UNRBA – October 3, 2023

NC State Stormwater Research Update

Bill Hunt, PE, PhD

WNR Professor & Extension Specialist

Biological & Agricultural Engineering

NC State University

Aha! Moment

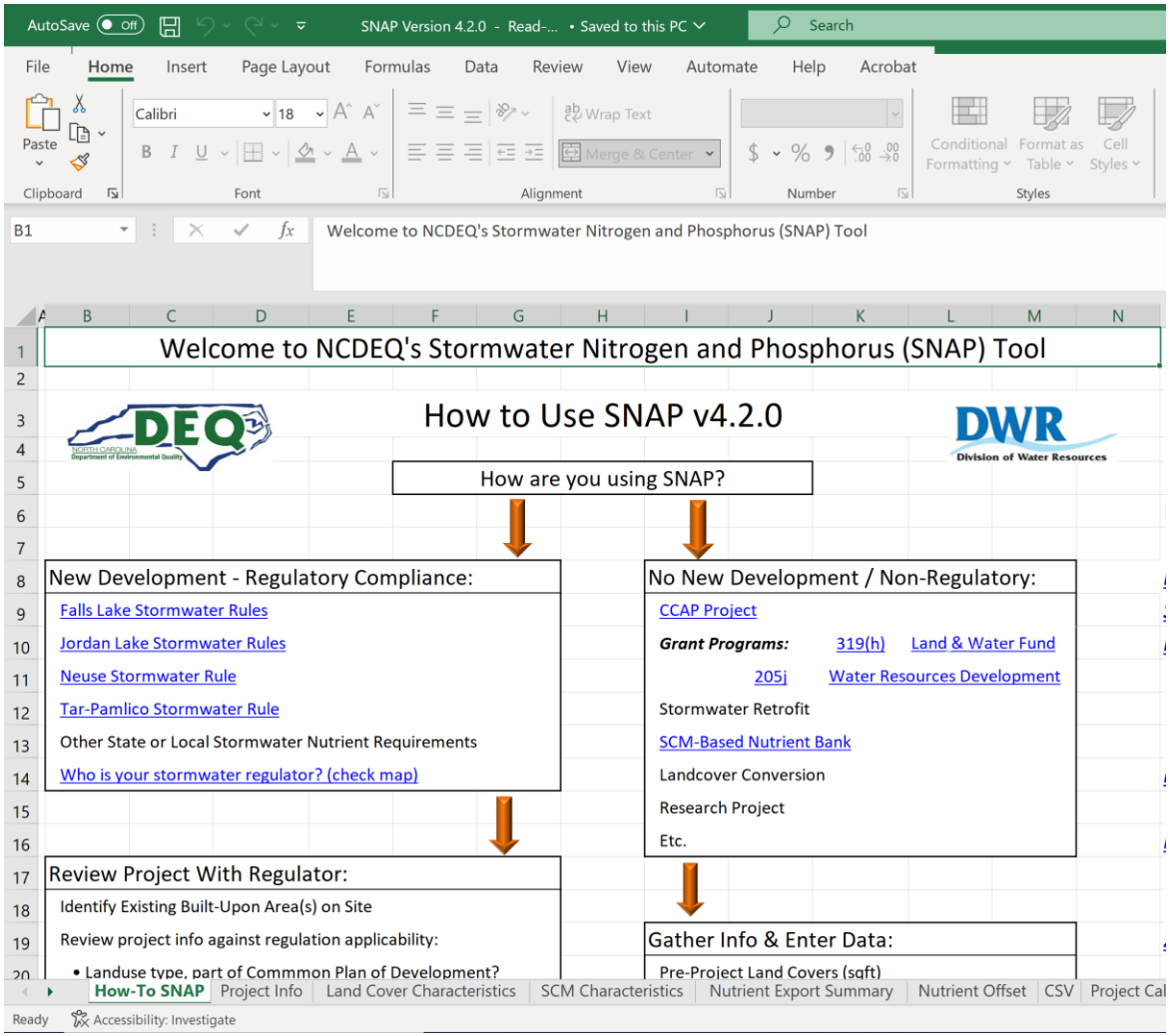
Stormwater Quiz

- What is the Water Quality Design Storm?

- What does “First Flush” entail?

Stormwater Quiz (continued)

- How dirty are our urban surfaces? (related: which ones are the biggest polluters?)

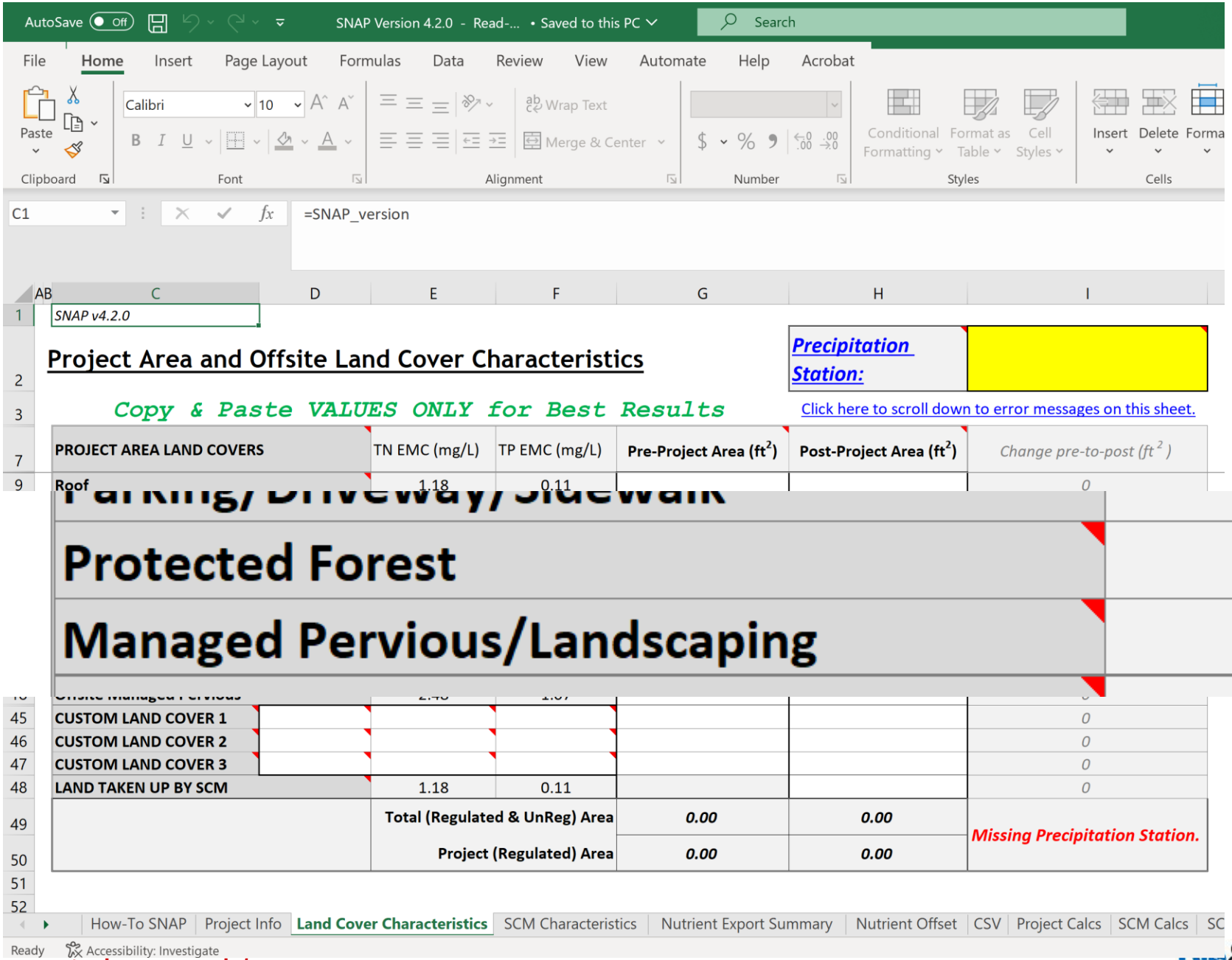


Ohhhh… SNAP

- How are pollutant loads calculated in SNAP?

NC Environmental Quality

Bio&Ag Engineering



AutoSave Off | SNAP Version 4.2.0 - Read-... • Saved to this PC | Search

File Home Insert Page Layout Formulas Data Review View Automate Help Acrobat

Clipboard Font Alignment Number Styles Cells

C1 =SNAP_version

SNAP v4.2.0

Project Area and Offsite Land Cover Characteristics

Precipitation Station:	

Copy & Paste VALUES ONLY for Best Results

Click here to scroll down to error messages on this sheet.

