MWS Stormwater Management Manual Volume 5 Low Impact Development Training

Welcome

September 7, 2012

Today's Agenda

Time	Topic
8:00 – 8:30	Overview of Green infrastructure and the Runoff Reduction Method
8:30 – 9:30	Green Infrastructure Design Steps and GIPs
9:30 – 9:45	Break
9:45 – 10:30	Calculation Tool and Simple Example
10:30 – 11:00	Nashville Site Example

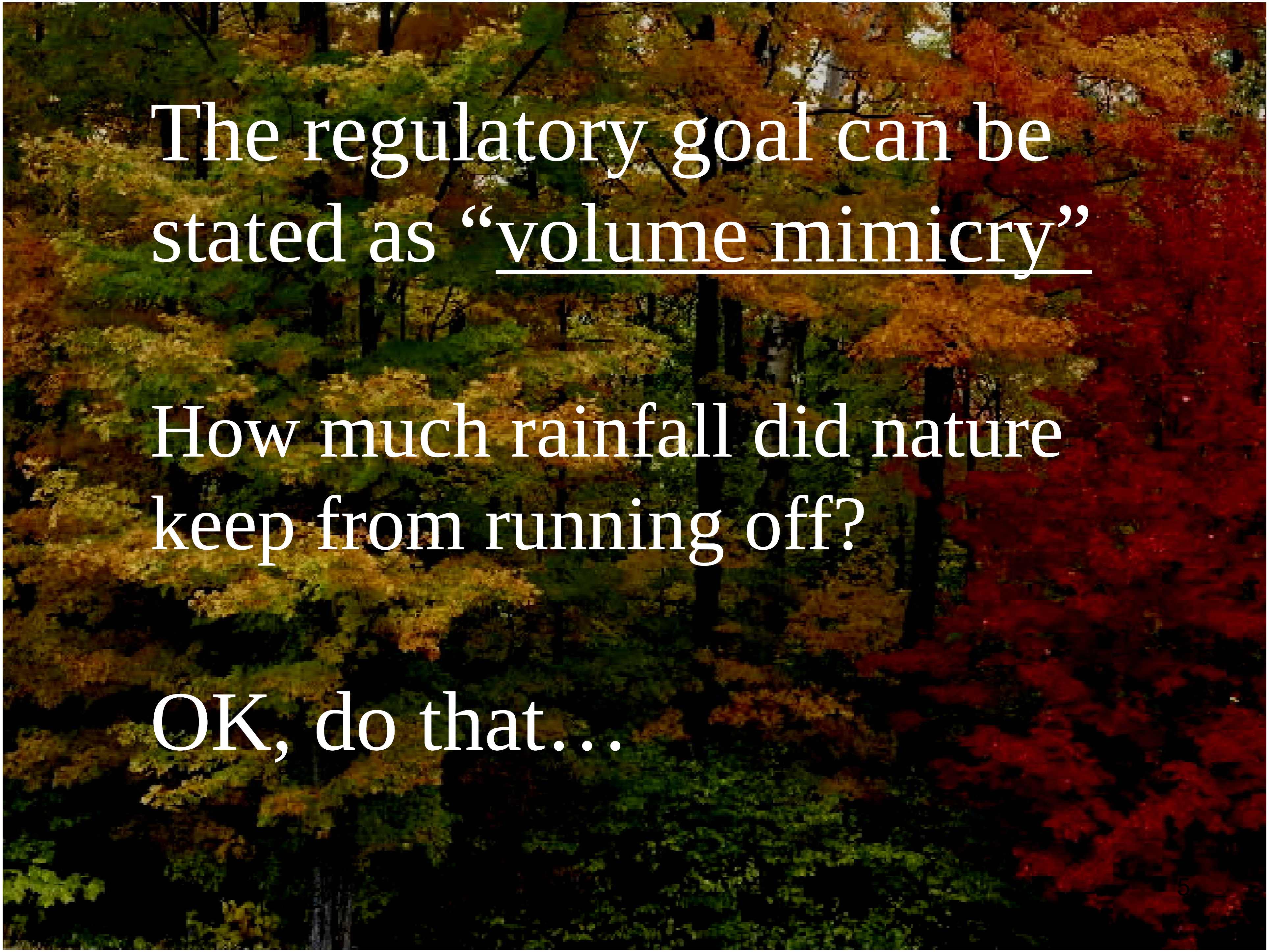
Overview of Green Infrastructure and the Runoff Reduction Method

Andy Reese

AMEC

EPA is saying:

TSS removal is cute… just not powerful enough…


The regulatory goal can be stated as "volume mimicry"
How much rainfall did nature keep from running off?
OK, do that…

“Green Infrastructure” to the rescue

Green Infrastructure is…

- Parks
- Walking trails
- Open space plans
- Conservation areas
- Urban forests
- Water features
- Stream preservation
- Recharge zones
- Cisterns
- Bioretention
- Tree planters
- Reforestation
- Infiltration practices
- Permeable pavement
- Green roofs
- Rain gardens

This sort of boils down to:

“For ❶ Metro’s program the ❷ right volume must be ❸ retained on site”

Why should I Retain ?

"For Metro's program…"

Green Infrastructure: What are the drivers?

- TDEC – MS4: Post Construction Water Quality Treatment
- TMDL Regulatory Mandate
- CSO Reduction
- Rainwater Reuse
- Water Supply
- Groundwater Replenishment
- Pollution Removal
- Sustainable Cities
- LEED and other Ratings

MWS MS4 Permit Approach to Green Infrastructure (GI)

- **Currently voluntary**
  - – This is a national standard
  - – Try things out and learn together
  - – Mistakes are not noncompliance

- **Will be mandatory**
  - – We will make compliance-based changes and tweaks based on experience
  - – We will be ready

Metro's incentives for the use of GI

Table 1. Green Infrastructure Incentives	
Incentive	**Requirement/Benefit**
Waiver of Plan Review Fees	Certain stormwater and water/sewer plans review and application fees will be waived if GIPs are implemented according to this Volume.
Stormwater Fee Reduction	The stormwater user fee can be reduced 75% through implementation of the methods provided in the LID Manual.
Infill Water Quality	Sites within the Infill Boundary will have a runoff reduction credit of 60 % (versus 80%).
Green Roof Credit	Bonus Runoff Reduction percentage above the actual reduction rate has been incorporated into the Green Roof GIP to further encourage the use of green roofs.
Cisterns	While previously not allowed, in the LID Manual cisterns can be used to meet water quality requirements.
Reduced Detention Requirement (see Chapter 3.2.5.)	GIPs can reduce the required stormwater detention quantity.

Information on incentives will be updated on the Metro Stormwater LID Manual webpage

http://www.nashville.gov/stormwater/LIDManual.asp

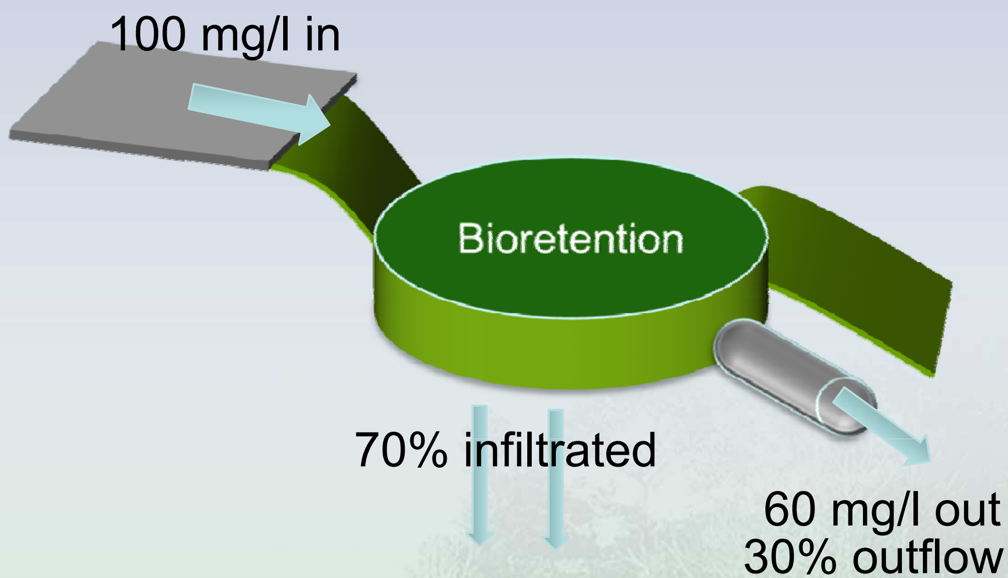
How much should I retain ?

“…the right volume…”

Why Is Volume Reduction Important?

- **Why Volume**
  - Groundwater recharge, maintain baseflow, reduce bank erosion
  - Volume is surrogate for pollution
  - Volume carries pollutants
- **Controls that remove volume are "golden"**

Average Annual Runoff

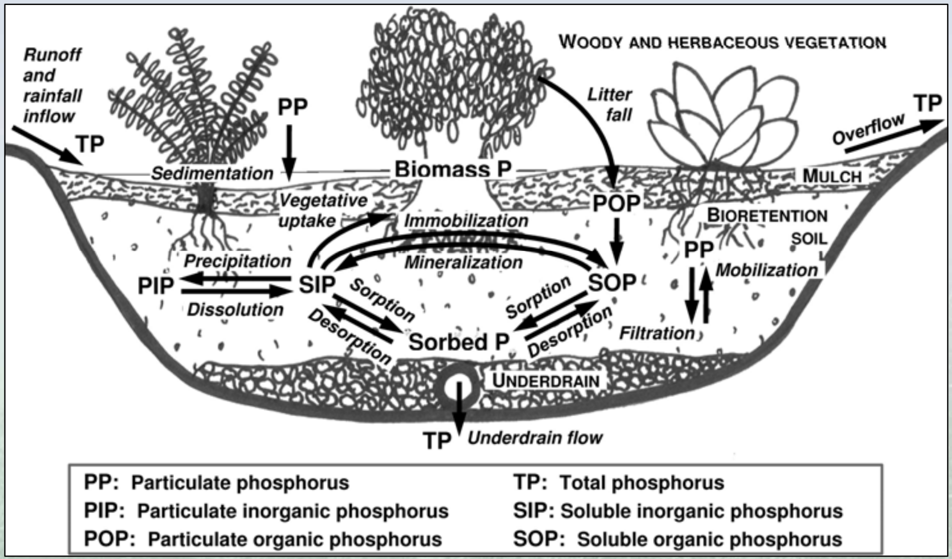


Old way = **40%** TSS removal

New way = **82%** TSS removal
also accounts for volume removal

Routing Pollutants to Soil Media

- **Studies have shown that with the exception of runoff from highly polluted urban hotspots groundwater is not contaminated and pollutants are broken down naturally or the concentrations are insufficient to cause pollution problems.**



Phosphorus Cycle within a typical Bioretention Cell Published in *Environ. Rev.* 18:159-173.

Weiss, et al, "Contamination of Soil and Groundwater Due to Stormwater Infiltration Practices – a Literature Review", University of Minnesota Proj. Rpt. No. 515, June 2008

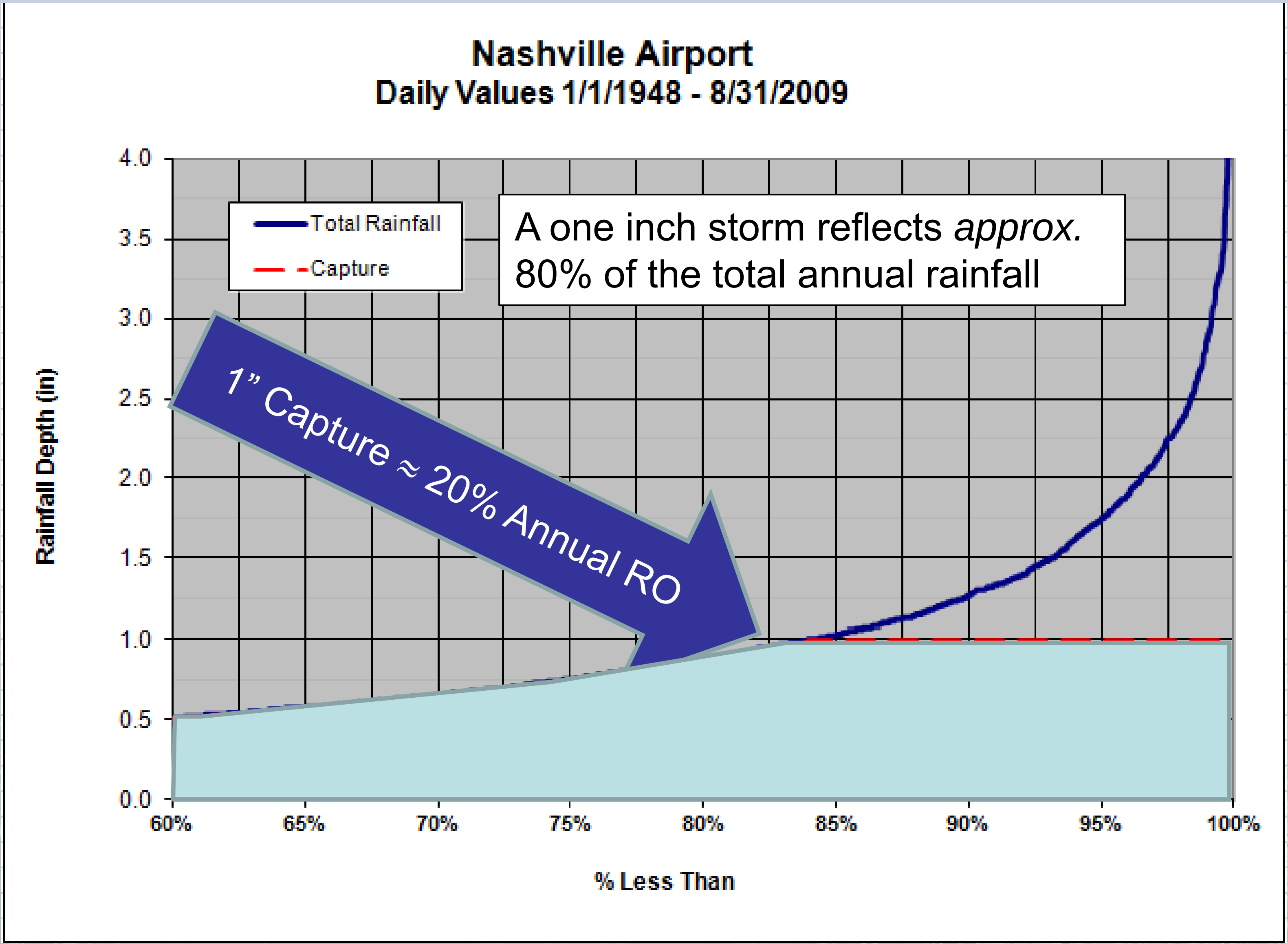
Permit Language

…built and maintained to infiltrate, evapotranspire, harvest and/or use… the stormwater runoff generated at a site by the first inch of every rainfall event preceded by 72 hours of no measurable precipitation… no runoff

