Volume Loss from Biofiltration Basins with Drain Tile

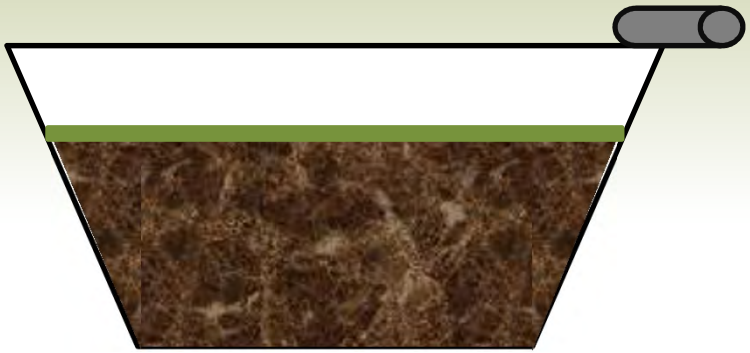
MIDS Work Group

January 18, 2013

Background

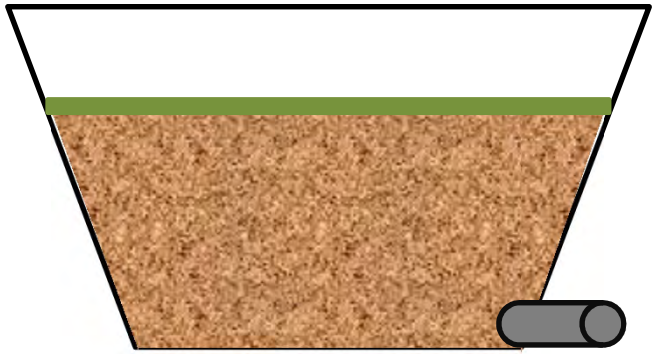
- Re-evaluating November 2012 MIDS workgroup meeting:
  - Barr suggested zero volume reduction for systems with drain tile at the bottom
  - Work Group asked that volume be quantified
- Walk through approach to quantify volume reduction
- Examples
  - Biofiltration basin in C & D soils
  - Biofiltration basin with Elevated Draintile

Bioretention/Biofiltration Variations



No Drain Tile

Elevated Drain Tile



Bottom Drain Tile (Biofiltration)

Quantifying Reduction in Runoff Volume

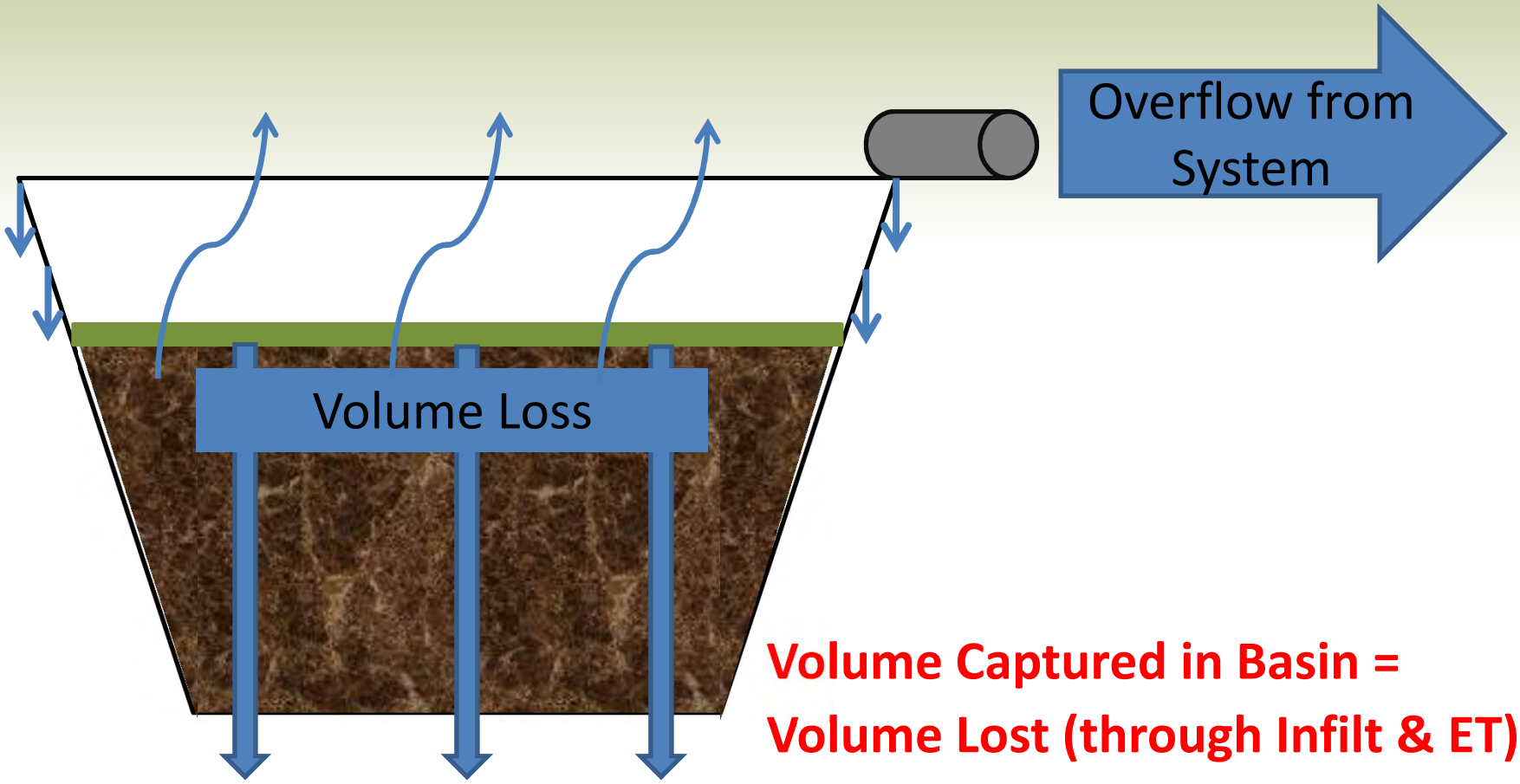
Goal: quantify water "loss", versus temporary water storage or off-site discharge

Key Question: What are the mechanisms for water loss?

- Evapotranspiration (ET)
- Infiltration

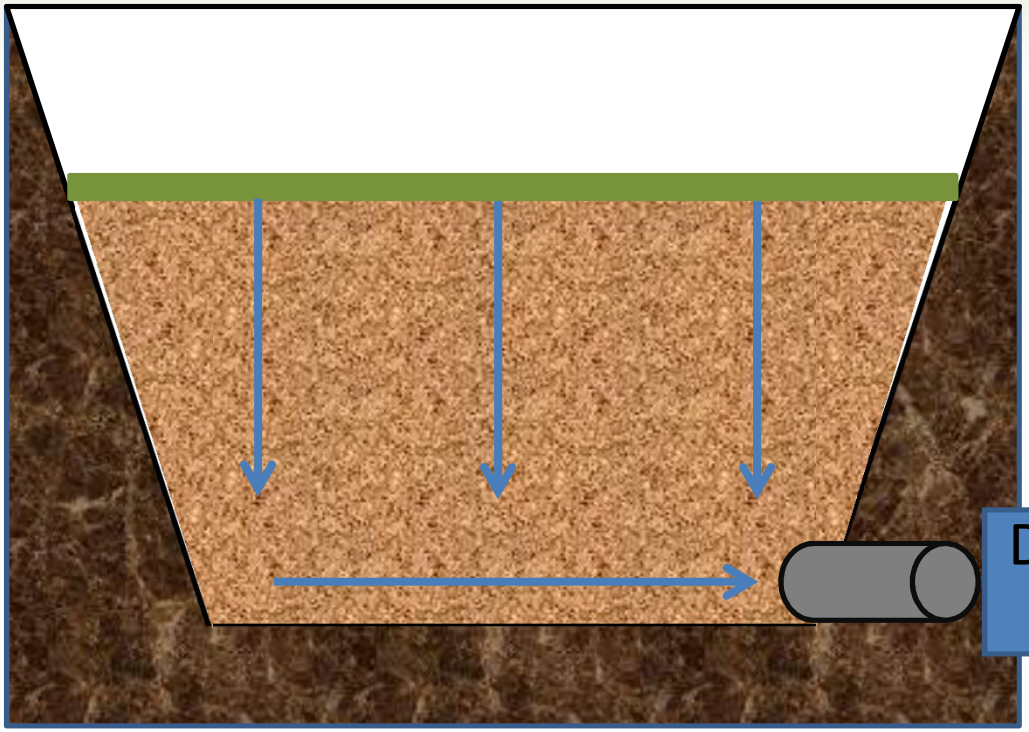
Bioretention Basin without Drain Tile

Bioretention Basin without Drain Tile



Volume Captured in Basin =
Volume Lost (through Infilt & ET)

