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Module 4

Runoff Reduction and Water Quality

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Module 4 Content

- 4a: Overview of the Runoff Reduction Method
- 4b: Land Cover & Volumetric Runoff Coefficier PG 27
- 4c: The Simple Method
- 4d: Virginia Water Quality Requirements
- 4e: Introduction to stormwater Runoff Reduction Practices
- 4f: VRRM Compliance Spreadsheet Example

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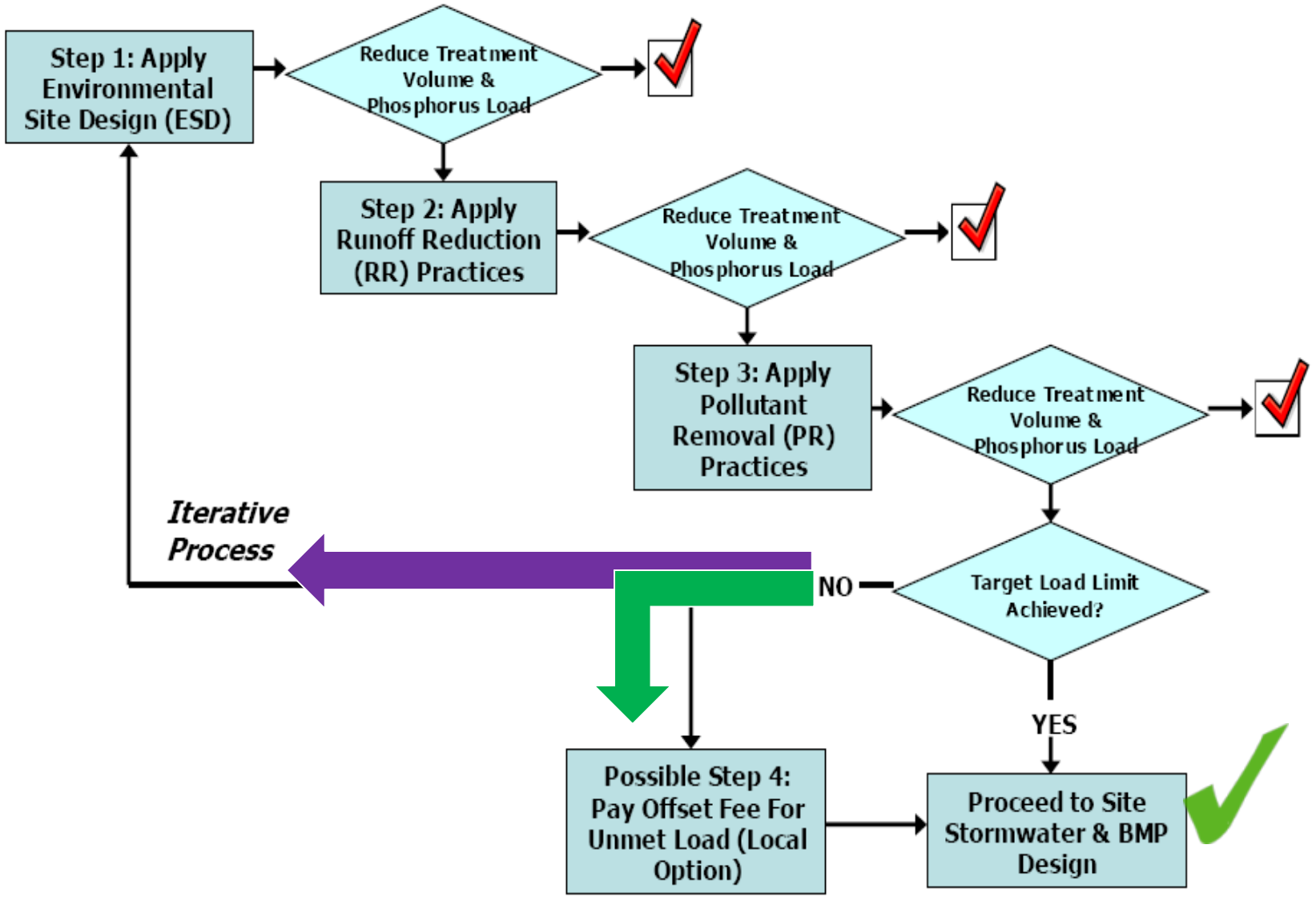
4a. Overview of the Virginia Runoff Reduction Method (VRRM)

- Incentive for **Environmental Site Design**
- Inclusion of **land cover type** in pollutant and hydrologic loading factors
- New treatment options with performance credit breakouts **(RR and EMC ➔ Mass Load)**
- Step-wise (iterative) compliance process

4a. Overview of the VRRM



4a. Overview of the VRRM

- Virginia Runoff Reduction Method Technical Memorandum
  - Documentation for all elements of VRRM

www.deq.virginia.gov/Programs/Water/Laws,Regulations,Guidance/Guidance/StormwaterManagementGuidance.aspx

4a. Overview of the VRRM

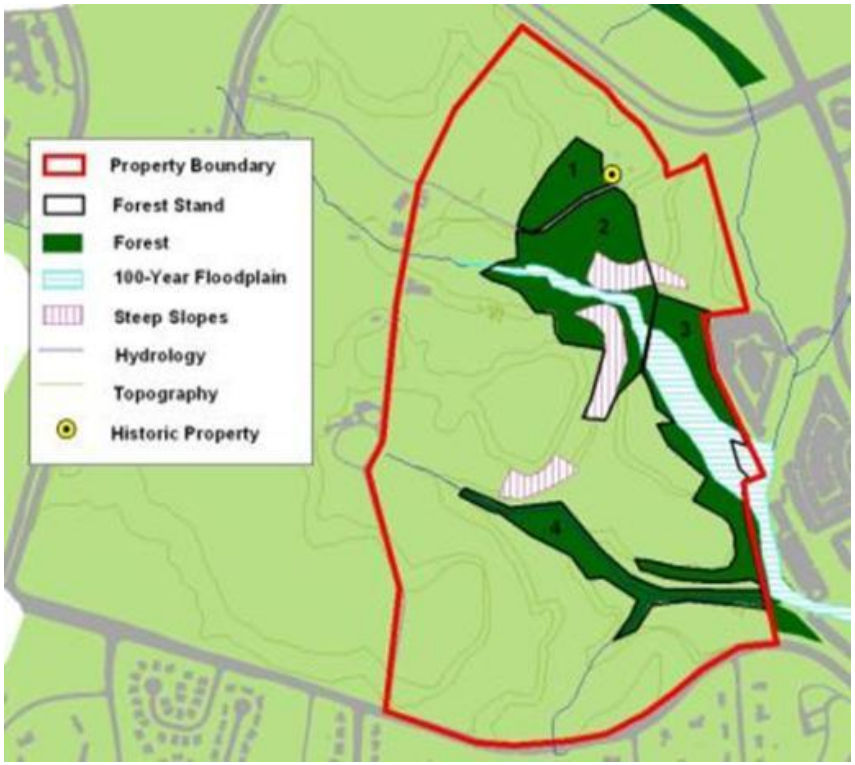
- Key Terminology Review
  - Runoff Reduction (RR)
  - Pollutant Removal (PR)
  - Total Performance
  - VRRM Compliance Spreadsheet

4b. Land Cover and Volumetric Runoff Coefficients in the VRRM

- **Codifies & incentivizes minimization and avoidance**
- Goes beyond impervious cover as a water quality indicator
- Utilizes latest BMP research for Total Performance (Total Mass Load Removal)
- Credits total BMP performance

4b. Land Cover and Volumetric Runoff Coefficients in the VRRM

- Environmental site inventory and assessment



4b. Land Cover and Volumetric Runoff Coefficients in the VRRM

- **Reduced** runoff coefficients for undisturbed pervious areas
- **Increased** runoff coefficients for impacted soils & managed turf

4b. Land Cover and Volumetric Runoff Coefficients in the VRRM

- Impacts from grading and compaction of soils

4b. Land Cover and Volumetric Runoff Coefficients in the VRRM

- Impacts from turf management activities

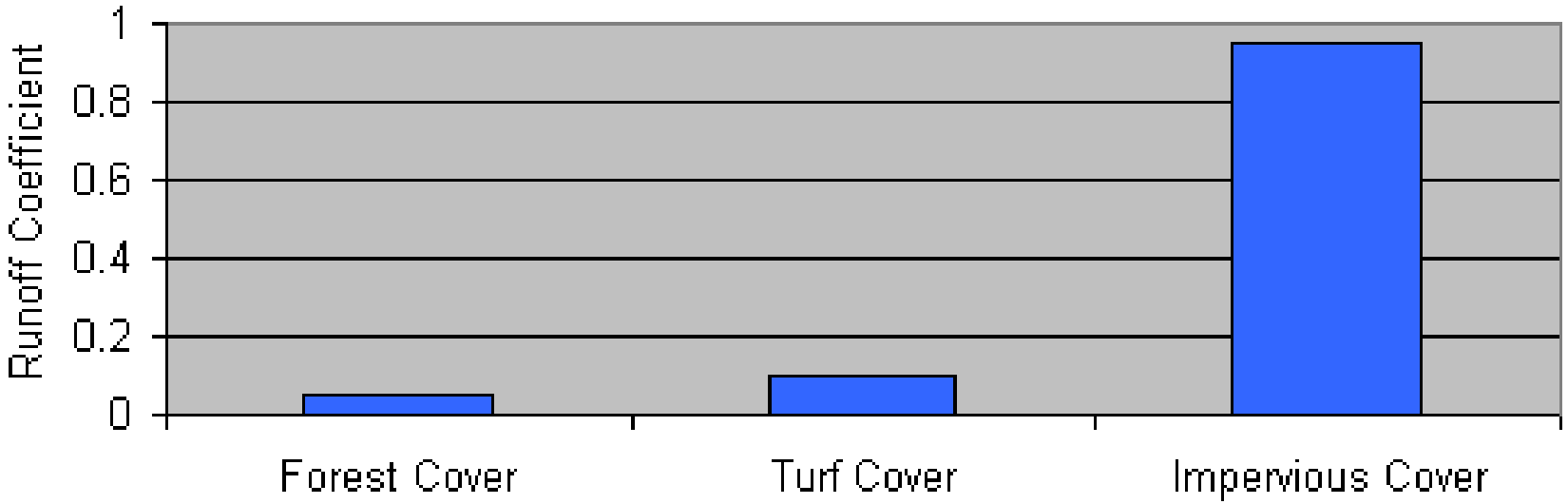
4b. Land Cover and Volumetric Runoff Coefficients in the VRRM

- Treatment Volume:
  Site Runoff Coefficients (Rv)1

Cover	HSG A	HSG B	HSG C	HSG D
Forest/Open	**0.02**	**0.03**	**0.04**	**0.05**
Managed Turf / Disturbed Soil	**0.15**	**0.20**	**0.22**	**0.25**
Impervious Cover	**0.95**	**0.95**	**0.95**	**0.95**

4b. Land Cover and Volumetric Runoff Coefficients in the VRRM

- Comparison of Runoff Coefficients for Different Land Cover



4b. Land Cover and Volumetric Runoff Coefficients in the VRRM

- Land Cover Definitions

Forest and Open Space
Portions of residential lots will **not** be disturbed during construction
Portions of road rights-of-way that will be used will be used as **filter strips**, **grass channels**, or **stormwater treatment areas**
Community open space areas that will **not** be mowed routinely

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4b. Land Cover and Volumetric Runoff Coefficients in the VRRM

- Land Cover Definitions

Forest and Open Space

Utility rights-of-way that will be left in natural vegetated state

4b. Land Cover and Volumetric Runoff Coefficients in the VRRM

- Land Cover Definitions

Forest and Open Space
Surface area of stormwater BMPs:
NOT wet ponds
Some type of vegetative cover
Do not replace otherwise impervious surface

4b. Land Cover and Volumetric Runoff Coefficients in the VRRM

- Land Cover Definitions

Forest and Open Space
Other areas of existing forest and/or open space:
Protected during construction
Remain undisturbed
Includes wetlands

4b. Land Cover and Volumetric Runoff Coefficients in the VRRM

- Land Cover Definitions

Forest and Open Space Op & Management
Undisturbed portions of yards, community open space, and other areas:
Must be shown outside the **LOD** on approved ESC plans
Demarcated in the field (e.g., fencing) prior to commencement of construction

4b. Land Cover and Volumetric Runoff Coefficients in the VRRM

- Land Cover Definitions

Forest and Open Space Op & Management
Roadway rights-of-way that will count as forest/open space:
Assumed to be disturbed during construction
Must follow most recent design specifications for **soil restoration** and, if applicable, **site reforestation**
Other relevant specifications if area will be **used as a BMP**

4b. Land Cover and Volumetric Runoff Coefficients in the VRRM

- Land Cover Definitions

Forest and Open Space Op & Management

Documentation that prescribes that the area will remain in a natural, vegetated state, with only approved management activities

4b. Land Cover and Volumetric Runoff Coefficients in the VRRM

- Land Cover Definitions

Managed Turf	
Areas intended to be mowed and maintained as turf within:	
Residential	Industrial
Commercial	Institutional settings

4c. The Simple Method

- Estimates annual pollutant load exported in stormwater runoff from small urban catchments

$$L = P \times P_i \times Rv \times C \times A \times 2.72/12$$

4c. The Simple Method

$$L = P \times P_i \times Rv \times C \times A \times 2.72/12$$

L = total post-development pollutant load (pounds/year)

P = average annual rainfall depth (inches) = **43** inches (VA)

P_j = fraction of rainfall events that produce runoff = 0.9

Rv = volumetric runoff coefficient C = flow-weighted event mean concentration (EMC) of TP (mg/L) = 0.26 mg/L

A = area of the development site (acres)

2.72 = unit conversion factor: L to ft^3, mg to lb, and acres to ft^2

12 = unit conversion factor: rainfall inches to feet

4c. The Simple Method

$$L = P \times P_i \times Rv \times C \times A \times 2.72/12$$

Old Rules (Part IIC)

- Impervious cover is the only water quality indicator (Rv based on 16% impervious cover)
- C = 0.26 mg/l
- **Load Limit (*L*) = 0.45 lb/ac/yr**

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4c. The Simple Method

$$L = P \times P_i \times Rv_{composite} \times C \times A \times 2.72/12$$

New Rules (Part IIB)

- C = 0.26 mg/l

Runoff Reduction Method Technical Memorandum, April 2008

Parameter	Median EMC (mg/L)
Total Nitrogen	
National	1.9
Virginia	1.86
Residential	2.67
Non-Residential	1.12
Virginia Coastal Plain	2.13
Residential	2.96
Non-Residential	1.08
Virginia Piedmont	1.70
Residential	1.87
Non-Residential	1.30
Total Phosphorus	
National	0.27
Virginia	0.26
Residential	0.28
Non-Residential	0.23
Virginia Coastal Plain	0.27
Virginia Piedmont	0.22
Total Suspended Solids	
National	62
Virginia	40