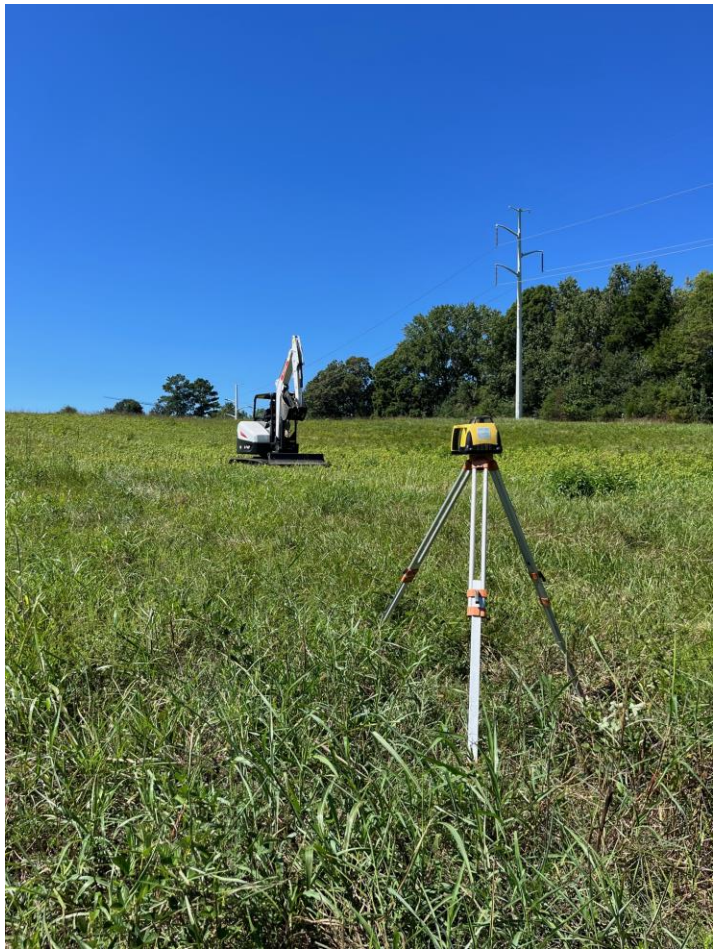
PROJECT AREA LAND COVERS	TN EMC (mg/L)	TP EMC (mg/L)	Pre-Project Area (ft²)	Post-Project Area (ft²)	Change pre-to-post (ft²)
Roof	1.18	0.11			0
Parking/ Driveway/ Sidewalk					
Protected Forest					0
Managed Pervious/Landscaping					2
CUSTOM LAND COVER 1					0
CUSTOM LAND COVER 2					0
CUSTOM LAND COVER 3					0
LAND TAKEN UP BY SCM	1.18	0.11			0
	Total (Regulated & UnReg) Area		0.00	0.00	Missing Precipitation Station.
	Project (Regulated) Area		0.00	0.00	

How-To SNAP | Project Info | Land Cover Characteristics | SCM Characteristics | Nutrient Export Summary | Nutrient Offset | CSV | Project Calcs | SCM Calcs | SC

Ready Accessibility: Investigate

DWR Asked Us to:

- Determine Pollutant Loadings from Pervious Land Uses
  - Managed Woods, Meadow, Managed Lawns
- To Calculate Pollutant Loadings, we need 2 things:
- Annual VOLUME of Runoff, and
- The Concentration of Pollutants (EMC's)



By Measuring Event Runoff Volumes (& Precipitation Depths) to Determine Annual Runoff Volume, we can back-calculate…

The NRCS Curve Number !!!

$$Q^* = \frac{(P - 0.2\,S)^2}{(P + 0.8\,S)}$$

$$S = \frac{1000}{CN} - 10$$

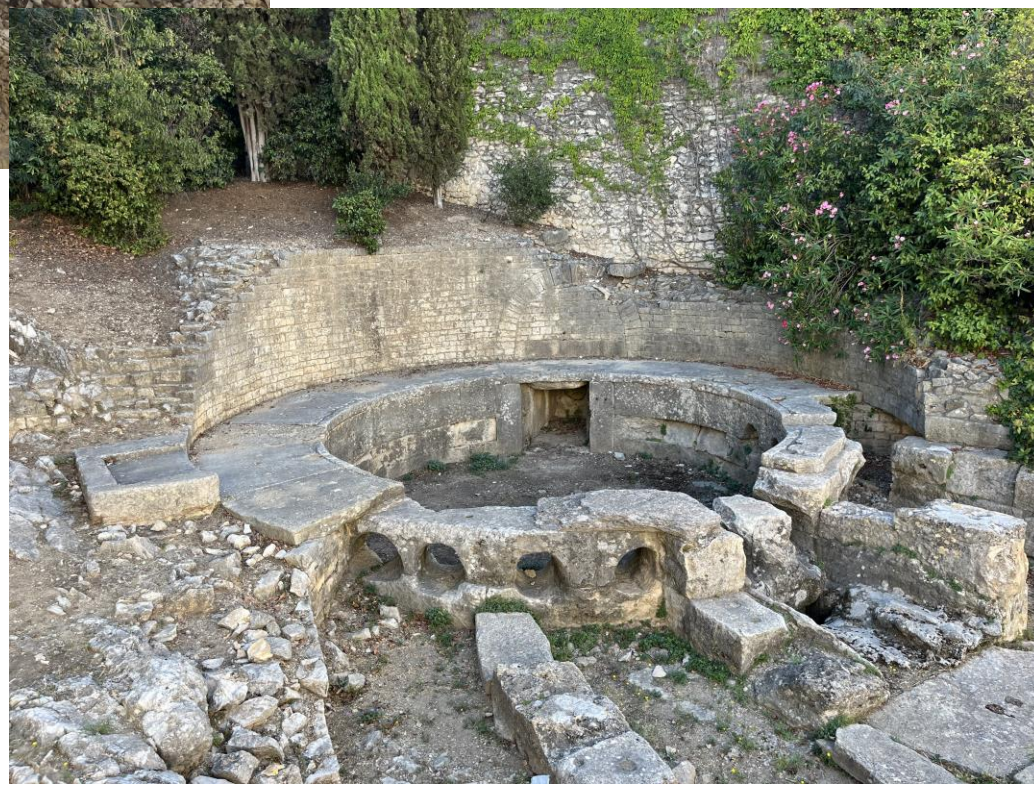
- Where: Q* = Runoff Depth (in)
- P = Precipitation Depth (in)
- S = Potential Maximum Soil Moisture Retention (in)
- CN = Curve Number