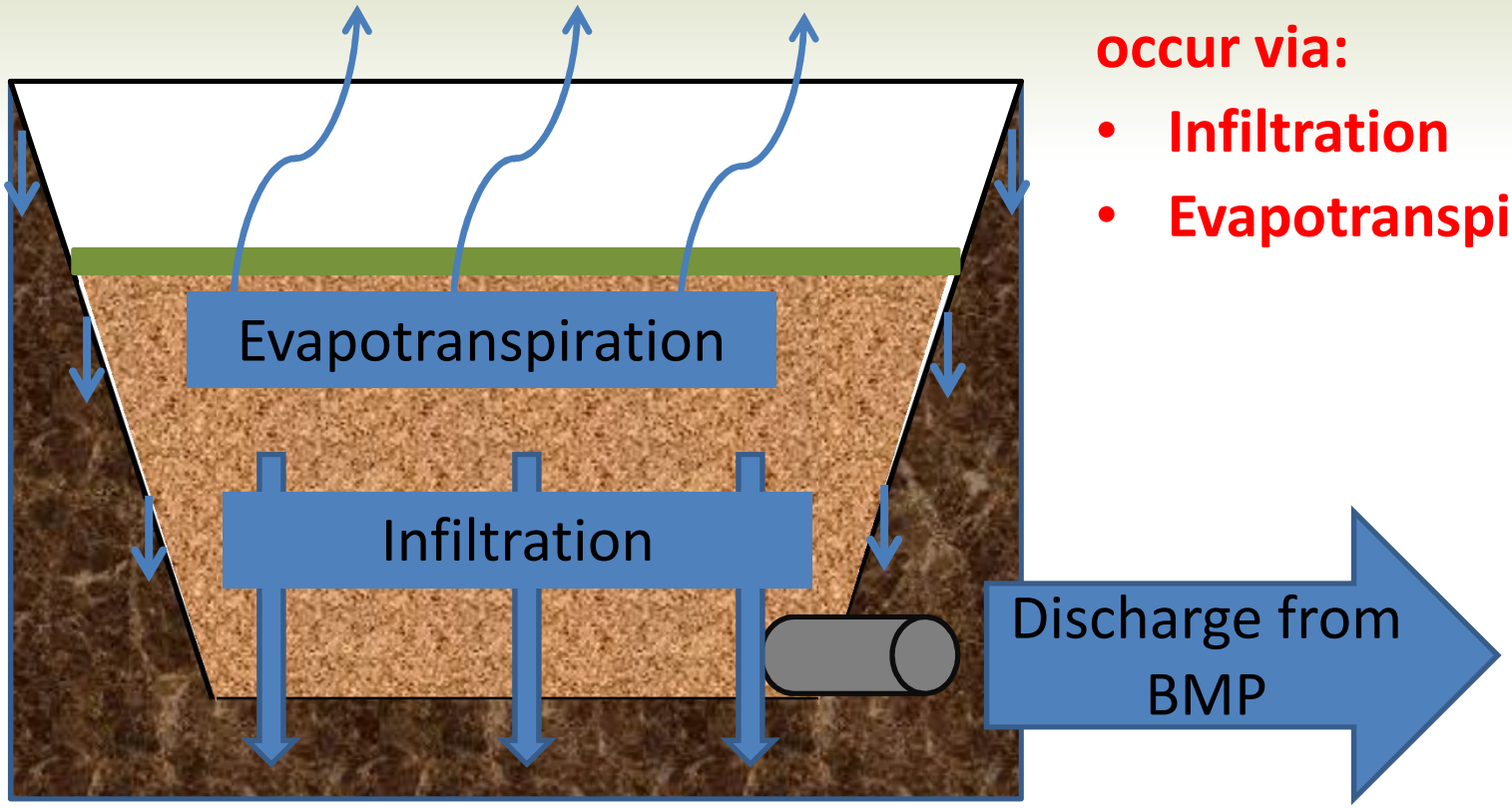
Biofiltration Basin with Drain Tile



Volume Captured in Basin ≠ Volume Lost

Discharge from BMP

But there's some volume loss, even with a drain tile, right?



Yes. Volume losses will occur via:

- **Infiltration**
- **Evapotranspiration**

Quantifying Volume Losses

Goal: To quantify the volume of captured water that will infiltrate or be lost to ET

- evaluated on an event basis to determine conformance with the 1.1-inch performance goal

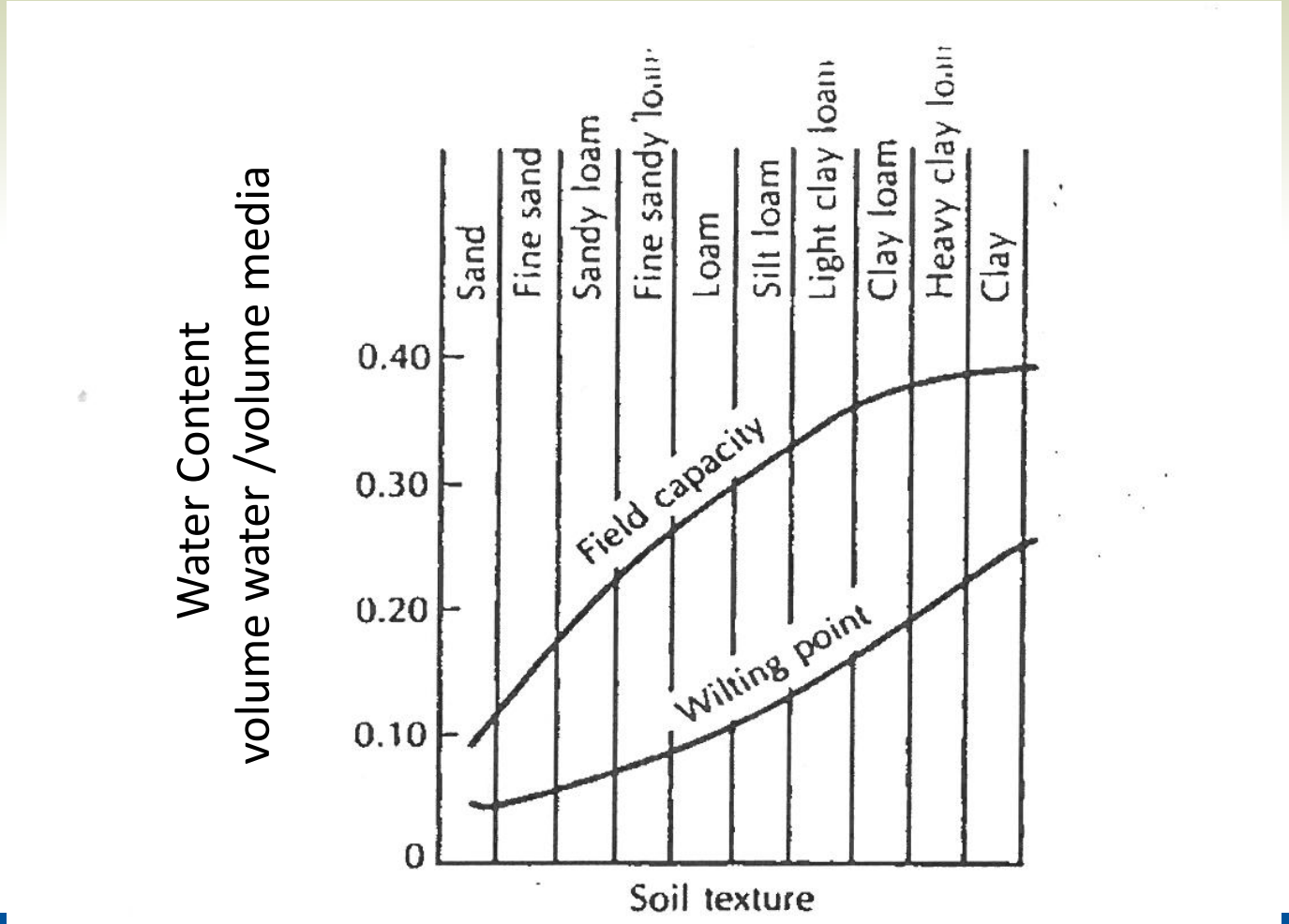
Let's start by looking at volume loss from ET