Section 4.2.5.2.1

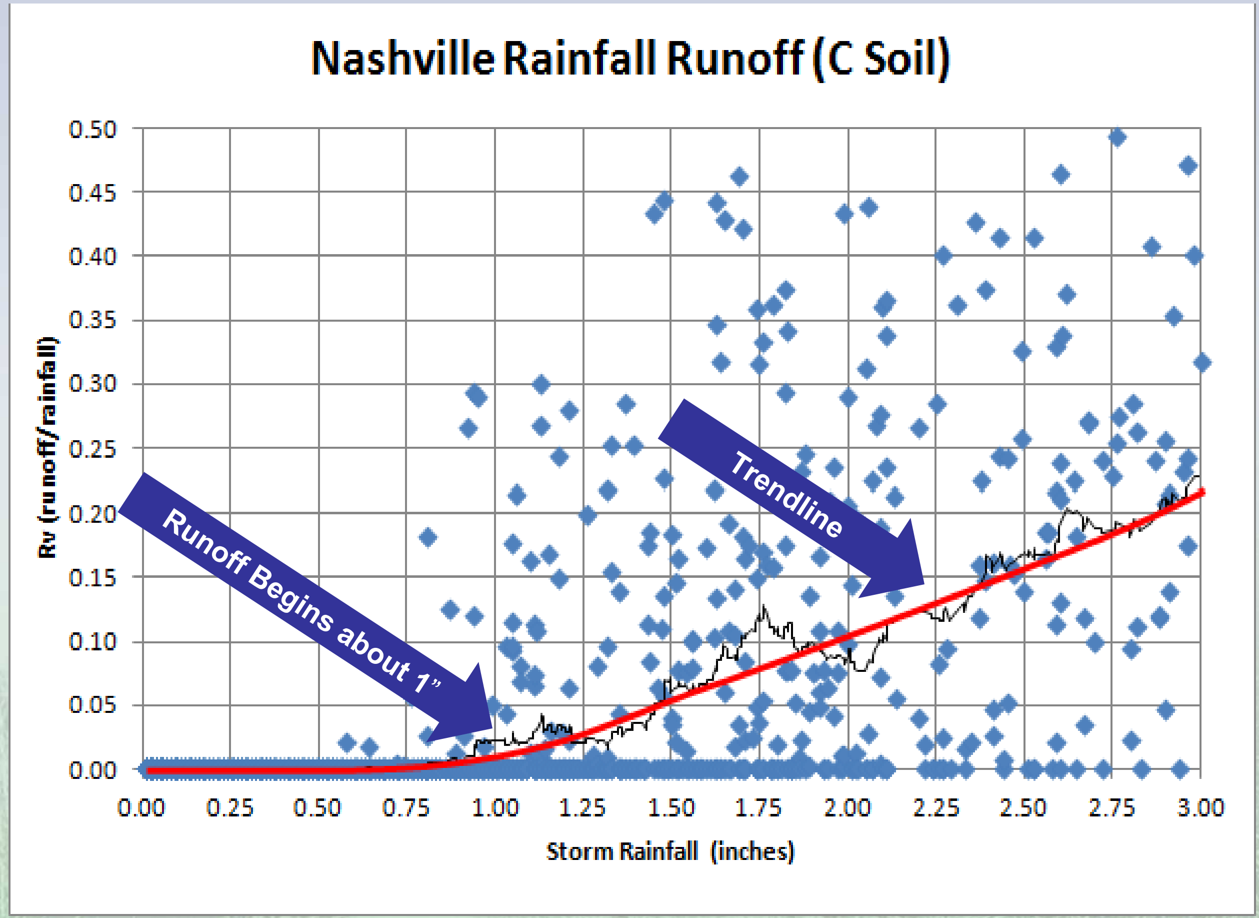
New Standard = Old Standard

Rainfall Capture



Choice of C Soil as Standard

- **72 hr IEDP Storms**
- **C Soil with turf demonstrates an ability to capture the first inch of most storms and give an overall Rv of 0.20**



MWS Standard

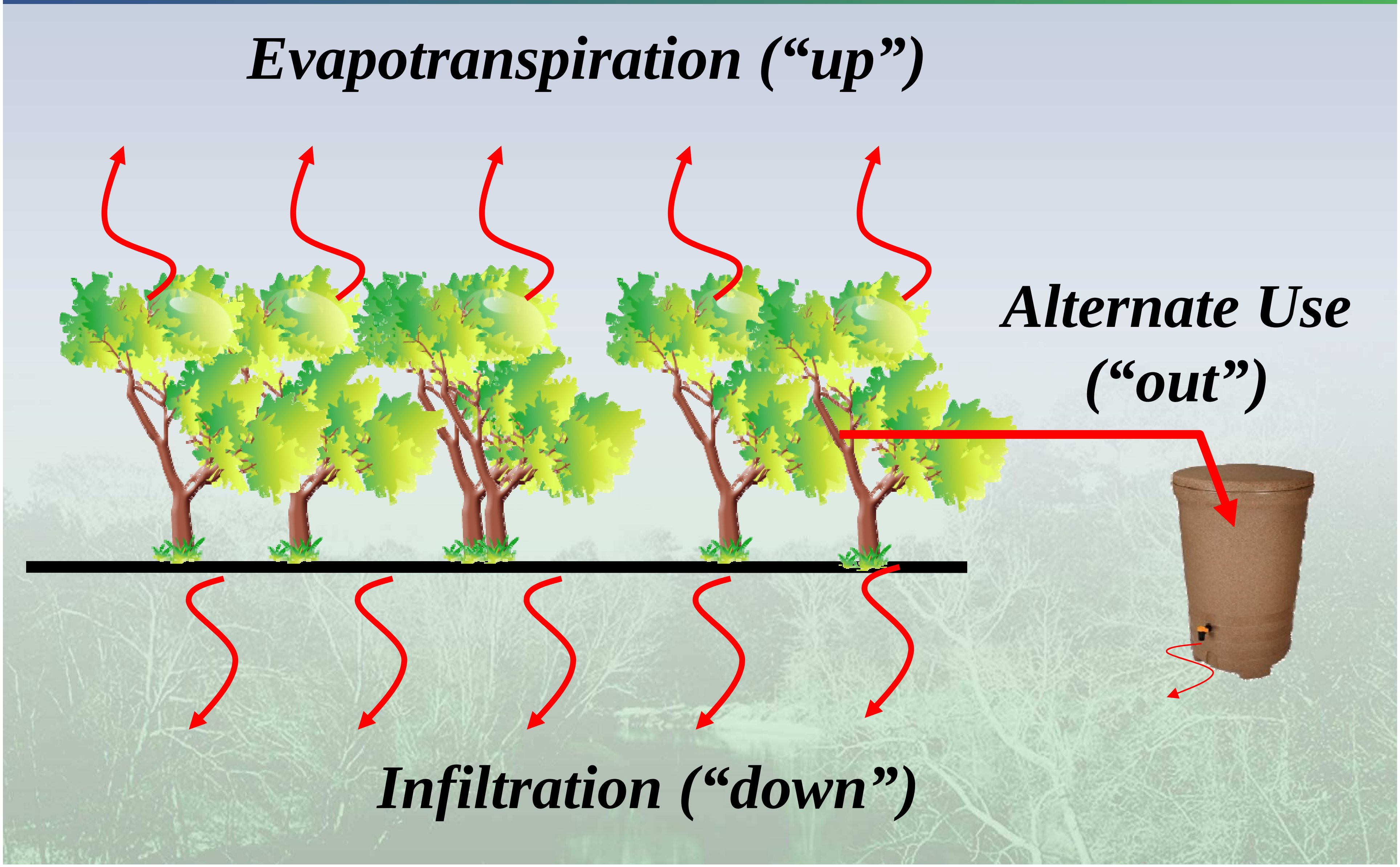
- Capture values based on national data and the Chesapeake Bay approach, modified by local analysis, and simplified
- One single criteria: Rv ≤ 0.20 is compliance
  - If the site has an Rv ≤ 0.20 then on average the site captures the first inch of rainfall
  - Structures are designed to capture the right volume to bring about an Rv ≤ 0.20

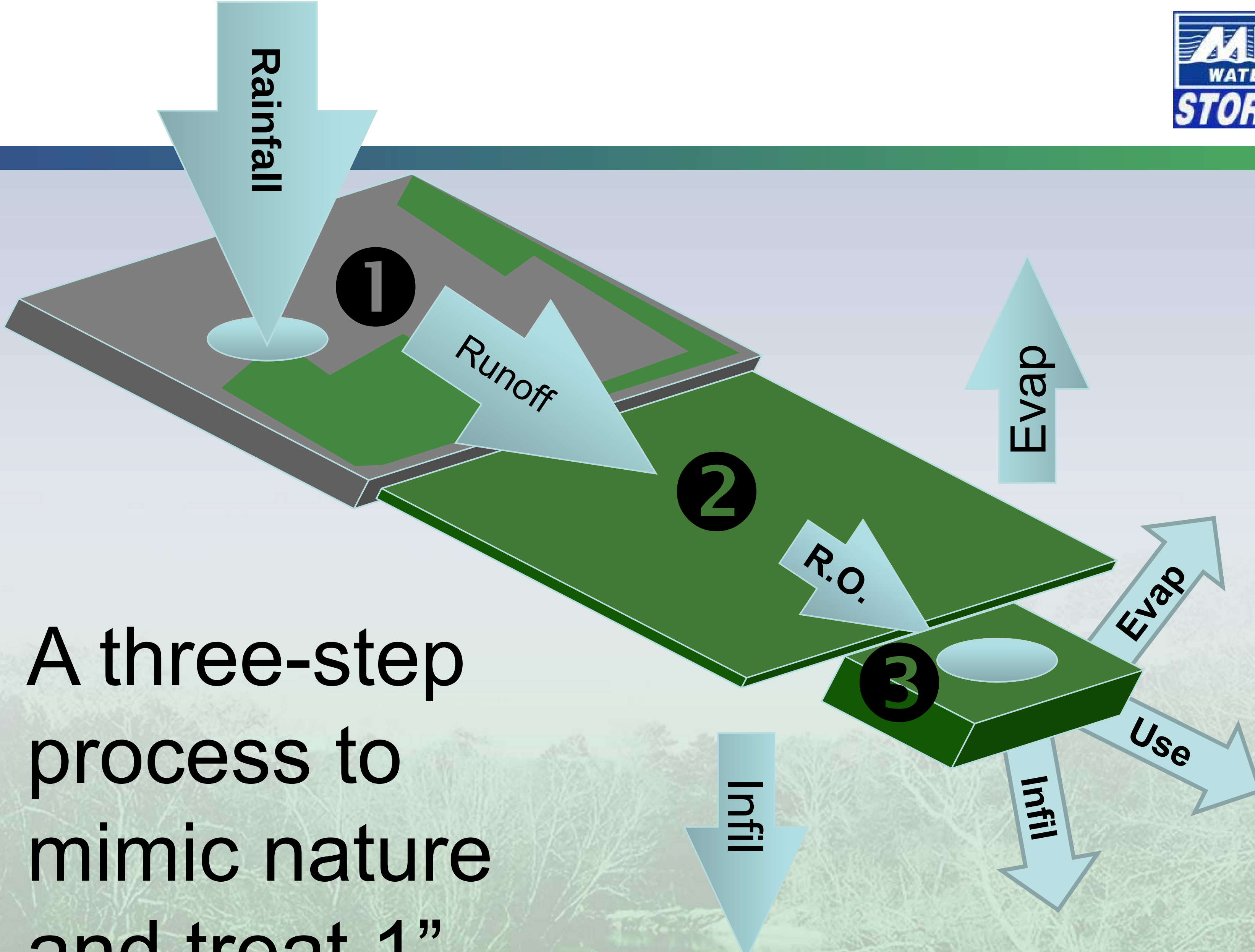
So – defining a site with an annual Rv of 0.20 is like saying we will capture one inch

What does "retain" mean and how do I do it?

"…must be <u>retained</u> on site"

“retain” means...





A three-step process to mimic nature and treat 1”

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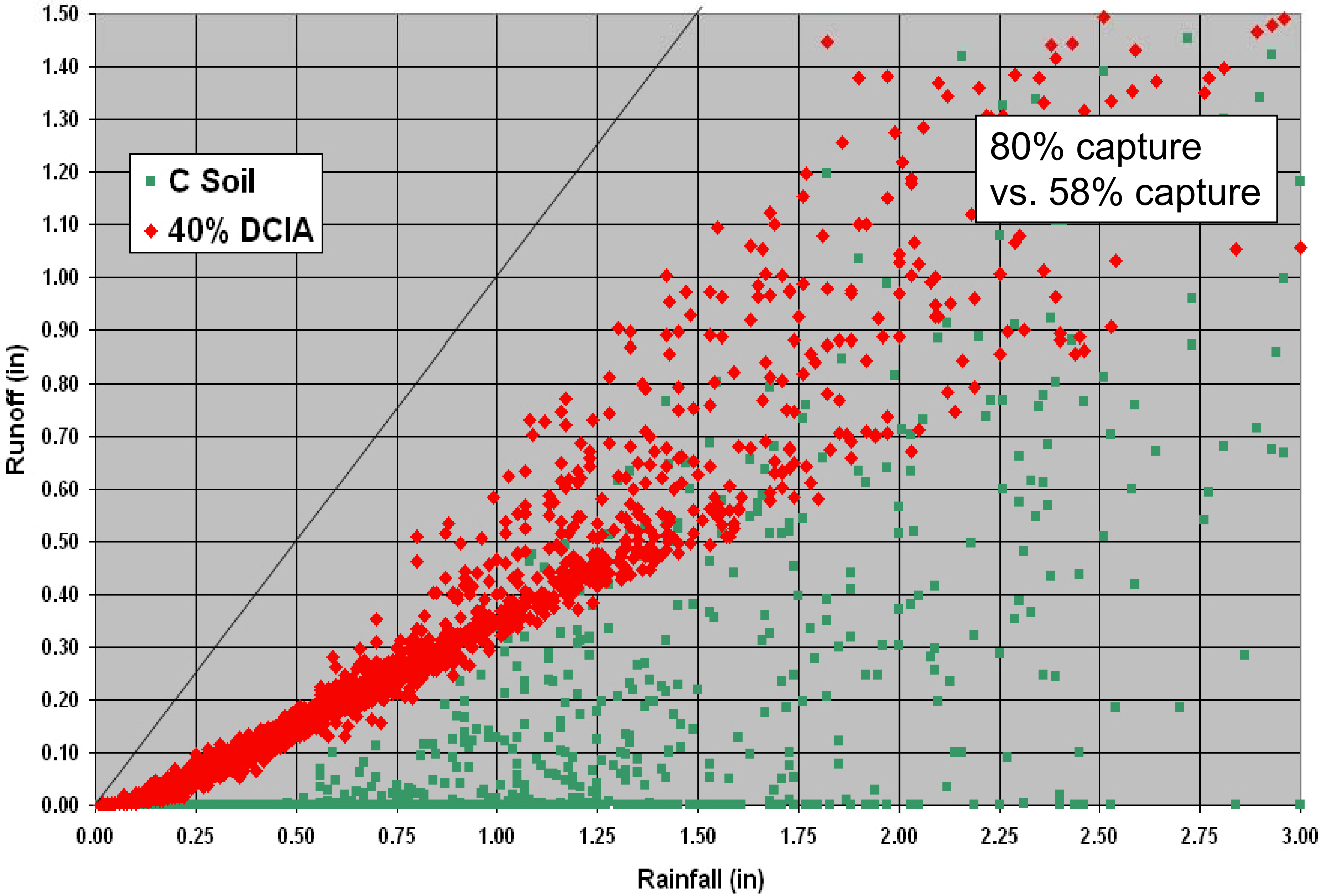
Green Infrastructure Design Steps and Associated GIPs

Andy Reese

AMEC


40% Directly Connected Impervious
Area (DCIA), HSG-C, 2.5 Acres

C Soil + 40% DCIA



Step 1 – Land Cover Layout

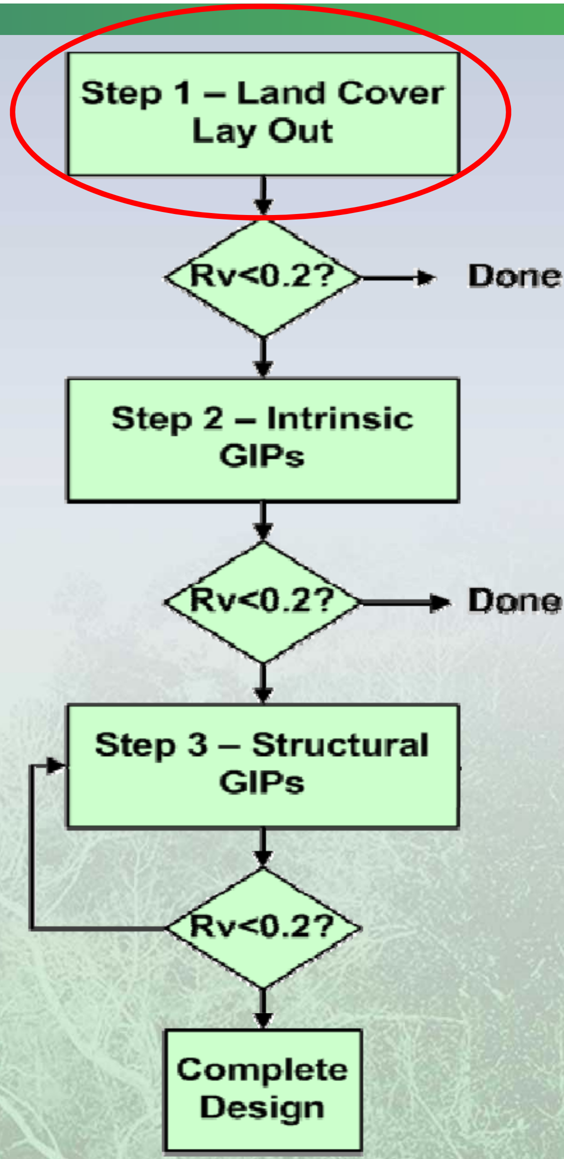
1. Landcover lay out

Goal:

(1) minimize impervious cover and mass site grading

(2) maximize the retention of forest and vegetative cover, natural areas and undisturbed soils; especially those most conducive to landscape-scale infiltration.

