# *The Annual Rv Method for Site-Level Green Infrastructure*


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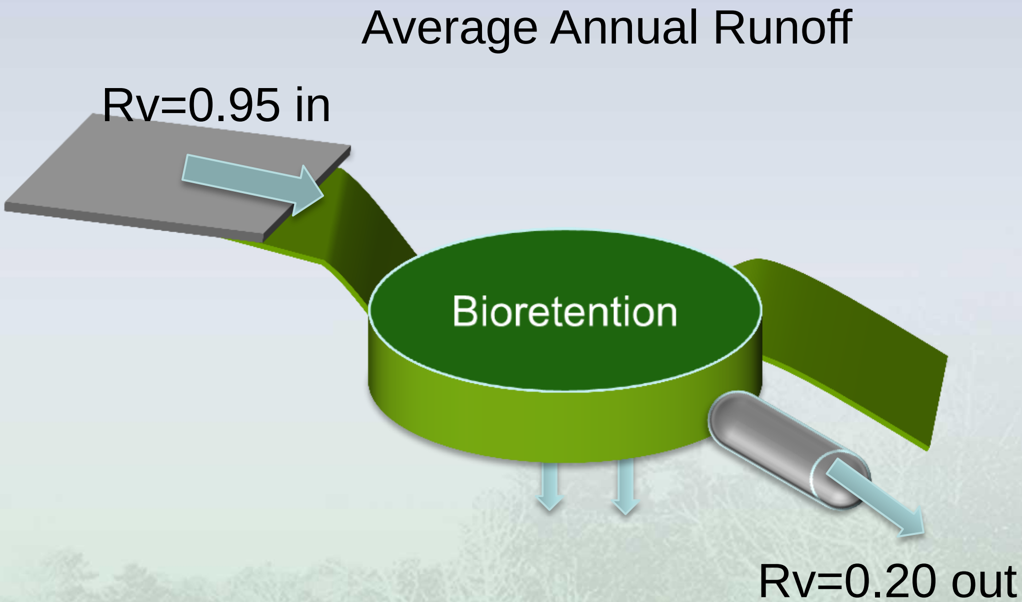
*"Everything should be made as simple as possible, but not simpler"*

Albert Einstein

# The Gist of the Rv Method

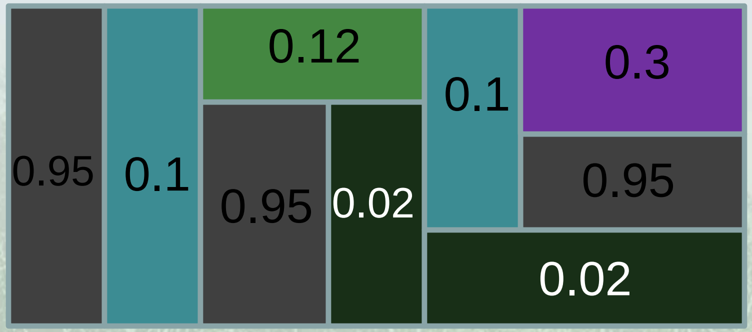
1. **Average annual runoff ratio (Rv) must hit a target value**
2. **Each land use has an Rv estimated**
3. **Flow thorough natural and structural GIPs reduces the Rv from the combination**




**The weighted sum of Rv's for each land use or combination must be less than the target value.**

# So this ends up looking just like a C Factor or CN calculation on a site:

# The land-use weighted Rv must be ≤ 0.20




$$\frac{\sum Rv_i * A_i}{A_{site}} \leq 0.20$$

# Brief overview of why and how we derived the method.

# TN's 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

# Unintended Consequences

- **If we take this literally we would have to create storage space for 1” rain every time thus reducing natural treatment’s value**
- **Capturing the first inch after 72 HR IEPD would only capture 54% of the rainfall in Nashville**

- **We felt these were unintended consequences of the language at the time**

# MWS Overall Approach

Do a voluntary program to introduce Green Infrastructure to our community two years ahead of its mandatory use.

Develop an approach that has a high probability of success.

Remember there was no technical guidance at the time.

# So…we talked to some smart old friends about lessons learned.

Dr. Rob Traver

Dr. Barrett Kays

Dr. Bob Pitt

Dr. Bill Hunt

# A few key ideas:

- **Urban soils are very complex and are never mapped – use a constant and conservative infiltration rate**
- **Modeling of individual urban sites is overly complex and highly inaccurate for every day use – you will never have enough data**
- **Instantaneous pollution is not normally the problem why not use a longer term metric**
- **In tight soils or bedrock underdrains mimic natural hydrology**
- **Capture depth requirements can produce overdesign and grey solutions – “Kerplunk” design**
- **Your method should integrate natural vegetation and processes in a non-artificial way**
- **Promote natural, low maintenance approaches as a priority**

Tom Schueler Chesapeake Bay, Center for Watershed Protection and Washington DC Stormwater program