Quantifying Loss via Evapotranspiration

When it rains, water is stored in the filter media and utilized by plants

How much water is stored in the filter media and <u>available</u> for plant utilization?

Quantifying Plant Available Water Capacity



Source: U.S. Department of Agriculture, Yearbook. 1955.

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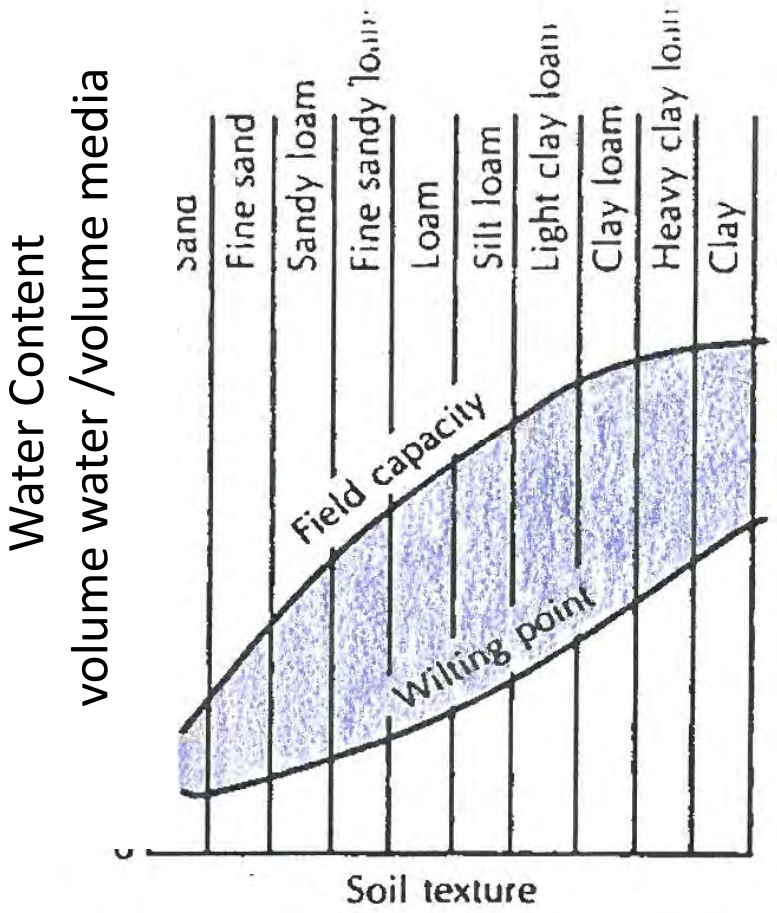
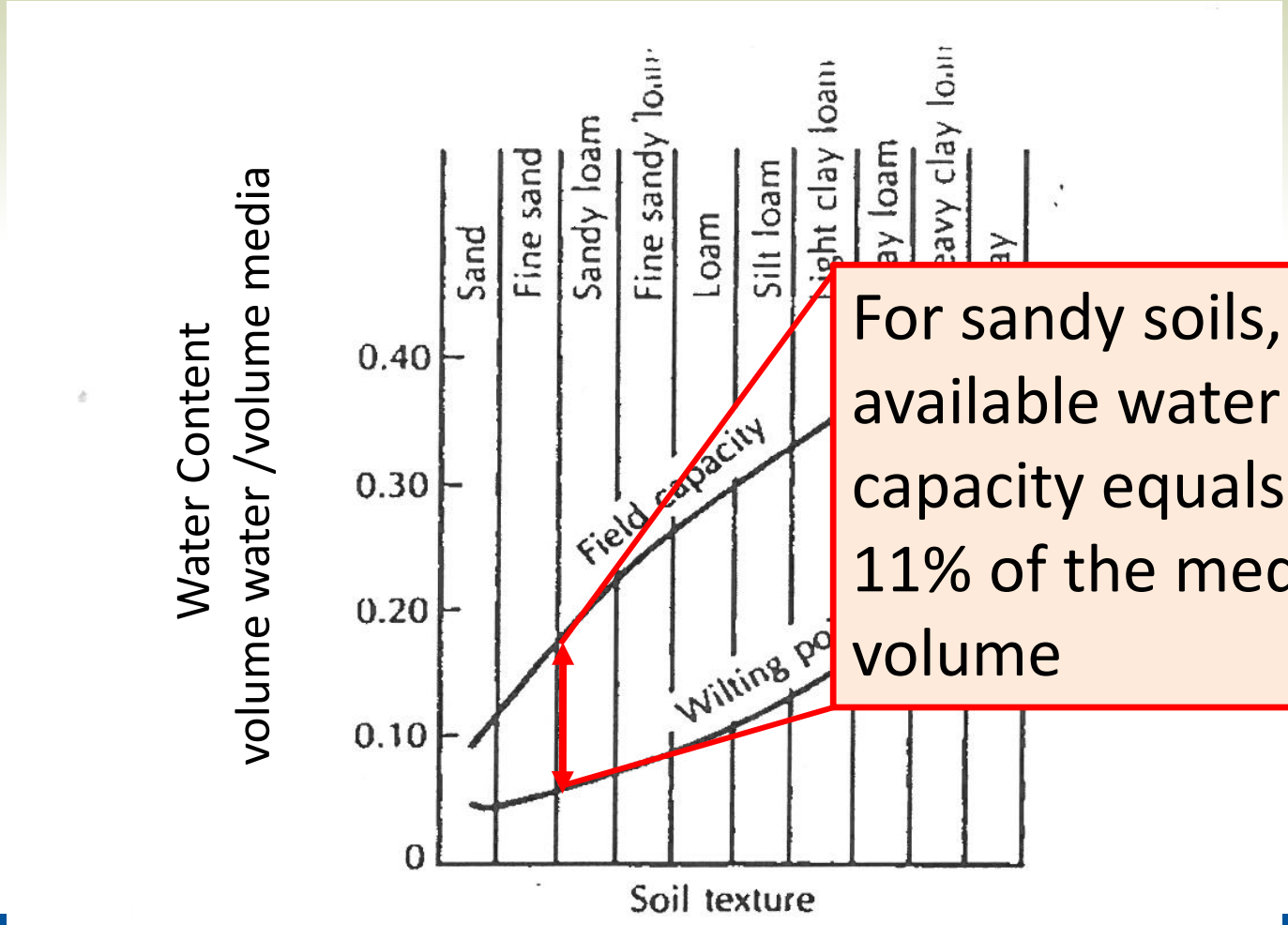
Quantifying Plant Available Water Capacity