Design activities: impervious area minimization, reduced soil disturbance, forest preservation, etc.



Establish Site Weighted Rv

Step 1 - Site Cover Runoff Coefficients				
Soil Condition	**Runoff Coefficient (Rv)**			
Impervious Cover	0.95			
Hydrologic Soil Group	**A**	**B**	**C**	**D**
Forest Cover	0.02	0.03	0.04	0.05
Turf	0.15	0.18	0.20	0.23

$$Rv = \frac{\text{Runoff}}{\text{Rainfall}} \leq 0.2$$

Step 1 - Rv Calculation

Area	Acres	Rv
IA	1	0.95
Turf C	1.5	0.20
TOTALS	**2.5**	**0.50**

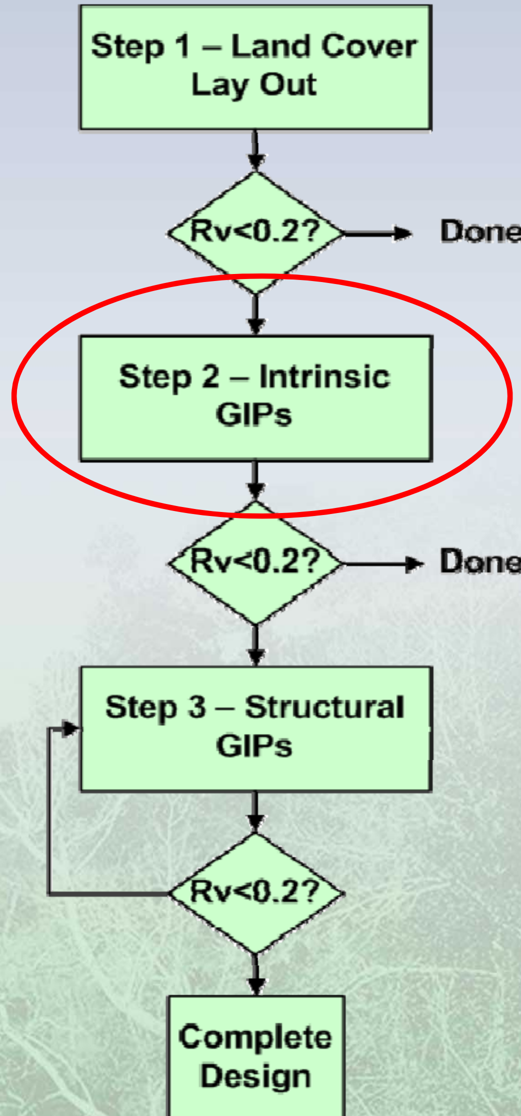
Weighted Rv
Goal is to get this ≤ 0.20

Step 1a & 2 – Intrinsic Green Infrastructure Practices (GIPs)

1. **Landcover lay out**
2. **Intrinsic GIPs**

Goal: enhance the ability of the background land cover to reduce runoff volume

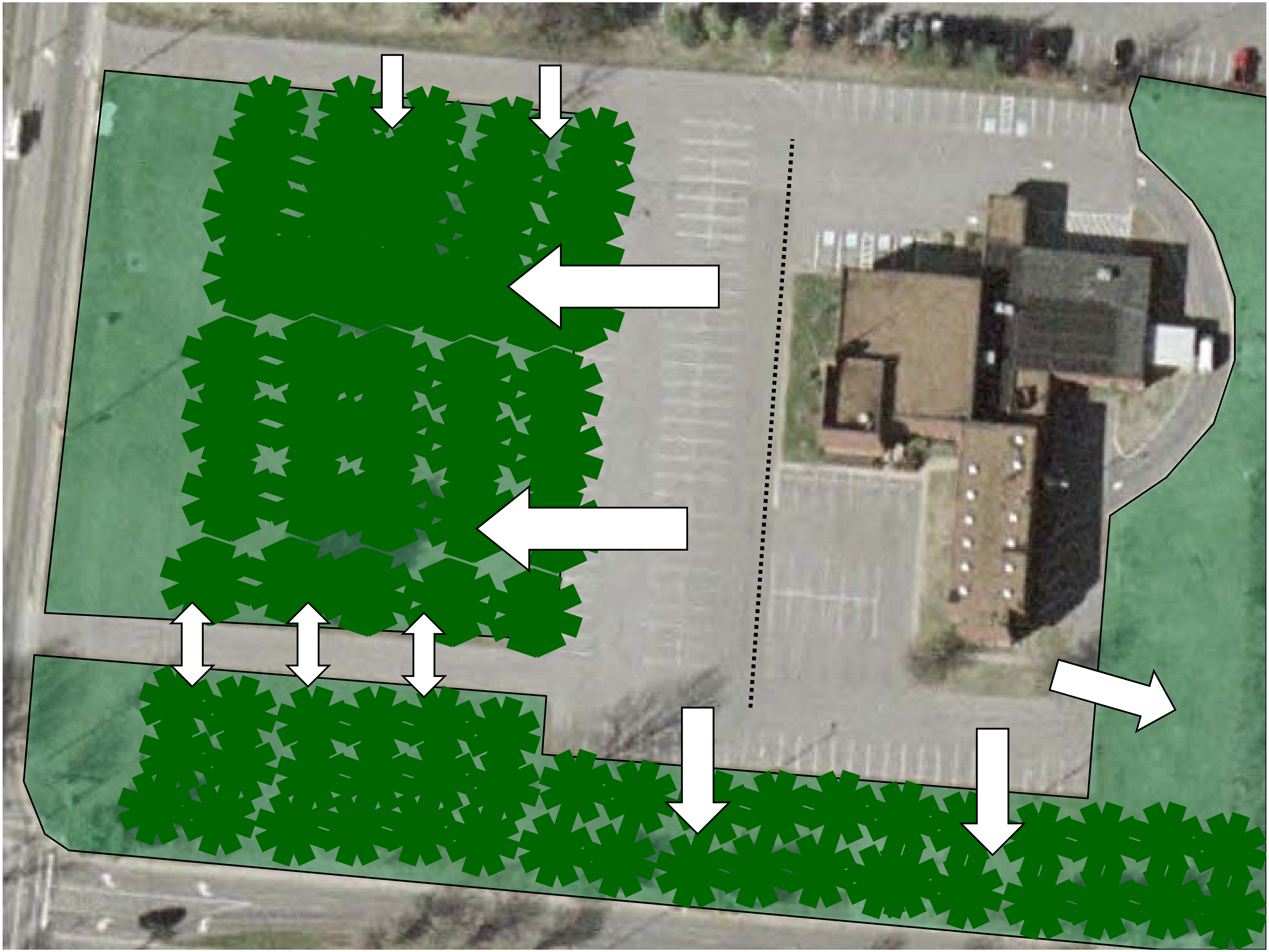
Design activities: disconnection of impervious areas (e.g. rooftops) to sheet flow, amended soils, green roofs, and reforestation.



Step 2 Design Information

Step 2 - Green Infrastructure Practices				
Soil Condition	Percent Capture			
	Level 1		Level 2	
Disconnection – downspout	25		50	
Grass Channel	10/20		20/40	
Disconnection – sheet flow	50		75	
Reforestation (A, B, C, D soils)	96	94	92	90
Green Roof	80		90	

Percent Capture = 1 - Rv

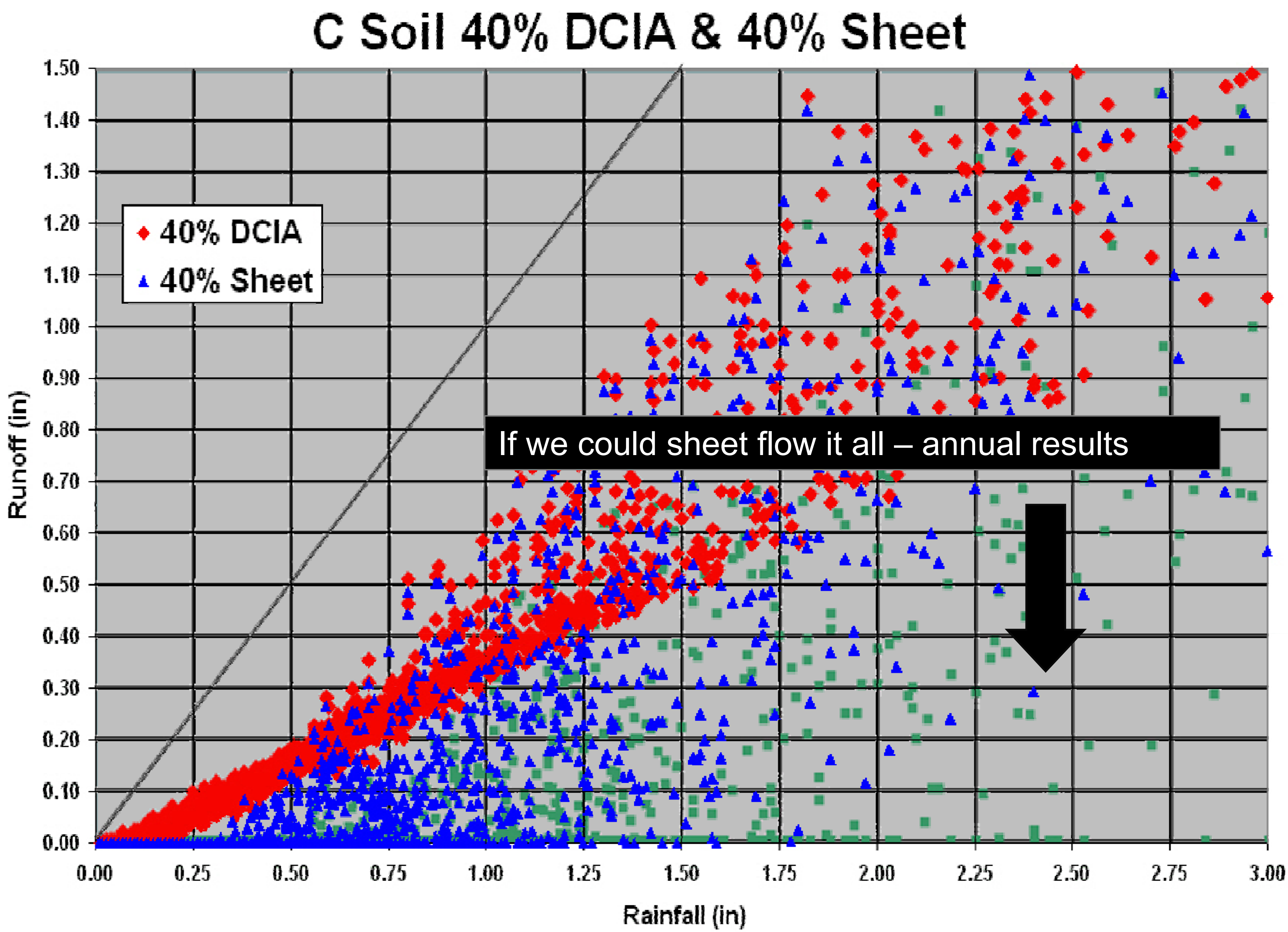


Step 2 - Rv Calculation

Reforestation and Sheet Flow

New Rv = 0.322 > 0.20

Almost there…



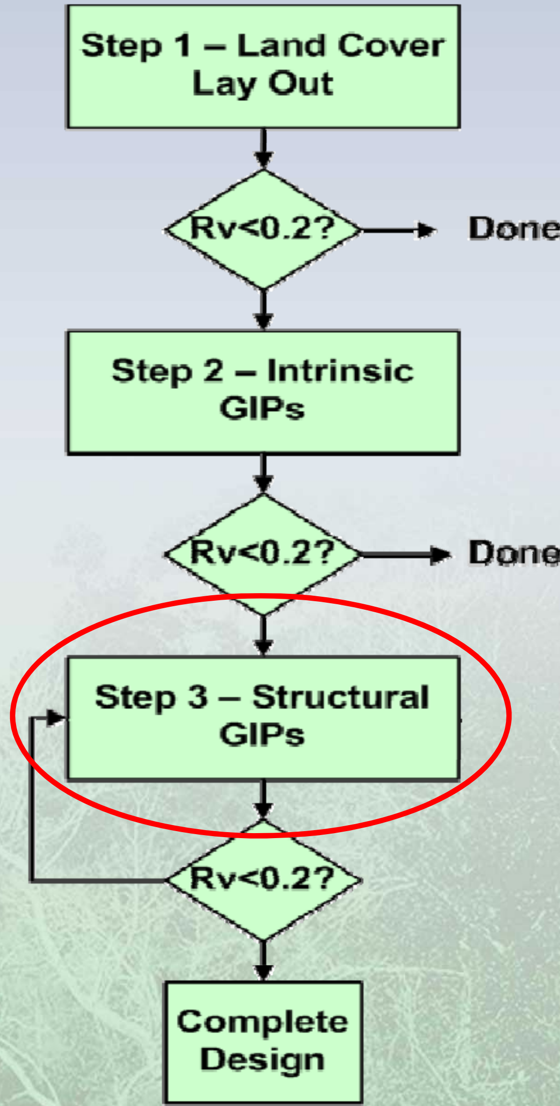
C Soil 40% DCIA & 40% Sheet
40% DCIA
40% Sheet
If we could sheet flow it all – annual results
Runoff (in)
Rainfall (in)
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
2.75
3.00

Step 3 Structural GIPs

1. **Landcover lay out**
2. **Intrinsic GIPs**
3. **Structural GIPs**

Goal: Use GIPs to attain 1” capture and Rv ≤ 0.20

Design activities: infiltration trench, bioretention, permeable pavement, cisterns, water quality swales and dry pond.



