# Infiltration Stormwater Control Practices – Guidelines

# And Lessons Learned

Roger Bannerman
WDNR

# Determination of Policy

- **State Laws**
  - Describe intent
- **Administrative Rules**
  - Establish specific goals: Performance standards
  - Local Ordinances
- **Technical Standards**
  - How to achieve performance standards

# The Runoff Management Rules (NR 151)

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HTTP://www.dnr.state.wi.us/org/water/wm/nps/stormwater.htm

Click on Administrative Rules & Technical Standards

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# Post Construction Infiltration Performance Standards (by design)

By design, infiltrate sufficient runoff volume so that the post-development average annual infiltration volume shall be a portion of pre-development infiltration volume.

| **Residential** | **Non-residential** |
|---|---|
| 90% (1% Cap) | 60% (2% Cap) |

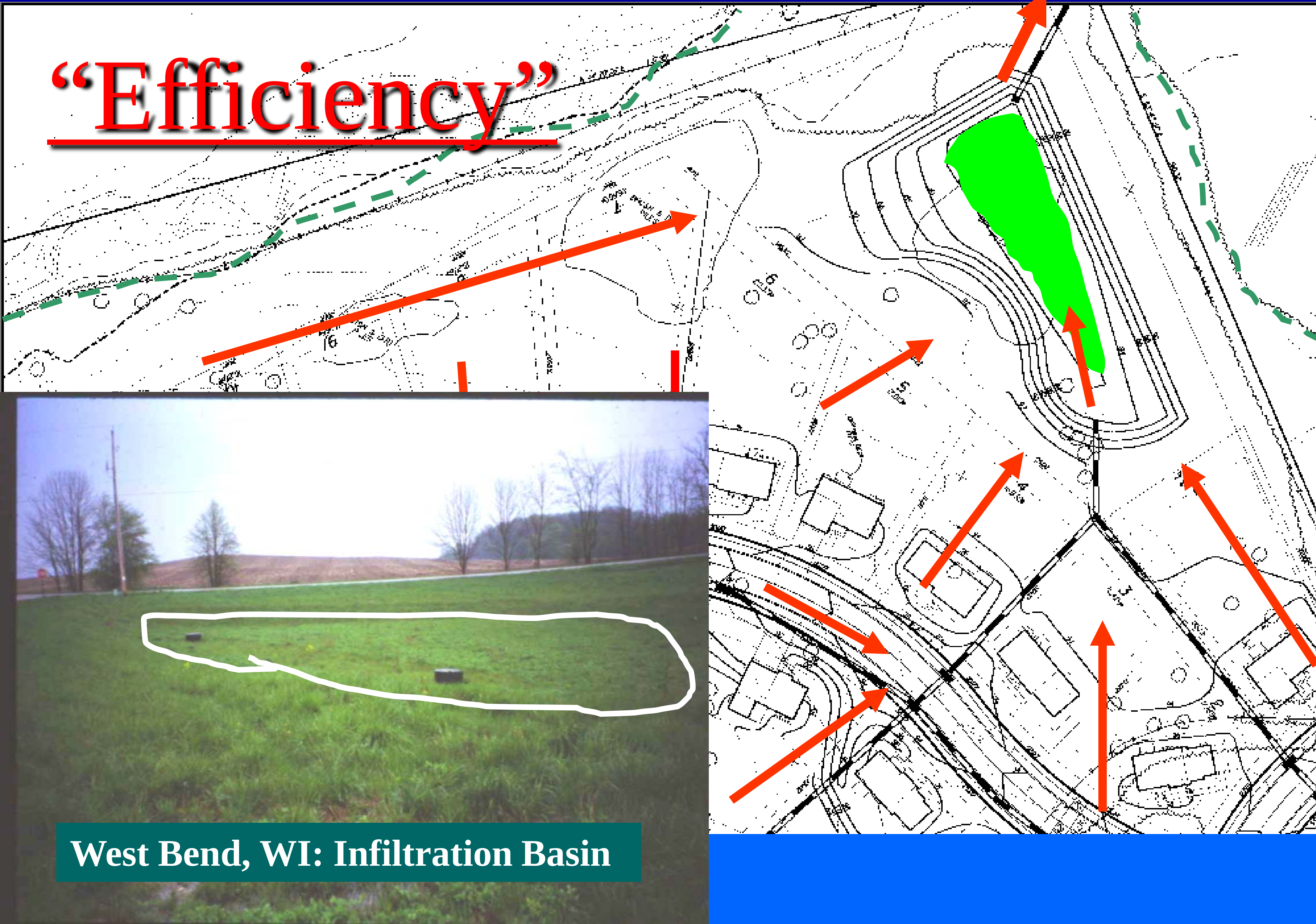
# Pre-Development Curve Numbers

- Standard based on pre-development condition
- CN shall assume "good hydrologic condition" as identified in TR-55 or equivalent methodology
- Maximum Cropland Curve Numbers are:

| Hydrologic Soil Group | A | B | C | D |
|---|---|---|---|---|
| Runoff Curve Number | 56 | 70 | 79 | 83 |

# Conventional Pipe and Pond  Centralized Control

## “Efficiency”



**West Bend, WI: Infiltration Basin**

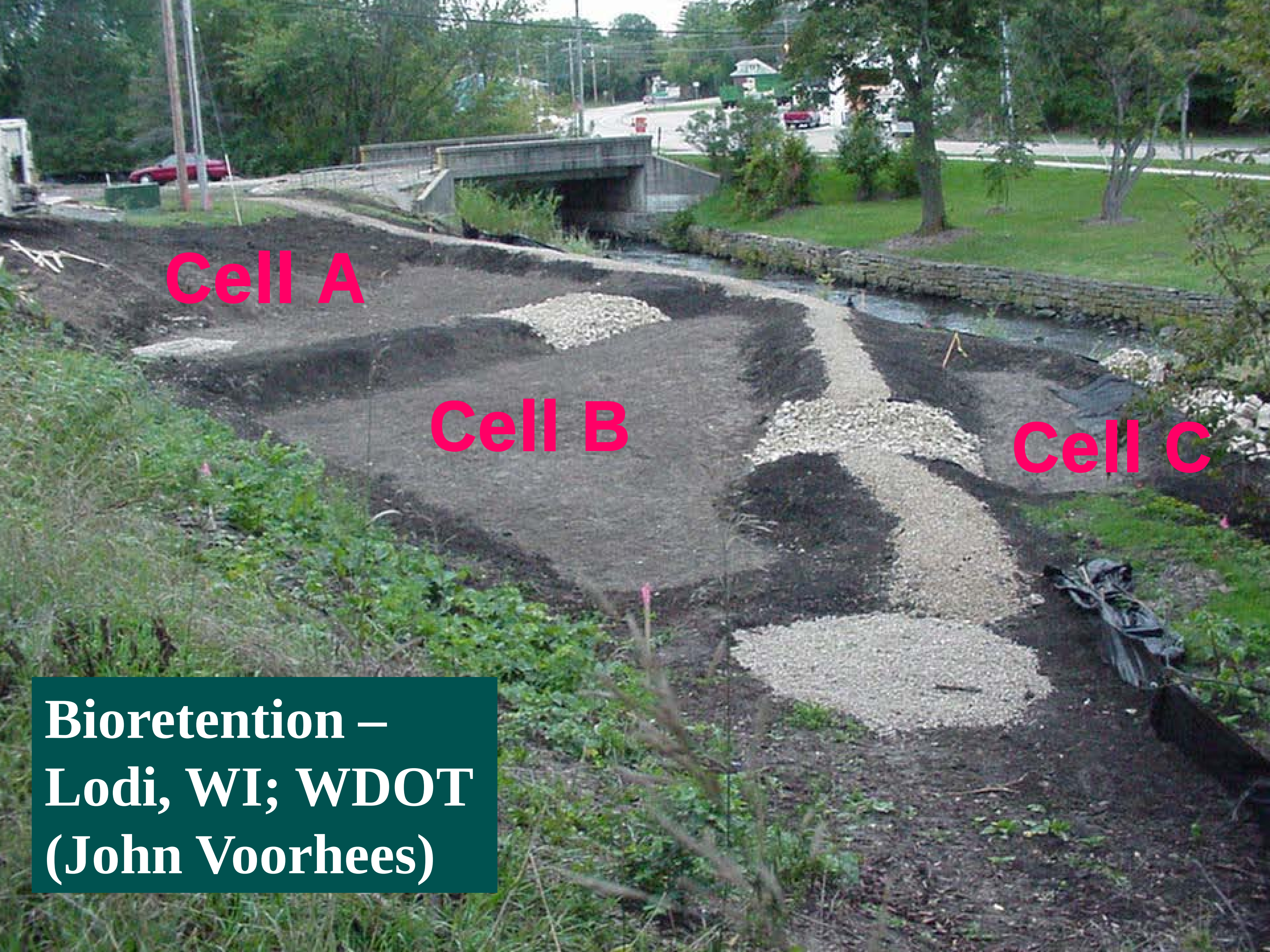

Rock County Office

# Backyard Rain Garden – 300 sq. ft. Madison, WI

Roof Area: 1000 square feet

# Bioretention – Middleton, WI

# Adam St. Inlets to Rain Gardens – Madison, WI


Cell A
Cell B
Cell C
Bioretention –
Lodi, WI; WDOT
(John Voorhees)

# Exclusions

- Based on ***groundwater quality protection***
- Two categories of exclusions
  - Based on land uses & source areas:
    - » Industrial sites; fueling & vehicle maintenance
  - Based on site restriction for infiltration devices
    - » Karst topography, nearness to wells, etc.