Quantifying Plant Available Water Capacity



For sandy soils, plant available water capacity equals about 11% of the media volume

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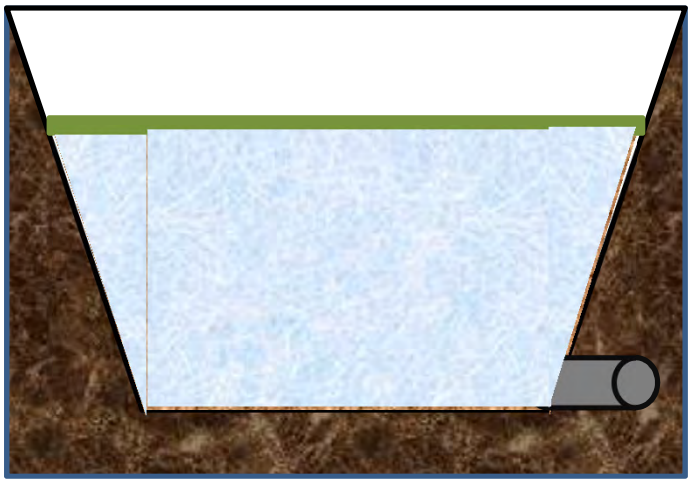
Quantifying Plant Available Water Capacity

For a BMP sized for 10-acre, 50% impervious site:

- Available water at field capacity approximately <u>3,000 ft^3</u>

- So how much of the 3,000 ft^3 will be lost to evapotranspiration?



Quantifying Loss via Evapotranspiration

- Evapotranspiration varies based on many factors, including:
  - Plant type
  - Plant density
  - Weather conditions

- Approximately 20 inches of ET per year in Twin Cities area

Pan evaporation variation throughout growing season

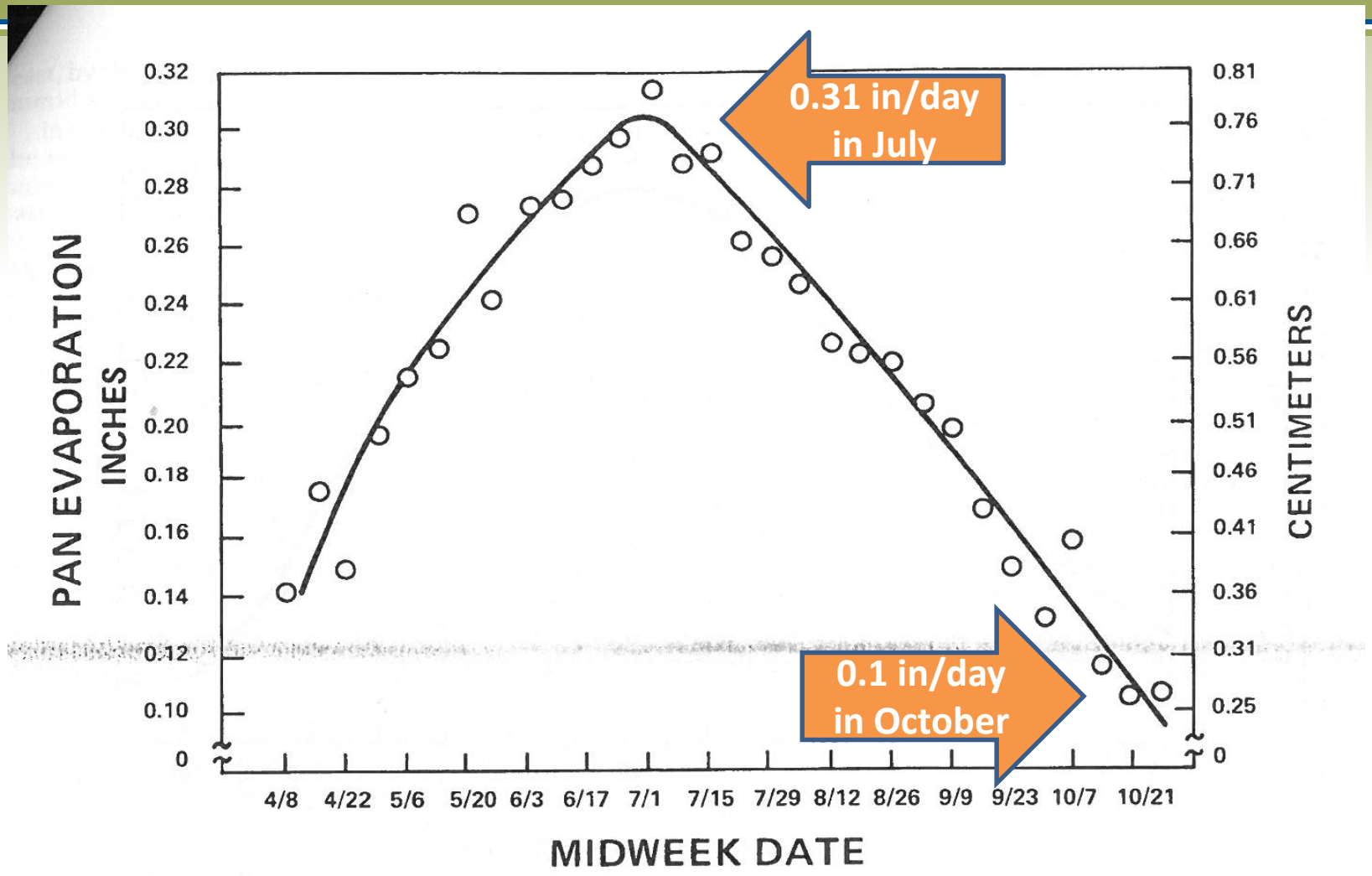


Figure 11. Average daily pan evaporation at the Southwest Agricultural Experiment Station, Lamberton, 1961-1976.

Source: Climate of Minnesota Part XII- The Hydrologic Cycle and Soil Water, U of MN

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Quantifying Loss via Evapotranspiration

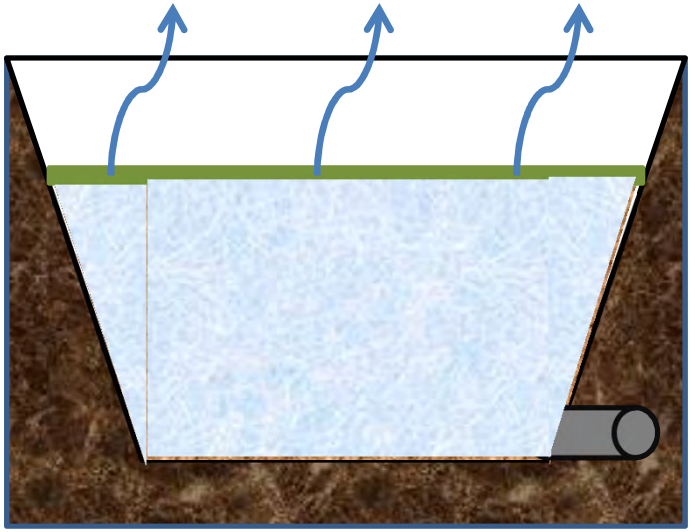
Assumptions to quantify ET volume loss from BMP on an event basis:

- Average daily pan evaporation rate = 0.2 inches
- Factor to convert pan evaporation to ET = 0.5
- Duration of ET = 72 hours ("typical" time period between precipitation events)

Evapotranspiration is the limiting factor

For a BMP sized for 10-acre, 50% impervious site:

- Available water at field capacity is 3,000 ft^3
- ET Loss in 72 hours = 366 ft^3
- **366 ft^3 < 3,000 ft^3**



