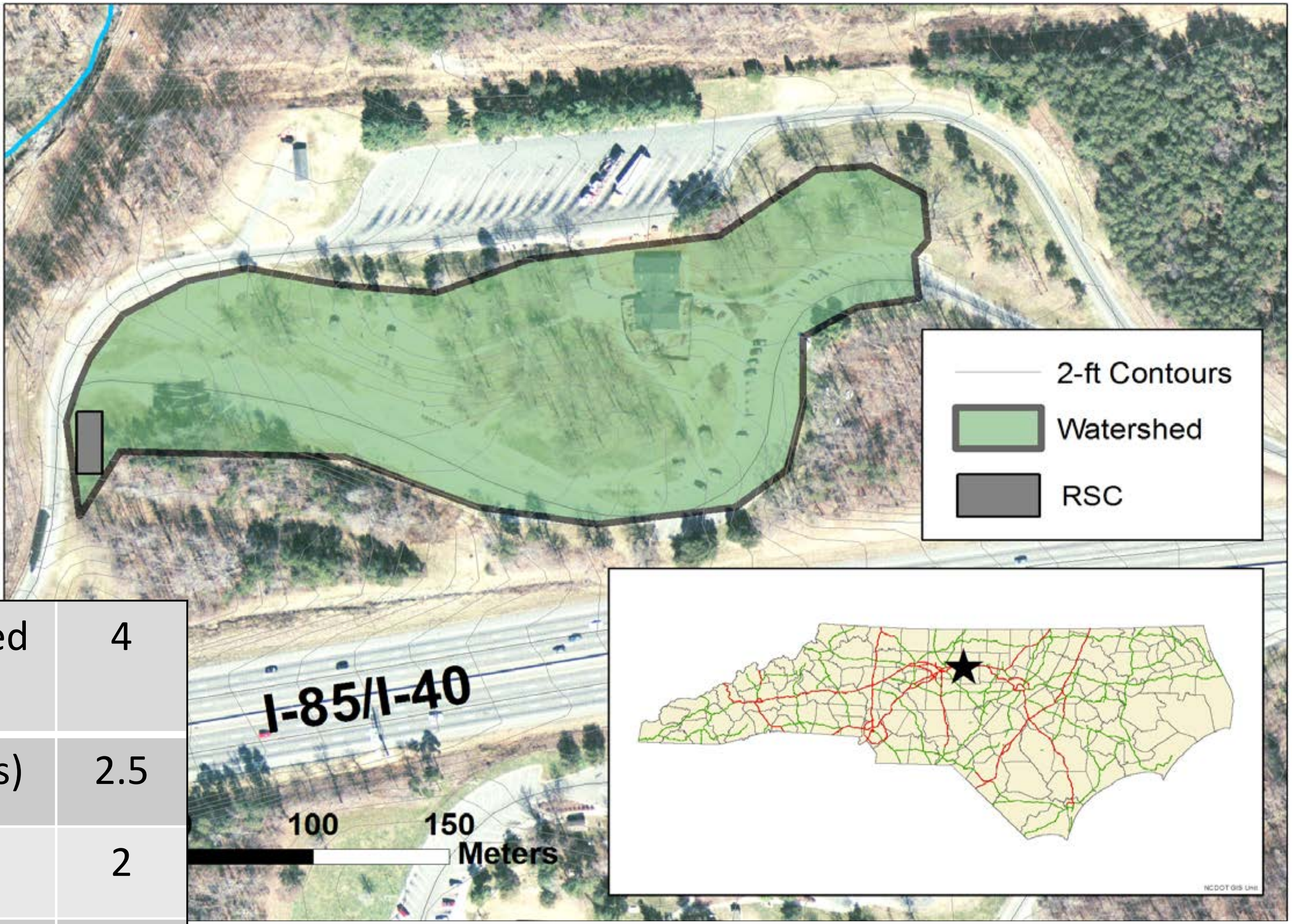
Site Description



Contributing Watershed Area (acres)	4
Impervious Area (acres)	2.5
DCIA (aces)	2
HSG	D