# Exemptions

- Based on *feasibility*
- Two categories of exemptions
  - – Based on land uses & source areas:
    - » Small parking areas & access roads; redevelopment sites; small in-fill sites; roads/arterial roads in specified areas
  - – Based on site restriction for infiltration devices
    - » Measured soil infiltration rate less than 0.6”/hr
    - » Infiltration when soil is frozen

# Technical Standards for Infiltration

- Site Evaluation Standard
- Bioretention Standard
- Infiltration Basin Standard
- Grass Swale Standard
- Rain Garden Standard

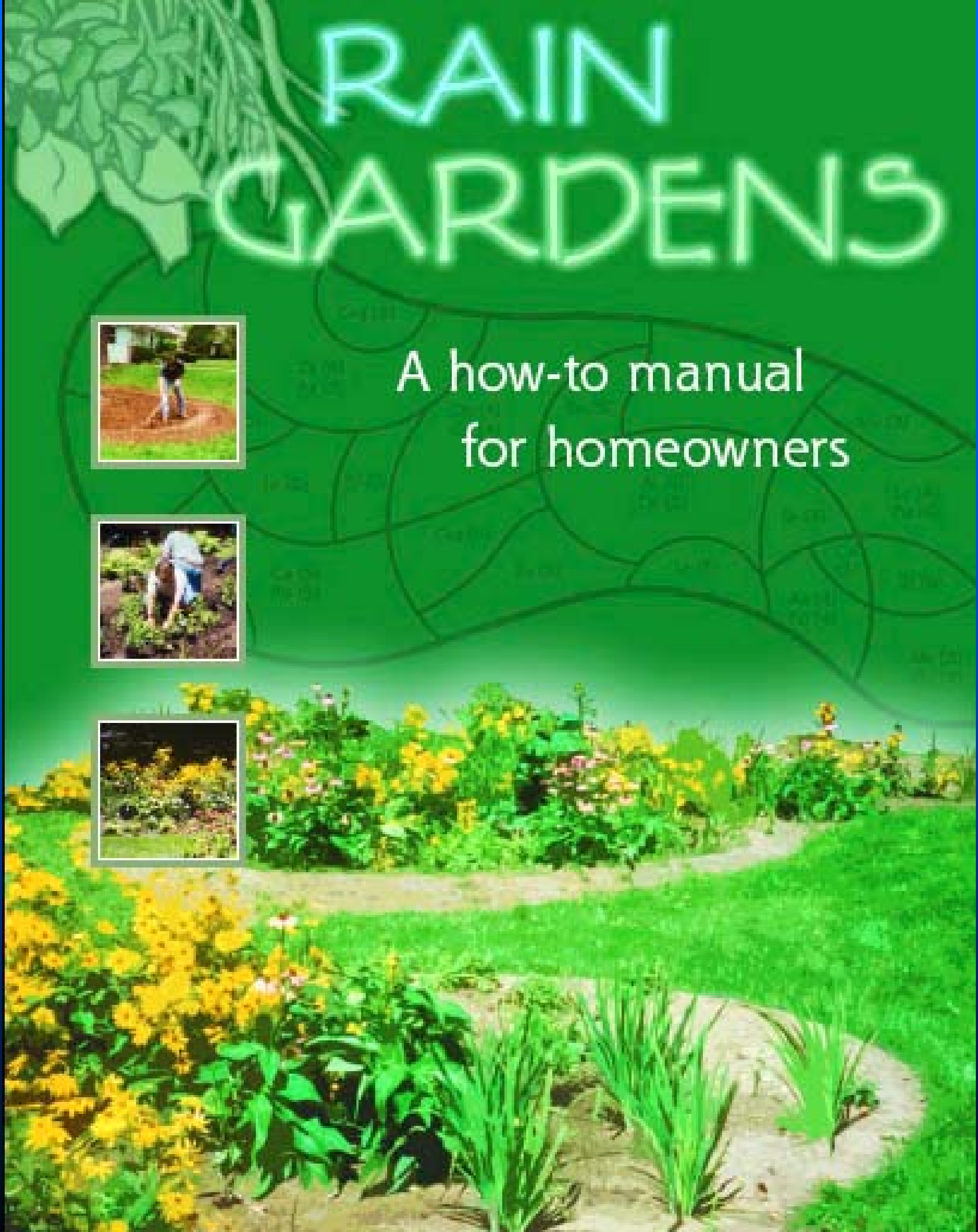
- HTTP://dnr.wi.gov/org/water/wm/nps/stormwater/techstds.htm

**Contents of Technical Std.:**

1. Criteria
2. Considerations
3. Plan or Report
4. Op. and Maintenance

# Rain Garden Manual on WDNR Web Site

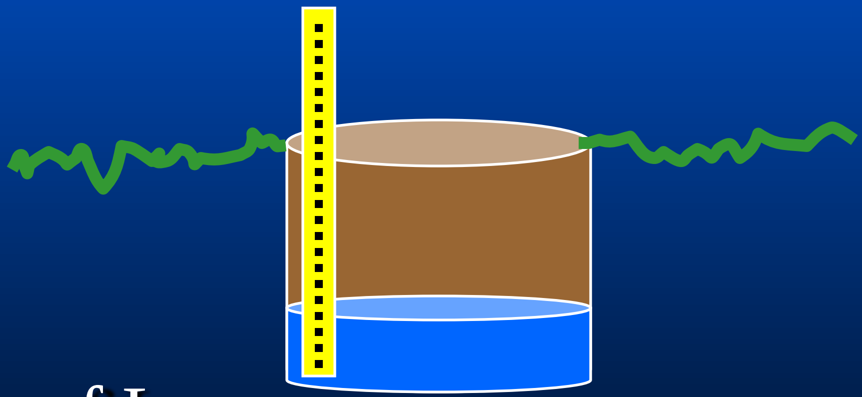
**http://www.dnr.state.wi.us/org/water/wm/nps/rg/index.htm**



# New Rain Garden – Cross Plains, WI

# Determining Your Soil Type

- Some hints:
  - 1. Soil feels gritty and coarse = sandy
  - 2. Soil feels smooth not sticky = silty
  - 3. Soil feels sticky and clumpy = clayey
- Have soil analyzed
- Use infiltration test
  - Make 6” diameter hole
  - Fill & Let Stand
  - Fill Again & Time Rate of Loss



# Long-Term Water Budget of Two Rain Gardens in Madison, WI

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# Breaking Ground

# Adding Compost

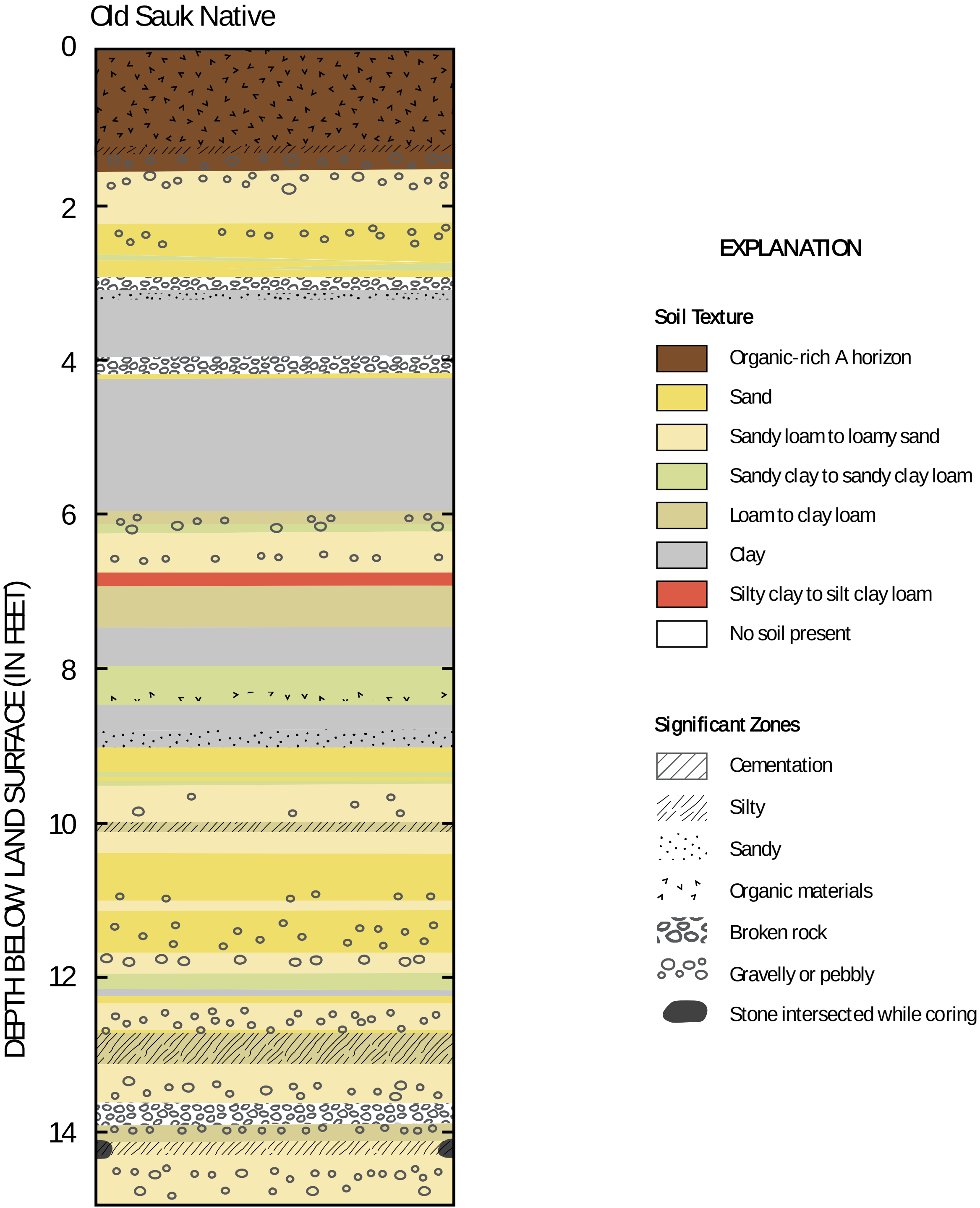
# Two Rain Gardens in Silt/Clay Soil – 4 to 1 Ratio of Roof To Rain Garden Area


Evapotranspiration
Volume In
Datalogger
Soil Moisture
Pond Depth
Volume Out
11/3/2003