4c. The Simple Method

$$L = P \times P_i \times Rv_{composite} \times C \times A \times 2.72/12$$

New Rules:

$Rv_{composite}$ = Composite or weighted runoff coefficient

$$Rv_{composite} = (Rv_I \times \%I) + (Rv_T \times \%T) + (Rv_F \times \%F)$$

Where:

Rv_I = Runoff coefficient for Impervious cover (**0.95**)

Rv_T = Runoff coefficient for Managed Turf/Disturbed soils (**Table 4-1**)

Rv_F = Runoff coefficient for Forest/Open Space (**Table 4-1**)

4c. The Simple Method

$$Rv_{composite}\ (Rv_I \times \%I) + (Rv_T \times \%T) + (Rv_F \times \%F)$$

New Development Water Quality Requirements:

- **Old** Requirement: 0.45 lb/ac/yr TP
- New Proposal: 0.28 lb/ac/yr TP
- **Final Adopted: 0.41 lb/ac/yr TP**

(annual load limit)

- **Where did I get that number?**

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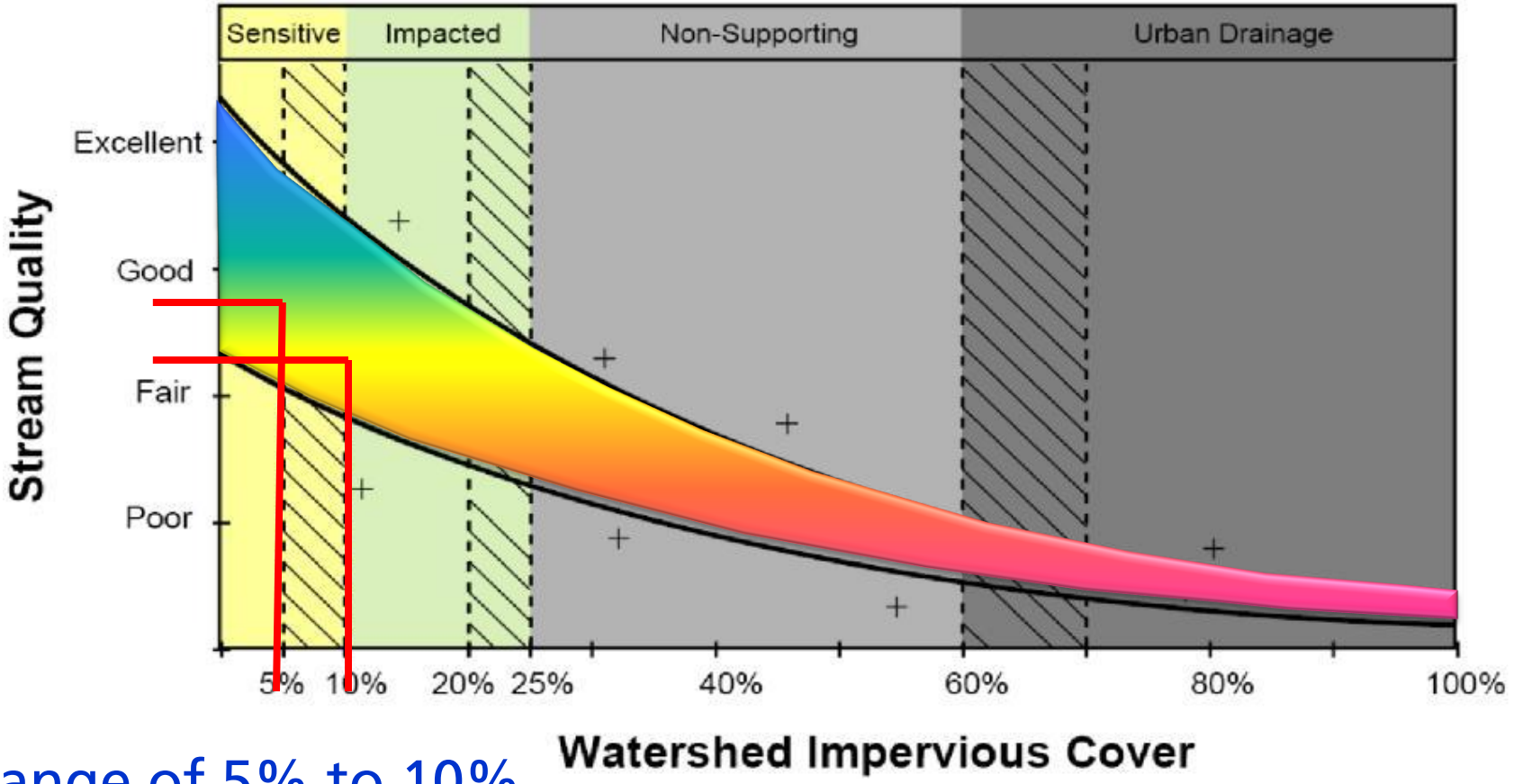
Impervious Cover Model (ICM)

Over **10% impervious cover:**

- Streams visibly impacted
- Stream channel widened and/or deepened
- Tree roots exposed
- Pool and riffle structure compromised

Impervious Cover Model Revisited



Range of 5% to 10% Impervious Cover

Watershed-Based Site Load Limit

$$L = P \times P_i \times Rv \times C \times A \times 2.72/12$$

State-wide Requirement Based on Percentage of Impervious Cover and STATSGO average soil cover [1]		Potential Compromise	Chesapeake Bay Requirement Based on "No Increase" from previous land uses	
5% impervious, 65% forest, 30% turf	0.30	0.41	0.51	36% forest, 64% agriculture
7.5% impervious, 62.5% forest, 30% turf [2]	0.36		0.56	28% forest, 72% agriculture
10% impervious, 60% forest, 30% turf	0.41		0.56	29% forest, 71% agriculture

1. Weighted average soil cover derived from STATSGO state-wide soils database soil breakdown for VA outside of the Chesapeake Bay Watershed.

2. Schueler, T., Fraley-McNeal, L., and Capiella, K. "Is Impervious Cover Still Important? Review of Recent Research" Journal of Hydrologic Engineering, April 2009

Treatment Volume & BMP Sizing

$$Tv_{BMP} = \frac{(P \times Rv_{composite} \times A)}{12}$$

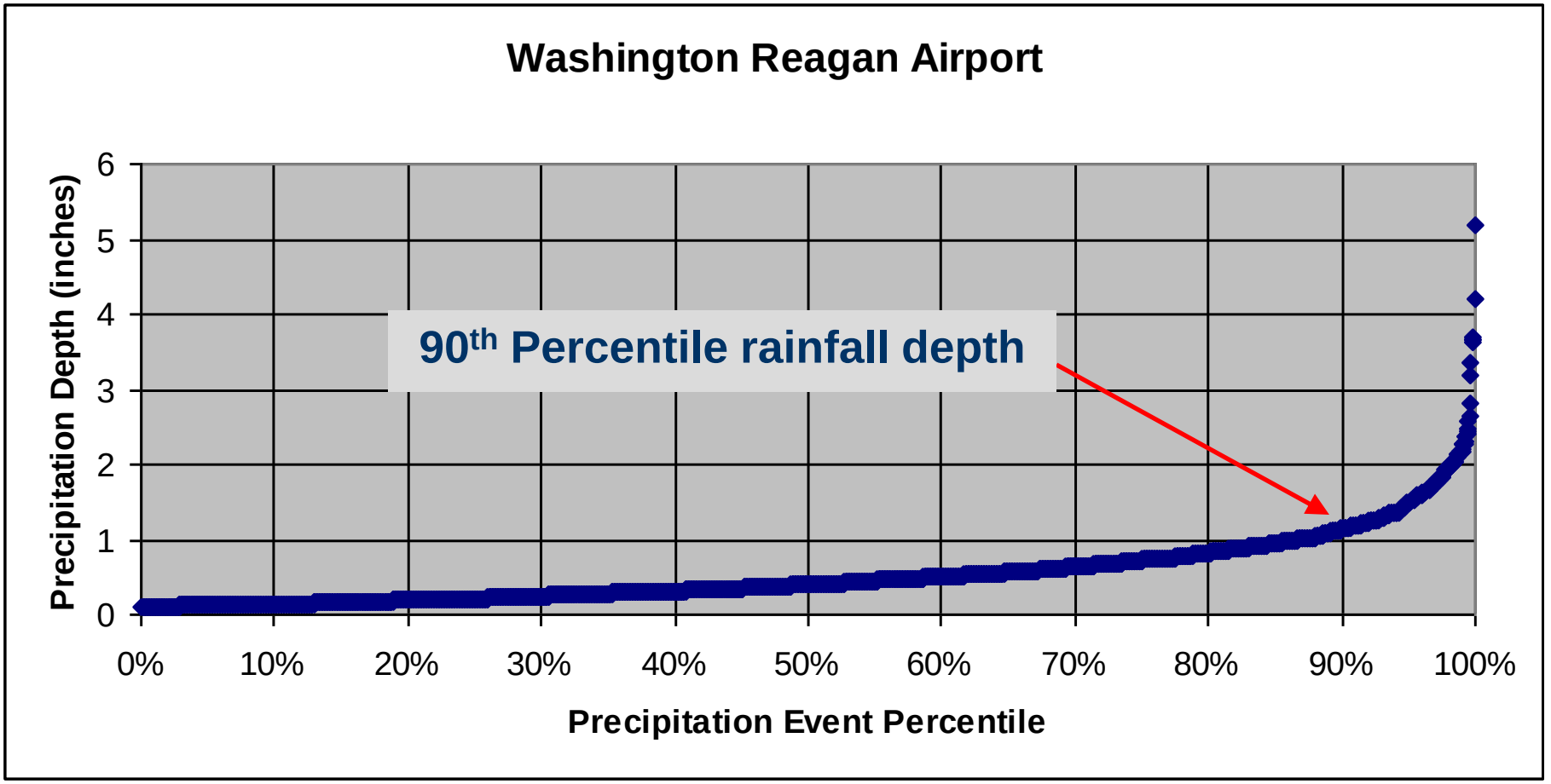
Tv_{BMP} = Design Treatment Volume from contributing drainage area to stormwater practice (does not include remaining runoff from upstream practices)

P = 90th Percentile rainfall depth = 1”

$Rv_{composite}$ = Composite runoff coefficient

A = Contributing drainage area to the stormwater practice

Design Rainfall = 90th percentile rainfall depth = 1”



1” annual average: Washington Reagan Airport, Richmond Airport, Harrisonburg, Lynchburg, Bristol

90th percentile rainfall depth of 1”

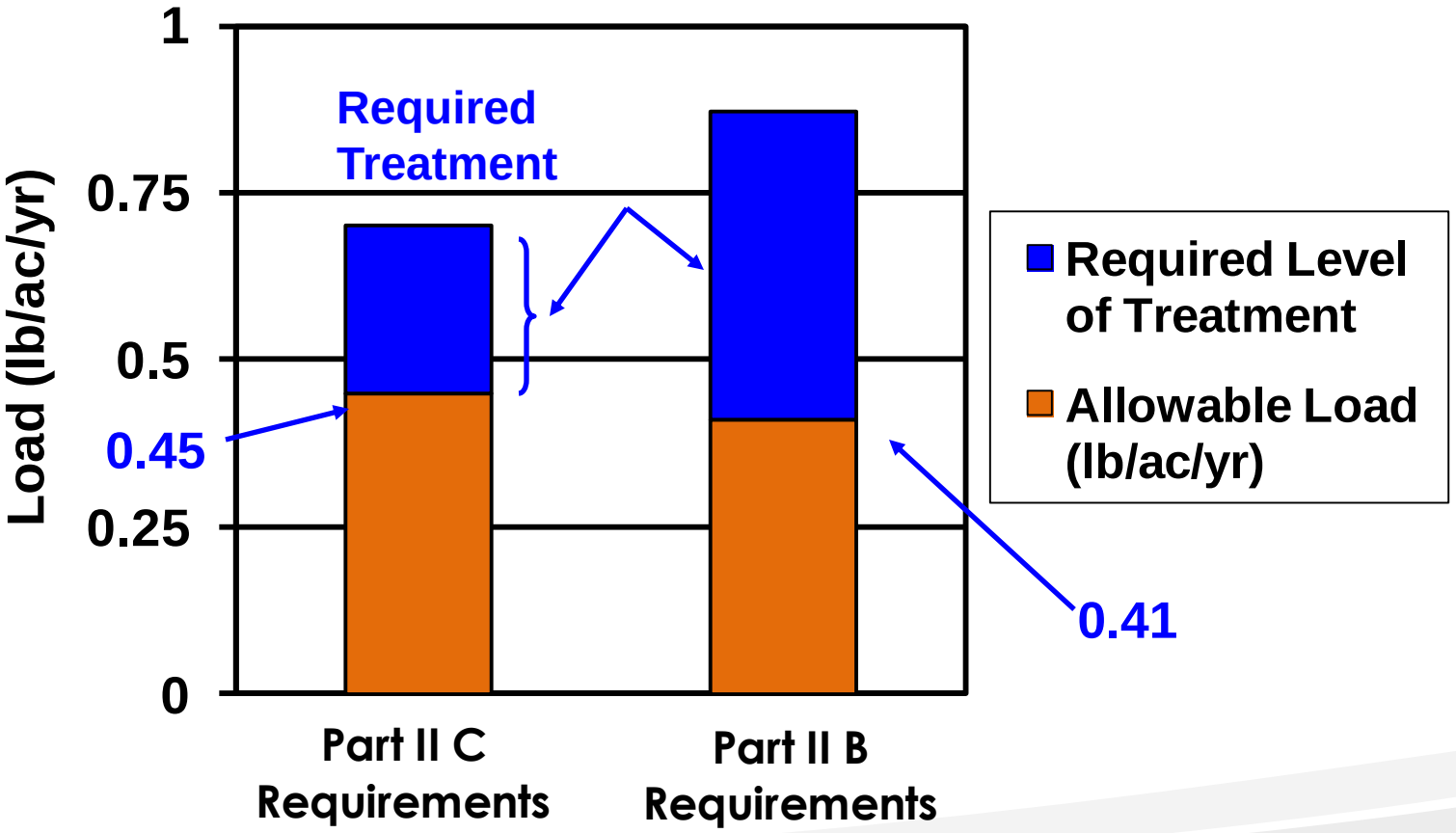
Using the 90th percentile rainfall depth translates to an annual average reduction

- Represents average over all storms and not individual single-event modeled storms
- Oversizing practice does not necessarily provide for increase in “annual” RR or PR performance (unless entire Level 2 upgrade included)
- Oversizing can help meet quantity control storage requirements when modeled on single event basis