ET losses are limiting

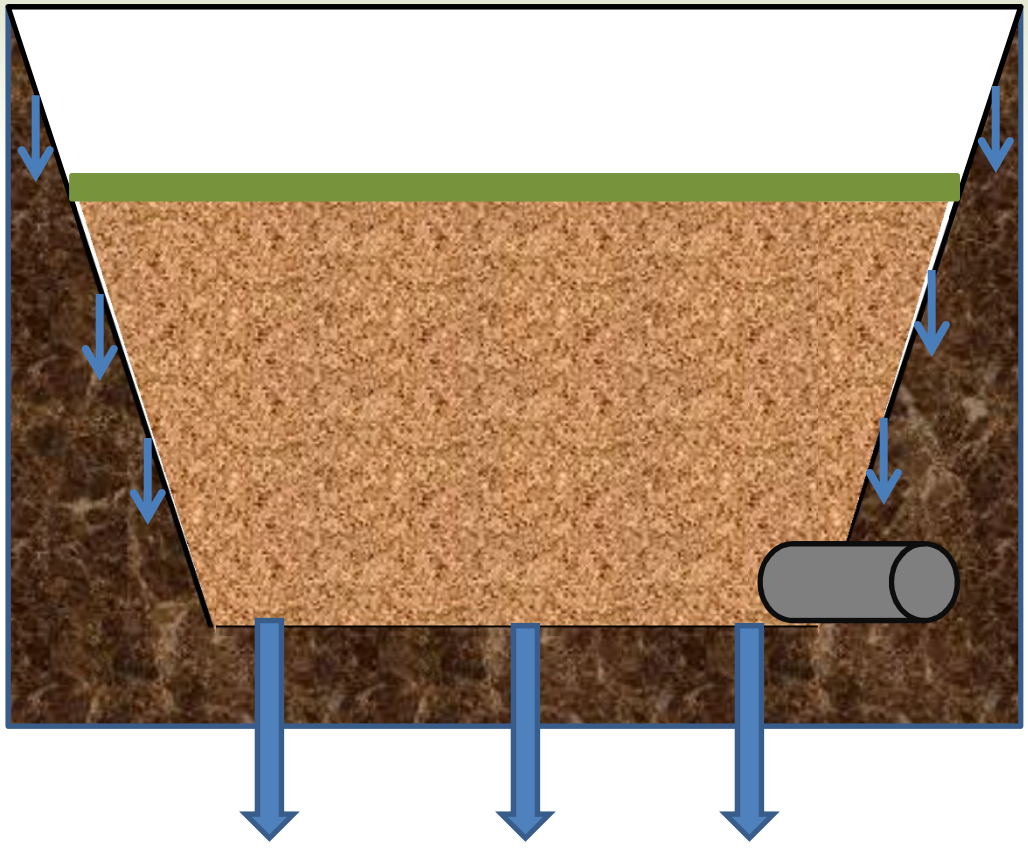
How does this relate to our 1.1-inch performance goal?

For a BMP sized for 10-acre, 50% impervious site:

- Performance goal of 1.1 inches off impervious area = 19,965 ft^3
- ET Loss = 366 ft^3/19,965 ft^3

  = 2% of performance goal

Quantifying volume loss from infiltration



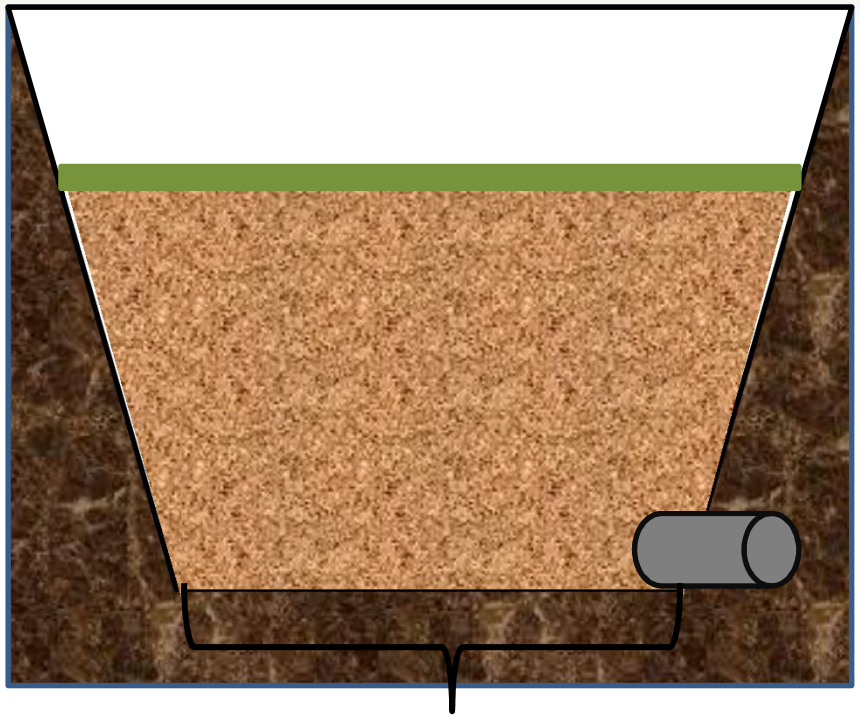
During the time that water drains through the drain tile, some infiltration will occur from:

- Basin Bottom
- Basin Sides

Infiltration from Bottom of Basin

Loss from bottom =

Bottom Area * Infiltration Rate of Underlying Soils * 48 hours



Bottom Surface Area

Infiltration from Bottom of Basin

For a BMP sized for 10-acre, 50% impervious site on D soils:

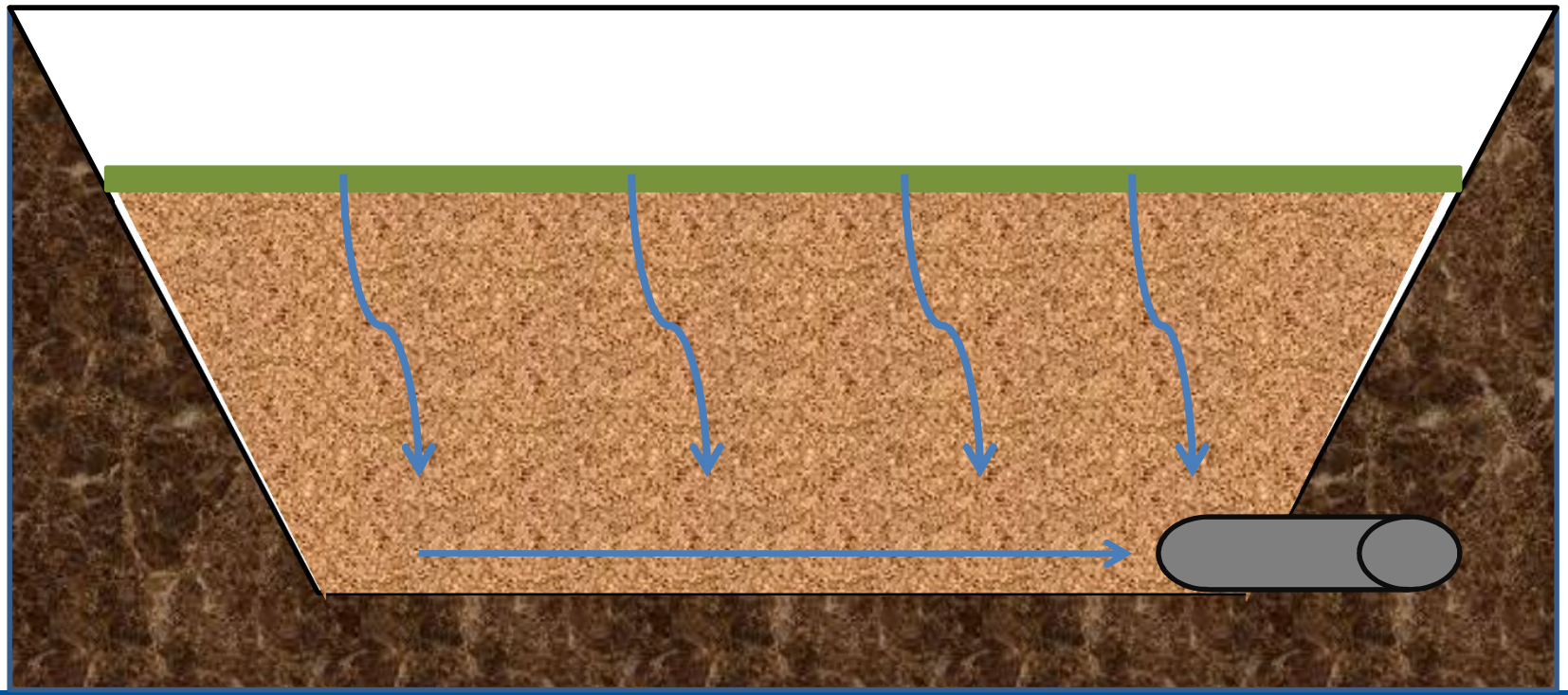
Loss from bottom:

= Bottom Area * Infiltration Rate of Underlying Soils * 48 hours

= $(85\ ft)^2$ * 0.06 in/hr * 48 hr * (1 ft/12 in) = <u>1,734 ft^3</u>

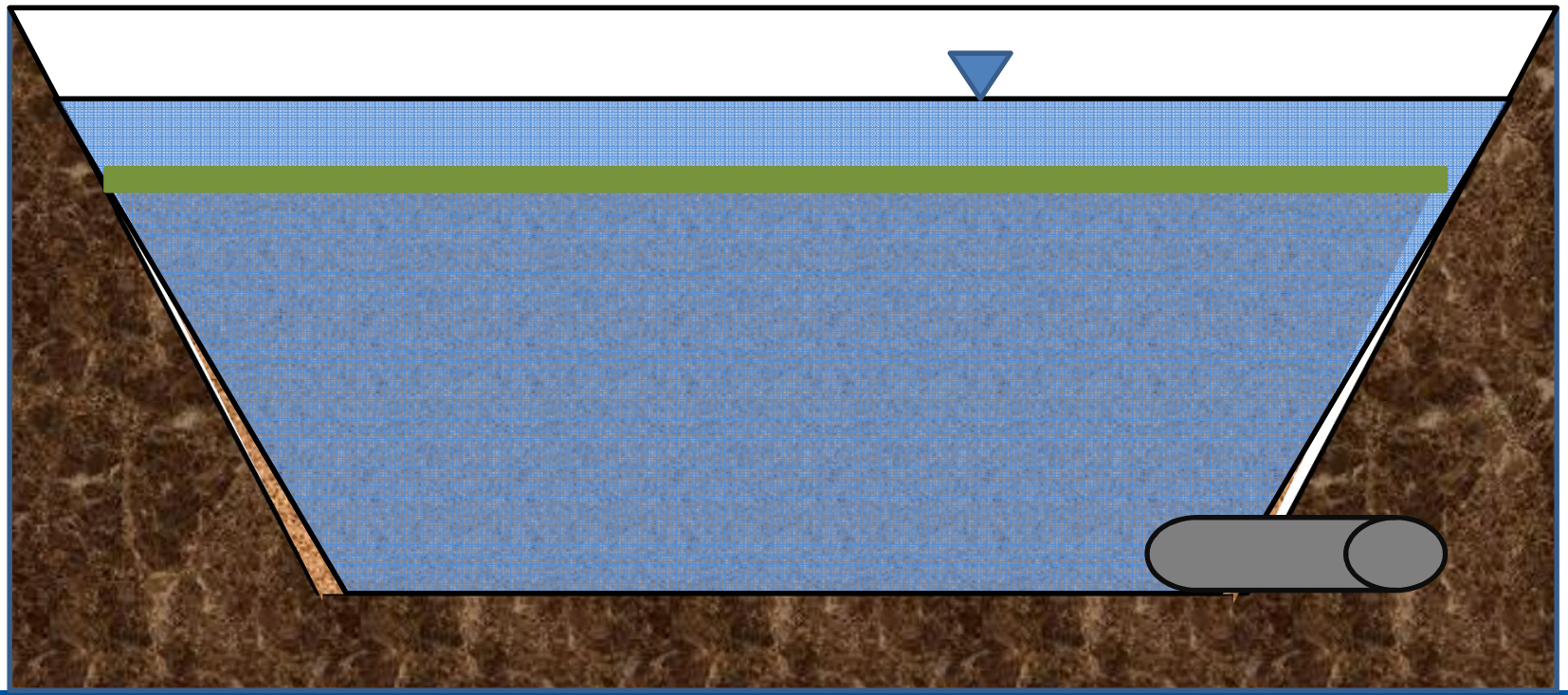
Infiltration from side slopes of basin

- When unsaturated conditions in media, infiltration from side slopes will be very small (easier for water to go toward drain tile than into sides)



Infiltration from side slopes of basin

- When saturated conditions in media (drain tile is restricting flow), infiltration from side slopes is likely.

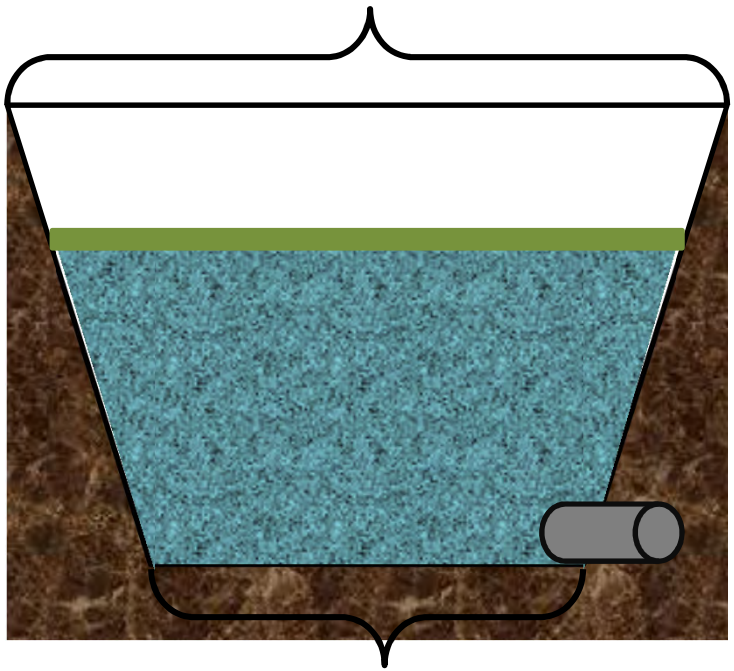


Infiltration from side slopes of basin

Loss from sides =

Side Slope Area* Infiltration Rate of Underlying Soils * 24 hr

Overflow Surface Area (A_O)



Bottom Surface Area (A_B)

- Side Slope Area = $A_O - A_B$
- 24 hours reflects average duration of infiltration from sides

Infiltration from Side Slopes of Basin

For a BMP sized for 10-acre, 50% impervious site on D soils:

Loss from side slopes:

= Side Slope Area* Infiltration Rate of Underlying Soils * 24 hr

= $[(121\ ft)^2 - (85\ ft)^2] * 0.06\ in/hr * 24\ hr * (1\ ft/12\ in)$

= $\underline{890\ ft^3}$

Quantifying total volume loss from infiltration

Total Loss from Infiltration (bottom + sides)

= 1,734 ft^3 + 890 ft^3

= 2,624 ft^3

How does this relate to the 1.1-inch performance goal?