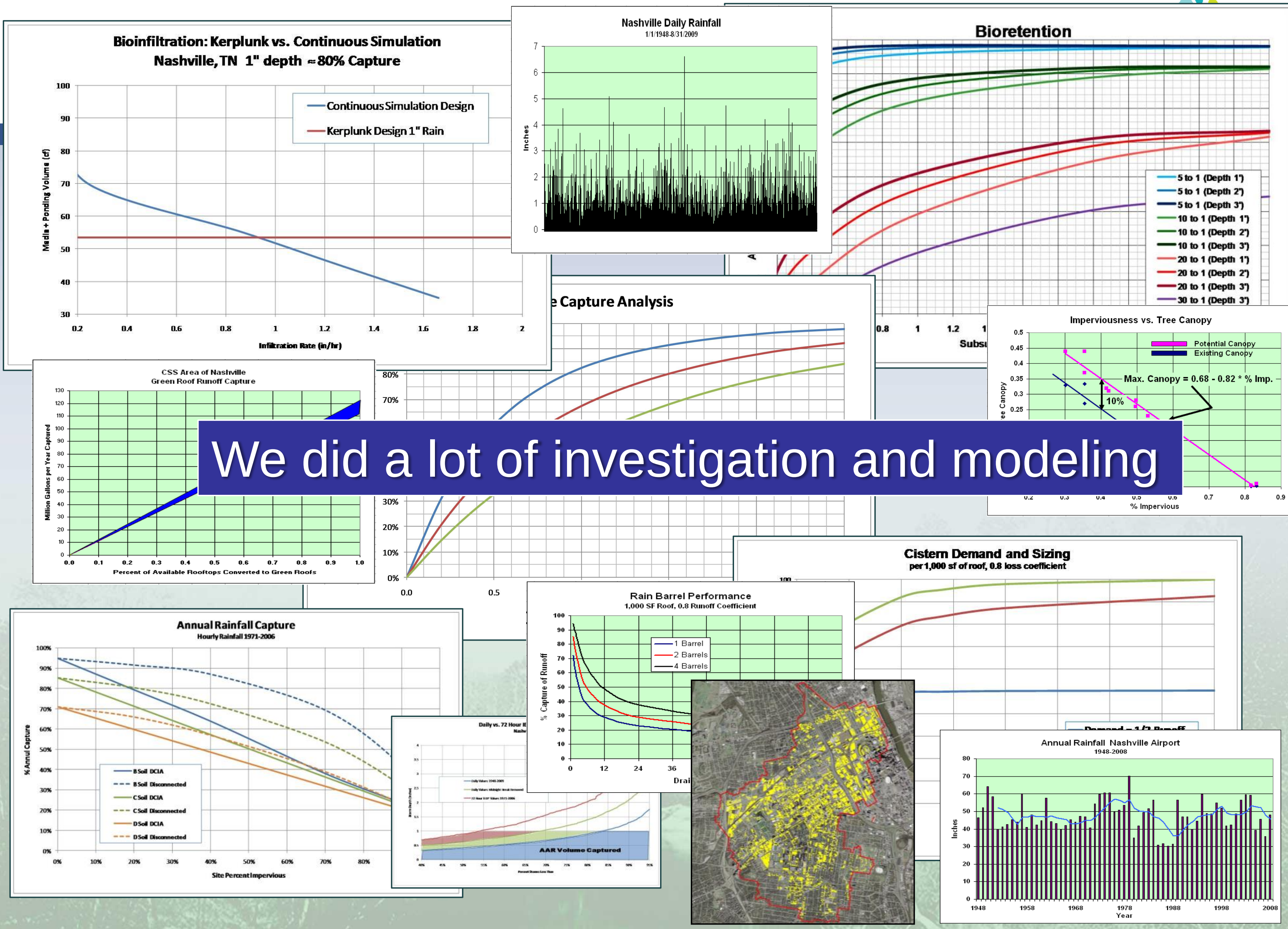
How we think
GI gets built

How GI
actually gets
built

# In Summary

- **We can be smarter than we are wise**
- **You would be far better off creating a framework that:**
  - realistically reflects the urban facts on the ground
  - Balances hydrologic mimicry and an ability to capture and treat about the right volume
  - relatively easy to use given the experience and skills of the common user

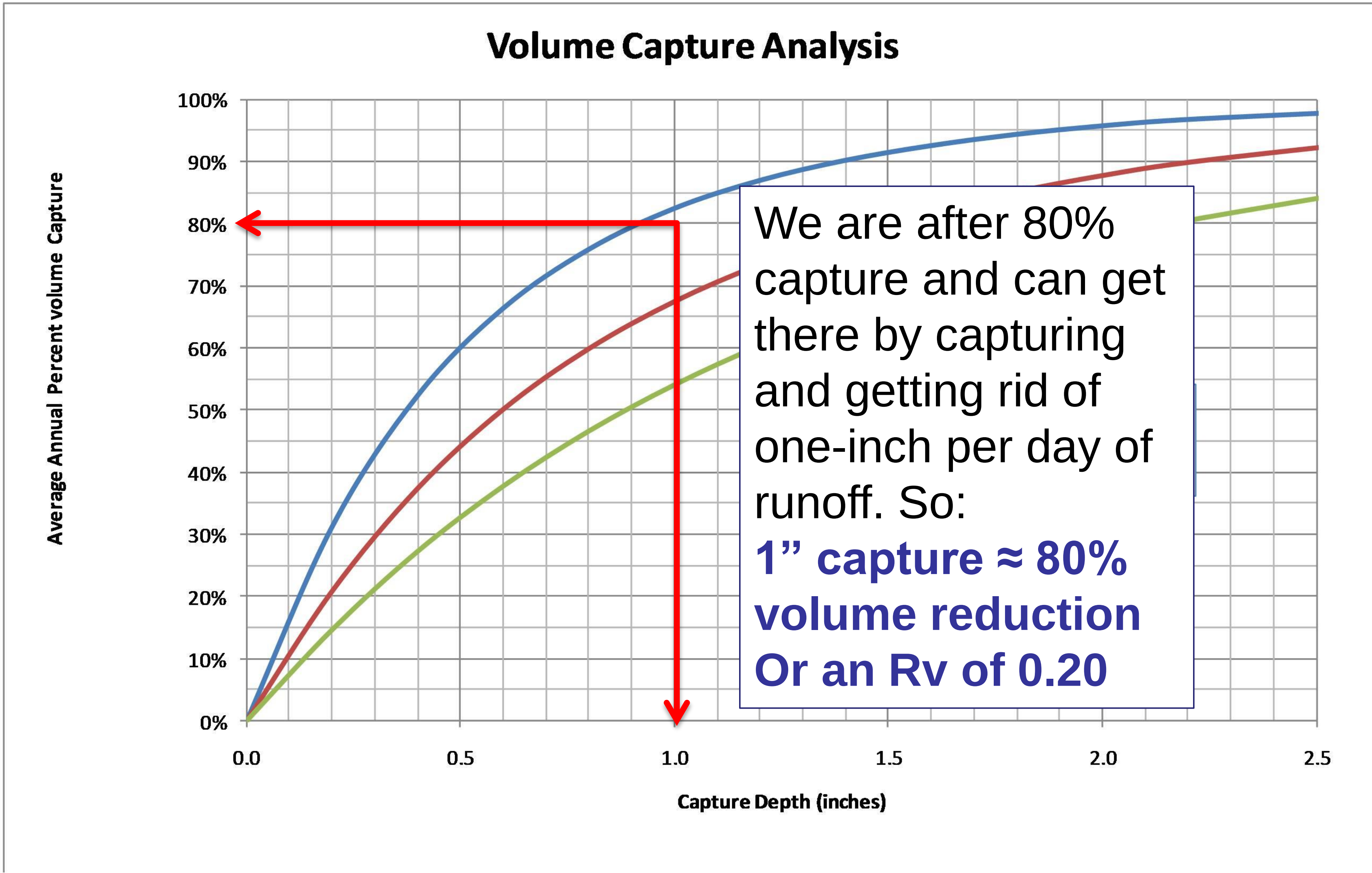
# We did a lot of investigation and modeling



