AWRA – PMAS
Engineers Club of Philadelphia

A Geologic Perspective on Stormwater

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September 10, 2014

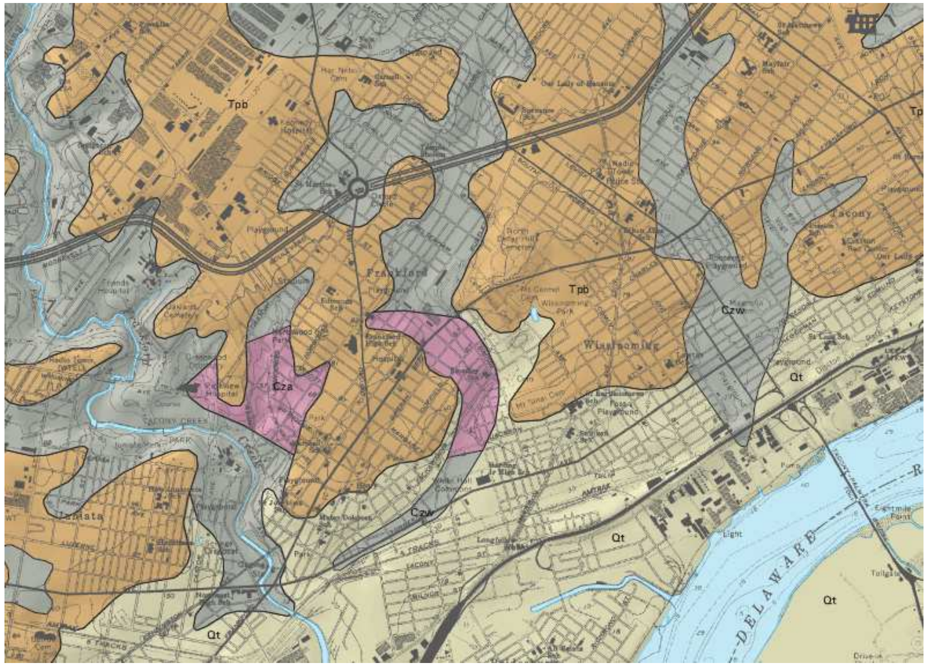
Gilmore & Associates, Inc.

Course Outline

- **Geology and Hydrogeology of Philadelphia** – Review of the subsurface in Philadelphia and how geologic conditions relate to stormwater infiltration

- **Groundwater Recharge of Stormwater** – Discuss opportunities and constraints for infiltration of stormwater

- **Subsurface Investigation & Analysis** – Discuss soil and geologic investigative techniques and project examples



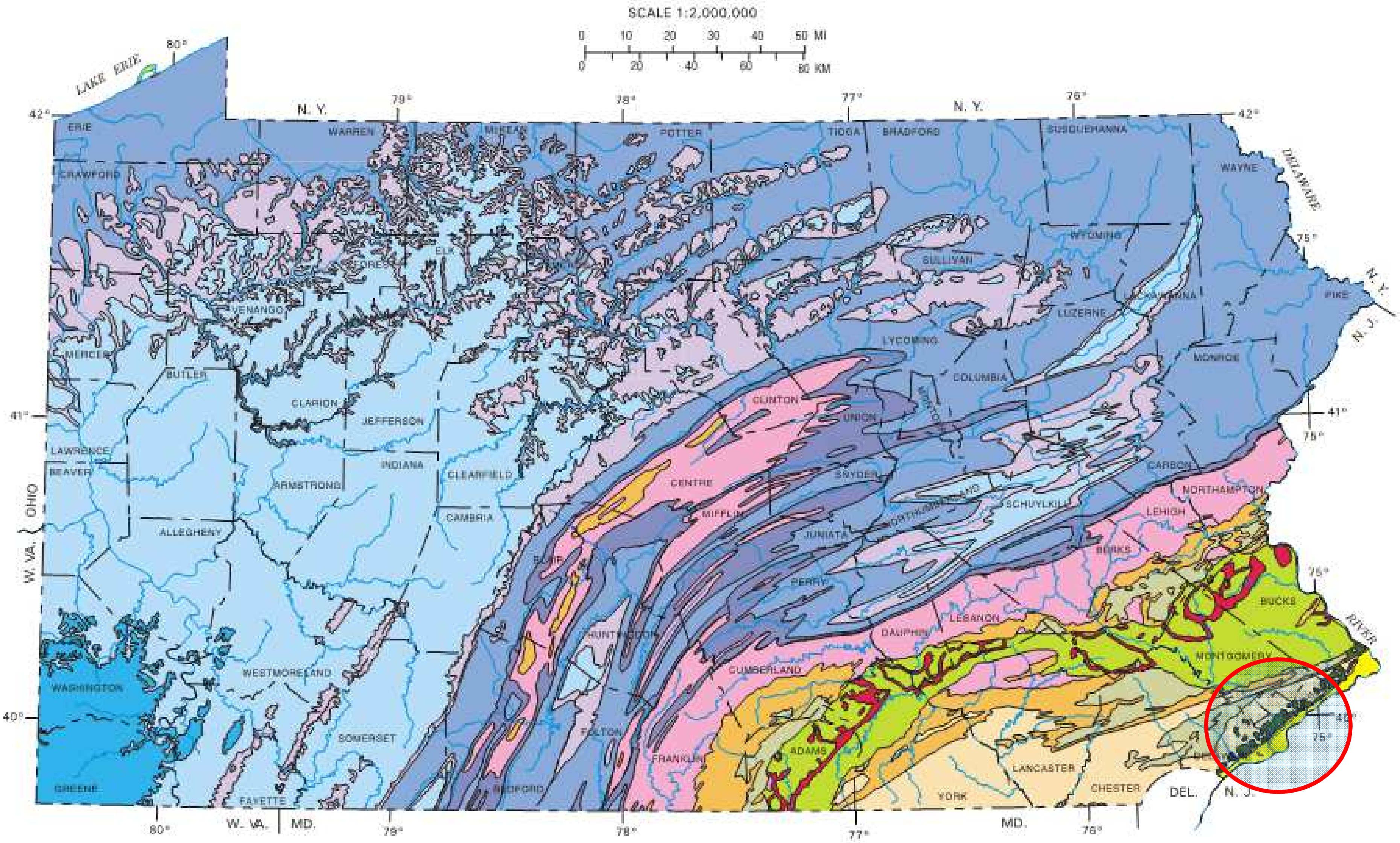
Learning objectives

- Attendees will gain knowledge of the subsurface profile in the Philadelphia area including soil, fill, sediment, bedrock, and aquifers.
- Attendees will learn how the subsurface environment affects design of stormwater management systems in the City of Philadelphia.
- Attendees will learn investigative techniques as they pertain to geologic constraints in the city.
- Attendees will be introduced to the concept of groundwater mounding and how stormwater recharge can impact nearby properties.

Note on References

The information contained in these slides was derived from publicly available publications/sites including the PA DCNR, USGS, PWD, and others. Reference material available upon request.