- Performance goal of 1.1 inches = 19,965 ft^3

- Infiltration Loss = 2,624 ft^3/19,965 ft^3

  = 13% of performance goal

Quantifying volume losses for systems with drain tile

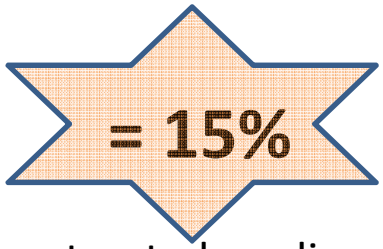
For a BMP sized for 10-acre, 50% impervious site on D soils:

- Total volume loss = ET Loss + Infiltration Loss*

  = 366 ft^3 + 2,624 ft^3

  = 2,990 ft^3

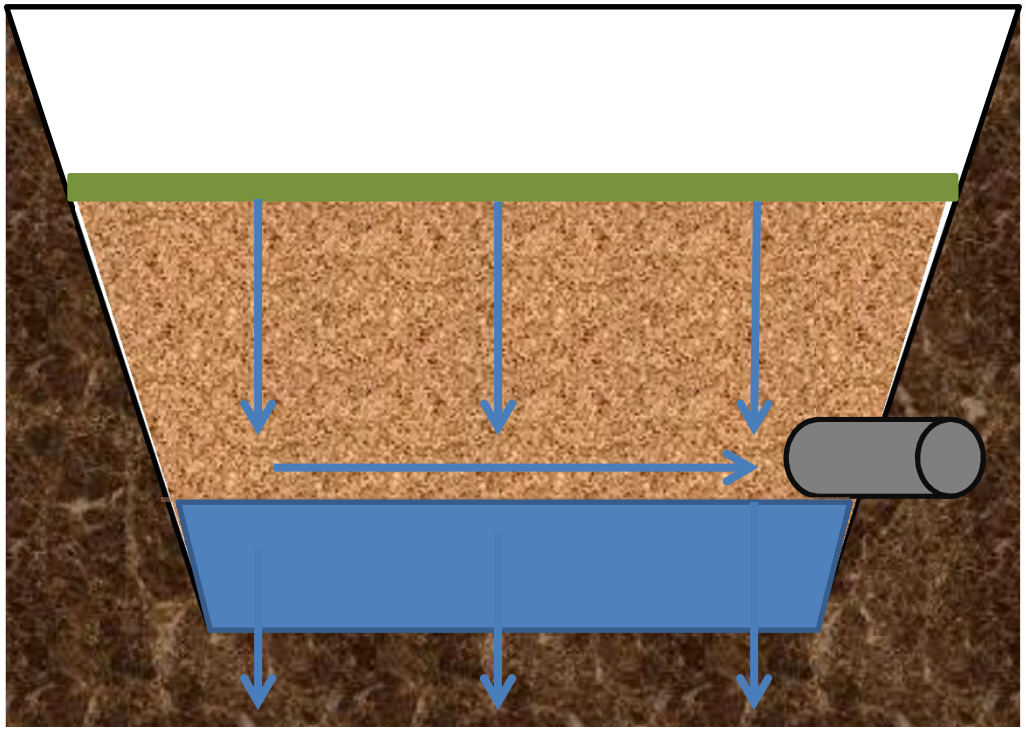
% of Performance Goal = 2,990 ft^3 / 19,965 ft^3



* Note that side slope loss assumes saturated media conditions

Biofiltration Basin with Elevated Drain Tile

With elevated drain tile, volume losses from infiltration increase



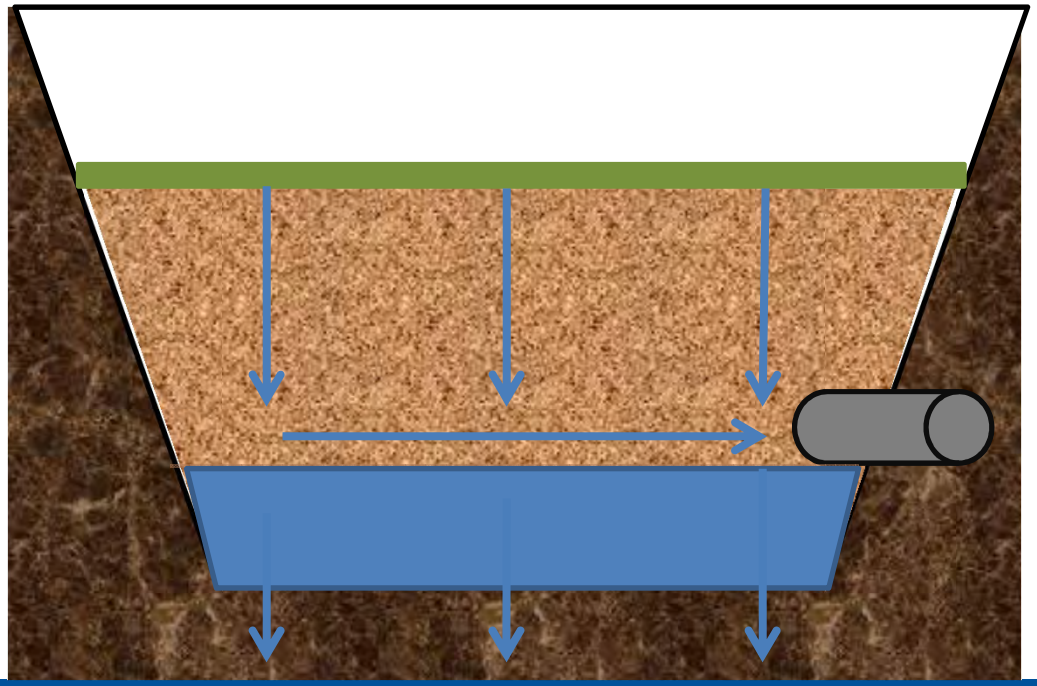
Question:

How to credit additional volume loss on an event basis?

Biofiltration Basin with Elevated Drain Tile

Loss from bottom (with elevated drain tile) =

Bottom Area*Infiltration Rate of Underlying Soils * ~~48~~72 hrs



•Additional 24 hours is allowed for bottom area to drain

Infiltration losses from the basin bottom

For the same BMP sized for 10-acre, 50% impervious site, but with 1-foot of media below drain tile:

Loss from bottom (with elevated drain tile) =

Bottom Area*Infiltration Rate of Underlying Soils * 72 hrs

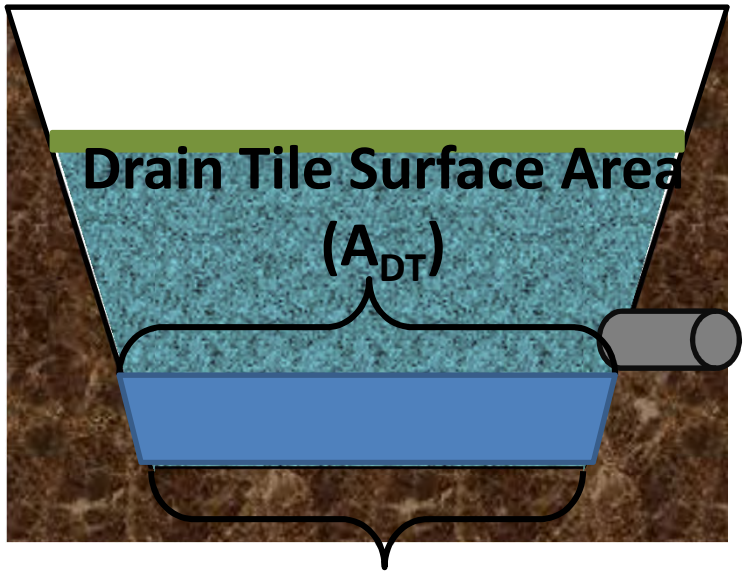
= (77 ft^2) * 0.06 in/hr * 72 hr * (1 ft/12 in)

= 2,134 ft^3 (vs. 1,734 ft^3 for non-elevated drain tile)

Infiltration from side slopes of basin with elevated drain tile

Loss from sides above drain tile = same as previous side slope computation

Losses from sides below drain tile =
Side Slope Area* Infiltration Rate of Underlying Soils * 60 hr



- Side Slope Area = $A_{DT} - A_B$
- 60 hours reflects average duration of infiltration from sides (48 hours + additional drainage time ranging from zero at drain tile to 24 hrs at bottom.

