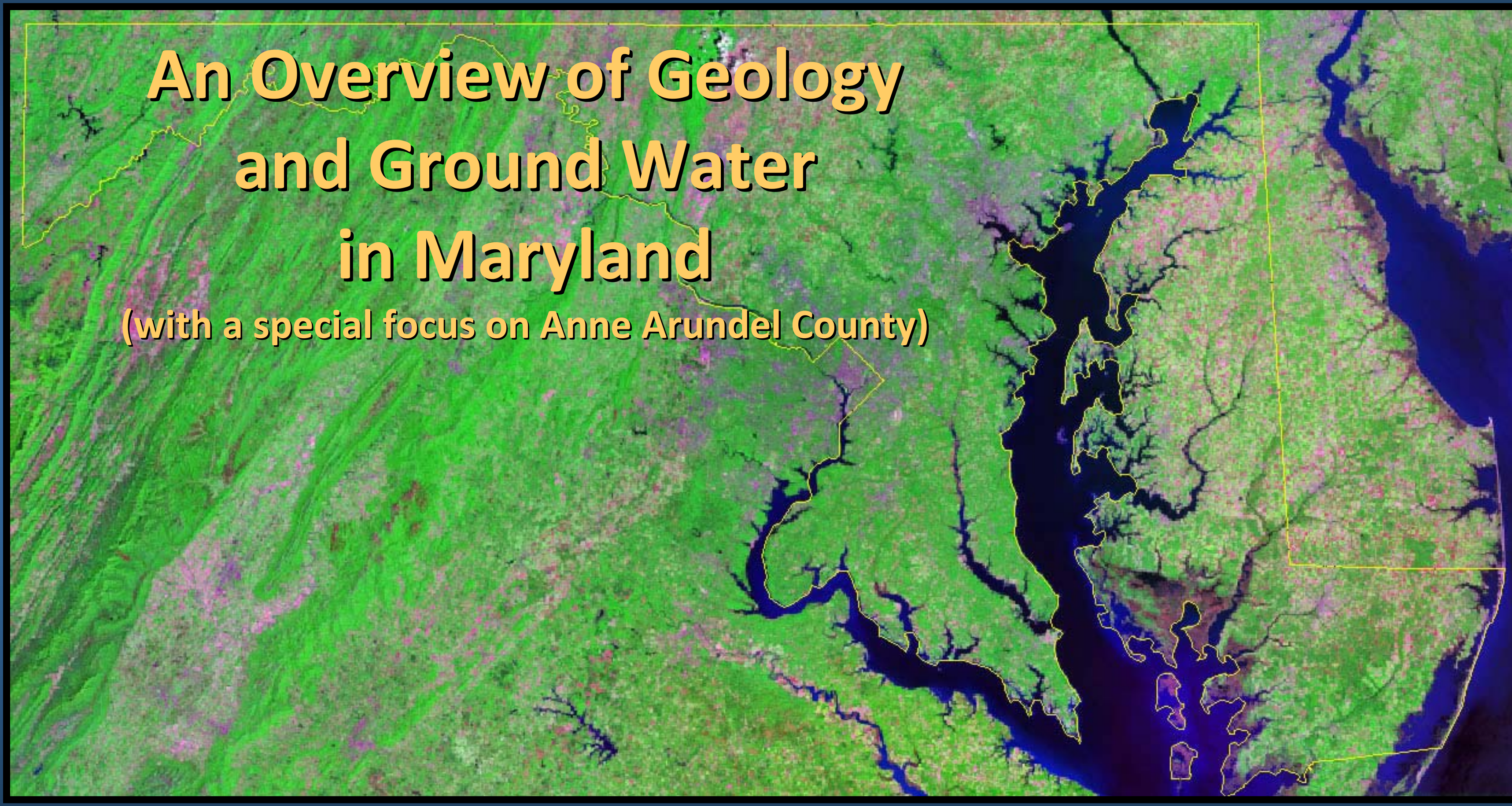
An Overview of Geology and Ground Water in Maryland

(with a special focus on Anne Arundel County)



Heather Quinn
MARYLAND GEOLOGICAL SURVEY

General Overview of

Geology and Physiography of Maryland

Hydrologic Cycle

Watersheds

Ground Water, Aquifers and Wells

Ground Water Availability Issues

Ground Water Quality Issues

General Overview of Geology and Physiography

Rocks and Sediments

Sediments – mainly loose particles

“unlithified” or “unconsolidated”

(sand, silt, clay, gravel, cobbles, boulders;

can contain other materials such as shell, bone, teeth)

3 Basic Rock Types:

Igneous

Metamorphic

Sedimentary

Igneous Rocks

crystallized from molten rock (magma)

(extrusive, e.g., basalt; intrusive, e.g., granite)

Metamorphic Rocks

recrystallized by intense heat and/or pressure

(e.g., slate, quartzite, marble, schist, gneiss)

Sedimentary Rocks

Compacted and/or cemented particles

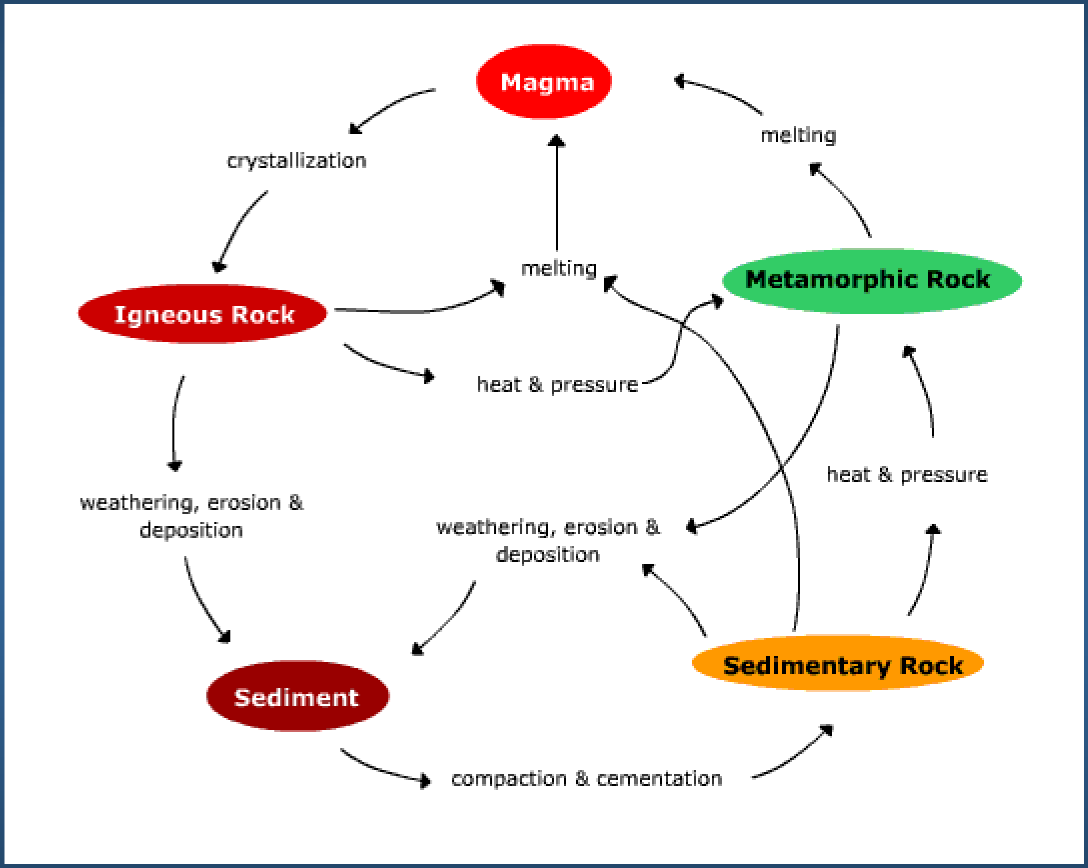
clastic: e.g., sandstone, shale, conglomerate

chemical: e.g., salt, gypsum

organic/biochemical: e.g., coal, chalk, limestone



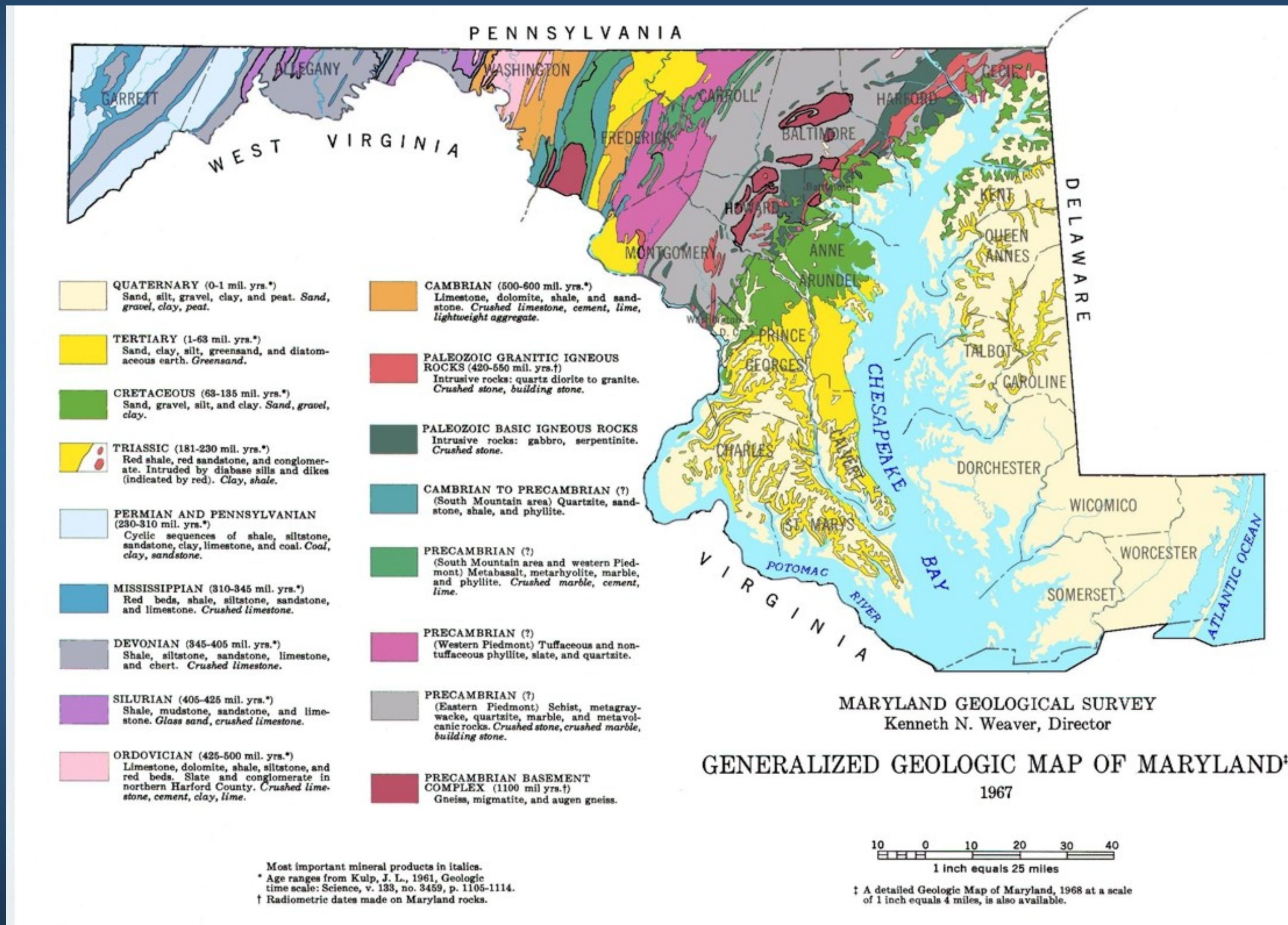

Rock Cycle



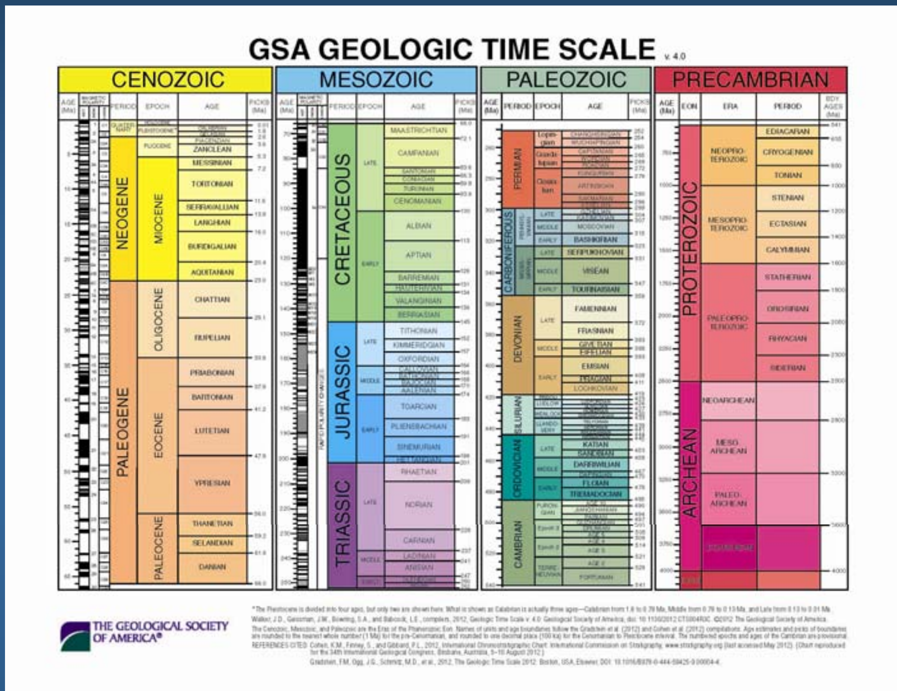
from: http://www4.uwsp.edu/geo/faculty/ritter/images/lithosphere/rock_cycle.gif

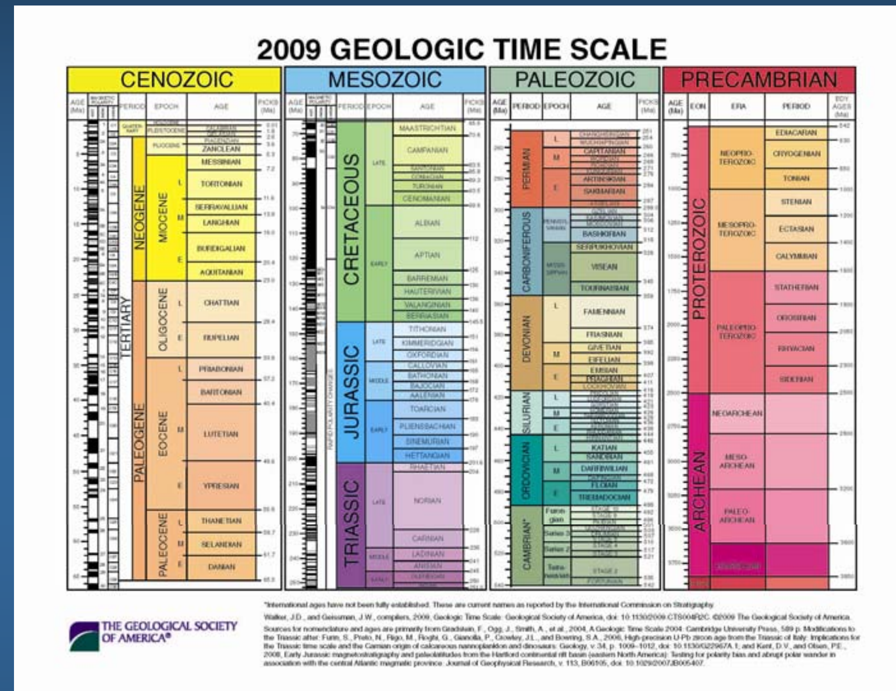
Generalized Geologic Map of Maryland

Units shown grouped by age



Geologic Time Scales





http://www.geosociety.org/science/timescale/

Physiography

the study of landscapes and landforms

Physiographic Province:

a region in which all elements of the landscape are similar in geologic structure and gross lithologies and which has had a unified geomorphic history

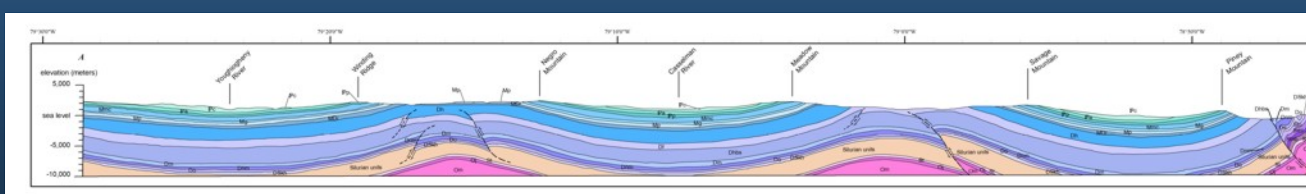
Physiographic Provinces of Maryland

Physiographic Provinces of Maryland

Appalachian Plateaus

Landscape - some steep-sided plateaus; often rugged surface dissected by streams

Geology - gently folded shale, siltstone, and sandstone of Devonian to Permian age



Appalachian Plateaus Province

Deep Creek Lake

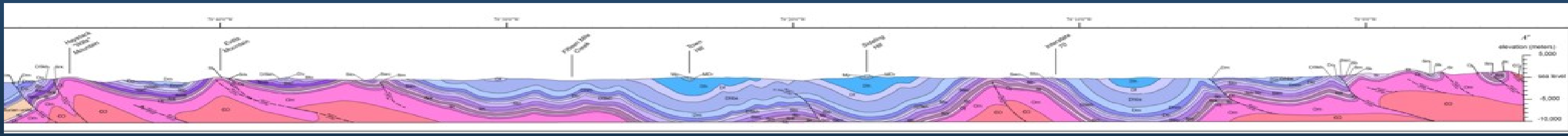
Physiographic Provinces of Maryland

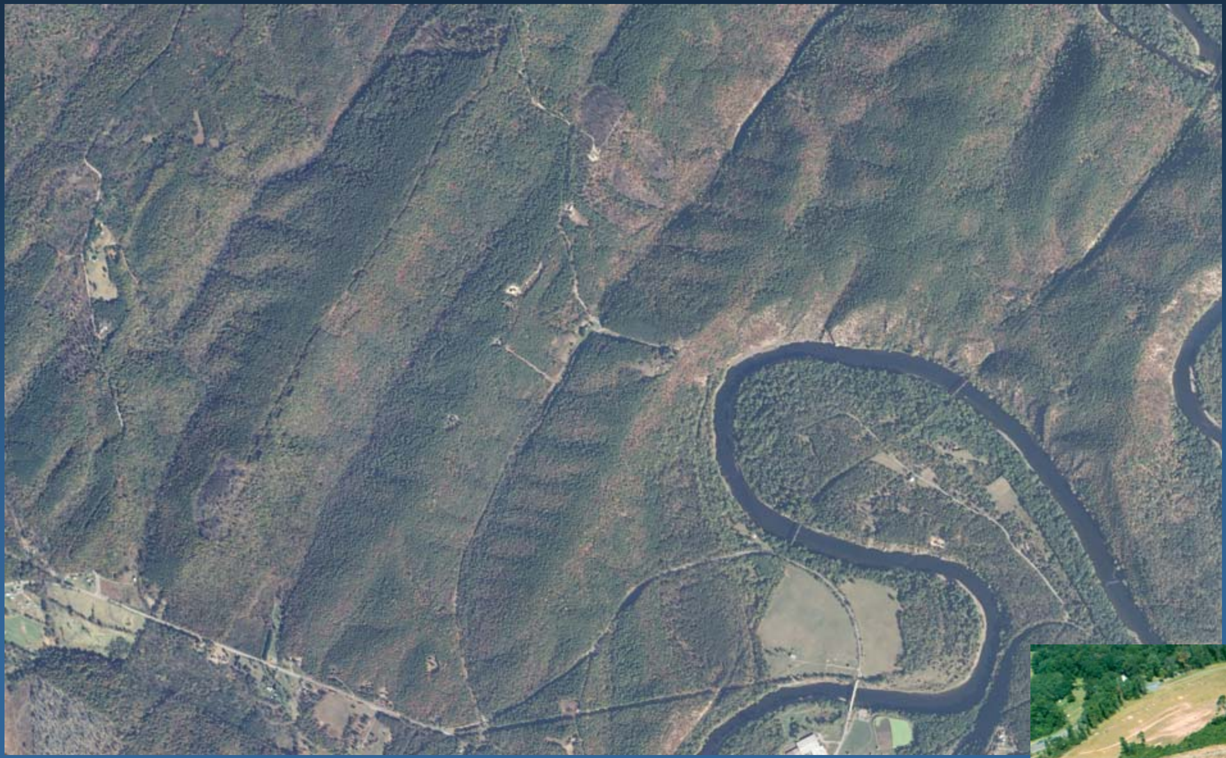
Ridge and Valley

Landscape - generally long ridges and valleys

Geology - strongly folded & faulted sedimentary rocks of Cambrian to Mississippian age.

Resistant units form ridges; less resistant underlie valleys

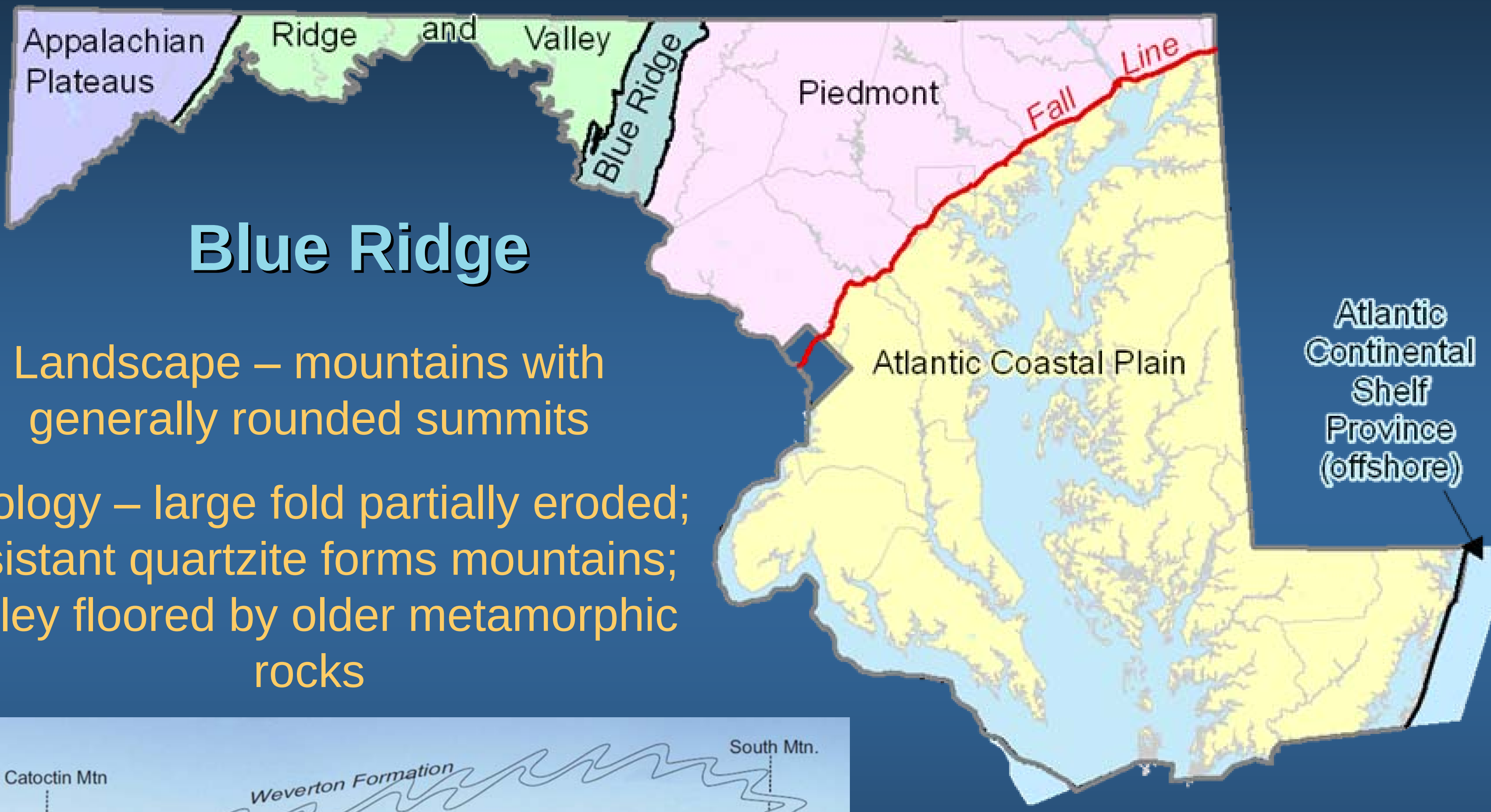




Sideling Hill

Ridge & Valley Province

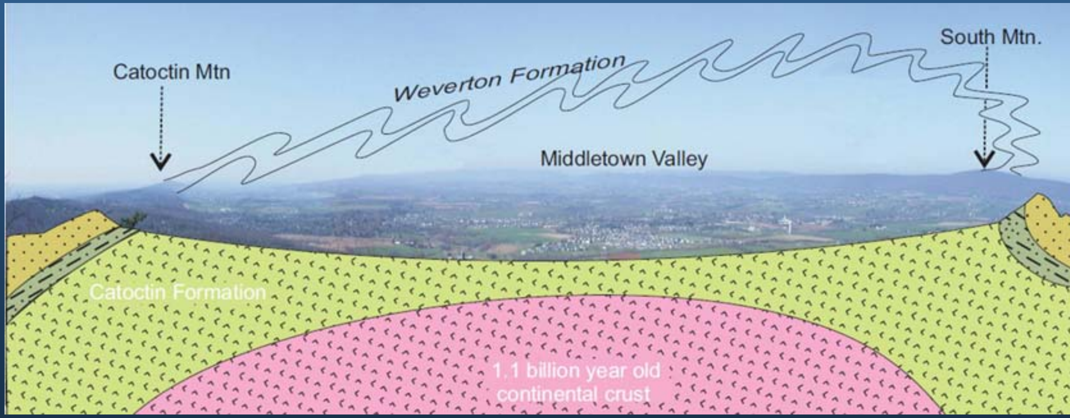
Physiographic Provinces of Maryland



Blue Ridge

Landscape – mountains with generally rounded summits

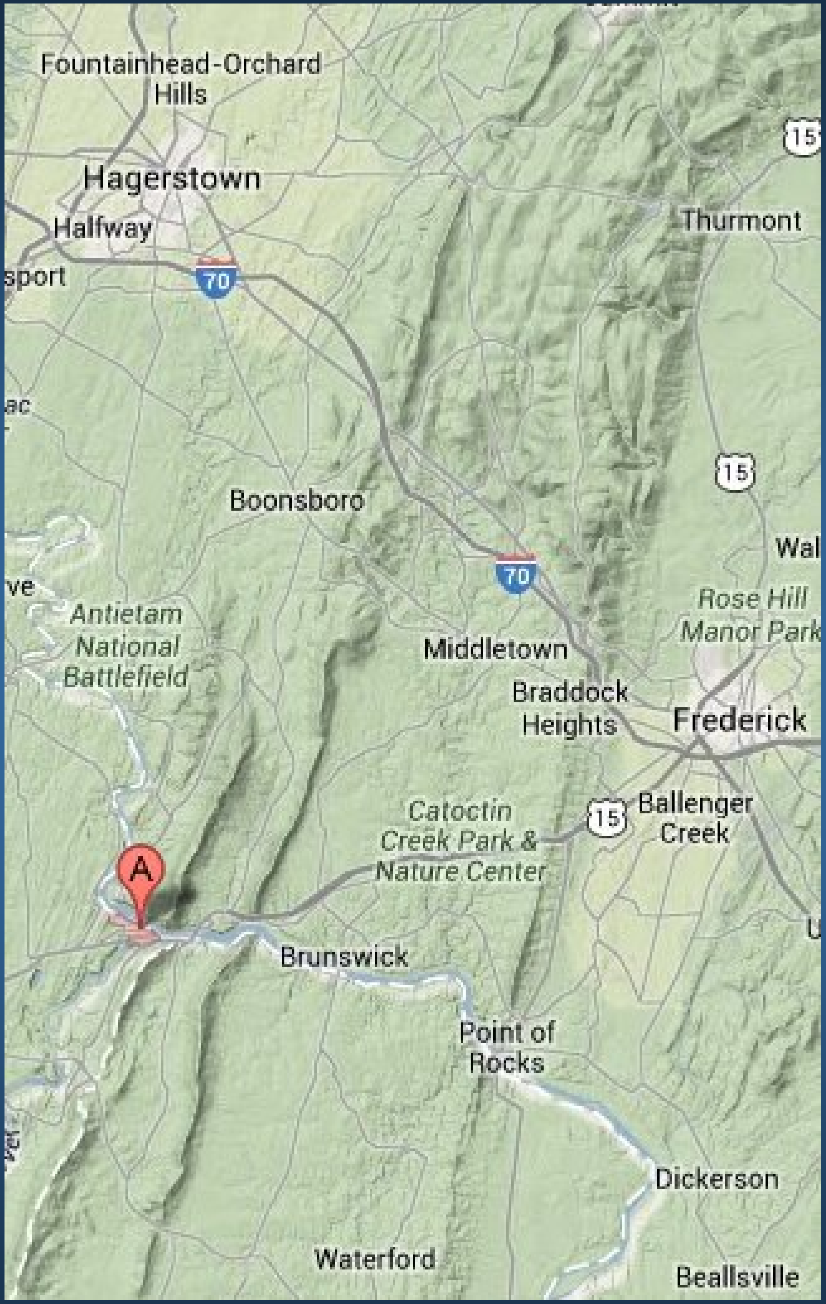
Geology – large fold partially eroded; resistant quartzite forms mountains; valley floored by older metamorphic rocks