GEOLOGIC MAP OF PENNSYLVANIA

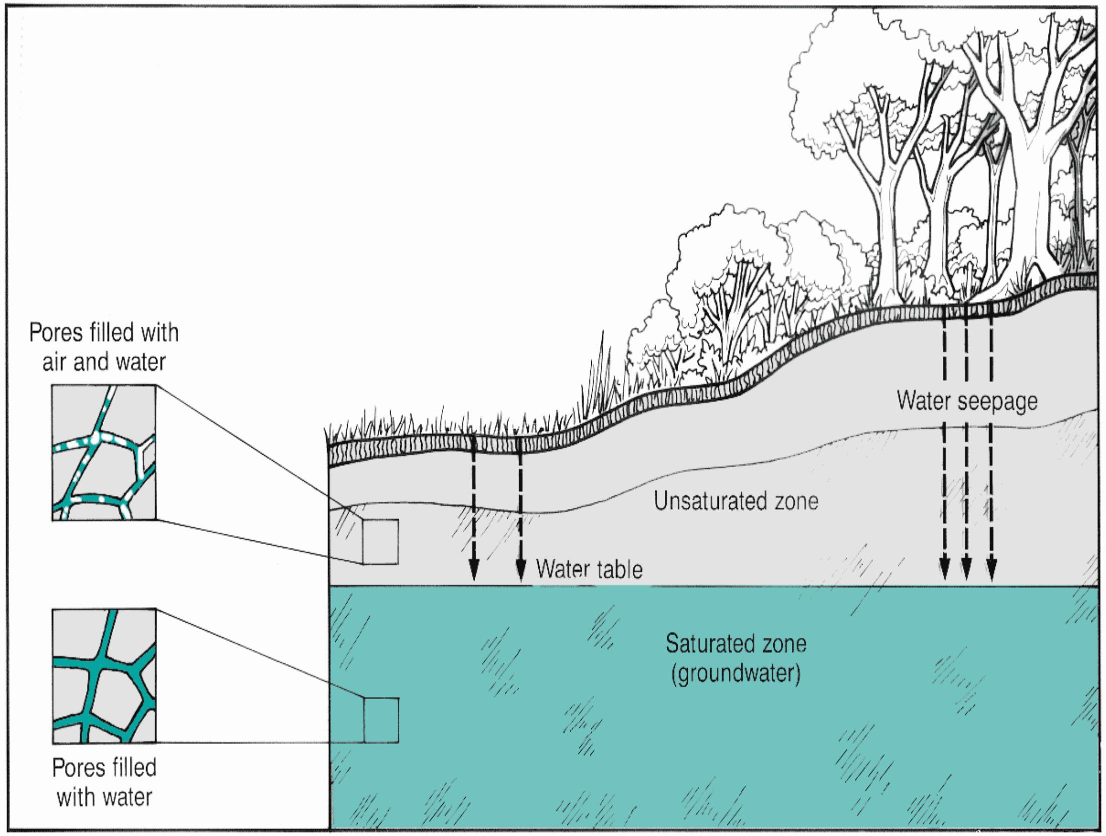


EXPLANATION

- 🟨 QUATERNARY (0–1.8 mil. yrs.) Sand, gravel, and silt.
- 🟩 TERTIARY (1.8–65 mil. yrs.) Sand, gravel, silt, and clay.
- * 🟩 JURASSIC AND TRIASSIC (144–248 mil. yrs.) Red sandstone, shale, and conglomerate (green), intruded by diabase (red).
- 🟦 PERMIAN (248–290 mil. yrs.) Cyclic sequences of shale, sandstone, limestone, and coal.
- 🟦 PENNSYLVANIAN (290–323 mil. yrs.) Cyclic sequences of sandstone, red and gray shale, conglomerate, clay, coal, and limestone.
- 🟪 MISSISSIPPIAN (323–354 mil. yrs.) Red and gray sandstone, shale, and limestone.
- 🟦 DEVONIAN (354–417 mil. yrs.) Red sandstone, gray shale, black shale, limestone, and chert.
- 🟪 SILURIAN (417–443 mil. yrs.) Red and gray sandstone, conglomerate, shale, and limestone.
- 🟥 ORDOVICIAN (443–490 mil. yrs.) Shale, limestone, dolomite, and sandstone.
- 🟧 CAMBRIAN (490–570 mil. yrs.) Limestone, dolomite, sandstone, shale, quartzite, and phyllite.
- 🟫 LOWER PALEOZOIC (443–570 mil. yrs.) Metamorphic rocks (metasedimentary and meta-igneous); schist, gneiss, quartzite, serpentine, slate, and marble.
- 🟩 PRECAMBRIAN (older than 570 mil. yrs.) Gneiss, granite, anorthosite, metadiabase, metabasalt, metarhyolite, and marble.

Geology and Hydrogeology of Philadelphia

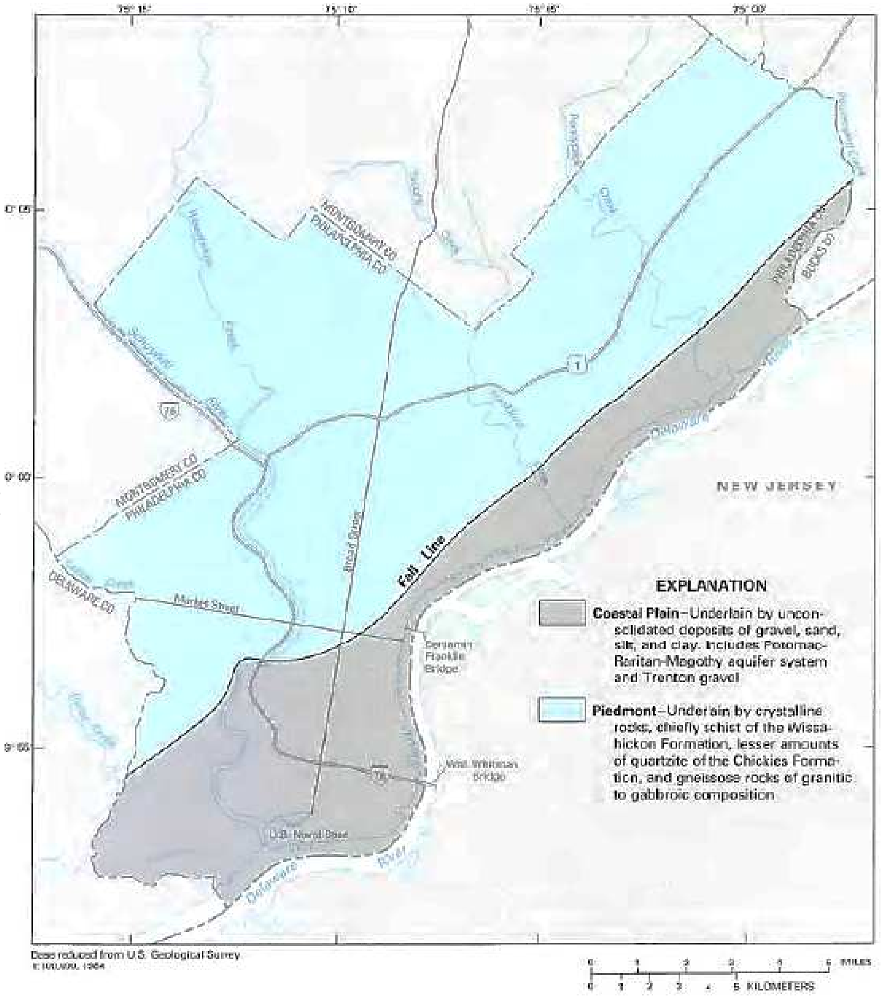
What is, soil, fill, sediment, bedrock, groundwater, surface water?



Geology and Hydrogeology of Philadelphia

Geologic Formations

- Wissahickon Formation (Paleozoic) is overlain by alluvial sediments (Quaternary & Tertiary).
- Along Delaware river, glacial outwash sediments (Trenton Gravel) are found at the surface.
- Beneath the Trenton gravel, Cretacious Sediments are up to 200 feet thick.
- Fall line separates Coastal Plain from Piedmont.

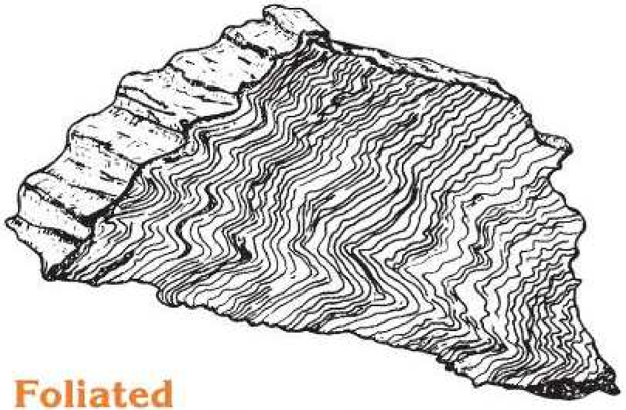


Base reduced from U.S. Geological Survey 1:100,000, 1984

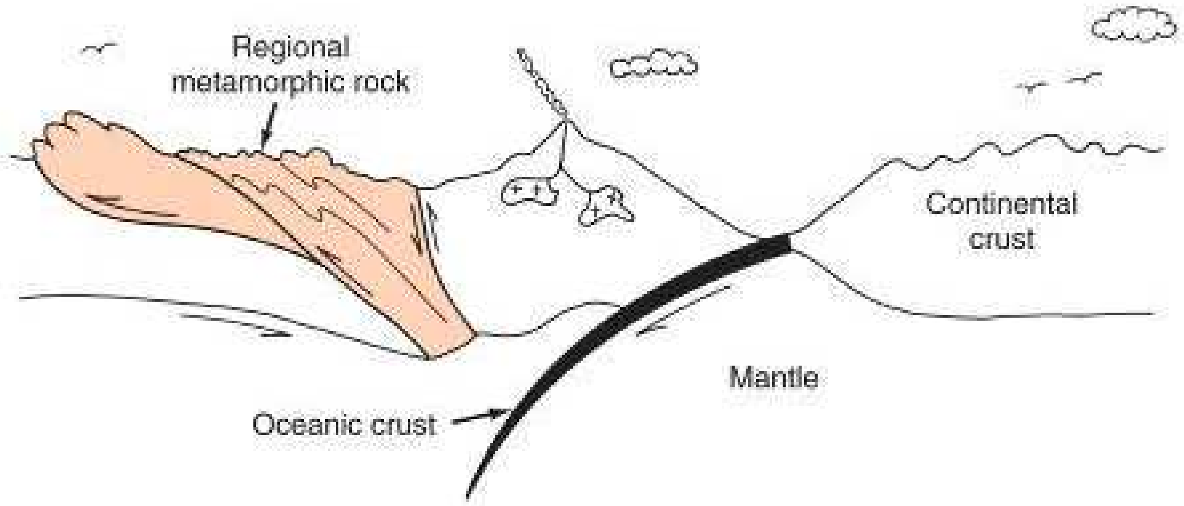
Geology and Hydrogeology of Philadelphia

Wissahickon Formation

- **Metamorphic Schist and Gneiss**
- **Early Paleozoic Age**
- **Fractured to depth of 300 feet**