Rain Gauges! – Manual & Tipping Bucket

Your WQ Workhorse: The Weir

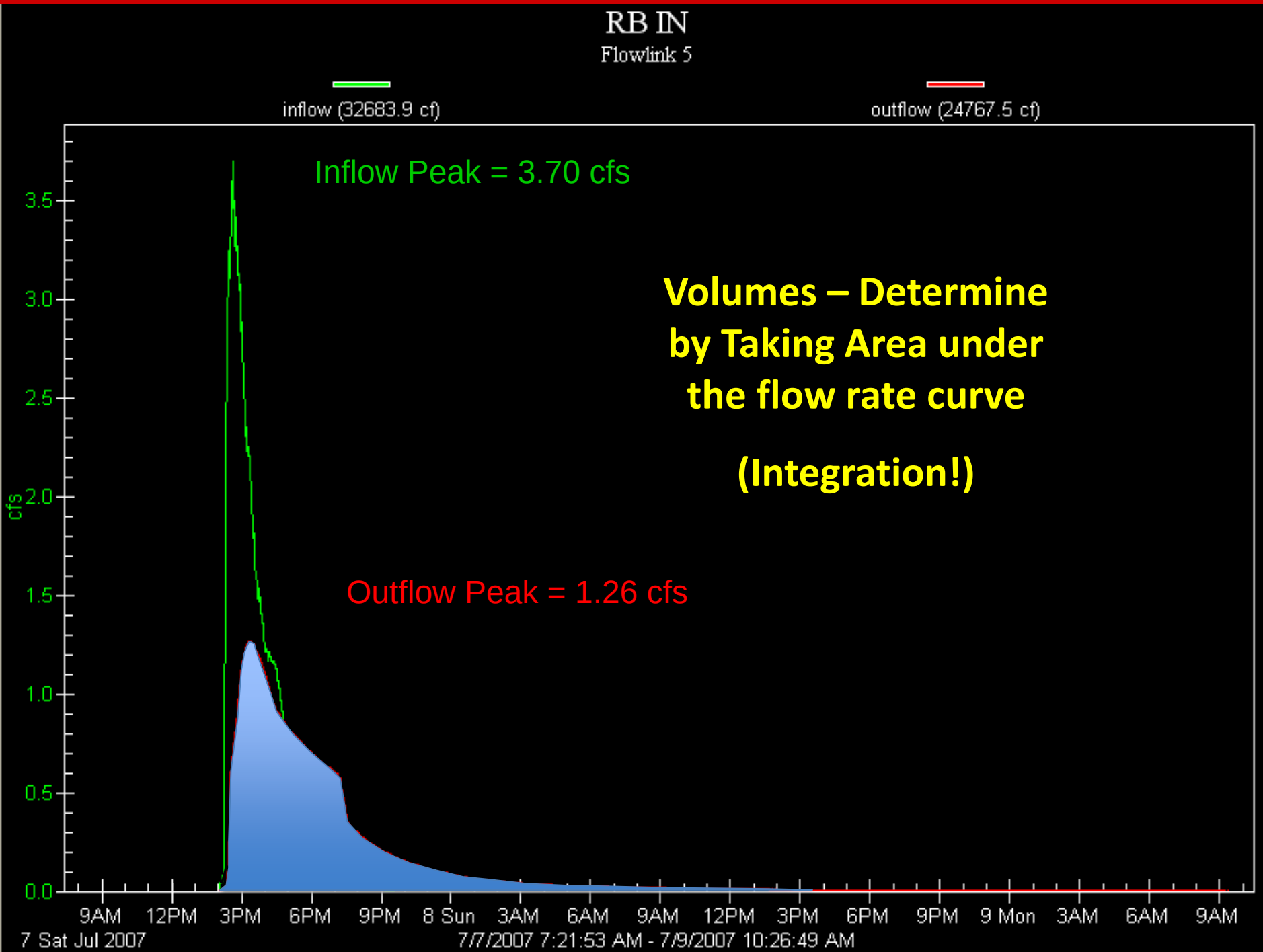
Rectangular Weir

Separated by a mere 2000 years?



Roman *Castellum Aquae* in Nimes, France

Measuring Flow


RB IN
Flowlink 5
inflow (32683.9 cf)
outflow (24767.5 cf)
Inflow Peak = 3.70 cfs
Outflow Peak = 1.26 cfs
Volumes – Determine by Taking Area under the flow rate curve
(Integration!)
cfs
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
9AM
12PM
3PM
6PM
9PM
8 Sun
3AM
6AM
9AM
12PM
3PM
6PM
9PM
9 Mon
3AM
6AM
9AM
7 Sat Jul 2007
7/7/2007 7:21:53 AM - 7/9/2007 10:26:49 AM

The Automated Sampler

The sampler “pulls” aliquots based on:

1. Flow Rates
2. Rainfall Rates
3. Time Intervals

This is how EMC’s are measured/ calculated.

OK, Let's look at the monitoring sites

(Please take mental note… Quiz following)

Managed Pervious Surface Study Sites

- Woods
- Durham Co.
- HSG D
- Monitored since Feb ‘22

Managed Pervious Surface Study Sites

- Woods
- NCMA, Wake Co.
- HSG B
- Monitored since Jan ‘23

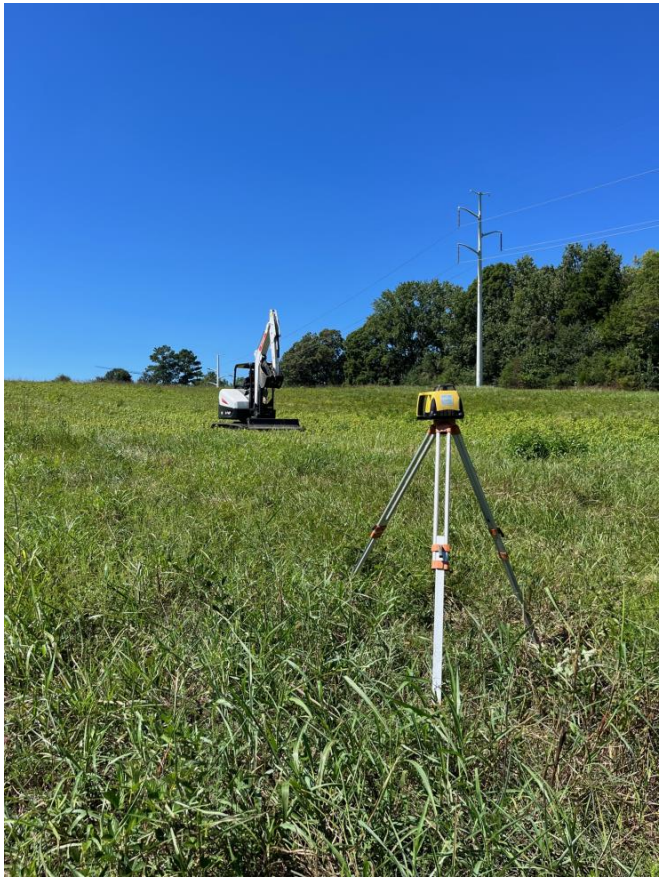
Managed Pervious Surface Study Sites

- Woods(?)
- Wilmington
- HSG A/B
- Monitored since Sep ‘22

Pervious Surface Study Sites

- Meadow
- Duke Forest, Orange Co
- HSG D/C
- Monitored since Sep ‘22

Managed Pervious Surface Study Sites



- Meadow
- NCMA, Wake Co.
- HSG B
- Monitored since Aug ‘22

Pervious Surface Study Sites

- Managed Lawn
- NC State, Wake Co.
- HSG B
- Monitored since Mar ‘22

Pervious Surface Study Sites

- Managed Lawn
- Veteran's Park, Wilmington
- HSG A
- Monitored since Aug '22

What Site Produced Runoff Most Reliably?

What Site Produced the Least Amount of Runoff?

Guess How Many Storms Produced Runoff?

Includes 3.56” and 4.35” events

Underlying Soil Really Matters!!!

- Score One (Big One) for the Curve Number Method!

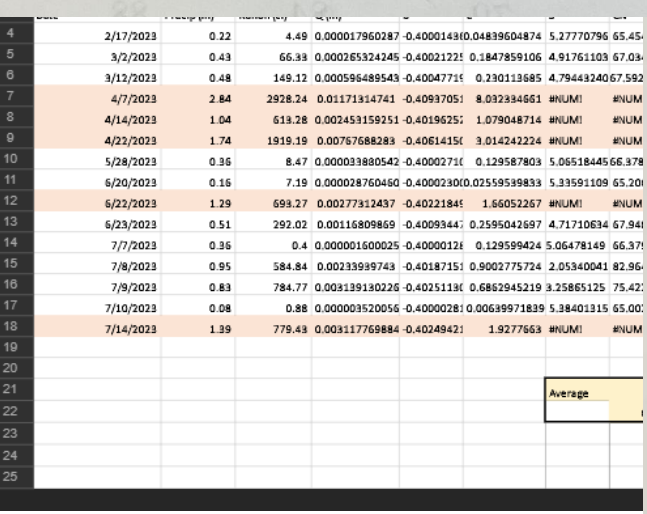
All other Sites have yielded at least 4 runoff-producing events

- Woods sites
  - Wet antecedent conditions, storms as small as 0.7” can trigger runoff
  - Normal ADP, runoff-producing storms > 1.0”
- Meadow sites
  - Typically need at least 1.0” of rainfall to generate runoff
- All (but NCSU lawn) had some storms > 1.5” that did not generate runoff

Table 20.4 Runoff Curve Numbers of Urban Areas (ARC II)

cover description: cover type and hydrologic condition	average percent impervious area	curve numbers for hydrologic soil: group A	group B	group C	group D
fully developed urban areas (vegetation established)					
open space (lawns, parks, golf courses, cemeteries, etc.)					
poor condition (grass cover < 50%)		68	79	86	89
fair condition (grass cover 50 to 75%)		49	69	79	84
good condition (grass cover > 75%)		39	61	74	80
right-of-way)		98	98	98	98
paved; open ditches (including right-of-way)		83	89	92	93
gravel (including right-of-way)		76	85	89	91
dirt (including right-of-way)		72	82	87	89
western desert urban areas					
natural desert landscaping (pervious areas only)		63	77	85	88
artificial desert landscaping (impervious weed barrier, desert shrub with 1 to 2 in sand or gravel mulch and basin borders)		96	96	96	96
urban districts					
commercial and business	85	89	92	94	95
industrial	72	81	88	91	93
residential districts by average lot size					
$\frac{1}{8}$ acre or less (townhouses)	65	77	85	90	92
$\frac{1}{4}$ acre	38	61	75	83	87
$\frac{1}{3}$ acre	30	57	72	81	86
$\frac{1}{2}$ acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
developing urban areas					
newly graded areas (pervious areas only, no vegetation)		77	86	91	94

Reprinted from *Urban Hydrology for Small Watersheds*, Technical Release TR 55, United States Department of Agriculture, Soil Conservation Service, Table 2-2a, 1986.