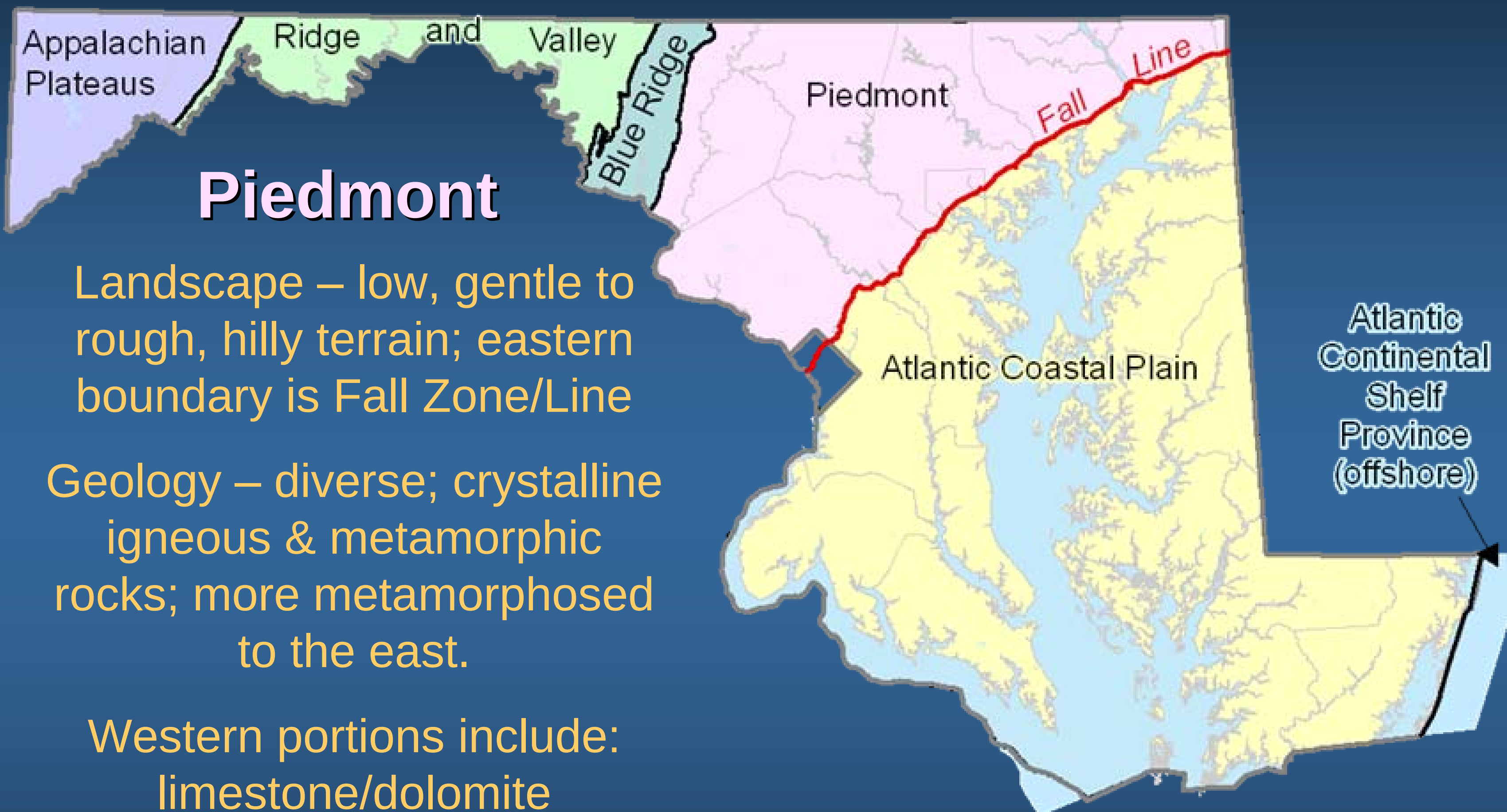
E View looking south W

Blue Ridge Province

Harper's Ferry



Physiographic Provinces of Maryland



Piedmont

Landscape – low, gentle to rough, hilly terrain; eastern boundary is Fall Zone/Line

Geology – diverse; crystalline igneous & metamorphic rocks; more metamorphosed to the east.

Western portions include: limestone/dolomite

Triassic sedimentary rocks (ancient rift basins)

Piedmont Province

Great Falls

Serpentine Barrens

Physiographic Provinces of Maryland

Coastal Plain

Landscape – low, hilly to nearly flat terraced plains

Geology – sediments of mainly Cretaceous to Recent age; gently dip and thicken to southeast

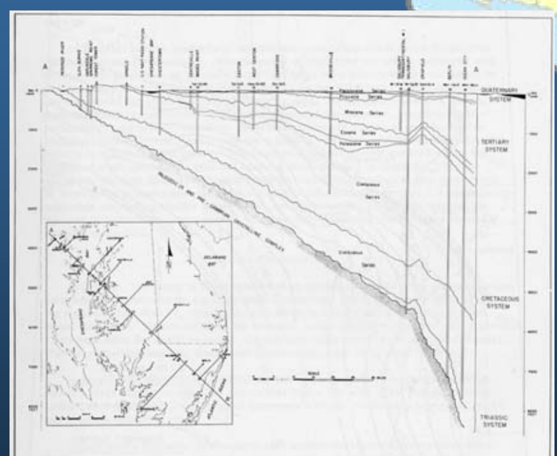


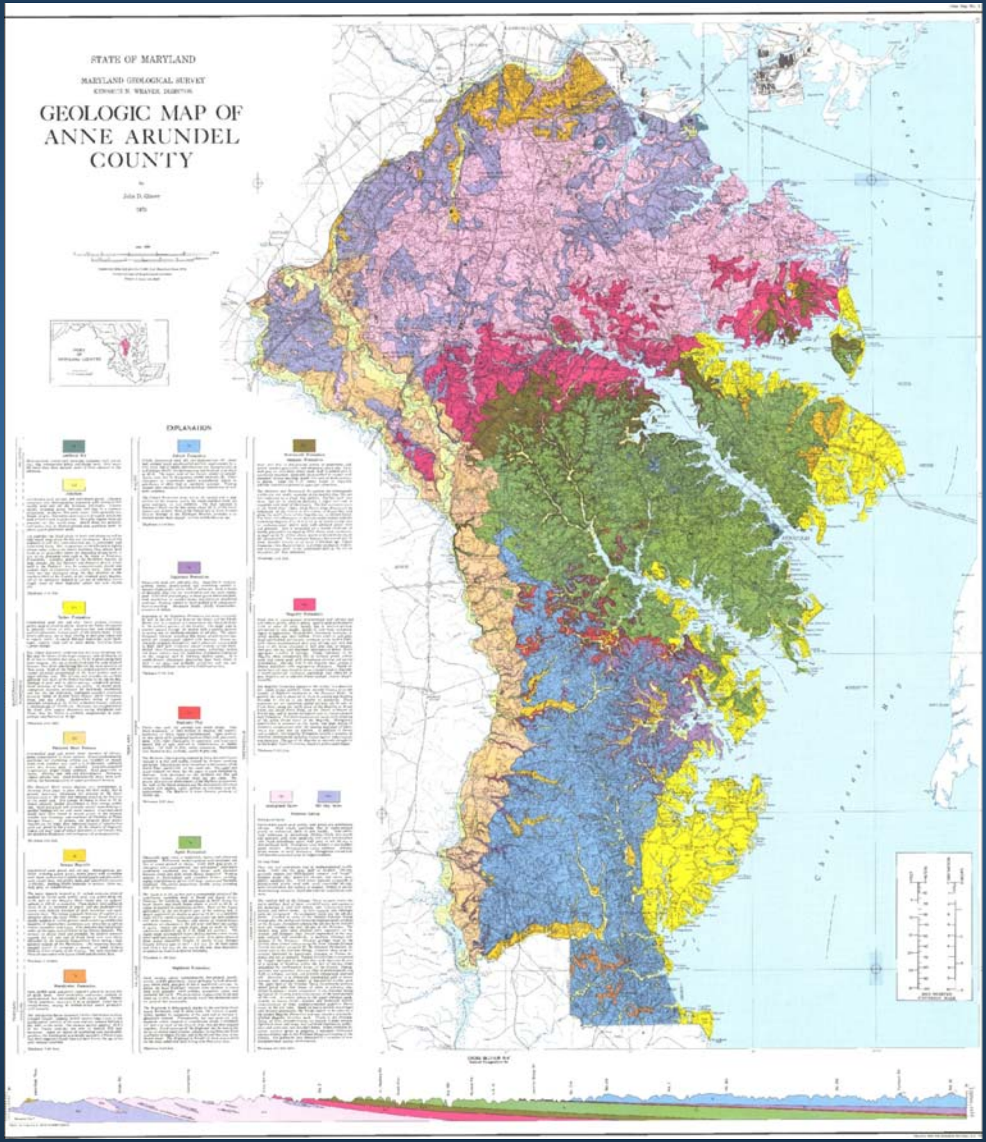
Figure 2 - Geologic cross-section showing seaward thickening of sedimentary wedge beneath Coastal Plain Maryland (from Rasmussen and Slaughter, 1955, plate 1).

Calvert Cliffs

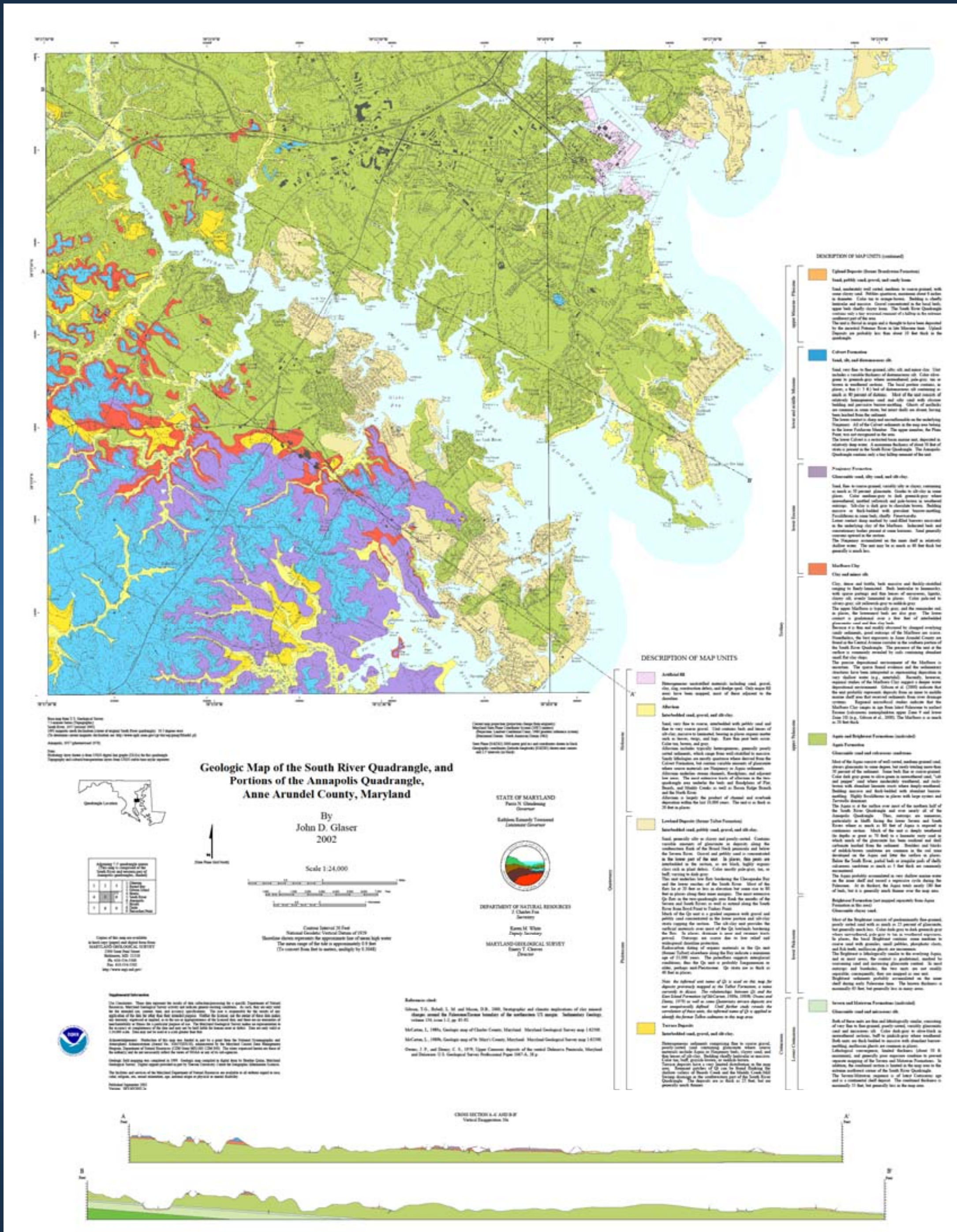
Coastal Plain Province

Assateague Island

Geology Overview Anne Arundel County



In general,
successively older sediments
crop out at the surface
from southeast to the northwest
(see cross-section)



Geology of South River-Annapolis Vicinity

Aquia Formation –

glauconitic sand;
olive-green (unweathered);
reddish brown (weathered).

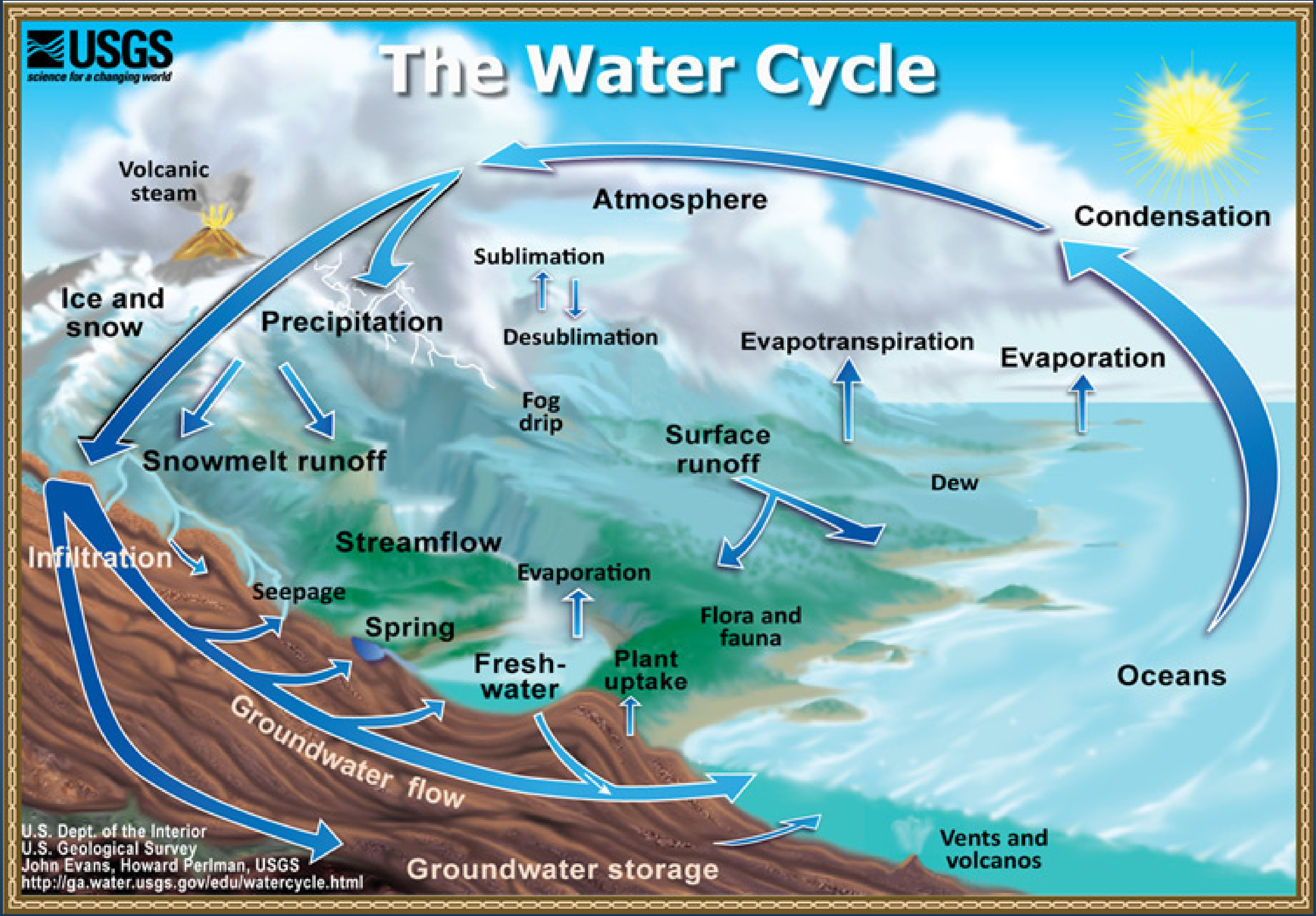
Variably clayey and shelly
(shells sometimes leached);
cemented in places to
calcareous sandstone or
iron-cemented layer.

Maryland Department of Natural Resources

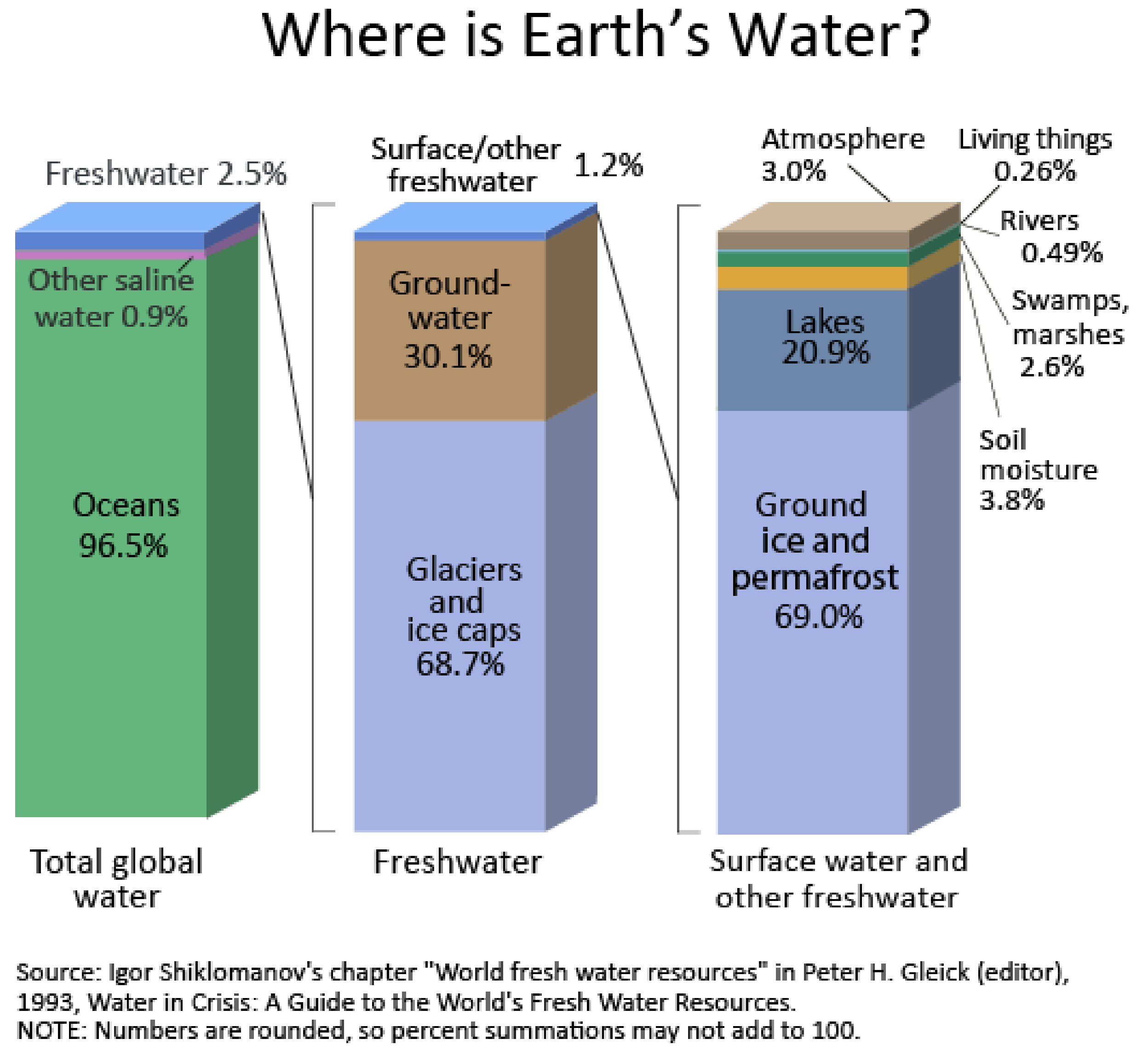
Geology – hands-on

Rocks, minerals and maps

General Overview of
Hydrologic Cycle or Water Cycle

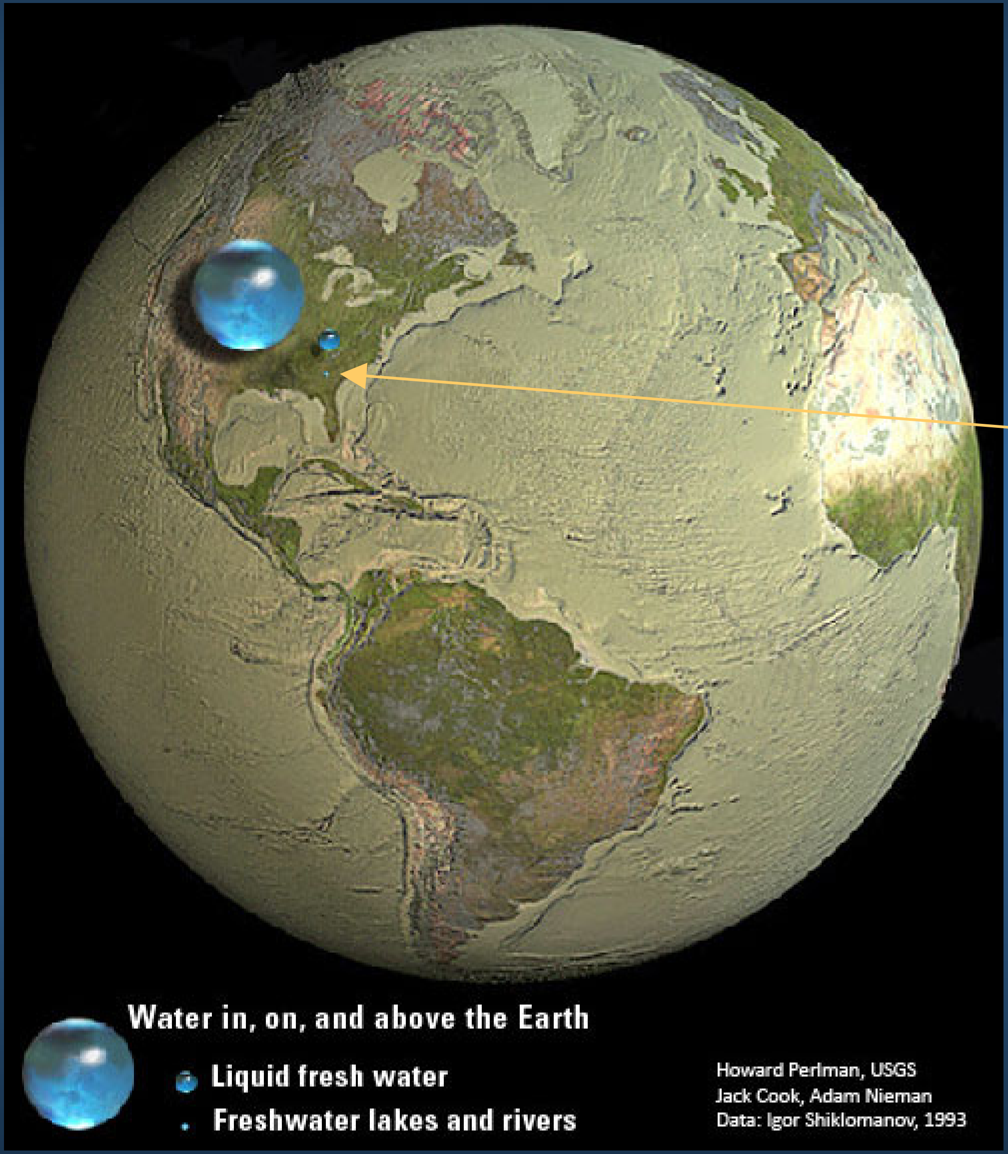

USGS
science for a changing world
The Water Cycle
Volcanic steam
Atmosphere
Condensation
Sublimation
Desublimation
Ice and snow
Precipitation
Evapotranspiration
Evaporation
Fog drip
Surface runoff
Snowmelt runoff
Dew
Streamflow
Infiltration
Evaporation
Seepage
Flora and fauna
Spring
Fresh-water
Plant uptake
Oceans
Groundwater flow
U.S. Dept. of the Interior
U.S. Geological Survey
John Evans, Howard Perlman, USGS
http://ga.water.usgs.gov/edu/watercycle.html
Groundwater storage
Vents and volcanos