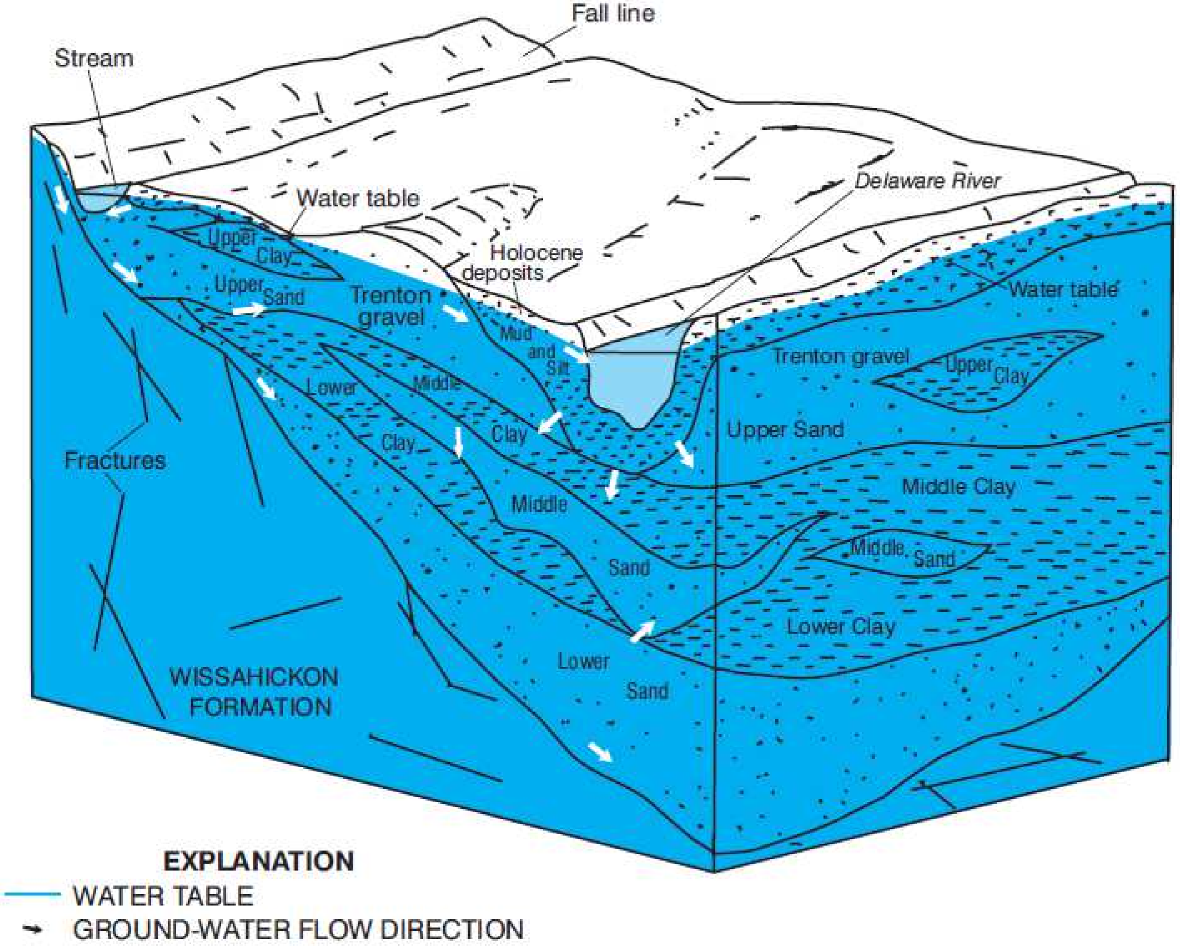
Foliated metamorphic rock



Geology and Hydrogeology of Philadelphia

Sediments in Philadelphia

- ➢Coastal Plain
- ➢Alluvial
- ➢Glacial
- ➢More Alluvial

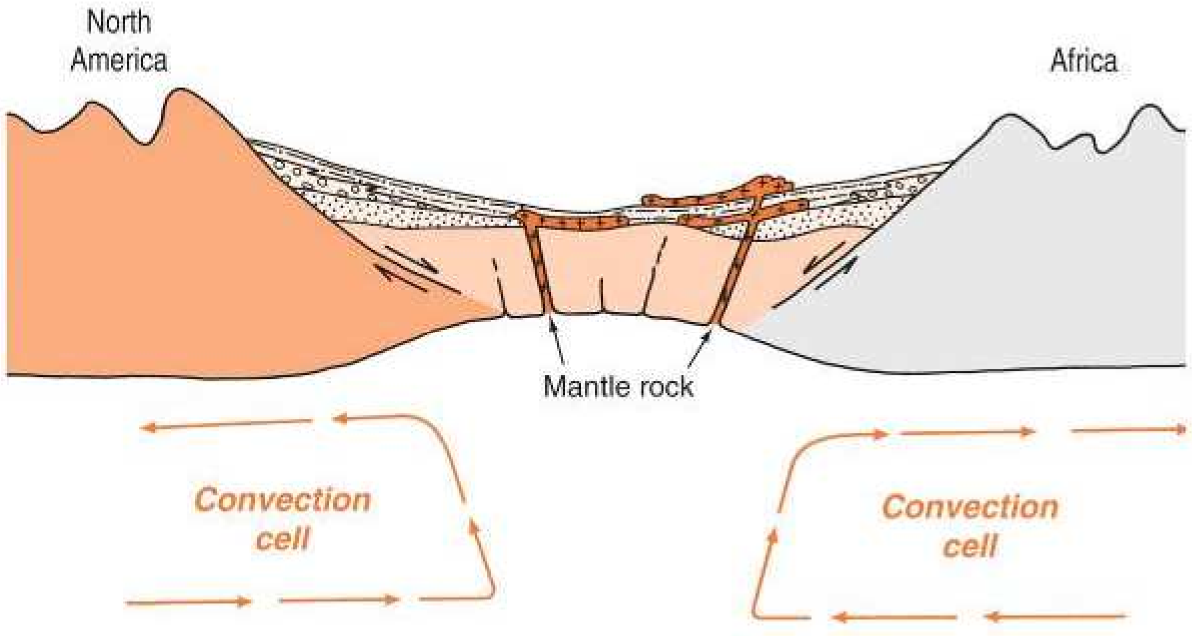


Geology and Hydrogeology of Philadelphia

Sediments in Philadelphia

Potomac-Raritan-Magothy (Cretaceous)

- Alternating layers of sand and clay in Coastal Plain
- High porosity and permeability

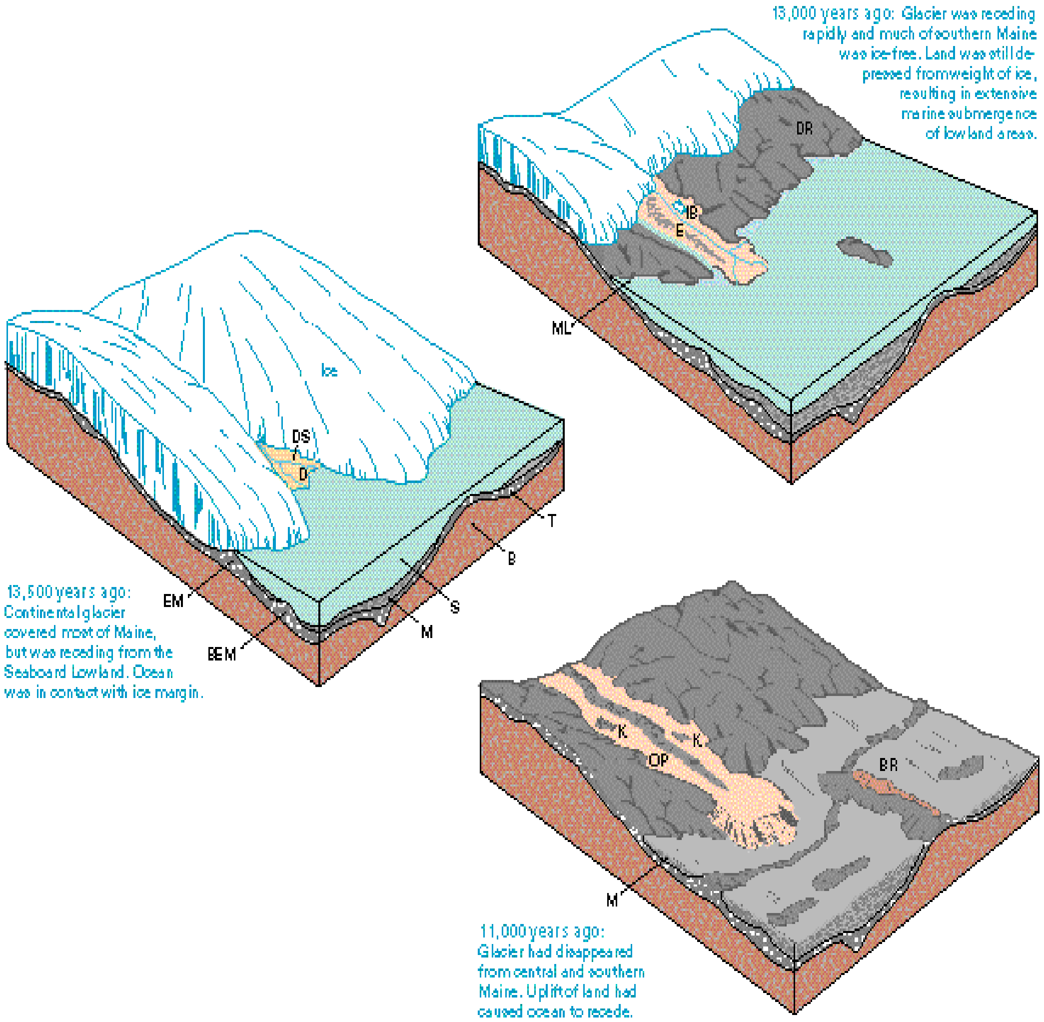


Geology and Hydrogeology of Philadelphia

Sediments in Philadelphia

Trenton Gravel (Quaternary)

- Gravely sand along Delaware River
- Overlays older coastal plain sediments
- Interbedded, Cross-bedded
- High Porosity and Permeability


13,000 years ago: Glacier was receding rapidly and much of southern Maine was ice-free. Land was still depressed from weight of ice, resulting in extensive marine submergence of lowland areas.

13,500 years ago: Continental glacier covered most of Maine, but was receding from the Seaboard Lowland. Ocean was in contact with ice margin.

11,000 years ago: Glacier had disappeared from central and southern Maine. Uplift of land had caused ocean to recede.