# Right – so you're saying if all my developers can do continuous simulation then I can use this method?

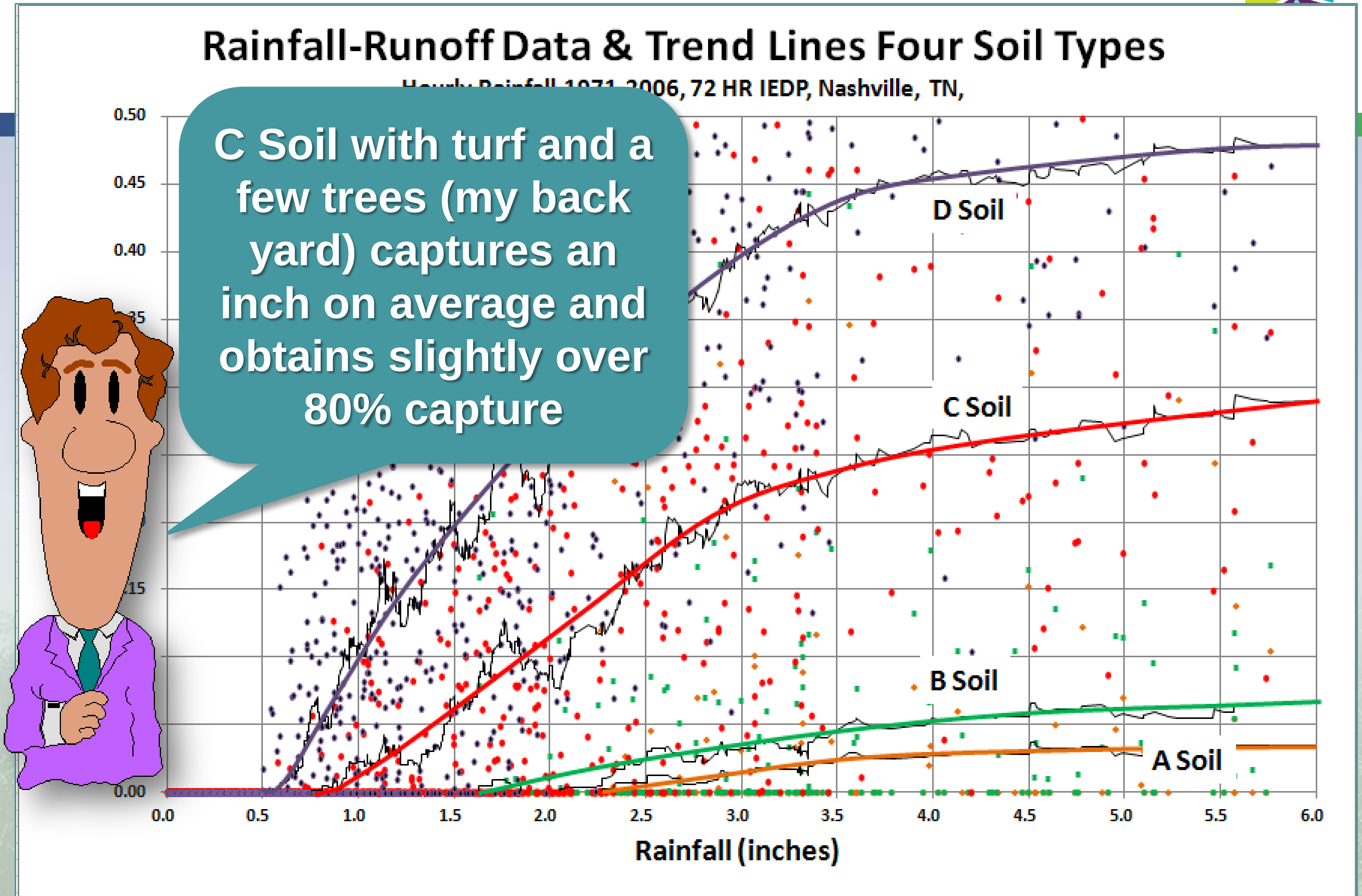
# And that is simpler how again?

# 1” Storm Volume Captured: 80%



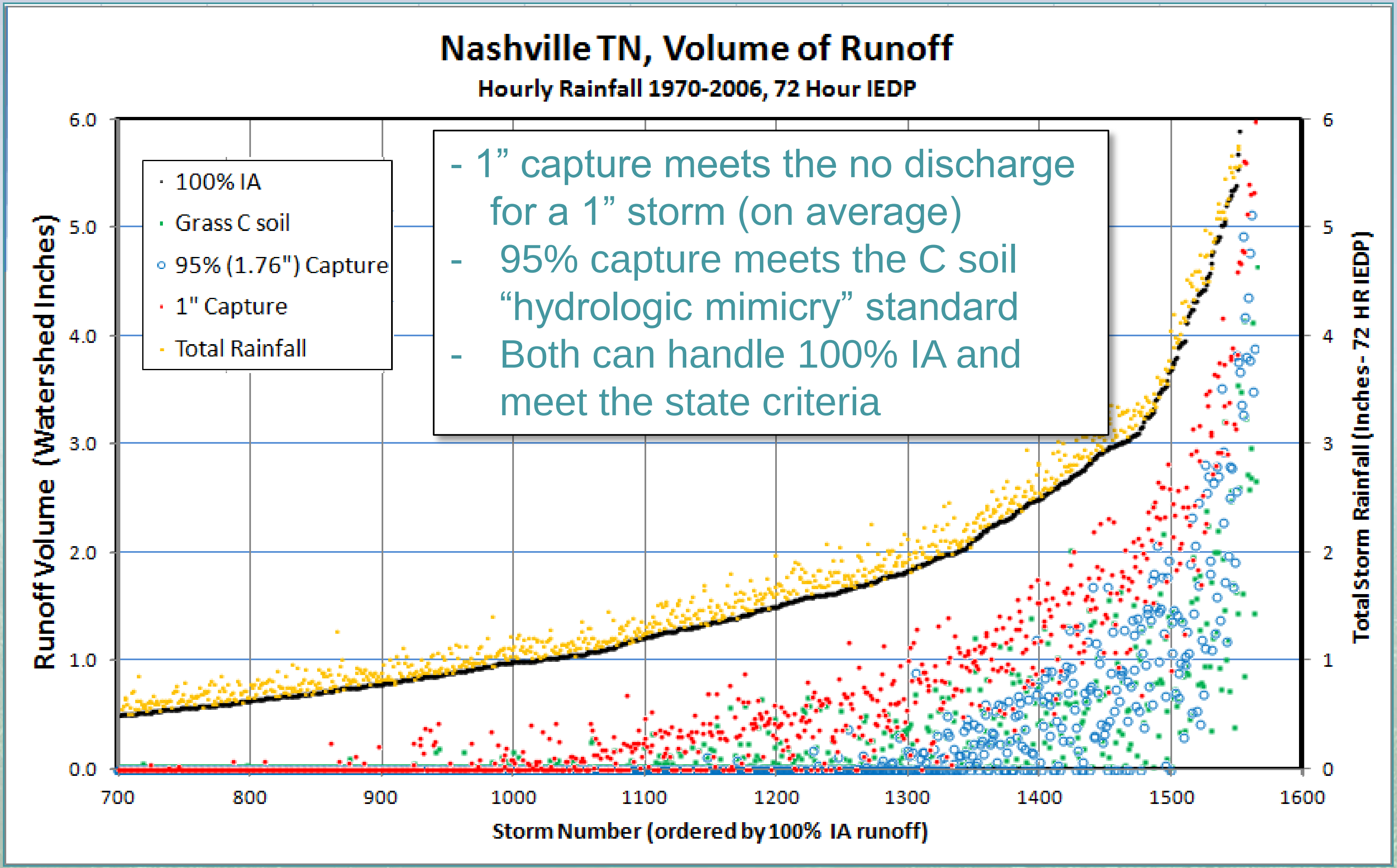

We are after 80% capture and can get there by capturing and getting rid of one-inch per day of runoff. So:

**1” capture ≈ 80% volume reduction**
**Or an Rv of 0.20**



Rainfall-Runoff Data & Trend Lines Four Soil Types
Hourly Rainfall 1971-2006, 72 HR IEDP, Nashville, TN,
C Soil with turf and a few trees (my back yard) captures an inch on average and obtains slightly over 80% capture
D Soil
C Soil
B Soil
A Soil
0.50
0.45
0.40
0.00
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
Rainfall (inches)