Infiltration losses from the basin sides

For the same BMP sized for 10-acre, 50% impervious site, but with 1-foot of media below drain tile:

Loss from sides above elevated drain tile = 890 ft^3

Loss from sides below elevated drain tile = 467 ft^3

Total loss from side slopes = 890 ft^3 + 467 ft^3 = 1,357 ft^3

Quantifying volume losses for systems with elevated drain tile

For a BMP sized for 10-acre, 50% impervious site on D soils:

- Total volume loss = ET Loss + Infiltration Loss*
  = 366 ft^3 + 2,134 ft^3 (bottom) + 1,357 ft^3 (sides)
  = 3,857 ft^3

% of Performance Goal = 3,857 ft^3 / 19,965 ft^3

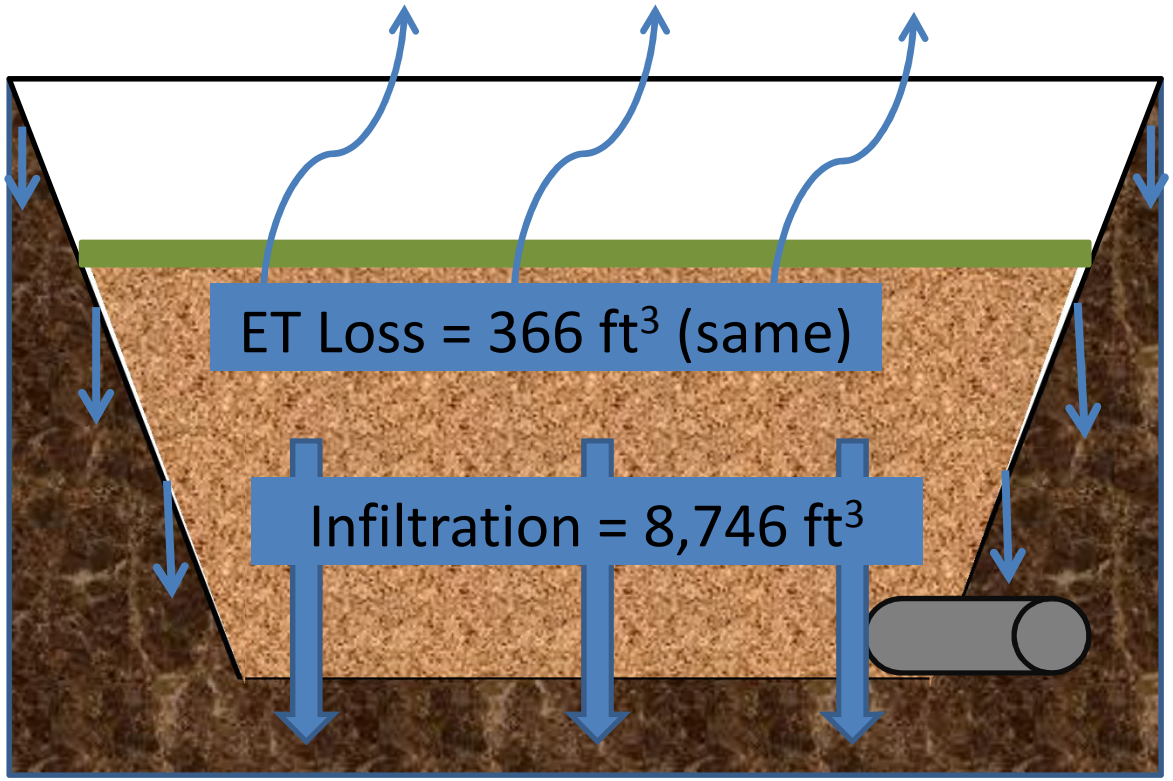
= 19%

* Note that side slope loss assumes saturated media conditions

How do the volume losses vary with a "C" soil?

Non-elevated drain tile:

For the same BMP sized for 10-acre, 50% impervious site on D soils:



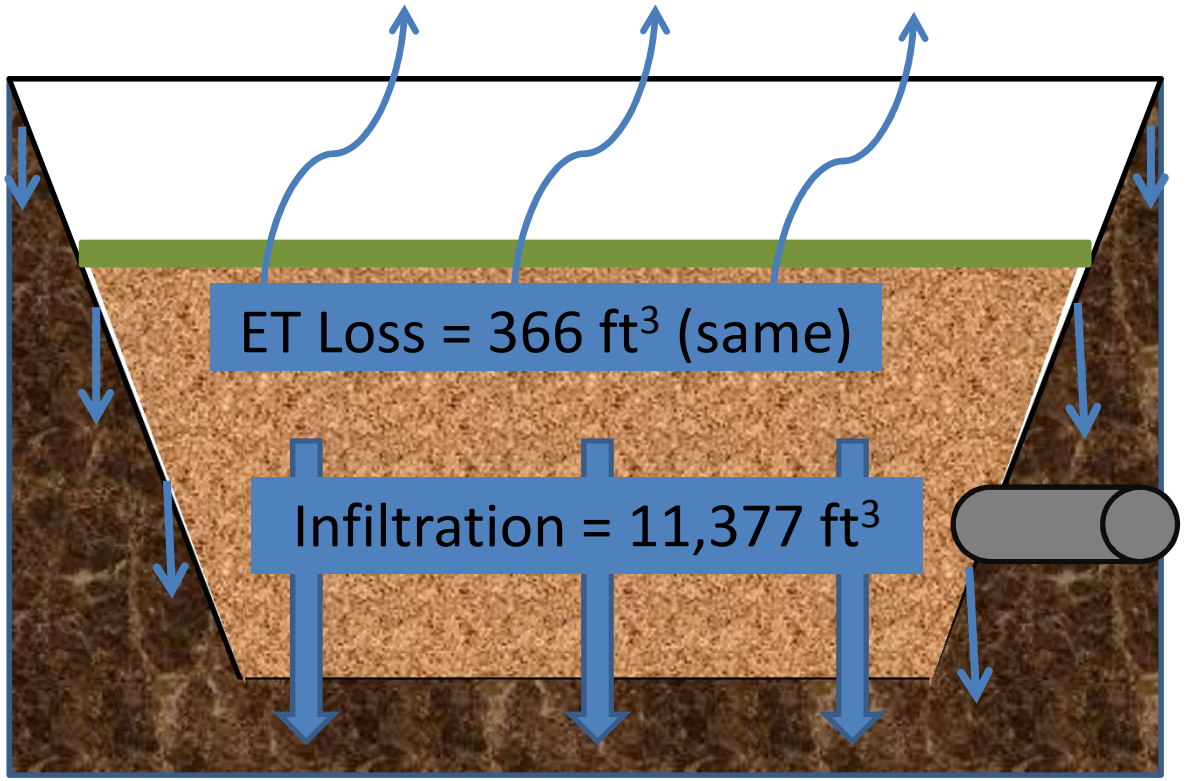
- Total volume loss **= 9,112 ft³**
- % of Performance Goal **= 45%**

  (vs 15% for D soils)

How do the volume losses vary with a "C" soil?

Non-elevated drain tile:

For the same BMP sized for 10-acre, 50% impervious site on D soils:



- Total volume loss **=11,743 ft³**
- % of Performance Goal **= 59%**

  (vs 19% for D soils)

Questions?