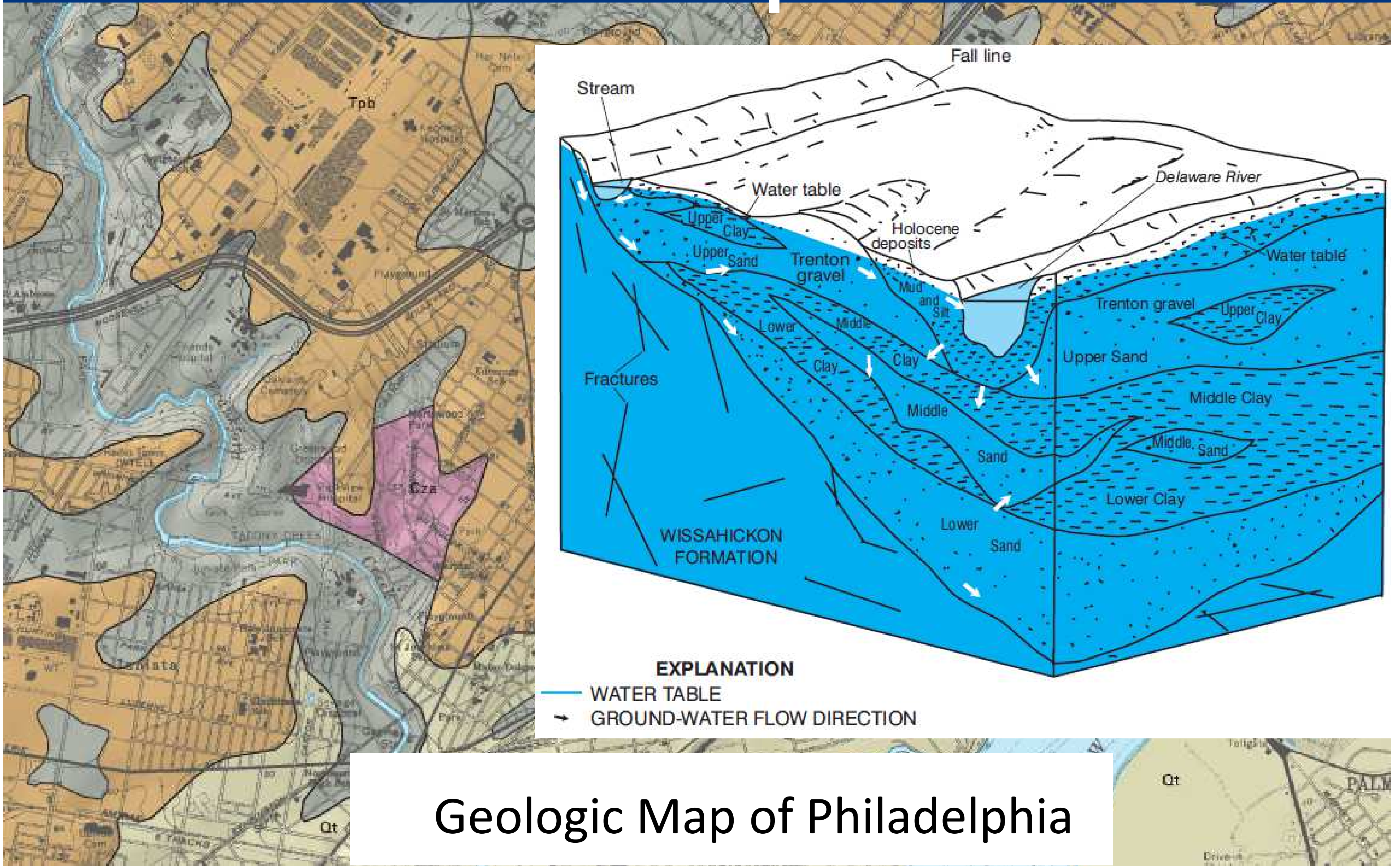
Geology and Hydrogeology of Philadelphia

Sediments in Philadelphia

Alluvial sediments

- Pennsauken-Bridgeton – Cretaceous, Tertiary deposits on upland terraces
- Holocene (recent) – Along streams and rivers
- Variable porosity and permeability

Geology and Hydrogeology of Philadelphia

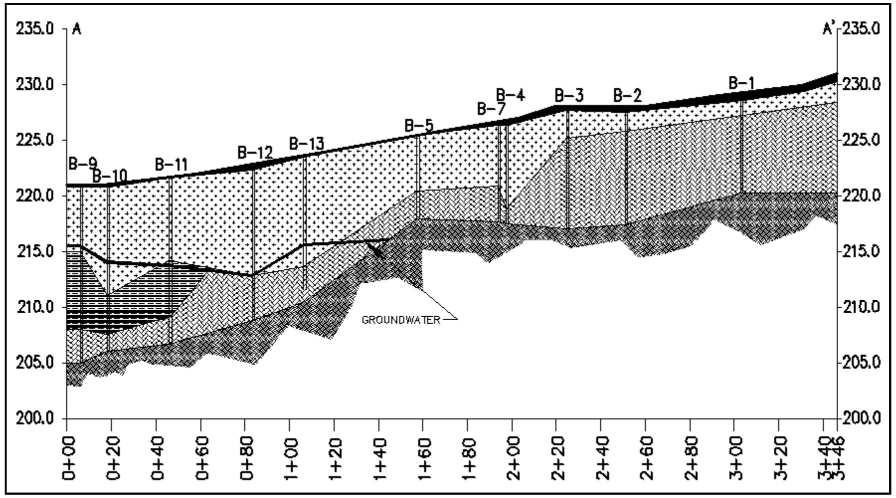


Geologic Map of Philadelphia

Geology and Hydrogeology of Philadelphia

Fill

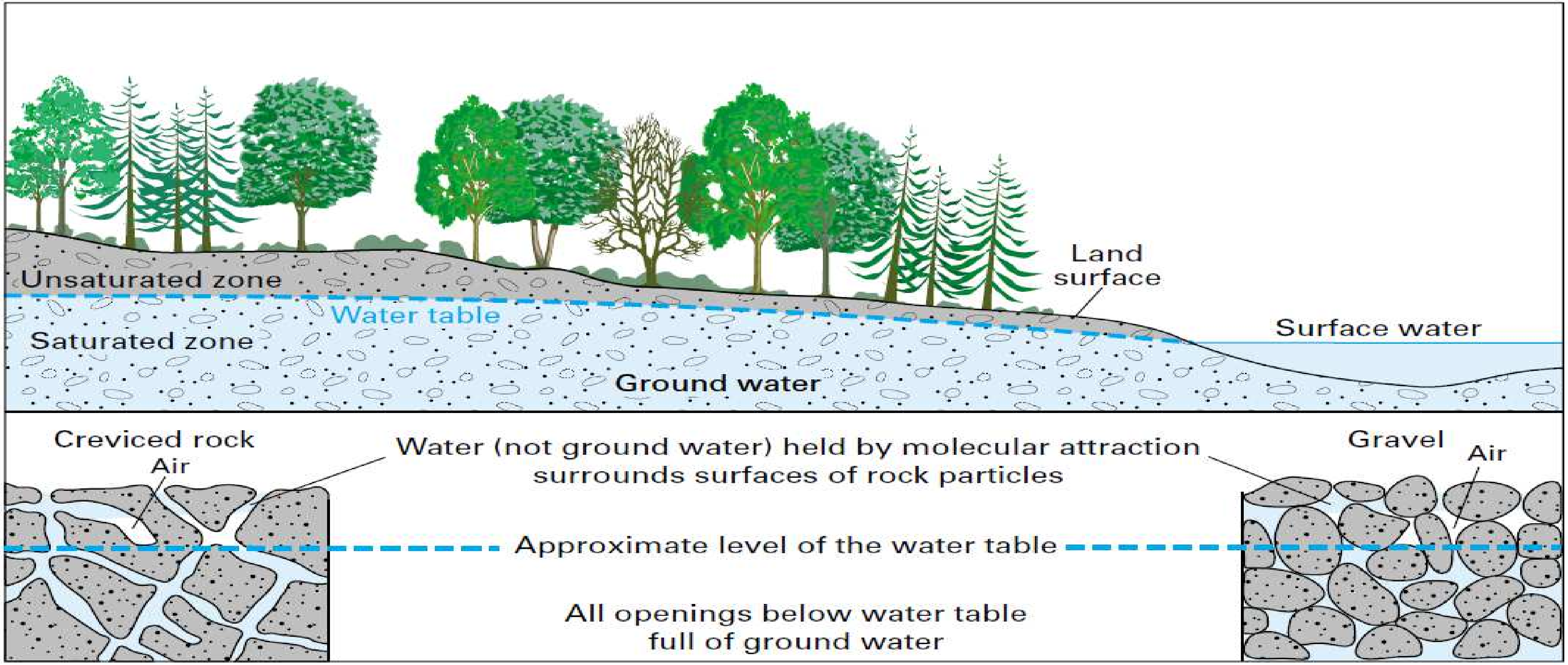
- “Fill” refers to any material that is present in the ground that is not considered natural soil or bedrock
- Geotechnical Investigation will identify fill
- Fill occurs throughout the city
- Infiltrating into fill is possible so long as fill does not pose structural or environmental hazard
- Environmental due diligence required if exporting fill from property



Geology and Hydrogeology of Philadelphia

We discussed geologic materials… how does water flow through these materials?