4	2/17/2023	0.22	4.49	0.000017960287	-0.4000143	0.04839604874	5.27770796	65.45
5	3/2/2023	0.43	66.33	0.000265324245	-0.4002122	0.1847859106	4.91761103	67.03
6	3/12/2023	0.48	149.12	0.000596489543	-0.4004771	0.230113685	4.79443240	67.592
7	4/7/2023	2.84	2928.24	0.01171314741	-0.4093705	8.032334661	#NUM!	#NUM
8	4/14/2023	1.04	613.28	0.002453159251	-0.4019625	1.079048714	#NUM!	#NUM
9	4/22/2023	1.74	1919.19	0.00767688283	-0.4061415	3.014242224	#NUM!	#NUM
10	5/28/2023	0.36	8.47	0.000033880542	-0.4000271	0.129587803	5.06518445	66.378
11	6/20/2023	0.16	7.19	0.000028760460	-0.4000230	0.02559539833	5.33591109	65.20
12	6/22/2023	1.29	693.27	0.002773124 37	-0.4022184	1.66052267	#NUM!	#NUM
13	6/23/2023	0.51	292.02	0.00116809869	-0.4009344	0.2595042697	4.71710634	67.94
14	7/7/2023	0.36	0.4	0.000001600025	-0.4000012	0.129599424	5.06478149	66.37
15	7/8/2023	0.95	584.84	0.00233939743	-0.4018715	0.9002775724	2.05340041	82.96
16	7/9/2023	0.83	784.77	0.003139130226	-0.4025113	0.6862945219	3.25865125	75.42
17	7/10/2023	0.08	0.88	0.000003520056	-0.4000028	0.006399718 39	5.38401315	65.00
18	7/14/2023	1.39	779.43	0.003117769884	-0.4024942	1.9277663	#NUM!	#NUM
19								
20								
21						Average		
22								
23								
24								
25								

- CN Calculation f

  66-69

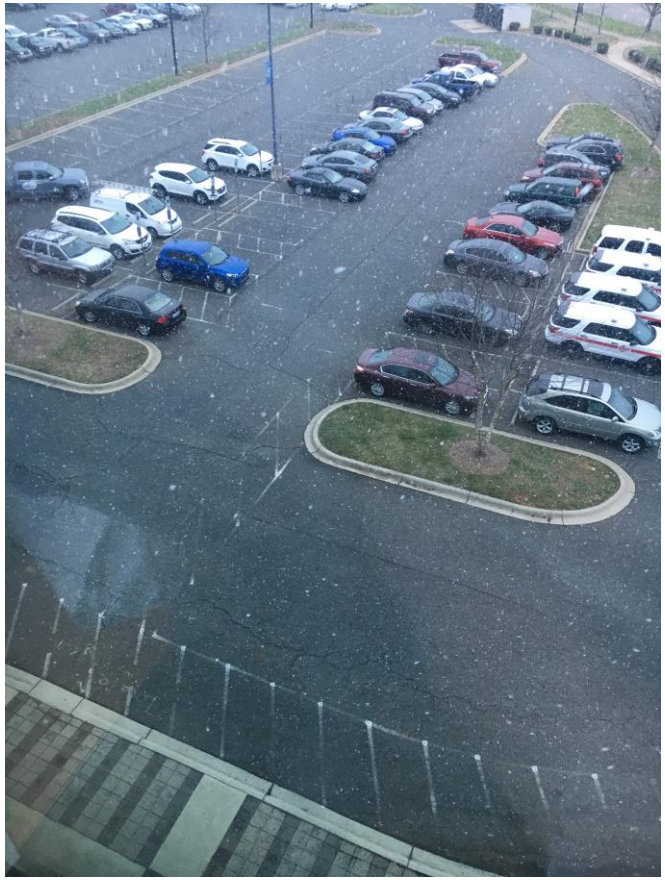
Antecedent Moisture Conditions Really Matter…

- Another “Win” for the Curve Number Method

Let's Talk (Nutrient) Pollution!!!

What is your guess at typical nutrient concentrations coming off parking lots?

- TN: 1.63 mg/L (mean).
  - Range: 1 to 2.5 mg/L
- TP: 0.21 mg/L
  - Range: 0.1 to 0.3 mg/L



What land use yielded the highest nutrient concentrations?

- TN: 6.53 mg/L (!)
- TP: 1.56 mg/L (!!!)

How do you think these other pervious landuses compare to (typical) asphalt runoff?

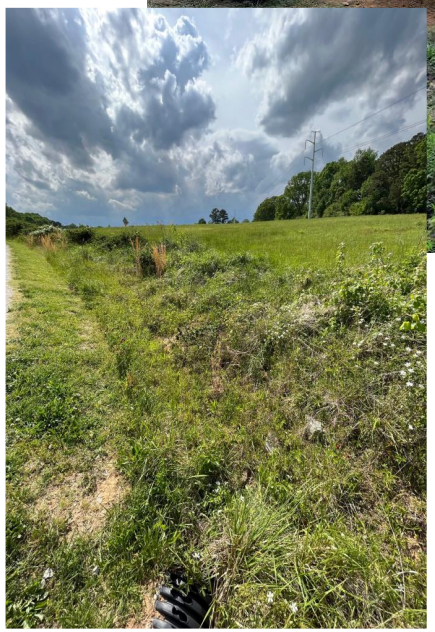
TN: 1.79 – 3.97 mg/L

TP: 0.37 – 0.58 mg/L

How do you think these other pervious landuses compare to (typical) asphalt runoff?

TN: 0.84 – 1.49 mg/L

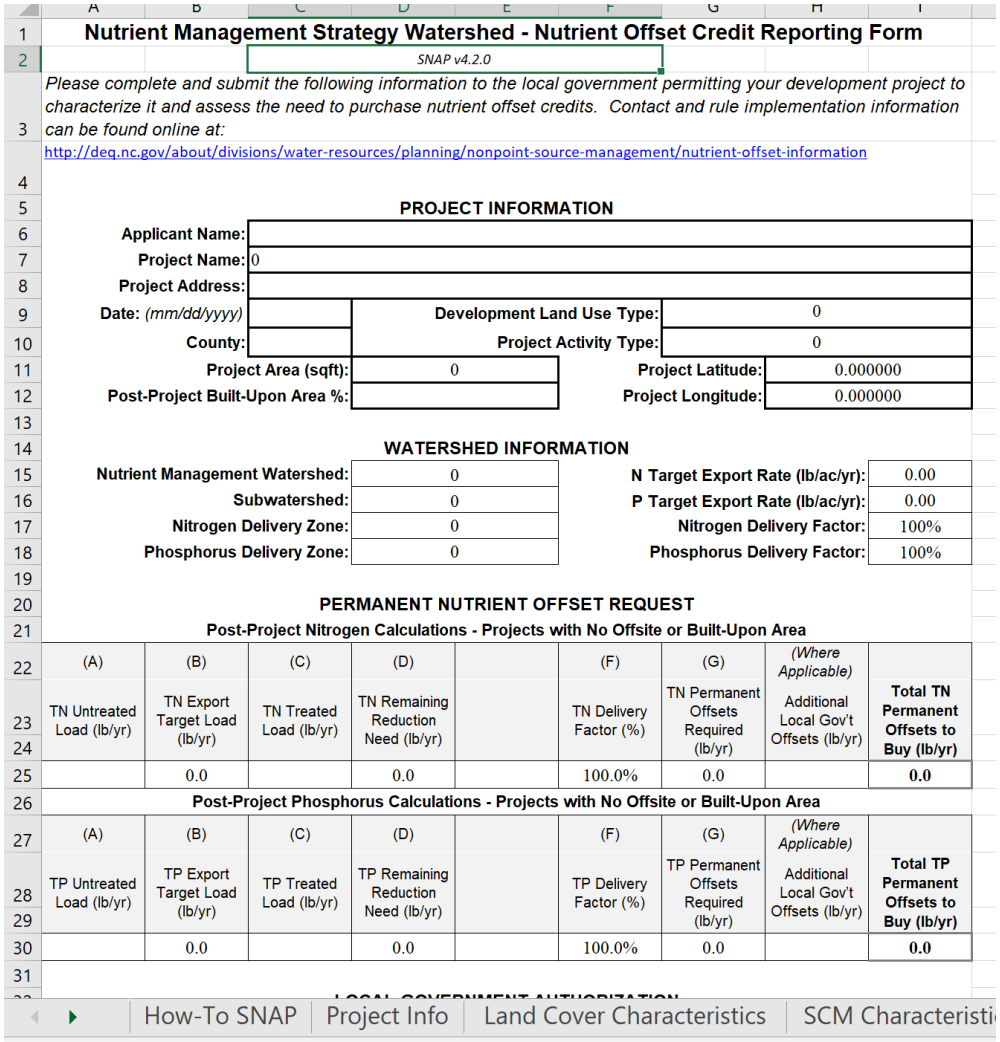
TP: 0.08 – 0.44 mg/L



These 2 sites have the fewest amount of data. One of which, only 2 WQ samples

This Study will continue through next Spring

- These Data will support some significant re-vamping of SNAP
  - Curve Number- based hydrology in lieu of the Simple Method
  - Changes to nutrient concentrations assigned to pervious land uses