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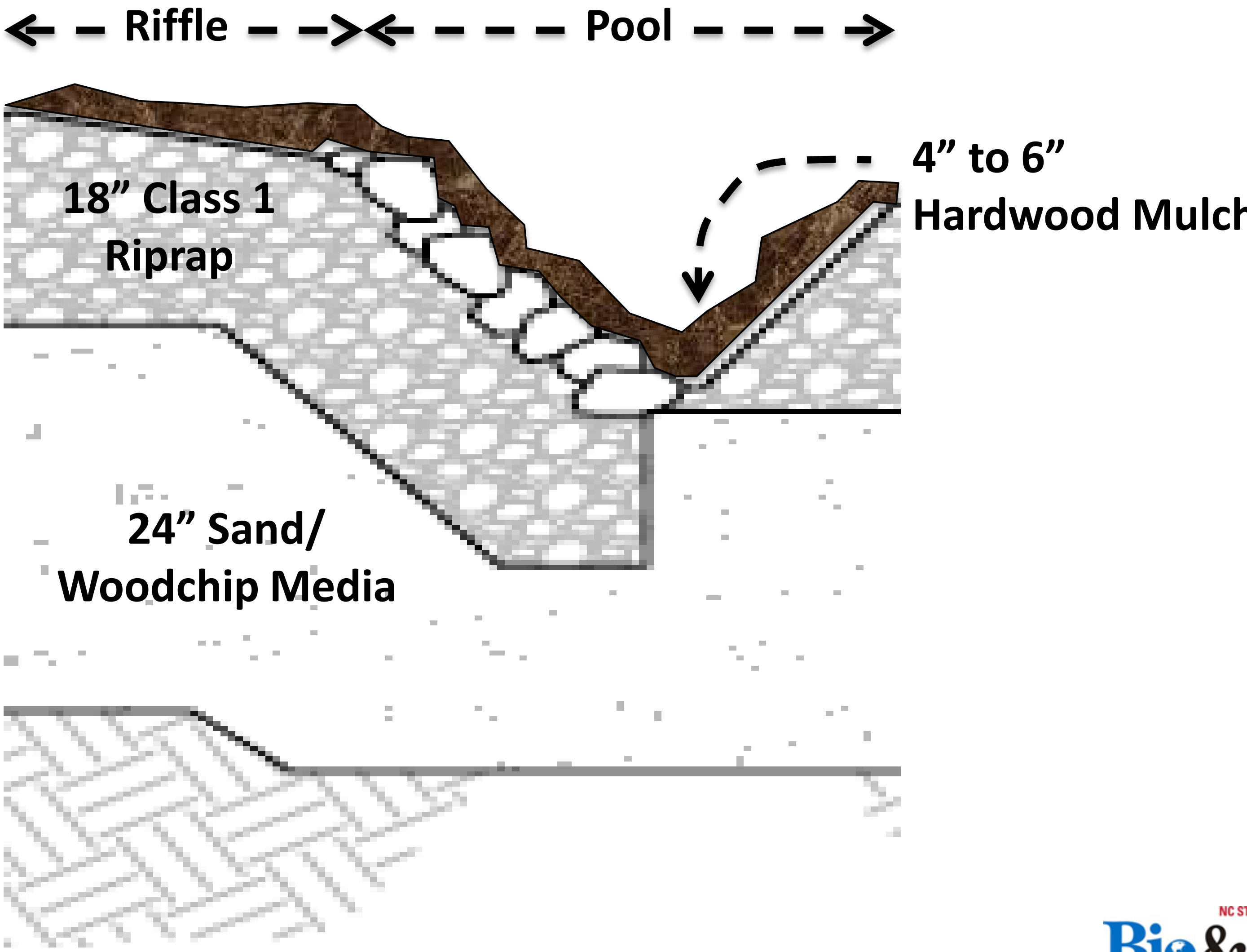
Cells 1 through 3