- **Hydraulic conductivity**: determines rate that water can flow through ground under a gradient
- **Transmissivity**: volume of water that can flow through aquifer = hydraulic conductivity x thickness
- **Specific Yield / Effective porosity:** volume of pore space available for groundwater flow



Geology and Hydrogeology of Philadelphia

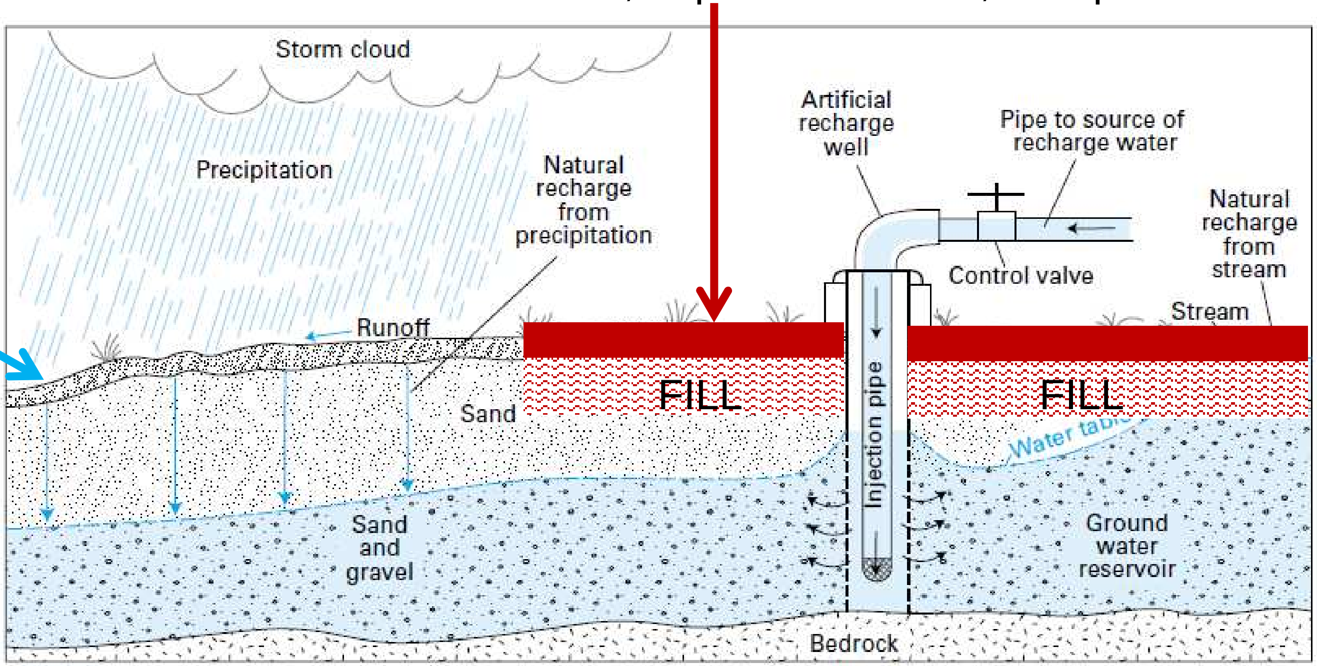
Stormwater infiltration BMPs restore natural Groundwater Recharge

Pavement, Impervious Cover, Compacted Soils

Infiltration through Natural Soils

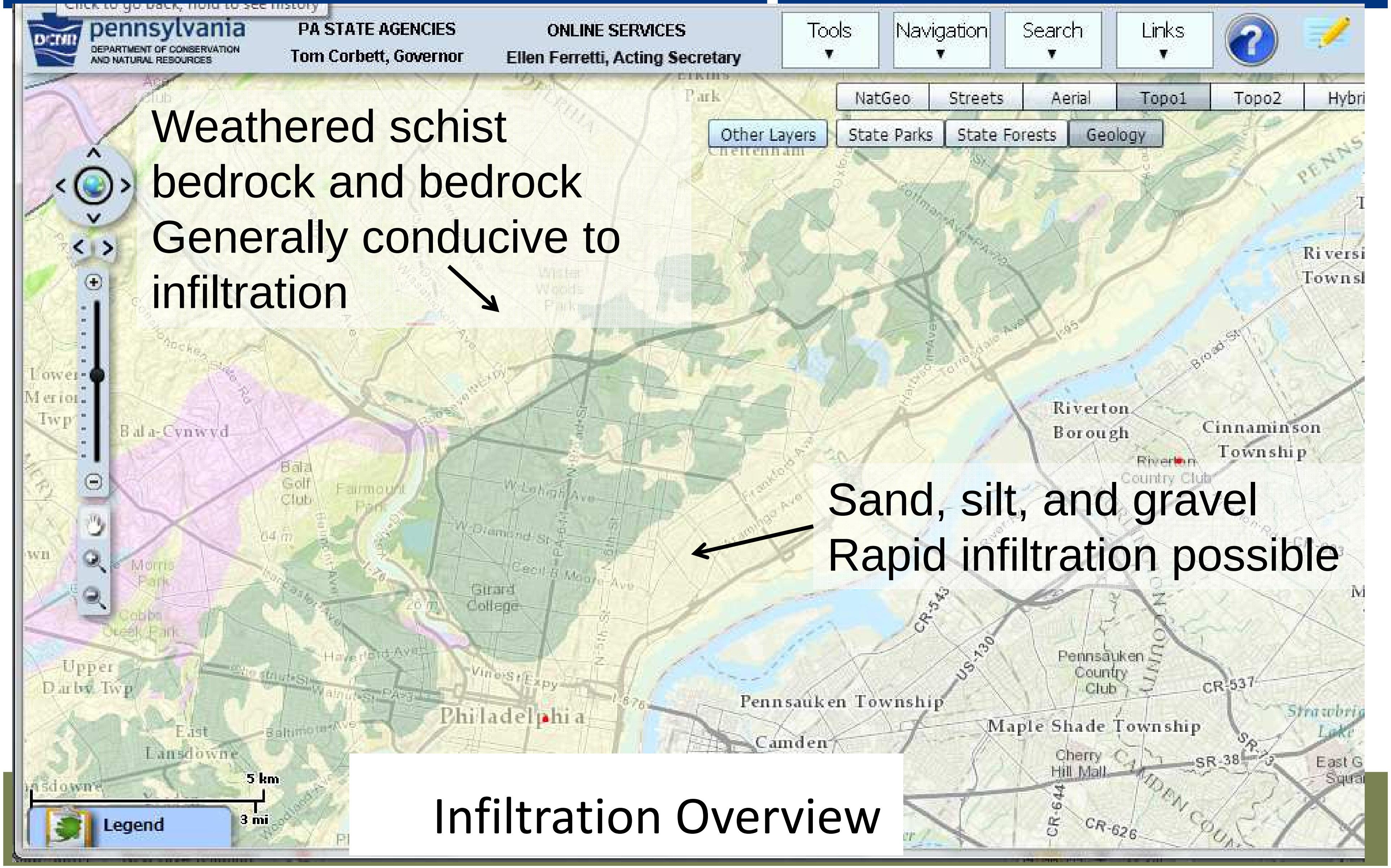
Trenton Gravel, Alluvial Sediments Weathered Bedrock

Wissahickon Schist



Natural and artificial recharge of an aquifer.

Geology and Hydrogeology of Philadelphia



Weathered schist bedrock and bedrock Generally conducive to infiltration

Sand, silt, and gravel Rapid infiltration possible

Infiltration Overview

Stormwater Management

Regionally - Stormwater management practices safegauard and restore our water resources.

- Reduce Runoff (Volume, Rate, Quality)
- Promote Baseflow in Streams
- These goals are integrated to provide overlapping social, economic, and environmental benefits (Triple Bottom Line)

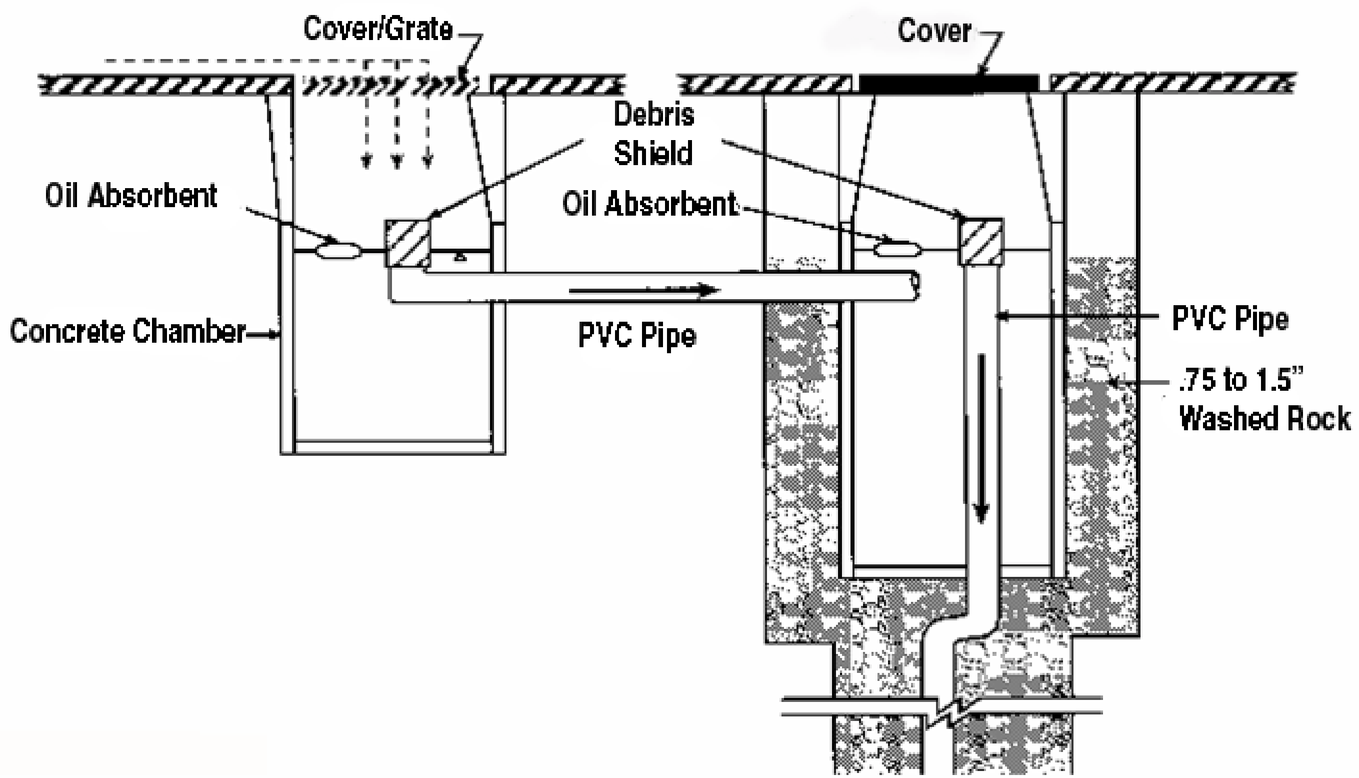

Historic Waterways


Current Waterways

Stormwater Management & CSO’s

Opportunities / Constraints

Class V storm water drainage wells manage surface water runoff (rainwater or snow melt) by placing it below the ground surface. They are typically shallow disposal systems designed to infiltrate storm water runoff below the ground surface. Storm water drainage wells may have a variety of designs and may be referred to by other names including dry wells, stormwater manholes, bored wells, and infiltration galleries. The names may be misleading so it is important to note that **"A Class V well by definition is any bored, drilled, or driven shaft, or dug hole that is deeper than its widest surface dimension**…"