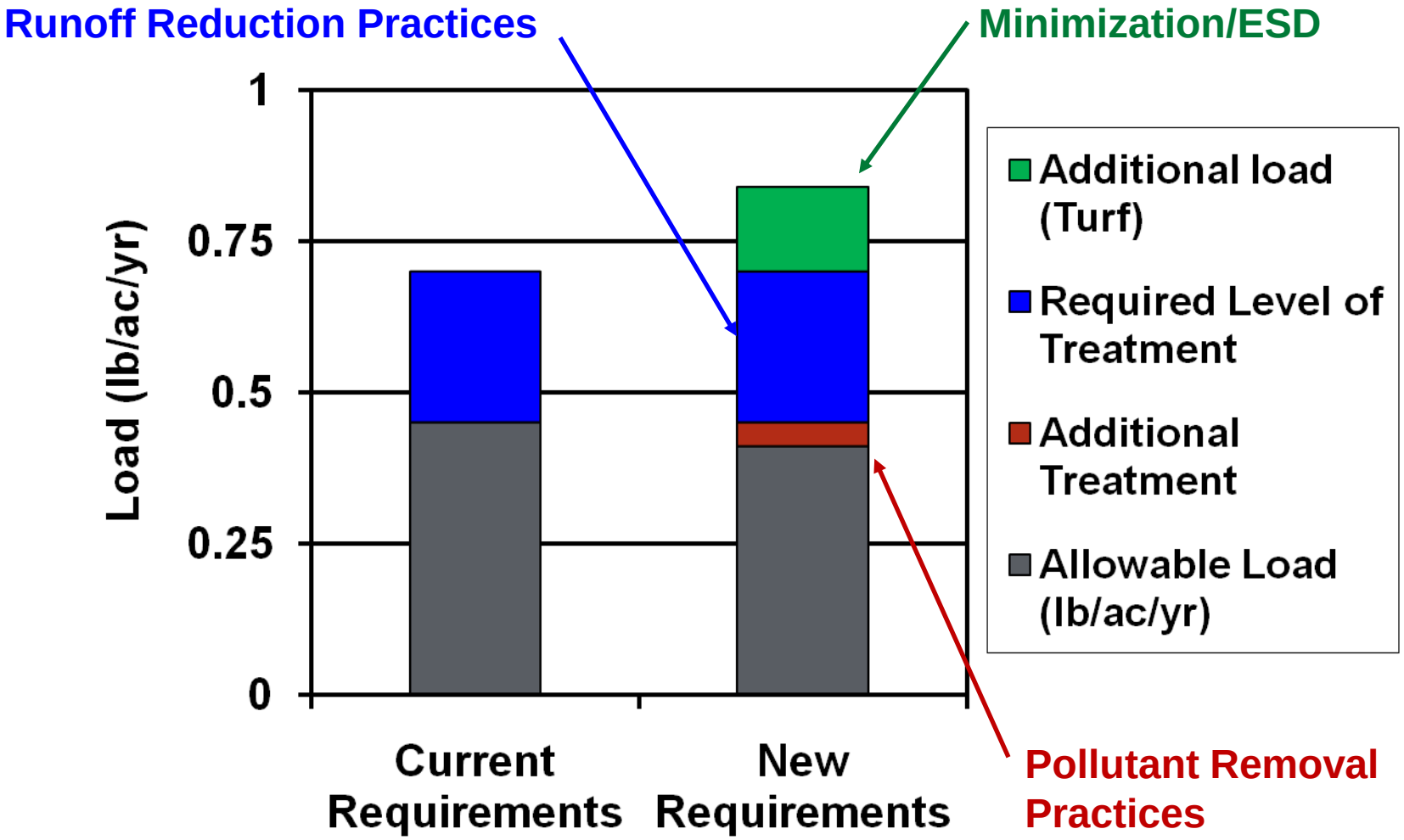
4d. Water Quality Requirements

- New Development:
  - 0.41 lb/ac/yr TP
- Re-Development:
  - LDA $\geq$ 1 acre: 20% reduction in exist annual TP load
  - LDA < 1 acre: 10% reduction in exist annual TP load

4d. Water Quality Requirements

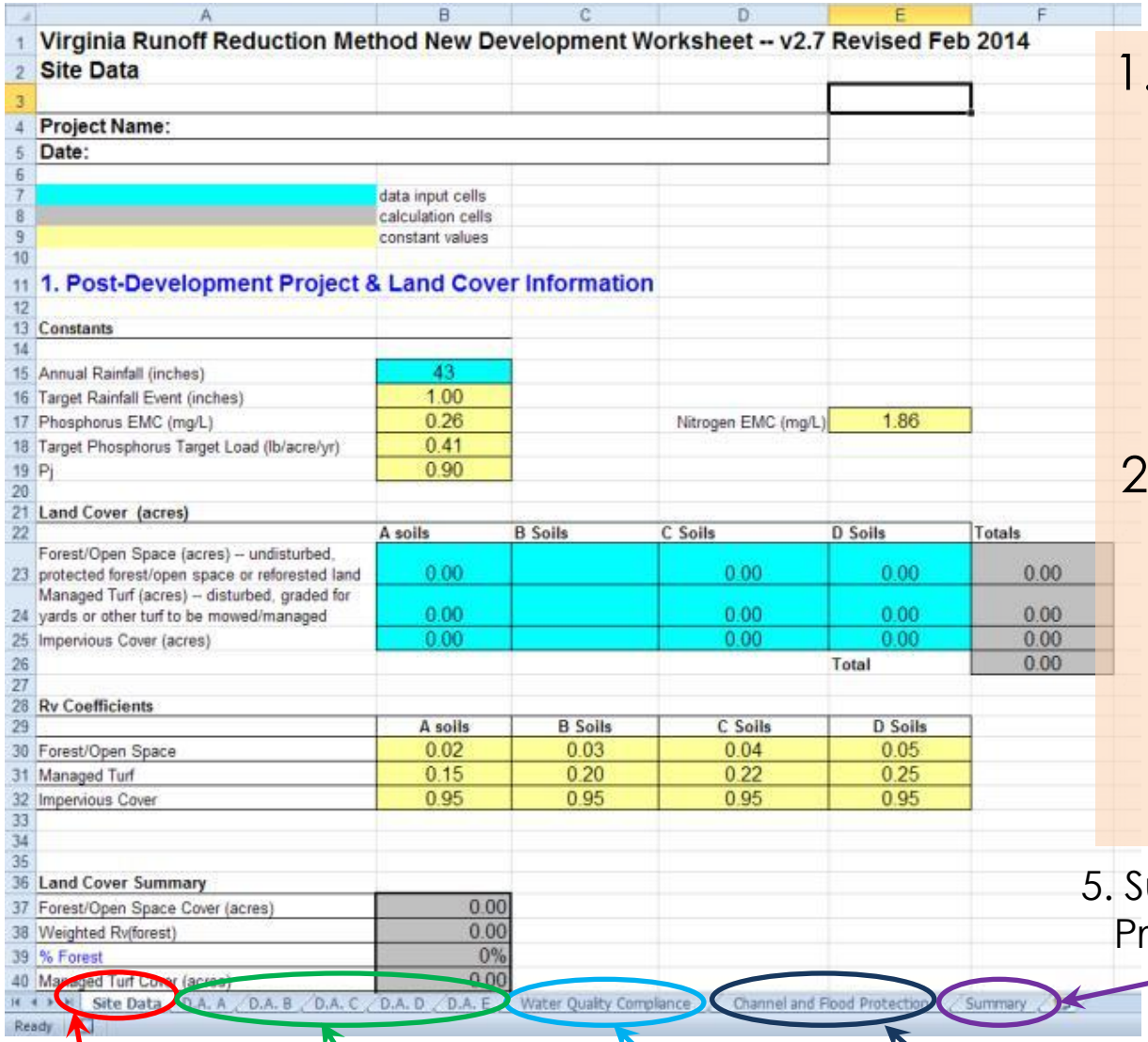


Treatment Options Made Simple



How Does This Apply to The Project

Virginia Runoff Reduction Spreadsheet



Virginia Runoff Reduction Method New Development Worksheet -- v2.7 Revised Feb 2014

Site Data

Project Name:

Date:

data input cells
calculation cells
constant values

1. Post-Development Project & Land Cover Information

Constants

Annual Rainfall (inches)	43
Target Rainfall Event (inches)	1.00
Phosphorus EMC (mg/L)	0.26
Nitrogen EMC (mg/L)	1.86
Target Phosphorus Target Load (lb/acre/yr)	0.41
Pj	0.90

Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals
Forest/Open Space (acres) -- undisturbed, protected forest/open space or reforested land	0.00		0.00	0.00	0.00
Managed Turf (acres) -- disturbed, graded for yards or other turf to be mowed/managed	0.00		0.00	0.00	0.00
Impervious Cover (acres)	0.00		0.00	0.00	0.00
				Total	0.00

Rv Coefficients

	A soils	B Soils	C Soils	D Soils
Forest/Open Space	0.02	0.03	0.04	0.05
Managed Turf	0.15	0.20	0.22	0.25
Impervious Cover	0.95	0.95	0.95	0.95

Land Cover Summary

Forest/Open Space Cover (acres)	0.00
Weighted Rv(forest)	0.00
% Forest	0%
Managed Turf Cover (acres)	0.00

Site Data | D.A. A | D.A. B | D.A. C | D.A. D | D.A. E | Water Quality Compliance | Channel and Flood Protection | Summary

Ready

1. Site Data Input:

- Site Land cover
- Site level Treatment Volume (Tv)
- Site level pollutant loads and Removal Requirement

2. Drainage Area Inputs:

- DA Land Cover
- Tv_{BMP} (used for BMP sizing)
- Area treated check
- DA pollutant removal

5. Summary Print-out

1. Site Data Input

2. Drainage Area Inputs

3. Water Quality Check

4. Channel/Flood Protection Check

Virginia Runoff Reduction Spreadsheet

Virginia Runoff Reduction Method Worksheet -- Revised 1/25/12

Site Data

Project Name:
Date:

data input cells
calculation cells
constant values

1. Post-Development Project & Land Cover Information

Constants

Annual Rainfall (inches)	43
Target Rainfall Event (inches)	1.00
Phosphorus EMC (mg/L)	0.26
Target Phosphorus Target Load (lb/acre/yr)	0.41
Pj	0.90

Nitrogen EMC (mg/L)

Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals
Forest/Open Space (acres) -- undisturbed, protected forest/open space or reforested land	0.00	0.00	0.00	0.00	0.00
Managed Turf (acres) -- disturbed, graded for yards or other turf to be mowed/managed	0.00	0.00	0.00	0.00	0.00
Impervious Cover (acres)	0.00	0.00	0.00	0.00	0.00
				Total	0.00

Rv Coefficients

	A soils	B Soils	C Soils	D Soils
Forest/Open Space	0.02	0.03	0.04	0.05
Managed Turf	0.15	0.20	0.22	0.25
Impervious Cover	0.95	0.95	0.95	0.95

Land Cover Summary

Forest/Open Space Cover (acres)	0.00
Weighted Rv(forest)	0.00
% Forest	0%
Managed Turf Cover (acres)	0.00
Weighted Rv(turf)	0.00
% Managed Turf	0%
Impervious Cover (acres)	0.00
Rv(impervious)	0.95
% Impervious	0%
Total Site Area (acres)	0.00
Site Rv	0.00
Post-Development Treatment Volume (acre-ft)	0.00
Post-Development Treatment Volume (cubic feet)	0
Post_Development Load (TP) (lb/yr)	0.00
Total Load (TP) Reduction Required (lb/yr)	0.00

Post_Development Load (TN) (lb/yr)

Site Data | D.A. A | D.A. B | D.A. C | D.A. D | D.A. E | Water Quality Compliance

- Land Cover (acres) by HSG
- Definitions Provided in Guidance

Volumetric Runoff Coefficients

Weighted (by HSG) Rv for Forest, Turf, & Imp

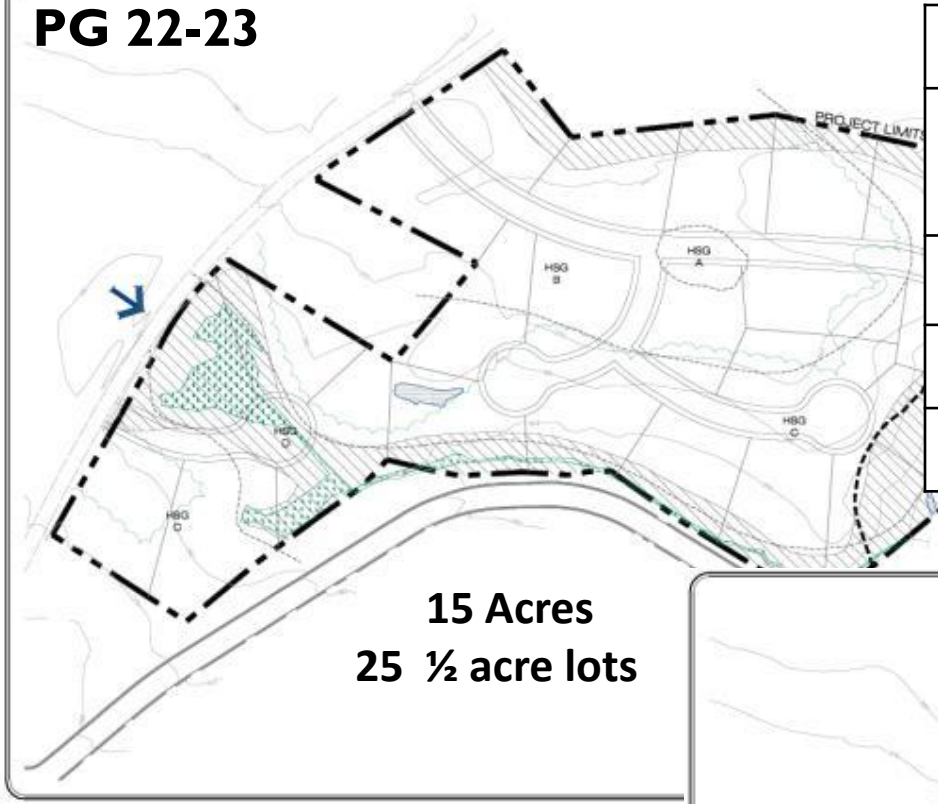
Composite Site Rv

Post-Dev Tv

Pollutant Load (TP & TN)