Step 3 GIPs

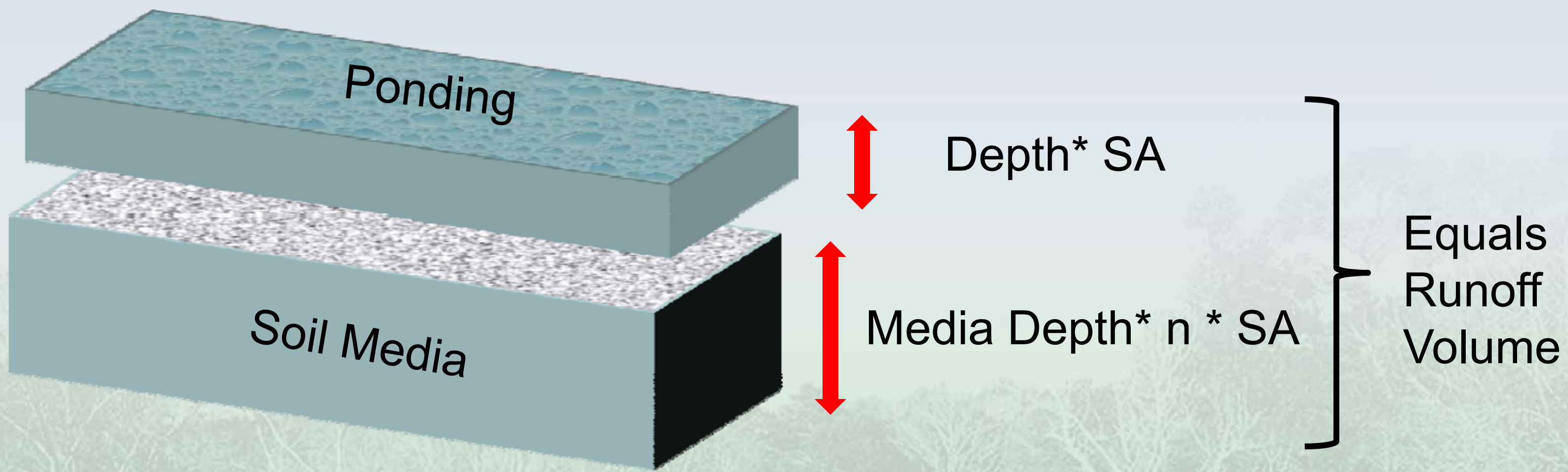
Step 3 - Green Infrastructure Practices		
Soil Condition	Percent Capture	
	Level 1	Level 2
Bioretention/Bioinfiltration	60	80
Urban Bioretention	60	-
Permeable Pavement	45	75
Infiltration Trench	50	90
Water Quality Swale	40	60
Dry Pond (Extended Det.)	0	15

Percent Capture = 1-Rv

$$T_v = \frac{P R_v A}{12}$$

Sizing of Infiltration GIPs

Simplified sizing based on continuous simulation modeling results

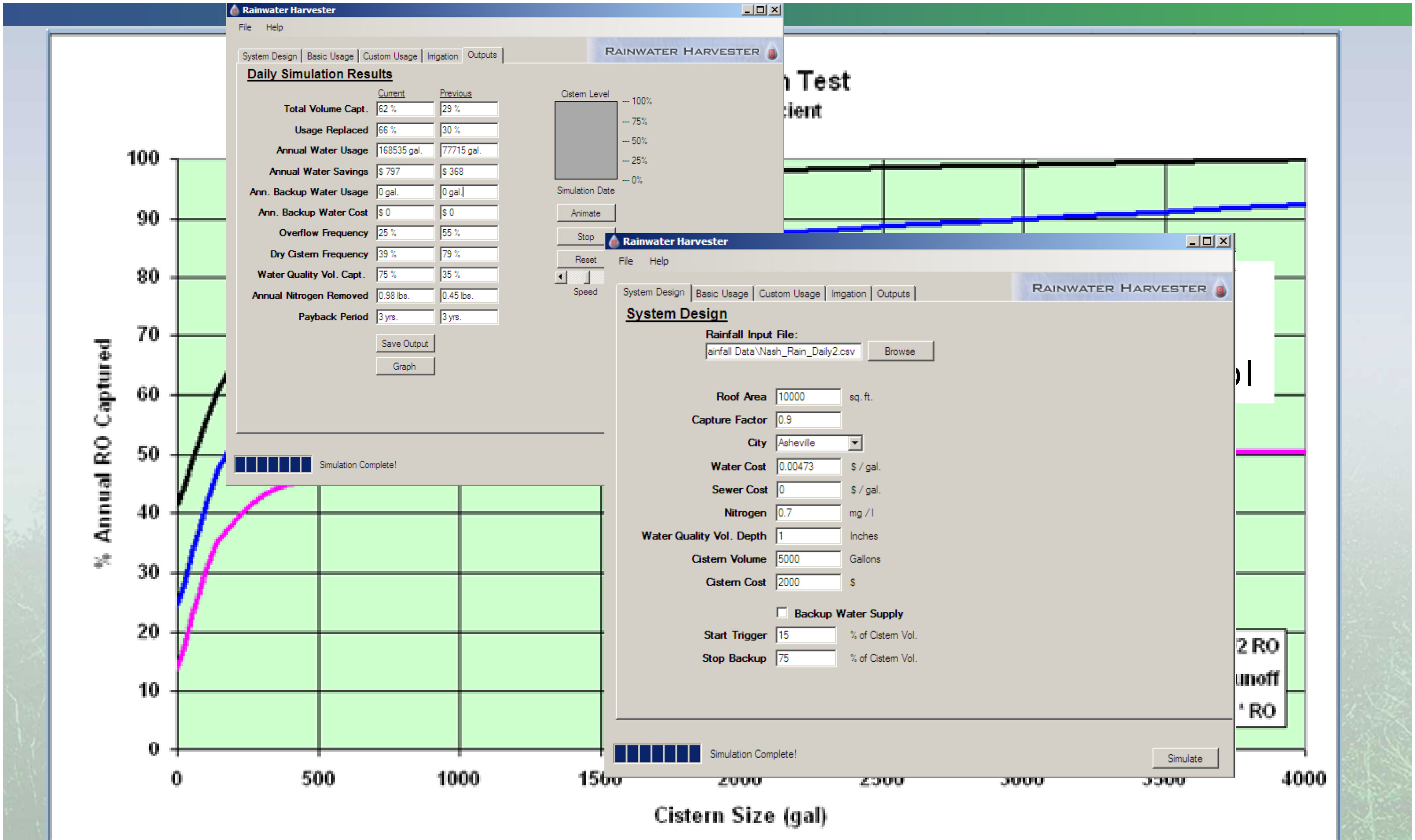


CN is reduced for flood control predictions
Can do controls in series

Design Modifications for Volume

Table 2. Level 1 and Level 2 Design Summaries				
Control	**Level 1**		**Level 2**	
Bioretention	C or D soils with Underdrain		Infiltration > 0.5 in/hr or stone sump, 3' media depth, less than 20:1 ratio	
Tree Planter Boxes*	n/a		n/a	
Permeable Pavement	C or D soils with Underdrain		Infiltration > 0.5 in/hr	
Infiltration	C or D soils with Underdrain		Infiltration > 0.5 in/hr	
Dry Swale	C or D soils with Underdrain		Stone layer or Infiltration > 1.0 in/hr, flat slope	
Grass Channel	C/D soils to A/B soils		Bed of amended soils	
Extended Detention	Lined		Unlined	
Soil Amendment	Downstream from disconnection		Soil surface only	
Disconnection – downspout	To grassy areas C/D soils		To grassy areas A/B soils	
- To amended soils	50		50	
- To rain garden	50		75 with infiltration > 0.5 in/hr	
Disconnection – sheet flow	C or D soils		A or B soils	
Reforestation (A, B, C, D soils)	96	94	92	90
- With amended soils below	98	97	96	95
Rain Tanks/Cisterns	n/a		n/a	
Green Roof	n/a		n/a	

Rainwater Tanks/Cisterns



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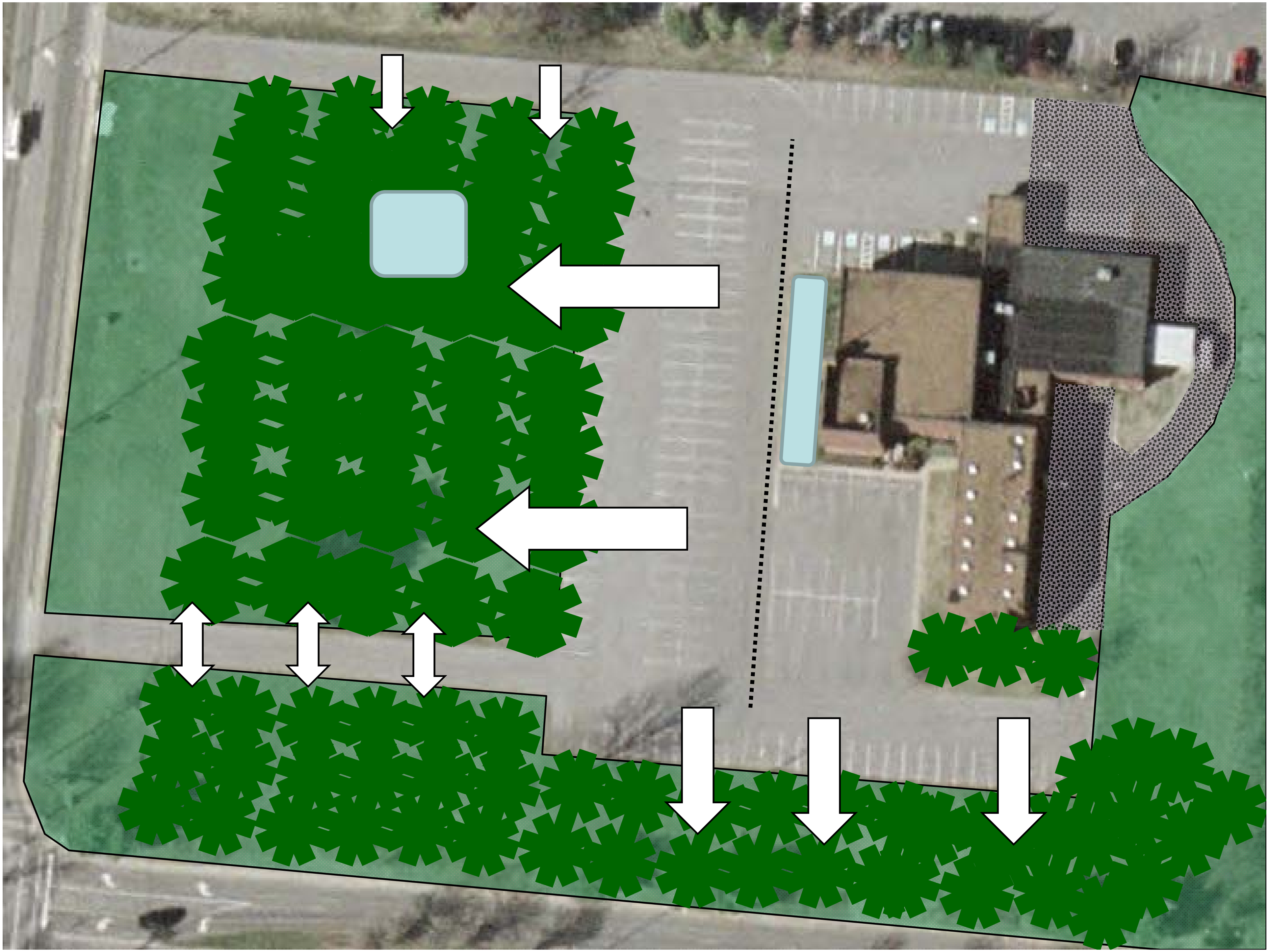


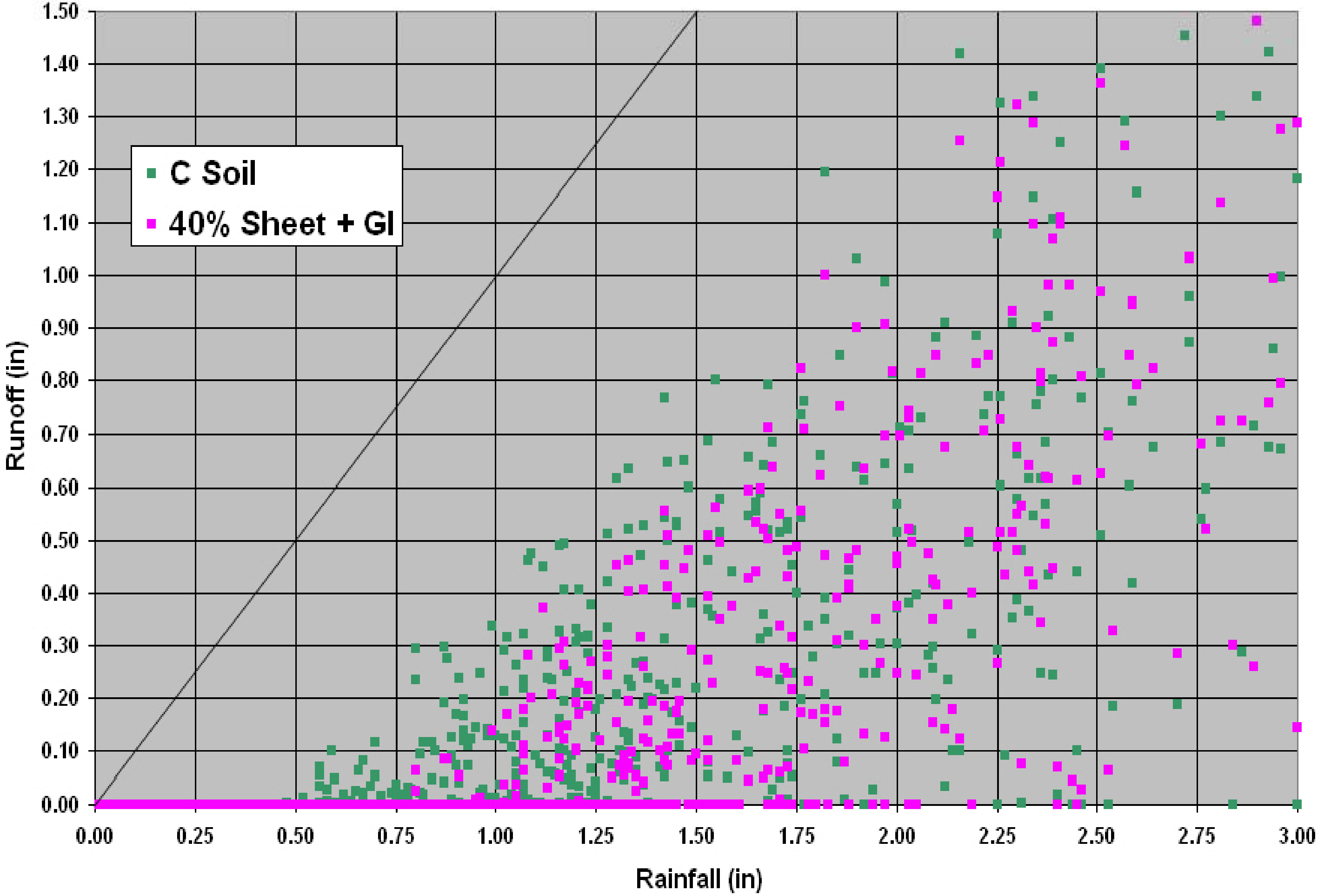
Step 3 - Rv Calculation

Reforestation, Sheet Flow, and Structural GIPs

New Rv = 0.184 < 0.20

You have arrived

C Soil + Sheet Flow and Green Infrastructure



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Simple Example Site and the Tool

Sara Johnson

AMEC

Runoff Coefficient and Runoff Reduction Credit

Rv

Table 2. Site Cover Runoff Coefficients				
Soil Condition	Volumetric Runoff Coefficient (Rv)			
Impervious Cover	0.95			
Hydrologic Soil Group	A	B	C	D
Forest Cover	0.02	0.03	0.04	0.05
Turf	0.15	0.18	0.20	0.23