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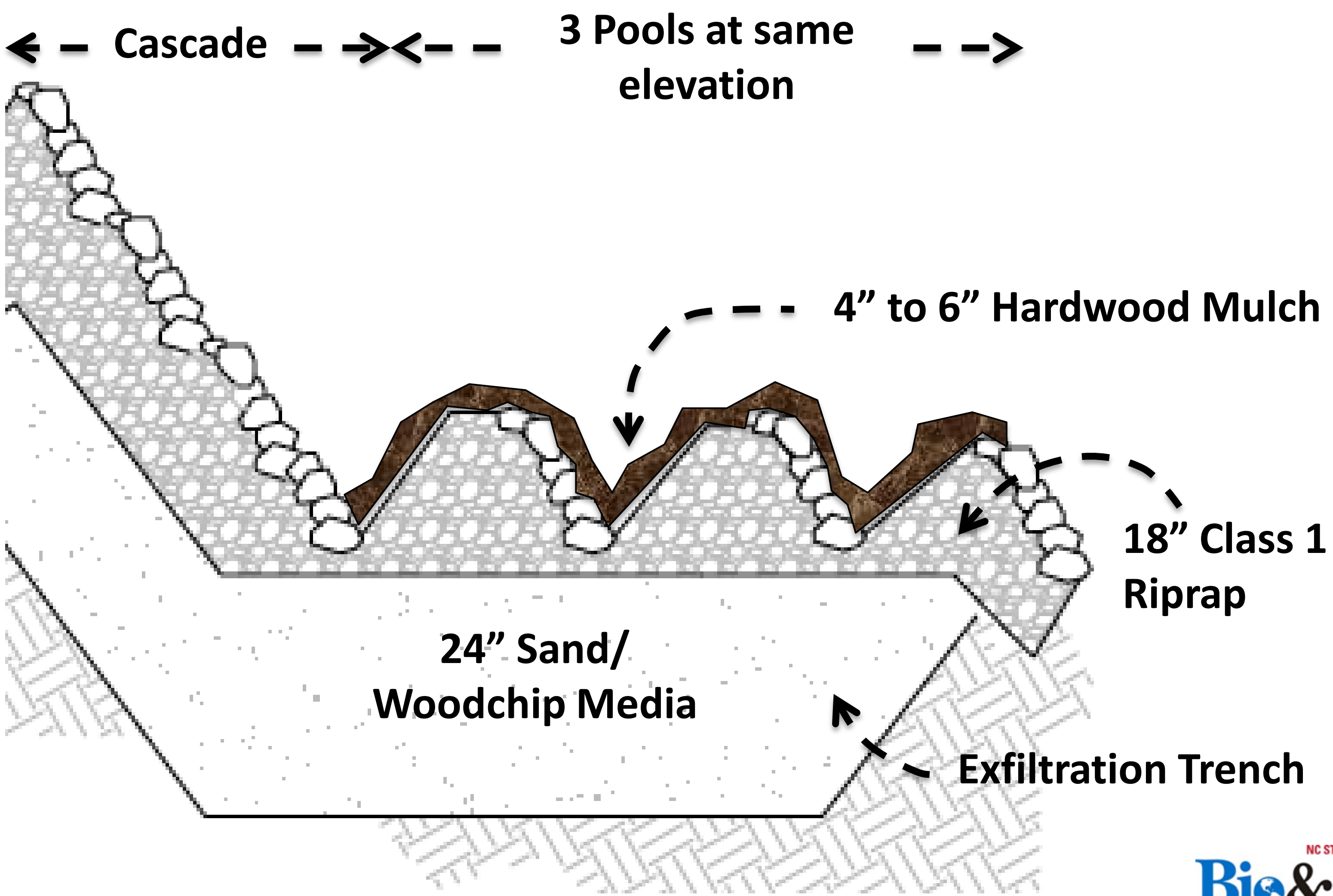
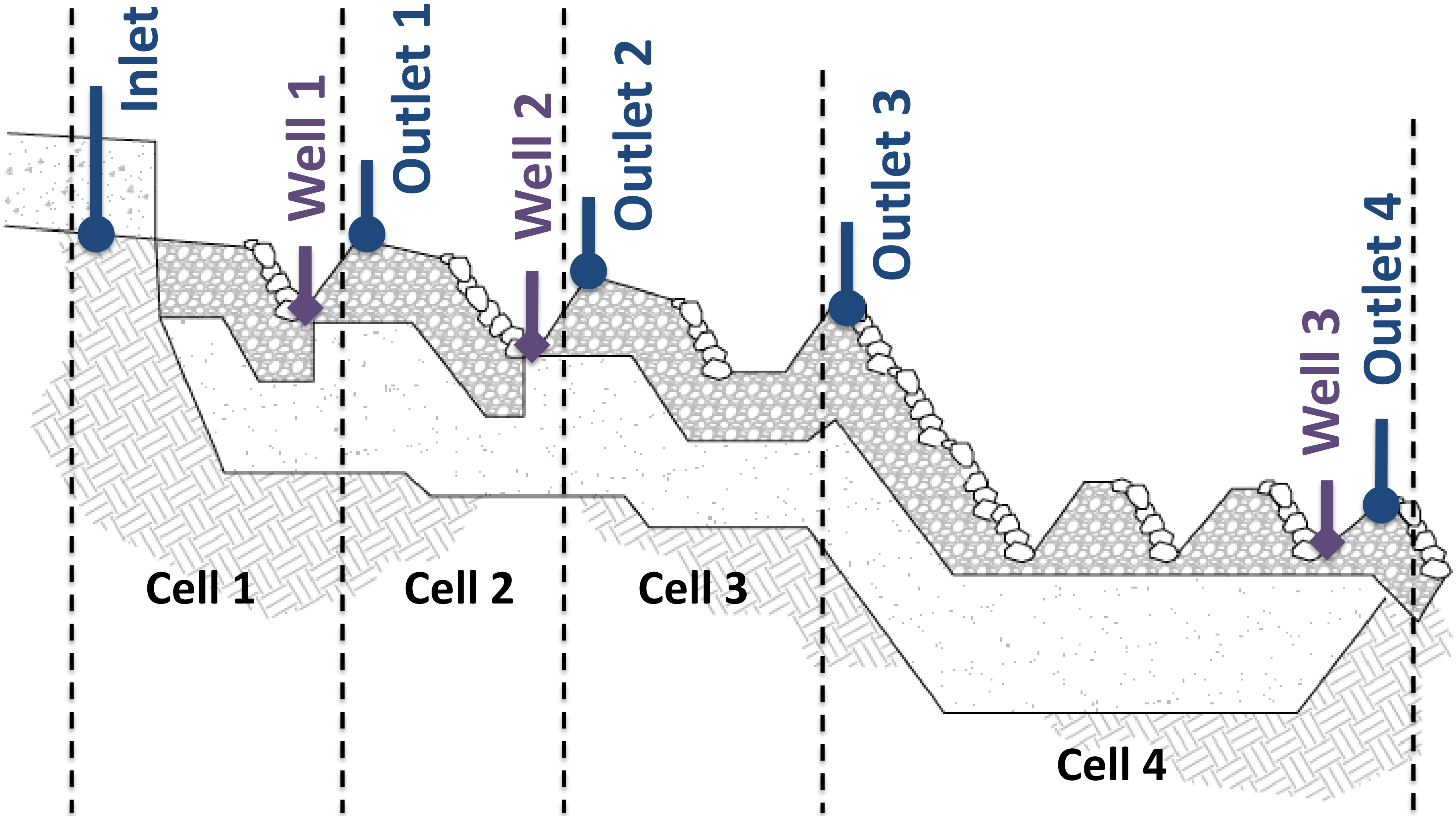
Cell 4