Water Distribution on Earth



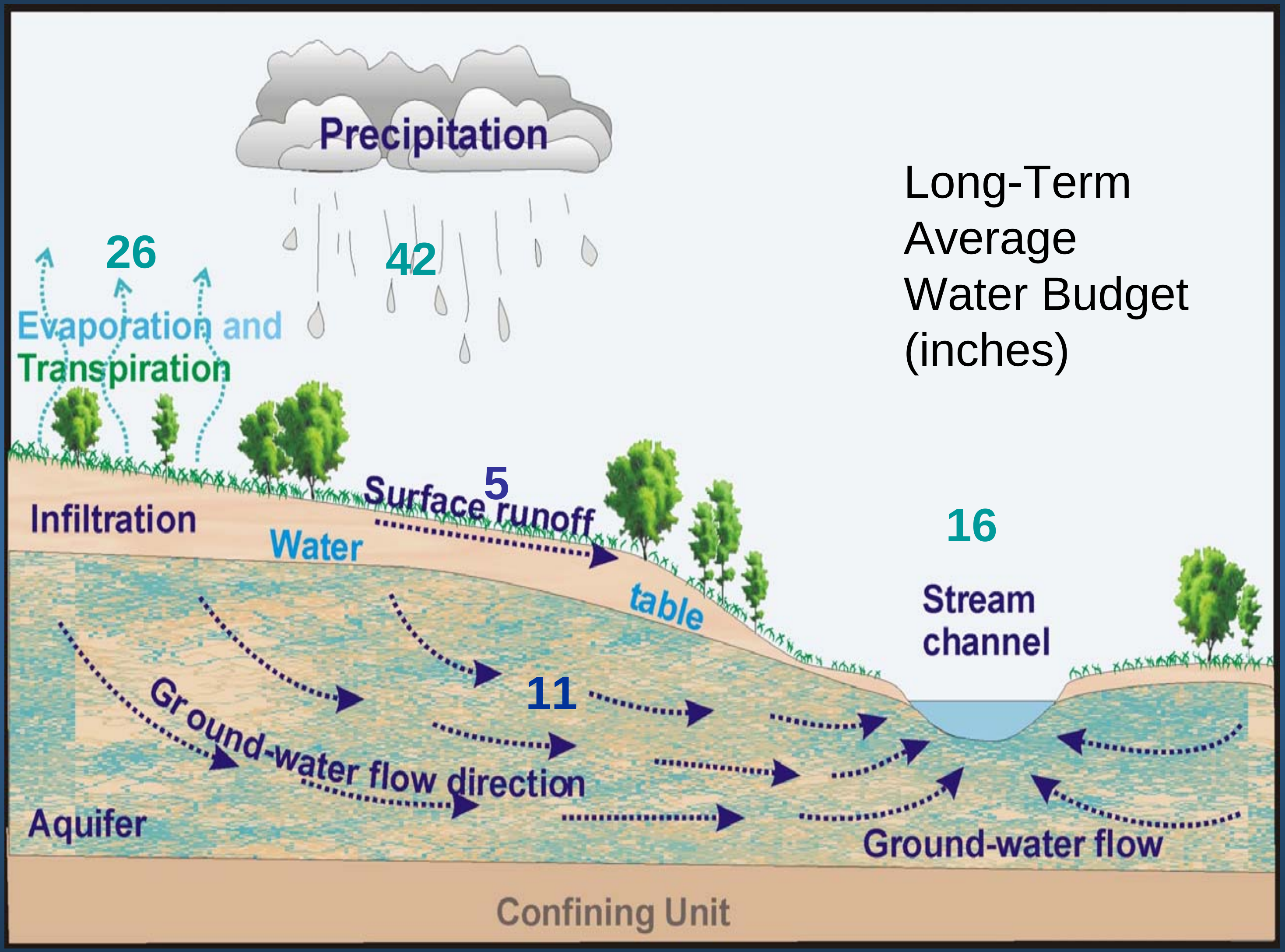
From USGS at http://ga.water.usgs.gov/edu/earthwherewater.html

Proportion of Global Freshwater



Freshwater
lakes and rivers

The Hydrologic Cycle and MD Water Budget



Water budget shown based on estimates from Beaverdam Creek (Rasmussen & Andreasen 1959, USGS Water Supply Paper 1472)

General Overview of Watersheds

Watershed

Definition has changed over time

Originally: the ridge of high ground separating two drainage basins

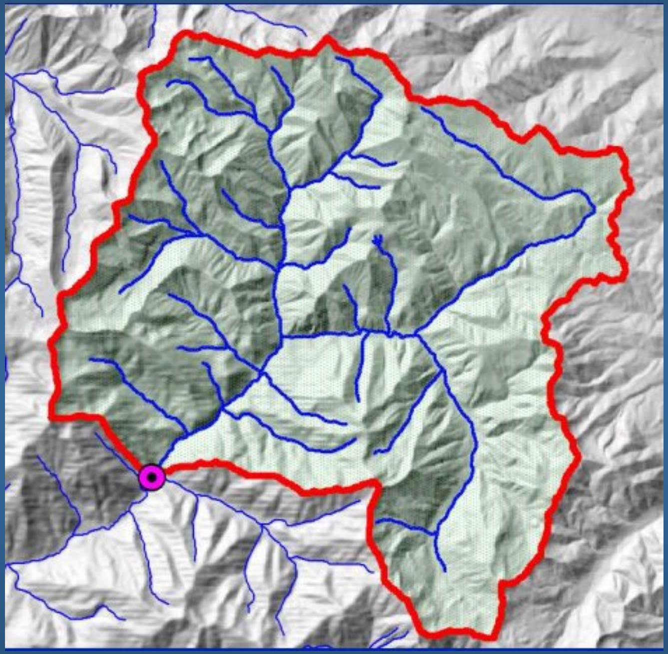
Now commonly used to refer to:

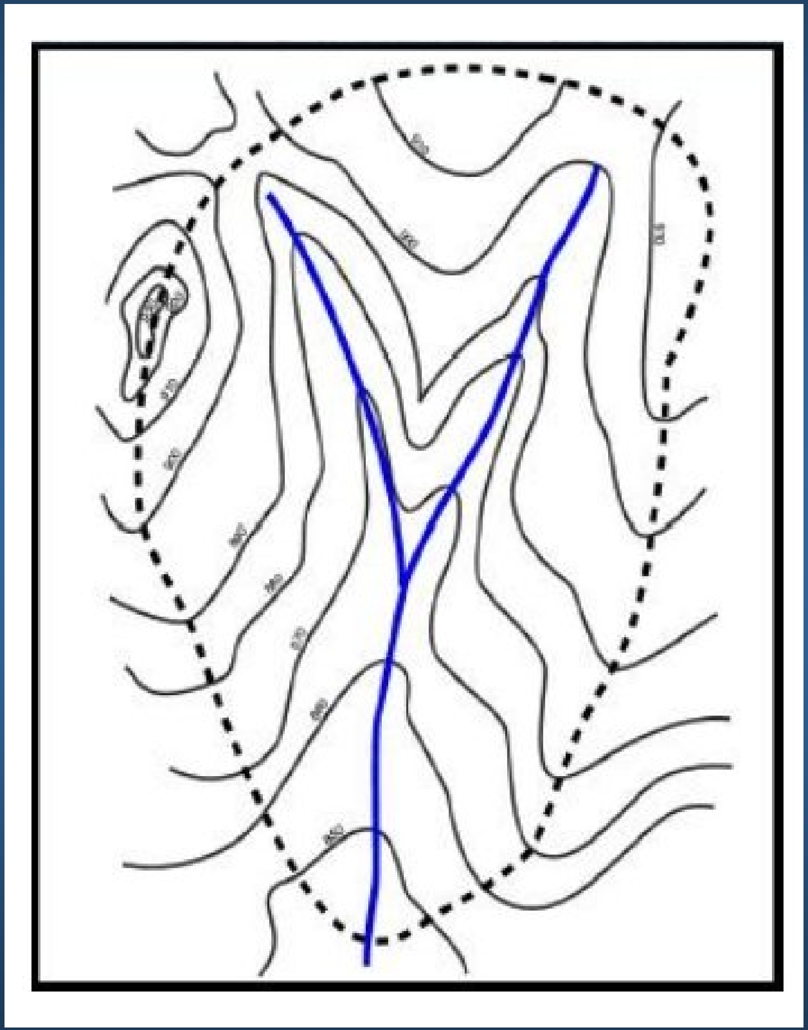
the drainage basin;

the region drained by, or contributing to,

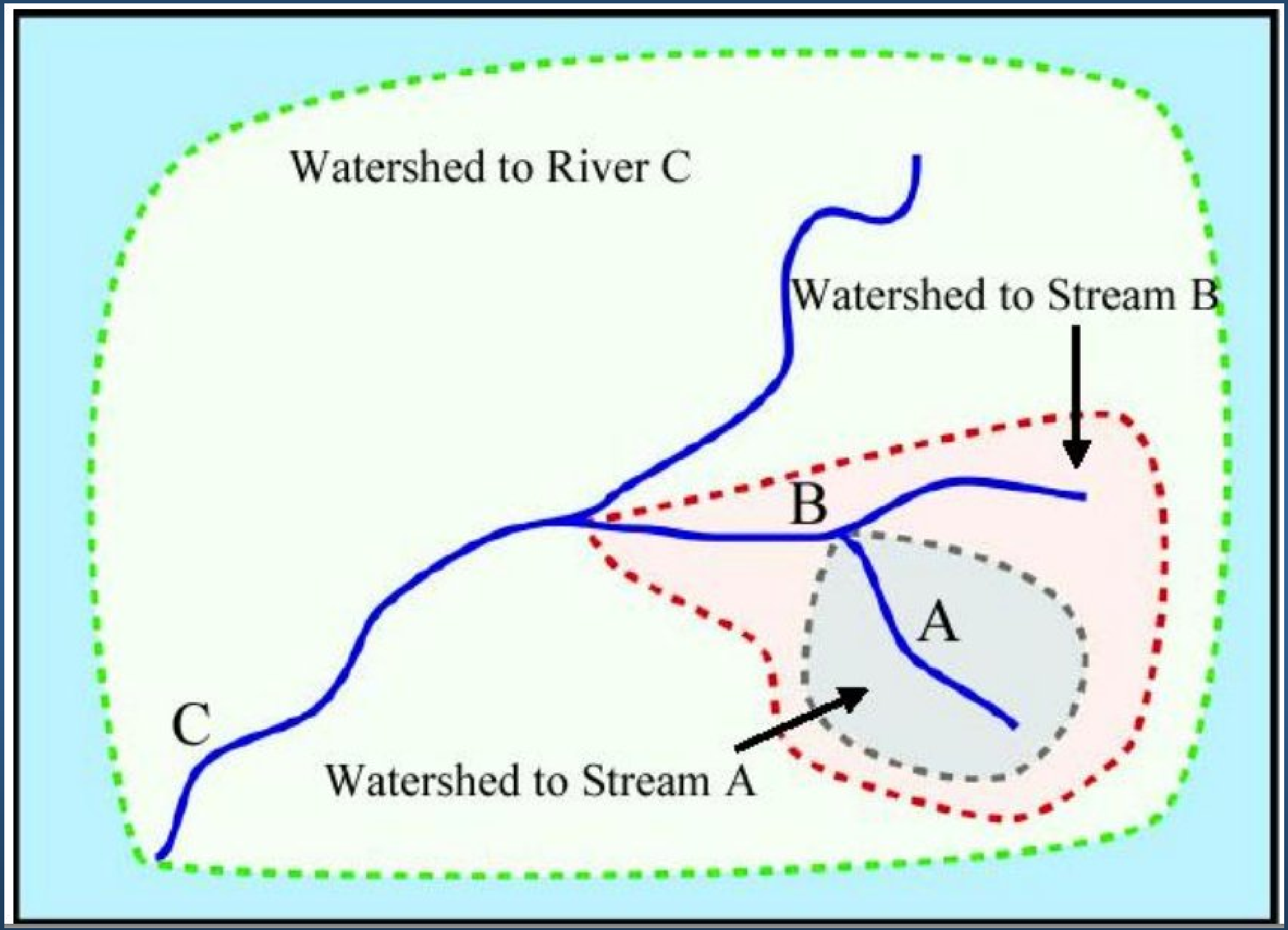
a stream, lake or other water body.

Watershed Delineation

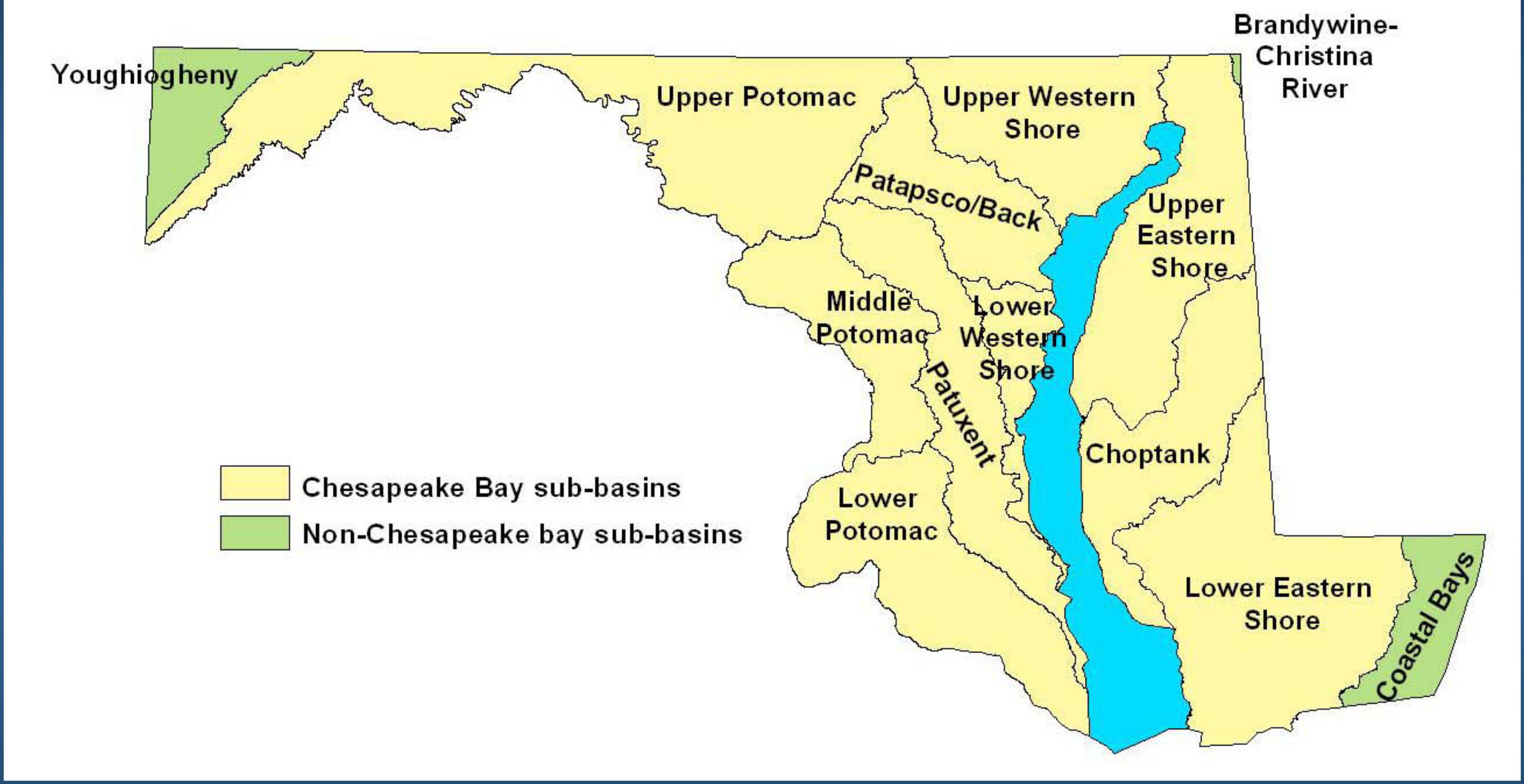




Watershed Hierarchies

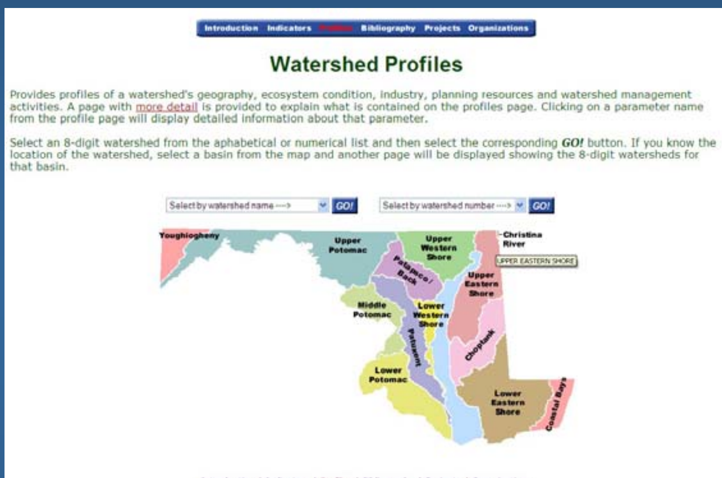


Watershed – Maryland sub-basins



Maryland sub-basins are also referred to as tributary basins

Watersheds - Maryland



http://mddnr.chesapeakebay.net/wsprofiles/surf/prof/prof.html

Maryland's
Surf Your Watershed site

South River Watershed
is an 8-digit code

Maryland's Surf Your Watershed - Watershed Profile

South River

WATERSHED INFORMATION

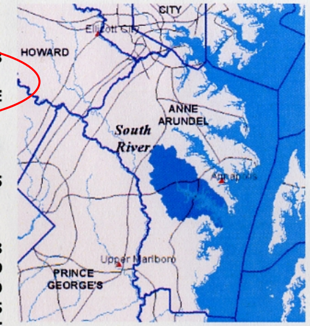
Maryland 8-Digit Watershed Code:	**02131003**
Tributary Basin:	**LOWER WESTERN SHORE**

Population (1990 US Census)

1990 Est. Population Density (Ppl per ac)	**1.55**

1994 Land Use (MdOP Data)

Urban Acres	**10,583**
Agricultural Acres	**7,269**
Forest Acres	**18,459**
Wetland Acres	**145**
Barren Acres	**65**
Total Acres (non-water)	**36,521**



NON-TIDAL WETLAND REGULATORY ACTIONS

Authorizations by Type (since 1991)

Letter of Authorization	**53**
Permit	**4**
Emergency Permit	**0**
Authorization to Proceed	**0**

Wetland Impact Data (since 1991)

Acres of Permanent Loss	**-2.28**
Acres of Permitted Mitigation	**0.07**
Acres of Programmatic Gains	**0**
Acres of Other Gains	**0.36**
Net Gain/Loss	**-1.85**

WATERSHED INDICATORS

Restoration Indicators	Indicator Value	Failed Indicator
Water Quality		
Monitored Nutrient Concentrations		
- eutrophication	**7.33**	
- habitat	**6.33**	
Modeled Nitrogen Loading Rate per ac. (lbs.)	**14.01**	Yes
Modeled Phosphorus Loading Rate per ac. (lbs.)	**1.13**	Yes
Aquatic Living Resources		
SAV Abundance	**1.0**	Yes
SAV Habitat	**4.0**	Yes
Tidal Benthic Index of Biotic Integrity		
Tidal Fish Index of Biotic Integrity	**5.0**	
Anadromous Fish Index	**4.59**	
Non-Tidal Benthic Index of Biotic Integrity	**4.63**	Yes
Non-Tidal Fish Index of Biotic Integrity	**7.0**	
Non-Tidal Instream Habitat Index	**3.96**	
Landscape Parameters		
Percent Impervious Surface	**10.3**	Yes
Population Density (people per land acre)	**1.55**	Yes
Historic Wetland Loss (acres)	**2,495**	
Percent Unforested Stream Buffer	**13**	
Soil Erodibility	**0.33**	Yes
Clean Water Requirements		
303d List	**3**	Yes

Protection Indicators	Indicator Value	Select Indicator
Aquatic Living Resources		
Tidal Fish Index of Biotic Integrity	**5.0**	
Non-Tidal Instream Habitat Index	**3.96**	
Non-Tidal Fish Index of Biotic Integrity	**7.0**	
Imperiled Aquatic Species Indicator	**0**	
Migratory Fish Spawning Area	**3**	Yes
Anadromous Fish Index	**4.59**	
Wetland-Dependent Species	**56.2**	
Trout Spawning Area		
Fish Hatchery Water Supply		
Landscape Parameters		
% Headwater Streams occurring in Interior Forest	**37**	Yes
Percent Watershed Forested	**60**	
Wildland Acres	**0**	
Number of Drinking Water Intakes	**0**	
Wetlands Acres of Special Concern	**11**	

Unified Watershed Assessment Categorization

Priority Category 1 (Does Not Meet Clean Water or Natural Resource Goals)	**Yes**
Priority Category 2 (Meets Clean Water or Natural Resource Goals)	**No**
Select Category 3 (Need for Special Protection of Natural Resources)	**No**

MGS

MARYLAND DEPARTMENT OF NATURAL RESOURCES

Watershed - Federal

EPA's
Surf Your Watershed
site

Severn Watershed,
an 8-digit hydrologic unit

roughly comparable to
Lower Western Shore
sub-basin or tributary basin of
MD hydrologic subdivision

Surf Your Watershed

Severn Watershed -- 02060004

Severn

Watershed Profile

Watershed Name: Severn
USGS Cataloging Unit: 02060004
MD 1st Congressional District
MD 2nd Congressional District
MD 3rd Congressional District
MD 5th Congressional District

Citizen-based Groups at work in this watershed (Provided by Adopt your Watershed)

Water quality monitoring data from this watershed (Provided by STORET)

Environmental Websites Involving this Watershed

Assessments of Watershed Health

Impaired Water for this watershed

Assessed Waters by Watershed
Maryland

Information provided by the United States Geological Survey (USGS) EXIT Disclaimer

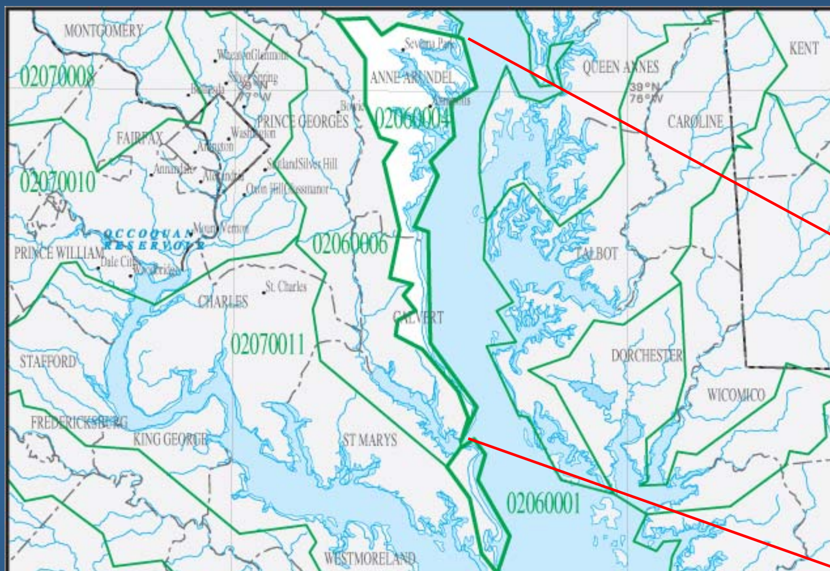
Stream Flow (Source: USGS)
Science in Your Watershed
Water use data (1985-2000): Information about the amount of water used and how it is used.
Selected USGS Abstracts

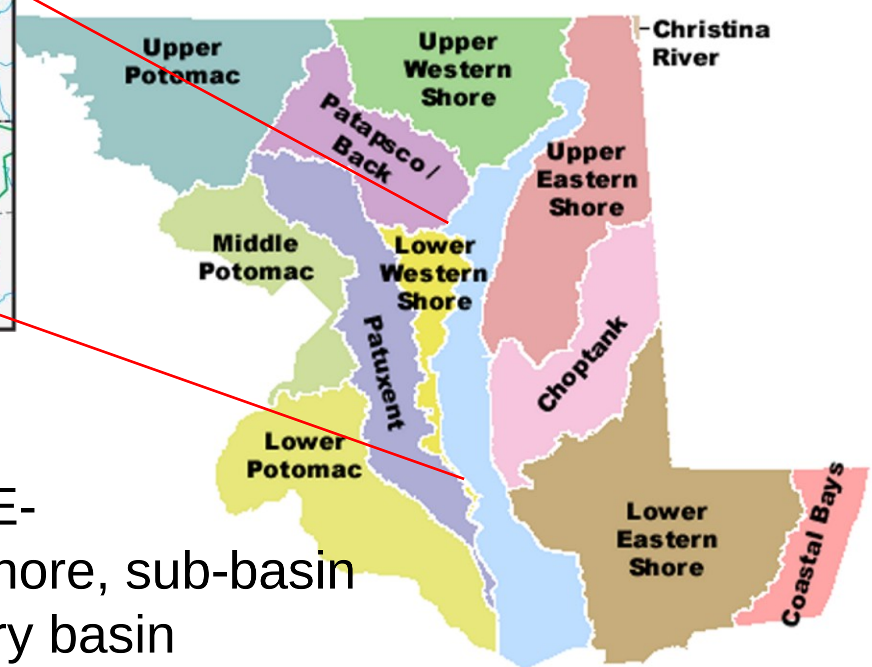
Places Involving this Watershed

Counties:
Anne Arundel
Calvert
St. Marys
National Estuary Programs:
None
States:
Maryland
Other Watersheds Upstream:
None
Other Watersheds Downstream:

Watershed Comparison

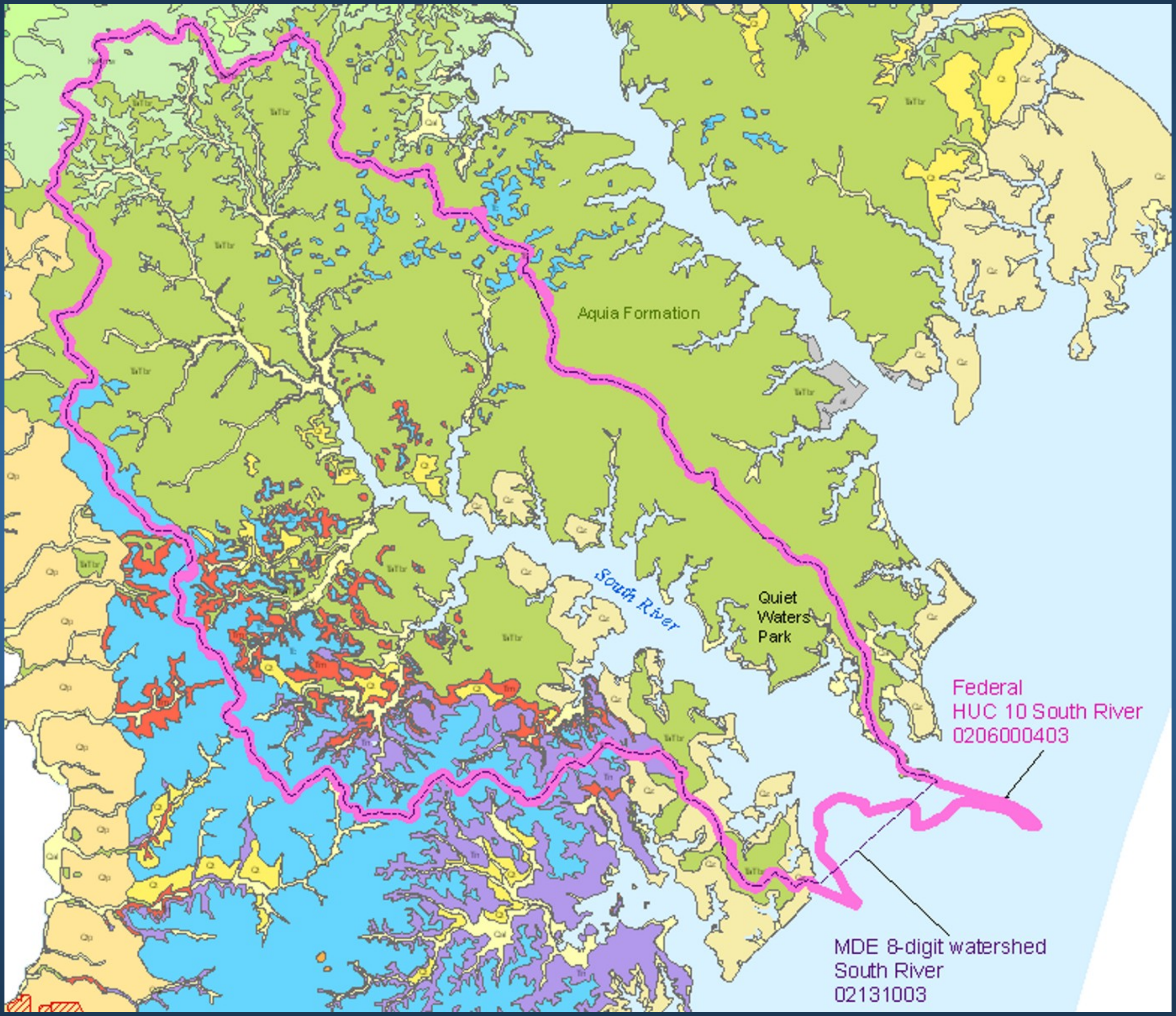
(Federal) Severn Watershed,
an 8-digit hydrologic unit code





MDE-
Lower Western Shore, sub-basin
or Tributary basin

Watershed Comparison



General Overview of
Ground Water, Aquifers and Wells

Aquifer

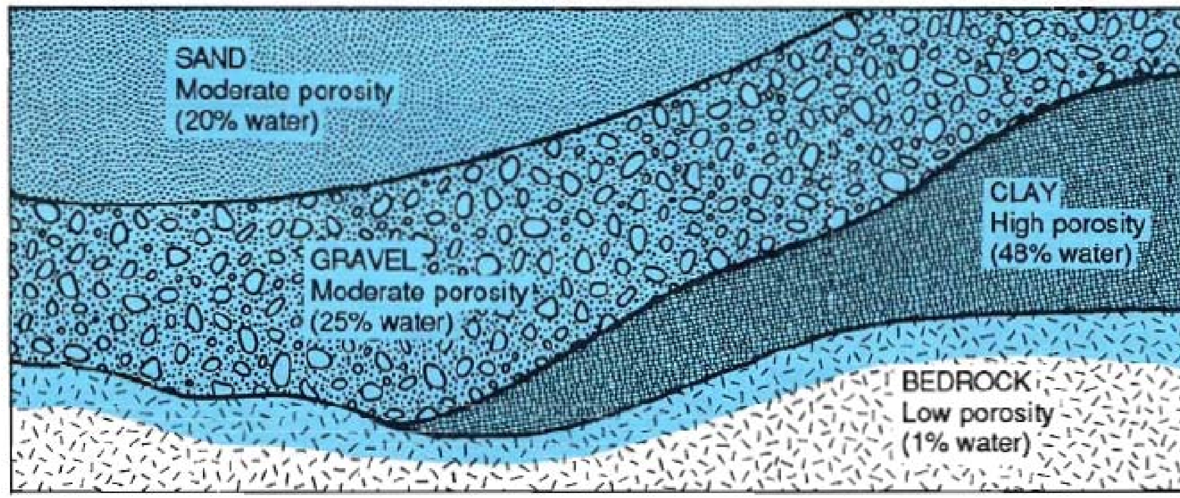
A geologic unit that stores and transmits ground water in sufficient quantity to supply wells

Porosity

Porosity is a ratio of pore space to the total volume of the rock.

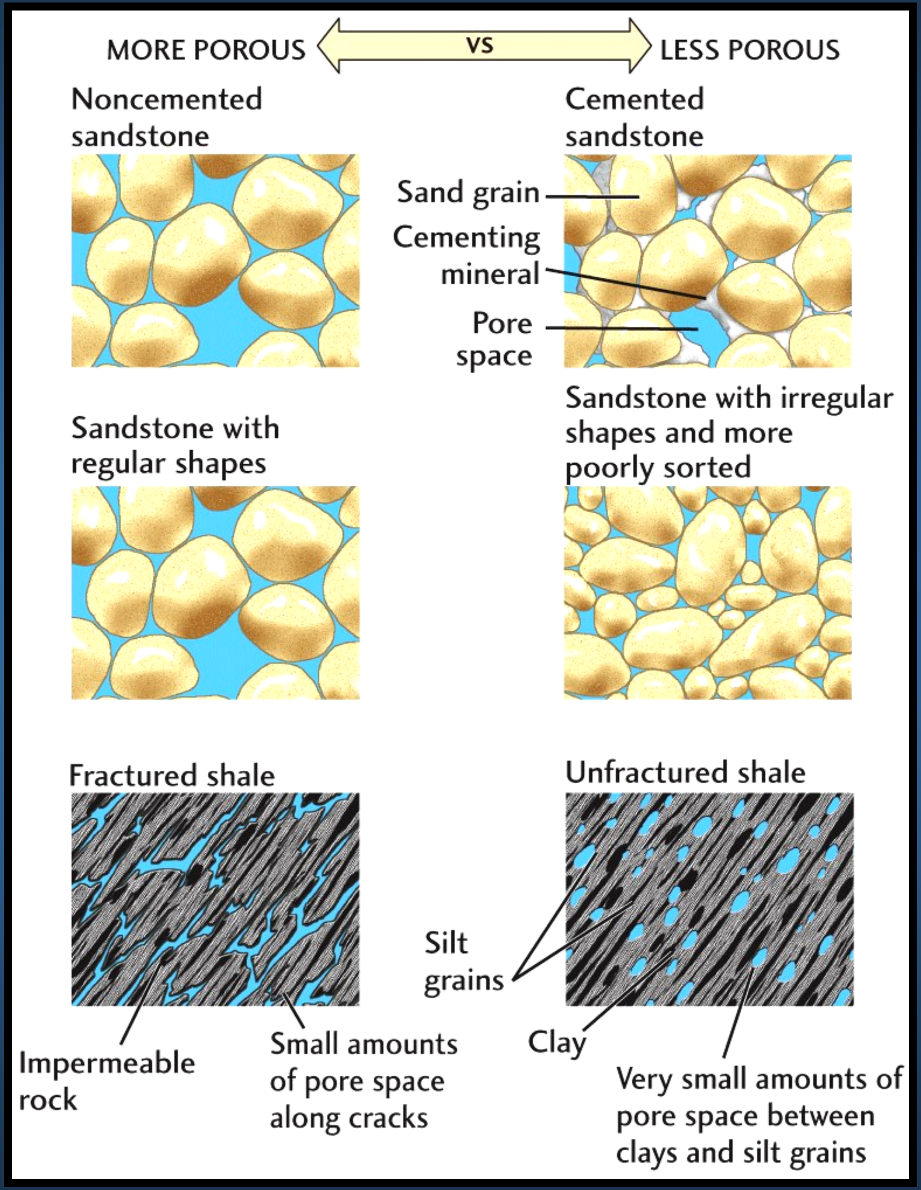
POROSITY

The capacity of soil or rock to hold water is called **porosity.** Saturated sand contains about 20% water; gravel, 25%; and clay, 48%. Saturated bedrock with few crevices commonly contains less than 1% water. Clay is not a good water source despite its high water content, or porosity, because the extremely small size of the openings between microscopic clay particles creates friction that effectively halts water movement. Saturated clay is virtually impermeable.



From: What Is Groundwater?, Lyle S. Raymond, 1988

Porosity



Porosity varies with

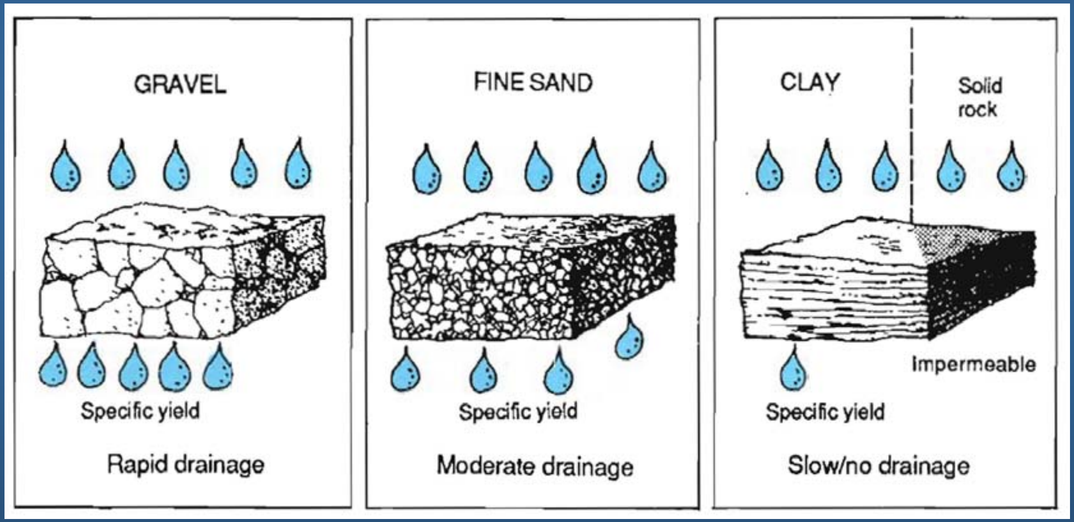
% Cement

Sorting

Fracturing

Permeability

A measure of how fast water will flow through connected openings



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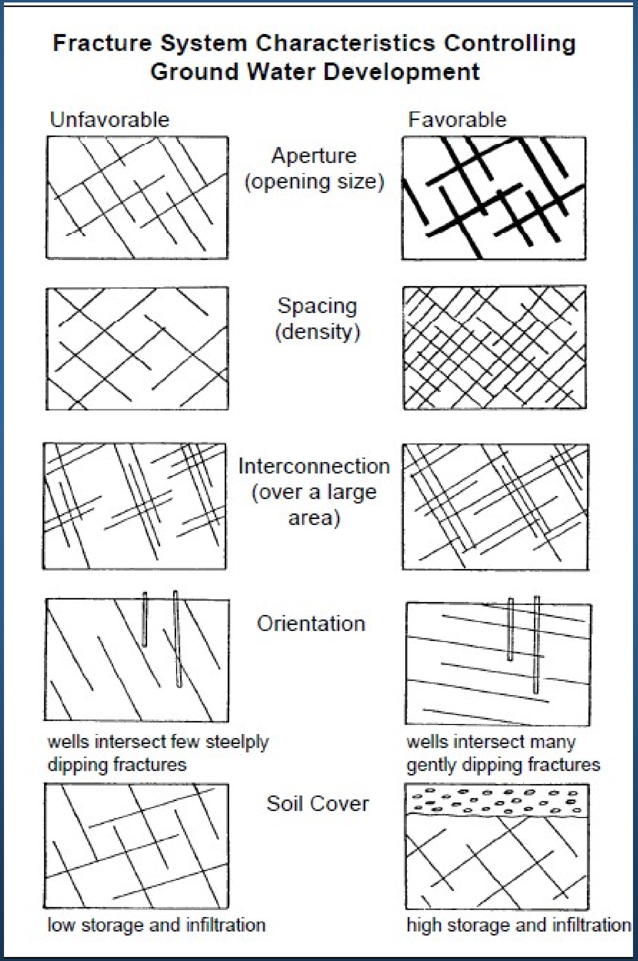
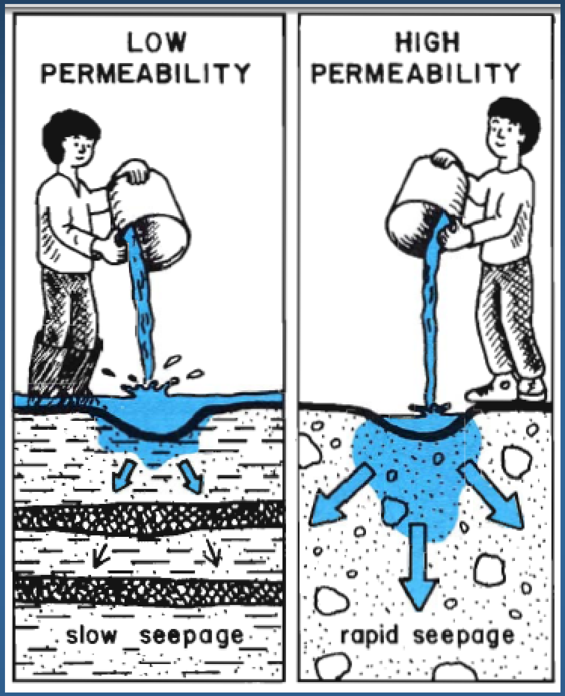
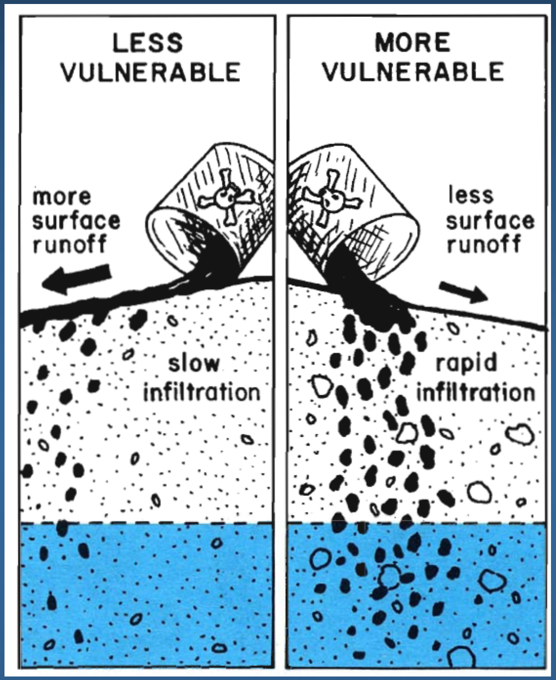


Permeability



From: Aquifers, Lyle S. Raymond, 1990

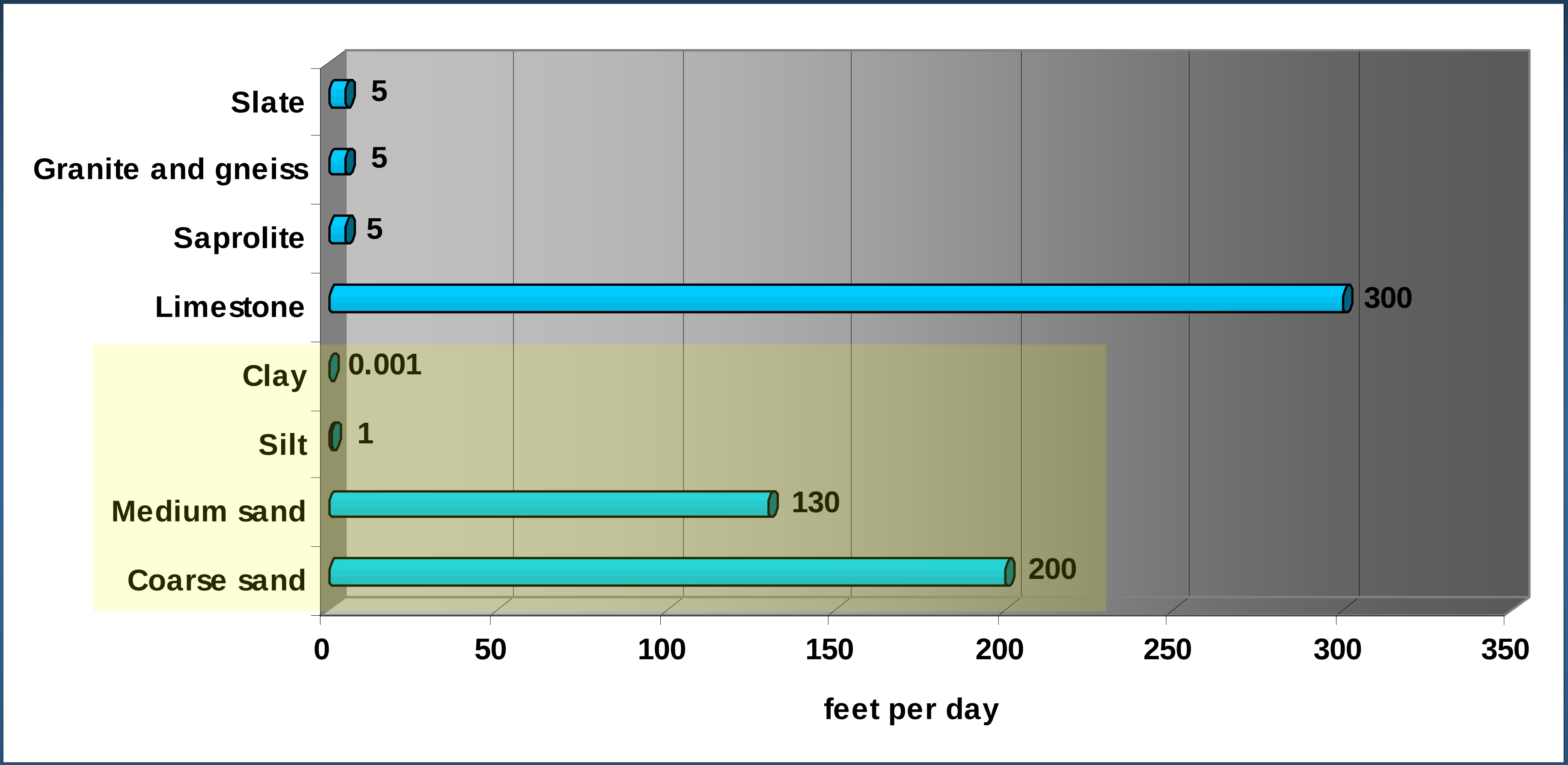


From: Aquifers, Lyle S. Raymond, 1990

Highly permeable materials
will allow for rapid infiltration
of precipitation
in addition to high yield to wells

Highly permeable materials
are more vulnerable to contamination

Groundwater Movement

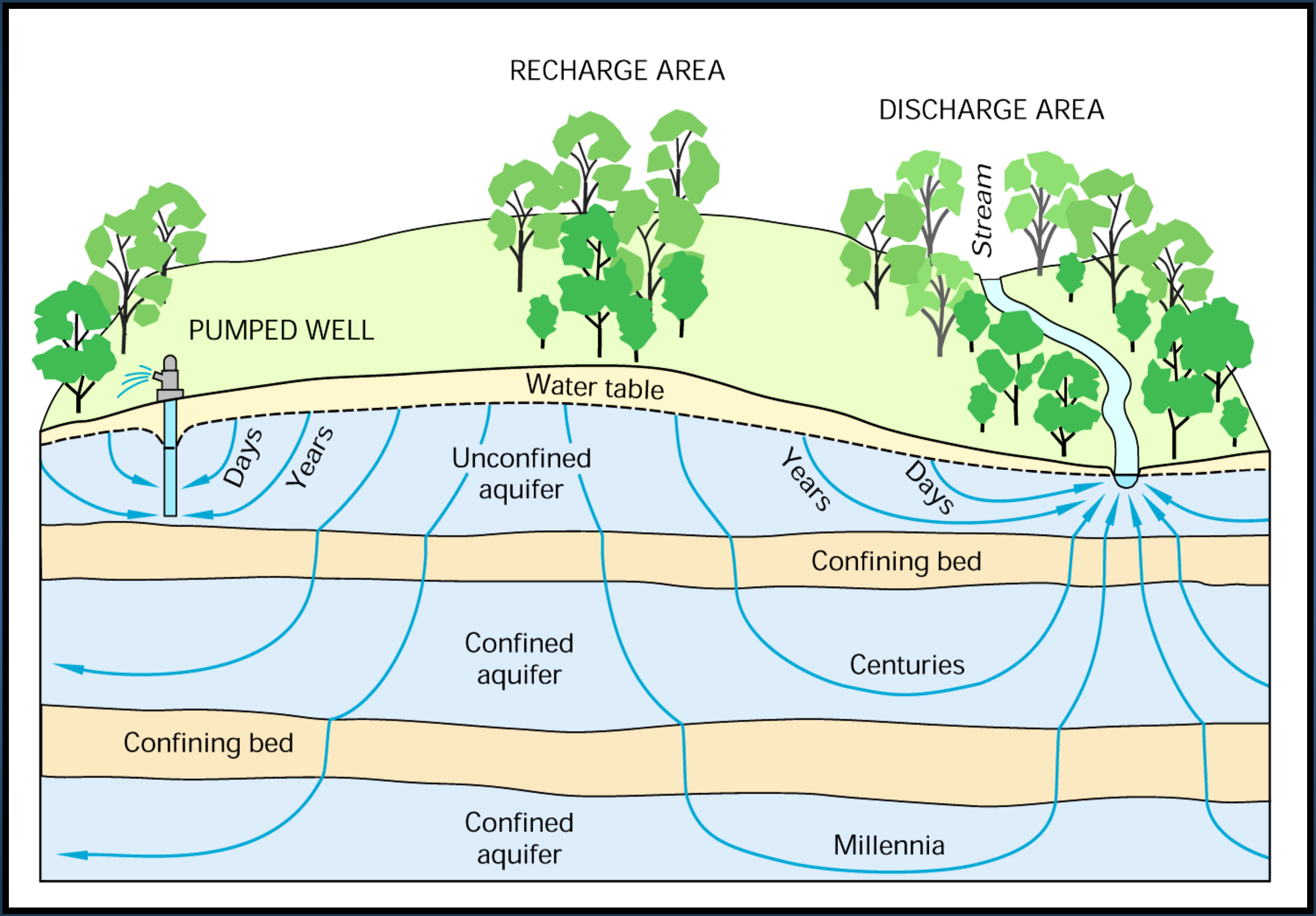


From: Basic ground-water hydrology, U.S. Geological Survey, Water Supply Paper 2220, by Ralph C. Heath

