Applications to Stormwater Management

Presented by:

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Project/Research Sponsors

- Wilkes University
  http://www.wilkes.edu
- Pocono Northeast Resource Conservation & Development Council
  http://www.pnercd.org
- C-SAW Program - **Consortium for Scientific Assistance to Watersheds Program**
  http://pa.water.usgs.gov/csaw/
- PA Association of Environmental Professionals
  http://www.paep.org

Why Manage Stormwater?

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- Adversely impacts water quality, streamflows, reduces groundwater recharge, increases pollutant loading, and impacts stream/watershed ecology.
- Health and safety concerns- sourcewater protection , navigation, and travel hazards.
- Financial Impact – if we do not properly manage stormwater it will cost us more money, lost economic efficiency, and wasting resources over the long-term.

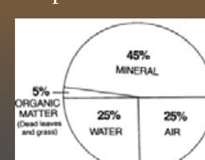
Which is most important?

Evaluate Long-Term Costs- Improper management will cost us more in the Long-Term- This one will likely get the biggest audience and help to generate the most local support.

Soils

- A Natural 3 - Dimensional Body at the Earth Surface
- Capable of Supporting Plants
- Properties are the Result of Parent Material, Climate, Living Matter, Landscape Position and Time.

Soil Composed of 4 Components (mineral matter, organic matter, air, and water)
Air and Water – 35 to 55 %
Solid Material – 45 to 65 %



Nearly 50% of Soil is Space or Space Filled with Water

- Water – 25+ %
- Air – 25 + %
- Pore Space Makes Up 35 to 55 % of the total Soil Volume
- This Space is called Pore Space

Therefore, soil can be used as a storage system, treatment system, and transport media.

Soil Properties Critical To Stormwater Management

- Soil Texture
- Porosity and Pore Size
- Water Holding Capacity
- Bulk Density
- Aggregate Stability
- Infiltration Capacity
- Hydraulic Conductivity

!!! Just to Name a Few Properties !!!!

Water Stable Aggregates I

Aggregates on left are more water stable, i.e., aggregate stays together and do not separate into the its components, i.e., three soil separates.

Water Stable Aggregates

Water Stable Aggregates – II The Classic Photo

FIGURE 4.17
The aggregates of soils high in organic matter are much more stable than are those low in this constituent. The low organic matter soil aggregates fall apart when they are wetted; those high in organic matter maintain their stability.

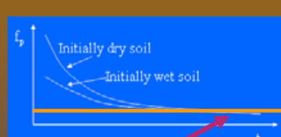
Source: Brady, Nyle, C. " The Nature and Properties of Soils" (1990) Great Desk Reference Text !!!!

Infiltration Rate Decreases with Time

1) Changes in Surface and Subsurface Conditions

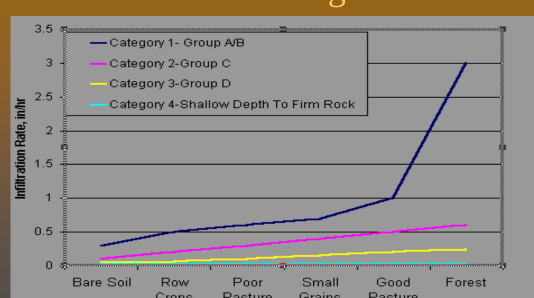
2) Change in Matrix Potential and Increase in Soil Water Content and Decrease in Hydraulic Gradient

3) Overtime - Matrix Potential Decreases and Gravity Forces Dominate - Causing a Reduction in the Infiltration Rate



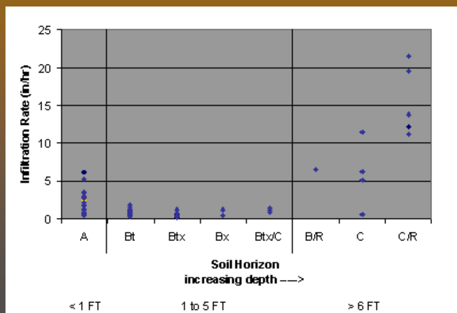
4) Reaches a steady-state condition fc – final infiltration rate

Infiltration Rate Function of Vegetation



Source: Gray, D., "Principles of Hydrology", 1973.