Cascade
3 Pools at same elevation
4” to 6” Hardwood Mulch
18” Class 1 Riprap
24” Sand/ Woodchip Media
Exfiltration Trench



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Storm Summary

Monitored 43 inflow producing events between July 2013 and June 2014

Max Rainfall Depth =3.2 in

- Inflow Volume = 23,308 ft^3, peak flow = 3900 gpm
- Outflow Volume = 8299 ft^3, peak flow = 1617 gpm

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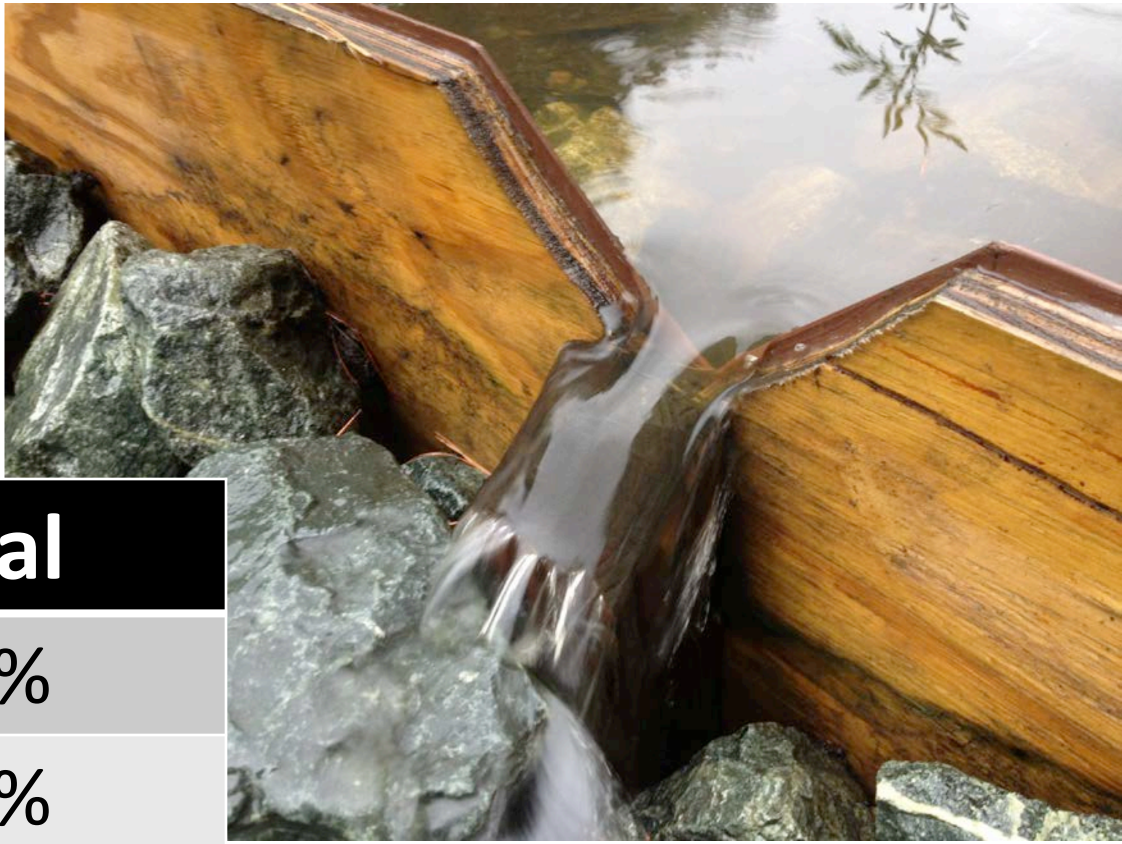
Overall Water Balance