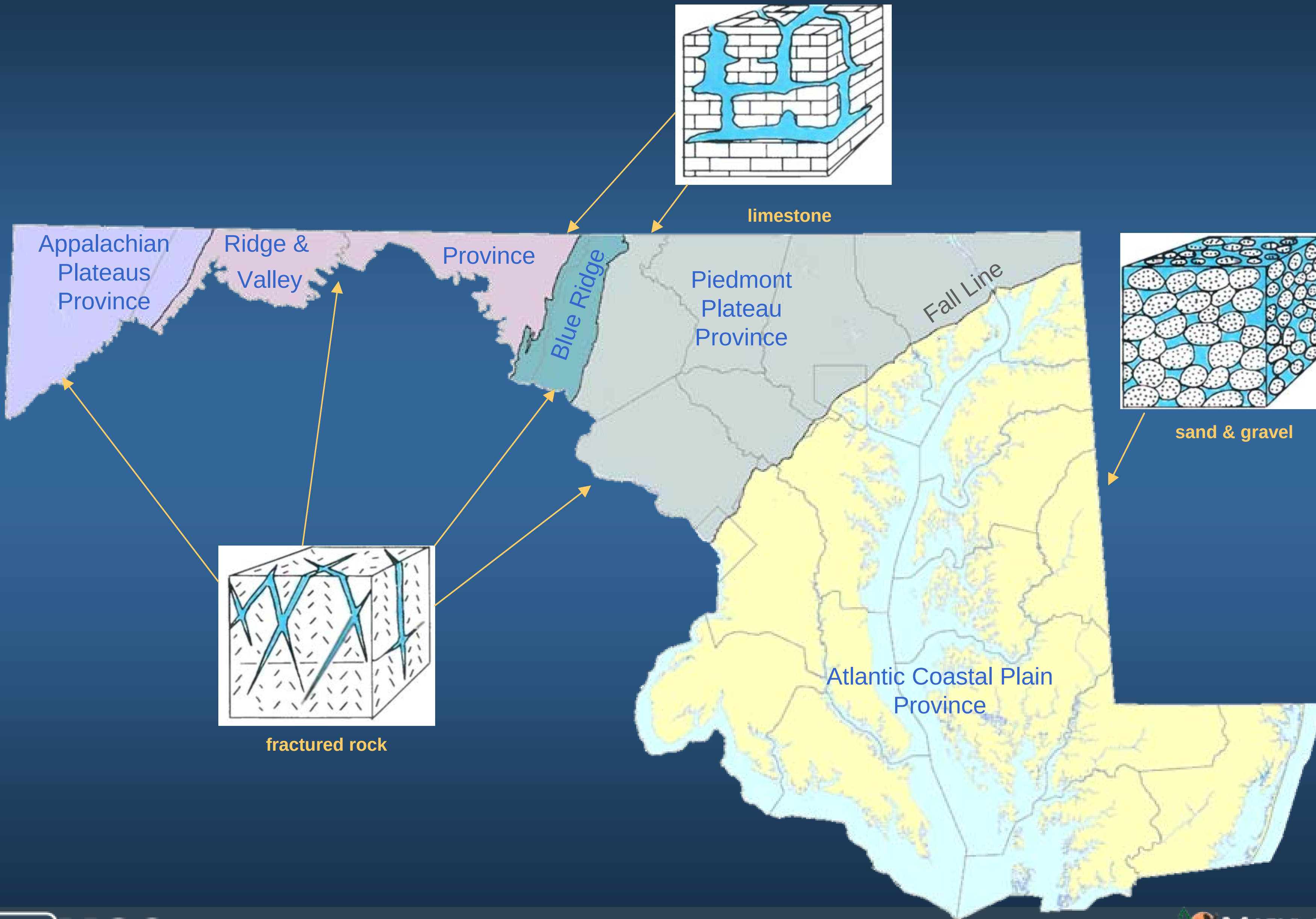
Salisbury Paleochannel = 350 ft/day

Manokin aquifer (fine sand) = 50 ft/day

Age of Ground Water

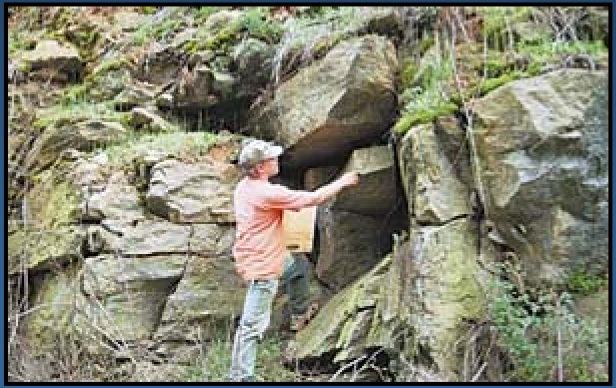


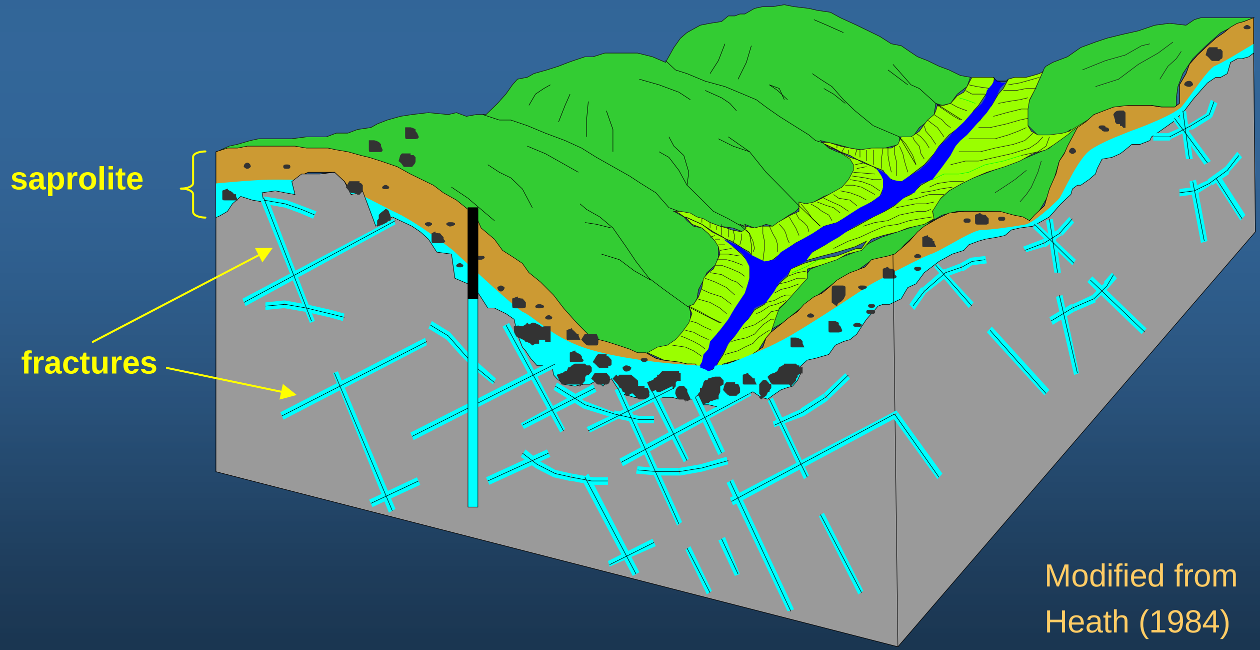
Physiographic Provinces and Aquifer Types in Maryland



Ground Water Characteristics in Fractured Rock Areas

- Fracture flow
- Unconfined aquifers
- Often low well yields

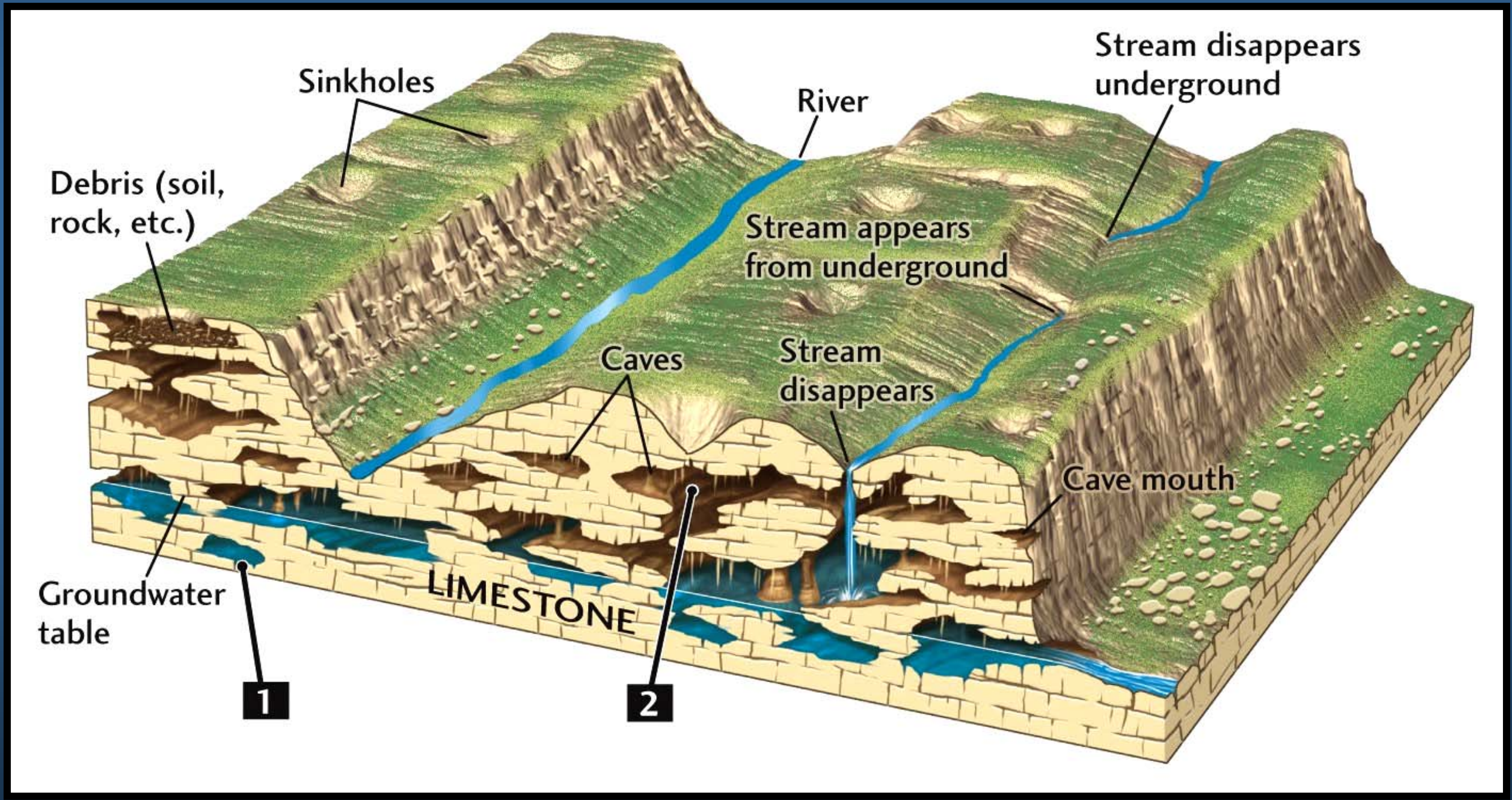




Modified from
Heath (1984)

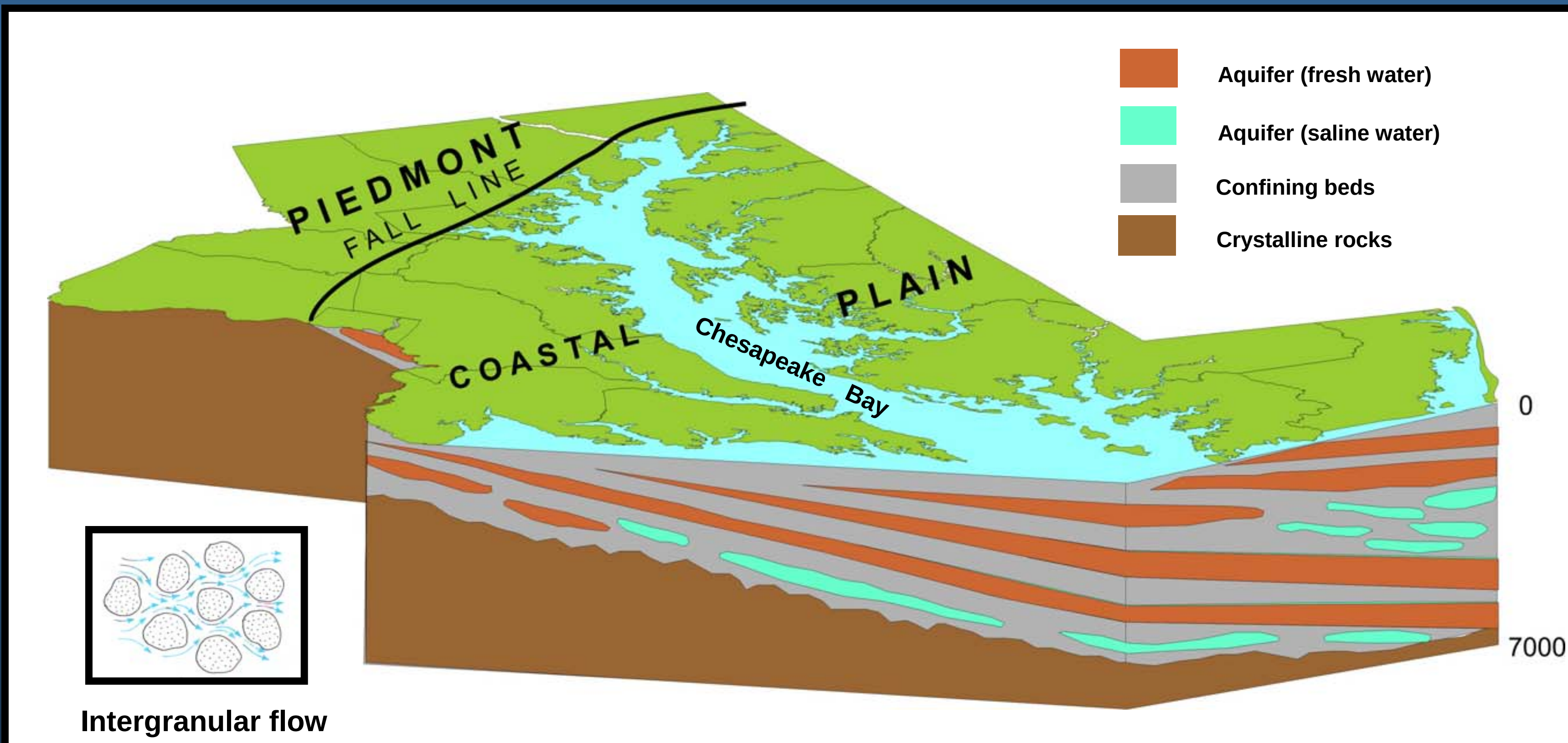
Ground Water in Limestone

- Sinkholes, rapid inflow
- Little filtration of water
- More susceptible to bacterial, nitrate, and other contamination

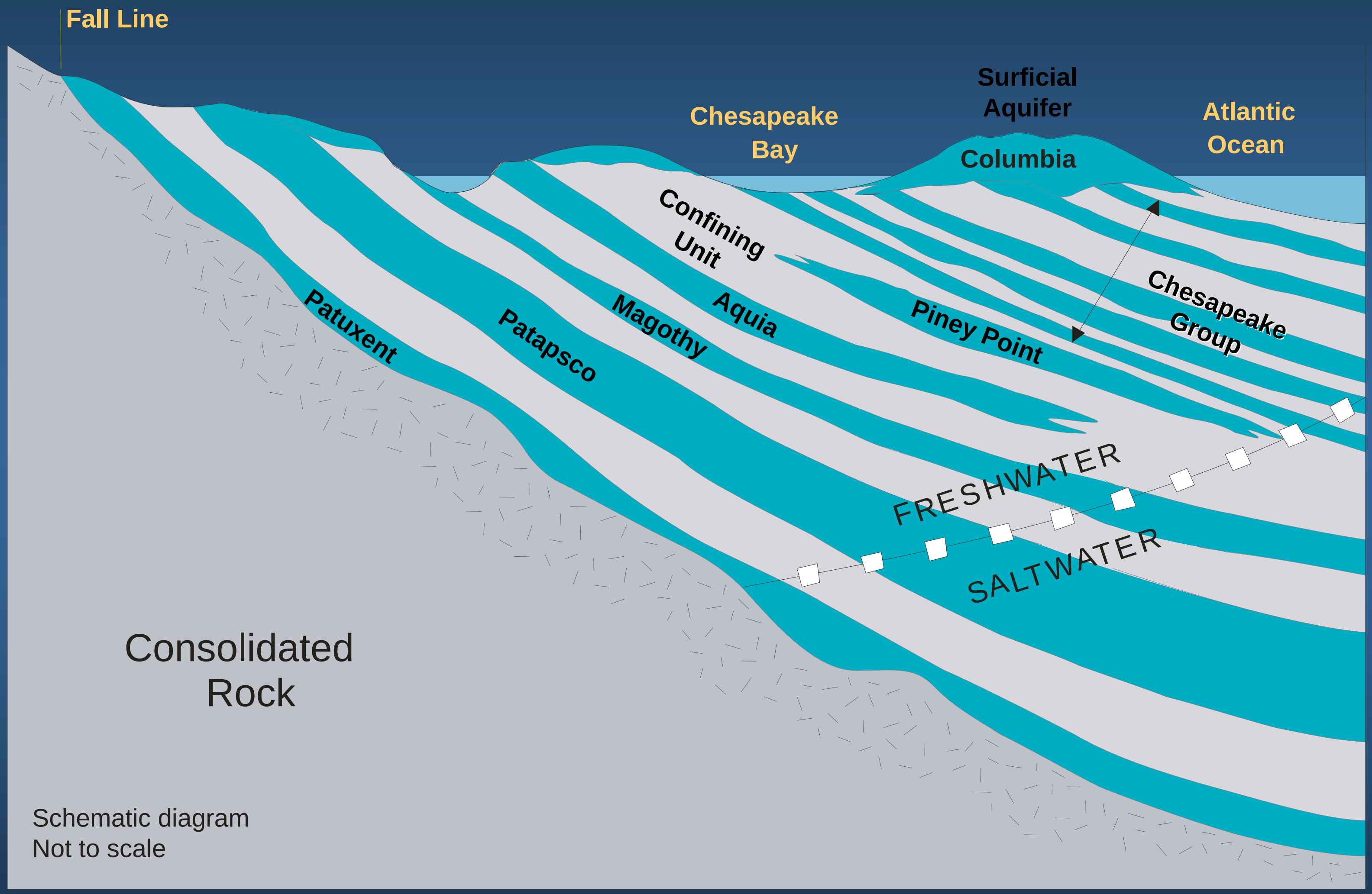


Coastal Plain Ground Water Characteristics

- Unconsolidated sediments
- Confined aquifers
- Usually high well yields



Maryland's Major Coastal Plain Aquifers



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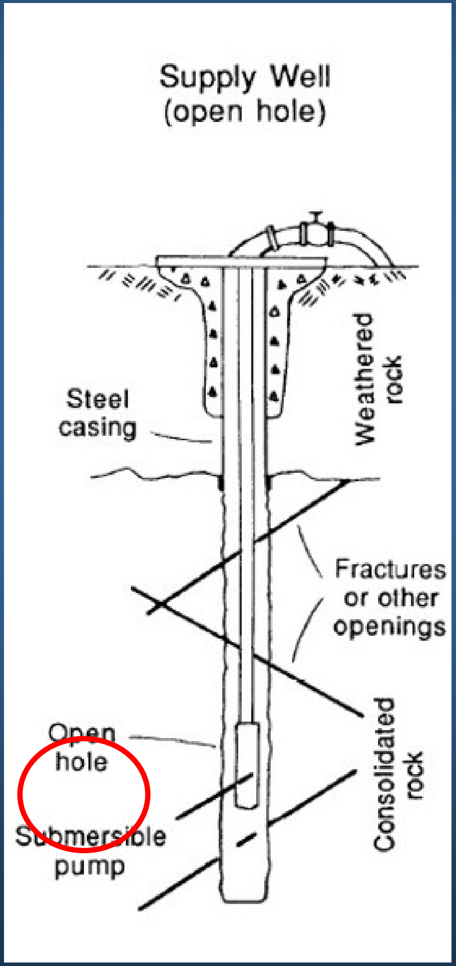
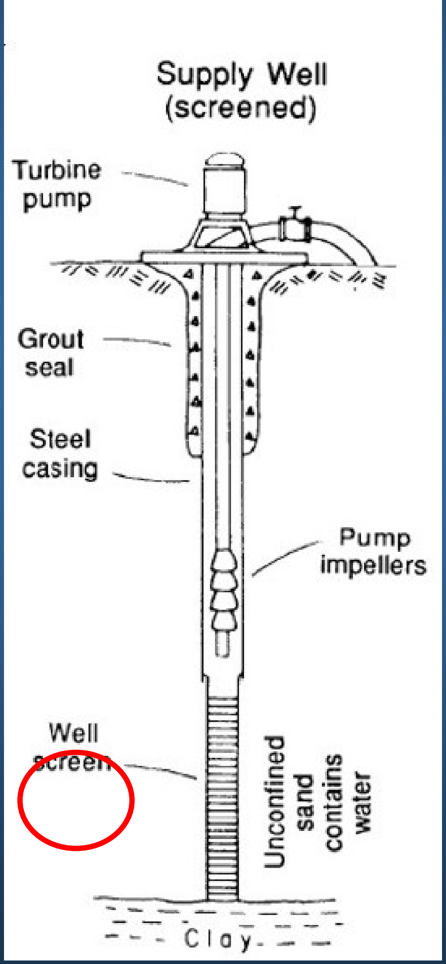
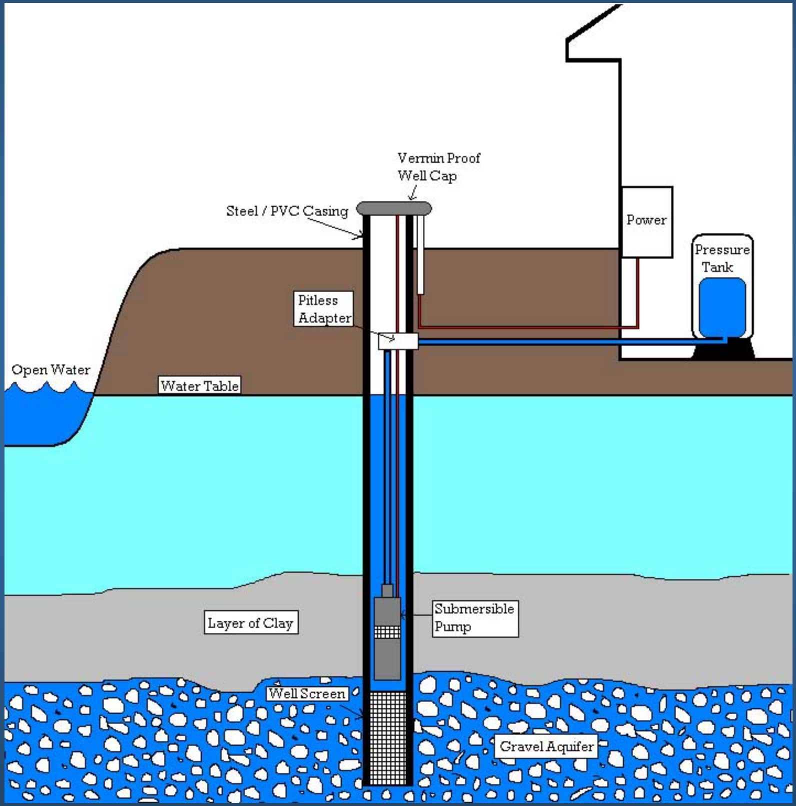
Wells in Different Aquifer Types

Rock Well

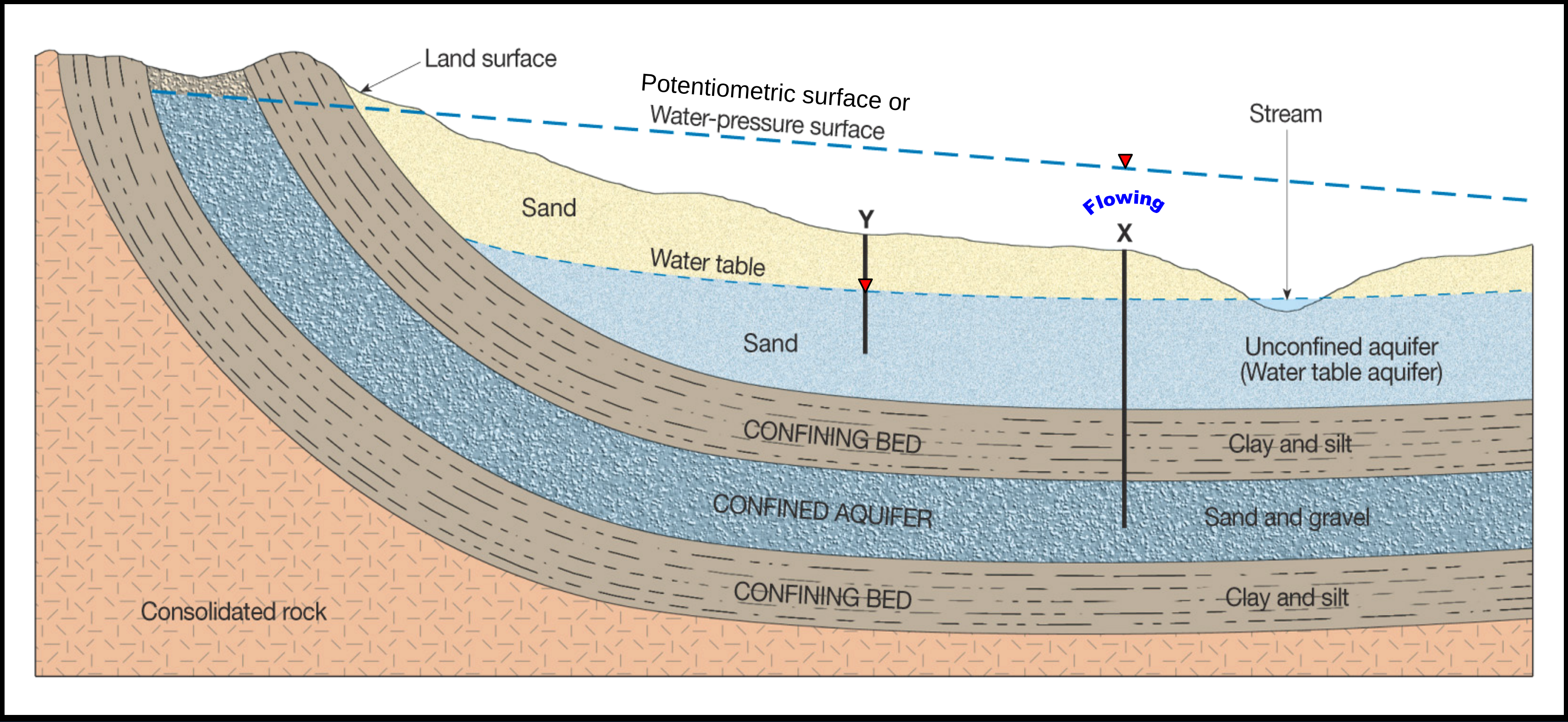
Coastal Plain (Unconsolidated Sediment) Wells