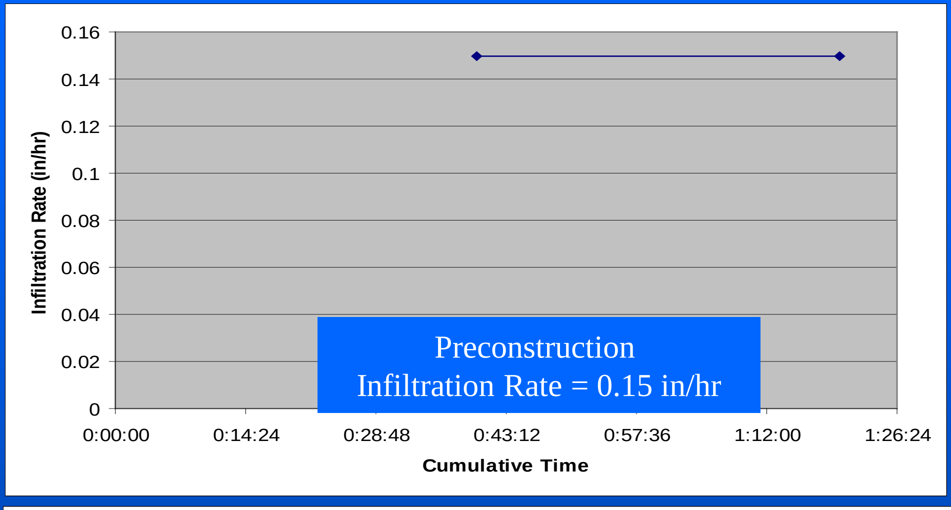
# Performance Summary for 2007 Gardens in Clay Soil

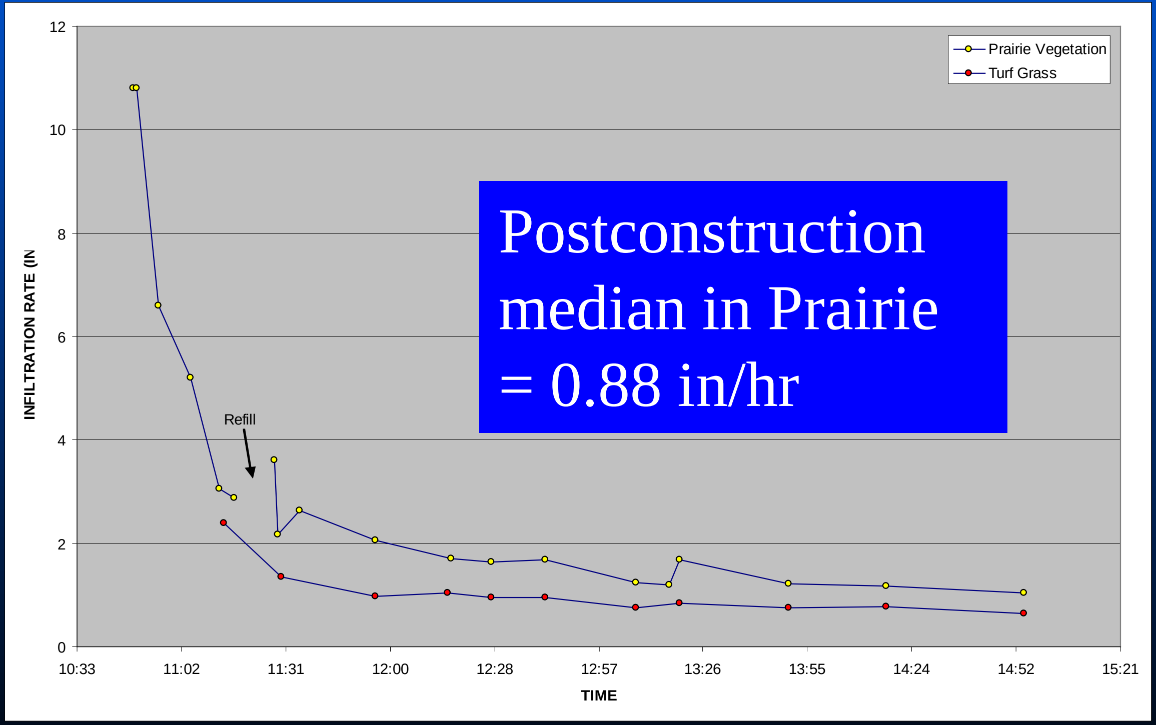
| Plant Type | Volume In, Gallons | Volume Out, Gallons | # Events with Ponding | **Percent Reduction** |
|---|---|---|---|---|
| Turf | 46,000 | 107 | 19 | **99%** |
| Native Plants | 42,000 | 0 | 9 | **100%** |

# Silt/Clay rain garden soil core reveals sand down to approximately 3 feet then turns to clay

# Verification of Infiltration Rates




10/15/2008

# Capacity of Prairie Clay Rain Gardens

Storage Volume = 200 cubic feet

Equal Roof Runoff = 1.56 inches (90% of Events)

Void Space Above Clay = 200 cubic feet

Equal Roof Runoff = 1.56 inches

Total Capacity = 3.12 inches of rain

# Winter had lowest infiltration rates and more pooled water

USGS
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# 30 Events Over Four Years in January, February, and March – Zero Discharge From Prairie Clay Garden

# Bioretention Perfomance in Cold Climates, Davidson and others, 2008, WERF

**Purpose: Conduct Simulated Snowmelt Events to Measure Response under Winter Conditions**

Crystal Lake Bioretention Cell
Burnsville, Mn

Cottage Grove Bioretention Cell
Cottage Grove, MN

Thompson Lake Bioretention Cell
West St. Paul, MN

Stillwater Bioretention Cell
Stillwater, Mn

**"Characteristically, the fastest rates occurred early winter in the testing season and progressively slowed as the tests were completed later in the season toward spring."**

Cottage Grove Cell

# Evapotranspiration

- Using modified Penman-Monteith equation
- Parameters:
  - Solar radiation
  - Wind speed
  - Precipitation depth
  - Humidity
  - Air Temperature
- Applies correction factor for vegetation type

# Water Balance in Prairie and Turf Clay Rain Gardens

| Water Year | Precip. , inches | Influent, inches | Effluent, inches | Evapo, inches | Recharge, inches |
|---|---|---|---|---|---|
| 2007 (Prairie) | 42 | 132 | 0 | 5 (3%) | 169 (97%) |
| 2007 (Turf) | 42 | 176 | 0 | 23 (11%) | 194 (89%) |


Edgewood College Bioretention Systems, Jim Lorman

# Bioretention Engineered Soil Mix – Technical Standard 1004


– ***40% Sand:*** ASTM C33 (Fine Aggregate Concrete Sand; 97% Silica)
– ***20 to 30%Topsoil:*** USDA sandy loam, loamy sand or loam (Verification by lab test or competent professional)
– ***30 to 40% Compost:*** Specification 100 (Compost)

# Soil Mixing

Technical Standard 1004 trying to achieve a balance between:

1. adequate infiltration rate
2. reducing pollutant concentration
3. Support plant growth


Jeremy Balousek
Clay Textured Topsoil Used

# Soil Texture for Two Bioretention Systems in Madison – Number 1 Had Failed

| Site Number | % Organic Matter | % Sand | % Silt | % Clay | Soil Texture |
|---|---|---|---|---|---|
| 1 (John Q) | 3.5 | 53 | 33 | 14 | Sandy Loam |
| 2 (Omo) | 3.0 | 59 | 28 | 13 | Sandy Loam |

**Prince George County, Maryland – No more than 5% fines.**


Linda and Mark Piotrowski
28020 El Dorado Place, Lathrup Village


**Fill Soil Media:**

**85 – 88% Washed Sand**

**8 – 12% Fines (Silt + Clay)**

**3 – 5% Organic Matter**

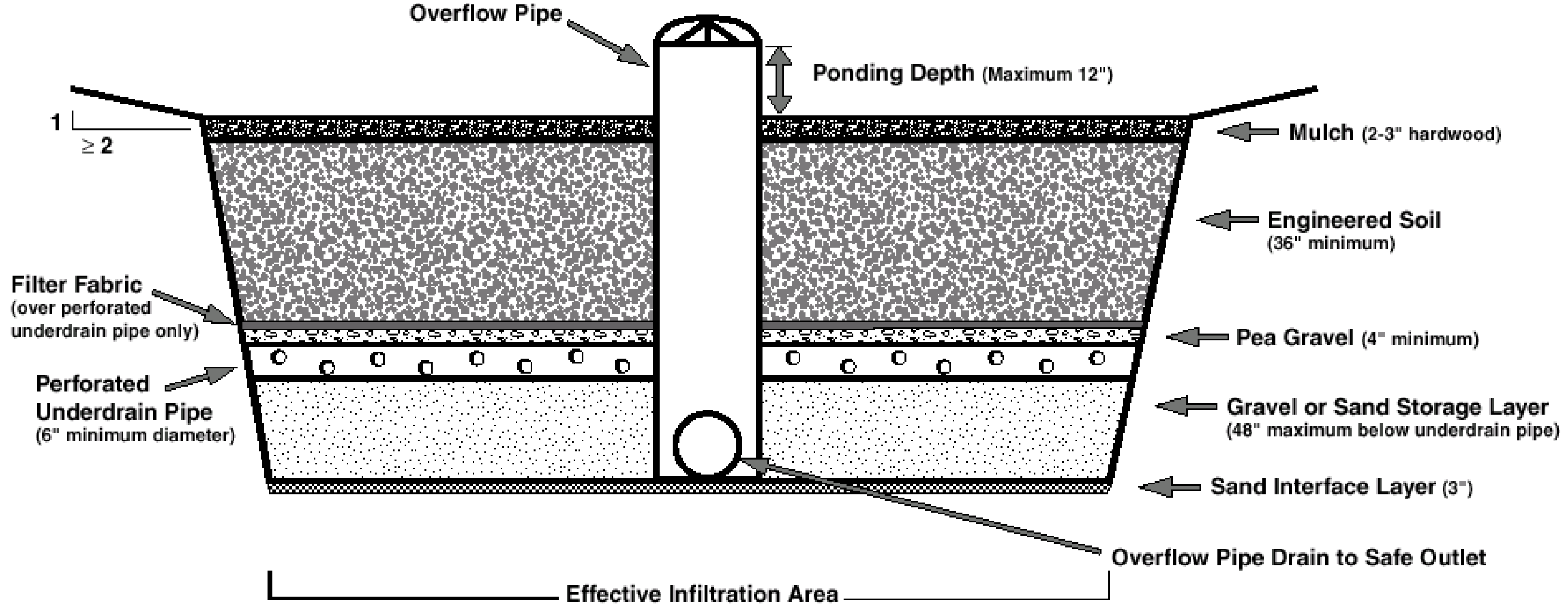
Engineered Soil Mix – University of North Carolina (William Hunt, 2006)