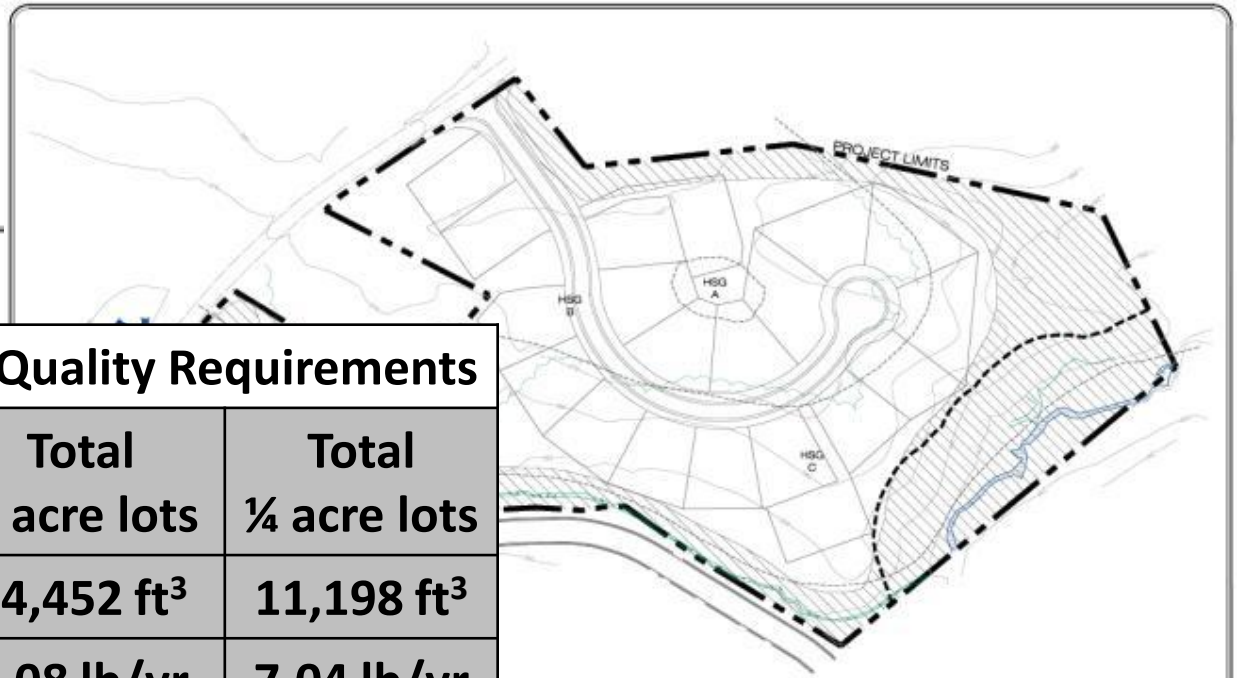
Total Load Reduction Reqd.

PG 22-23



15 Acres
25 ½ acre lots

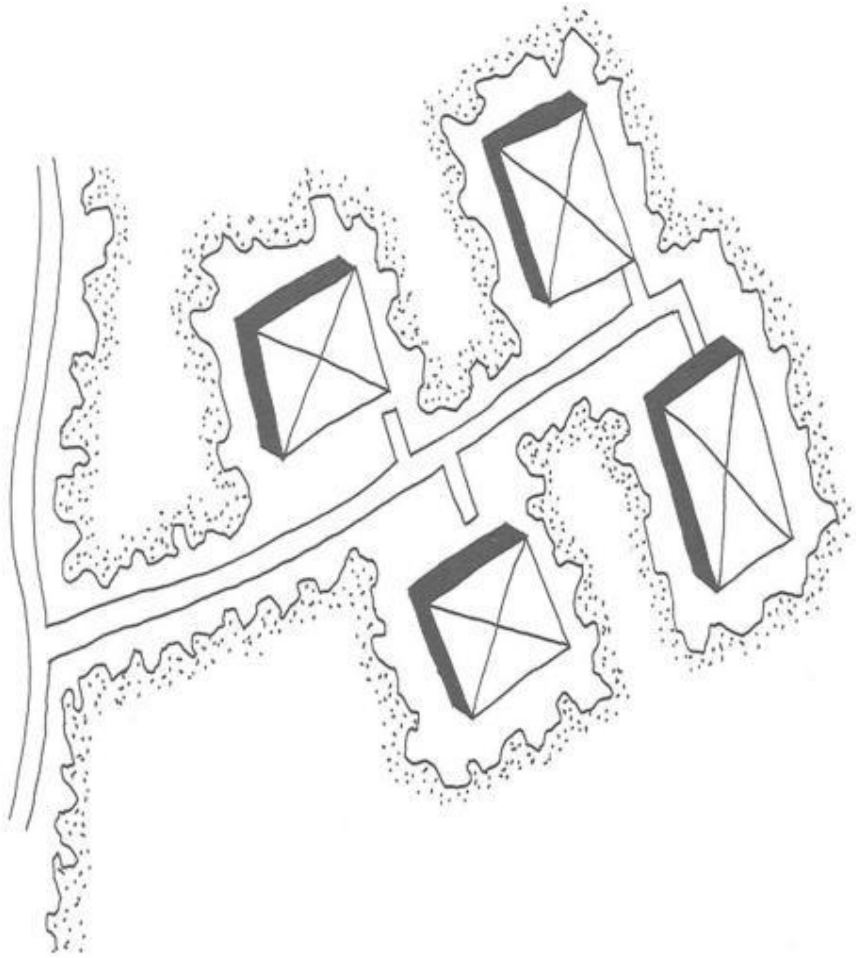
Drainage Area Land Cover (Acres)		
Land Cover	Total ½ acre lots	Total ¼ acre lots
Forest	0.87	4.31
Turf	8.32	5.26
Impervious	2.26	1.88



15 Acres
25 ¼ acre lots

Drainage Area Water Quality Requirements		
	Total ½ acre lots	Total ¼ acre lots
Post-Dev Treatment Vol	14,452 ft^3	11,198 ft^3
Post-Dev TP Load	9.08 lb/yr	7.04 lb/yr
Pollutant Removal Reqd.	4.39 lb/yr	2.34 lb/yr

Site Fingerprinting



Site Design


Open Space Development
Conventional Development
Photo courtesy of Randall Ar

Site Design

PG 24-25

Finger printing on large lot construction:

Save trees, soil, etc.

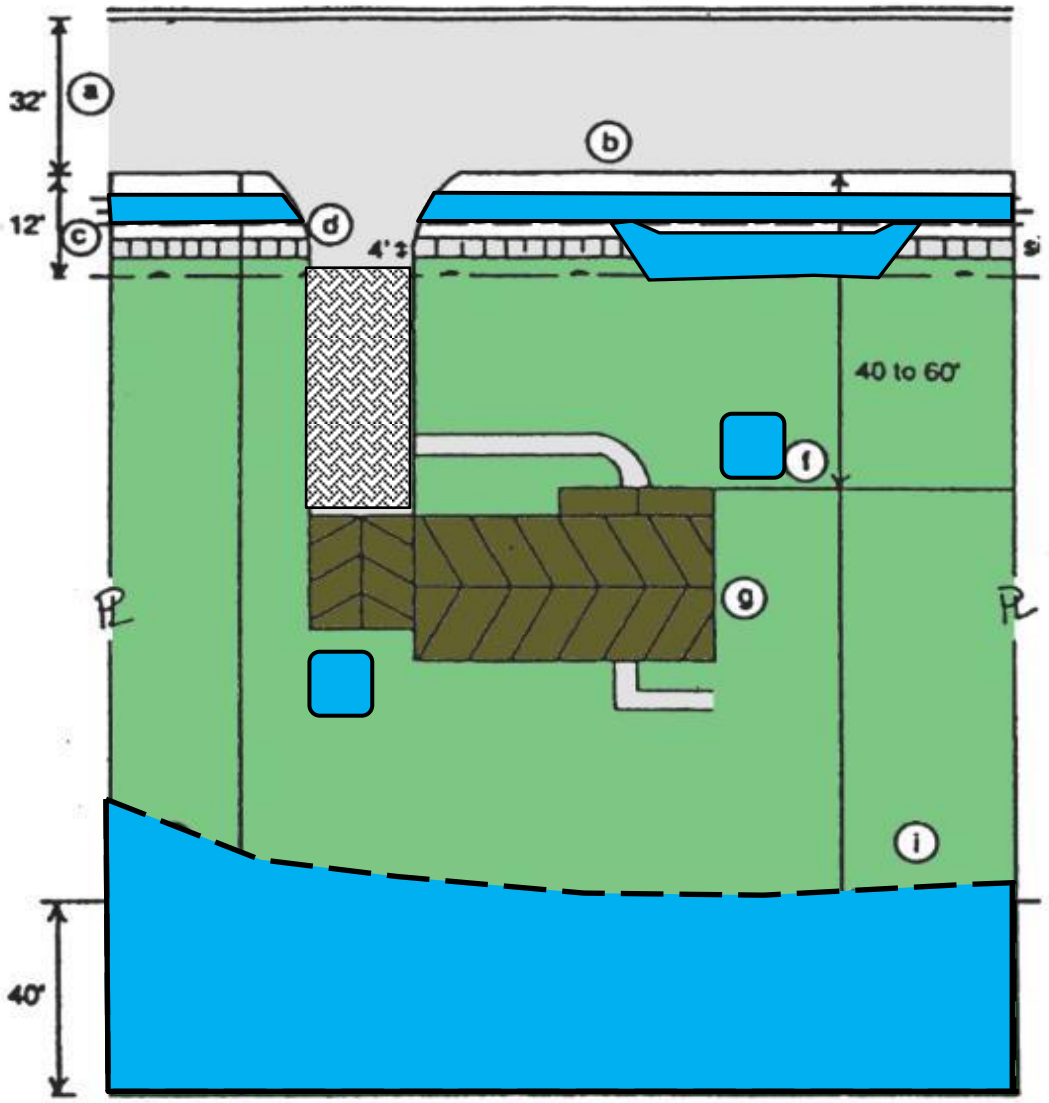
Finger-printing subdivision construction:

narrow streets, shorter setbacks, etc.

Site Design: Clustered Lots & Conserved Open Space

PG 24-25

Site Design: Decentralized Treatment



Right-of-way Treatment

Grass Channels

Bioretention

On-Lot Treatment

Simple Disconnection

Alternative Practice Disconnection

- Raingardens
- Drywells
- Cisterns

Permeable Pavement

Driveways

Soil Restoration

When soil disturbance is unavoidable on the site-scale or lot-scale

Recognized non-structural RR stormwater practice:

BMP Design Specification No. 4

Photo Credit: Jeremy Balousek, P.E., Dane County, WI Land and Water Resources Department

Photo Credit: Jeremy Balousek, P.E., Dane County, WI Land and Water Resources Department

Documentation

Transition from:

Plan Design

to

Plan Review

to

Implementation and Compliance

Stormwater Management Plan Review

- What types of plan design documentation have been required in the past?
- Do you need new or additional guidance for applicants?
- What do inspectors need?

4e. Introduction to Stormwater Runoff Reduction BMPs

- Codifies & incentivizes minimization and avoidance
- Goes beyond impervious cover as a water quality indicator
- **Utilizes latest BMP research for Total Performance**
- **Credits total BMP performance**

(New Specifications with Level 1 and Level 2)

Latest Science and Research

Total BMP Performance:

Runoff Reduction Reported Performance:

$$Runoff\ Vol_{IN}\ vs\ Runoff\ Vol_{OUT}$$

plus:

Pollutant Removal Reported Performance:

$$EMC_{IN}\ vs\ EMC_{OUT}$$

equals:

Total BMP Performance (reported as Load Reduction):

$$(Vol_{IN}) \times (EMC_{IN})\ vs\ (Vol_{OUT})(EMC_{OUT})$$

Total BMP Performance

Runoff Reduction (RR) and pollutant removal (PR):

- Reductions by reducing volume
- Beyond irreducible concentrations

Total BMP Performance

Runoff Reduction (RR) and pollutant removal (PR):

- Maximum performance through "Treatment Train" approach:
  - Reduction of site-generated pollutants using non-structural site design practices
  - Volume reduction using one or multiple **runoff reduction (RR) practices**
  - Pollutant removal by runoff reduction practices and additional **pollutant removal (PR) practices** as needed

Traditional BMPs

1,000,000 liters of stormwater (multiple storm events)

100 mg/L pollutant (average)

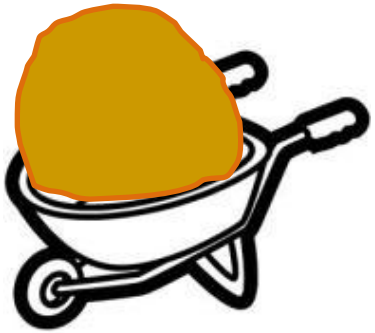
BMP

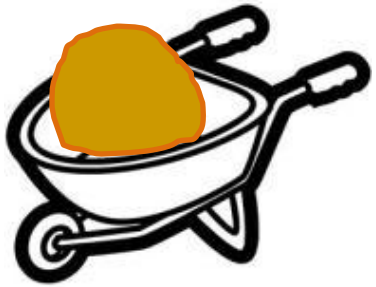
50% Total Mass Load Removal

1,000,000 liters of stormwater (multiple storm events)

50 mg/L of pollutant (average)

100 kg Total pollutant load





50 kg Total pollutant load discharged over time

RRM, "New" BMPs

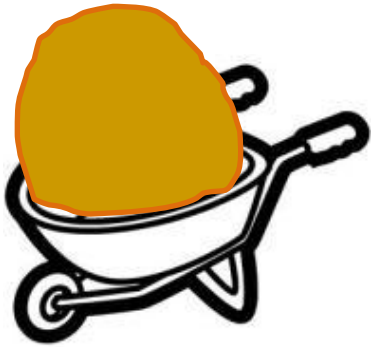
1,000,000 liters of stormwater (multiple storm events)

100 mg/L of pollutant (average)

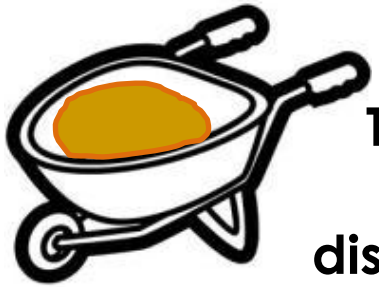
50% PR
+
50% RR

500,000 liters of stormwater (multiple storm events)

50 mg/L pollutants (average)



100 kg Total load of pollutant



25 kg Total load of pollutant discharged over time

Total Performance = 75% load reduction!