Water Table (Unconfined) Aquifer vs. Confined Aquifer



Water Table Wells and Artesian Wells

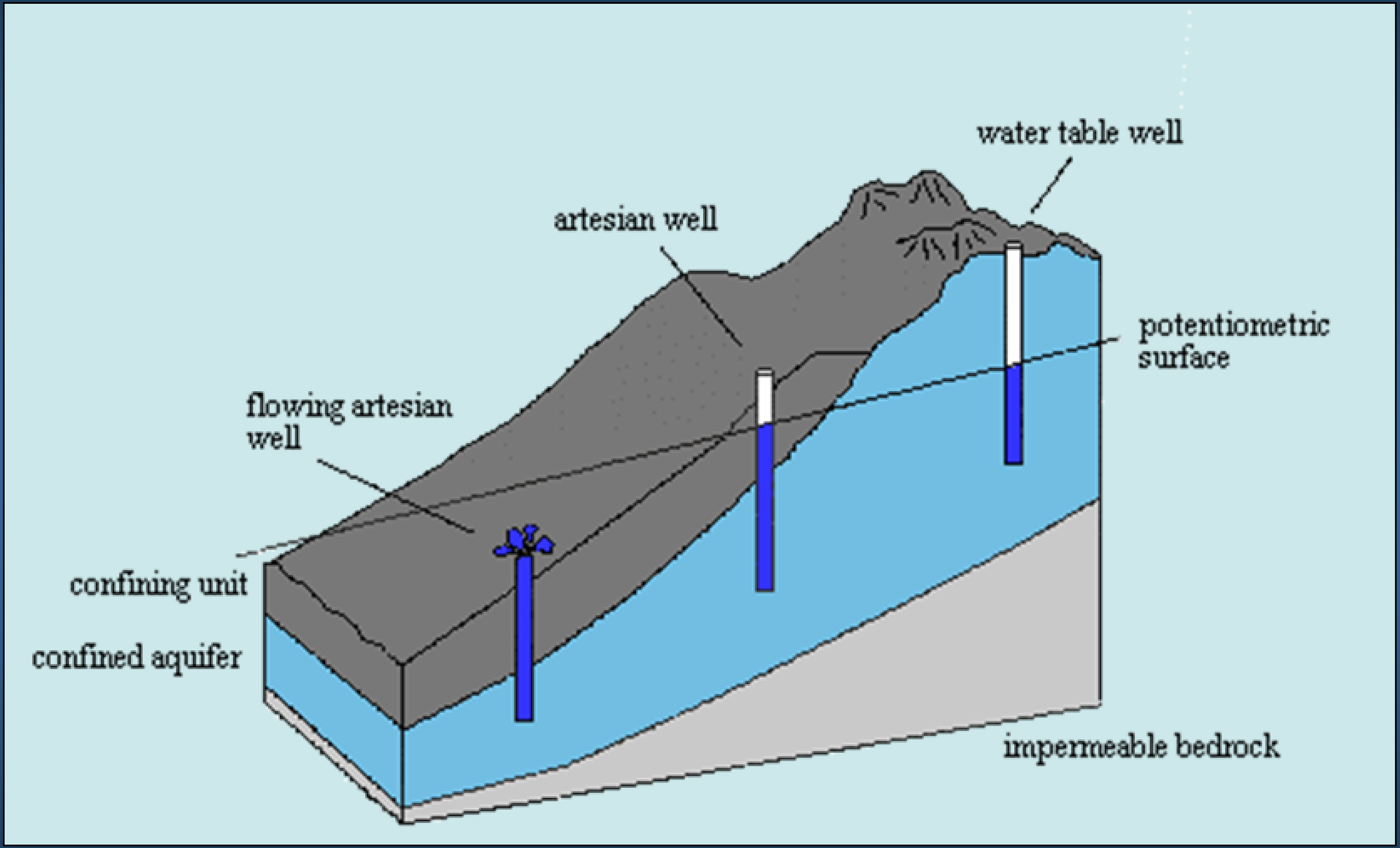
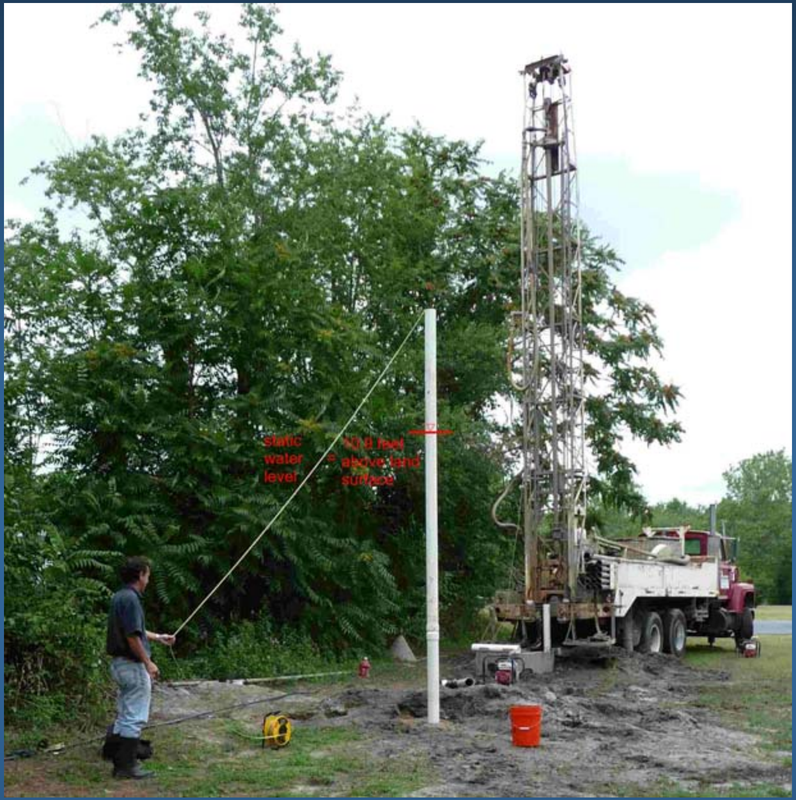


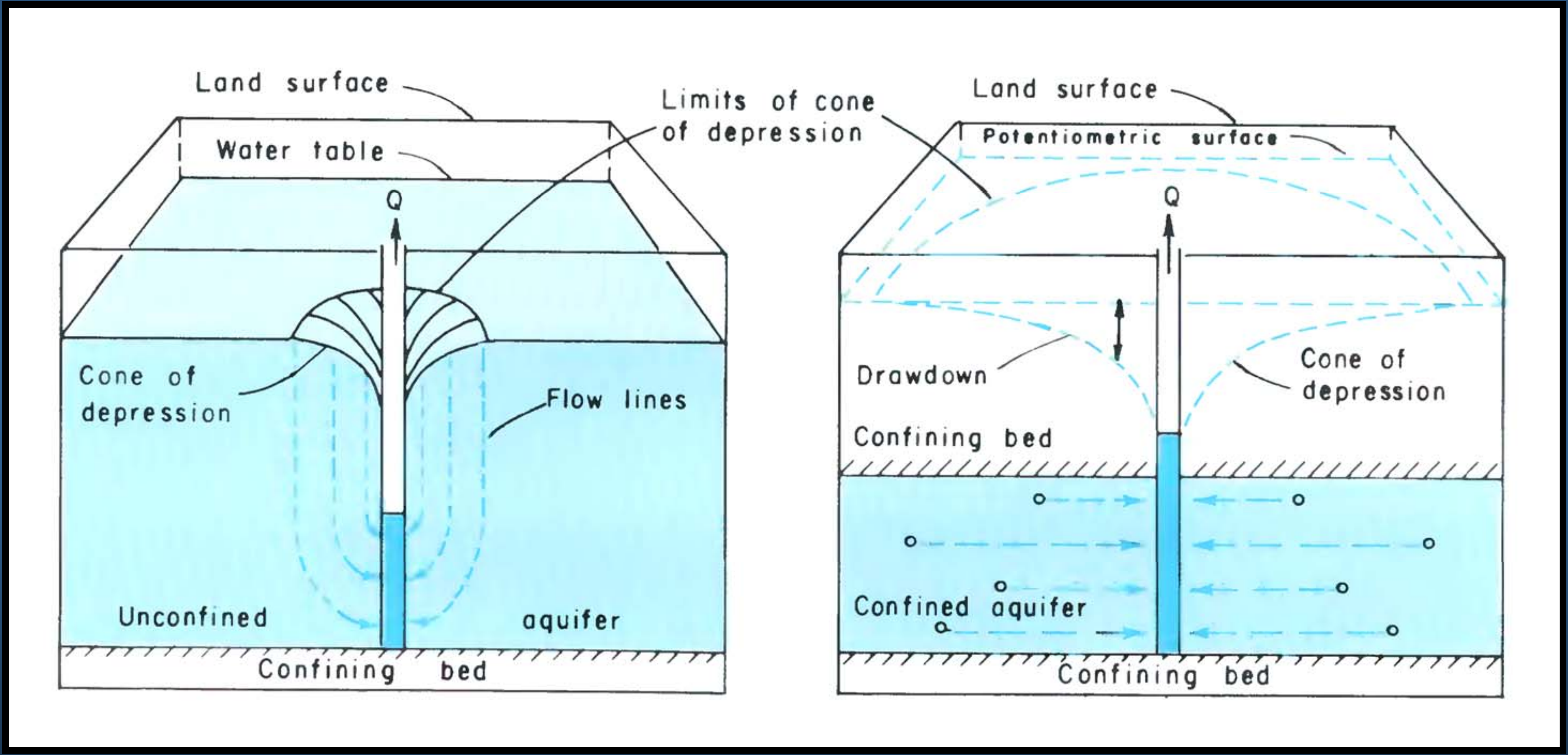
Diagram from purdue.edu

Artesian Conditions – flowing wells



Cone of Depression & Drawdown

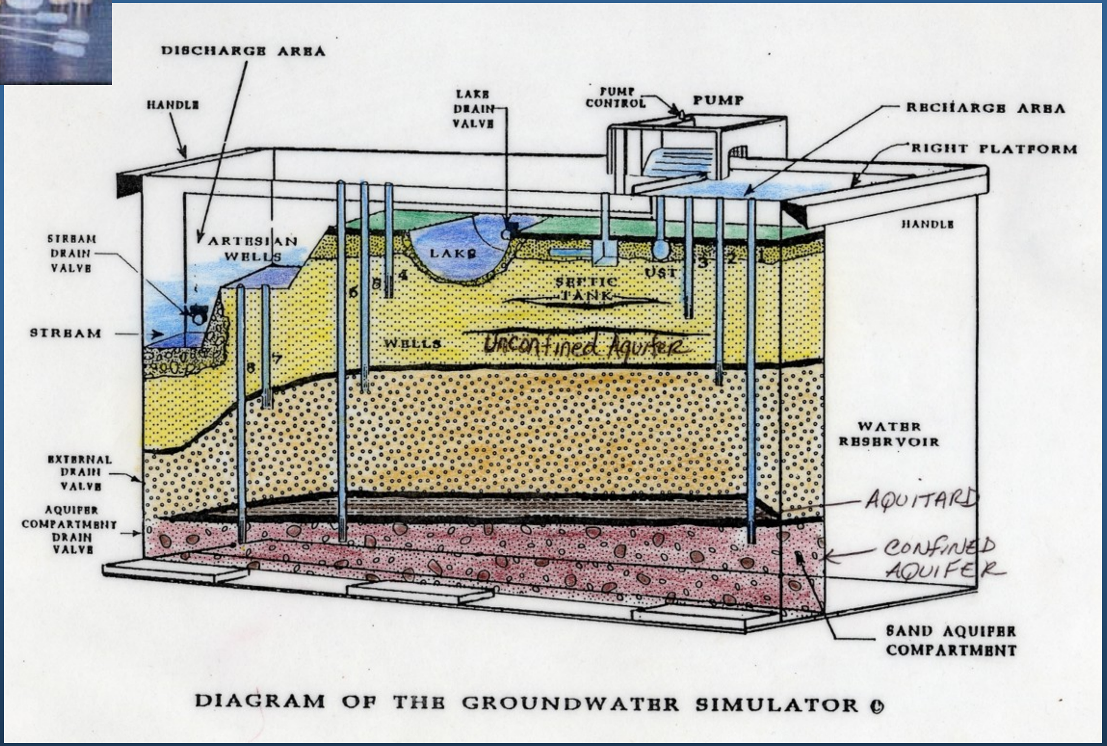
Unconfined Aquifer vs. Confined Aquifer



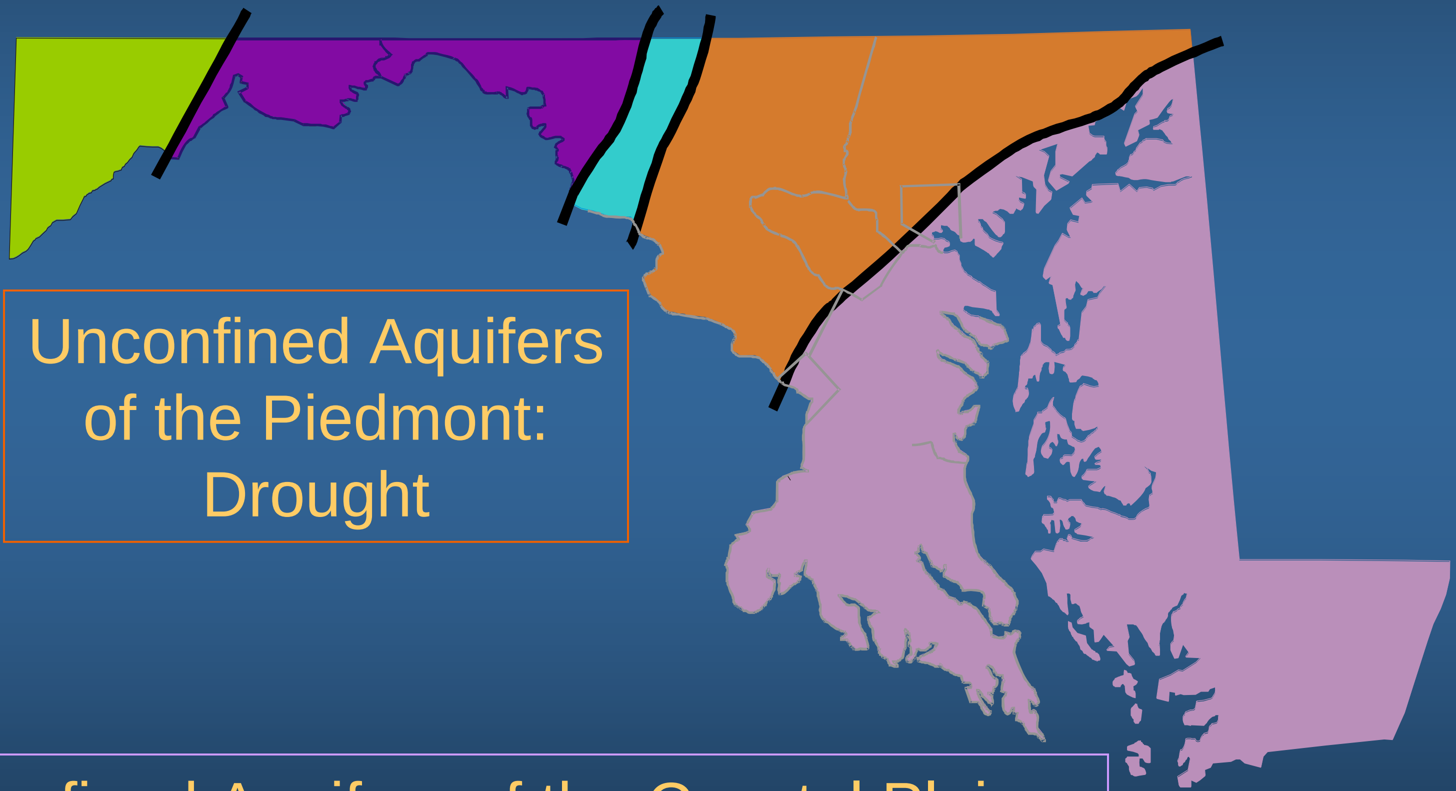
From: Basic ground-water hydrology, U.S. Geological Survey, Water Supply Paper 2220, by Ralph C. Heath

Aquifer – classroom exercise

Aquifer model



Ground-Water Availability:
What are the issues?

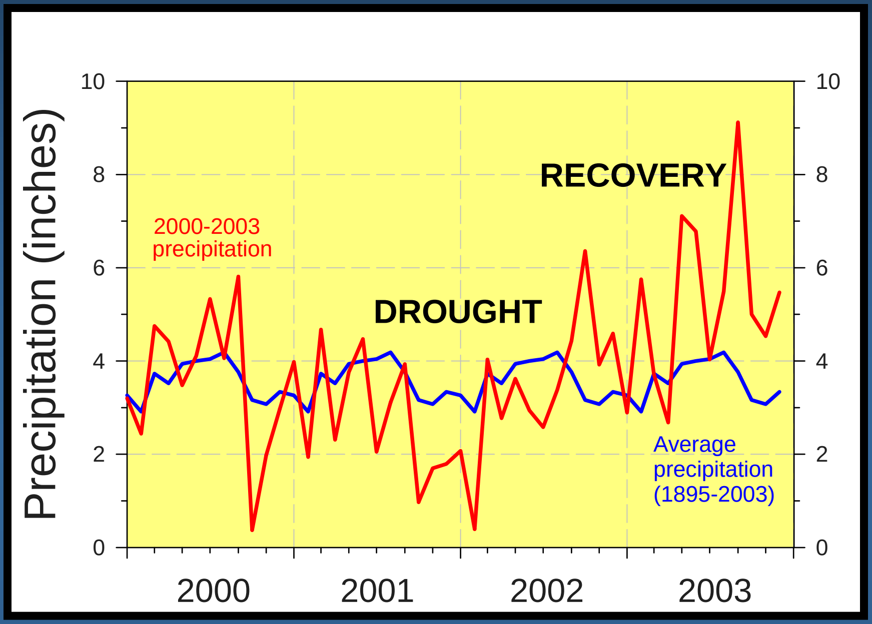


Unconfined Aquifers of the Piedmont: Drought

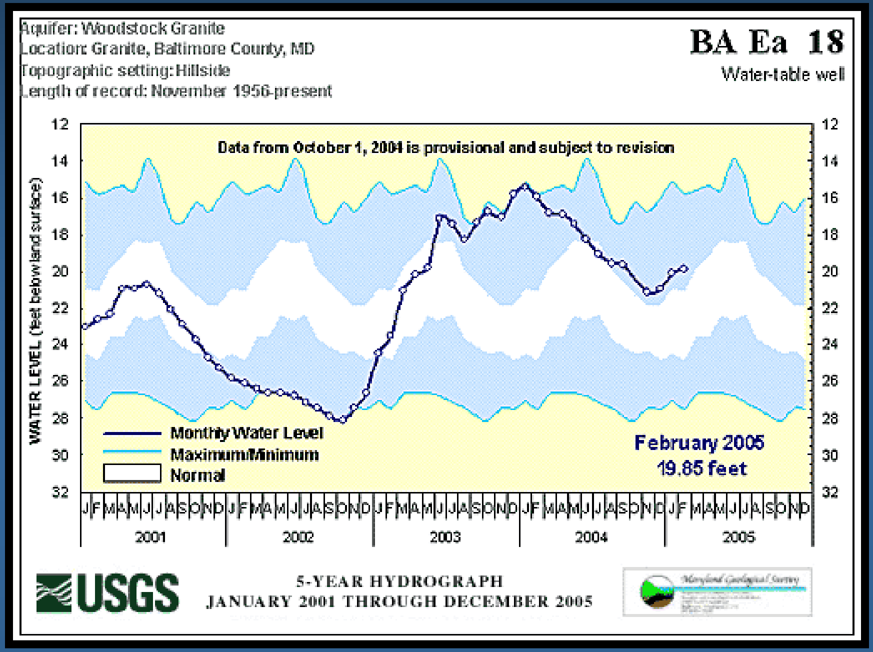
Confined Aquifers of the Coastal Plain: Long-term water level declines