Nutrient Management Strategy Watershed - Nutrient Offset Credit Reporting Form

SNAP v4.2.0

Please complete and submit the following information to the local government permitting your development project to characterize it and assess the need to purchase nutrient offset credits. Contact and rule implementation information can be found online at:
http://deq.nc.gov/about/divisions/water-resources/planning/nonpoint-source-management/nutrient-offset-information

PROJECT INFORMATION

Applicant Name:			
Project Name:	0		
Project Address:			
Date: *(mm/dd/yyyy)*		Development Land Use Type:	0
County:		Project Activity Type:	0
Project Area (sqft):	0	Project Latitude:	0.000000
Post-Project Built-Upon Area %:		Project Longitude:	0.000000

WATERSHED INFORMATION

Nutrient Management Watershed:	0	N Target Export Rate (lb/ac/yr):	0.00
Subwatershed:	0	P Target Export Rate (lb/ac/yr):	0.00
Nitrogen Delivery Zone:	0	Nitrogen Delivery Factor:	100%
Phosphorus Delivery Zone:	0	Phosphorus Delivery Factor:	100%

PERMANENT NUTRIENT OFFSET REQUEST

Post-Project Nitrogen Calculations - Projects with No Offsite or Built-Upon Area

(A) TN Untreated Load (lb/yr)	(B) TN Export Target Load (lb/yr)	(C) TN Treated Load (lb/yr)	(D) TN Remaining Reduction Need (lb/yr)		(F) TN Delivery Factor (%)	(G) TN Permanent Offsets Required (lb/yr)	*(Where Applicable)* Additional Local Gov't Offsets (lb/yr)	Total TN Permanent Offsets to Buy (lb/yr)
	0.0		0.0		100.0%	0.0		**0.0**

Post-Project Phosphorus Calculations - Projects with No Offsite or Built-Upon Area

(A) TP Untreated Load (lb/yr)	(B) TP Export Target Load (lb/yr)	(C) TP Treated Load (lb/yr)	(D) TP Remaining Reduction Need (lb/yr)		(F) TP Delivery Factor (%)	(G) TP Permanent Offsets Required (lb/yr)	*(Where Applicable)* Additional Local Gov't Offsets (lb/yr)	Total TP Permanent Offsets to Buy (lb/yr)
	0.0		0.0		100.0%	0.0		**0.0**

How-To SNAP | Project Info | Land Cover Characteristics | SCM Characteristi

A Curiosity…

- Some of the Biggest Storms had the highest concentrations…
- E.g., a 1.86 in event yielded a 6.85 mg/L TN concentration @ NCMA Woods
  - 50% higher than mean

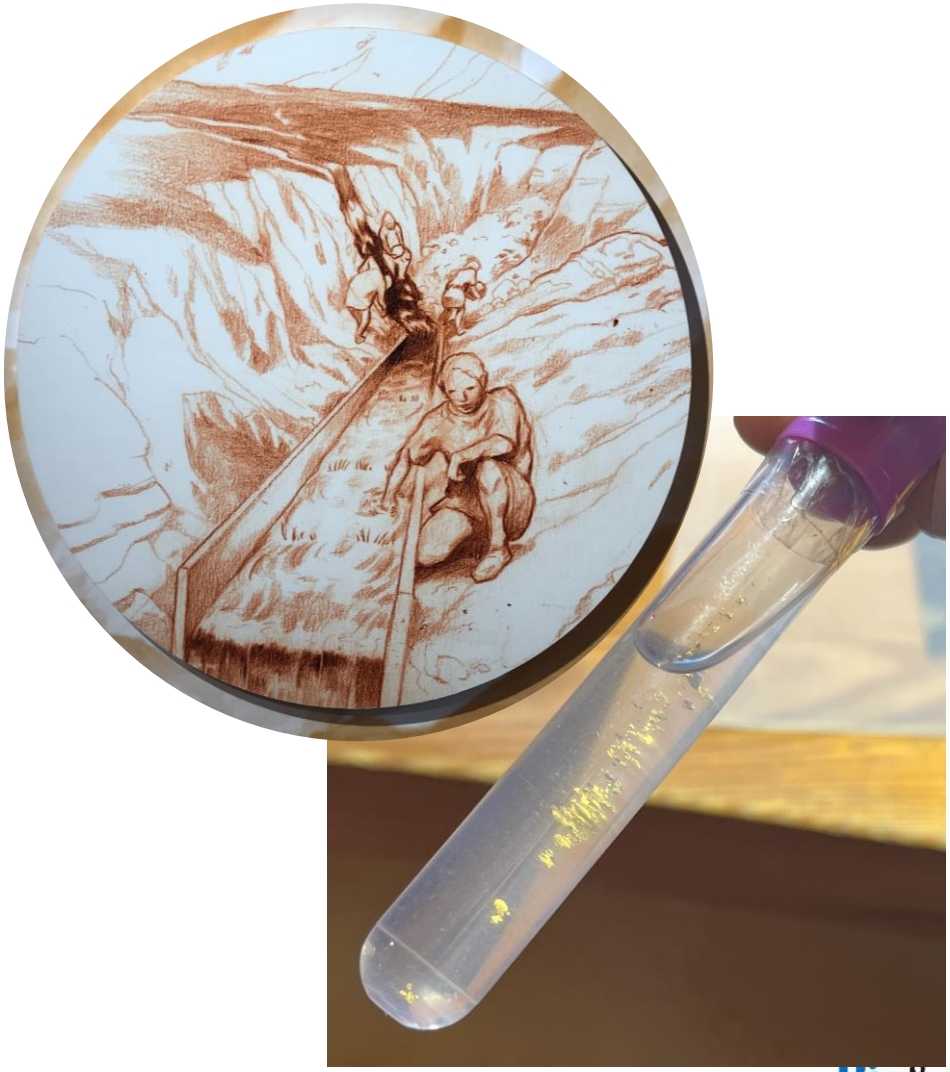
Tell Me About the Water Quality Storm (Please)

- What is it (in NC)?
- How do we treat it?

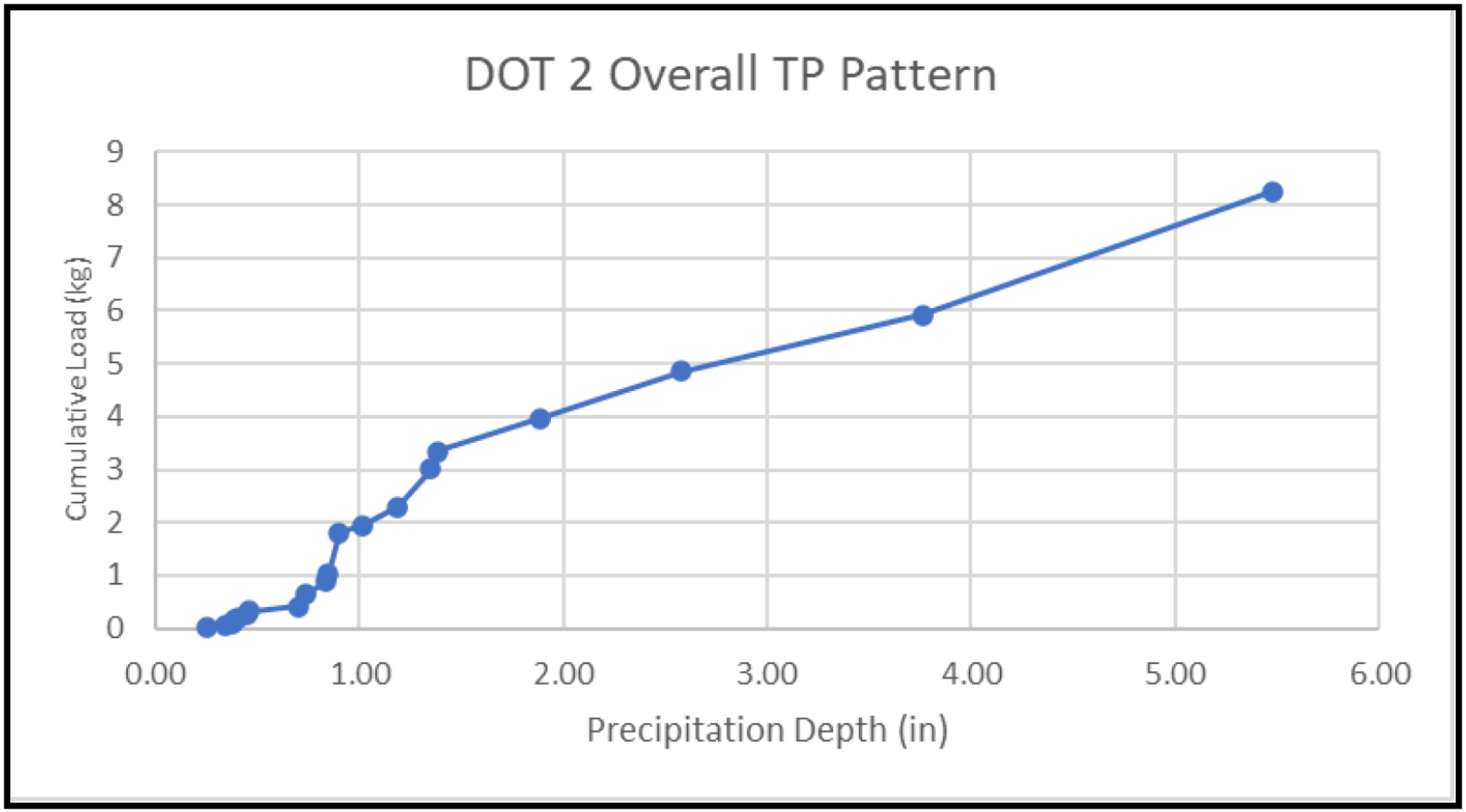
When testing SCMs, we try to capture all storms b/w 0.25 & 2.0 in

We (BAE Stormwater) Have a Fair Amount of Data

- Examined Data from 11 Sites
- Did Big Storms (>> 1 inch) carry a disproportional amount of load? Or
- Did capturing 1-in-ish events yield the clear majority of pollutant load?