RSC System Total	
Surface	21%
Seep	77%
Exfiltration	2%
ET	0%

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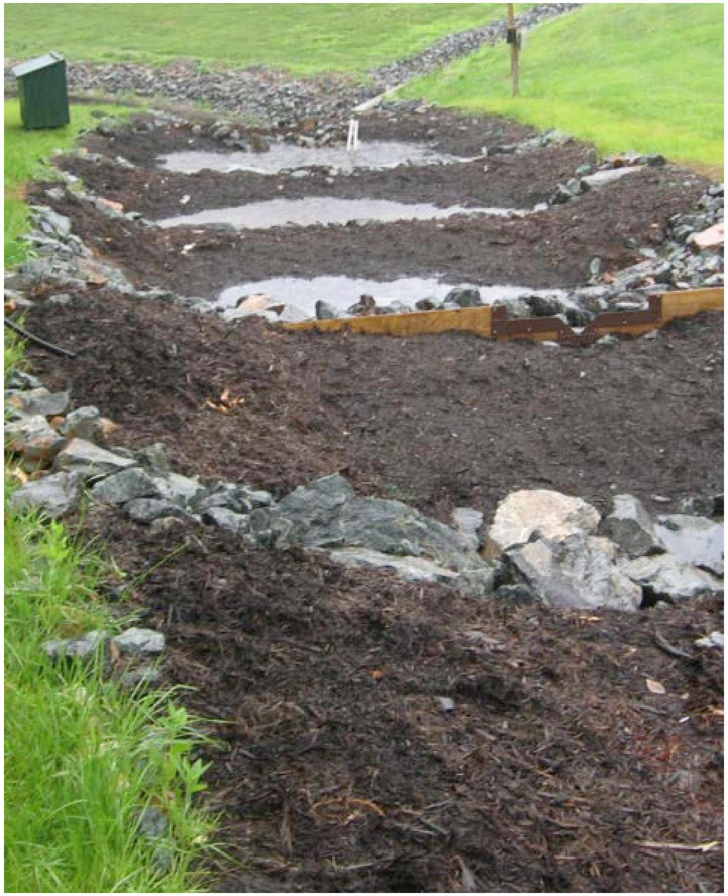
Storm Summary

Monitored 20 water quality events between July 2013 and June 2014



Inflow concentrations

- **TN**: median = 2.40 mg/L (1.59 to 9.96 mg/L)
- **TP**: median = 0.44 mg/L (0.24 to 2.14 mg/L)
- **TSS**: median = 69.1 mg/L (8.82 to 297 mg/L)

Outflow concentrations

- **TN**: median = 1.76 mg/L (1.05 to 3.85 mg/L)
- **TP**: median = 0.34 mg/L (0.18 to 1.23 mg/L)
- **TSS**: median = 11.56 mg/L (7.57 to 68.5 mg/L)