Drought of 2001-2002

Precipitation

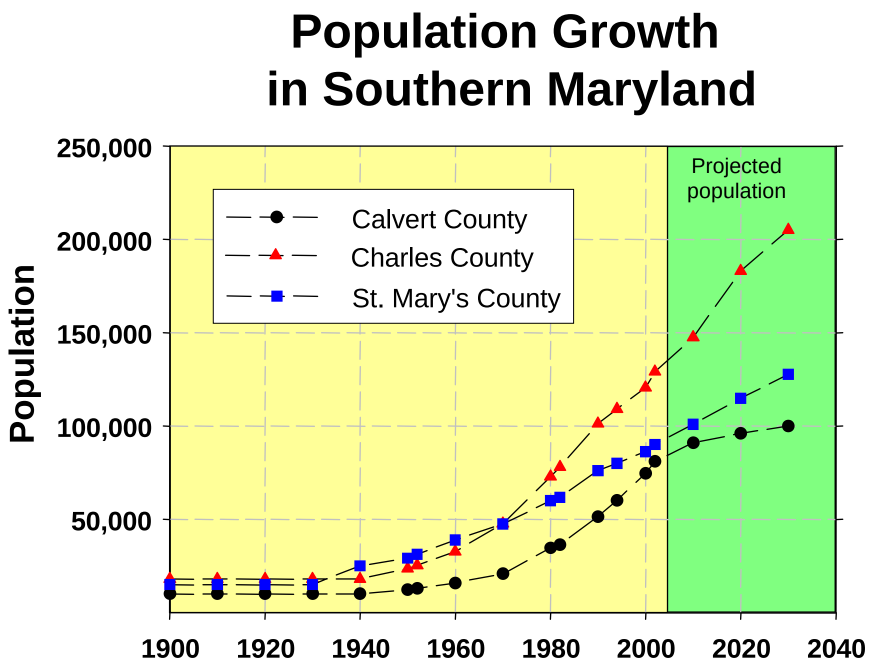


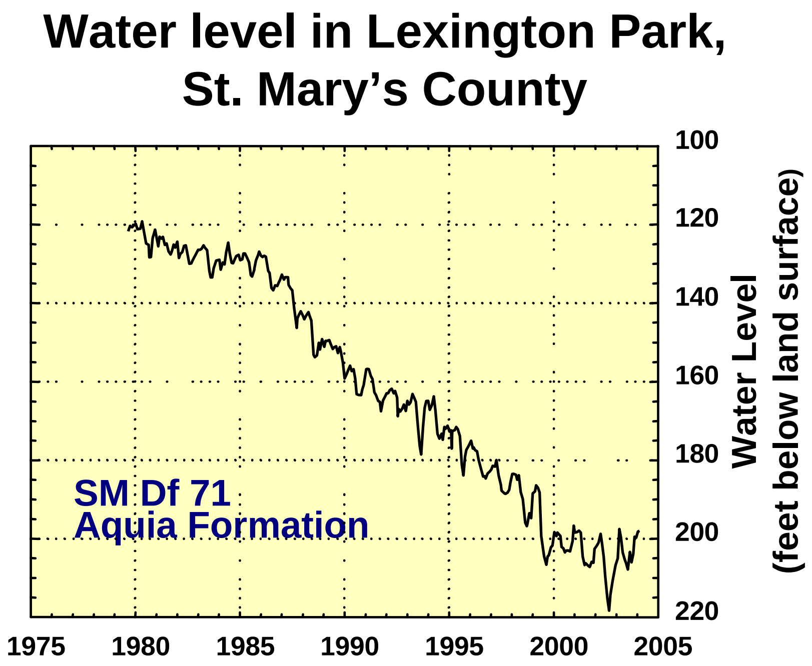
Groundwater level



Prettyboy Reservoir 2002

Maryland Coastal Plain: Long-term ground-water-level declines



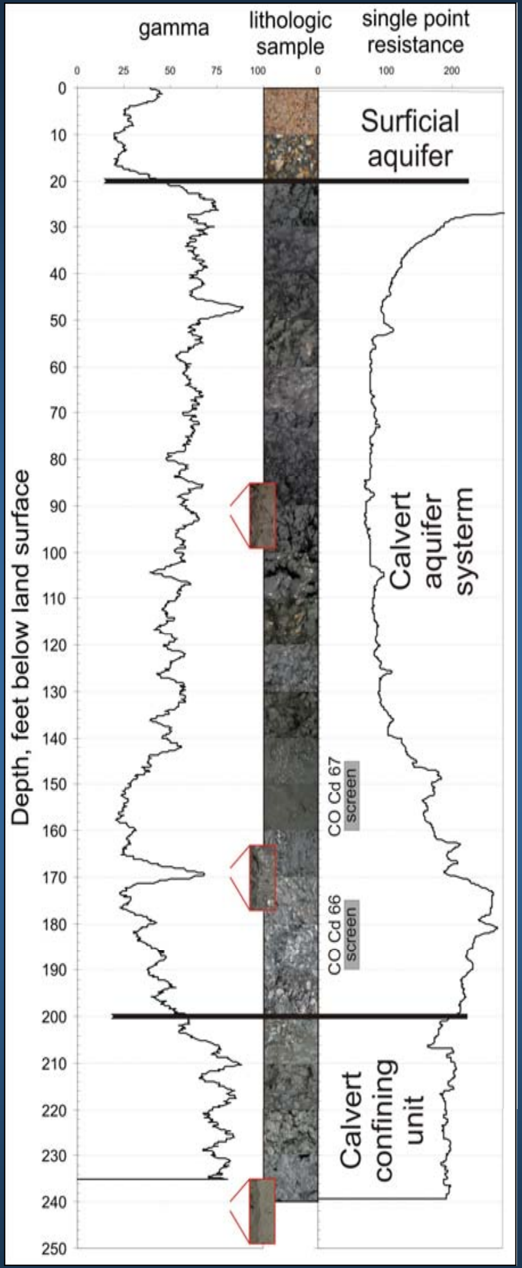


Drilling wells, test holes and cores and geophysical logging

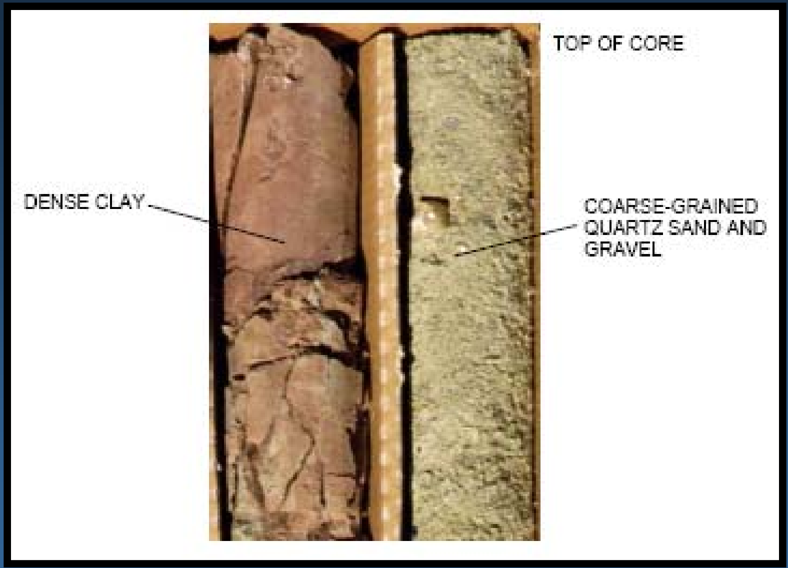
Cuttings/ ditch samples

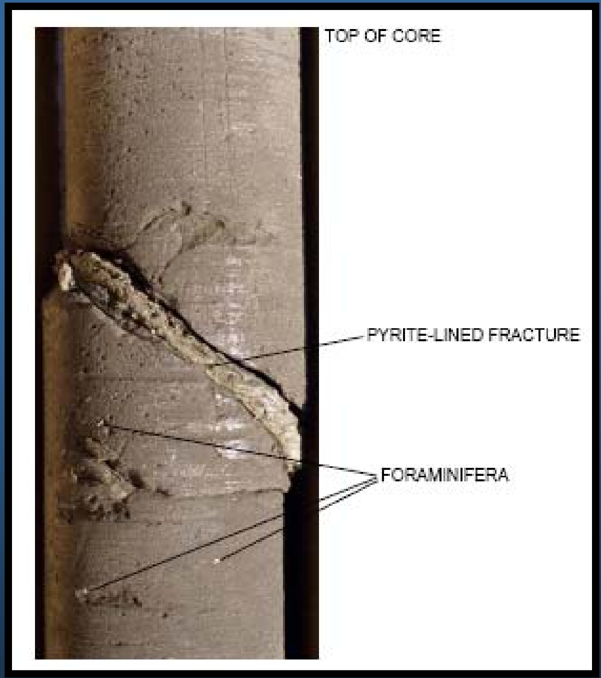
Collecting a split-spoon core

Geophysical logging



Types of Data: Lithologic descriptions from cores

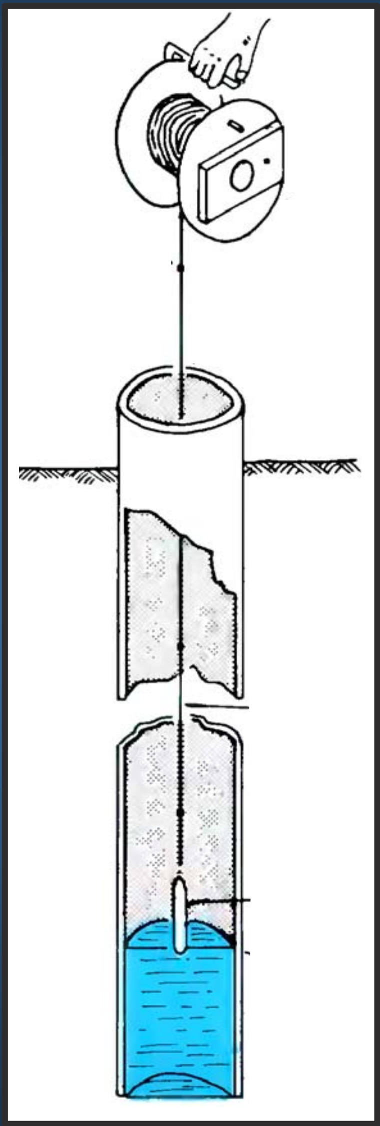


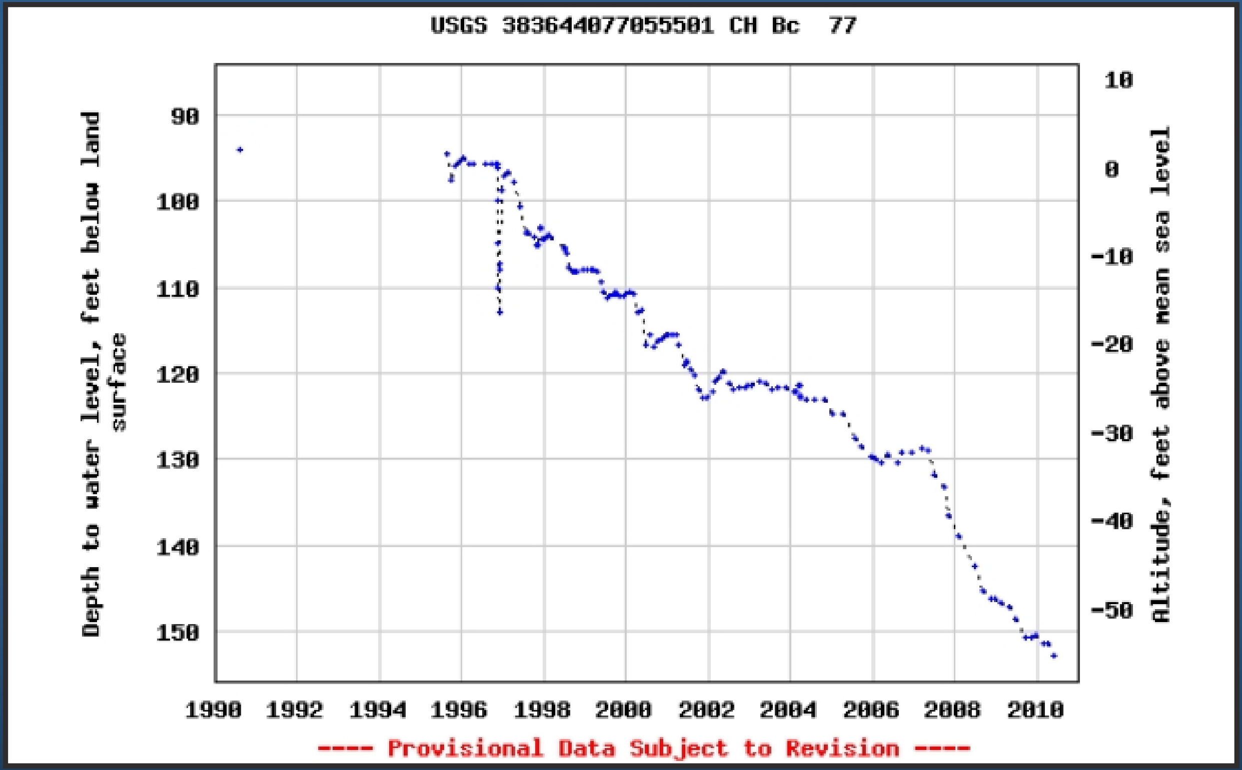


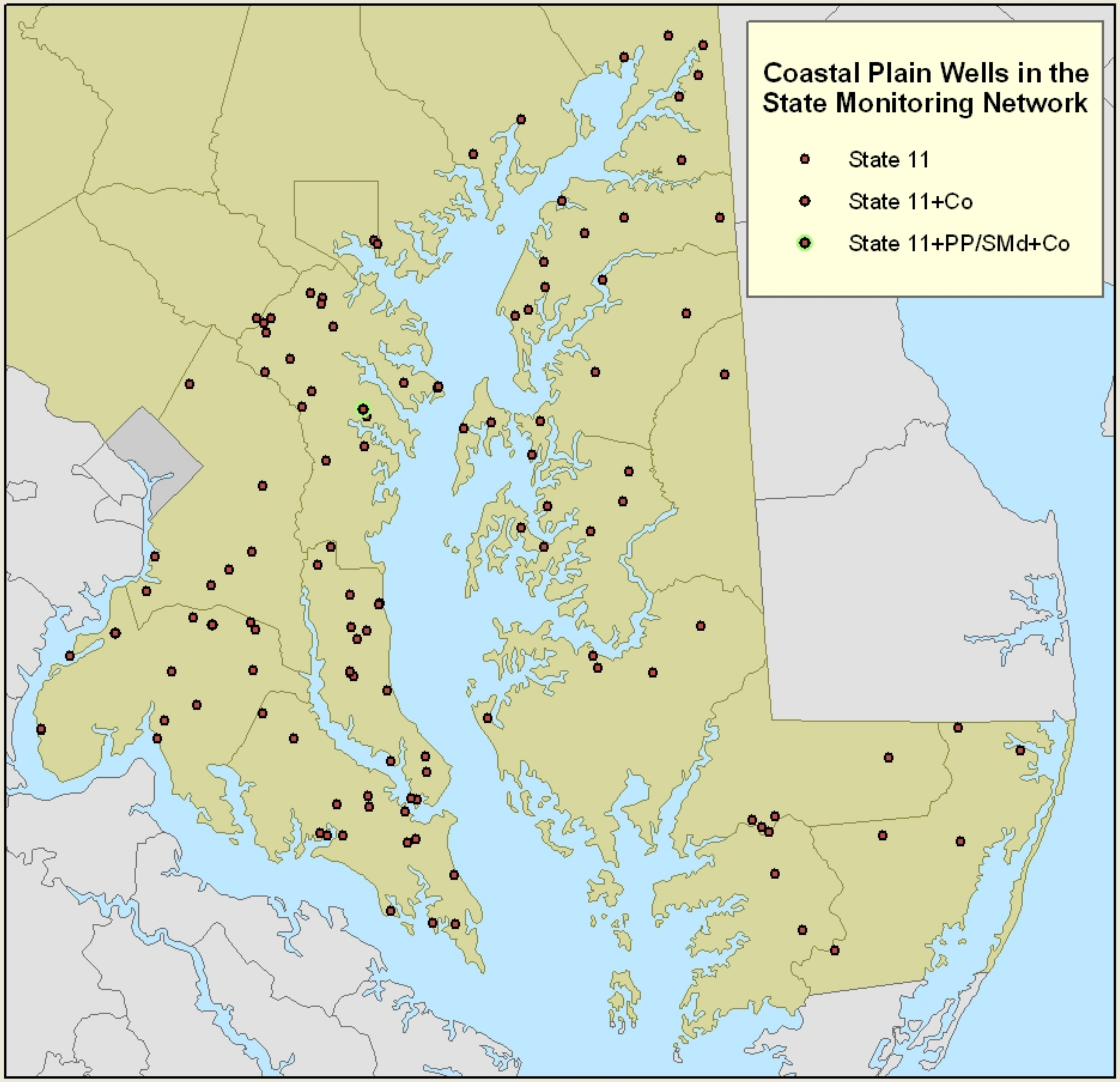
Types of Data:
Lithologic descriptions from cuttings

Well No.	CO Fc 28
Altitude	50 ft
Depth, ft	**Description**
Surficial aquifer	
0 - 0.5	Top soil
0.5 - 4	Clay, sandy brown
4 - 6	Sand, with clay layers, brown
6 - 58	Sand, tan and brown
Base of Surficial aquifer	
58 - 59	Clay, blue, with iron ore

Types of Data:
Water level measurements

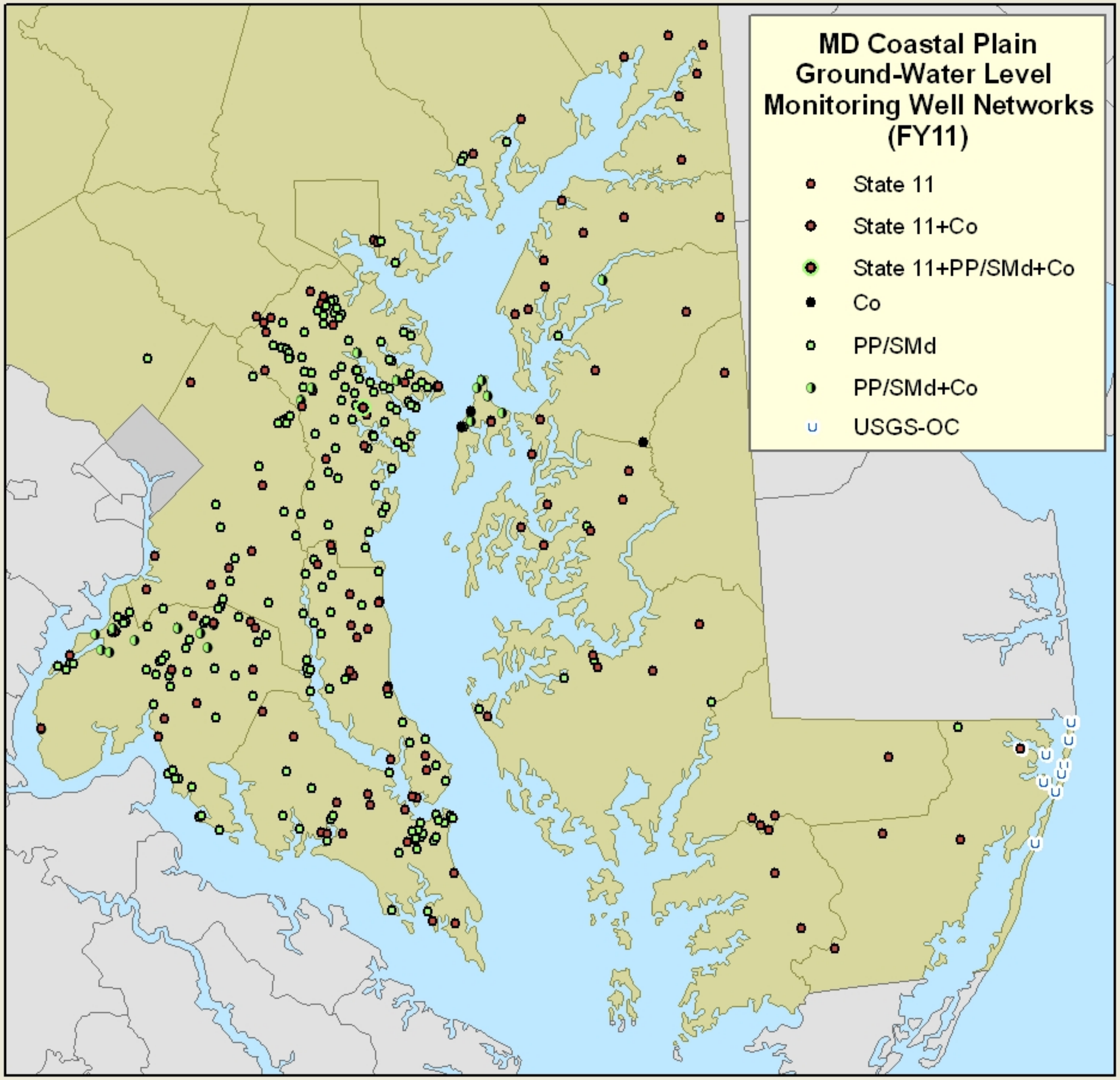






State network - wells in the Coastal Plain (2011)

~145 wells



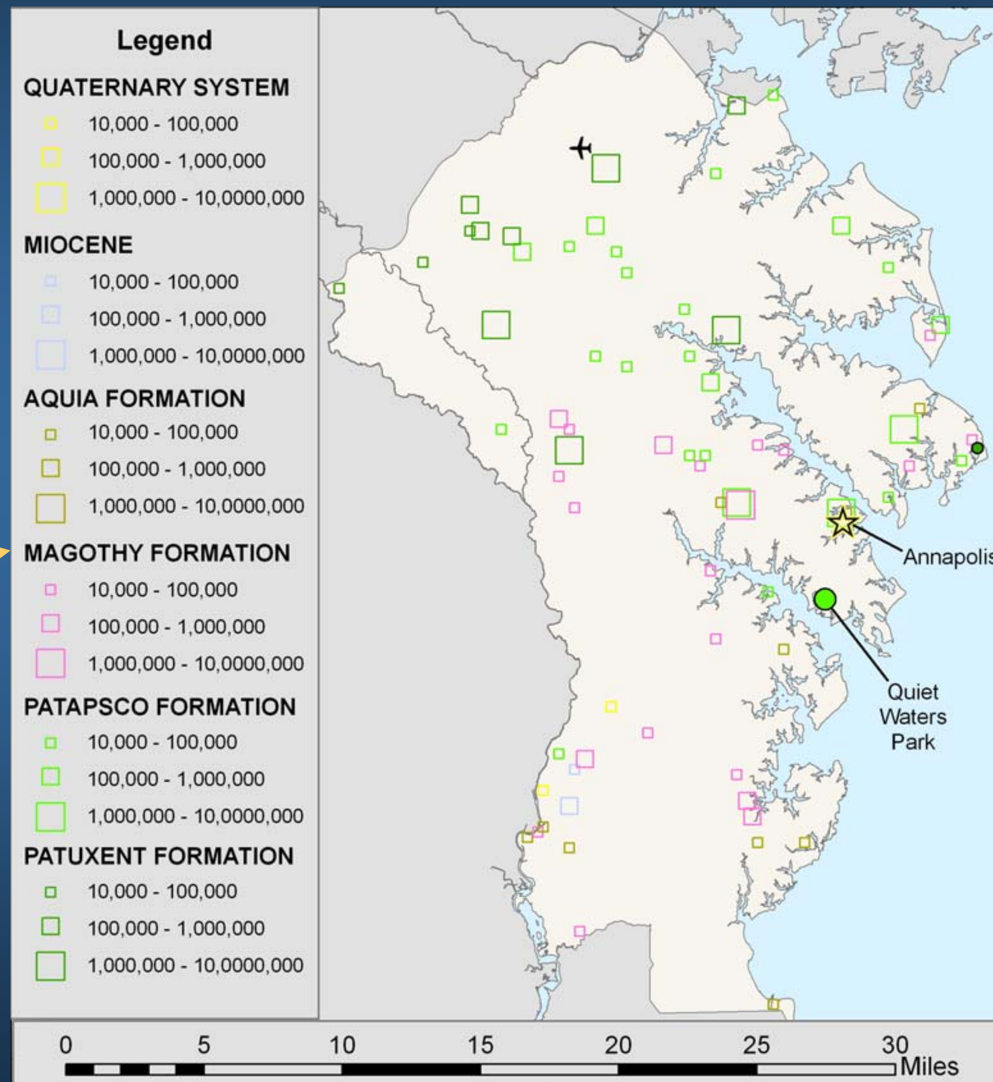
State plus County and Regional networks - wells in the Coastal Plain (2011)

~438 wells

Groundwater Withdrawals

>10,000 gallons per day
Anne Arundel County

Many permits in Magothy, Patapsco and Patuxent aquifers



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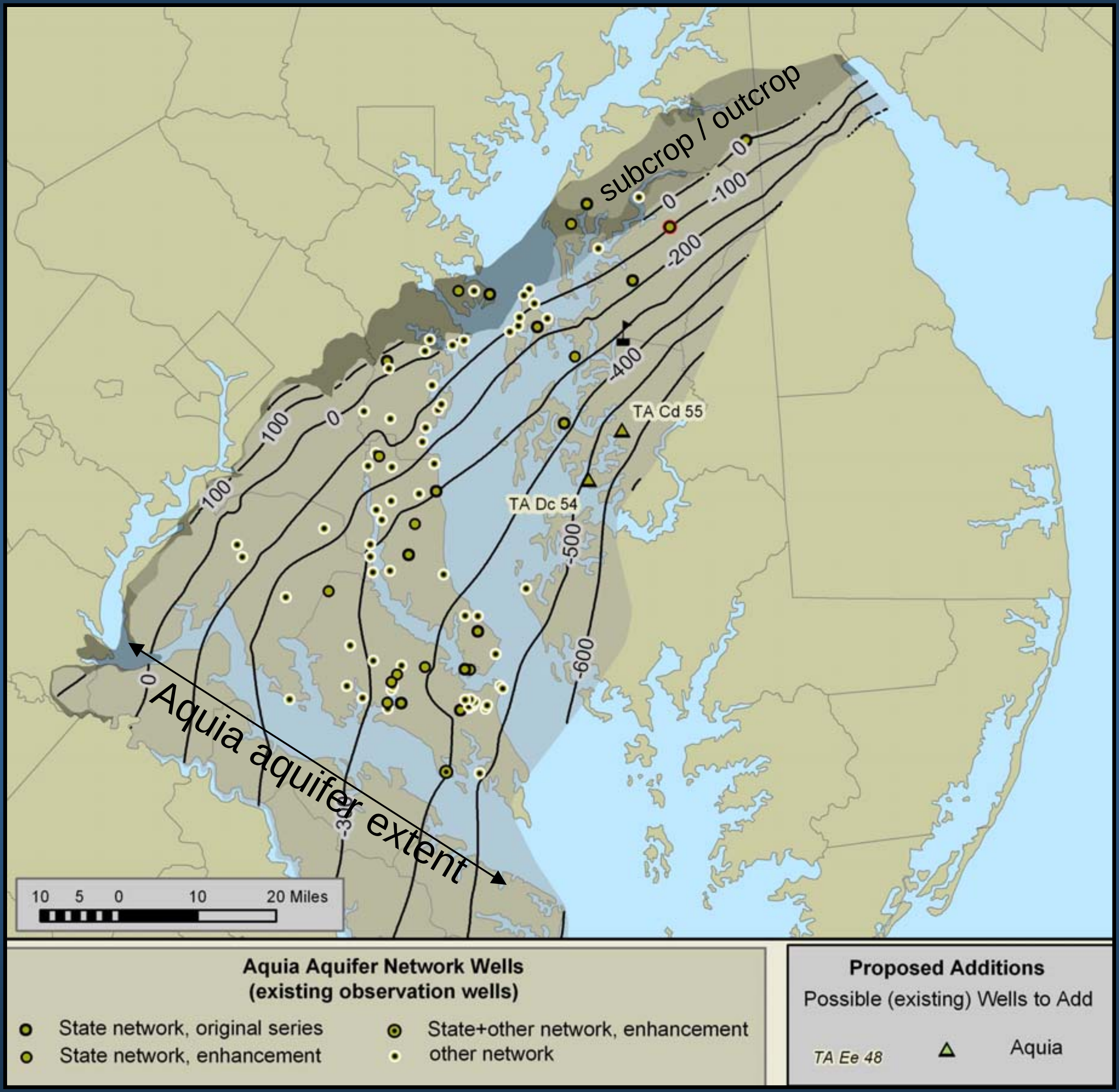
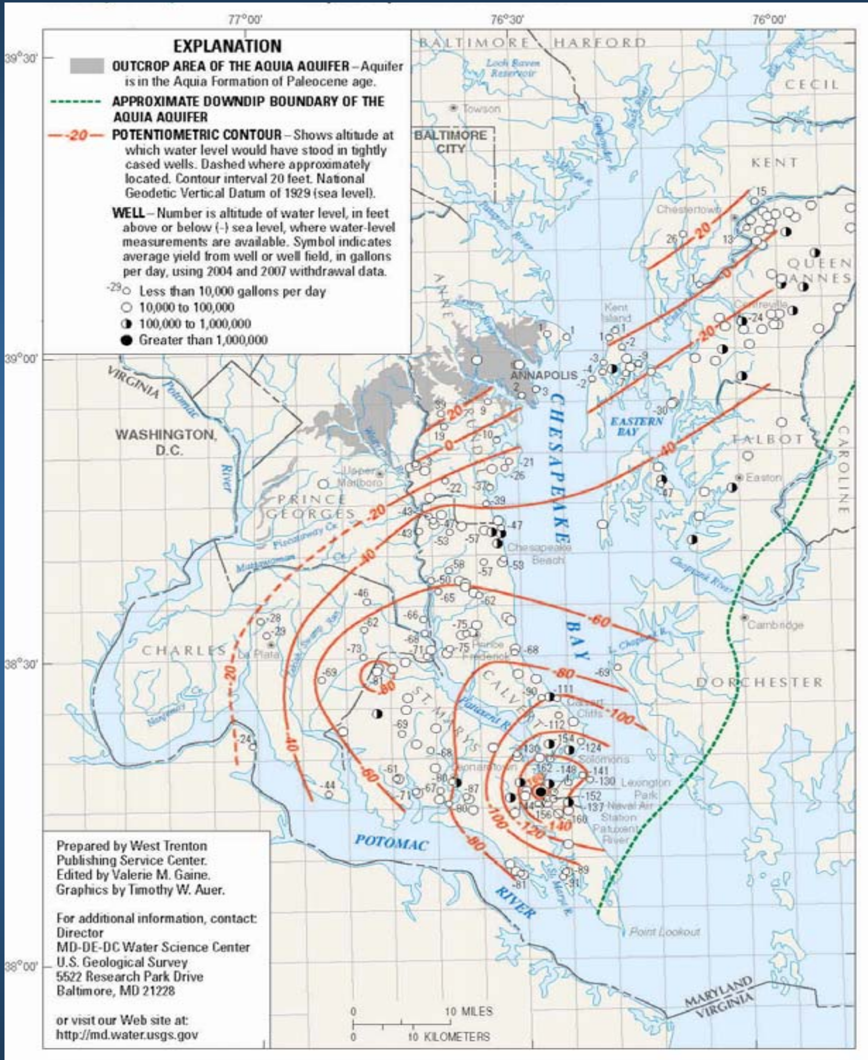
Aquia Aquifer Monitoring Wells



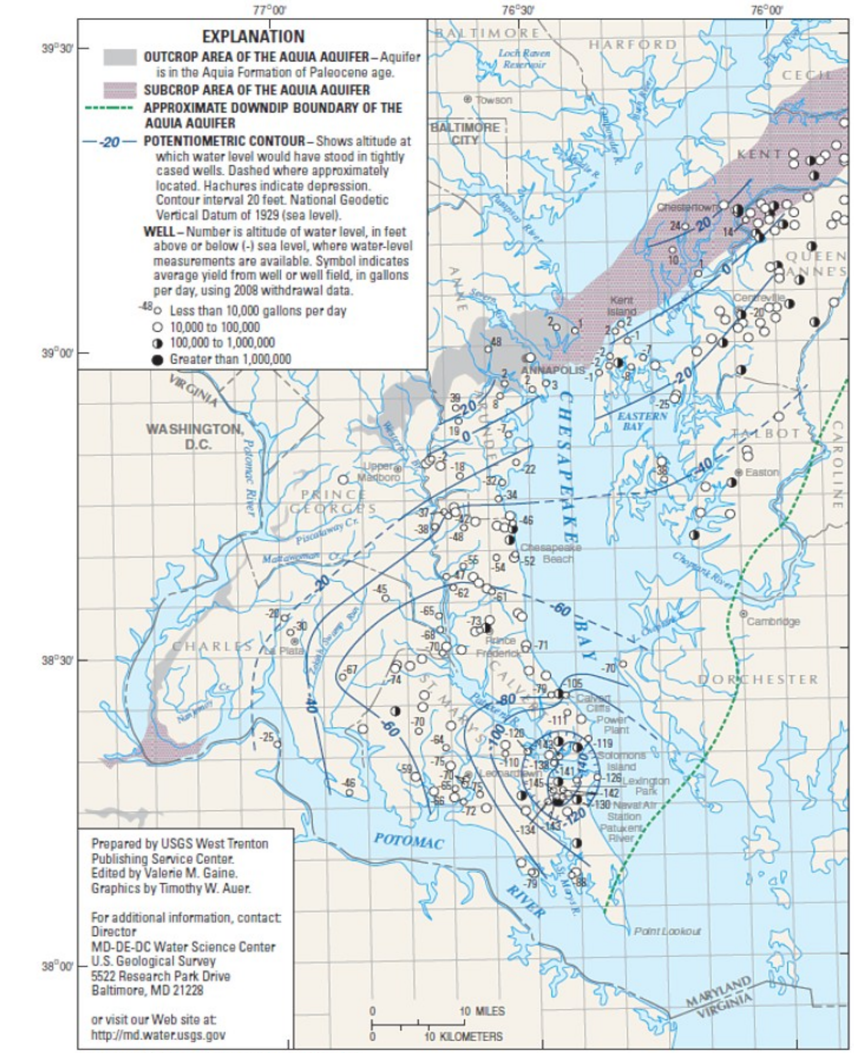
Contour lines showing elevation of the top of the aquifer (ft mean sea level)

Aquia Formation (largely an aquifer here) outcrops and subcrops locally

Water Levels in Aquia Aquifer



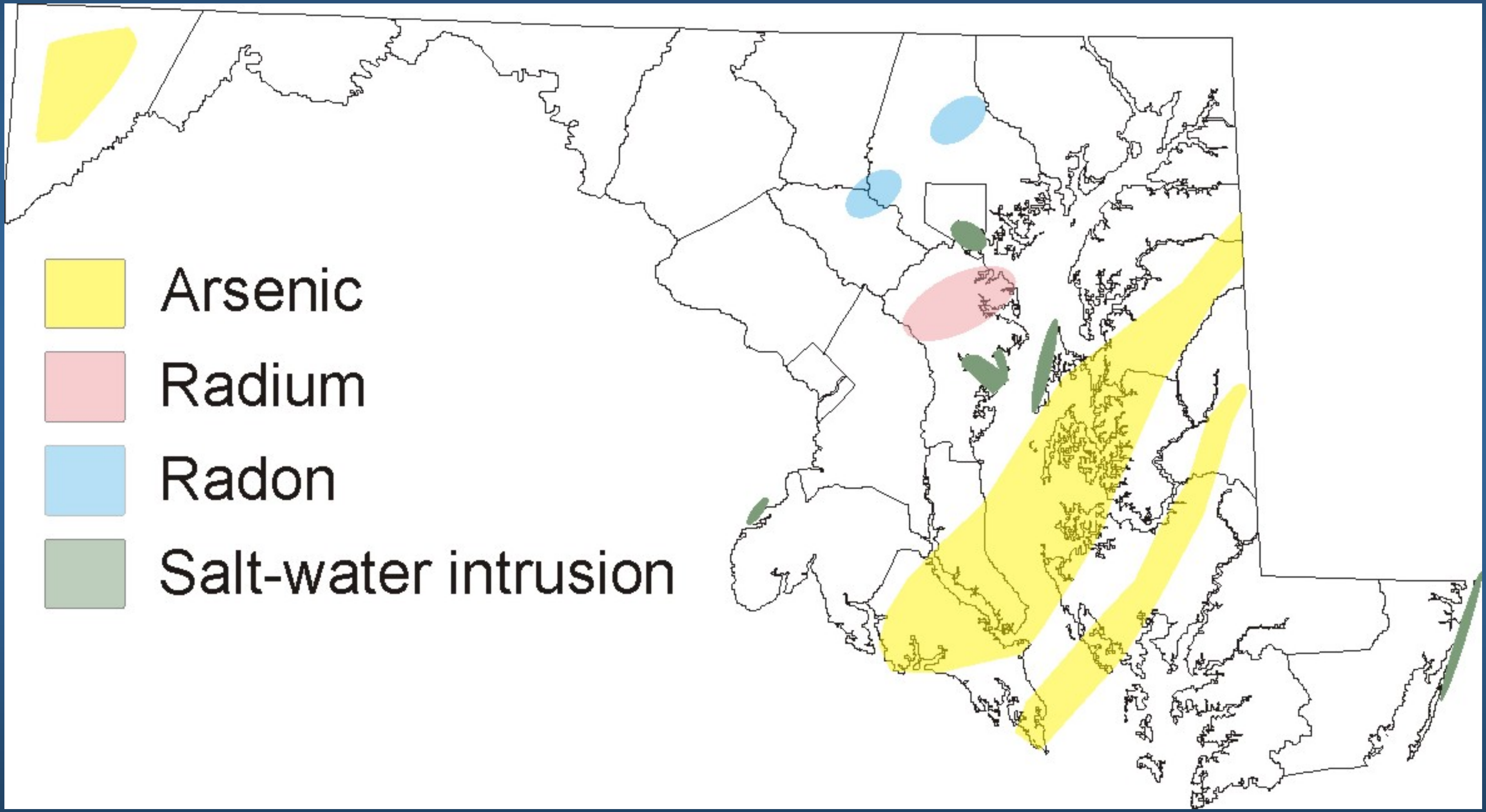
Potentiometric Surface of the Aquia Aquifer in Southern Maryland, September 2007