Stormwater Practices Differ Sharply in Ability to Reduce Runoff Volume

Wet Ponds, ED Ponds, Constructed Wetlands, Filters:

= 0 to10% Runoff Volume Reduction

Bioretention, Infiltration, Dry Swales, Soil Amendments, disconnection, Related Practices Reduce:

= 50 to 90% Runoff Volume Reduction

Multi-Function Practices

	Site Design	Runoff Reduction	Pollutant Removal
1. Rooftop Disconnection	✓	✓	
2. Filter Strip	✓	✓	
3. Grass Channel		✓	✓
4. Soil Amendments	✓*	✓	
5. Green Roof		✓	
6. Rain Tanks & Cisterns		✓	
7. Permeable Pavement		✓	✓
8. Infiltration		✓	✓
9. Bioretention		✓	✓
10. Dry Swales		✓	✓
12. Filtering Practices			✓
13. Constructed Wetlands			✓
14. Wet Ponds			✓
15. ED Ponds		✓	✓

BMP Performance

VRRM Technical Memo documented BMP performance:

- RR capabilities of stormwater practices much more consistent than PR performance
- Nutrient PR in stormwater BMPs inconsistent
- RR rates are annual average based on individual study site water balance
- Recommended rates are conservative estimates
- RR rates in stormwater regulations dependent on Level 1 or Level 2 design criteria

BMP Performance - Level 1 and Level 2

Different levels of implementation and credited performance:

- Long term BMP performance, operation and maintenance
- Community acceptance
- Recognized design enhancements where improved performance required for compliance

BMP Performance - Level 1 and Level 2

Level 1 standard features:

- Function
- Safety
- Appearance
- Safe conveyance
- Performance longevity
- Maintenance

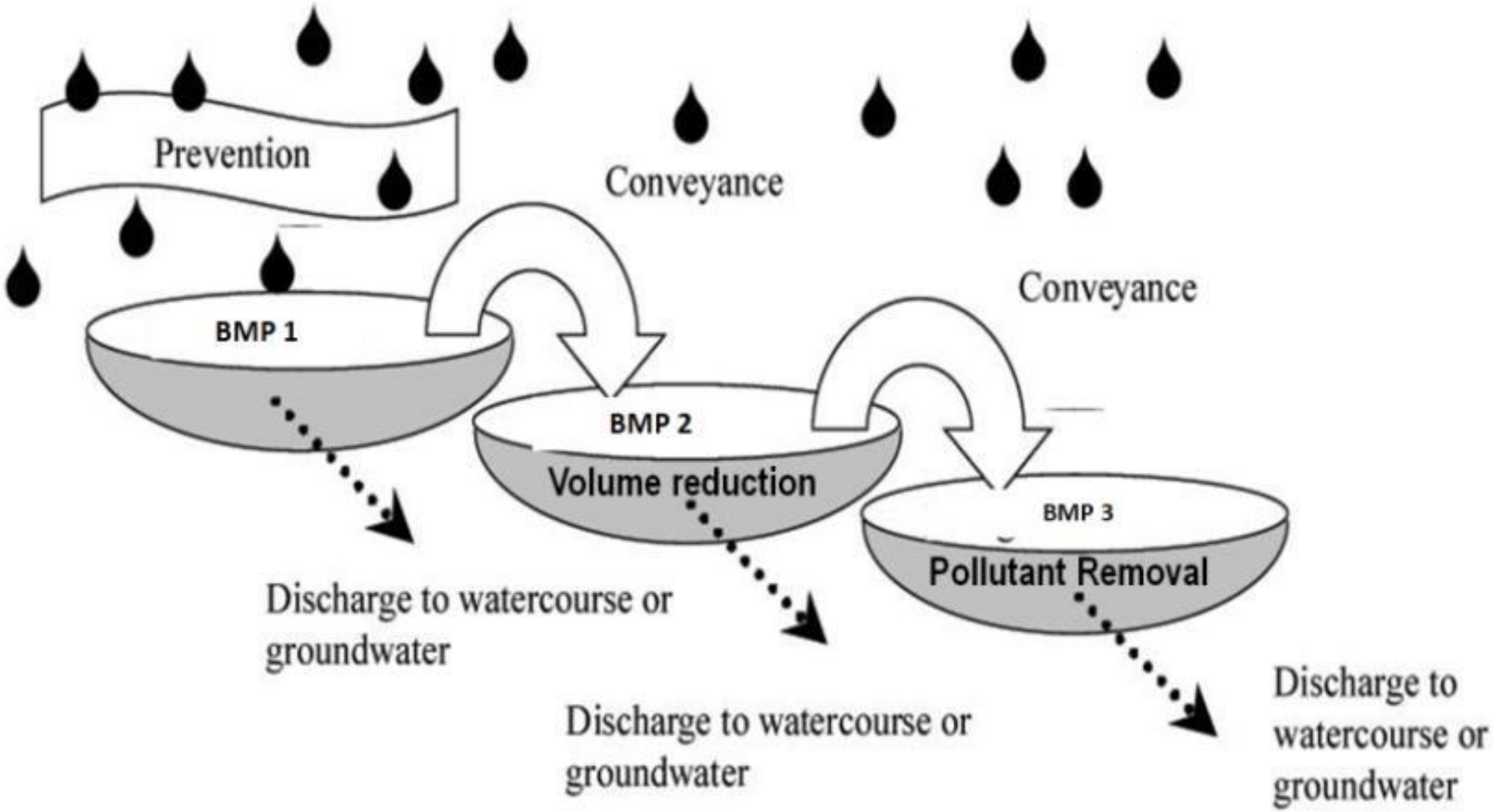
BMP Performance - Level 1 and Level 2

Level 2 design enhancements

- Increased RR, PR or both:

  - Increased Tv sizing (x 1.1, 1.25 or 1.5 times Tv)
  - Enhanced design geometry
  - Vegetative condition
  - Multiple cells
  - Multiple treatment pathways
  - Other bells and whistles
    (increased pretreatment/media depth, etc.)

BMP Treatment Train



BMP Treatment Trains

- Allow for compliance on high density sites *(high removal requirements)*
- Provide flexibility on tight sites by allowing multiple smaller BMPs to treat stormwater near the source
  - As drainage area incrementally **increases** (with each RR practice)
  - RR practices incrementally **reduce** runoff volume and Tv_{BMP},
  - Each successive BMP not sized on entire upstream drainage area
  - BMP sized by Tv_{BMP} from directly contributing drainage area + any remaining runoff from upstream RR practices

Level 1 and Level 2 & BMP Treatment Trains

Design Summary Table BMP Design Specification No. 9: Bioretention

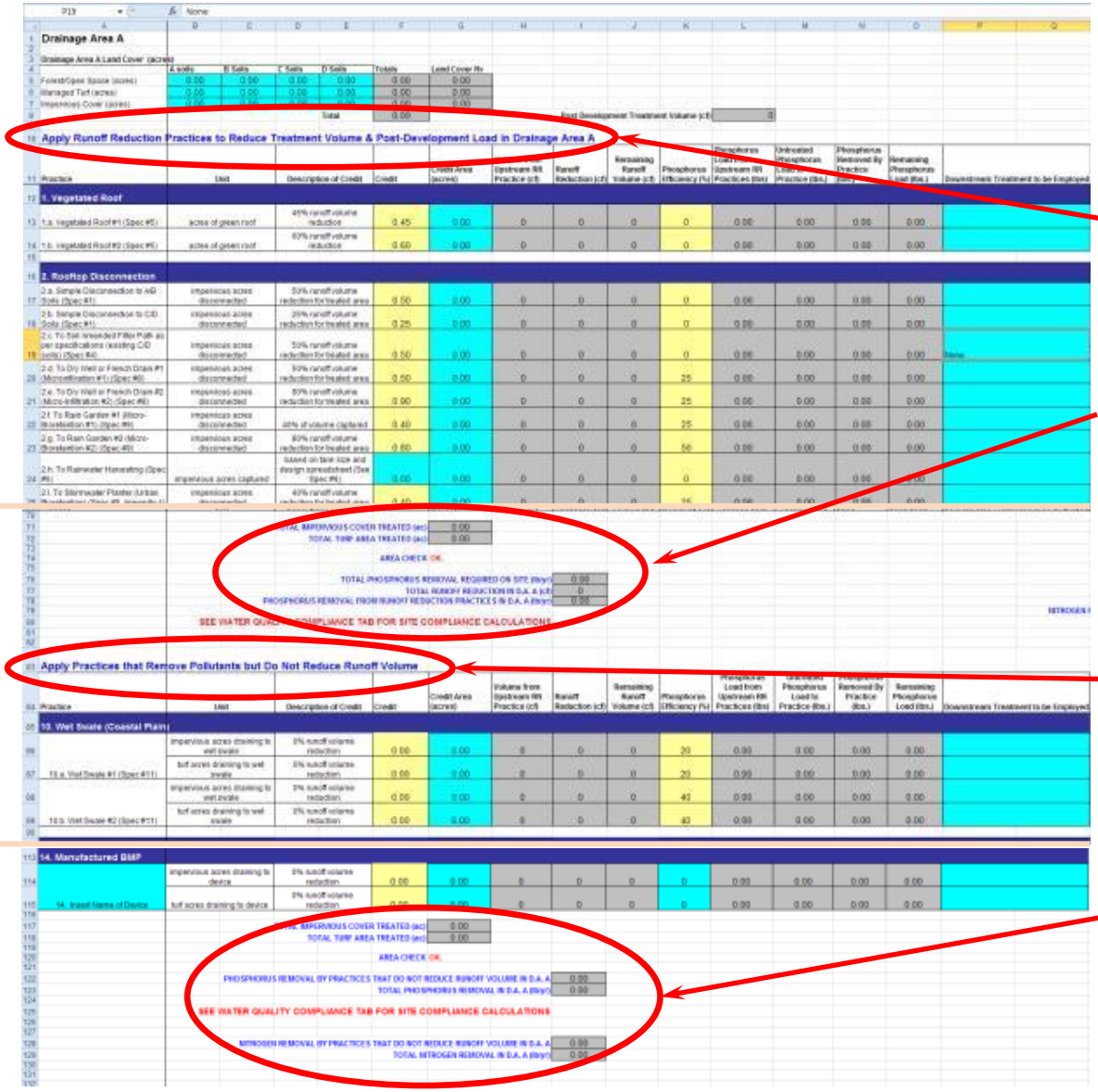
Level 1 (RR 40 TP: 25)	Level 2 (RR: 80 TP: 50)
Sizing (**Section 6.1**): Tv_{BMP} = [(1)(Rv)(A) / 12] + any remaining volume from upstream BMP	Sizing (**Section 6.1**): Tv_{BMP} = [(1.25)(Rv)(A) / 12] + any remaining volume from upstream BMP

Comparative BMP Level 1 & Level 2 Performance

Practice	Design Level	Runoff Reduction	TN EMC Removal[3]	TN Mass Load Removal	TP EMC Removal	TP Mass Load Removal [6]
Rooftop Disconnect	1 [2]	25 to 50 [1]	0	25 to 50 [1]	0	25 to 50 [1]
	No Level 2 Design					
Sheet Flow to Veg. Filter or Conserv. Open Space	1	50	0	50	0	50
	2 [5]	50 to 75 [1]	0	50 to 75 [1]	0	50 to 75 [1]
Grass Channels	1	10 to 20 [1]	20	28 to 44 [1]	15	24 to 41 [1]
	No Level 2 Design					
Soil Compost Amendment	Can be used to Decrease Runoff Coefficient for Turf Cover at Site. See the design specs for Rooftop Disconnection, Sheet Flow to Vegetated Filter or Conserved Open Space, and Grass Channel					
Vegetated Roof	1	45	0	45	0	45
	2	60	0	60	0	60
Rainwater Harvesting	1	Up to 90 [3, 5]	0	Up to 90 [3, 5]	0	Up to 90 [3, 5]
	No Level 2 Design					
Permeable Pavement	1	45	25	59	25	59
	2	75	25	81	25	81
Infiltration Practices	1	50	15	57	25	63
	2	90	15	92	25	93
Bioretention Practices	1	40	40	64	25	55
	2	80	60	90	50	90
Urban Bioretention	1	40	40	64	25	55
	No Level 2 Design					
Dry Swales	1	40	25	55	20	52
	2	60	35	74	40	76
Wet Swales	1	0	25	25	20	20
	2	0	35	35	40	40
Filtering Practices	1	0	30	30	60	60
	2	0	45	45	65	65
Constructed Wetlands	1	0	25	25	50	50
	2	0	55	55	75	75
Wet Ponds	1	0	30 (20) [4]	30 (20) [4]	50 (45) [4]	50 (45) [4]
	2	0	40 (30) [4]	40 (30) [4]	75 (65) [4]	75 (65) [4]
Ext. Det. Ponds	1	0	10	10	15	15
	2	15	10	24	15	31