Subsurface Investigation and Analysis

GROUNDWATER

SURFACE FEATURES

Soil Evaluation

REDOX FEATURES

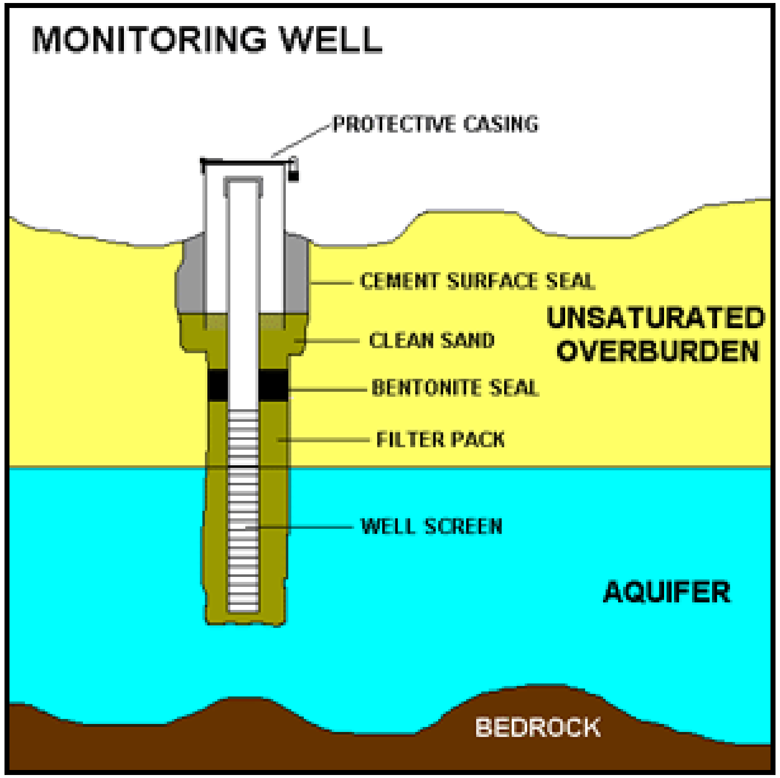
BEDROCK

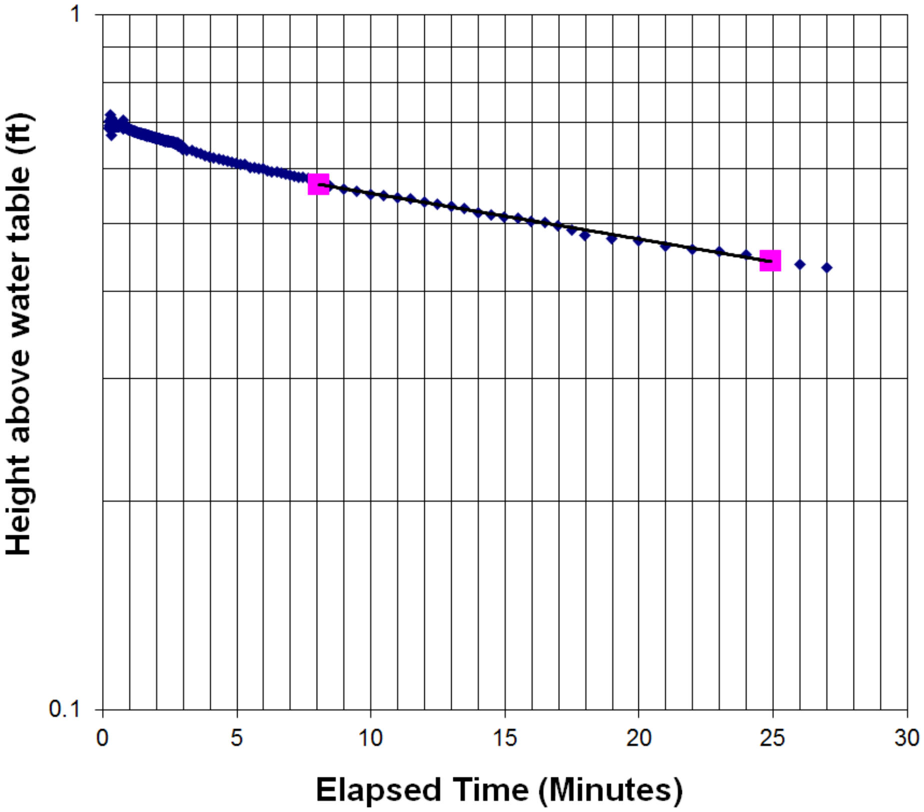
Subsurface Investigation and Analysis

Soil Infiltration Testing – E.G.:Borehole Infiltration Test

Subsurface Investigation and Analysis

Aquifer Test (Slug Test) – Horizontal Permeability

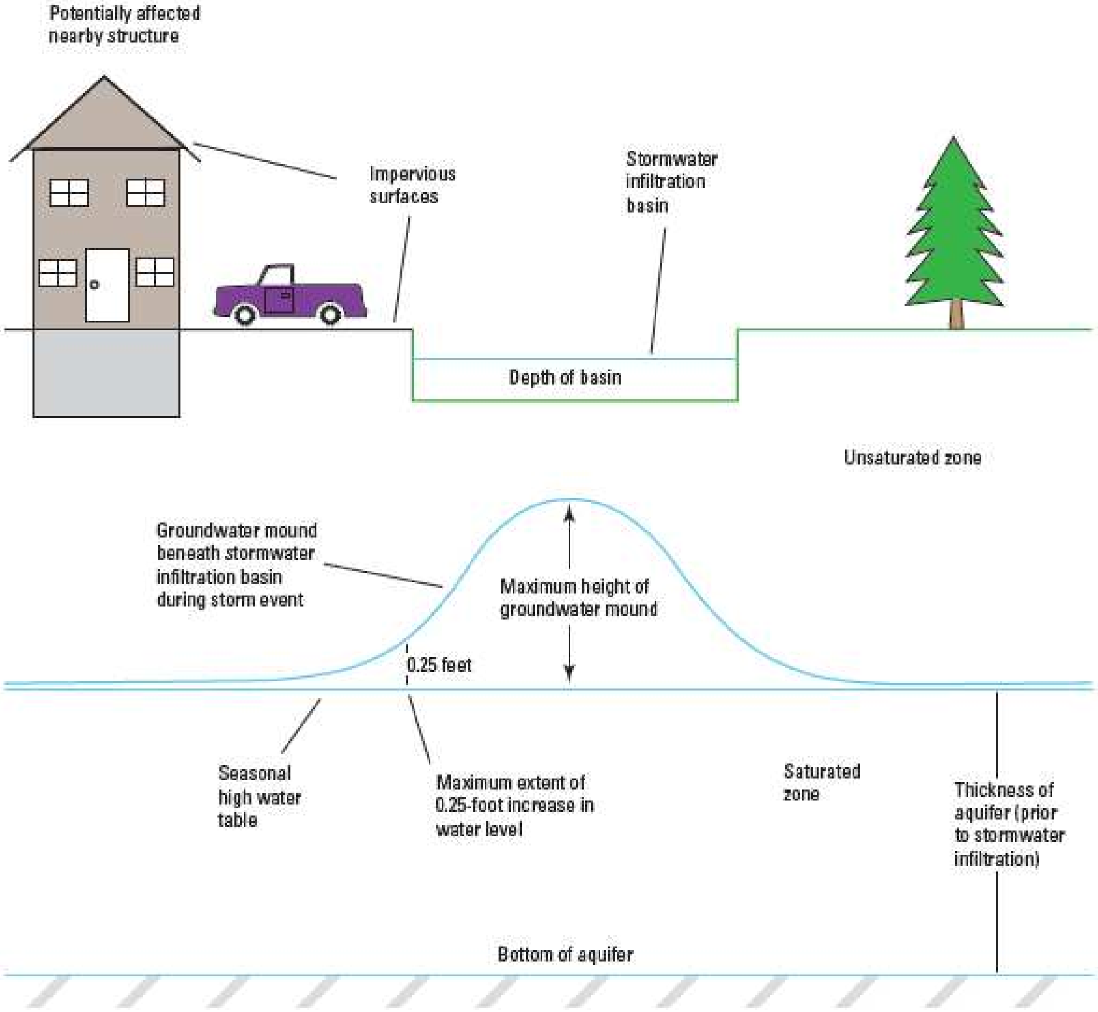




Subsurface Investigation and Analysis

Groundwater Mounding

- Groundwater mounding occurs beneath stormwater infiltration structures
- Concentrated groundwater recharge can potentially affect nearby buildings and critical infrastructure
- The time for the groundwater mound to reach the infiltration structure may be needed for design purposes