RR Credit

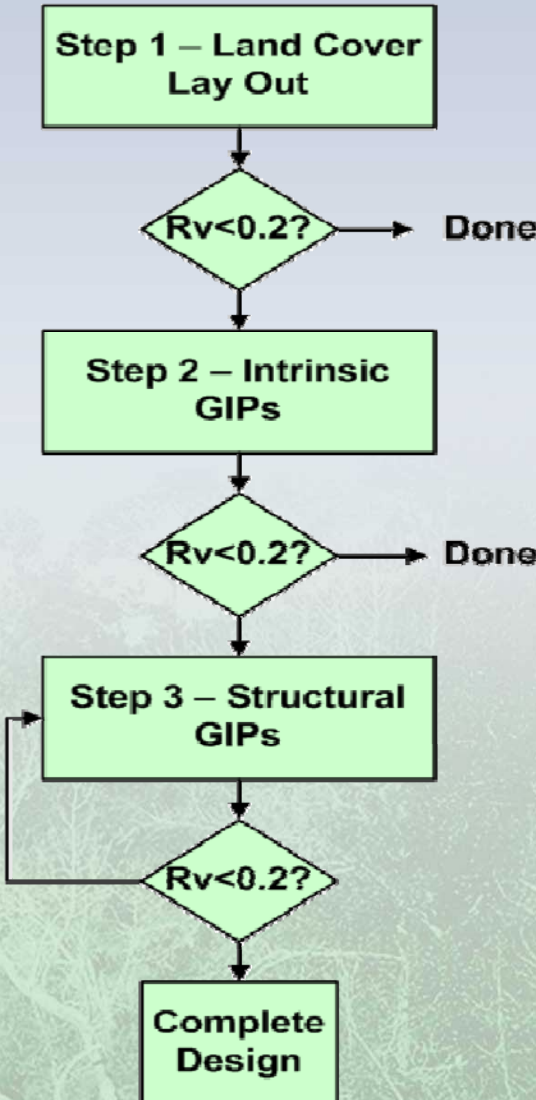
Table 3. Green Infrastructure Practices Runoff Reduction Credit Percentages								
Green Infrastructure Practice	% Rainfall Volume Removed/Captured – RR Credit							
	Level 1				Level 2			
1. Bioretention	60				80			
2. Urban Bioretention	60				N/A			
3. Permeable Pavement	45				75			
4. Infiltration Trench	50				90			
5. Water Quality Swale	40				60			
6. Extended Detention	15				N/A			
7. Downspout Disconnection*	25				50			
8. Grass Channel	10/20				20/30			
9. Sheet Flow *	50				75			
10. Reforestation (A, B, C, D soils)	96	94	92	90	98	97	96	95
11. Rain Tanks/Cisterns	Design dependant							
12. Green Roof	80				90			

Design Considerations

- **What lies beneath the surface on a site?**
  - What hydrologic soil group: A, B, C, D
  - Depth to seasonal high water table
  - Depth to bedrock, karst features
  - Infiltration rate
  - Existing infiltration issues on site/in vicinity
- **Amended soils**
  - Must follow specifications for credit

LID Calculation Tool Preview

- **3 Design Steps**
- **Rv Weighted Average (site)**
- **Treatment Volume Calculations**
- **Easy "What if _____?" scenarios**



MWS Green Infrastructure Site Worksheet

Project Name	*Sample*
Parcel Identification #	*1234*
Engineer	*John E. Designer*
Address	*Low Impact Designers, 100 Green Street, Nashville, TN, 37206*
E-mail	*john.e.designer@green.com*

Instructions

1. Input cells are in Green
2. Break Site Into Sub areas by single soils and land use type combinations
3. Assign a code to each subarea and input the code into column R
4. Input the subarea drainage area in column S
5. Input treatment credit code (Column U) for the first tier of treatments
6. Input additional treatment code as desired (Column X) for any subarea
7. Adjust until you reach 80% reduction or better (**Cell AC34** turns green if 80% reached)
8. If 80% reduction is not reached and it has been decided that GIPs in series is an option use Step 3a to place GIPs in series . Their respective treatment volumes are calculated in column AL. This volume is separate from GIPs upstream.
9. When using GIPs in Series the user will look to **Cell AI34** for confirmation the 80% goal has been met.

	Basic Land Use Category	Land Use	Code (Lookup Table)	Rv	R Credit
Step 1 Basic Land Use	**Basic Land Use**	Impervious Surface	**IA**	0.95	0.05
		Forest A Soil	**FA**	0.02	0.98
		Forest B Soil	**FB**	0.03	0.97
		Forest C Soil	**FC**	0.04	0.96
		Forest D Soil	**FD**	0.05	0.95
		Turf A Soil	**TA**	0.15	0.85
		Turf B Soil	**TB**	0.18	0.82
		Turf C Soil	**TC**	0.2	0.8
		Turf D Soil	**TD**	0.23	0.77
Step 1a Modified Land Use	**Reforestation**	A	**RA**	0.04	0.96
		B	**RB**	0.06	0.94
		C	**RC**	0.08	0.92
		D	**RD**	0.1	0.9
		A Amended	**RAA**	0.02	0.98
		B Amended	**RBA**	0.03	0.97
		C Amended	**RCA**	0.04	0.96
		D Amended	**RDA**	0.05	0.95
	Green Roof	1	**G1**	0.2	0.8
		2	**G2**	0.1	0.9

	GI Practice	Level	Code (Lookup Table)	R Credit	Rv	Tv Multiplier
Step 2 Intrinsic GIPs	Downspout Disconnection	A/B Soil	**DAB**	0.5	0.5	0.00
		C/D Soil	**DCD**	0.25	0.75	0.00
		Amended	**DAS**	0.5	0.5	0.00
	Sheet Flow	Cons Area A/B	**SAB**	0.75	0.25	0.00
		Cons Area C/D	**SCD**	0.5	0.5	0.00
		Strip A	**SA**	0.5	0.5	0.00
		Strip Amended	**SAS**	0.5	0.5	0.00
Step 3 & 3a Structural GIPs	Permeable Pavement	1	**P1**	0.45	0.55	1.00
		2	**P2**	0.75	0.25	1.10
	Grass Channel	A/B Soil	**GAB**	0.2	0.8	0.00
		C/D Soil	**GCD**	0.1	0.9	0.00
		A/B Amended	**GAA**	0.4	0.6	0.00
		C/D amended	**GCA**	0.2	0.8	0.00
	Biorentention/ Rain Garden	1	**B1**	0.6	0.4	1.00
		2	**B2**	0.8	0.2	1.25
	Water Quality Swales	1	**S1**	0.4	0.6	1.00
		2	**S2**	0.6	0.4	1.10
	Infiltration Trench	1	**I1**	0.5	0.5	1.00
		2	**I2**	0.9	0.1	1.10
	Urban Bioretention	1	**UB**	0.4	0.6	1.00
	Dry Pond	2	**D1**	0.15	0.85	0.00
	Cistern		**CIS**	0.01	0.99	1.00

Capture Depth=	**1**	**inch**
Cistern Capture=	**1**	**inch(es) capture**

Percent Volume Reduction-Based Calculations

Step 1: Lay out the site and divide it into sub-areas each of a specific land use type and Rv.				Step 1a: Change any basic land use types through reforesting or green roofs - or through use of open space for a GIP.			Step 2: Treat impervious areas through the use of disconnection or sheet flow			Step 3: Treat primarily impervious areas with structural GIPs either in series with Step 2 intrinsic GIPs or alone downstream from Steps 1 and 1a land use.			Size controls for Step 3 by assigning structure ID to each sub-area, combining sub-areas into one structure if appropriate.			Step 3a Treatment in Series Calculation - Place Structural GIPs in same row as upstream GIP			Size controls for Step 3a in series by assigning a sequential structure ID to each area treated in series.		
Step1 Basic Land Use				**Step 1a Modified LU**			**Step 2 Intrinsic GIPs**			**Step 3 Structural GIPs**			**Structure ID**	**IA Capture**		**Step 3a Structural GIPs in Series**			**Structure ID**	**IA Capture**	
Subarea	Code	Acres	Base Rv	Code	Acres	Eff Rv1	Code	Trtmt VR1	Eff Rv2	Code	Trtmt VR2	Eff Rv3		Tv Multiplier	Tv (cf)	Code	Trtmt VR2	Eff Rv4		Tv Multiplier	Structure in Series Tv (cf)
1	IA	0.5	0.95	G2	0.5	0.10		0	0.10		0	0.10		0.00	-		0	0.10		0.00	-
2	IA	1	0.95	IA	1	0.95		0	0.95	B2	0.8	0.19	1	1.25	4,311		0	0.19		0.00	-
3			0.00		0	0.00		0	0.00		0	0.00		0.00	-		0	0.00		0.00	-
4			0.00		0	0.00		0	0.00		0	0.00		0.00	-		0	0.00		0.00	-
5			0.00		0	0.00		0	0.00		0	0.00		0.00	-		0	0.00		0.00	-
6			0.00		0	0.00		0	0.00		0	0.00		0.00	-		0	0.00		0.00	-
7			0.00		0	0.00		0	0.00		0	0.00		0.00	-		0	0.00		0.00	-
8			0.00		0	0.00		0	0.00		0	0.00		0.00	-		0	0.00		0.00	-
9			0.00		0	0.00		0	0.00		0	0.00		0.00	-		0	0.00		0.00	-
10			0.00		0	0.00		0	0.00		0	0.00		0.00	-		0	0.00		0.00	-
11			0.00		0	0.00		0	0.00		0	0.00		0.00	-		0	0.00		0.00	-
12			0.00		0	0.00		0	0.00		0	0.00		0.00	-		0	0.00		0.00	-
13			0.00		0	0.00		0	0.00		0	0.00		0.00	-		0	0.00		0.00	-
14			0.00		0	0.00		0	0.00		0	0.00		0.00	-		0	0.00		0.00	-
15			0.00		0	0.00		0	0.00		0	0.00		0.00	-		0	0.00		0.00	-
16			0.00		0	0.00		0	0.00		0	0.00		0.00	-		0	0.00		0.00	-
17			0.00		0	0.00		0	0.00		0	0.00		0.00	-		0	0.00		0.00	-
18			0.00		0	0.00		0	0.00		0	0.00		0.00	-		0	0.00		0.00	-
19			0.00		0	0.00		0	0.00		0	0.00		0.00	-		0	0.00		0.00	-
20			0.00		0	0.00		0	0.00		0	0.00		0.00	-		0	0.00		0.00	-
	Weighted Rv		0.95	Weighted Rv		0.667	Weighted Rv		0.667	Weighted Rv		0.160		Step 3 Tv Total	**4,311**			0.160		Final Tv Total	**4,311**
	Total Area=	1.5	1.43	Total Area=	1.5	1.00			1.00			0.24						0.24			
% Removal (Goal ≥80%)-->			5.0%	% Removal		33.3%	% Removal		33.3%	% Removal		**84.0%**				% Removal		**84.0%**			

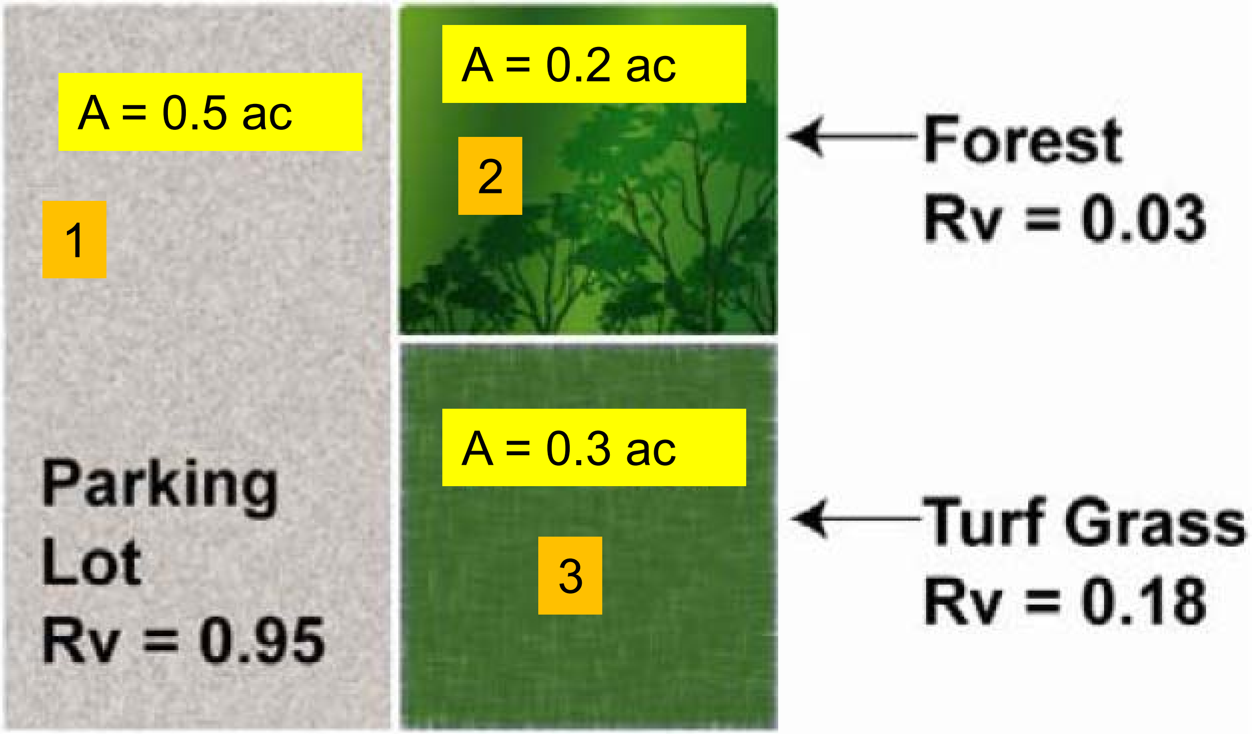
THIS MUST BE 80% OR GREATER
IT WILL TURN GREEN WHEN IT IS

THIS MUST BE 80% OR GREATER
IT WILL TURN GREEN WHEN IT IS

Example Site

- **1 ac site, B soils**

Table 2. Site Cover Runoff Coefficients				
Soil Condition	Volumetric Runoff Coefficient (Rv)			
Impervious Cover	0.95			
Hydrologic Soil Group	A	B	C	D
Forest Cover	0.02	0.03	0.04	0.05
Turf	0.15	0.18	0.20	0.23



Step 1- Basic Land Use

- **Site Weighted Rv**

$$= \frac{\sum(A_i \times Rv_i)}{A_T}$$

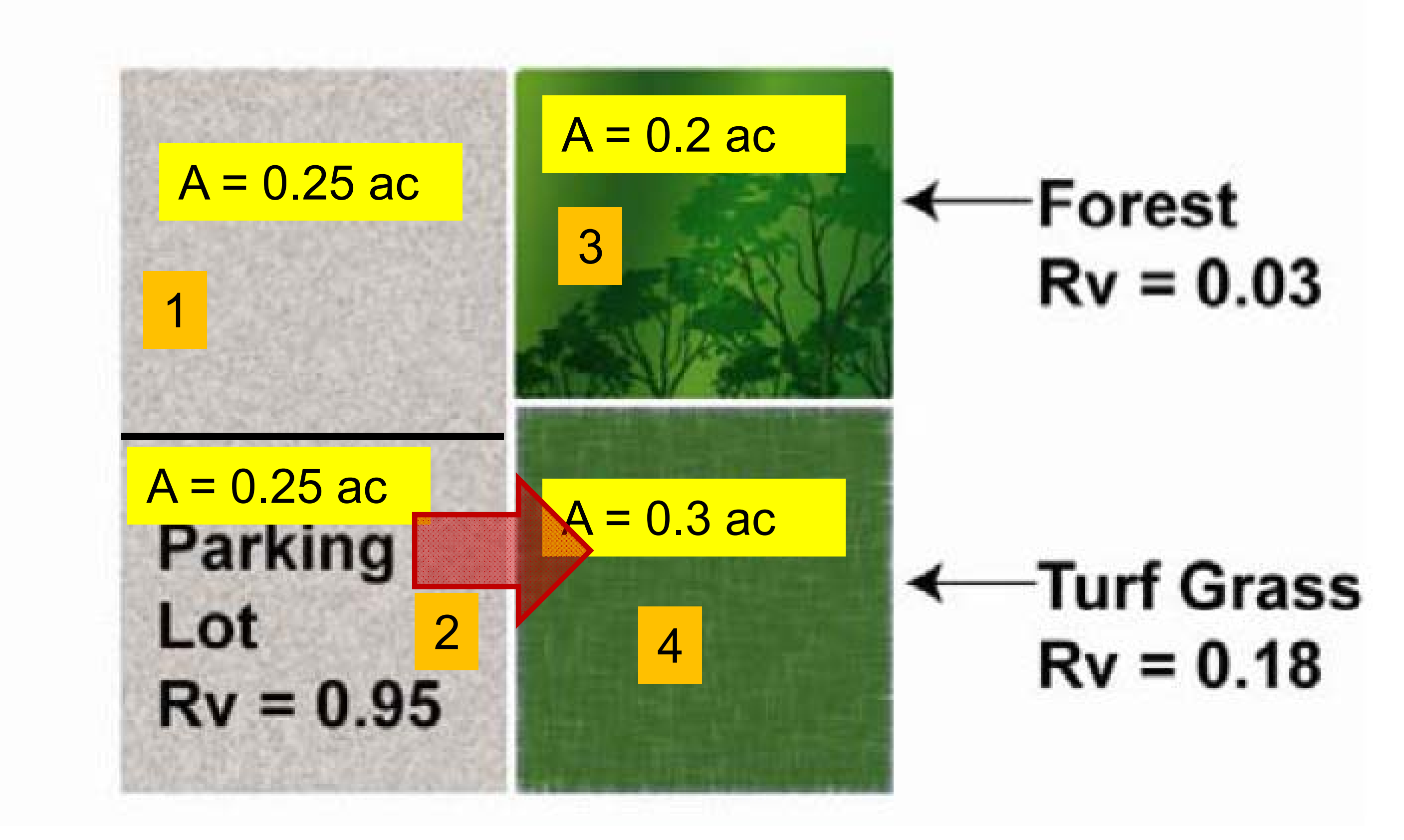
Site Weighted Rv = 0.54 >> 0.20

Step 1: Lay out the site and divide it into sub-areas each of a specific land use type and Rv.