# Proposed Bioretention Engineered Soil Mix – Technical Standard 1004


- ***50% Sand:*** ASTM C33 (Fine Aggregate Concrete Sand; 97% Silica)
- ***50% Compost:*** Specification 100 (Compost)
- Use Dolomite or Carbonate Sand, But Not Constructed Sand

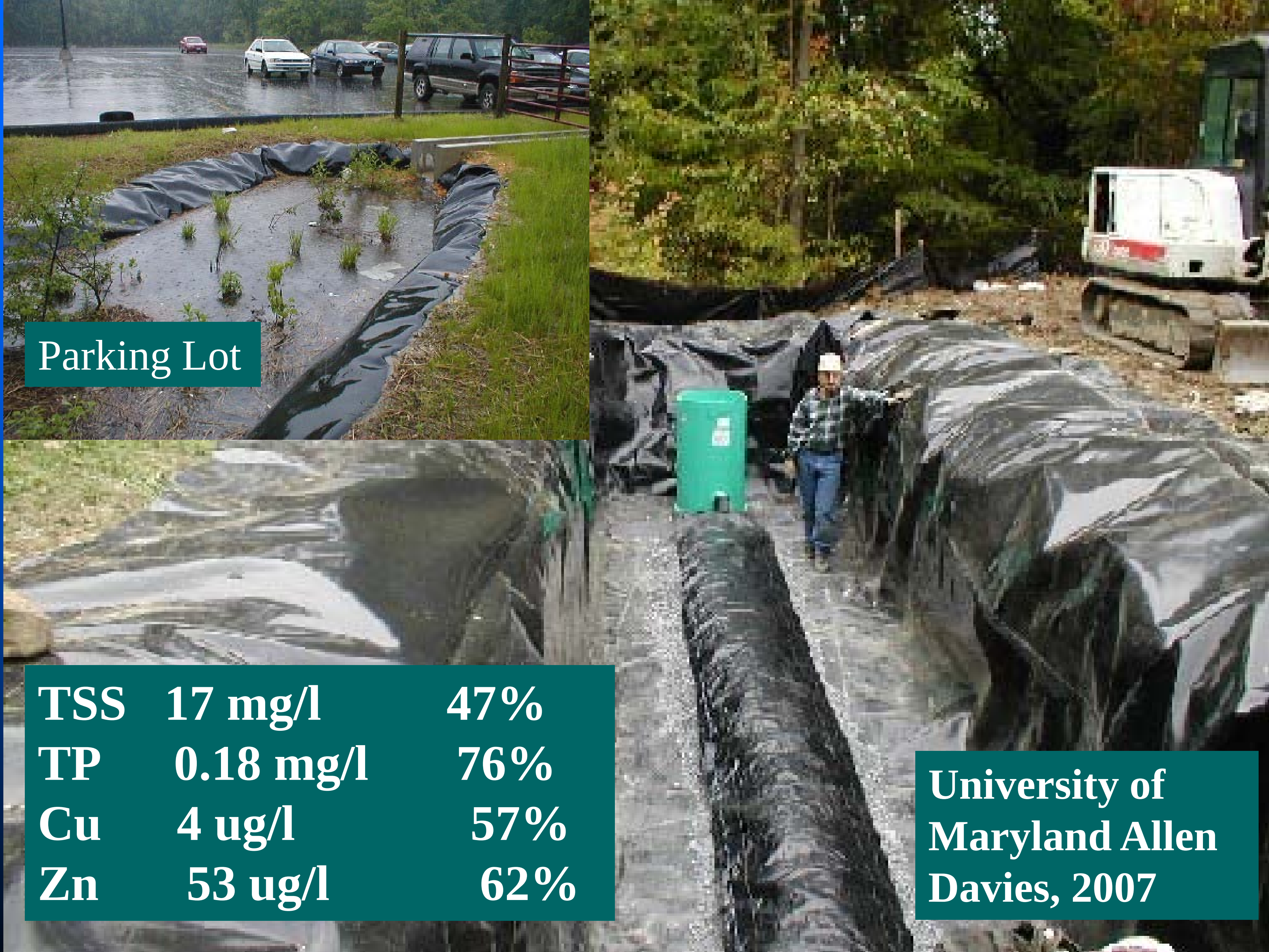
# Depth of Engineered Soil (3 Feet = 90% TSS Reducton) – Bioretention Standard 1004

Figure 3. Example of **Bioretention Device – cross-section across length of device**



# Bioretention Efficiency – University of North Carolina, William Hunt, 2006

| Location (depth) | TN Removal, % | TP Removal, % | Other, % |
|---|---|---|---|
| Greensboro (4 ft.) | 33 | 240 increase – yr 1<br>39 increase – yr 2 | 65 – 99 Cu & Zn |
| Greensboro (4 ft.) | 43 | 9 | 56 – 86 Cu & Zn |
| Chapel Hill (4 ft.) | 40 | 65 | |
| Louisburg (2.5 ft.) | 64 | 66 | |
| Louisburg (2.5 ft.) | 68 | 22 | |
| Charlotte (4 ft.) | 65 | 68 | Fecal Col – 90% |


Parking Lot
TSS 17 mg/l 47%
TP 0.18 mg/l 76%
Cu 4 ug/l 57%
Zn 53 ug/l 62%
University of Maryland Allen Davies, 2007

# Cumulative Percent Removal by Depth – Allen Davis, University of Maryland (Lab & Field Results)

| Depth | Cu | Zn | P | TN |
|---|---|---|---|---|
| 1 ft. | 90 | 87 | 0 | -29 |
| 2 ft. | 93 | 98 | 73 | 0 |
| 3 ft. | 93 | 99 | 81 | 43 |

# Guidelines for Depth of Engineered Soil – William Hunt, 2006

| Pollutant | Minimum Engineered Mix Depth |
| --- | --- |
| TSS | No Minimum |
| Metals | 18 inches |
| TN | 36 inches |
| TP | 24 inches |

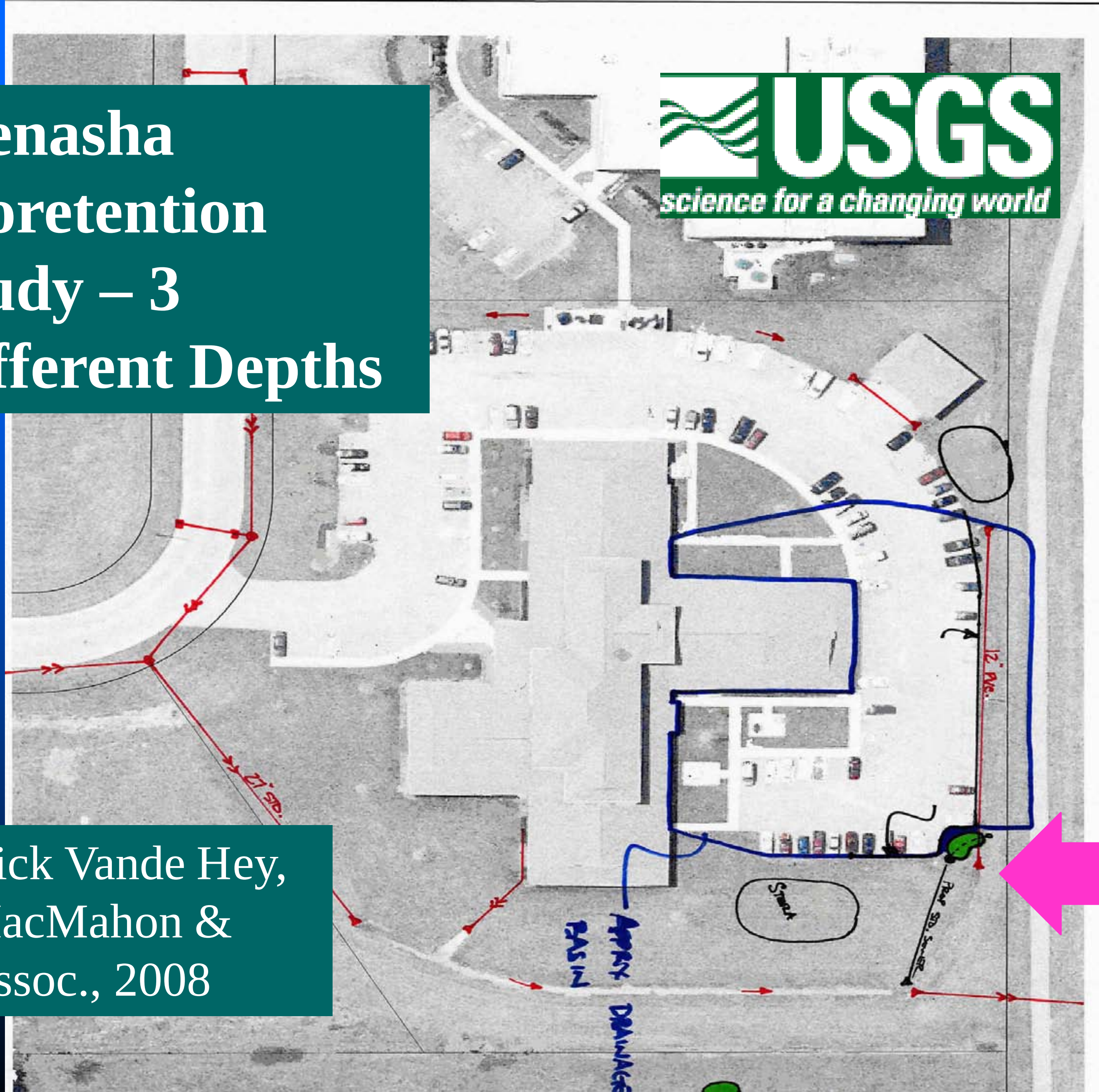
| | | | |
|---|---|---|---|
| TSS | 78 | 75 | 87% |
| TP | 27 | 59 | 61% |
| Zn | 60 | 82 | 80% |
| TN | 27 | 44 | 32% |

Austin Surface Sand Filter – 18 to 24 inches Thick


University of Maryland
Allen Davis, 2003
Flow Peaks Reduced 50% & Peak Flows Delayed 2 Times or More – Small Storms No Flow