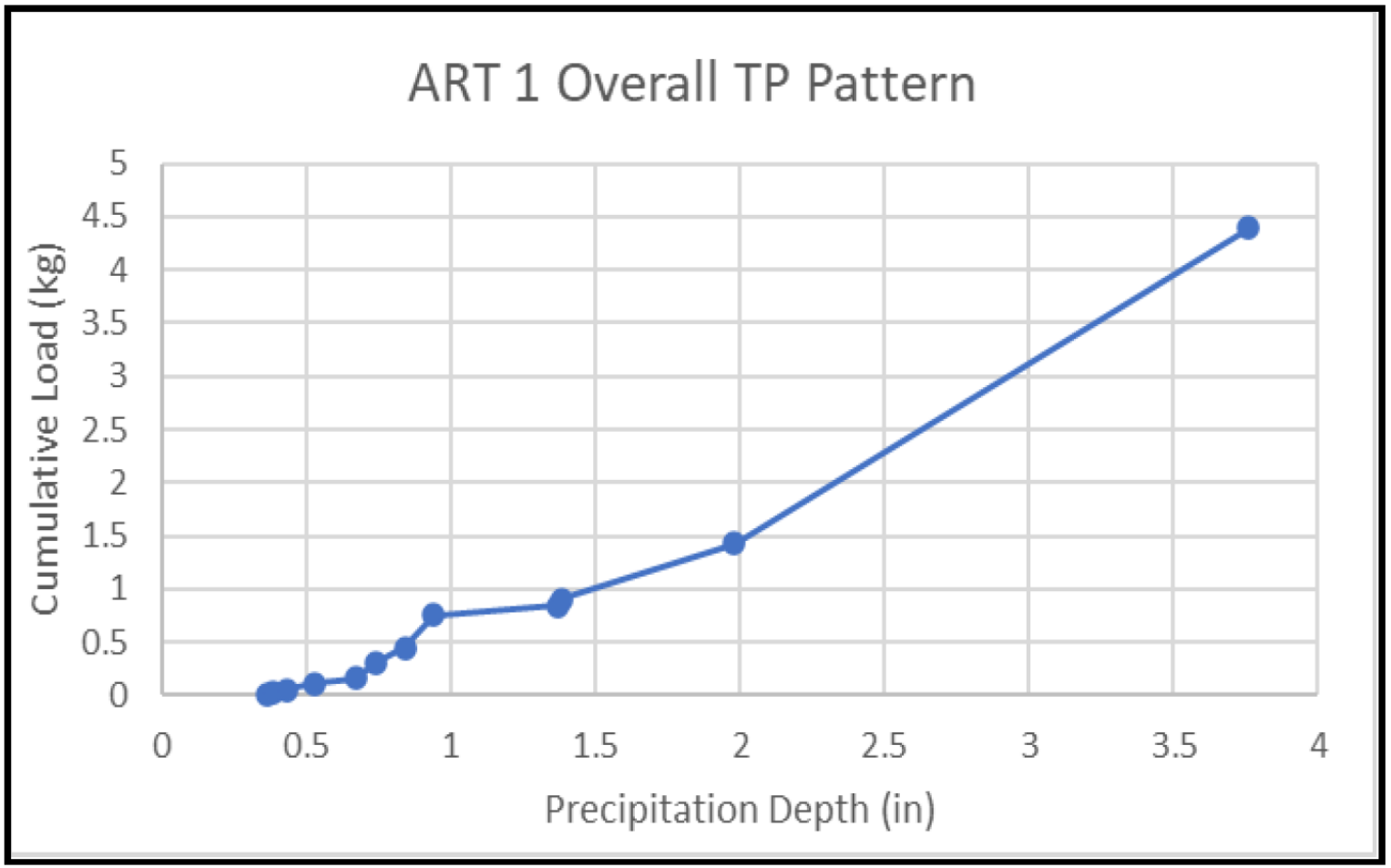


Cumulative TP Load, by Storm Rank



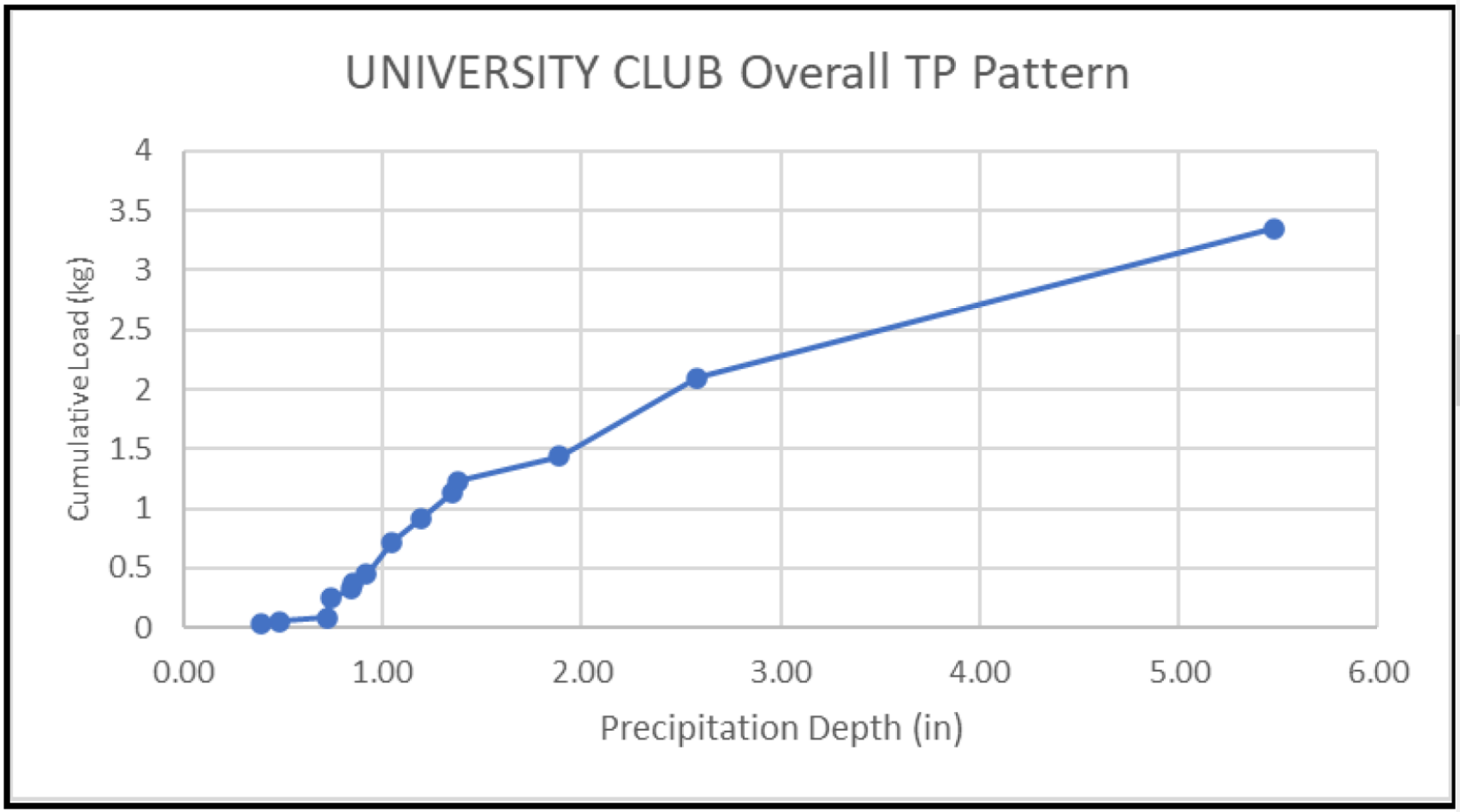
40% of Load, in 2 storms (3.8” & 5.4”) 2 out of 18 storms