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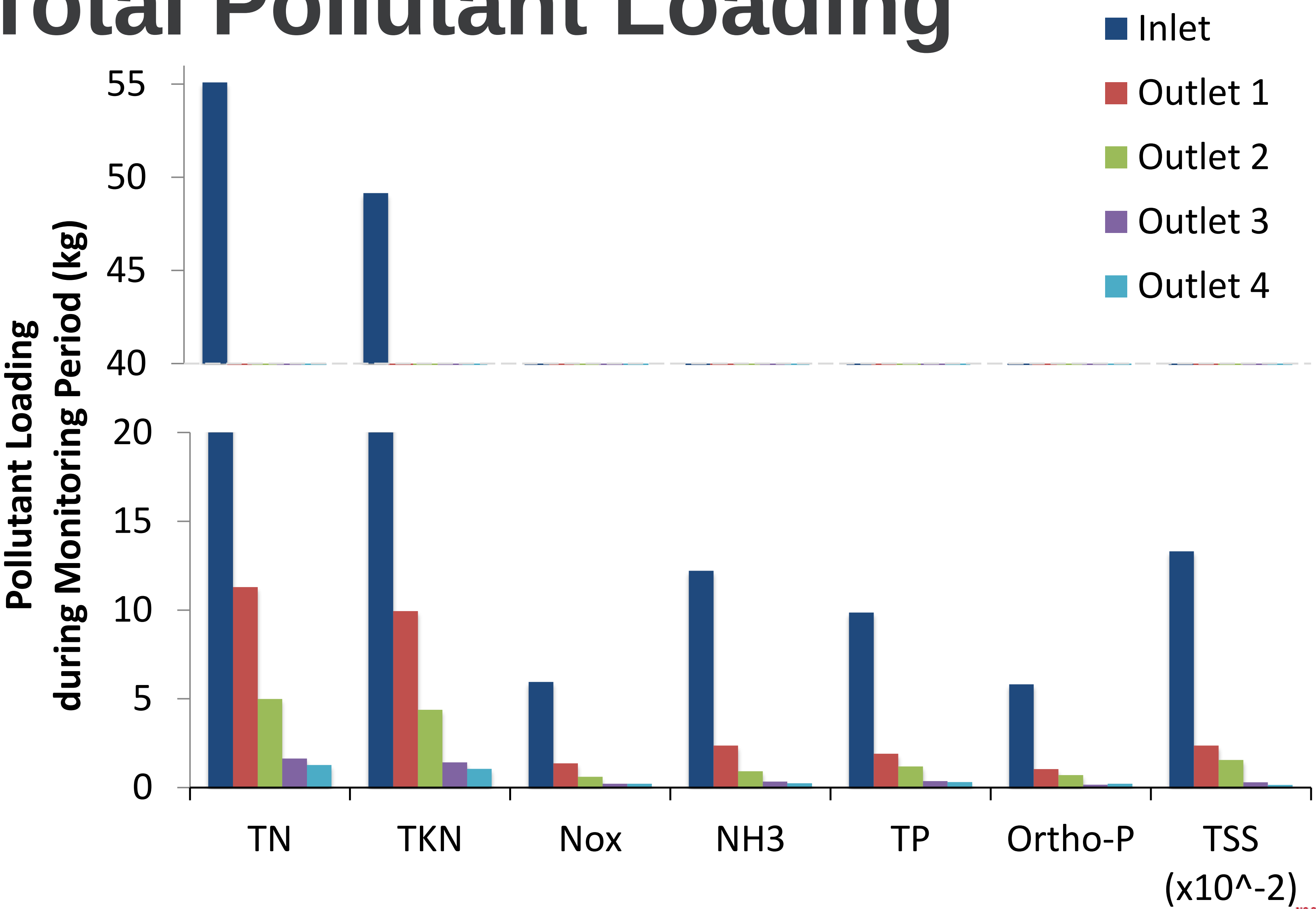
Total Pollutant Loading



Previous RSC Research

DRY CHANNEL								
Summary of Previous RSC Monitoring Results								
	Location	HSG	Surface Flow Volume Reductions	Peak Flow Reductions	TSS	TP	TN	Additional Findings
Cizek (2014)	Brunswick Co, NC	A	94-100%	90-96%	na	na	na	Able to mimic predevelopment hydrograph for events 1 year or less, but not all events. **High water table**.
Cizek (2014)	Alamance Co, NC	D	84%	80%	72%	28%	30%	Able to mimic predevelopment hydrograph and flow pathways. **Low water table for majority of system and high water table in last section.**
Koryto (2016)	Durham Co, NC	D	8%	49%	17%	17%	3%	Hydrologic reductions were only seen for rainfall less than 12.7 mm. **High water table.**

Table 2-12. Comparison of load reduction and design event depth at North Carolina Piedmont RSCs to State of Maryland regulations