William Hunt, 2006
Media Depth for Plants:
Trees – 3 feet
Shrubs – 2 feet
Grass – 18 inches

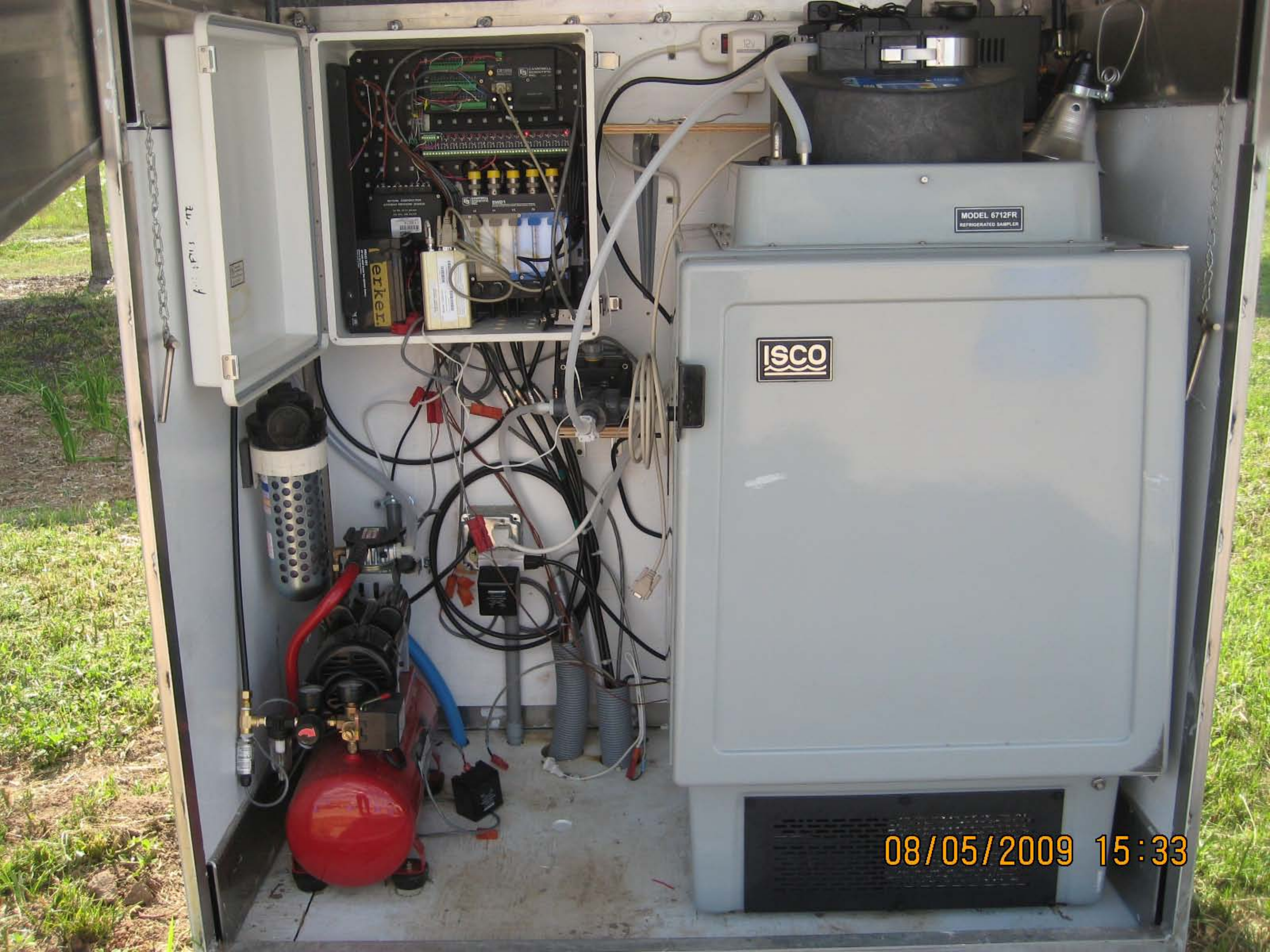
# Menasha Bioretention Study – 3 Different Depths



Nick Vande Hey, MacMahon & Assoc., 2008


Biofiltration Research Project brought to you by:
SCA
Miron
McMAHON
ENGINEERS ARCHITECTS
USGS
science for a changing world
• Schmalz Custom Landscaping
• Waupaca Sand & Solutions
• White Oak Farm
• Town of Menasha
• Faith Technologies
• Wittman Construction, LLC
• Fox-Wolf Watershed Alliance
• Northeast Wisconsin Stormwater Consortium
• City of Appleton
The purpose of the Biofiltration Research Project is to determine the appropriate amount of engineered soil which is needed to cost-effectively remove stormwater pollutants.
Typical Biofiltration Device Cross-Section
TORK
08/05/2009 15:35


08/21/2009 14:33


MODEL 6712FR
REFRIGERATED SAMPLER
ISCO
12V
08/05/2009 15:33


FLOW

# Infiltration Basin Technical Standard 1003

# Comparison of Stormwater Runoff Quality and Quantity Using Conventional and LID Strategies

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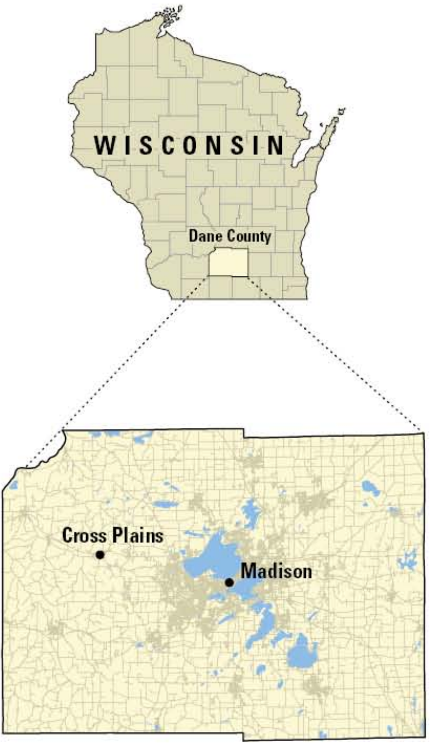
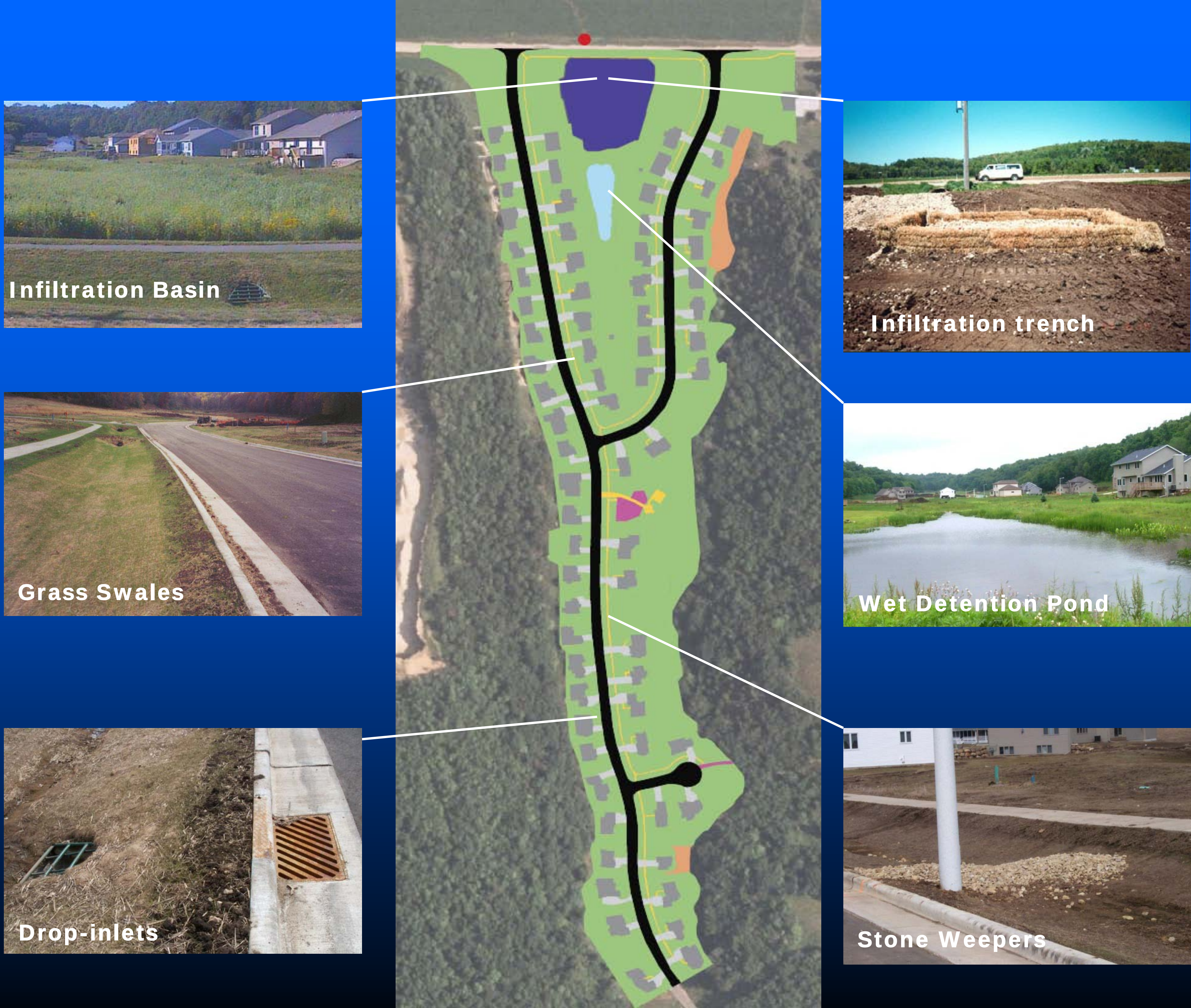