Step1 Basic Land Use			
Subarea	Code	Acres	Base Rv
1	IA	0.5	0.95
2	FB	0.2	0.03
3	TB	0.3	0.18
4			0.00
5			0.00
6			0.00
7			0.00
8			0.00
9			0.00
10			0.00
	Weighted Rv		0.54
	Total Area=	1	0.54
% Removal (Goal ≥80%)-->			46.5%

Step 2 – Intrinsic GIPs

- **Sheet Flow ½ of Parking Lot (IA) to Turf B**



Step 2 – Intrinsic GIPs

- **Sheet Flow ½ of Parking Lot (IA) to Turf B**
  - GIP Rv = Rv*(1-RR Credit)

Impervious Area

Impervious Area to Sheet Flow B Soil

Forest B soil

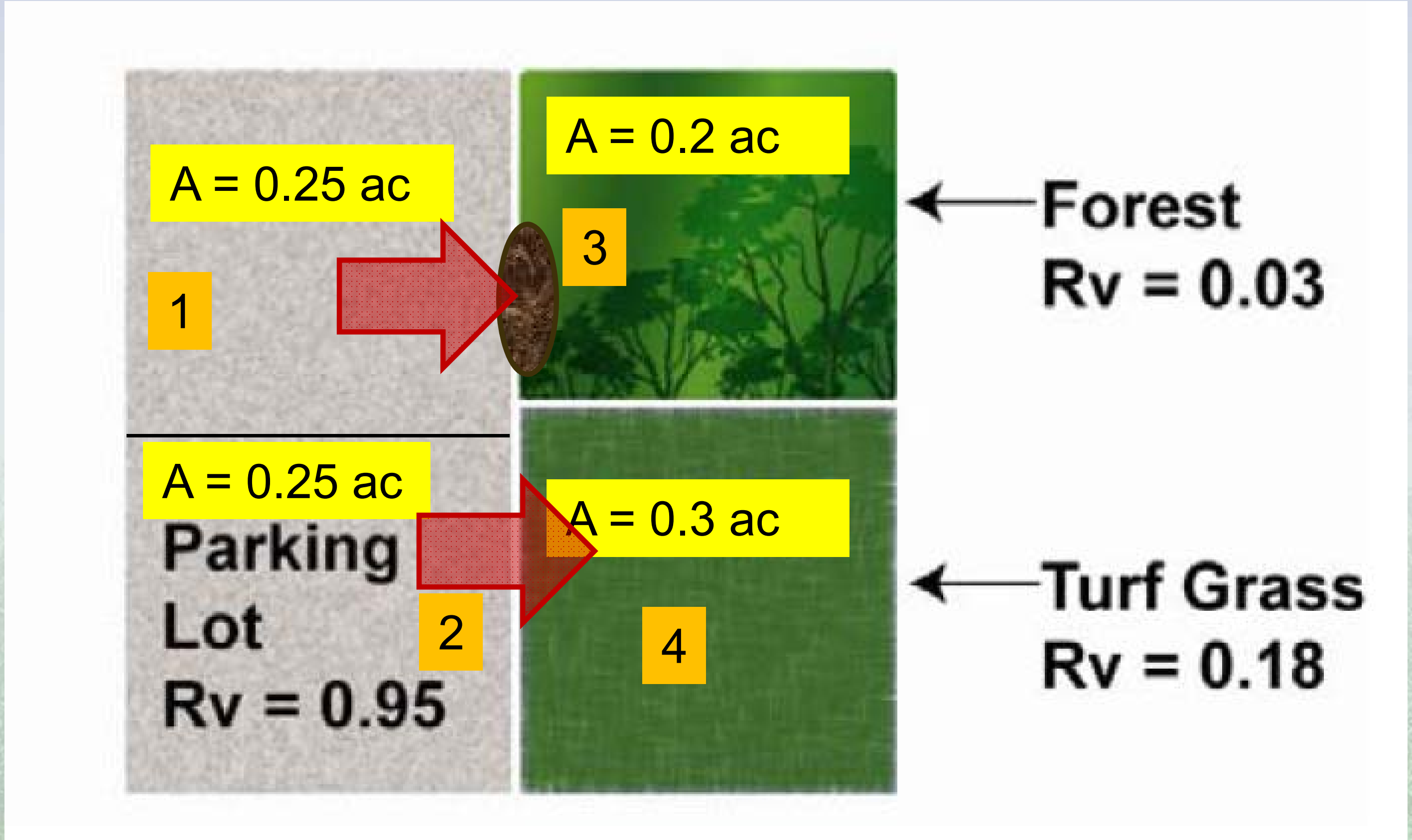
Turf B Soil

Rv = 0.357 > 0.20

Step 1a: Change any basic land use types through reforesting or green roofs - or through use of open space for a GIP.			Step 2: Treat impervious areas through the use of disconnection or sheet flow		
Step 1a Modified LU			**Step 2 Intrinsic GIPs**		
Code	Acres	Eff Rv1	Code	Trtmt VR1	Eff Rv2
IA	0.25	0.95		0	0.95
IA	0.25	0.95	SAB	0.75	0.24
FB	0.2	0.03		0	0.03
TB	0.3	0.18		0	0.18
	0	0.00		0	0.00
	0	0.00		0	0.00
	0	0.00		0	0.00
	0	0.00		0	0.00
	0	0.00		0	0.00
	0	0.00		0	0.00
Weighted Rv		0.535	Weighted Rv		0.357
Total Area=	1	0.54			0.36
% Removal		46.5%	% Removal		64.3%

Step 3 – Structural GIPs

- **0.25 ac → Bioretention Level 2 (80% RR Credit)**



Step 3 – Structural GIPs

- **Send remaining impervious to Bioretention Level 2**

Impervious Area to Bioretention Level 2

Impervious Area to Sheet Flow B Soil

Forest B soil

Turf B Soil

Rv = 0.167 < 0.20

Step 2: Treat impervious areas through the use of disconnection or sheet flow			Step 3: Treat primarily impervious areas with structural GIPs either in series with Step 3 intrinsic GIPs or alone downstream from Steps 1 and 2 land use.		
Step 2 Intrinsic GIPs			**Step 3 Structural GIPs**		
Code	Trtmt VR1	Eff Rv2	Code	Trtmt VR2	Eff Rv3
	0	0.95	B2	0.8	0.19
SAB	0.75	0.24		0	0.24
	0	0.03		0	0.03
	0	0.18		0	0.18
	0	0.00		0	0.00
	0	0.00		0	0.00
	0	0.00		0	0.00
	0	0.00		0	0.00
	0	0.00		0	0.00
	0	0.00		0	0.00
Weighted Rv		0.357	Weighted Rv		0.167
		0.36			0.17
% Removal		64.3%	% Removal		83.3%

Sizing

- **Area 1 – Bioretention Level 2**

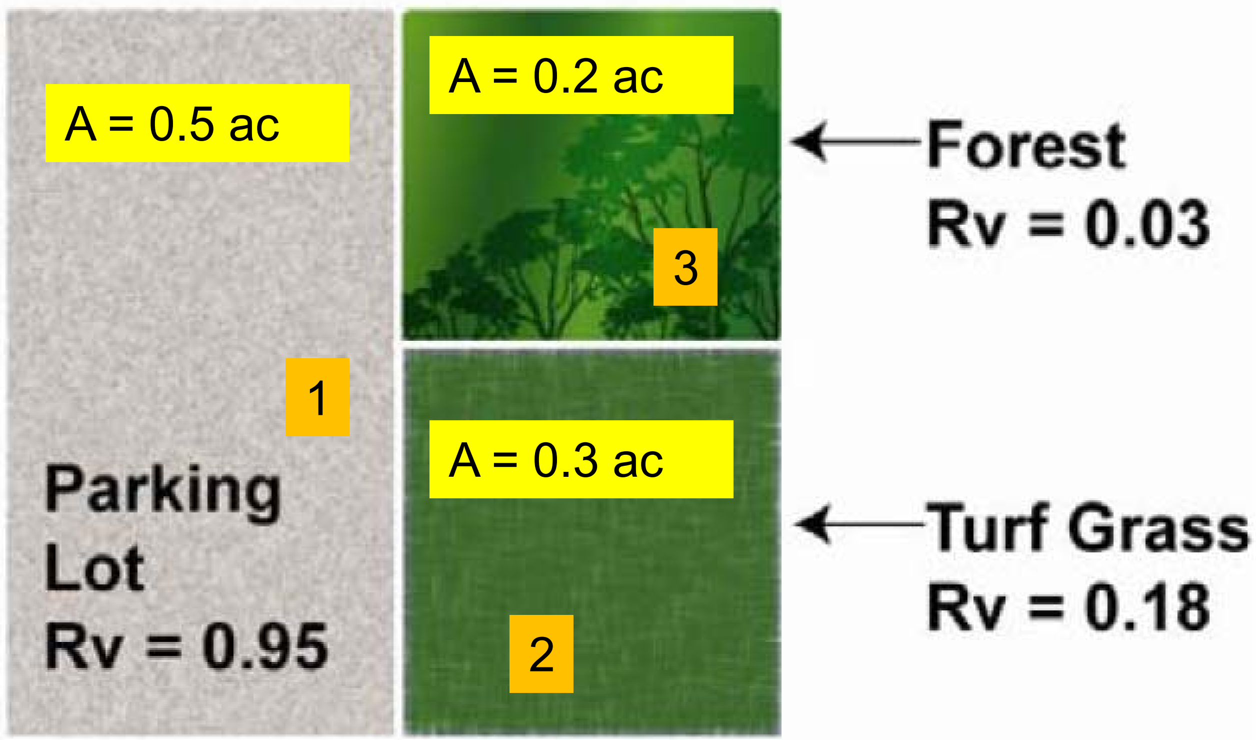
$$T_v\ ft^3 = \frac{1.25*P(in)*Rv*A(ac)*43560(ft^2/ac)}{12(in/ft)}$$

$$T_v = 1078\ ft^3$$

Step 3: Treat primarily impervious areas with structural GIPs either in series with Step 3 intrinsic GIPs or alone downstream from Steps 1 and 2 land use.			Size controls for Step 3 by assigning structure ID to each sub-area, combining sub-areas into one structure if appropriate.		
Step 3 Structural GIPs			**Structure ID**	**IA Capture**	
Code	Trtmt VR2	Eff Rv3		Tv Multiplier	Tv (cf)
B2	0.8	0.19	1	1.25	1,078
	0	0.24		0.00	-
	0	0.03		0.00	-
	0	0.18		0.00	-
	0	0.00		0.00	-
	0	0.00		0.00	-
	0	0.00		0.00	-
	0	0.00		0.00	-
	0	0.00		0.00	-
	0	0.00		0.00	-
Weighted Rv		0.167		Step 3 Tv Total	**1,078**
		0.17			
% Removal		83.3%			

GIPs in Series

Table 2. Site Cover Runoff Coefficients				
Soil Condition	Volumetric Runoff Coefficient (Rv)			
Impervious Cover	0.95			
Hydrologic Soil Group	A	B	C	D
Forest Cover	0.02	0.03	0.04	0.05
Turf	0.15	0.18	0.20	0.23



Step 1 - Site Weighted Rv

- **Site Weighted Rv**

$$= \frac{\sum(A_i \times Rv_i)}{A_T}$$

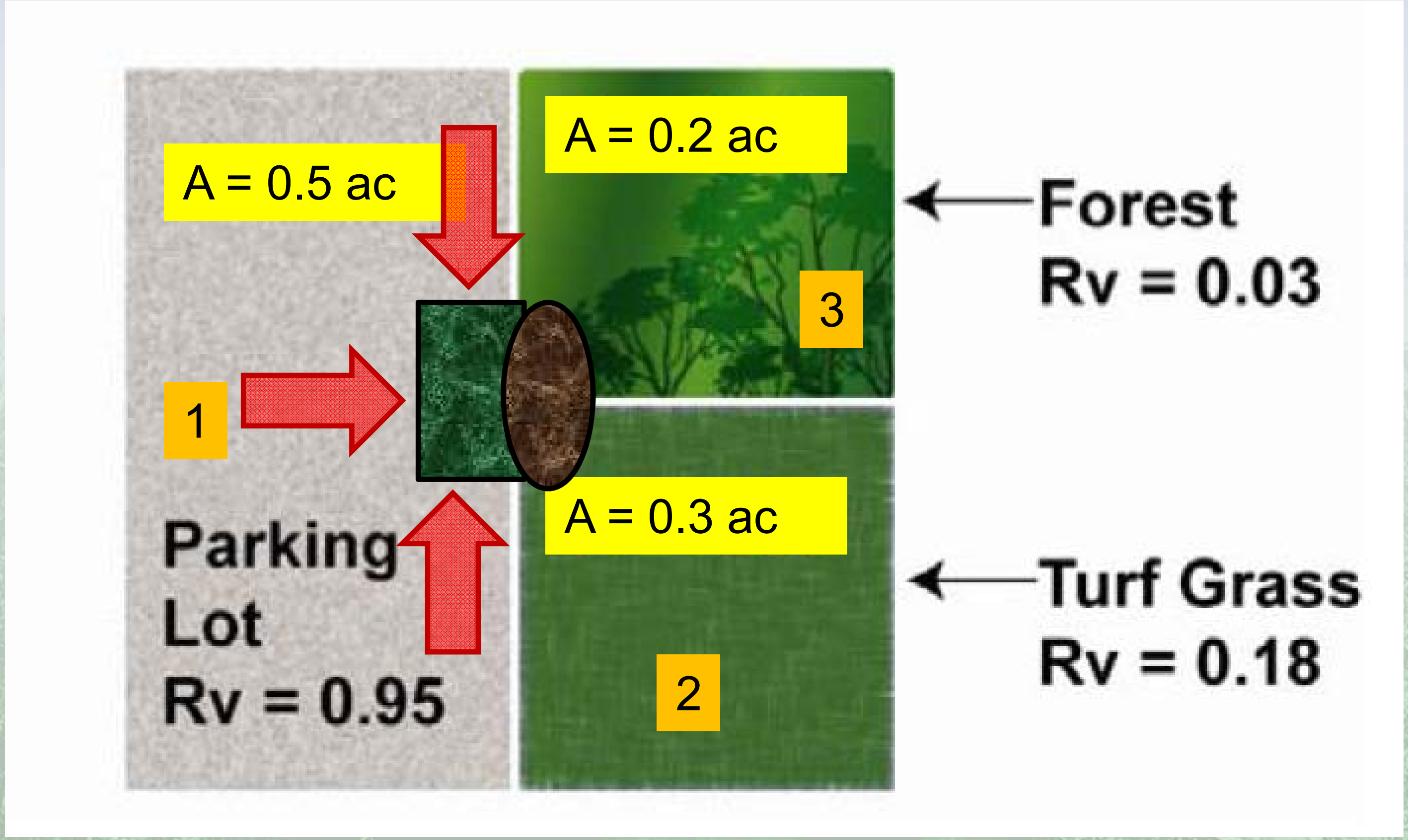
Site Weighted Rv =
0.54 >>0.20

Step 1: Lay out the site and divide it into sub-areas each of a specific land use type and Rv.