Regulation/Study	*Design Event Depth*	*TSS Load Reduction*	*TN Load Reduction*	*TP Load Reduction*
State of Maryland[a]	25.4 mm	70%	57%	66%
Alamance RSC[b]	18 mm	72%	28%	30%
Durham RSC[c]	6 mm	10%	4.4%	7%

[a](Maryland Department of the Environment, 2014)
[b]Surface flow REs applied to media flow (Cizek, 2014)
[c]Event load reductions (Table 2-11)

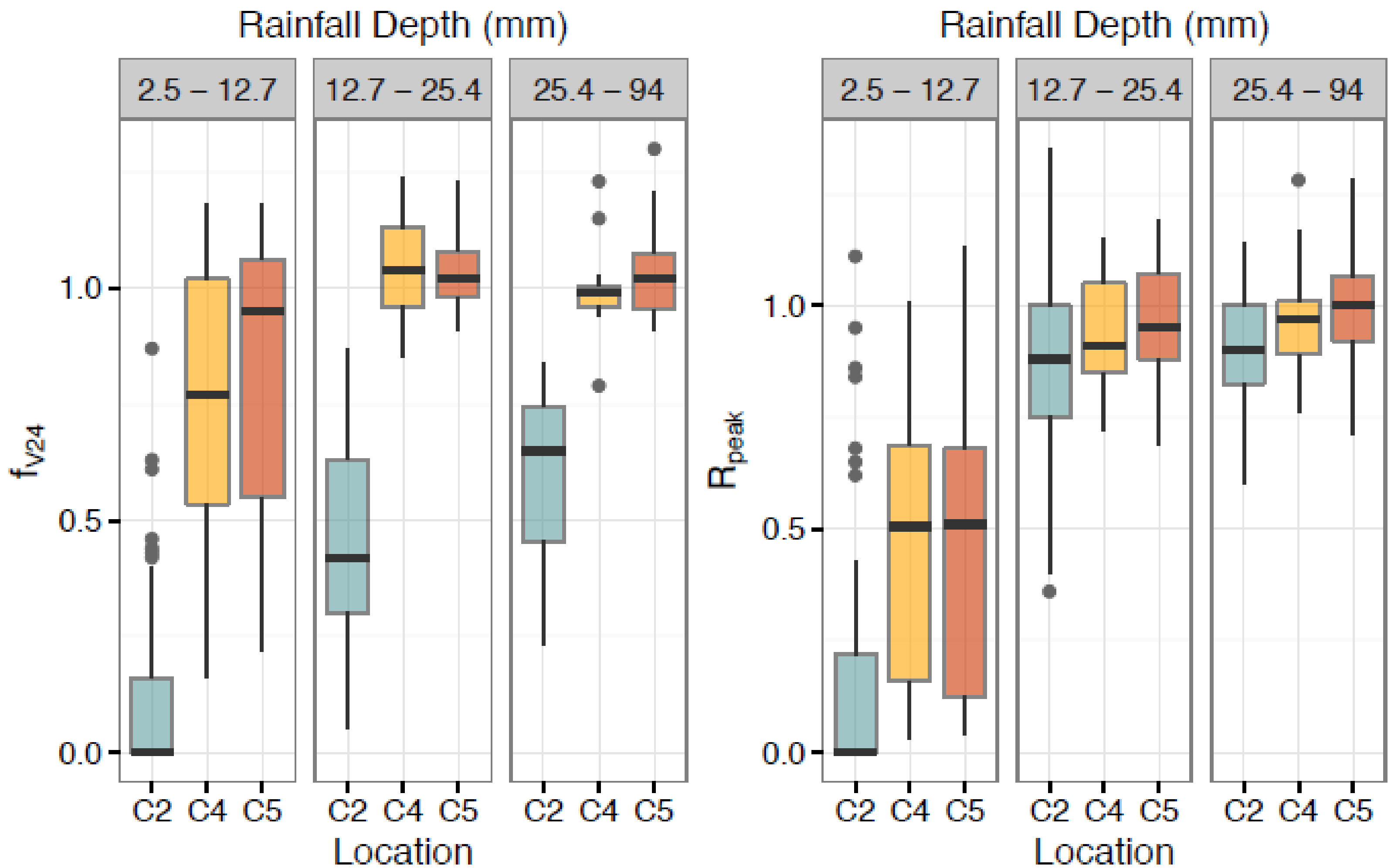


Figure 2-12. Hydrologic mitigation based on rainfall depth: cell location box plots for f_{V24} (left) and R_{peak} (right)