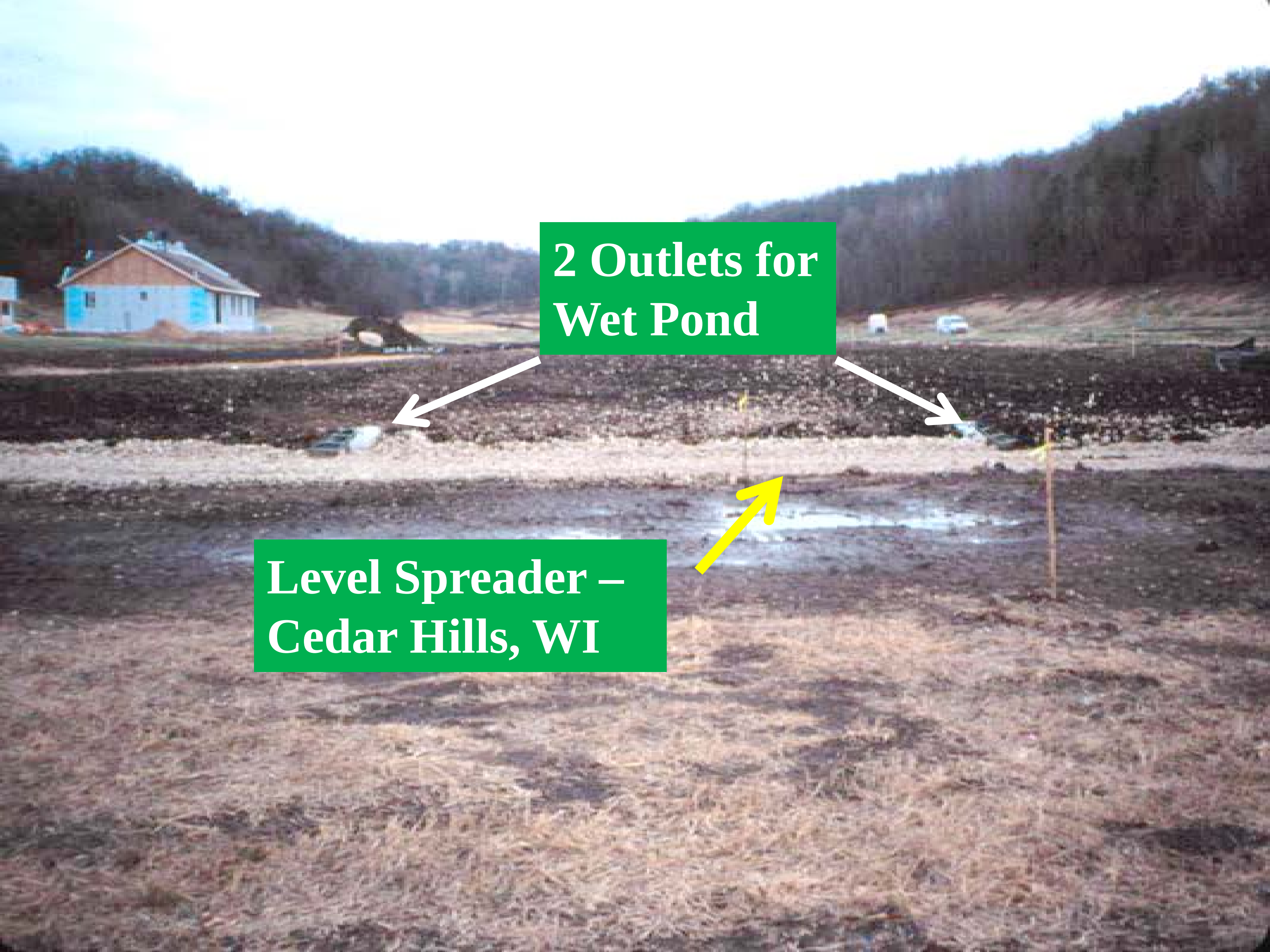


Base from Dane County Land Information Office Orthophotography, 1:10,000, 2005. Map Projection: Dane County Coordinate System.

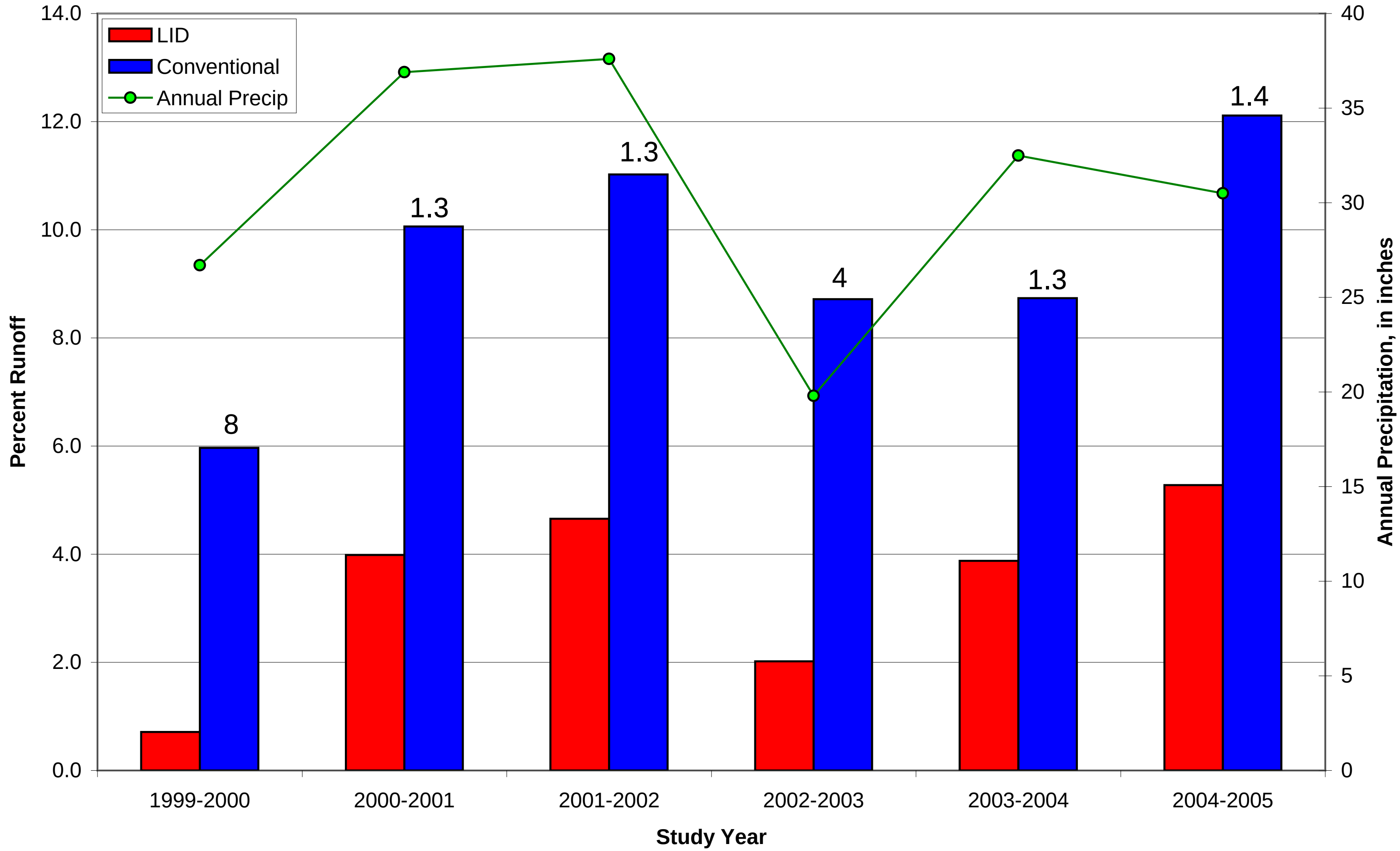

Infiltration Basin
Infiltration trench
Grass Swales
Wet Detention Pond
Drop-inlets
Stone Weepers