# Green Infrastructure Bioretention Runoff Volume Reduction Effectiveness



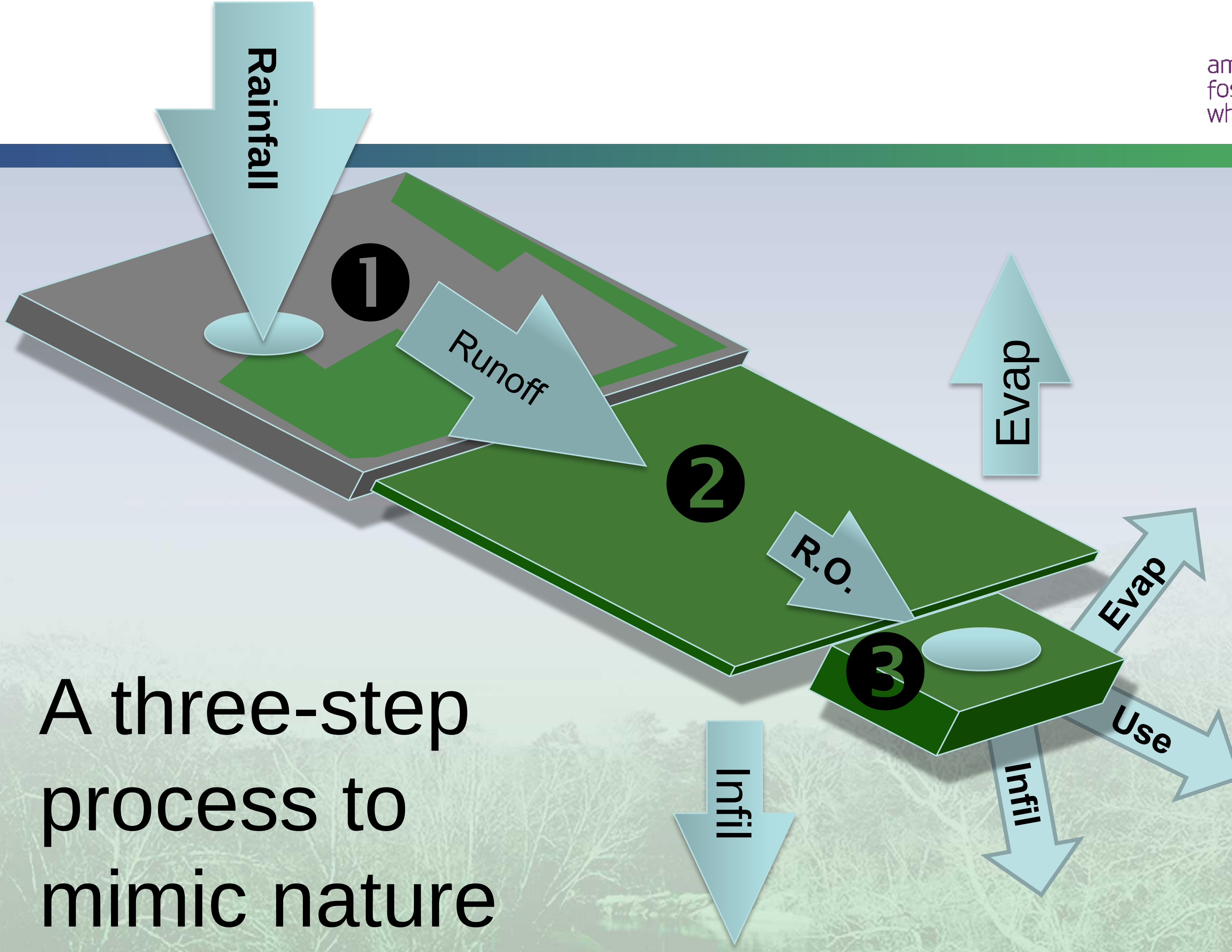
# So…

- A 1” storm is about 80% average annual volume capture
- C Soil with turf and some trees is about 80% average annual volume capture
- That is my back yard & streams in these areas are fairly stable and healthy
- GIPs can attain this 80% capture if appropriately sized to recognize underperformance rates
- ERGO: $Rv \leq 0.2$ is the single criterion we need and can encompass all these things

# Skip to the end…

If I can design a site with an average annual runoff of 20% I will both capture about an inch from all impervious area and mimic an acceptable urban hydrology looking like the typical Nashville back yard.

So if I can reliably assign annual Rv numbers to land uses and treatments (Rv out), insure conservatism, and close any technical loopholes I am there.




# A three-step process to mimic nature

# Tweaks:

- Derivation across the state
- Controls in series
- Use with the 80% TSS approach
- Reduced CN for flood control
- Maximum size of IA  before mandatory structural treatment (the golf course problem)
- Minimum distance from streams before mandatory structural treatment

Table 2. Basic Land Uses

| Step 1 Basic Land Use | | CODE | Memphis | Nashville | Chattanooga | Knoxville | Tri-Cities |
|---|---|---|---|---|---|---|---|
| Target Rv | | | 0.24 | 0.20 | 0.20 | 0.14 | 0.10 |
| Basic Land Use | Impervious Surface | IA | 0.95 | 0.95 | 0.95 | 0.93 | 0.90 |
| | Forest A Soil | FA | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 |
| | Forest B Soil | FB | 0.04 | 0.03 | 0.03 | 0.02 | 0.02 |
| | Forest C Soil | FC | 0.05 | 0.04 | 0.04 | 0.03 | 0.02 |
| | Forest D Soil | FD | 0.06 | 0.05 | 0.05 | 0.04 | 0.03 |
| | Turf A Soil | TA | 0.18 | 0.15 | 0.15 | 0.11 | 0.08 |
| | Turf B Soil | TB | 0.22 | 0.18 | 0.18 | 0.13 | 0.09 |
| | Turf C Soil | TC | 0.24 | 0.20 | 0.20 | 0.14 | 0.10 |
| | Turf D Soil | TD | 0.28 | 0.23 | 0.23 | 0.16 | 0.13 |

Table 3. Modified Land Uses

| Step 1a Modified Land Use | | CODE | Memphis | Nashville | Chattanooga | Knoxville | Tri-Cities |
|---|---|---|---|---|---|---|---|
| Natural or Amended Soil | A | AA | 0.03 | 0.03 | 0.03 | 0.02 | 0.01 |
| | B | AB | 0.10 | 0.08 | 0.08 | 0.05 | 0.04 |
| | C | AC | 0.16 | 0.13 | 0.13 | 0.09 | 0.07 |
| | D | AD | 0.28 | 0.23 | 0.23 | 0.16 | 0.13 |
| Urban Forest | A | UA | 0.12 | 0.10 | 0.10 | 0.07 | 0.05 |
| | B | UB | 0.14 | 0.12 | 0.12 | 0.08 | 0.06 |
| | C | UC | 0.16 | 0.13 | 0.13 | 0.09 | 0.07 |
| | D | UD | 0.19 | 0.16 | 0.16 | 0.11 | 0.08 |
| Reforestation | A | RA | 0.12 | 0.10 | 0.10 | 0.07 | 0.05 |
| | B | RB | 0.14 | 0.12 | 0.12 | 0.08 | 0.06 |
| | C | RC | 0.16 | 0.13 | 0.13 | 0.09 | 0.07 |
| | D | RD | 0.192 | 0.16 | 0.16 | 0.112 | 0.08 |
| | A Amended | RAA | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 |
| | B Amended | RBA | 0.04 | 0.03 | 0.03 | 0.02 | 0.02 |
| | C Amended | RCA | 0.05 | 0.04 | 0.04 | 0.03 | 0.02 |
| | D Amended | RDA | 0.06 | 0.05 | 0.05 | 0.04 | 0.03 |
| Green Roof | Level 1 | G1 | 0.24 | 0.20 | 0.20 | 0.14 | 0.10 |
| | Level 2 | G2 | 0.12 | 0.10 | 0.10 | 0.07 | 0.05 |