Cumulative Loads, by Storm Rank



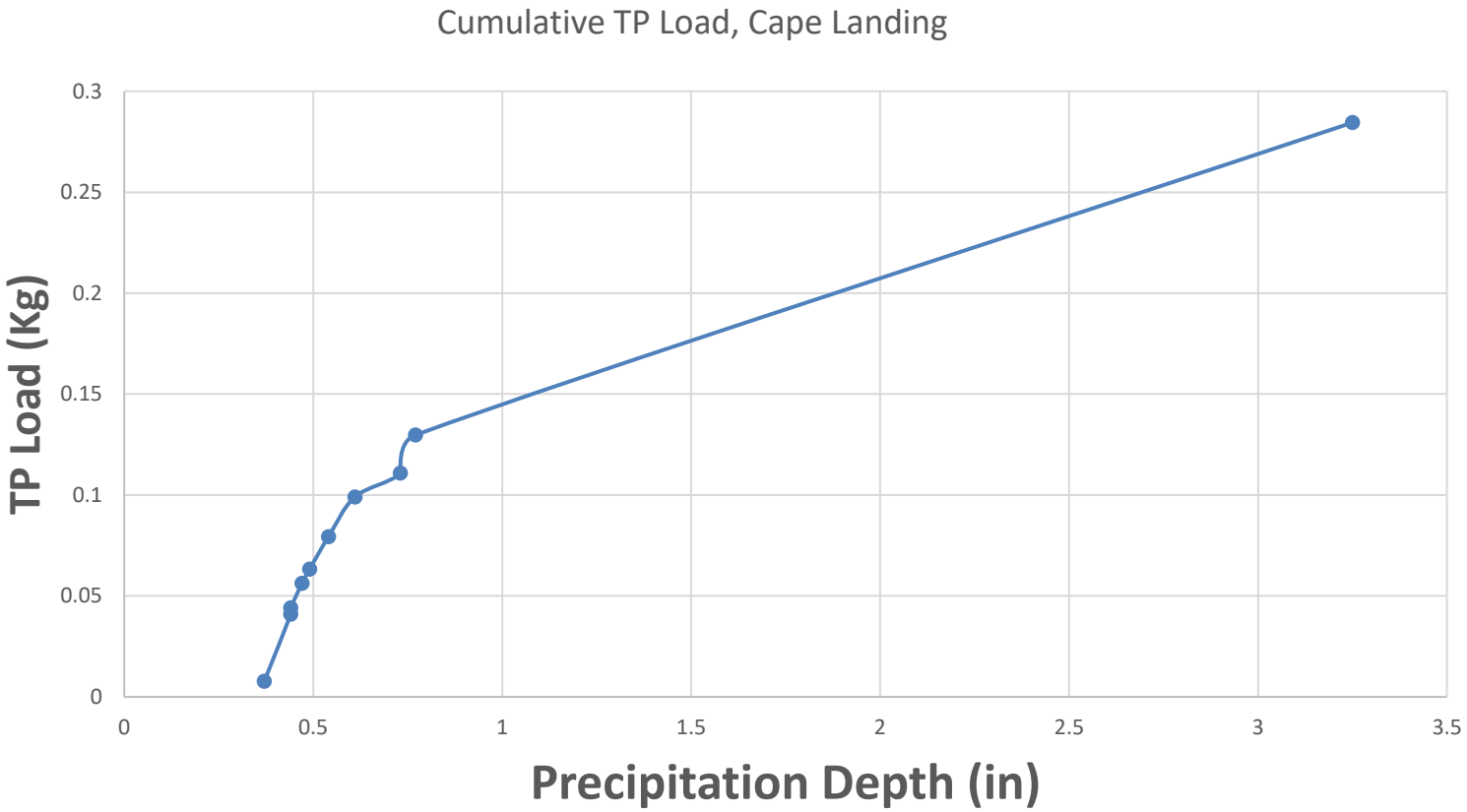
68% of Total Load in 1 storm, 3.76” 1 out of 12

Cumulative TP Loads, by Storm Rank



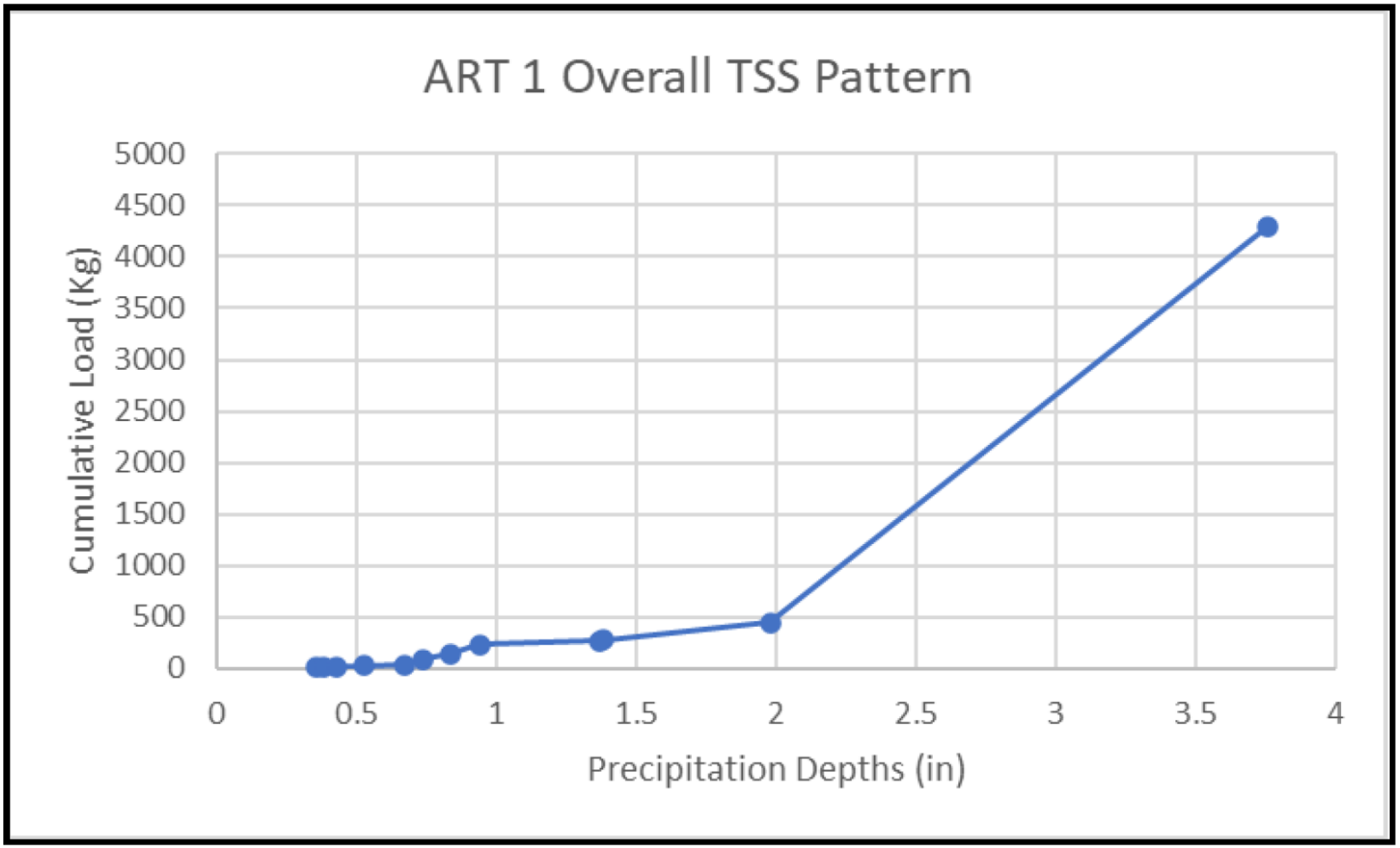
37% of Total Load in 1 storm, 5.4” 1 out of 14