Infiltration Rate
Function of Horizon A, B, Btx, Bt, C, R
C/R Testing - Areas Fractured Rock



Source: On-site Infiltration Testing - Mr. Brian Oram, PG (2003) and FX. Browne, Inc. (Lansdale, PA)

Percolation Rate

Percolation -Downward Movement of Water through the soil by gravity. (minutes per inch) at a hydraulic gradient of 1 or less.

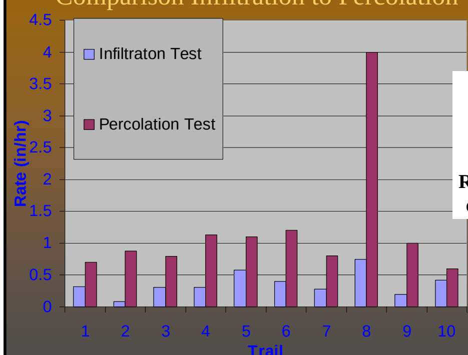
Used and Developed for Sizing Small Flow On-lot Wastewater Disposal Systems.

On-lot Disposal Regulations (Act 537) has preliminary Loading equations, but for large systems regulations typically require permeability testing.

Also none as the Perc Test, Soak-Away Test (UK)

Not Directly Correlated to or a Component of Unsaturated or Saturated Flow Equations

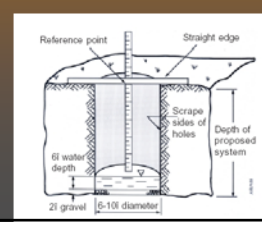
Comparison Infiltration to Percolation Testing



Percolation Testing Over Estimated Infiltration Rate by 40% to over 1000% *

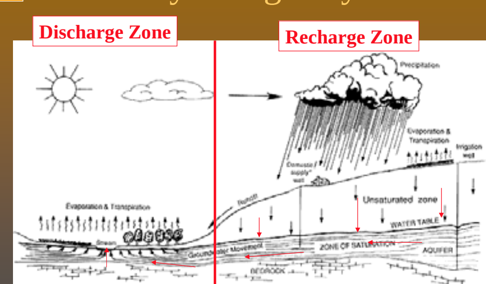
Source: On-site Soils Testing Data, (Oram, B., 2003)

My Recommendation and Opinion Please Do NOT Use a Conventional Percolation Rate or Percolation Test for Developing Engineering Designs !



What NOW ?

The Hydrologic Cycle

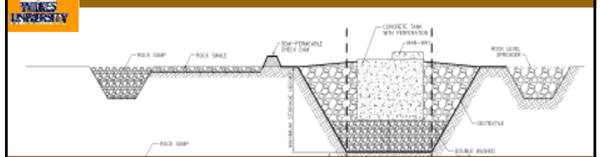


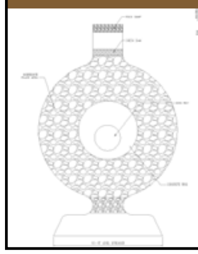
Where is the Project Site ?

Infiltration System Approach
Individual Infiltration BMP Units

Soil: Tunkhannock Series
Soil had stratified sand and gravel lenses
Water Table > 8 feet
Open Voids
(Gravel and Cobbles)
3 to 6 feet

Infiltration Unit Configuration





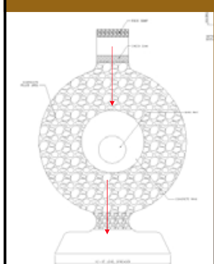
Installed:

Sump and Grass Swale Prior to Unit and Geotextile within unit to capture large organic material

Concrete – Open bottom perforated tank not filled with gravel for storage.

Conceptual Design by:
Malcolm Pirnie (Scranton, PA) and Brian Oram (October 2004), Anticipated Installation 2007.

Designed to Retain – 100% of the Roof Runoff

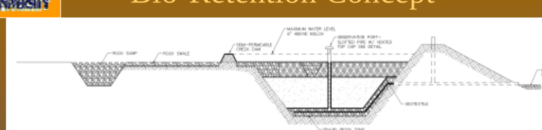


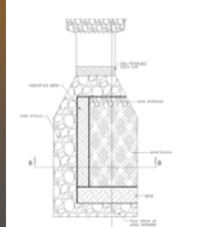
No Plant Facilitated Bioremediation – Some bioremediation will likely occur on the wetted surface of the subsurface rock fill.