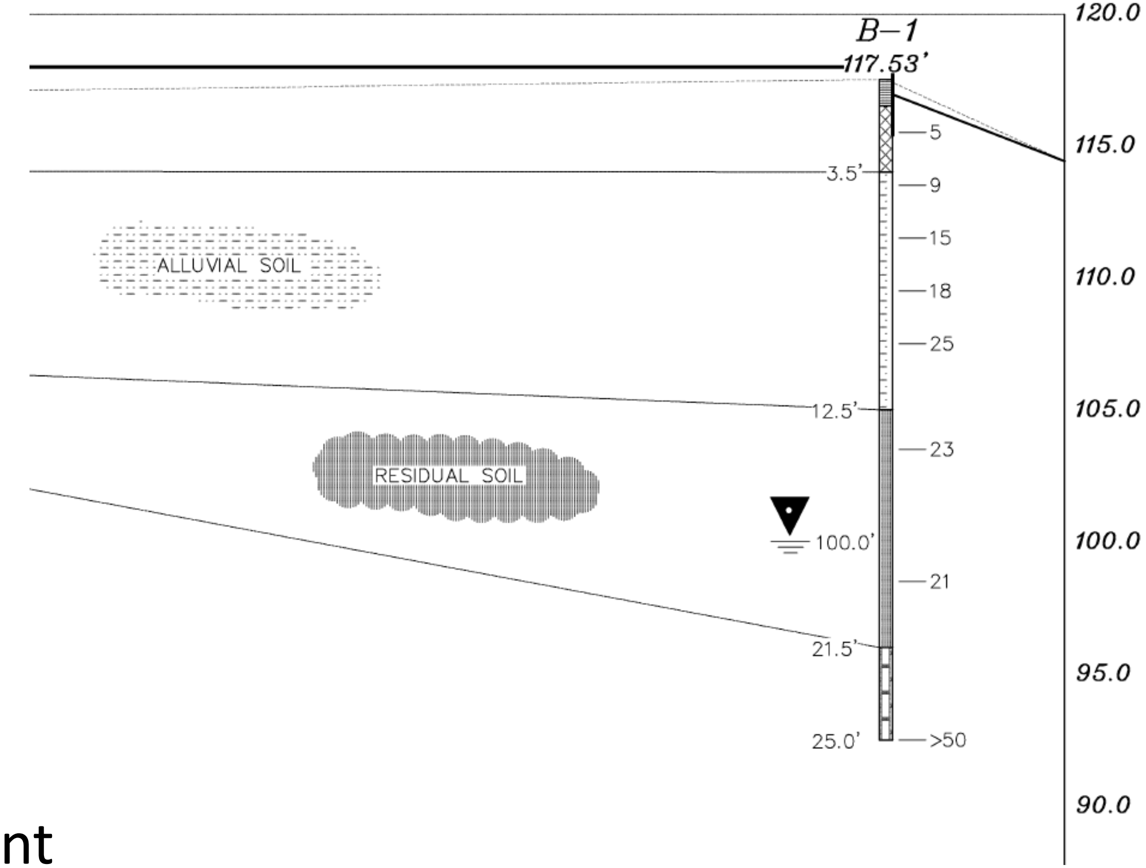


Subsurface Investigation and Analysis

Groundwater Mounding

Geologic Evaluation

- ➢ Test Borings
- ➢ Piezometers
- ➢ Test Pits
- ➢ Geologic Mapping
- ➢ Infiltration Testing
- ➢ Slug Testing
- ➢ Professional Judgment



Subsurface Investigation and Analysis

Groundwater Mounding

Parameters used for Groundwater Mounding Analysis

- Dimensions
- Distance to critical structure
- Infiltration Rate
- Time
- Porosity
- Depth to Water table
- Aquifer thickness and hydraulic conductivity

Subsurface Investigation and Analysis

Example – Confidential Shopping Center, Philadelphia PA:

Objective was to evaluate the potential impact of a proposed infiltration structure on an adjacent railroad cut.

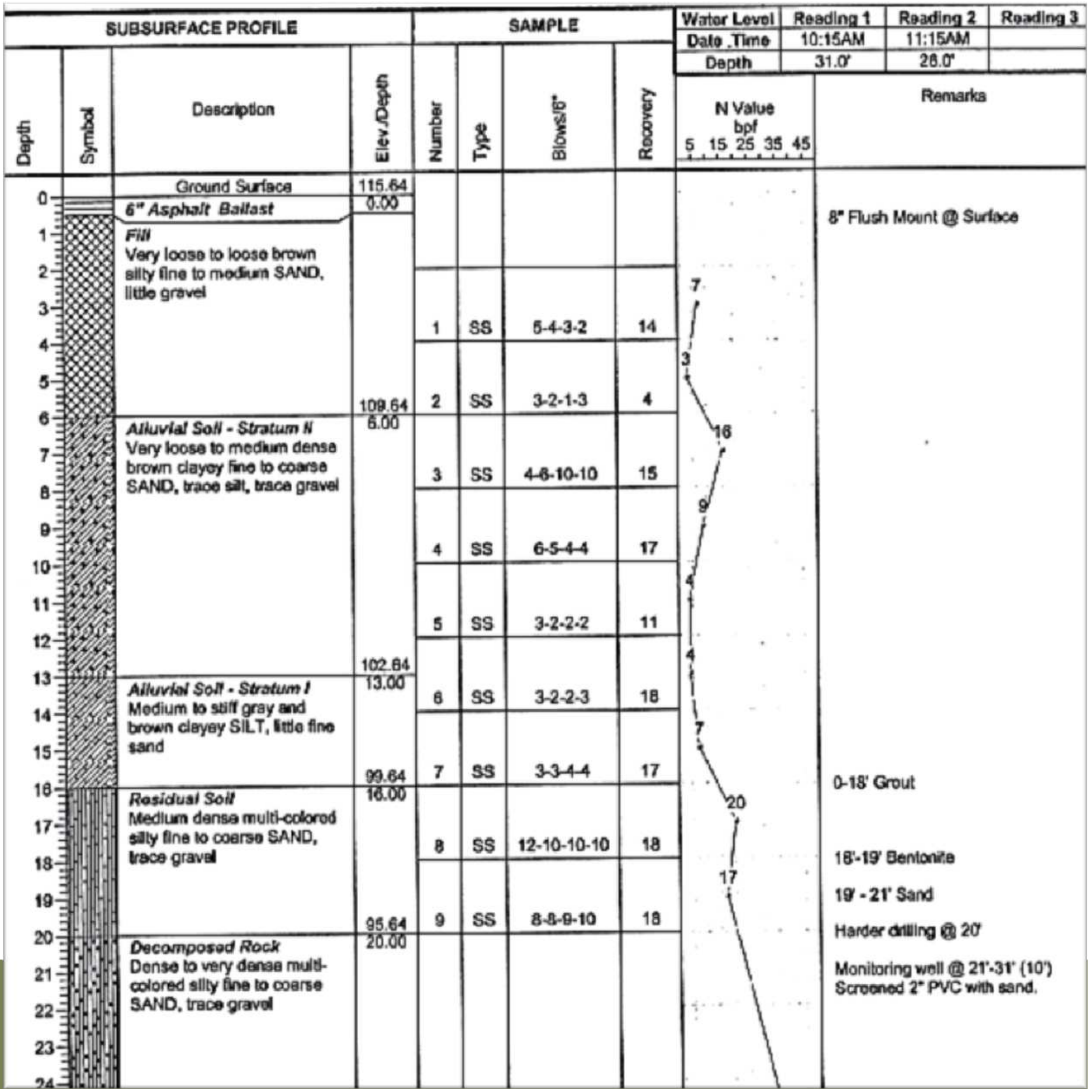
Analyses included geologic evaluation, groundwater mounding analysis, and slope stability analysis.

Subsurface Investigation and Analysis

Example – Confidential Shopping Center, Philadelphia PA:

Geologic Evaluation

- Fill (0-6’)
- Alluvial soils (6-16’)
- Residual soil (16-20’)
- Decomposed rock (20-31’)
- Schist Bedrock (31’+)
- Groundwater (26.2’)



Water Level	Reading 1	Reading 2	Reading 3
Date ,Time	10:15AM	11:15AM	
Depth	31.0'	26.0'	

SUBSURFACE PROFILE				SAMPLE					
Depth	Symbol	Description	Elev./Depth	Number	Type	Blows/6"	Recovery	N Value bpf	Remarks
		Ground Surface	115.64						
0		***6" Asphalt Ballast***	0.00						8" Flush Mount @ Surface
1		***Fill*** Very loose to loose brown silty fine to medium SAND, little gravel		1	SS	5-4-3-2	14	7	
			109.64	2	SS	3-2-1-3	4	3	
6		***Alluvial Soil - Stratum II*** Very loose to medium dense brown clayey fine to coarse SAND, trace silt, trace gravel	6.00	3	SS	4-6-10-10	15	16	
				4	SS	6-5-4-4	17	9	
			102.64	5	SS	3-2-2-2	11	4	
13		***Alluvial Soil - Stratum I*** Medium to stiff gray and brown clayey SILT, little fine sand	13.00	6	SS	3-2-2-3	18	4	
			99.64	7	SS	3-3-4-4	17	7	0-18' Grout
16		***Residual Soil*** Medium dense multi-colored silty fine to coarse SAND, trace gravel	16.00	8	SS	12-10-10-10	18	20	18'-19' Bentonite
			95.64	9	SS	8-8-9-10	18	17	19' - 21' Sand
20		***Decomposed Rock*** Dense to very dense multi-colored silty fine to coarse SAND, trace gravel	20.00						Harder drilling @ 20' Monitoring well @ 21'-31' (10') Screened 2" PVC with sand.