4f. VRRM Compliance Spreadsheet Example

VRRM Spreadsheet DA Tabs



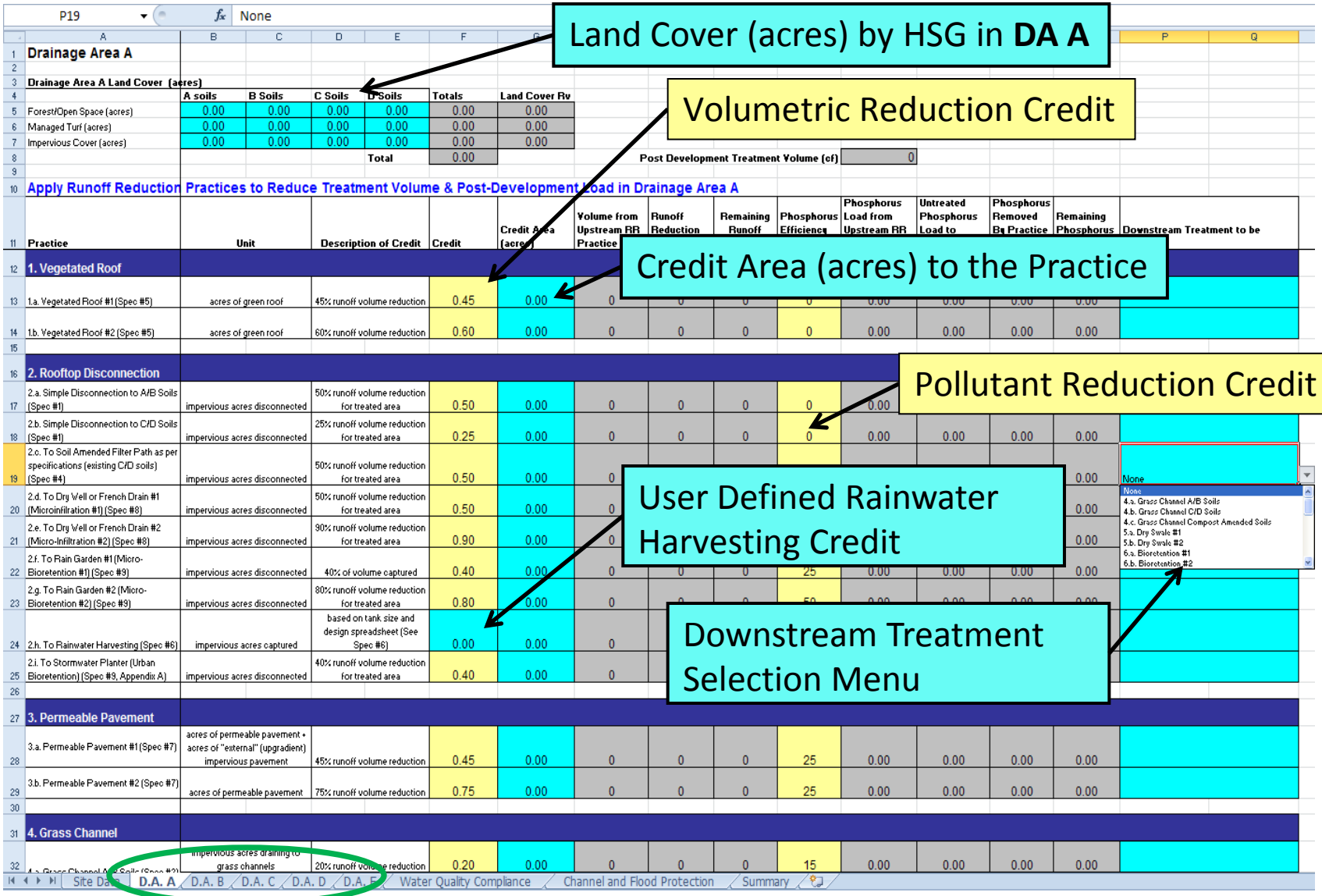
Upper half: Runoff Reduction Practices

Drainage Area Check

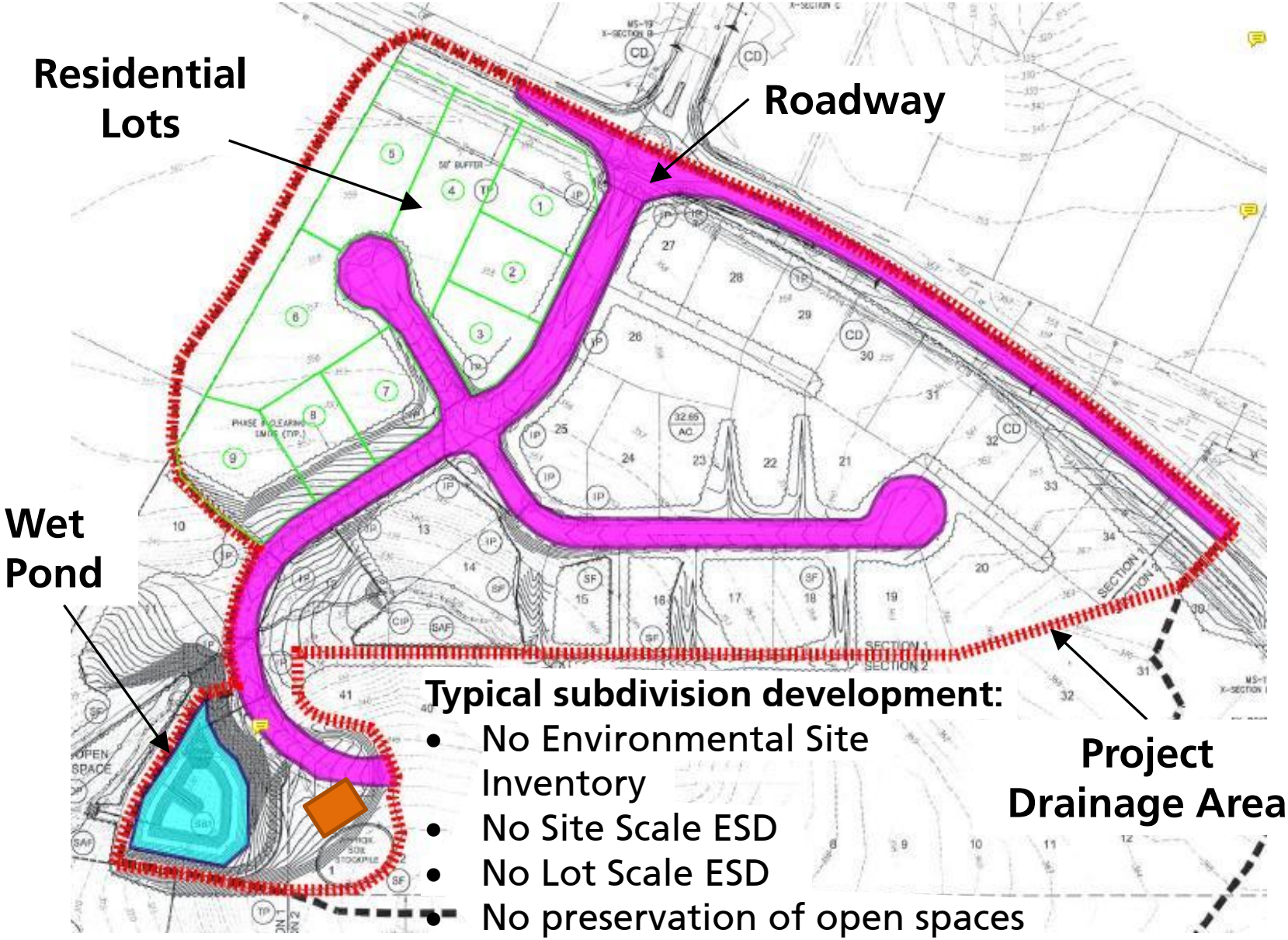
Lower half: Pollutant Removal Practices

Drainage Area Check

VRRM Spreadsheet DA Tabs

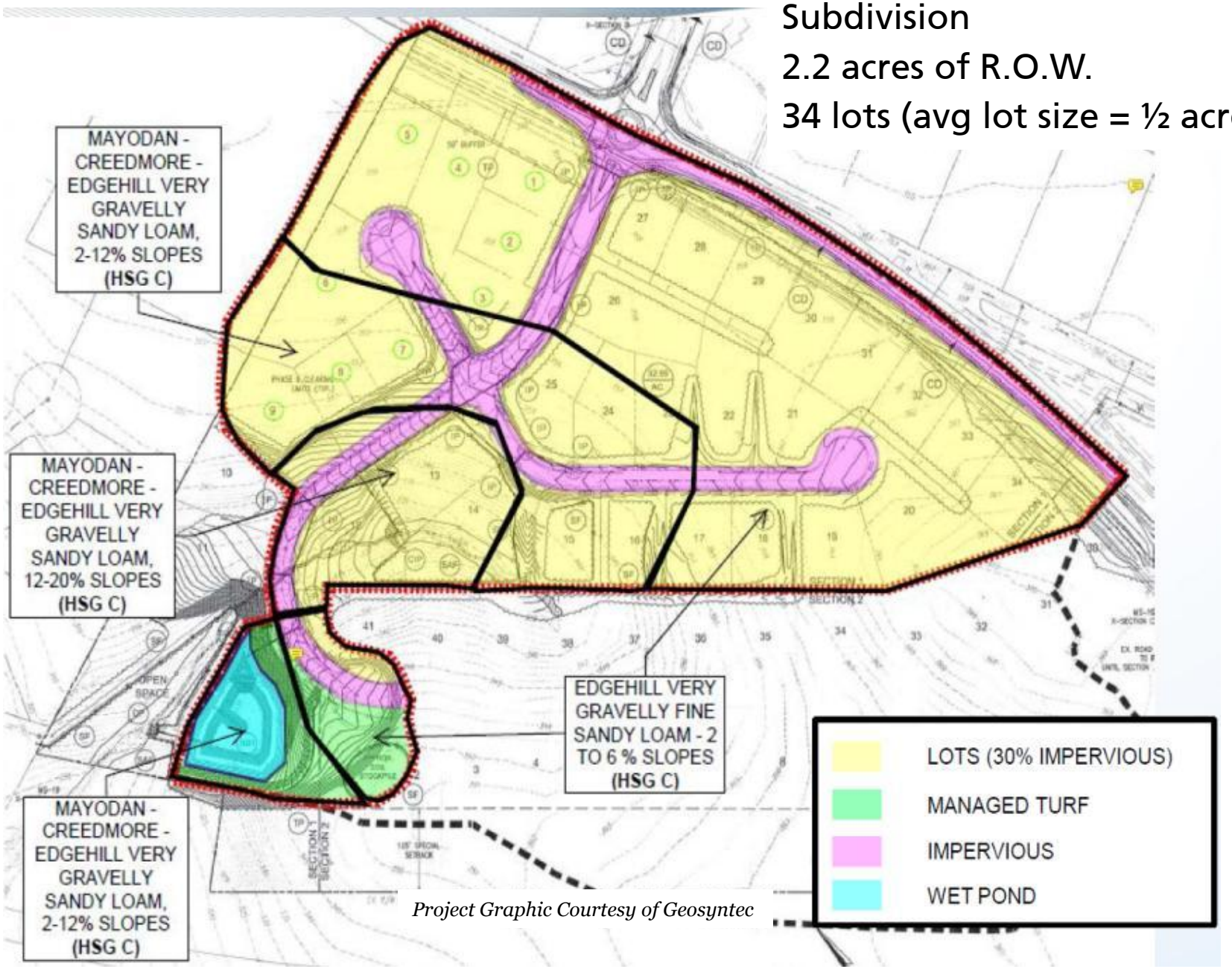


Spreadsheet Review



PG 36

19.8 acre single Family Subdivision
2.2 acres of R.O.W.
34 lots (avg lot size = ½ acre)



Project Graphic Courtesy of Geosyntec

Site Data Tab

Virginia Runoff Reduction Method Nev

Site Data

Project Name:	
Date:	

data input cells
calculation cells
constant values

1. Post-Development Project & Land Cover Information

Constants

Annual Rainfall (inches)	43		
Target Rainfall Event (inches)	1.00		
Phosphorus EMC (mg/L)	0.26	Nitrogen EMC (mg/L)	1.86
Target Phosphorus Target Load (lb/acre/yr)	0.41		
Pj	0.90		

Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals
Forest/Open Space (acres) -- undisturbed, protected forest/open space or reforested land	0.00		0.00	0.00	0.00
Managed Turf (acres) -- disturbed, graded for yards or other turf to be mowed/managed	0.00		12.09	0.00	12.09
Impervious Cover (acres)	0.00		7.71	0.00	7.71
				Total	19.80

Rv Coefficients

	A soils	B Soils	C Soils	D Soils
Forest/Open Space	0.02	0.03	0.04	0.05
Managed Turf	0.15	0.20	0.22	0.25
Impervious Cover	0.95	0.95	0.95	0.95

Land Cover Summary

Forest/Open Space Cover (acres)	0.00
Weighted Rv(forest)	0.00
% Forest	0%
Managed Turf Cover (acres)	12.09
Weighted Rv(turf)	0.22
% Managed Turf	61%
Impervious Cover (acres)	7.71
Rv(impervious)	0.95
% Impervious	39%
Total Site Area (acres)	19.80
Site Rv	0.50
Post-Development Treatment Volume (acre-ft)	0.83
Post-Development Treatment Volume (cubic feet)	36,243
Post_Development Load (TP) (lb/yr)	22.77
Total Load (TP) Reduction Required (lb/yr)	14.65

Post_Development Load (TN) (lb/yr) 162.90

Turf = 12.09
Imp = 7.71
Area Total = 19.8 acres

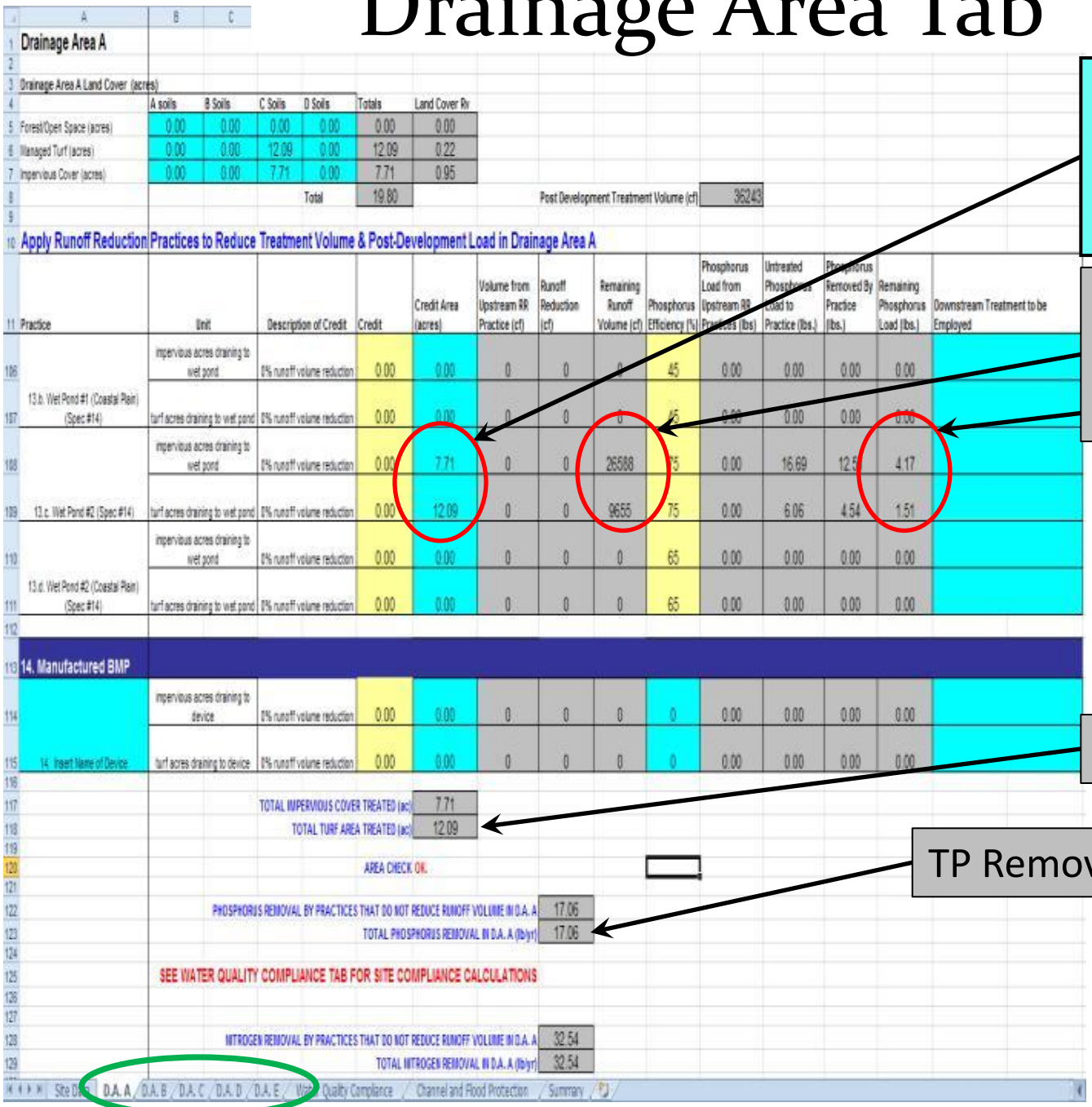
Site Rv = 0.50

Post Dev Tv = 0.83 ac-ft

Post Dev TP Load = 22.77 lb/yr

Load Reduction Required = 14.65 lb/yr

Drainage Area Tab



Drainage Area A

Drainage Area A Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	Land Cover Rv
Forest/Open Space (acres)	0.00	0.00	0.00	0.00	0.00	0.00
Managed Turf (acres)	0.00	0.00	12.09	0.00	12.09	0.22
Impervious Cover (acres)	0.00	0.00	7.71	0.00	7.71	0.95
			Total		19.80	