# Cedar Hills


Infiltration Basin: Cedar Hills


2 Outlets for Wet Pond
Level Spreader – Cedar Hills, WI

## Comparison of Annual Runoff Between the LID and Conventional Basins

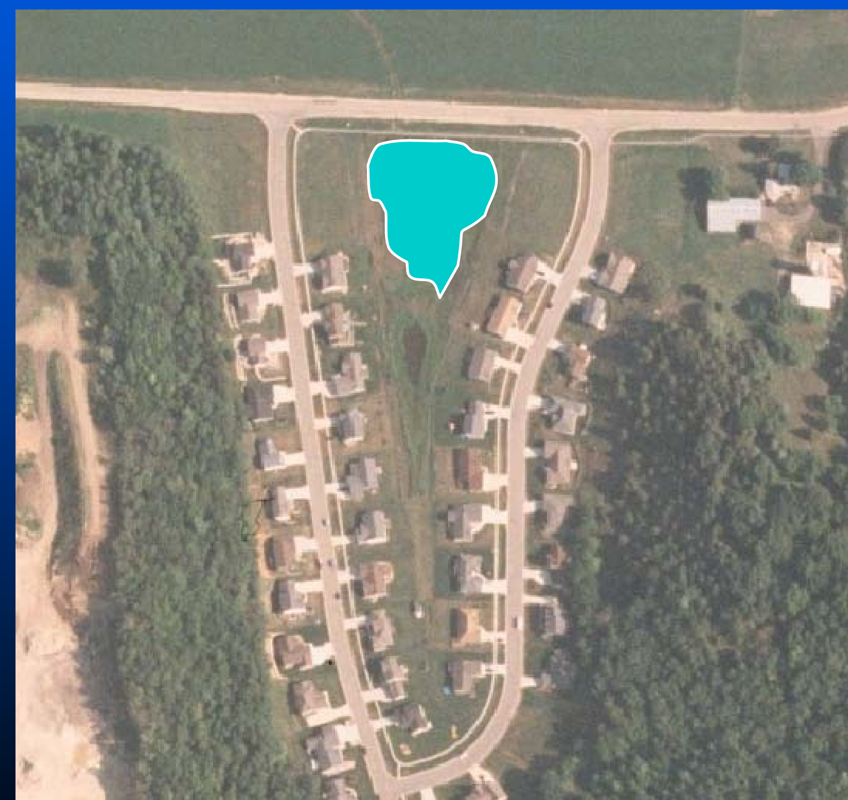



Annual cycle = May through April

1999 2000 2001 2002 2003 2004

# Infiltration Basin Performance

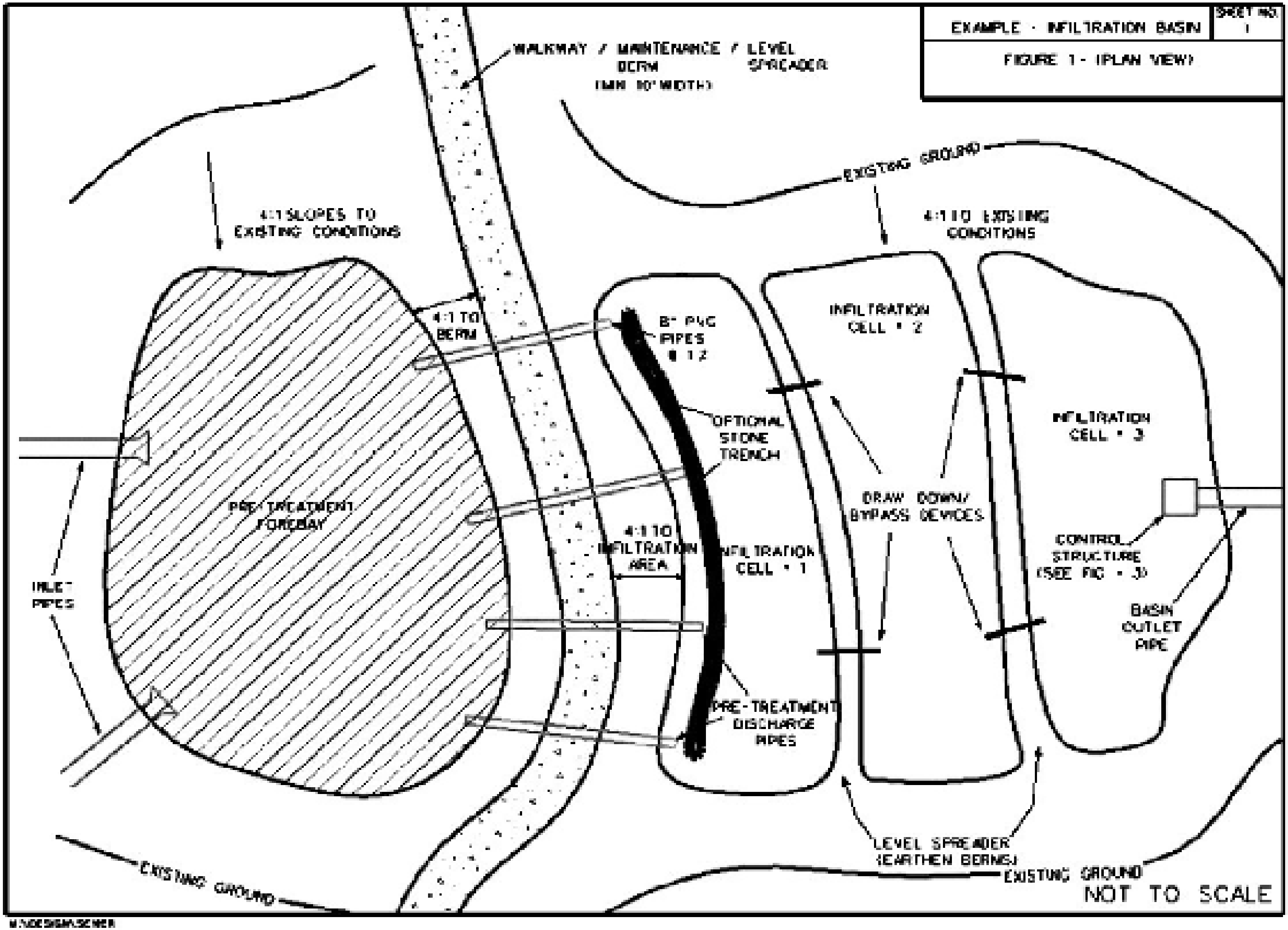
*Overall Reduction in Runoff Volume for Infil. Basin = 51%*

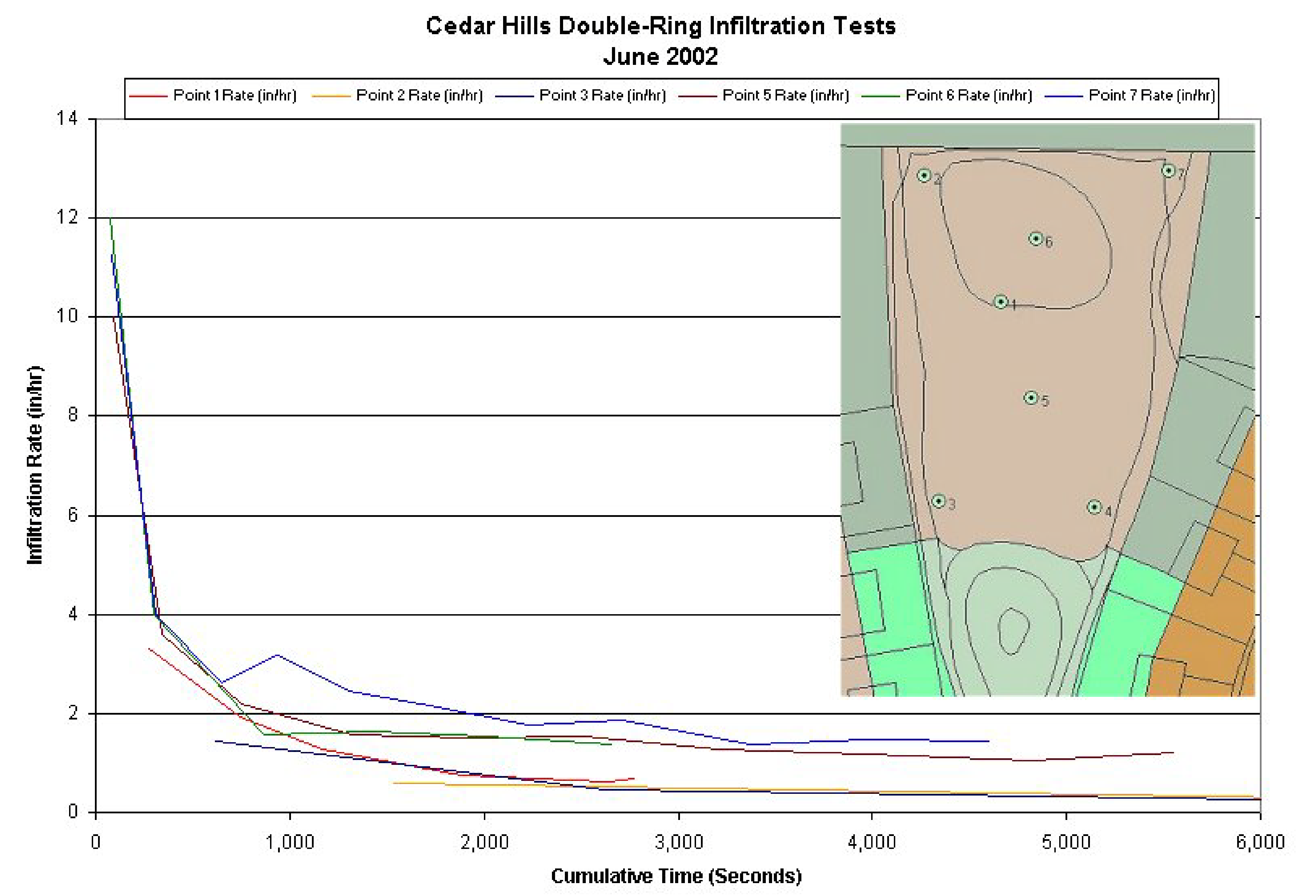


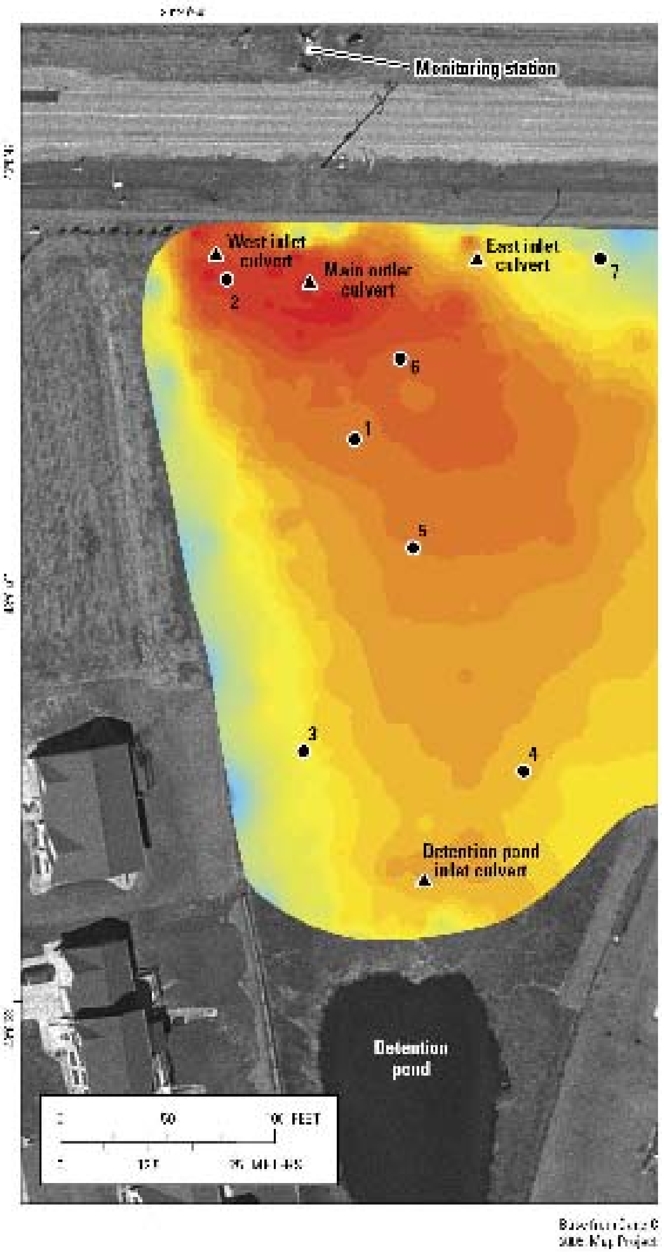
| | Percent Reduction | | |
|---|---|---|---|
| | Precipitation Intensity (inches/hour) | | |
| Statistic | 0 - 0.5 | 0.5 - 1.0 | > 1.0 |
| Mean | 69 | 43 | 32 |
| Median | 71 | 44 | 43 |