Cumulative TP Loading, by Storm Rank



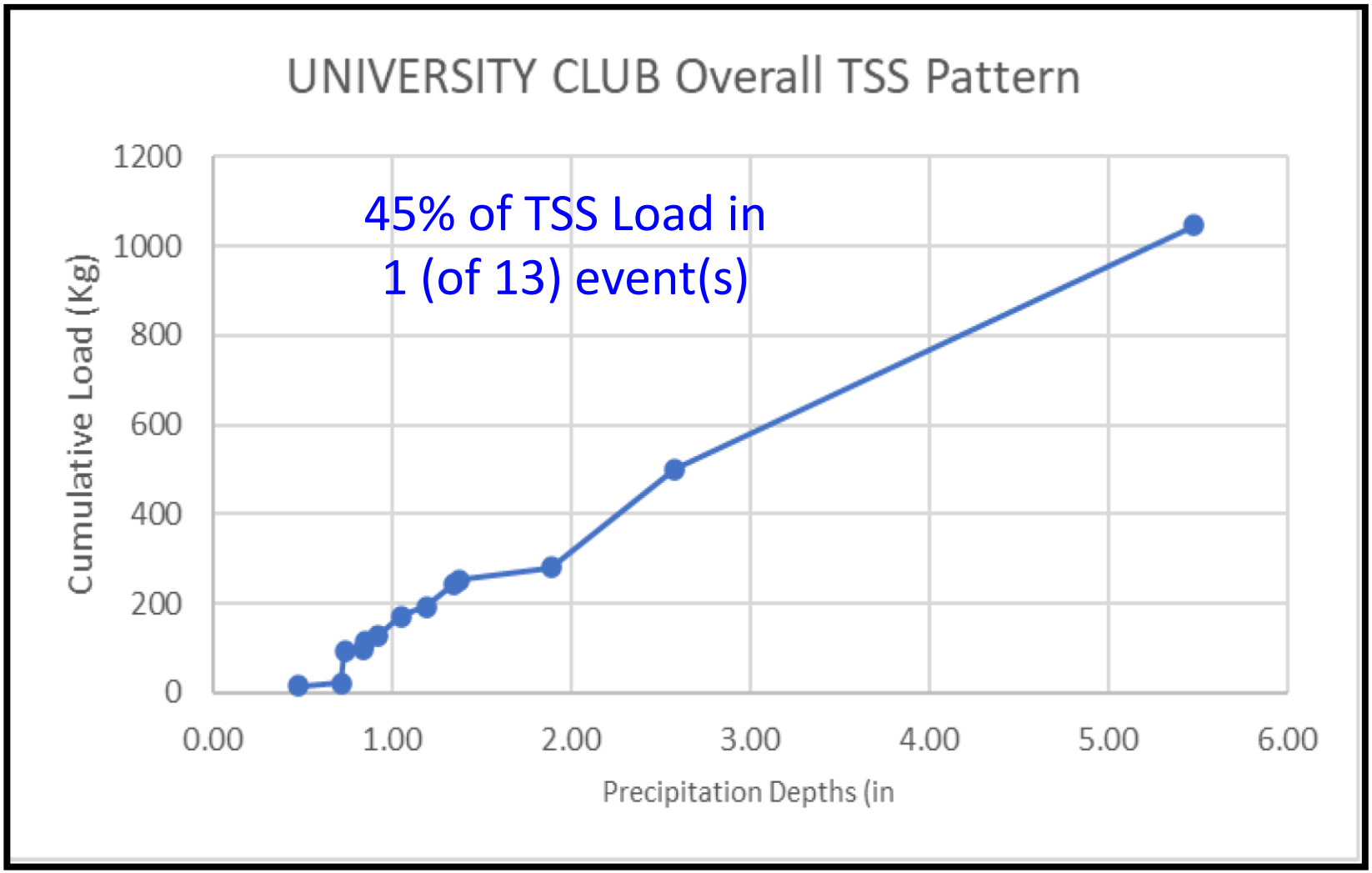
- 54% of load in 1 storm (of 10). 3.25 in

Cumulative TSS Loading, by Storm Rank

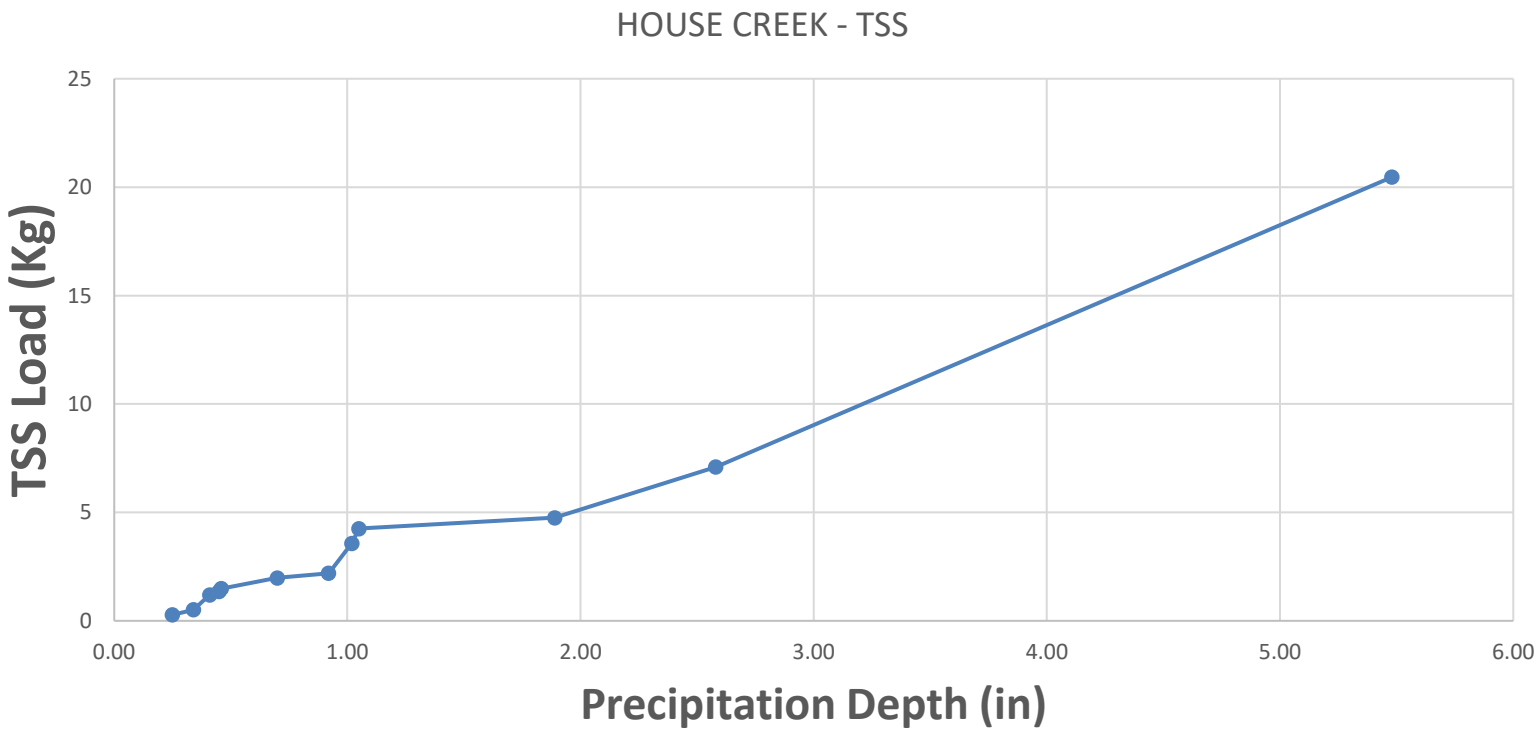


88% of Total TSS Load in 1 storm, 3.76 in

Cumulative TSS Load, by Storm Rank



Cumulative TSS Load, By Storm Rank



- 64% of TSS Load in 1 event (of 11). 5.45 in

So… What Does This Mean For Us?

- If these data are reflective of “normal”…
- How effective is catching a 1.0” event, treating it, and letting the rest of the storm bypass?
  - Particularly for Nutrient Abatement

Is the Future in Flow?

- Bioswales, like this one in Meck. Co, are designed for Flow Rates
- Not Capture Volumes

Is the Future in Flow?

- Designing Wetlands like this one in Lenoir…
- Based on Flow Rates
- Not Capture Volumes

Is the Future in Flow?

- Manufactured Treatment Devices are usually predicated on treating flow rates, not capture volumes.

Is Catch & Release "Dead"?

- Nope.
- Limitations may exist for nutrient (& TSS) load treatment.
- NOT: Peak Flow Mitigation
- NOT: Healthy Stream Flows
- Perhaps not: other pollutants
- Perhaps not: ultra-urban sites
- Plus…

Smart Controls!!!

Other Goings-on at your Land Grant

- Rip-rap v. Deep Rooted Natives v. Turfgrass
  - NCDOT
- RSC MDC's
  - NC DEQ & Greensboro
- Dry Detention Conversion to Wetlands
  - NC DEQ & City of Durham
- Bioswales
  - NCL&WF & City of Hillsborough
- Smart Control Outlet Discharge
  - NCL&WF & City of Wilson
- Wetland Design on Flow Rate
  - NCL&WF, Cities of Lenoir & Wilson
- Mountain SCM Design Supplement
- Wetland Maintenance Guidance

Upcoming Events @ NCStateBAE

- Swales, Bioswales & RSC Workshop
  - Gastonia, Raleigh, Coastal SC, On-line
  - November & December 2023
  - Co-hosted with Clemson University
- “Return of the MDC” Training (early ‘24)
- EPA Bioterrorism Workshop (Feb ‘24)
- Roman Engineering Events
  - Aqueducts for the Holidays (Dec. 15th)
  - Roman Engineering Marvels (in person, Edenton, June 6, 2024)
  - Study Tour: Italy (October ‘24)

Thank You (as always)! Questions?