Post Development Treatment Volume (cf): 36243

Apply Runoff Reduction Practices to Reduce Treatment Volume & Post-Development Load in Drainage Area A

Practice	Unit	Description of Credit	Credit	Credit Area (acres)	Volume from Upstream RR Practice (cf)	Runoff Reduction (cf)	Remaining Runoff Volume (cf)	Phosphorus Efficiency (%)	Phosphorus Load from Upstream RR Practices (lbs)	Untreated Phosphorus Load to Practice (lbs.)	Phosphorus Removed By Practice (lbs.)	Remaining Phosphorus Load (lbs.)	Downstream Treatment to be Employed
	impervious acres draining to wet pond	0% runoff volume reduction	0.00	0.00	0	0	0	45	0.00	0.00	0.00	0.00	
13.b. Wet Pond #1 (Coastal Plain) (Spec #14)	turf acres draining to wet pond	0% runoff volume reduction	0.00	0.00	0	0	0	45	0.00	0.00	0.00	0.00	
	impervious acres draining to wet pond	0% runoff volume reduction	0.00	7.71	0	0	26588	75	0.00	16.69	12.52	4.17	
13.c. Wet Pond #2 (Spec #14)	turf acres draining to wet pond	0% runoff volume reduction	0.00	12.09	0	0	9655	75	0.00	6.06	4.54	1.51	
	impervious acres draining to wet pond	0% runoff volume reduction	0.00	0.00	0	0	0	65	0.00	0.00	0.00	0.00	
13.d. Wet Pond #2 (Coastal Plain) (Spec #14)	turf acres draining to wet pond	0% runoff volume reduction	0.00	0.00	0	0	0	65	0.00	0.00	0.00	0.00	
14. Manufactured BMP													
	impervious acres draining to device	0% runoff volume reduction	0.00	0.00	0	0	0	0	0.00	0.00	0.00	0.00	
14. Insert Name of Device	turf acres draining to device	0% runoff volume reduction	0.00	0.00	0	0	0	0	0.00	0.00	0.00	0.00	

TOTAL IMPERVIOUS COVER TREATED (ac): 7.71

TOTAL TURF AREA TREATED (ac): 12.09

AREA CHECK OK

PHOSPHORUS REMOVAL BY PRACTICES THAT DO NOT REDUCE RUNOFF VOLUME IN D.A. A: 17.06

TOTAL PHOSPHORUS REMOVAL IN D.A. A (lb/yr): 17.06

SEE WATER QUALITY COMPLIANCE TAB FOR SITE COMPLIANCE CALCULATIONS

NITROGEN REMOVAL BY PRACTICES THAT DO NOT REDUCE RUNOFF VOLUME IN D.A. A: 32.54

TOTAL NITROGEN REMOVAL IN D.A. A (lb/yr): 32.54

Site Data | D.A. A | D.A. B | D.A. C | D.A. D | D.A. E | Water Quality Compliance | Channel and Flood Protection | Summary

Credit Area (acres) to Wet Pond Level 2:
Imp = 7.71 ac
Turf = 12.09 ac

0 RR
Remaining Runoff vol.
& Remaining TP load

Area Check: **OK**

TP Removed = 17.06 lb/yr

Water Quality Compliance Tab

	A	B	C	D	E	F	G
1	**Site Results**						
2							
3		**D.A. A**	**D.A. B**	**D.A. C**	**D.A. D**	**D.A. E**	**AREA CHECK**
4	IMPERVIOUS COVER	7.71	0.00	0.00	0.00	0.00	OK.
5	IMPERVIOUS COVER TREATED	7.71	0.00	0.00	0.00	0.00	OK.
6	TURF AREA	12.09	0.00	0.00	0.00	0.00	OK.
7	TURF AREA TREATED	12.09	0.00	0.00	0.00	0.00	OK.
8	AREA CHECK	OK.	OK.	OK.	OK.	OK.	
9							
10	**Phosphorus**						
11	TOTAL TREATMENT VOLUME (cf)	36,243					
12	TOTAL PHOSPHORUS LOAD REDUCTION REQUIRED (LB/YEAR)	14.65					
13							
14	RUNOFF REDUCTION (cf)	0					
15	PHOSPHORUS LOAD REDUCTION ACHIEVED (LB/YR)	17.06					
16							
17	ADJUSTED POST-DEVELOPMENT PHOSPHORUS LOAD (TP) (lb/yr)	5.71					
18							
19	REMAINING PHOSPHORUS LOAD REDUCTION (LB/YR) NEEDED	CONGRATULATIONS!! YOU EXCEEDED THE TARGET REDUCTION BY 2.4 LB/YEAR!!					
20							
21							
22							
23	**Nitrogen (for information purposes)**						
24	TOTAL TREATMENT VOLUME (cf)	36,243					
25							
26							
27	RUNOFF REDUCTION (cf)	0					
28	NITROGEN LOAD REDUCTION ACHIEVED (LB/YR)	32.54					
29							
30	ADJUSTED POST-DEVELOPMENT NITROGEN LOAD (TN) (lb/yr)	130.36					

Area Check: OK

Runoff Reduction = 0

TP Reduction = 17.06 lb/yr

Channel & Flood Protection Tab

	A	B	C	D	E	F	G	H
1				1-year storm	2-year storm	10-year storm		
2	Target Rainfall Event (in)			2.79	3.38	5.14		
3								
4	Drainage Area A							
5	Drainage Area (acres)		19.80					
6	Runoff Reduction Volume (cf)		0					
7								
8	Drainage Area B							
9	Drainage Area (acres)		0.00					
10	Runoff Reduction Volume (cf)		0					
11								
12	Drainage Area C							
13	Drainage Area (acres)		0.00					
14	Runoff Reduction Volume (cf)		0					
15								
16	Drainage Area D							
17	Drainage Area (acres)		0.00					
18	Runoff Reduction Volume (cf)		0					
19								
20	Drainage Area E							
21	Drainage Area (acres)		0.00					
22	Runoff Reduction Volume (cf)		0					
23								
24								
25	Based on the use of Runoff Reduction practices in the selected drainage areas, the spreadsheet calculates an adjusted $RV_{Developed}$ and adjusted Curve Number.							
26								
27	Drainage Area A			A soils	B Soils	C Soils	D Soils	
28	Forest/Open Space -- undisturbed, protected forest/open		Area (acres)	0.00	0.00	0.00	0.00	
29	space or reforested land		CN	30	55	70	77	
30	Managed Turf -- disturbed, graded for yards or other turf to be		Area (acres)	0.00	0.00	12.09	0.00	
31	mowed/managed		CN	39	61	74	80	
32			Area (acres)	0.00	0.00	7.71	0.00	
33	Impervious Cover		CN	98	98	98	98	
34							Weighted CN	S
35							83	2.05
36				1-year storm	2-year storm	10-year storm		
37			$RV_{Developed}$ (in) with no Runoff Reduction	1.28	1.76	3.30		
38			$RV_{Developed}$ (in) with Runoff Reduction	1.28	1.76	3.30		
39			Adjusted CN	83	83	83		

1, 2, and 10-year storm rainfall depths

No volume reduction

CN = 83

1, 2, and 10-year volume (RV) measured in watershed inches =

RV_1 = 1.28 inches

RV_2 = 1.76 inches

RV_{10} = 3.30 inches

No RR

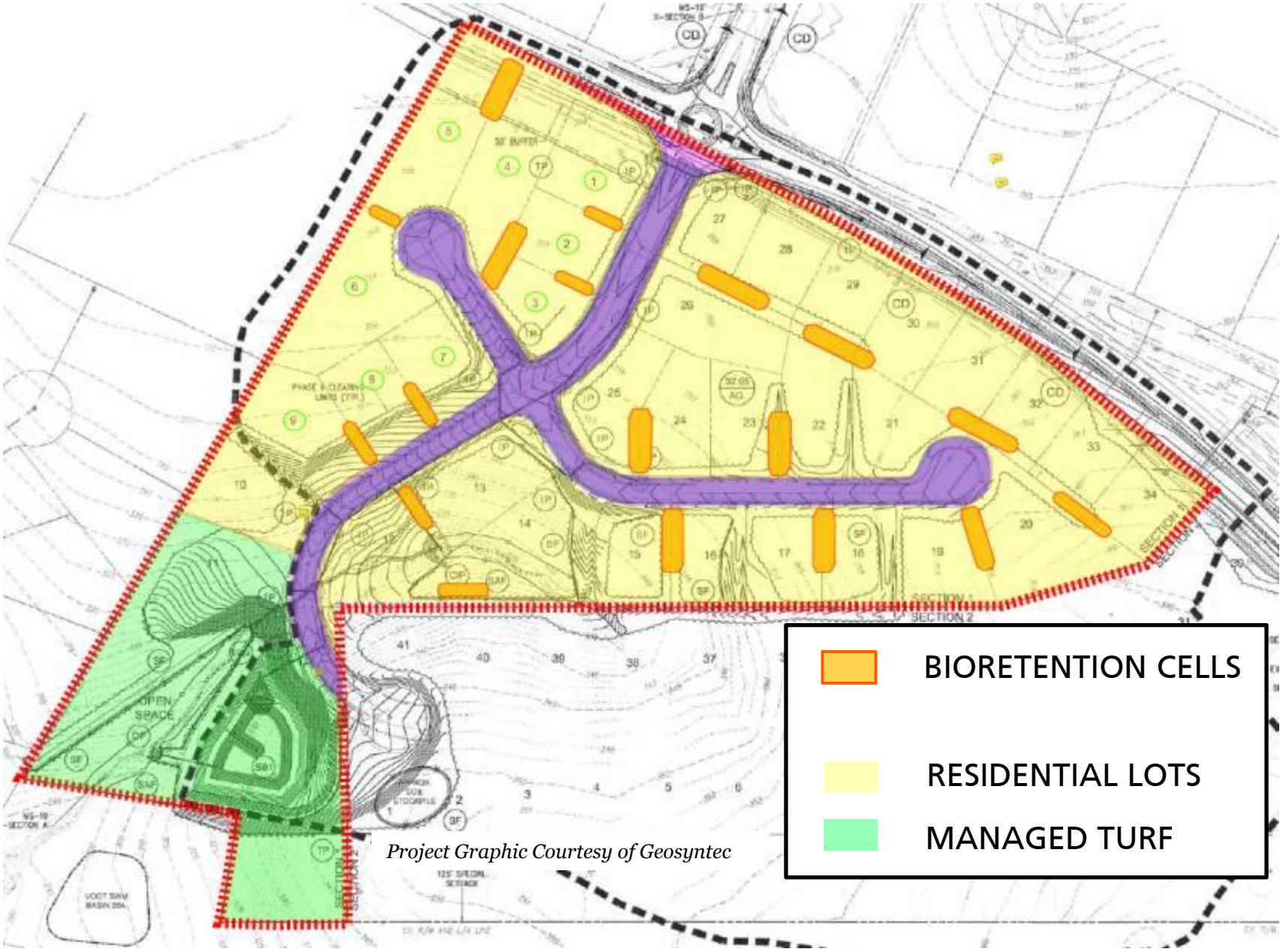
No CN Adjustment!

Alternative Design

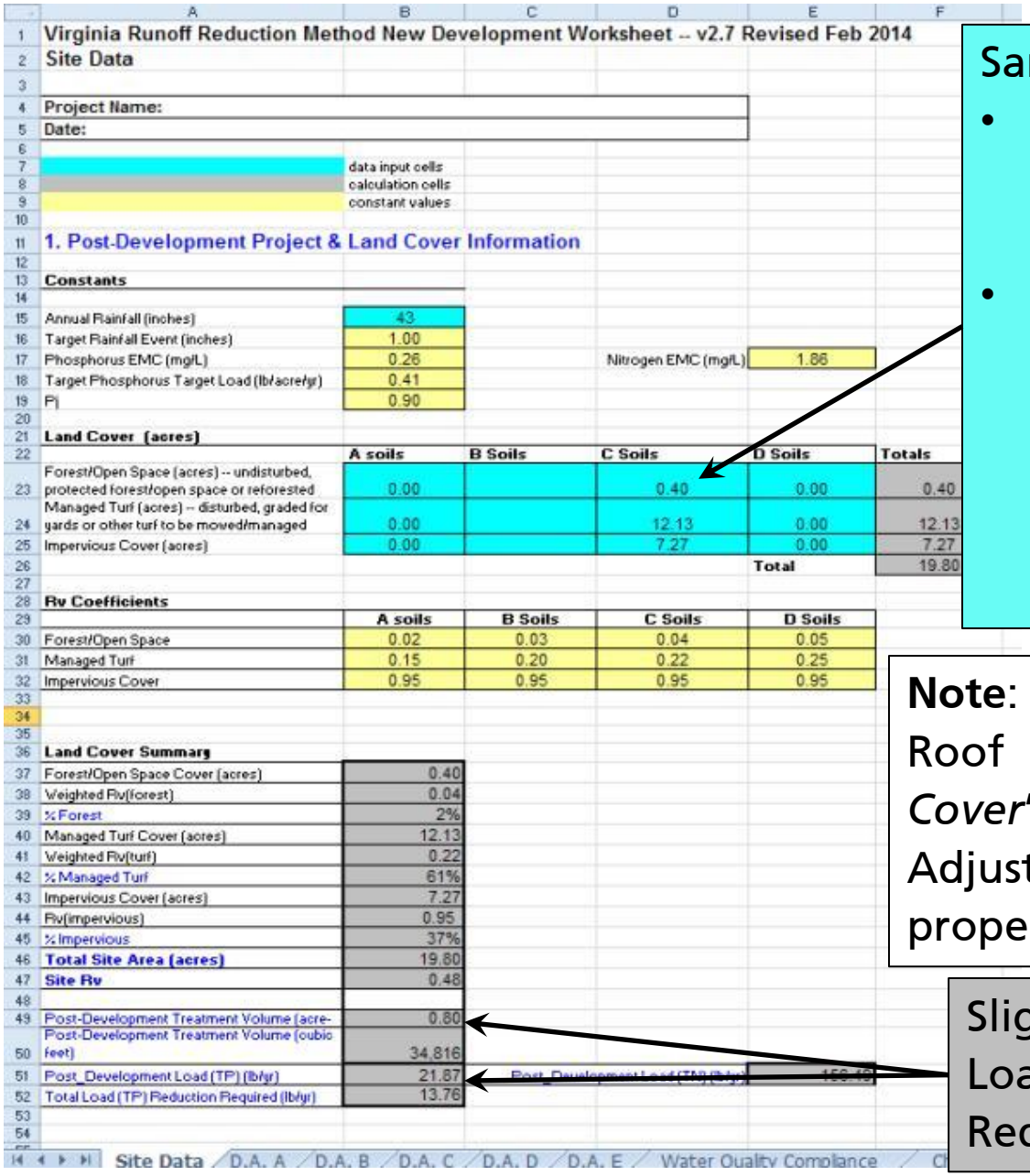
Goal: Replace wet pond with BMPs that will reduce runoff volume (and remove pollutants):