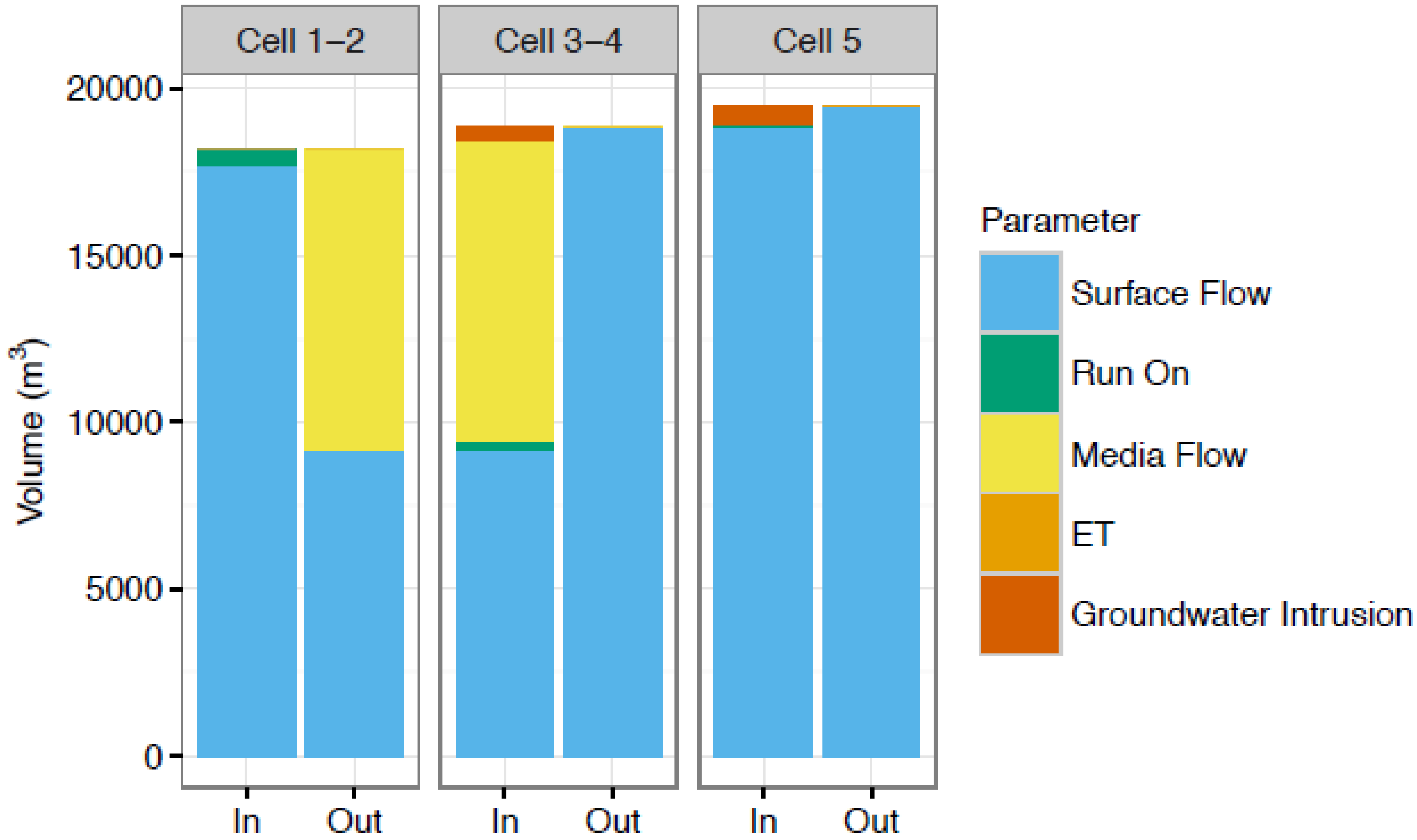


Figure-2-9. Fourteen-month water balance showing flow pathways based on location

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Previous RSC Research

- HSG A (Brunswick Co.)
  - High water table
  - Able to mimic predevelopment hydrograph for events 1 year or less, but not all events
  - Good water quality reductions

- HSG D (Alamance Co.)
  - Low water table for majority of system and high water table in last section.
  - Able to mimic predevelopment hydrograph and flow pathways.
  - Good water quality reductions

- HSG D (Durham Co.)
  - High water table
  - Hydrologic reductions were only seen for rainfall less than 12.7 mm.
  - Moderate water quality reductions

- Appears that soil conditions and location of water table are driving factors in performance. It is possible to have either dense soils or high water table and still achieve performance, but not both.