Subsurface Investigation and Analysis

Example - Confidential Shopping Center, Philadelphia PA

Groundwater Mounding Analysis

- Surface dimensions – approx. 300 x 91 ft
- Recharge rate – 1”/hr and 0.25”/hr
- Specific yield - 0.08
- Aquifer thickness – 15 feet
- Transmissivity - 2.81 ft^2/day (based on hydraulic conductivity)
- Hantush Method (1967) with Colorado Mound Software

Subsurface Investigation and Analysis

Example - Confidential Shopping Center, Philadelphia PA

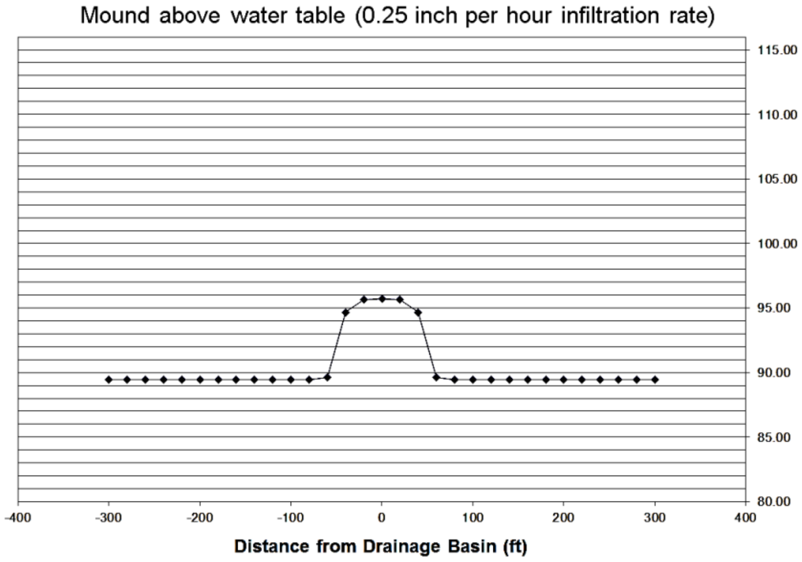
Slope Stability Analysis

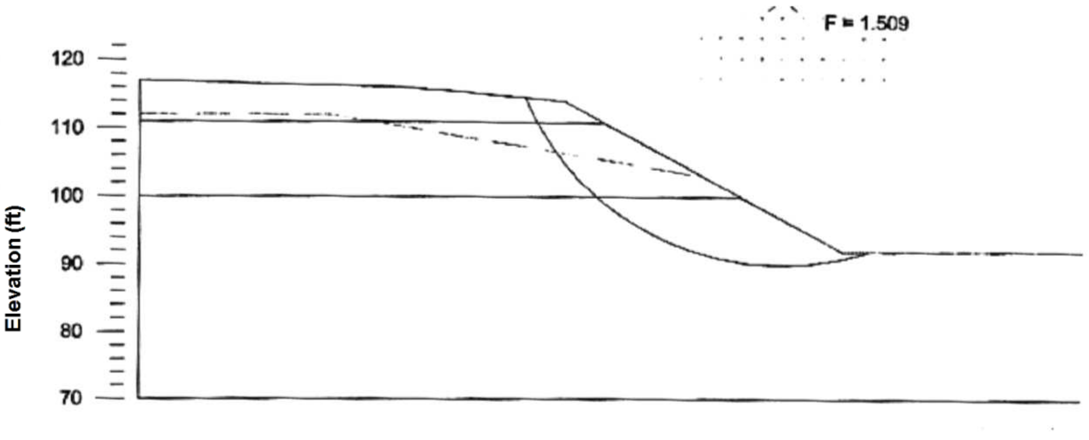
- A “worst case” scenario was used assuming water would travel laterally in the soil to slope
- Bishop’s Modified Method and Janbu’s Simplified Method Used with Gslope 4 software
- Industry standards require a permanent slope to have a minimum factory of safety between 1.3 and 1.5. Our model results in a factor of safety of 1.509

Subsurface Investigation and Analysis

Example – Confidential Shopping Center, Philadelphia PA

- The groundwater mounding analysis showed that reducing the infiltration rate to 0.25 inches per hour would be beneficial
- The slope stability analysis showed that horizontal movement of groundwater would not affect the slope

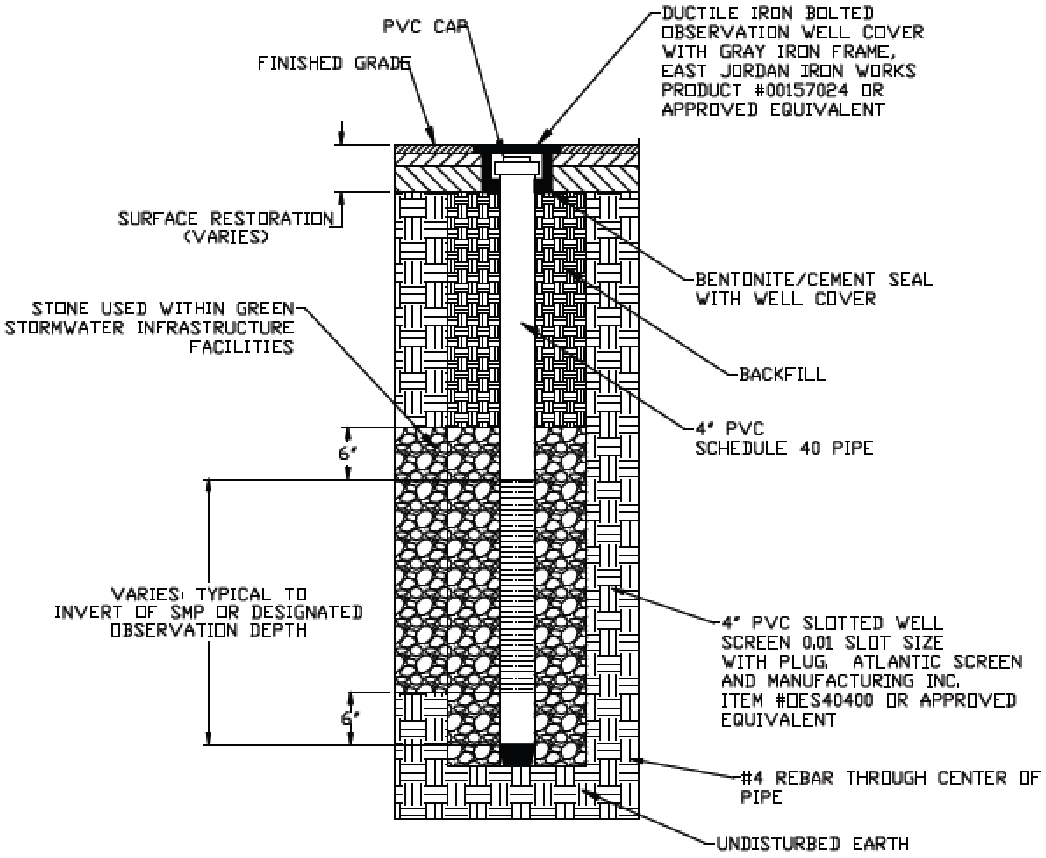

Mound above water table (0.25 inch per hour infiltration rate)



Modeling and Monitoring

Modeling and Monitoring of Individual Structures:

- Isolation distances between infiltration structures and buildings) have been set based on conservative models.
- Observation wells in pilot studies performed by PWD will provide further data to support or modify standard siting criteria.

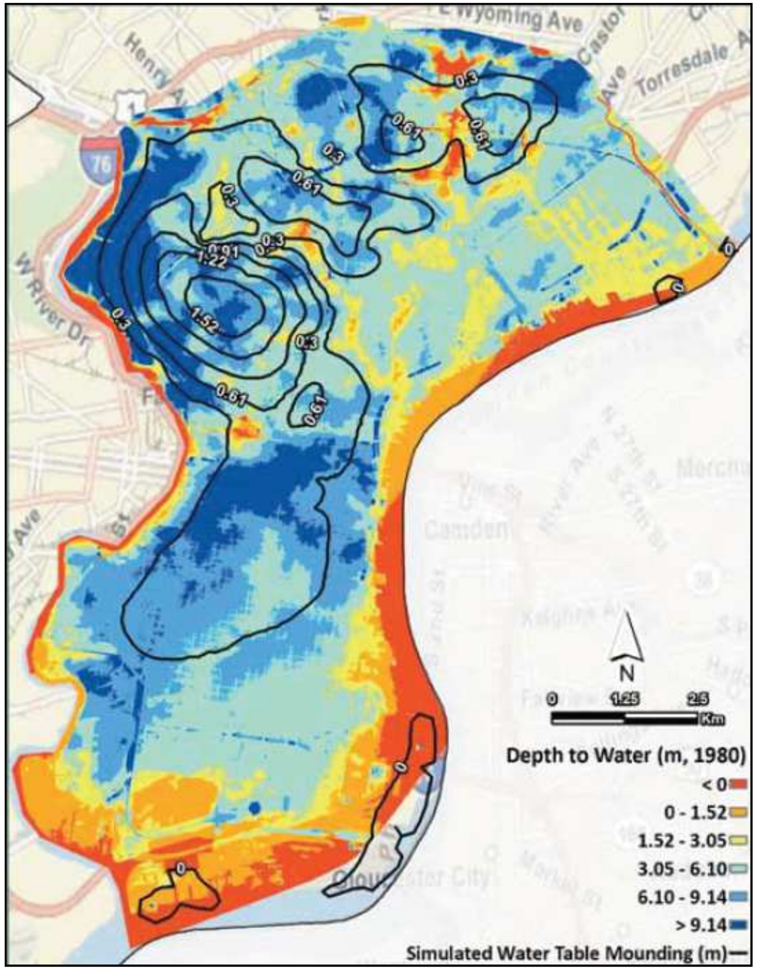


OBSERVATION WELL IN FOOTWAY

Modeling and Monitoring

Regional Models and Monitoring:

- The regional groundwater table in the Philadelphia Combined Sewer Area has been modeled by USGS, PWD and others
- CDM (2011) predicted up to 6 foot regional groundwater table rise in Piedmont and up to 1 foot rise in Coastal Plane.
- PWD is performing long term monitoring of groundwater and surface water in order to monitor regional impacts of enhanced groundwater recharge.



Questions??

This concludes The AWRA-PMAS and Philadelphia Engineer's Club Seminar