Step1 Basic Land Use			
Subarea	Code	Acres	Base Rv
1	IA	0.5	0.95
2	FB	0.2	0.03
3	TB	0.3	0.18
4			0.00
5			0.00
6			0.00
7			0.00
8			0.00
9			0.00
10			0.00
	Weighted Rv		0.54
	Total Area=	1	0.54
% Removal (Goal ≥80%)-->			46.5%

GIPs in Series

- **0.5 ac → Grass Channel Amended B soil → Bioretention Level 1**



Grass Channel Amended B soil

- **GIP Rv = Rv*(1-RR Credit);**

GIP Rv = 0.95*(1-0.4) = <u>0.57</u>

Site Weighted Rv = 0.345 > 0.20

Step 3: Treat primarily impervious areas with structural GIPs either in series with Step 3 intrinsic GIPs or alone downstream from Steps 1 and 2 land use.

Step 3 Structural GIPs		
Code	Trtmt VR2	Eff Rv3
GAA	0.4	0.57
	0	0.03
	0	0.18
	0	0.00
	0	0.00
	0	0.00
	0	0.00
	0	0.00
	0	0.00
	0	0.00
Weighted Rv		0.345
		0.35
% Removal		**65.5%**

Add Bioretention in Series

GIP Rv = Rv*(1-RR Credit)(1-RR Credit)

GIP Rv =0.95*(1-0.4)(1-0.6)= 0.23

New Site Weighted Rv

= 0.174 < 0.20

Step 3a Treatment in Series Calculation - Place Structural GIPs in same row as upstream GIP		
Step 3a Structural GIPs in Series		
Code	Trtmt VR2	Eff Rv4
B1	0.6	0.23
	0	0.03
	0	0.18
	0	0.00
	0	0.00
	0	0.00
	0	0.00
	0	0.00
	0	0.00
	0	0.00
		0.174
		0.17
% Removal		82.6%

Sizing

- **Grass Channel Amended B Soil**
- **Bioretention Level 1 – 1035 ft^3**

$$T_v\ ft^3 = \frac{P_{(in)} * Rv * A_{(ac)} * 43560_{(ft^2/ac)}}{12_{(in/ft)}}$$

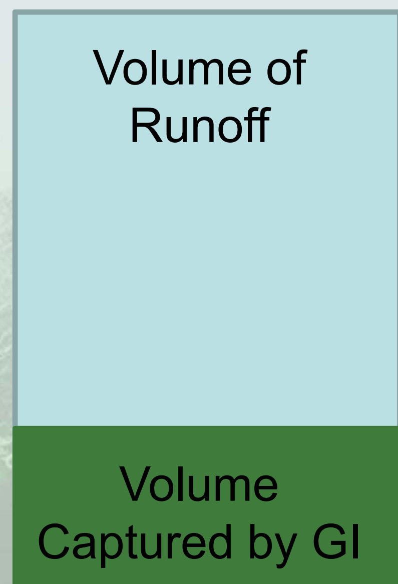
Step 3a Treatment in Series Calculation - Place Structural GIPs in same row as upstream GIP			Size controls for Step 3a in series by assigning a sequential structure ID to each area treated in series.		
Step 3a Structural GIPs in Series			**Structure ID**	**IA Capture**	
Code	Trtmt VR2	Eff Rv4		Tv Multiplier	Structure in Series Tv (cf)
B1	0.6	0.23	1.0	1.00	1,035
	0	0.03		0.00	-
	0	0.18		0.00	-
	0	0.00		0.00	-
	0	0.00		0.00	-
	0	0.00		0.00	-
	0	0.00		0.00	-
	0	0.00		0.00	-
	0	0.00		0.00	-
	0	0.00		0.00	-
		0.174		Final Tv Total	1,035
		0.17			
% Removal		82.6%			

Adjusted Curve Number

Flood Control Sizing

Adjusted Curve Number

- **Accounts for removal of volume by upstream GIPs**
- **CN_{adj}:"effective SCS curve number" < CN**



Adjusted Curve Number

- **Step 1. Calculate Total Runoff for Storm (Q)**

$$Q = \frac{(P - 0.2 \times S)^2}{(P + 0.8 \times S)} \quad \text{and} \quad S = \frac{1000}{CN} - 10$$

- **Step 2. Calculate GIP Capture Volume (Tv)**

$$T_v = P(CDA)(R_v)\left(\frac{43{,}560\ \text{ft}^2}{1\ \text{ac}}\right)\left(\frac{1\ \text{ft}}{12\ \text{in}}\right)$$

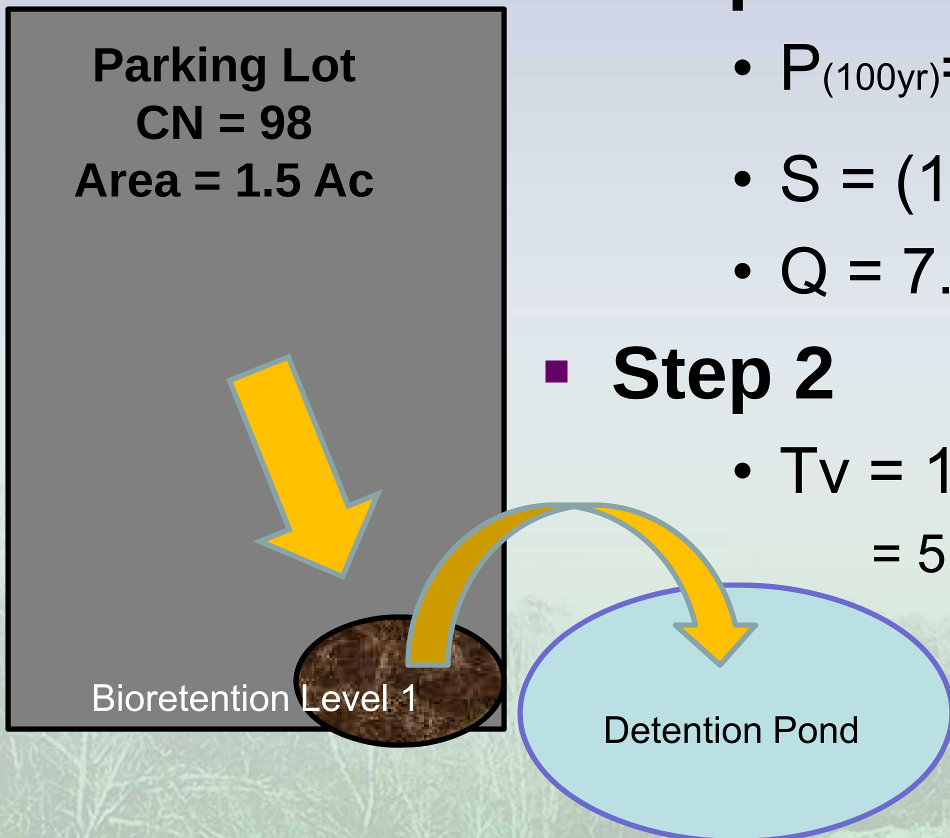
- **Step 3. Calculate Adjusted Total Runoff (Q_{adj})**

$$Q_{adj} = Q - \frac{12 * T_v}{43560 * CDA}$$

- **Step 4. Calculate Adjusted Curve Number (CN_{adj})**

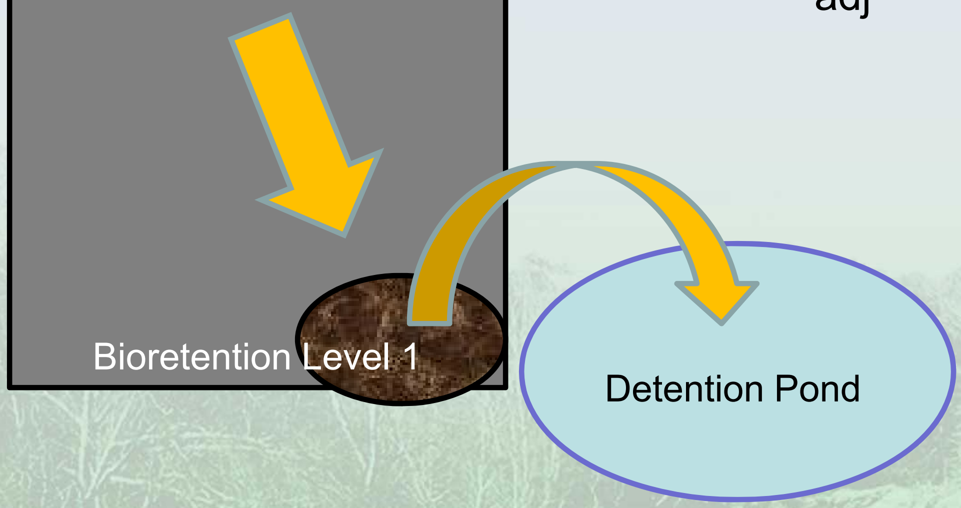
$$CN_{adj} = \frac{1000}{10 + 5P + 10Q_{adj} - 10\left(Q_{adj}^{\ 2} + 1.25Q_{adj}P\right)^{1/2}}$$

Adjusted Curve Number Example



- **Step 1**
  - $P_{(100yr)}$=7.53 in, CN = 98
  - S = (1000/98)-10 = 0.20
  - Q = 7.30 in
- **Step 2**
  - Tv = 1in*0.95*1.5ac*(43560/12)
    = 5,173 ft^3

Example

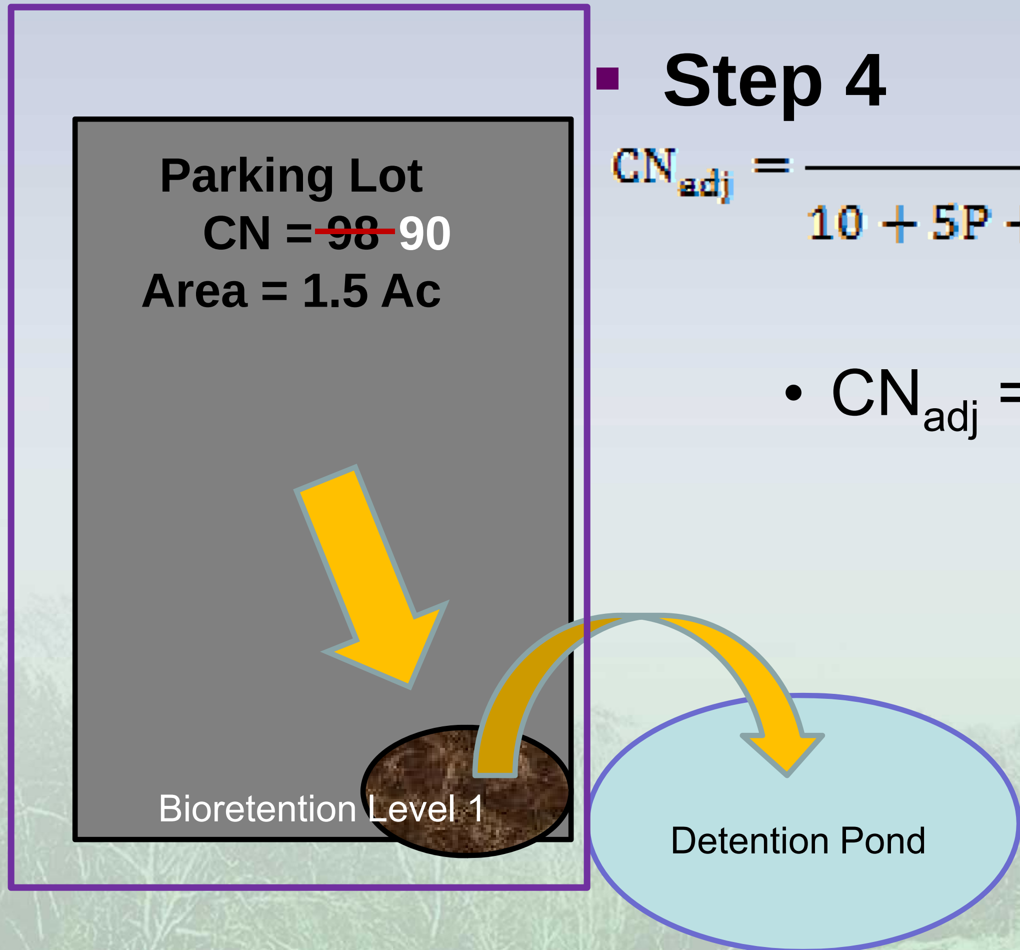


- **Step 3**
  - $Q_{removed}$= (5,173ft^3*12)/(43560*1.5ac) = 0.95 in
  - Q_{adj} = 7.30 – 0.95 = 6.35 in

Example

- **Step 4**

$$CN_{adj} = \frac{1000}{10 + 5P + 10Q_{adj} - 10\left(Q_{adj}^{\ 2} + 1.25Q_{adj}P\right)^{1/2}}$$



- $CN_{adj} = 90$

Today’s Agenda

Time	Topic
8:00 – 8:30	Overview of Green infrastructure and the Runoff Reduction Method
8:30 – 9:30	Green Infrastructure Design Steps and GIPs
9:30 – 9:45	Break
9:45 – 10:30	Calculation Tool and Simple Example
10:30 – 11:00	Nashville Site Example

Nashville Site

Sara Johnson

AMEC

Nashville Site

Site Area = 0.56 ac

100% Impervious

Step 1 – Basic Land Use

- 0.56 Acre Site
- Assume 100% Impervious
- Building Addition and Parking Lot Improvement

Step 1 – Basic Land Use

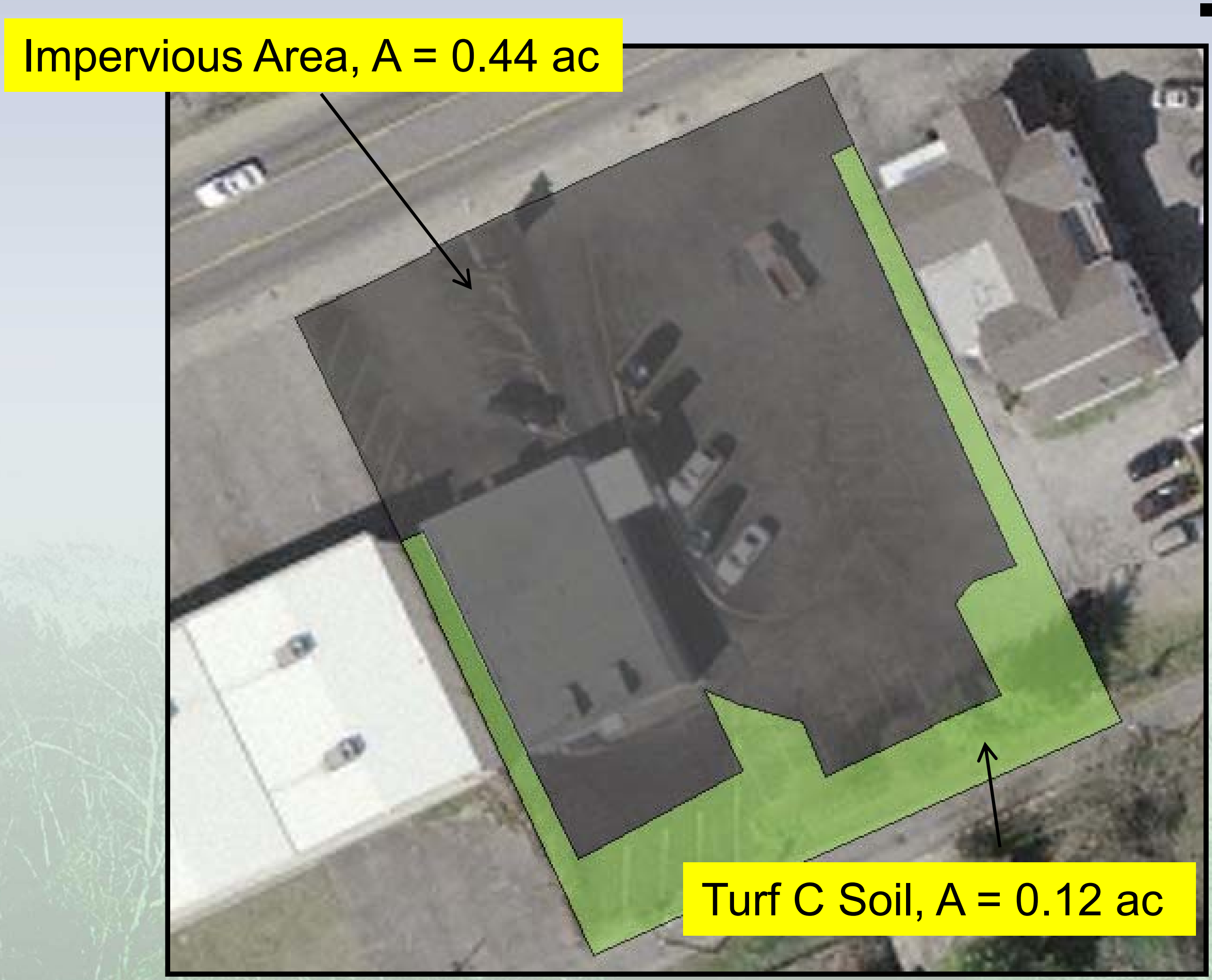
- 0.56 Acre Site
- Assume 100% Impervious
- Rv = 0.95

Step 1: Lay out the site and divide it into sub-areas each of a specific land use type and Rv.