| Step 2 Intrinsic RRPs | | CODE | Memphis | Nashville | Chattanooga | Knoxville | Tri-Cities |
|---|---|---|---|---|---|---|---|
| Downspout Disconnection | A/B Soil | DAB | 0.60 | 0.50 | 0.50 | 0.35 | 0.25 |
| | C/D Soil | DCD | 0.84 | 0.75 | 0.75 | 0.53 | 0.38 |
| | Amended | DAS | 0.60 | 0.50 | 0.50 | 0.35 | 0.25 |
| Sheet Flow | Cons Area A/B | SAB | 0.30 | 0.25 | 0.25 | 0.18 | 0.13 |
| | Cons Area C/D | SCD | 0.60 | 0.50 | 0.50 | 0.35 | 0.25 |
| | Strip A | SA | 0.60 | 0.50 | 0.50 | 0.35 | 0.25 |
| | Strip Amended | SAS | 0.60 | 0.50 | 0.50 | 0.35 | 0.25 |

| Step 3 & 3a Structural RRPs | | CODE | Memphis | Nashville | Chattanooga | Knoxville | Tri-Cities |
|---|---|---|---|---|---|---|---|
| Permeable Pavement | Level 1 | P1 | 0.66 | 0.55 | 0.55 | 0.39 | 0.28 |
| | Level 2 | P2 | 0.30 | 0.25 | 0.25 | 0.18 | 0.13 |
| Grass Channel | A/B Soil | GAB | 0.88 | 0.80 | 0.80 | 0.56 | 0.40 |
| | C/D Soil | GCD | 0.91 | 0.90 | 0.90 | 0.63 | 0.45 |
| | A/B Amended | GAA | 0.81 | 0.70 | 0.70 | 0.49 | 0.35 |
| | C/D amended | GCA | 0.88 | 0.80 | 0.80 | 0.56 | 0.40 |
| Biorentention/ Rain Garden | Level 1 | B1 | 0.48 | 0.40 | 0.40 | 0.28 | 0.20 |
| | Level 2 | B2 | 0.24 | 0.20 | 0.20 | 0.14 | 0.10 |
| Water Quality Swales | Level 1 | S1 | 0.70 | 0.60 | 0.60 | 0.42 | 0.30 |
| | Level 2 | S2 | 0.48 | 0.40 | 0.40 | 0.28 | 0.20 |
| Infiltration Trench | Level 1 | I1 | 0.60 | 0.50 | 0.50 | 0.35 | 0.25 |
| | Level 2 | I2 | 0.12 | 0.1 | 0.1 | 0.07 | 0.05 |
| Urb Bioretention | | UB | 0.48 | 0.40 | 0.40 | 0.28 | 0.20 |
| Dry Pond | | D1 | 0.90 | 0.85 | 0.85 | 0.60 | 0.43 |
| Cistern | | CIS | Des. Dep. | Des. Dep. | Des. Dep. | Des. Dep. | Des. Dep. |