Bio-Retention Systems

Image Source: http://www.co.monroe.in.us

Bio-Retention Concept

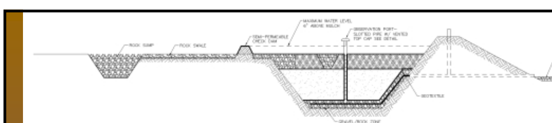




Sump and Grass Swale Prior to Unit and a By-pass Berm structure for large runoff events.

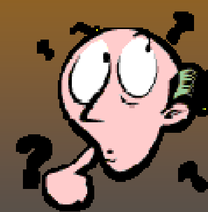
System has a controlled discharge that maintains a discharge elevation that this consistent with natural water table conditions.
Vegetation – Native Seed Mix
Soil Media – Native Soil from Site Modified to either a loam texture with 2 to 5 % organic material; covered with compost/mulch layer (on-site source).
Washed Stone at the Base of the Unit.
Sizing based on detention storage requirements and flow routing.

Conceptual Design by: Malcolm Pirnie (Scranton, PA) and Brian Oram (2004)



Cul-De-Sac Concept

Proper Site Management
Non-Structural BMPs



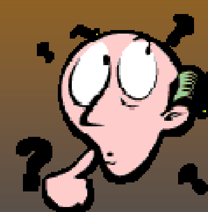
Reduce Stormwater Runoff

None Structural Development Practices

- Maintain Soil Quality and Maximize the Use of Current Grading to Minimize Loss of O, A, and upper B horizons.
- Minimize Compaction, Maximize Native Vegetation, and Use Good Construction Practices
- Consider Hydrological Setting and Existing Hydrological Features in Site Design and Layout

Answer: New Development/ Construction Practices and New and Updated Ordinances and Planning Documents !

Are We Missing Something?



What About Existing Developed Areas ?

1. The runoff from one acre of paved parking generates the same amount of annual runoff as:

a) 36 acres of forest
b) 20 acres of grassland
c) 14 acre subdivision – 2 acre lots
d) 10 acre subdivision – 0.5 acre lots

All of the above – Does this mean we are missing a possible effective means of "turning" back the stormwater clock. Maybe we need to consider – "greening" some of the existing impervious areas.

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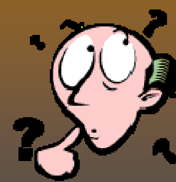
PADEP in the Field

Extra Slides



Percolation Testing

- Does not directly measure permeability or a flux velocity.
- Has been used to successfully design small flow on-lot wastewater disposal systems, but equations and designs have a number of safe factors.
- Results may need to be adjusted to take out an estimate of the amount of horizontal intake area.
- Without Correction Percolation Data over-estimated infiltration rate data by 40 to over 1000 % with an adjustment for intake area error could be reduced to 10 to 200% (Oram, 2003) , but infiltration rate can overestimate saturated permeability by a factor of 10 or more (Oram, 2005).
- May need to consider the use of larger safety factors and equations similar to sizing equations used for on-lot disposal systems. Safety factors of 50% reduction may not be enough !!

Sizing Calculations – Infiltration

- Impervious Area Roof and Driveway– 3500 ft2
- Design Storm – 1.3 inch
- Volume of Water to Recharge- 2840 gallons (379 ft3)
- Design Loading- Based on Field Measured Soil Permeability- 0.5 inch per hour or 0.5 in3/in2.hour = 7.481 gpd/ft2
- Minimum Recharge Period – 72 hours (PADEP Recommended)
- Recharge Volume per day – 945 gpd
- Minimum Recharge Area- (945 / 7.481) =126 ft2
- Internal Tank Storage – 3 ft * 8 ft perforated Concrete Tank, plus 3+ foot perimeter and subsurface aggregate storage to generate a minimum surface area of 150 ft2.
- Additional Gravel Layer was added to Meet System Storage Requirement.

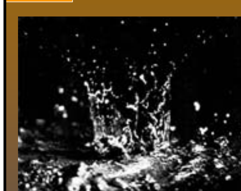
Primary Limiting Factor is Not Recharge Capacity but Providing Detention Storage or Storage in the System !