# Diminished Effective Infiltration Area


**Infiltration Standard Requires Breaking Effective Infiltration Area into Cells – when slope is indicated or the flow path exceeds 300 feet.**


EXAMPLE - INFILTRATION BASIN
SHEET NO. 1
FIGURE 1 - (PLAN VIEW)
WALKWAY / MAINTENANCE / LEVEL SPREADER BERM (MIN 10' WIDTH)
EXISTING GROUND
4:1 SLOPES TO EXISTING CONDITIONS
4:1 TO EXISTING CONDITIONS
4:1 TO BERM
8" PVC PIPES @ 1.2
INFILTRATION CELL # 2
INFILTRATION CELL # 3
OPTIONAL STONE TRENCH
PRE-TREATMENT FOREBAY
DRAW DOWN/ BYPASS DEVICES
4:1 TO INFILTRATION AREA
INFILTRATION CELL # 1
CONTROL STRUCTURE (SEE FIG # 3)
INLET PIPES
BASIN OUTLET PIPE
PRE-TREATMENT DISCHARGE PIPES
LEVEL SPREADER (EARTHEN BERMS)
EXISTING GROUND
EXISTING GROUND
NOT TO SCALE


Cedar Hills Double-Ring Infiltration Tests
June 2002
Point 1 Rate (in/hr)
Point 2 Rate (in/hr)
Point 3 Rate (in/hr)
Point 5 Rate (in/hr)
Point 6 Rate (in/hr)
Point 7 Rate (in/hr)
Infiltration Rate (in/hr)
0
2
4
6
8
10
12
14
Cumulative Time (Seconds)
0
1,000
2,000
3,000
4,000
5,000
6,000
1
2
3
4
5
6
7


Monitoring station
West inlet culvert
Main outlet culvert
East inlet culvert
7
2
6
1
5
3
4
Detention pond inlet culvert
Detention pond
50
100 FEET


Detention pond inlet culverts
West-inlet culvert

## Infiltration Basin with Compacted Soils

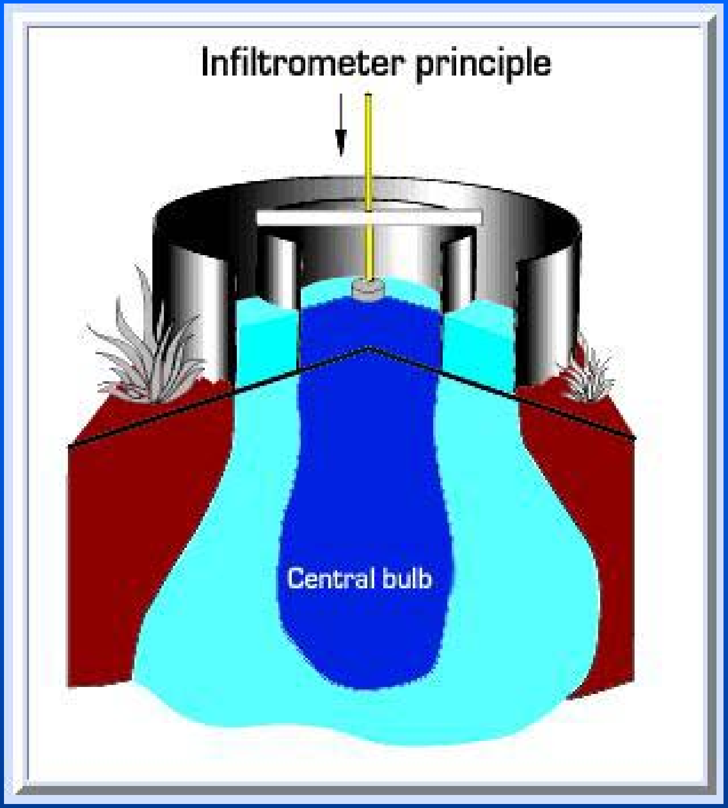
Standard requires adding 2 inches compost and chisel plowing to 12 inches

# Grass Swale Standard 1005 - Construction Criteria

Minimize or mitigate the effects of compaction from grading activities with incorporation of compost into subsoil.

Two inches of compost and top soil incorporated using chisel plow reaching 12 inches below surface.

# Double-Ring Infiltrometer – ASTM D3385 – Modified for Use in Wisconsin ( 2 hour test)



# Steps for Site Evaluation Standard 1002

- Step A – Initial Screening
- Step B – Field Verification of Information Collected in Step A.
- Step C – Evaluation of Specific Infiltration Area.
- Step D – Soil and Site Evaluation Reporting.

# Number of Pits and Borings – Step C

| *Infiltration Device* | *Tests Required* | *Minimum Number of Pits or Borings* | *Minimum Drill/Test Depth* |
|---|---|---|---|
| Bioretention | Pits or Borings; Mounding | 1 test/50 linear feet of device with a Minimum of 2 | 5 Feet or Depth to Limiting Layer |
| Infiltration Basin | Pits or Borings; Mounding | 2 Pits per Area; With 1 Pit or Boring for Every 10,000 sq. ft. | Pits to 10 Ft. or Borings to 20 Ft. |

# Determination of Policy

- **State Laws**
  – Describe intent
- **Administrative Rules**
  – Establish specific goals: Performance standards
  – Local Ordinances
- **Technical Standards**
  – How to achieve performance standards

# Technical Standards for Infiltration

- Site Evaluation Standard
- Bioretention Standard
- Infiltration Basin Standard
- Grass Swale Standard
- Rain Garden Standard

- HTTP://dnr.wi.gov/org/water/wm/nps/stormwater/techstds.htm

# Questions?

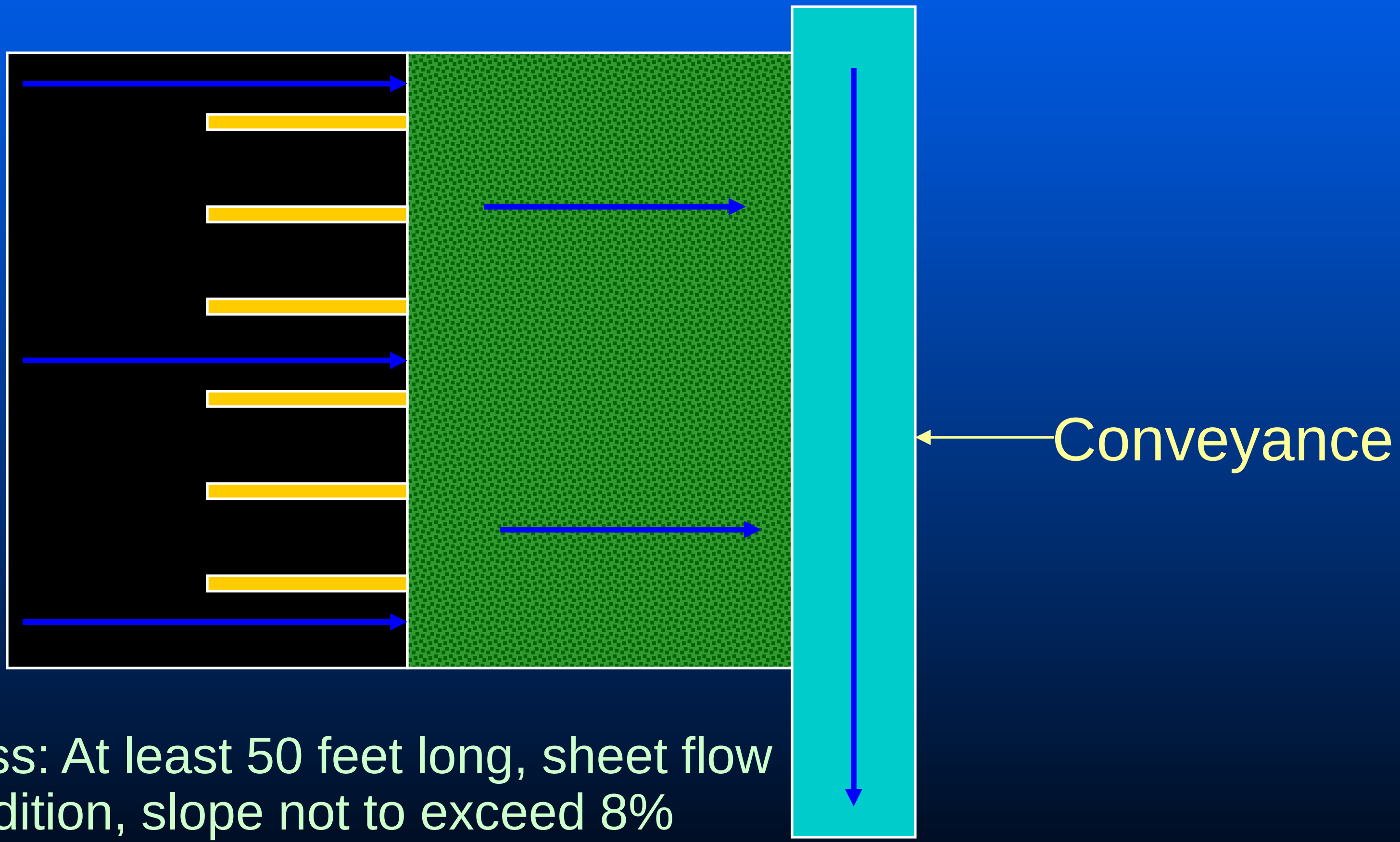
Jeremy Balousek

# Residential Rooftop Disconnection

Length: Not less than 20 feet.

# Parking Lot Disconnection

If Parking Lot: 50 feet long (must have sheet flow)




Then grass: At least 50 feet long, sheet flow good condition, slope not to exceed 8%

# Bioretention – Villanova University, Robert Traver, 2002

Storage: 0.46 in

Void Space: 0.54 in

Drainage Area: 1.2 acres – 50% imperv.

70% control