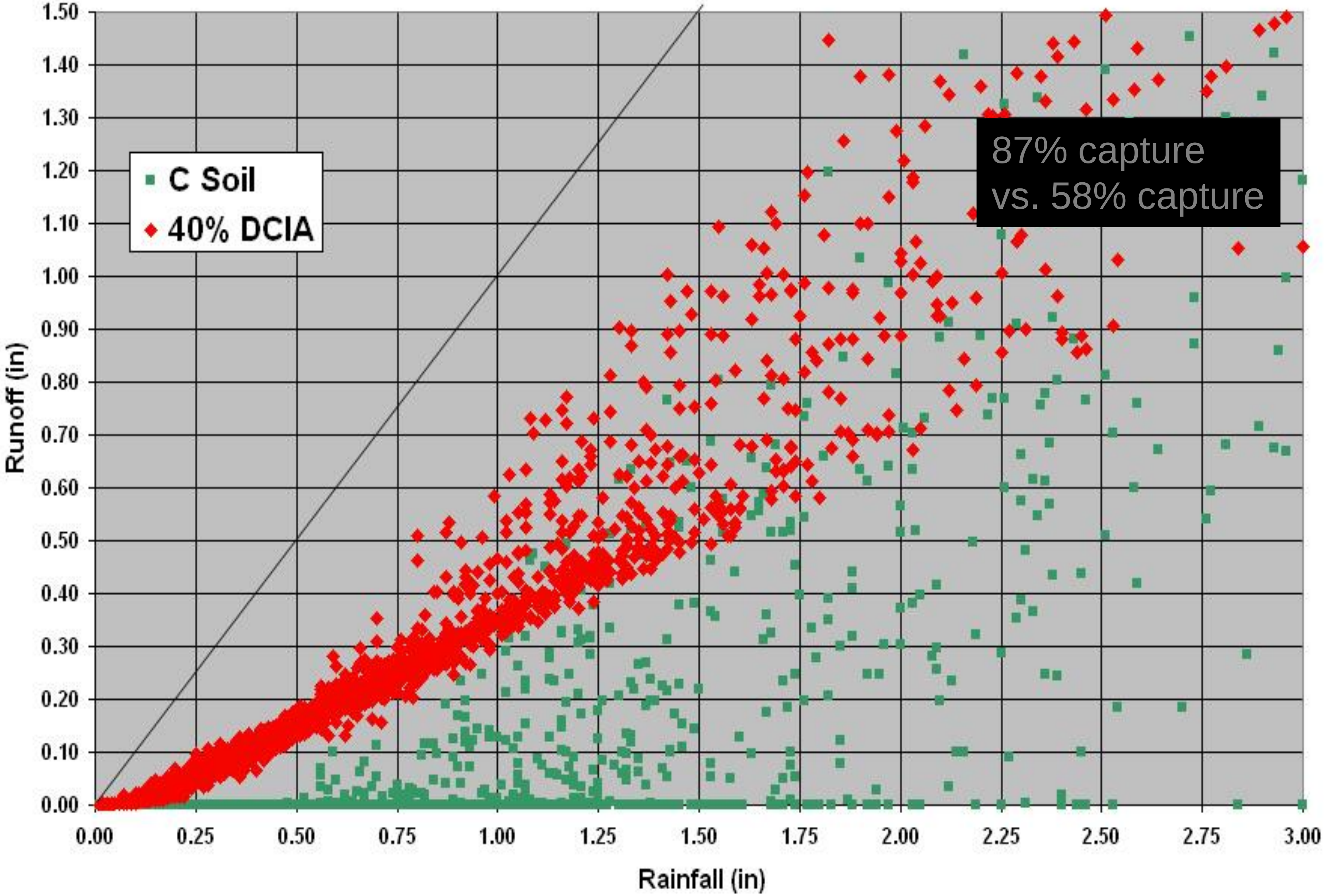
# Simple Spreadsheet Calcs

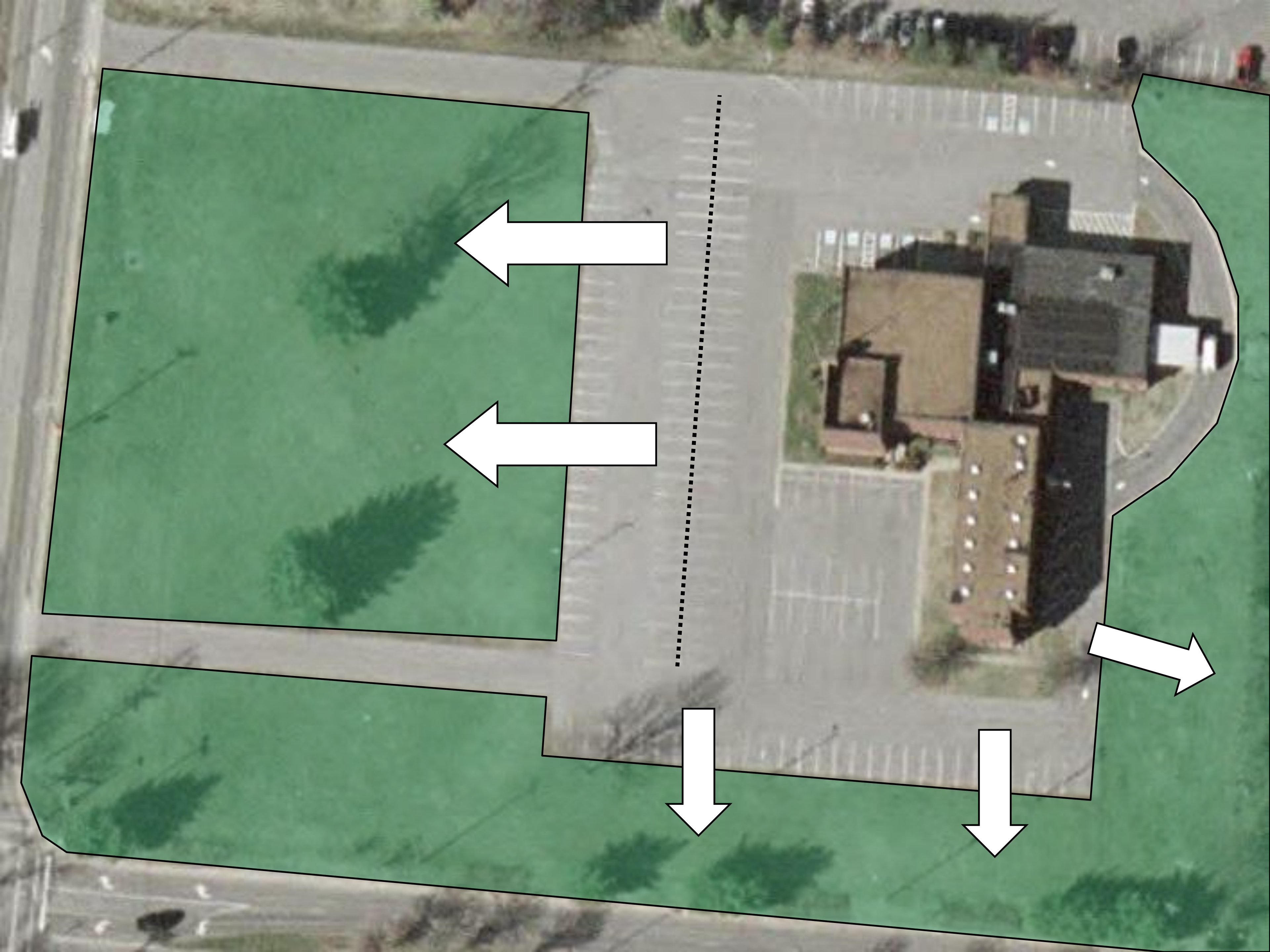
**Percent Volume Reduction-Based Calculations**

| 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 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 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 | IA | 0.5 | 0.95 | SCD | 0.5 | 0.48 | B1 | 0.6 | 0.19 | | 1.00 | - | | 0 | 0.19 | | 0.00 | - |
| 2 | IA | 0.4 | 0.95 | RC | 0.4 | 0.08 | | 0 | 0.08 | B1 | 0.6 | 0.04 | | 1.00 | - | | 0 | 0.04 | | 0.00 | - |
| 3 | IA | 0.3 | 0.95 | IA | 0.3 | 0.95 | SCD | 0.5 | 0.48 | B1 | 0.6 | 0.19 | | 1.00 | - | | 0 | 0.19 | | 0.00 | - |
| 4 | IA | 0.2 | 0.95 | IA | 0.2 | 0.95 | | 0 | 0.95 | GCD | 0.1 | 0.86 | | 0.00 | - | | 0 | 0.86 | | 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 | | 0.701 | Weighted Rv | | 0.430 | Weighted Rv | | 0.243 | | Step 5 Tv Total | **0** | | | 0.243 | | Final Tv Total | **0** |
| | Total Area | 1.4 | 1.33 | Total Area | 1.4 | 0.98 | | | 0.60 | | | 0.34 | | | | | | 0.34 | | | |
| % Removal (Goal ≥80%)--> | | | 5.0% | % Removal | | 29.9% | % Removal | | 57.0% | % Removal | | **75.7%** | | | | % Removal | | **75.7%** | | | |
| | | | | | | | | | | | | THIS MUST BE 80% OR GREATER | | | | | | THIS MUST BE 80% OR GREATER | | | |
| | | | | | | | | | | | | IT WILL TURN GREEN WHEN IT IS | | | | | | IT WILL TURN GREEN WHEN IT IS | | | |