- ***Rooftop disconnection***, downstream treatment to ***Bioretention*** to treat all impervious area on residential lots
- Remaining impervious (roads) and some pervious area on lots to ***Bioretention*** areas
- Conveyance to ***vegetated filter strip*** for downstream treatment

Additional Volume Reduction options: Permeable Pavement on roads; downstream Vegetated Filter Strips (or Conserved Open Space)



Project Graphic Courtesy of Geosyntec



Virginia Runoff Reduction Method New Development Worksheet -- v2.7 Revised Feb 2014

Site Data

Project Name:

Date:

data input cells
calculation cells
constant values

1. Post-Development Project & Land Cover Information

Constants

Annual Rainfall (inches)	43		
Target Rainfall Event (inches)	1.00		
Phosphorus EMC (mg/L)	0.26	Nitrogen EMC (mg/L)	1.86
Target Phosphorus Target Load (lb/acre/yr)	0.41		
Pj	0.90		

Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals
Forest/Open Space (acres) -- undisturbed, protected forest/open space or reforested	0.00		0.40	0.00	0.40
Managed Turf (acres) -- disturbed, graded for yards or other turf to be mowed/managed	0.00		12.13	0.00	12.13
Impervious Cover (acres)	0.00		7.27	0.00	7.27
				Total	19.80

Rv Coefficients

	A soils	B Soils	C Soils	D Soils
Forest/Open Space	0.02	0.03	0.04	0.05
Managed Turf	0.15	0.20	0.22	0.25
Impervious Cover	0.95	0.95	0.95	0.95

Land Cover Summary

Forest/Open Space Cover (acres)	0.40
Weighted Rv(forest)	0.04
% Forest	2%
Managed Turf Cover (acres)	12.13
Weighted Rv(turf)	0.22
% Managed Turf	61%
Impervious Cover (acres)	7.27
Rv(impervious)	0.95
% Impervious	37%
Total Site Area (acres)	19.80
Site Rv	0.48
Post-Development Treatment Volume (acre-	0.80
Post-Development Treatment Volume (cubic feet)	34,816
Post_Development Load (TP) (lb/yr)	21.87
Total Load (TP) Reduction Required (lb/yr)	13.76

Site Data | D.A. A | D.A. B | D.A. C | D.A. D | D.A. E | Water Quality Compliance

Same as traditional scenario, but:

- **Wet Pond** area partially converted from '*Impervious Cover*' to '*Managed Turf*'
- **BMP areas** converted from '*Managed Turf*' to '*Forest/Open Space*'
  - *Forest/Open = 0.4*
  - *Managed Turf = 12.13*
  - *Impervious = 7.27*

Note: Pervious Pavement & Green Roof is inventoried as '*Impervious Cover*' with an associated CN Adjustment to reflect the permeable properties.

Slight change in Tv, TP Load, and Reduction Requirement

Runoff Reduction Design

Credit Area to Simple Disconnection = 5 ac

Runoff Reduction = 4,311 ft³
Runoff Remaining = 12,932 ft³
Total = Tv_{BMP} = 17,243 ft³

Drainage Area A

Drainage Area A Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	Land Cover Rv
Forest/Open Space (acres)	0.00	0.00	0.40	0.00	0.40	0.04
Managed Turf (acres)	0.00	0.00	12.13	0.00	12.13	0.22
Impervious Cover (acres)	0.00	0.00	7.27	0.00	7.27	0.95
				Total	19.80	

Post Development Treatment Volume (cf) 34816

Apply Runoff Reduction Practices to Reduce Treatment Volume & Post-Development Load in Drainage Area A

Practice	Unit	Description of Credit	Credit	Credit Area (acres)	Volume from Upstream RR Practice (cf)	Runoff Reduction (cf)	Remaining Runoff Volume (cf)	Phosphorus Efficiency (%)	Phosphorus Load from Upstream RR Practices (lbs.)	Untreated Phosphorus Load to Practice (lbs.)	Phosphorus Removed By Practice (lbs.)	Remaining Phosphorus Load (lbs.)	Downstream Treatment to be Employed
1. Vegetated Roof													
1.a. Vegetated Roof #1 (Spec #5)	acres of green roof	45% runoff volume reduction	0.45	0.00	0	0	0	0	0.00	0.00	0.00	0.00	
1.b. Vegetated Roof #2 (Spec #5)	acres of green roof	60% runoff volume reduction	0.60	0.00	0	0	0	0	0.00	0.00	0.00	0.00	
2. Rooftop Disconnection													
2.a. Simple Disconnection to A/B Soils (Spec #1)	impervious acres disconnected	50% runoff volume reduction for treated area	0.50	0.00	0	0	0	0	0.00	0.00	0.00	0.00	
2.b. Simple Disconnection to C/D Soils (Spec #1)	impervious acres disconnected	25% runoff volume reduction for treated area	0.25	5.00	0	4311	12932	0	0.00	10.82	2.71	8.12	6.b. Bioretention #2
2.c. To Soil Amended Filter Path as per specifications (existing C/D soils) (Spec #4)	impervious acres disconnected	50% runoff volume reduction for treated area	0.50	0.00	0	0	0	0	0.00	0.00	0.00	0.00	None
2.d. To Dry Well or French Drain #1 (Microinfiltration #1) (Spec #8)	impervious acres disconnected	50% runoff volume reduction for treated area	0.50	0.00	0	0	0	25	0.00	0.00	0.00	0.00	
2.e. To Dry Well or French Drain #2		90% runoff volume											

Downstream Treatment: Bioretion L2

Runoff Reduction Design

Credit Area to Bioretention Level 2:
1.89 ac additional Impervious
5.0 ac turf

Volume from upstream RR practice:
12,932 ft³

Runoff Reduction = 15,560 + 3,194 ft³
+ Runoff Remaining = 3,890 + 799 ft³
= Total = Tv_{BMP} = 23,443 ft³

Drainage Area A

Drainage Area A Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	Land Cover Rv
Forest/Open Space (acres)	0.00	0.00	0.40	0.00	0.40	0.04
Managed Turf (acres)	0.00	0.00	12.13	0.00	12.13	0.22
Impervious Cover (acres)	0.00	0.00	7.27	0.00	7.27	0.95
				Total	19.80	

Apply Runoff Reduction Practices to Reduce Treatment Volume & Post-Development Load in Drainage Area A

Practice	Unit	Description of Credit	Credit	Credit Area (acres)	Volume from Upstream RR Practice (cf)	Runoff Reduction (cf)	Remaining Runoff Volume (cf)	Phosphorus Efficiency (%)	Phosphorus Load from Upstream RR Practices (lbs)	Untreated Phosphorus Load to Practice (lbs.)	Phosphorus Removed By Practice (lbs.)	Remaining Phosphorus Load (lbs.)	Downstream Treatment to be Employed
6. Bioretention													
6.a. Bioretention #1 or Urban Bioretention (Spec #9)	impervious acres draining to bioretention	40% runoff volume reduction	0.40	0.00	0	0	0	25	0.00	0.00	0.00	0.00	
	turf acres draining to bioretention	40% runoff volume reduction	0.40	0.00	0	0	0	25	0.00	0.00	0.00	0.00	
6.b. Bioretention #2 (Spec #9)	impervious acres draining to bioretention	80% runoff volume reduction	0.80	1.89	12932	15560	3890	50	8.12	4.09	10.99	1.22	None
	turf acres draining to bioretention	80% runoff volume reduction	0.80	5.00	0	3194	799	50	0.00	2.51	2.26	0.25	None
7. Infiltration													
7.a. Infiltration #1 (Spec #8)	impervious acres draining to infiltration	50% runoff volume reduction	0.50	0.00	0	0	0	25	0.00	0.00	0.00	0.00	
	turf acres draining to infiltration	50% runoff volume reduction	0.50	0.00	0	0	0	25	0.00	0.00	0.00	0.00	
7.b. Infiltration #2 (Spec #8)	impervious acres draining to infiltration	90% runoff volume reduction	0.90	0.00	0	0	0	25	0.00	0.00	0.00	0.00	
							0	25	0.00	0.00	0.00	0.00	
							0	15	0.00	0.00	0.00	0.00	
							0	15	0.00	0.00	0.00	0.00	
							0	15	0.00	0.00	0.00	0.00	
	turf acres draining to ED	reduction	0.15	0.00	0	0	0	15	0.00	0.00	0.00	0.00	

Site Data | D.A. A | D.A. B | D.A. C | D.A. D | D.A. E | Water Quality Compliance | Channel and Flood Protection | Summary

Water Quality Compliance Tab

Area Check - OK

	A	B	C	D	E	F	G
1	**Site Results**						
2							
3		**D.A. A**	**D.A. B**	**D.A. C**	**D.A. D**	**D.A. E**	**AREA CHECK**
4	IMPERVIOUS COVER	7.27	0.00	0.00	0.00	0.00	OK.
5	IMPERVIOUS COVER TREATED	6.89	0.00	0.00	0.00	0.00	OK.
6	TURF AREA	12.13	0.00	0.00	0.00	0.00	OK.
7	TURF AREA TREATED	5.00	0.00	0.00	0.00	0.00	OK.
8	AREA CHECK	OK.	OK.	OK.	OK.	OK.	
9							
10	**Phosphorus**						
11	TOTAL TREATMENT VOLUME (cf)	34,816					
12	TOTAL PHOSPHORUS LOAD REDUCTION REQUIRED (LB/YEAR)	13.76					
13							
14	RUNOFF REDUCTION (cf)	23065					
15	PHOSPHORUS LOAD REDUCTION ACHIEVED (LB/YR)	15.95					
16							
17	ADJUSTED POST-DEVELOPMENT PHOSPHORUS LOAD (TP) (lb/yr)	5.93					
18							
19	REMAINING PHOSPHORUS LOAD REDUCTION (LB/YR) NEEDED	CONGRATULATIONS!! YOU EXCEEDED THE TARGET REDUCTION BY 2.2 LB/YEAR!!					
20							
21							
22							
23	**Nitrogen (for information purposes)**						
24	TOTAL TREATMENT VOLUME (cf)	34,816					
25							
26							
27	RUNOFF REDUCTION (cf)	23065					
28	NITROGEN LOAD REDUCTION ACHIEVED (LB/YR)	124.60					
29							
30	ADJUSTED POST-DEVELOPMENT NITROGEN LOAD (TN) (lb/yr)	31.89					
31							

Runoff Reduction Achieved: 23,065 ft^3

Congratulations! You exceeded target reduction by 2.2 lbs/yr

Channel & Flood Protection Tab

	A	B	C	D	E	F	G	H
1				1-year storm	2-year storm	10-year storm		
2	Target Rainfall Event (in)			2.79	3.36	5.14		
3								
4	Drainage Area A							
5	Drainage Area (acres)		19.80					
6	Runoff Reduction Volume (cf)		23,065					
7								
8	Drainage Area B							
9	Drainage Area (acres)		0.00					
10	Runoff Reduction Volume (cf)		0					
11								
12	Drainage Area C							
13	Drainage Area (acres)		0.00					
14	Runoff Reduction Volume (cf)		0					
15								
16	Drainage Area D							
17	Drainage Area (acres)		0.00					
18	Runoff Reduction Volume (cf)		0					
19								
20	Drainage Area E							
21	Drainage Area (acres)		0.00					
22	Runoff Reduction Volume (cf)		0					
23								
24								
25	Based on the use of Runoff Reduction practices in the selected drainage areas, the spreadsheet calculates an adjusted $RV_{Developed}$ and adjusted C							
26								
27	Drainage Area A			A soils	B Soils	C Soils	D Soils	
28	Forest/Open Space -- undisturbed, protected forest/open		Area (acres)	0.00	0.00	0.40	0.0	
29	space or reforested land		CN	30	55	70	7	
30	Managed Turf -- disturbed, graded for yards or other turf to be		Area (acres)	0.00	0.00	12.13	0.0	
31	mowed/managed		CN	39	61	74	8	
32			Area (acres)	0.00	0.00	7.27	0.0	
33	Impervious Cover		CN	98	98	98	9	
34							Weighted CN	S
35							83	2.05
36				1-year storm	2-year storm	10-year storm		
37			$RV_{Developed}$ (in) with no Runoff Reduction	1.28	1.76	3.30		
38			$RV_{Developed}$ (in) with Runoff Reduction	0.96	1.44	2.98		
39			Adjusted CN	77	78	80		

1, 2, and 10-year storm rainfall depths

Volume Reduction = 23,065 ft³

1, 2, and 10-year volume (RV) reduction =

$RV_1 = 1.12" \rightarrow 0.96"$

CN_1 83 → 77

$RV_2 = 1.54" \rightarrow 1.44"$

CN_2 83 → 78

$RV_{10} = 3.30" \rightarrow 2.98"$

CN_{10} 83 → 80

Design Comparison

Original design:

- No Volume Reduction
- Treat 100% of site (19.8 ac) with Wet Pond Level 2
- Compliance: exceed reqmt. by 2.4 lb/yr

RR Design:

- Treat 11.9 acres
- Compliance: exceed reqmt. by 2.2 lb/yr
- No wet pond Reqd (for water quality)
- Reduce 23,065 ft^3 volume (from site Tv = 34,816 ft^3)
- Reduce 1-yr CN from 83 to 77

Alternative Design

Additional Volume Reduction:

Option of adding permeable pavement:

- Increases load reduction 1 pound/yr:

  2.2 to 3.2 lb/yr;

- Increases volume reduction approx 8%
- Increases CN Reduction for 1-yr storm:

  from 83 to 76 (versus 83 to 77)

Cost-Benefit analysis of incremental increase in performance?

Runoff Reduction Method

- Process Logic not intended to be difficult (even if individuals may try to make it so!)
- Spreadsheet Summary Tab output tracks BMP and corresponding reductions by DA
- Additional tracking tools (spreadsheets or other tools can be utilized)
- Ultimate goal is better BMP performance, quality designs, and practices designed for long term functioning

- Additional discussion on VRRM and Compliance Spreadsheet
  - Capabilities
  - Limitations

 (Modules 5, 8, and 9)

Questions & Discussion