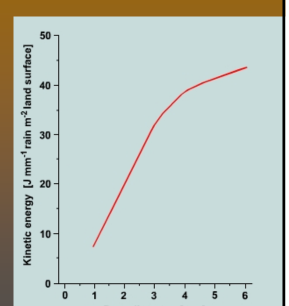
Sizing Calculations

- Impervious Area Roof and Driveway– 3500 ft2
- Design Storm – 1.3 inch
- Volume of Water to Recharge- 2840 gallons (379 ft3)
- Design Loading- Based on Field Measured Soil Permeability- 0.1 inch per hour or 0.1 in3/in2.hour =1.49 gpd/ft2
- Minimum Recharge Period – 72 hours (PADEP Recommended)
- Recharge Volume per day –945 gpd
- Minimum Recharge Area- (945 / 1.49) =634 ft2 (over 18 % of impervious)
- Recommended Changing the Recharge Period to 7 days to Reduce Infiltration Area to 270 ft2, but providing a system with 100 % detention storage. (7 % of impervious)
- This could not be approved and the project implemented a bioretention/ recharge design

Primary Limiting Factor is Area Requirement Caused by Recharge Period and not Recharge Capacity or Storage in the System !

Rain Drop Impact Bare Soil

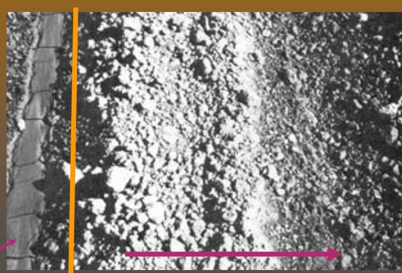




Destroys Soil Aggregates
Disperses Soil Separates
Seals Pore Space
Aids in Loss of Organic Material
Creates a Surface Crust

Source: (D. PAYNE, unpublished)
http://www.geographie.uni-muenchen.de

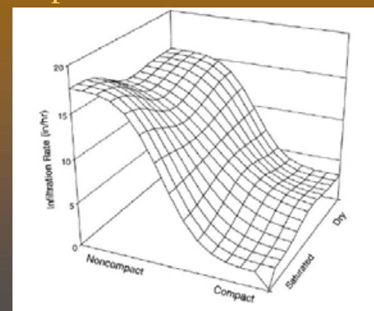
Artificial Soil Quality Improvement
Aggregate Stability- Using a Polymer



No Soil Conditioner **Less Soil Conditioner**

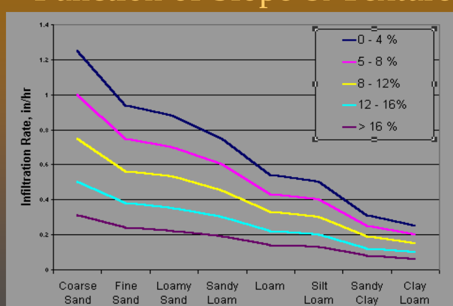
Source: Brady, N. C., 1990

Infiltration
(Compaction/ Moisture Level)



Site Compaction – Can Significantly Reduce Surface Infiltration Rate

Infiltration Rate
Function of Slope & Texture



Source: Rainbird Corporation, derived from USDA Data (Oram,2004)

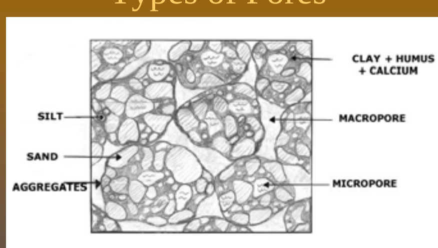
Use Of Manufactured Soils

Manufactured soils are loosely defined as soil amendment products comprised of treated residuals and various industrial by-products, such as foundry sand and coal ash.

- Use of Organic By-Products – Compost – Organic Soil and Mulch
- Recycling of Industrial By-Products and Wood Products
- Improving Quality Structural Stability and Nutrient Content of Unconsolidated Materials with Poor Soil Quality
- Use of Fly Ash, Incineration Ash, Recycling Remediated Soil or Unconsolidated Material, Spent Foundry Sands
- Use of Soil Conditioners
- Use of Dredge Materials and Sediment

I did not say these were off the shelf or easy options !

Types of Pores



Macropores (> 1,000 microns)-Large

Mesopores (10 to 1,000 microns)**- Medium**

Micropores (< 10 microns)- Small

Source: http://www2.ville.montreal.qc.ca