Step1 Basic Land Use

Subarea	Code	Acres	Base Rv
1	IA	0.03	0.95
2	IA	0.03	0.95
3	IA	0.15	0.95
4	IA	0.14	0.95
5	IA	0.09	0.95
6	IA	0.12	0.95
7			0.00
8			0.00
9			0.00
10			0.00
	Weighted Rv		0.95
	Total Area=	0.56	0.53
% Removal (Goal ≥80%)-->			5.0%

Step 1a – Modify Land Use



- **Site Weighted Rv = 0.79**

Step 1a: Change any basic land use types through reforesting or green roofs - or through use of open space for a GIP.

Step 1a Modified LU

Code	Acres	Eff Rv1
IA	0.03	0.95
IA	0.03	0.95
IA	0.15	0.95
IA	0.09	0.95
IA	0.14	0.95
TC	0.12	0.20
	0	0.00
	0	0.00
	0	0.00
	0	0.00
Weighted Rv		0.789
Total Area=	0.56	0.44
% Removal		21.1%

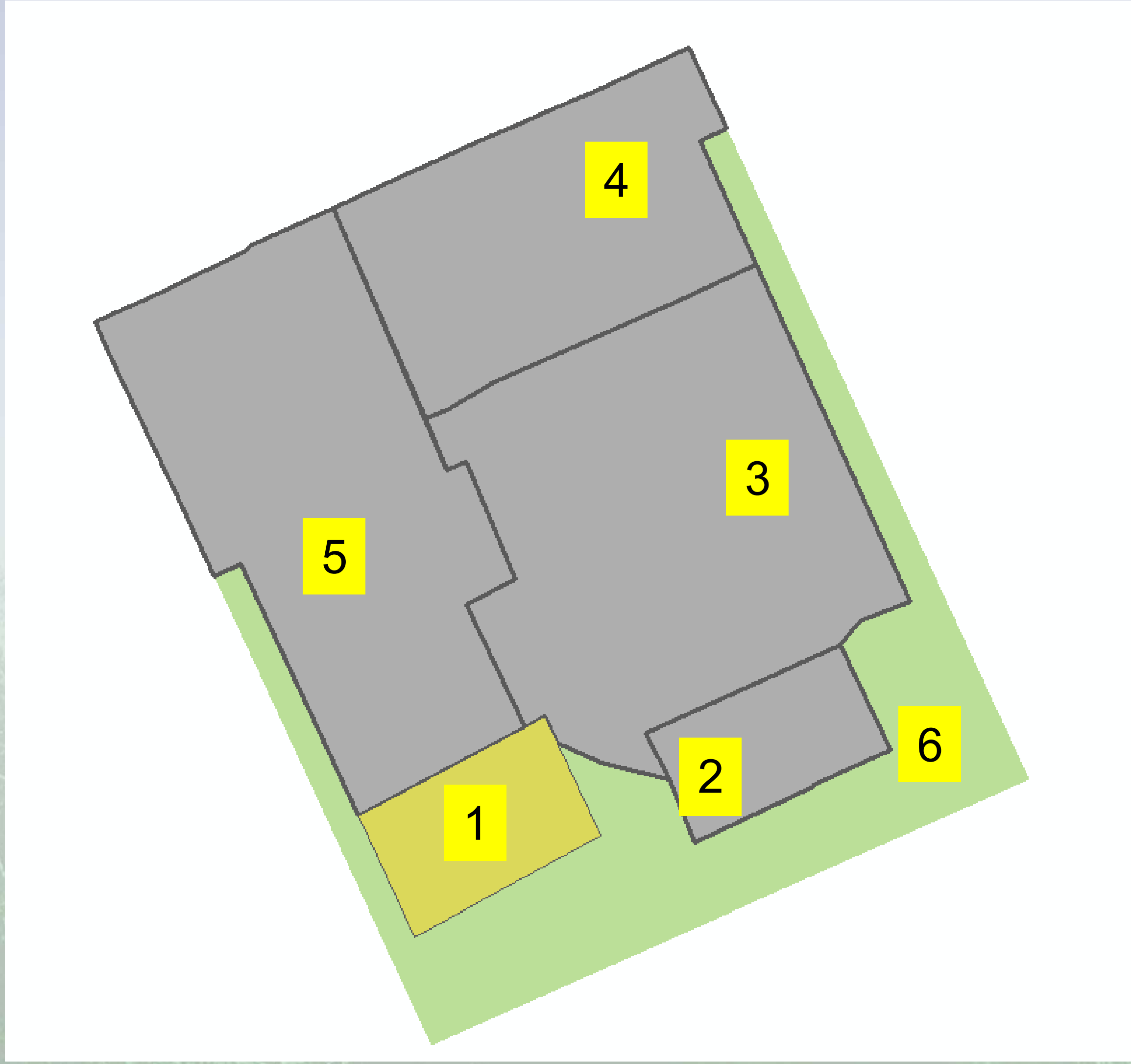
Step 2 – Intrinsic GIPs

- **Downspout Disconnection of new roof area to C soil**

Rv = 0.78

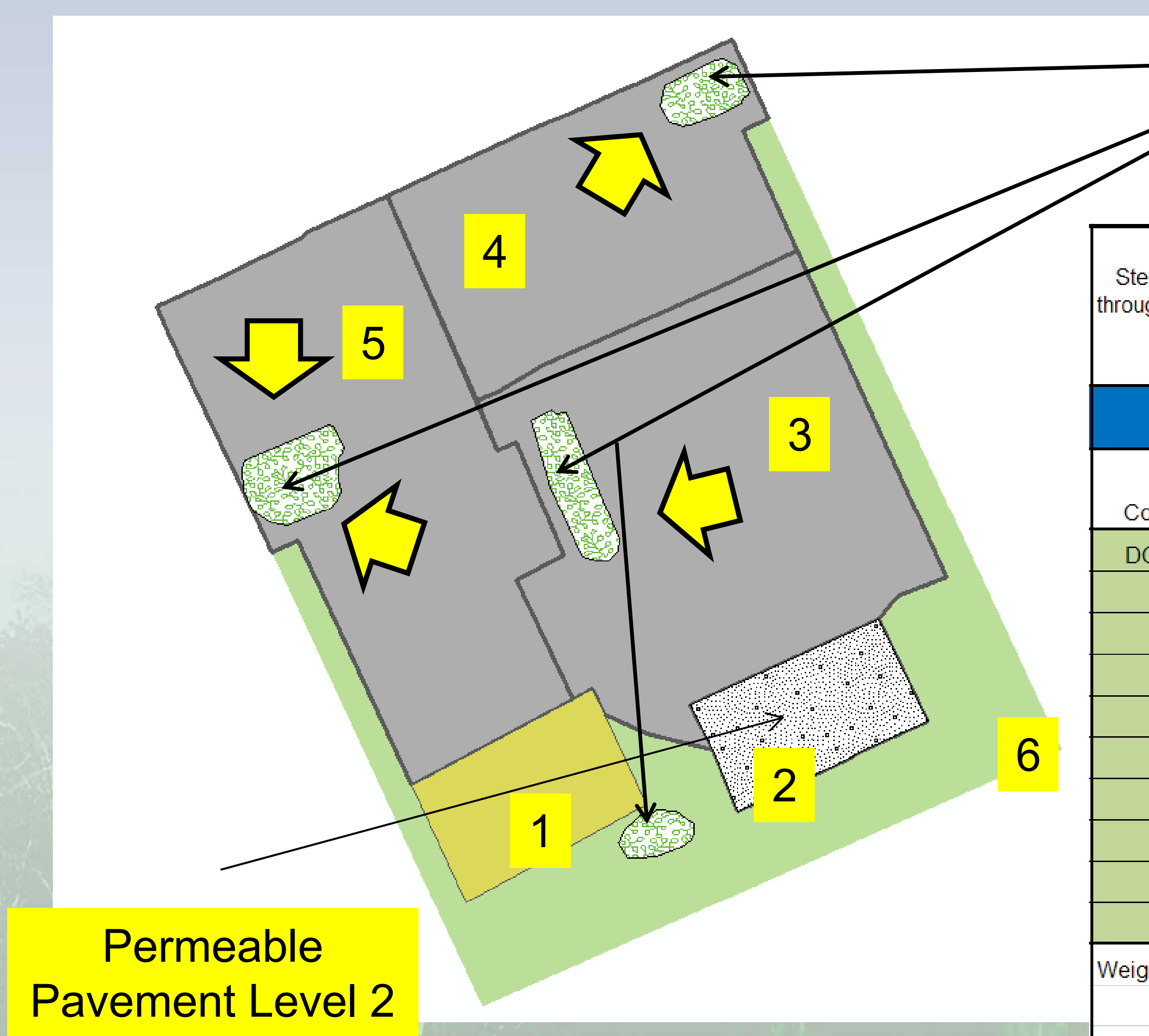
Step 2: Treat impervious areas through the use of disconnection or sheet flow		
Step 2 Intrinsic GIPs		
Code	Trtmt VR1	Eff Rv2
DCD	0.25	0.71
	0	0.95
	0	0.95
	0	0.95
	0	0.95
	0	0.20
	0	0.00
	0	0.00
	0	0.00
	0	0.00
Weighted Rv		0.777
		0.43
% Removal		22.3%

Step 3 – Structural GIPs



- Permeable Pavement – Sub Area 2
- Bioretention – Sub Area 1, 3, 4, and 5

Step 3 - Structural GIPs



Site Weighted Rv = 0.19

Step 2: Treat impervious areas through the use of disconnection or sheet flow			Step 3: Treat primarily impervious areas with structural GIPs either in series with Step 3 intrinsic GIPs or alone downstream from Steps 1 and 2 land use.		
Step 2 Intrinsic GIPs			**Step 3 Structural GIPs**		
Code	Trtmt VR1	Eff Rv2	Code	Trtmt VR2	Eff Rv3
DCD	0.25	0.71	B2	0.8	0.15
	0	0.95	P2	0.75	0.24
	0	0.95	B2	0.8	0.19
	0	0.95	B2	0.8	0.19
	0	0.95	B2	0.8	0.19
	0	0.20		0	0.20
	0	0.00		0	0.00
	0	0.00		0	0.00
	0	0.00		0	0.00
	0	0.00		0	0.00
Weighted Rv		0.777	Weighted Rv		0.193
		0.43			0.11
% Removal		22.3%	% Removal		80.73%

Specifications

- **Permeable Pavement Level 2**
  - 1.1*P
  - No Run-On
  - Soil Infiltration Rate >0.5 in/hr
  - Underdrain not required
- **Bioretention Level 2**
  - 1.25*P
  - CDA < 2.5 acres
  - Media Depth 3-6ft
  - Infiltration Rate > 0.5 in/hr for no underdrain
  - Measures to prevent short circuiting

Sizing

- **Permeable Pavement Level 2**

Tv ft³ = 1.1*P*Rv*A*3630 ft³/ac-in

- **Bioretention Level 2**

Tv ft³ = 1.25*P*Rv*A*3630 ft³/ac-in

Sizing

- **Area 1 – B2 – 97 ft^3**
- **Area 2 – P2 – 114 ft^3**
- **Area 3 – B2 – 647 ft^3**
- **Area 4 – B2 – 603 ft^3**
- **Area 5 – B2 – 647 ft^3**

Step 3: Treat primarily impervious areas with structural GIPs either in series with Step 2 intrinsic GIPs or alone downstream from Steps 1 and 1a land use.			Size controls for Step 3 by assigning structure ID to each sub-area, combining sub-areas into one structure if appropriate.		
Step 3 Structural GIPs			**Structure ID**	**IA Capture**	
Code	Trtmt VR2	Eff Rv3		Tv Multiplier	Tv (cf)
B2	0.8	0.15	1	1.25	97
P2	0.75	0.24	2	1.10	114
B2	0.8	0.19	3	1.25	647
B2	0.8	0.19	4	1.25	388
B2	0.8	0.19	5	1.25	603
	0	0.20		0.00	-
	0	0.00		0.00	-
	0	0.00		0.00	-
	0	0.00		0.00	-
	0	0.00		0.00	-
Weighted Rv		0.193		Step 3 Tv Total	1,849
		0.11			
% Removal		80.73%			

Tool

- **GIPs fit within existing site plan**

Drainage Connection

- Tie into existing drainage system

What if…?

- **…a Green Roof considered on the addition?**
  – Site Rv = 0.19

Step 1: Lay out the site and divide it into sub-areas each of a specific land use type and Rv.				Step 1a: Change any basic land use types through reforesting or green roofs - or through use of open space for a GIP.			Step 2: Treat impervious areas through the use of disconnection or sheet flow			Step 3: Treat primarily impervious areas with structural GIPs either in series with Step 2 intrinsic GIPs or alone downstream from Steps 1 and 1a land use.		
Step1 Basic Land Use				**Step 1a Modified LU**			**Step 2 Intrinsic GIPs**			**Step 3 Structural GIPs**		
Subarea	Code	Acres	Base Rv	Code	Acres	Eff Rv1	Code	Trtmt VR1	Eff Rv2	Code	Trtmt VR2	Eff Rv3
1	IA	0.03	0.95	G2	0.03	0.10		0	0.10		0	0.10
2	IA	0.03	0.95	IA	0.03	0.95		0	0.95	P2	0.75	0.24
3	IA	0.15	0.95	IA	0.15	0.95		0	0.95	B2	0.8	0.19
4	IA	0.09	0.95	IA	0.09	0.95		0	0.95	B2	0.8	0.19
5	IA	0.14	0.95	IA	0.14	0.95		0	0.95	B2	0.8	0.19
6	IA	0.12	0.95	TC	0.12	0.20		0	0.20		0	0.20
7			0.00		0	0.00		0	0.00		0	0.00
8			0.00		0	0.00		0	0.00		0	0.00
9			0.00		0	0.00		0	0.00		0	0.00
10			0.00		0	0.00		0	0.00		0	0.00
	Weighted Rv		0.95	Weighted Rv		0.744	Weighted Rv		0.744	Weighted Rv		0.190
	Total Area=	0.56	0.53	Total Area=	0.56	0.42			0.42			0.11
% Removal (Goal ≥80%)-->			5.0%	% Removal		25.6%	% Removal		25.6%	% Removal		**81.00%**

Infill Boundary Incentive

- **If within the Metro Planning Infill Boundary:**
  - Sites with a pre-redevelopment Rv of > 0.4 will have to reach only an Rv of 0.4 (obtain 60% runoff reduction)
  - Sites with a pre-redevelopment Rv ≤ 0.4 will need to reach and Rv of 0.2 (obtain 80% runoff reduction)

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10:15 – 11:00	Nashville Site Example