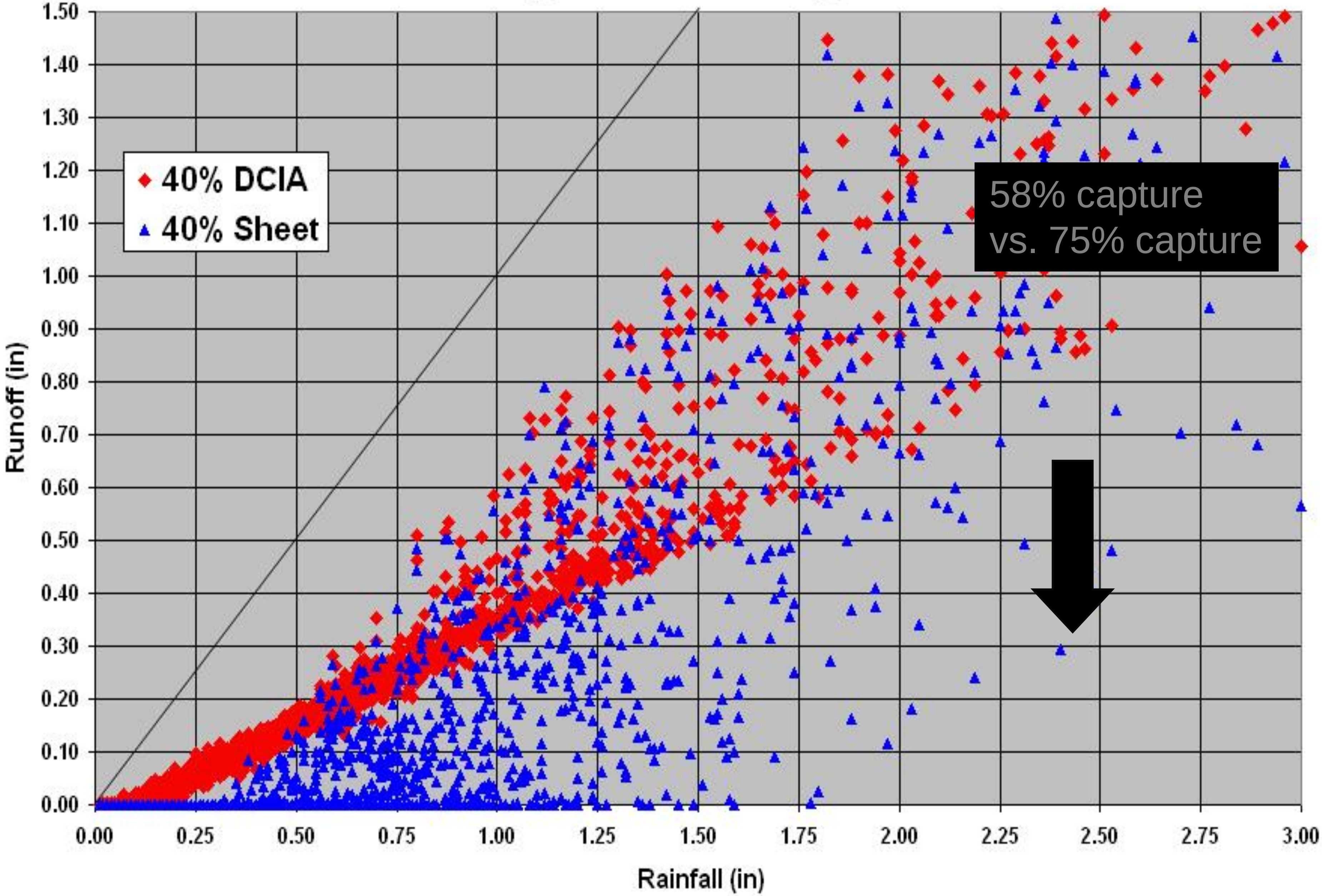
# 40% Impervious DCIA

# C Soil + 40% DCIA

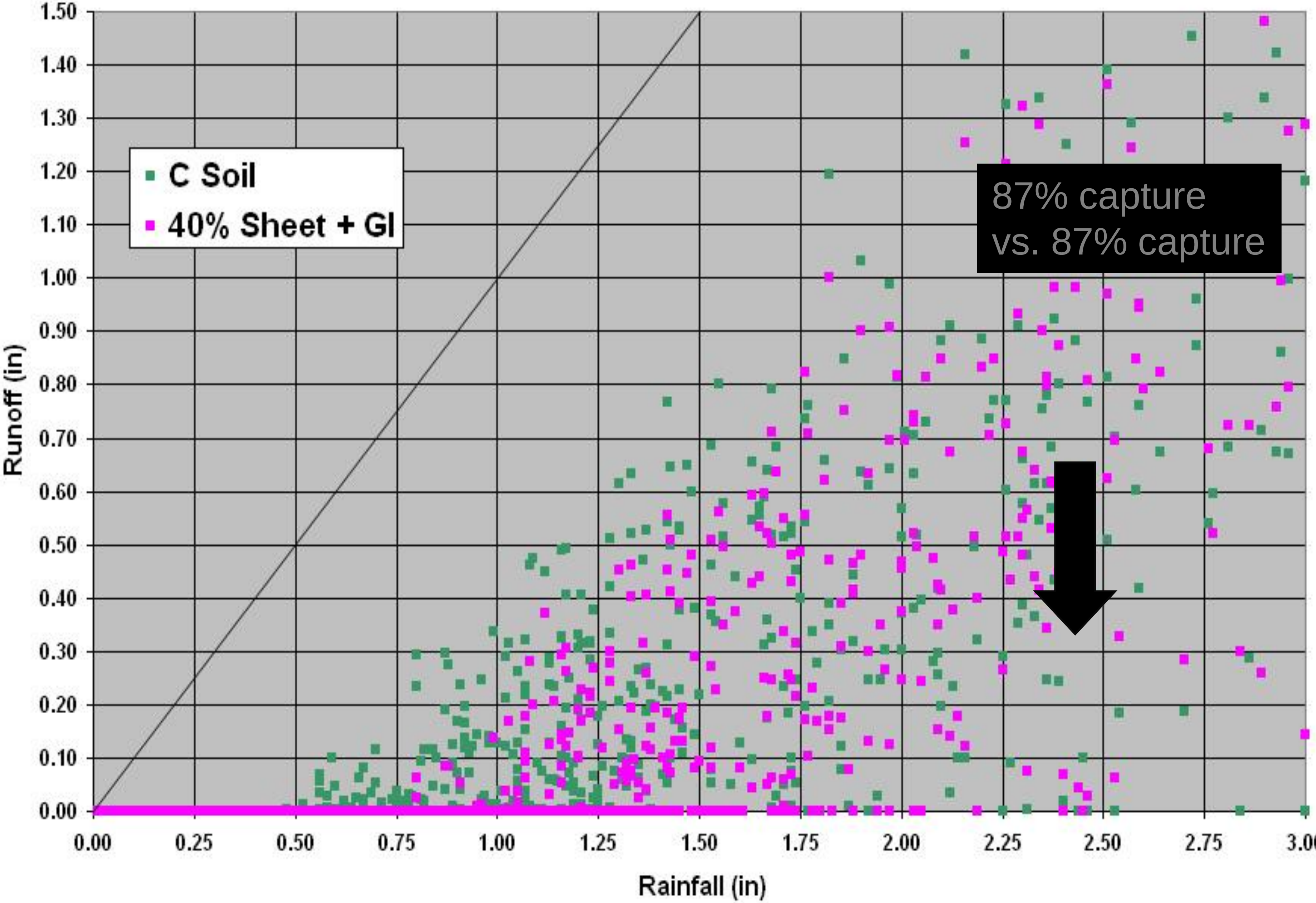




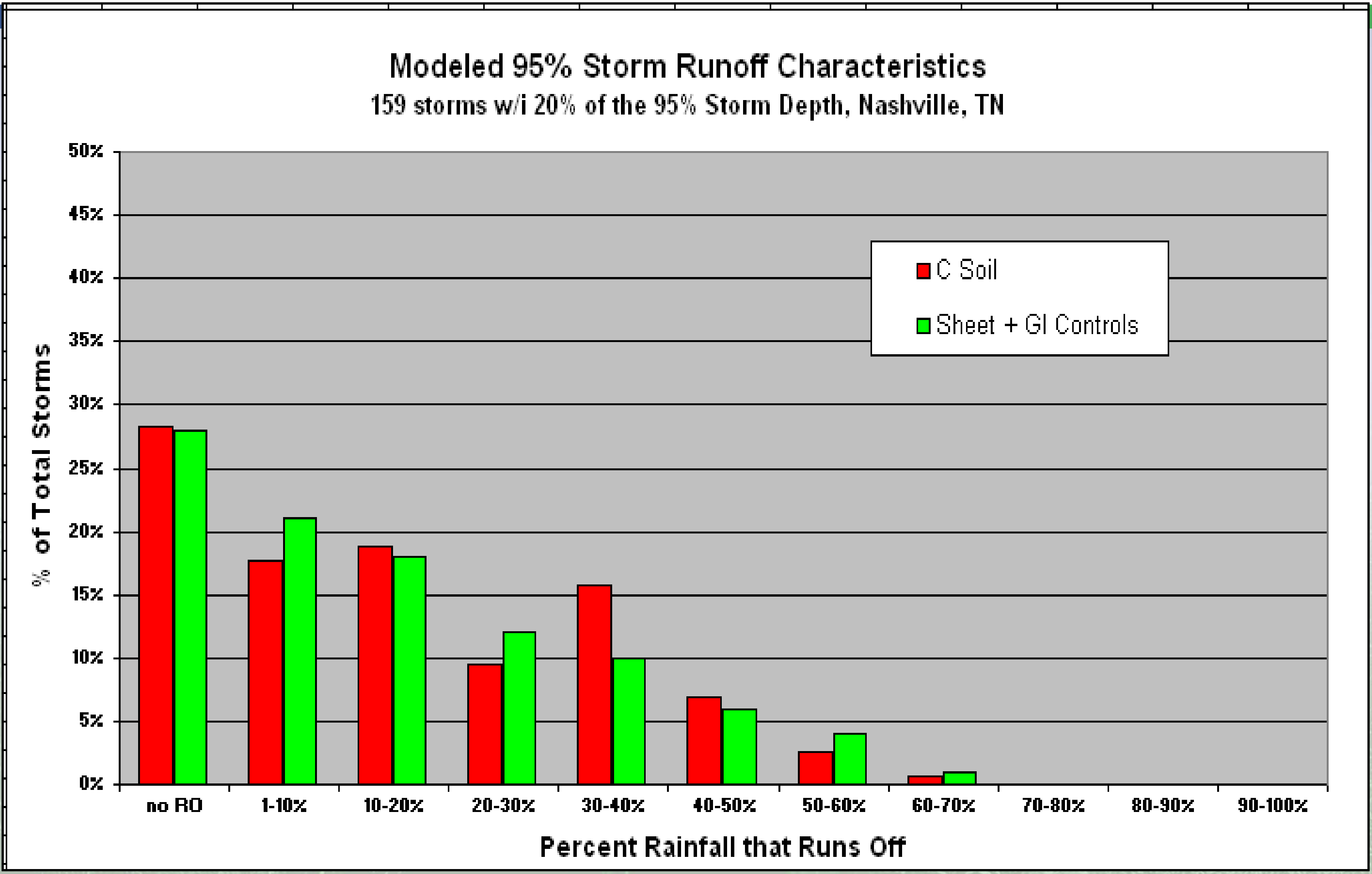
# C Soil 40% DCIA & 40% Sheet



# C Soil + Sheet Flow and Green Infrastructure



# Steps to "Mimic Nature"

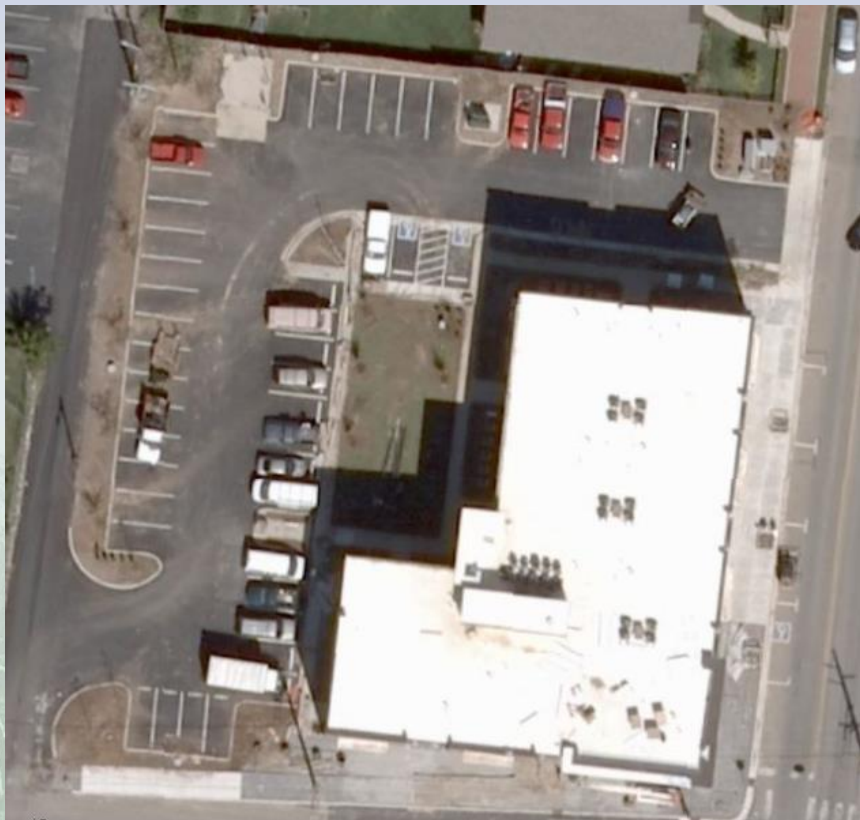


# Meeting the Standard by Example

- Site Area = 1 Acre
- Urban Setting
- Building Footprint = 26%
- Total Impervious = 86%
- Goal: Site composite of Rv = 0.2

# Calculate Site Weighted Rv

amec foster wheeler



- **Impervious = 0.86 Acres**
- **Turf C Soil = 0.14 Acres**

| 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 |

$$Rv = \frac{[(0.86Ac)(0.95)+(0.14Ac)(0.2)]}{1Ac}$$

$$Rv = 0.85 >> 0.2$$

# Structural Practices

- **Permeable Concrete (0.1 Ac)**
- **Bioretention (0.64 Ac)**
- **Green Roof (0.12 Ac)**
- **Turf C Soil (0.14 Ac)**

**Rv= (0.1Ac*0.24)+**
**(0.64Ac*0.19) +**
**(0.12Ac*0.2) +**
**(0.14Ac*0.2)/**
**1Ac**

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**Rv = 0.198 < 0.2**

# Some potential advantages

- It is simple to understand and little harder than a “C” Factor calculation
- It balances data, experience, and continuous modeling
- It’s three steps value natural treatment approaches first
- It is derived for an area and thus does not force a one-size-fits-all criteria
- It integrates natural vegetation without a logic break
- It is appropriately conservative where real-world failure rates are known

# Nashville to date:

- About 80 sites – generally successful
- Staff is in favor of the approach and feels it promotes its objectives and priorities
- About 25% of developers choose this approach over the older TSS approach
- It will become mandatory as the first line of water quality treatment next year

# Questions?

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