BASE MODIFIED FROM U.S. GEOLOGICAL SURVEY, 1:250,000

Potentiometric Surface of the Aquia Aquifer in Southern Maryland, September 2009

Regional Ground-Water Quality Issues



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Salt-Water & Brackish-Water Intrusion

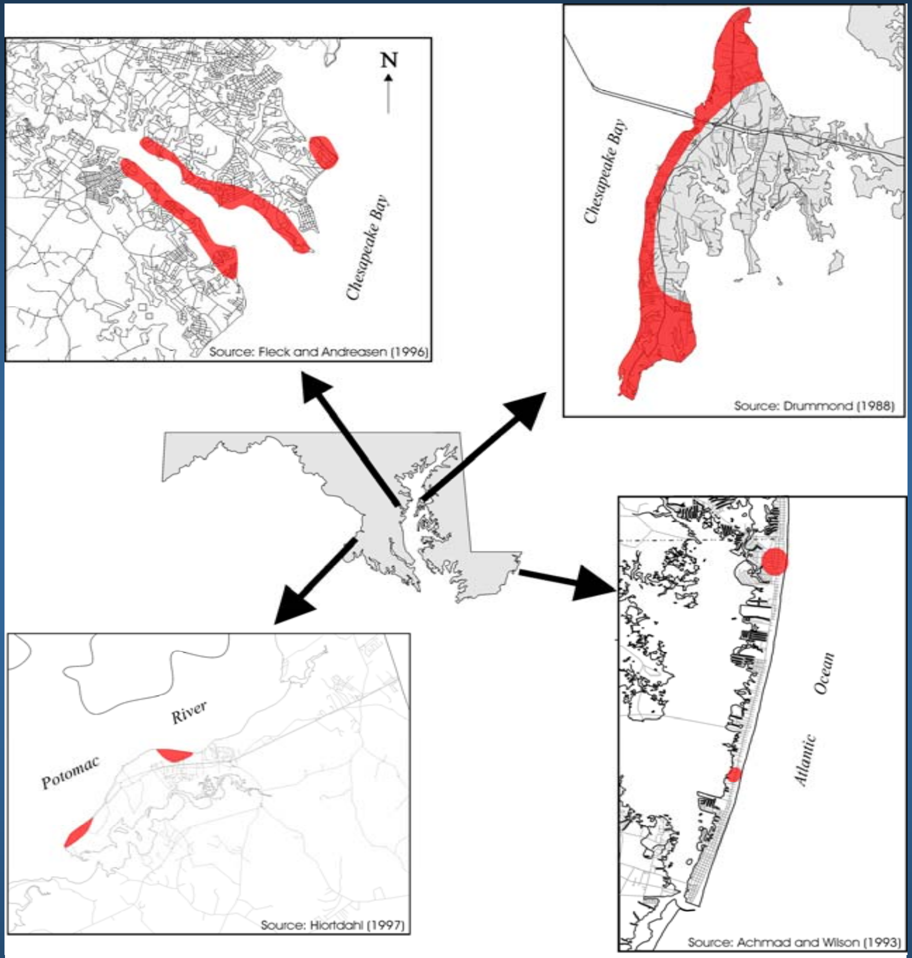
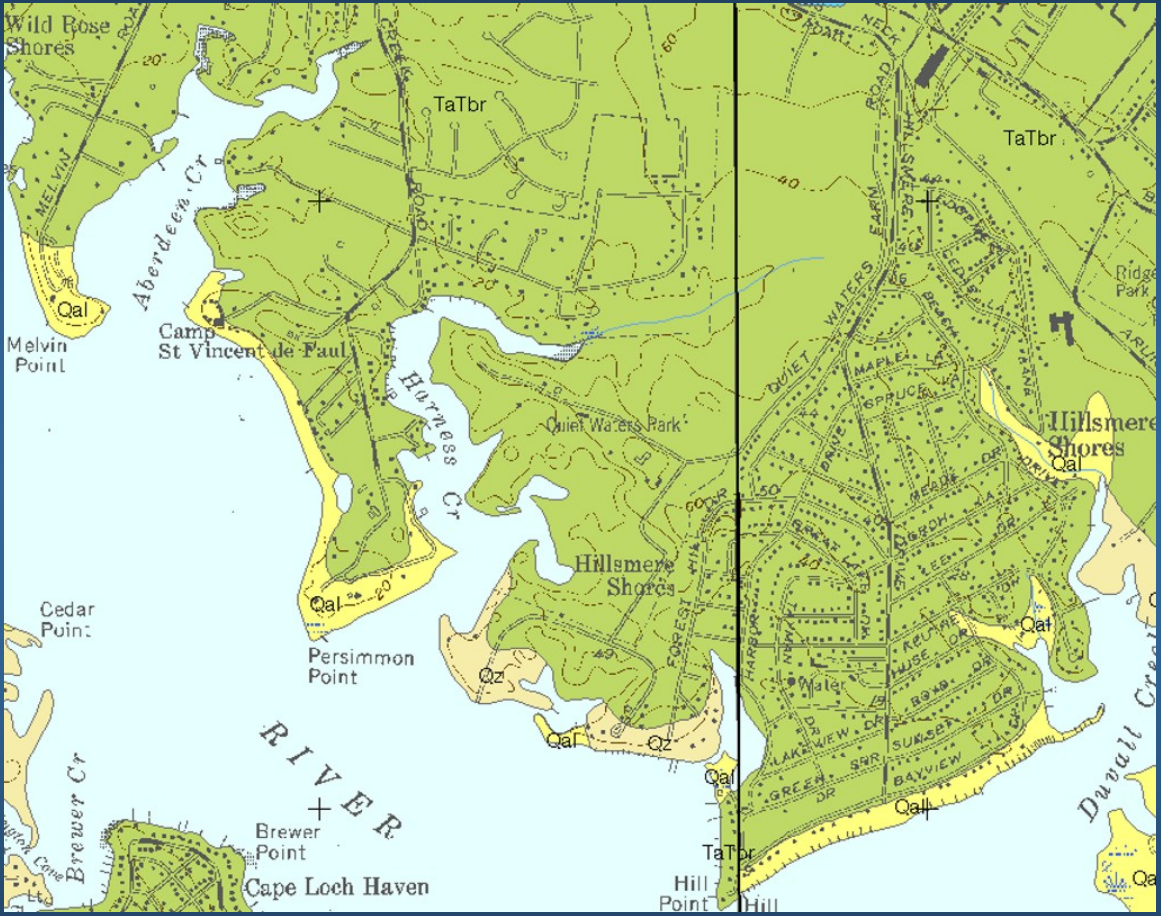


Figure D. Areas with salt- and brackish-water intrusion in Maryland.

Close-up of Geology at Park



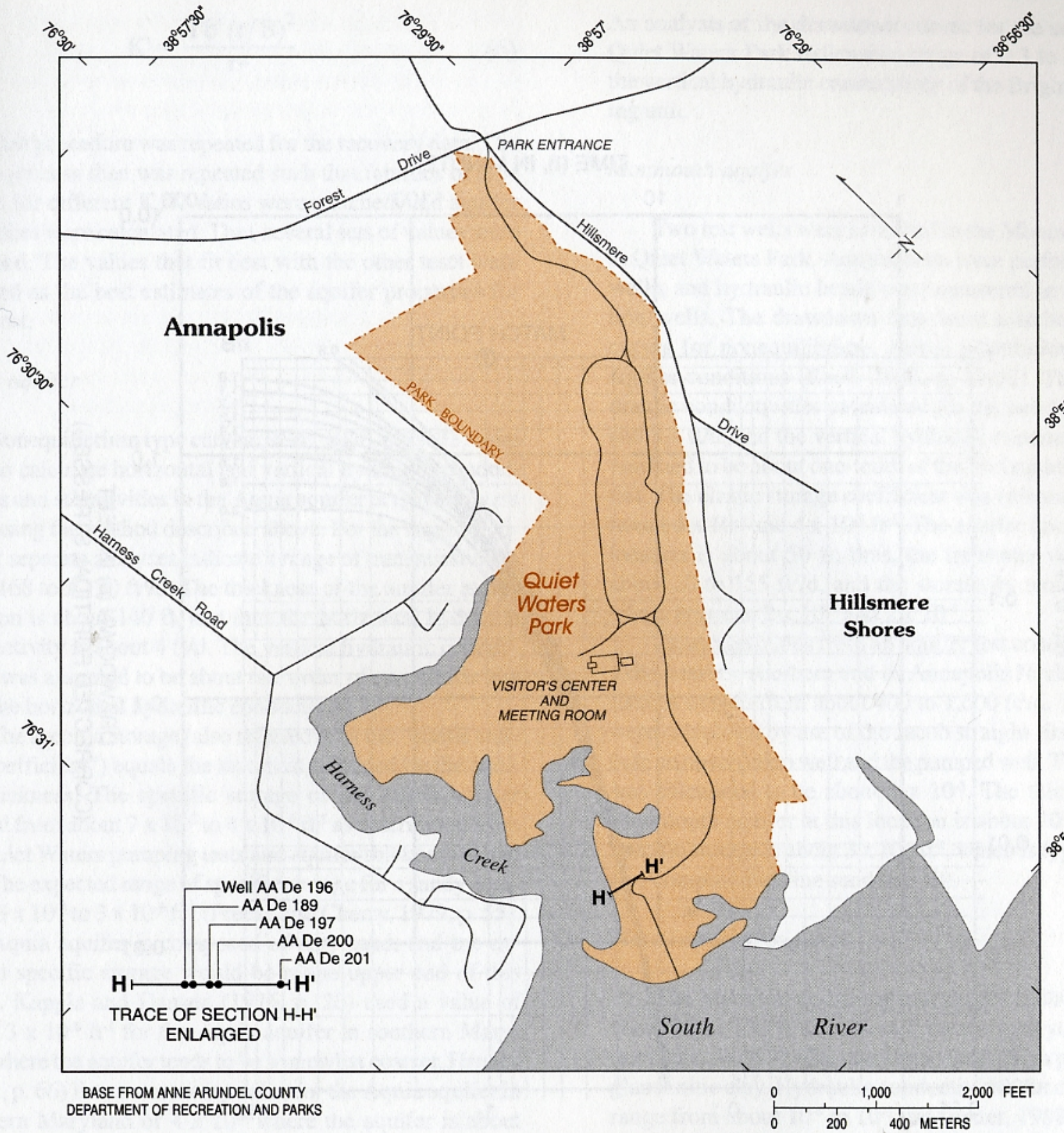


Figure 8. Location of test wells in Quiet Waters Park near Annapolis, Maryland.

Ground-Water Flow Cross Section:
Central Anne Arundel Co. toward Bay

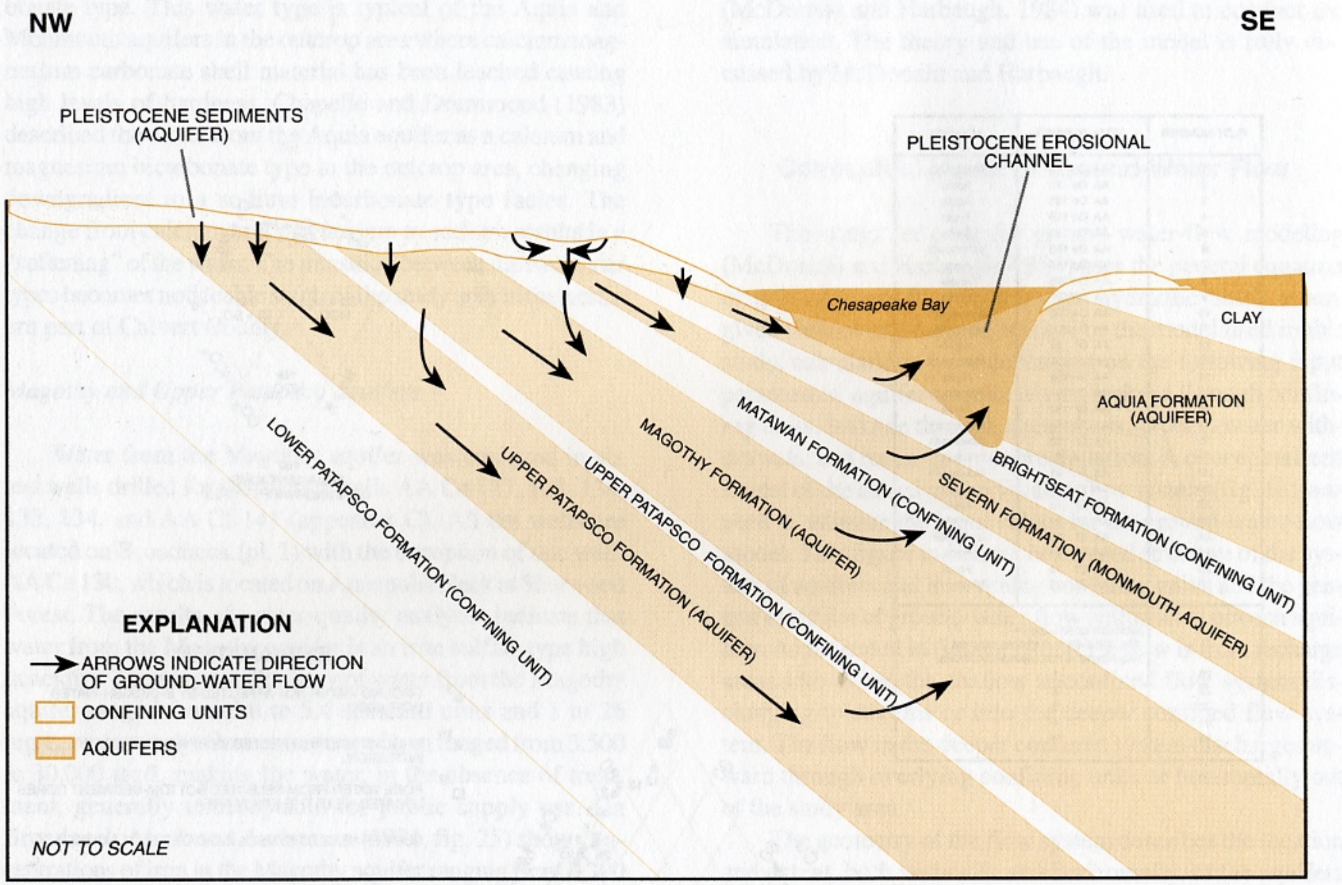


Figure 18. Generalized hydrologic section showing general ground-water-flow patterns along model row 11.

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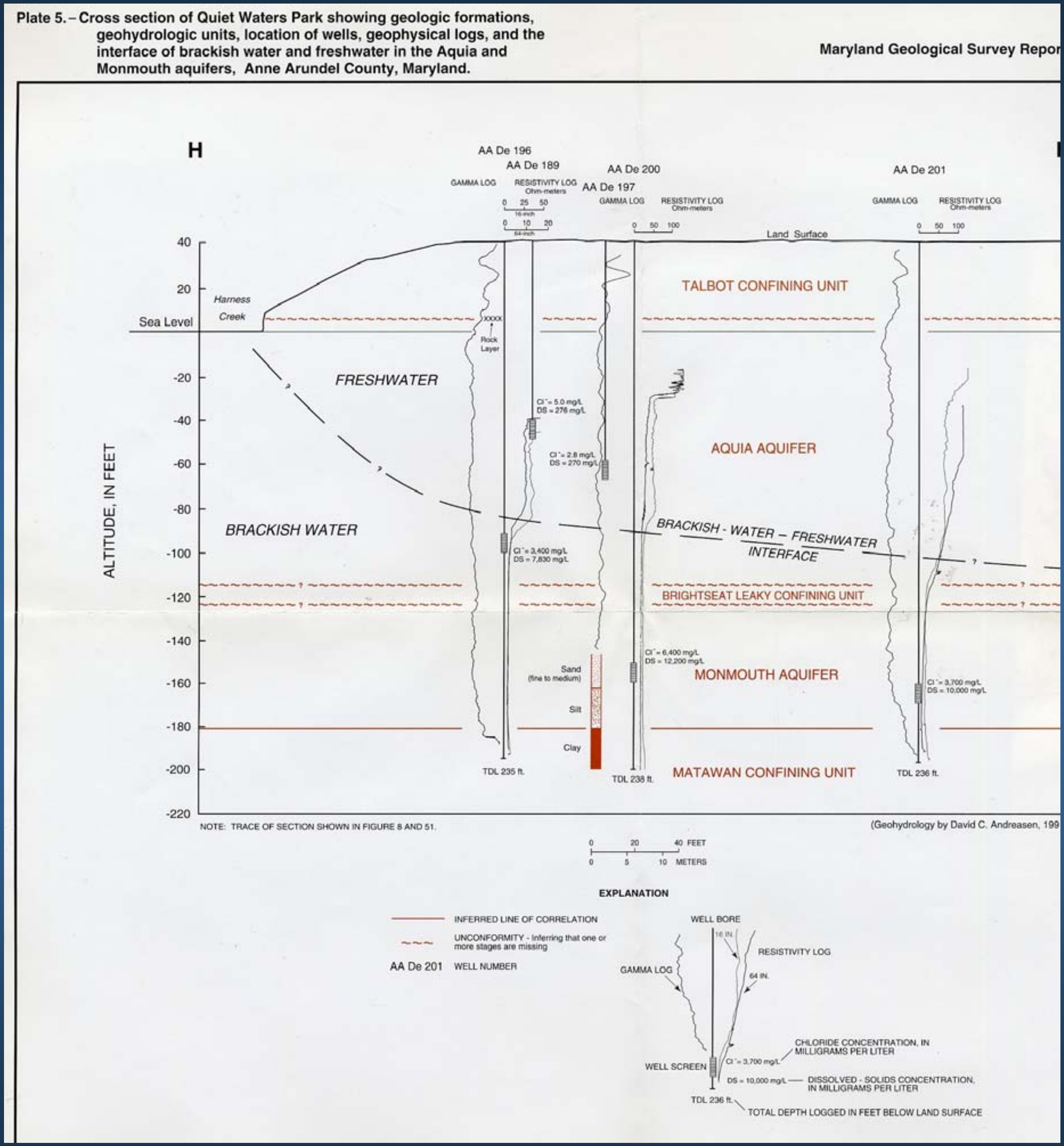
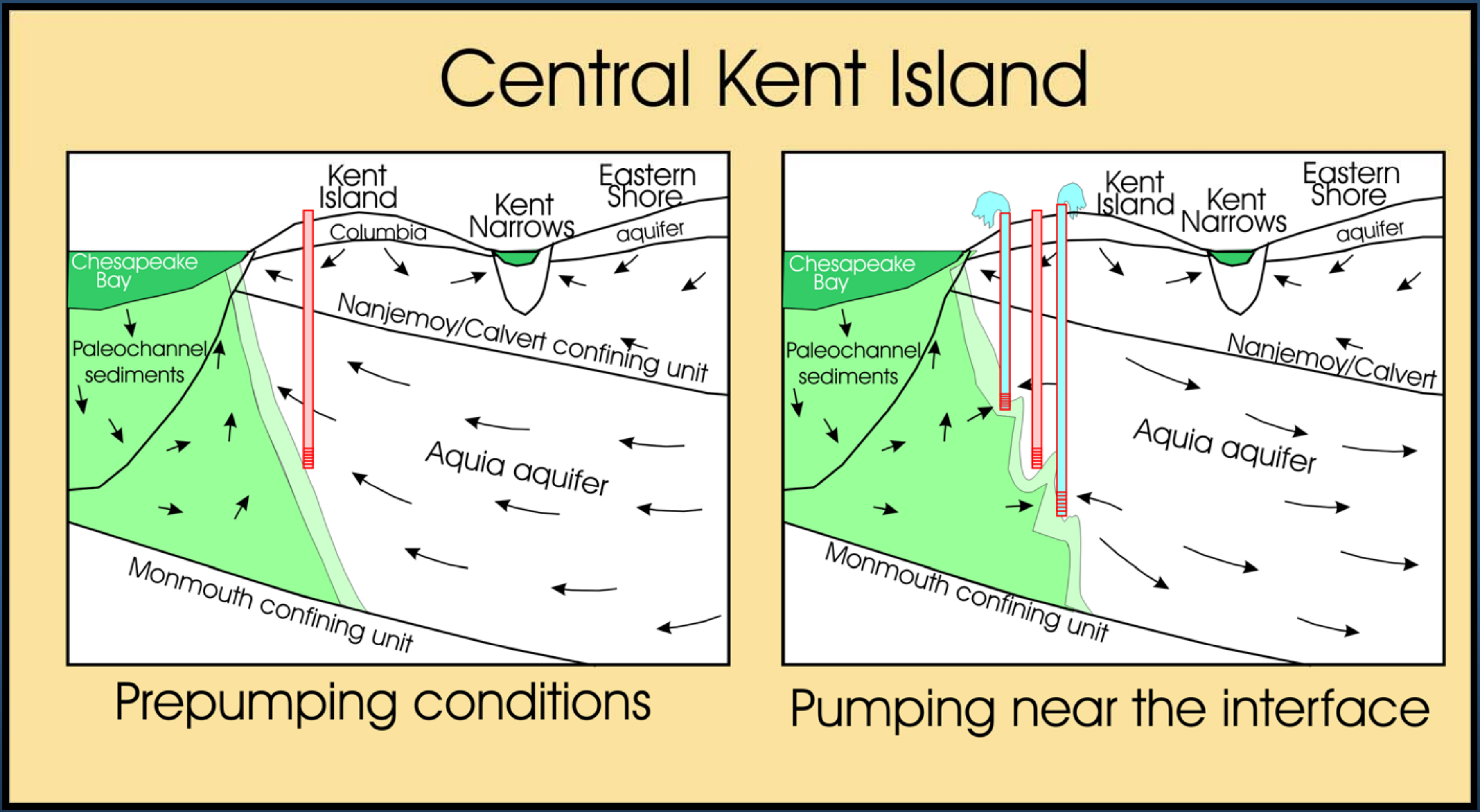
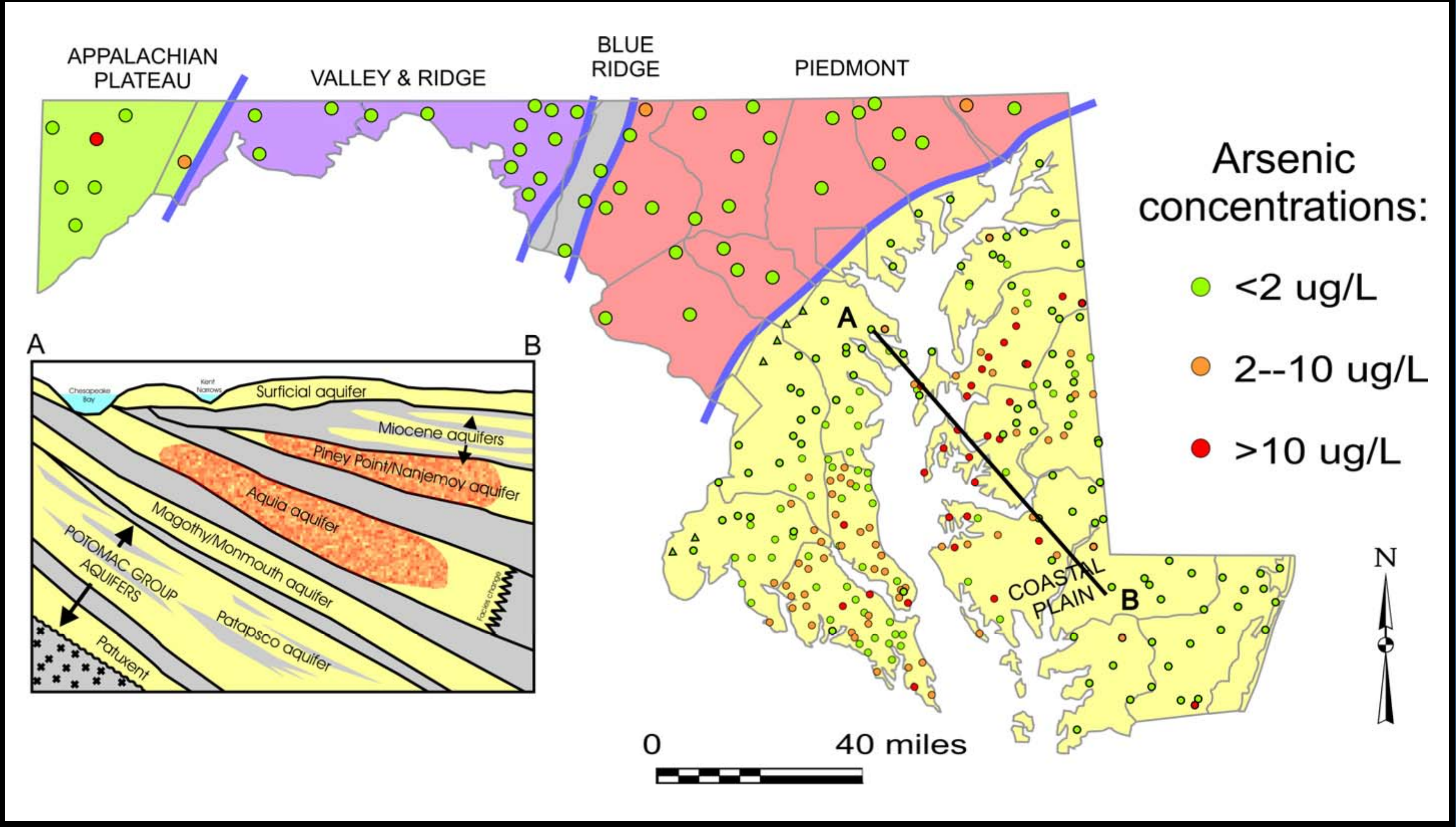
Brackish-Water Intrusion: Quiet Water Park



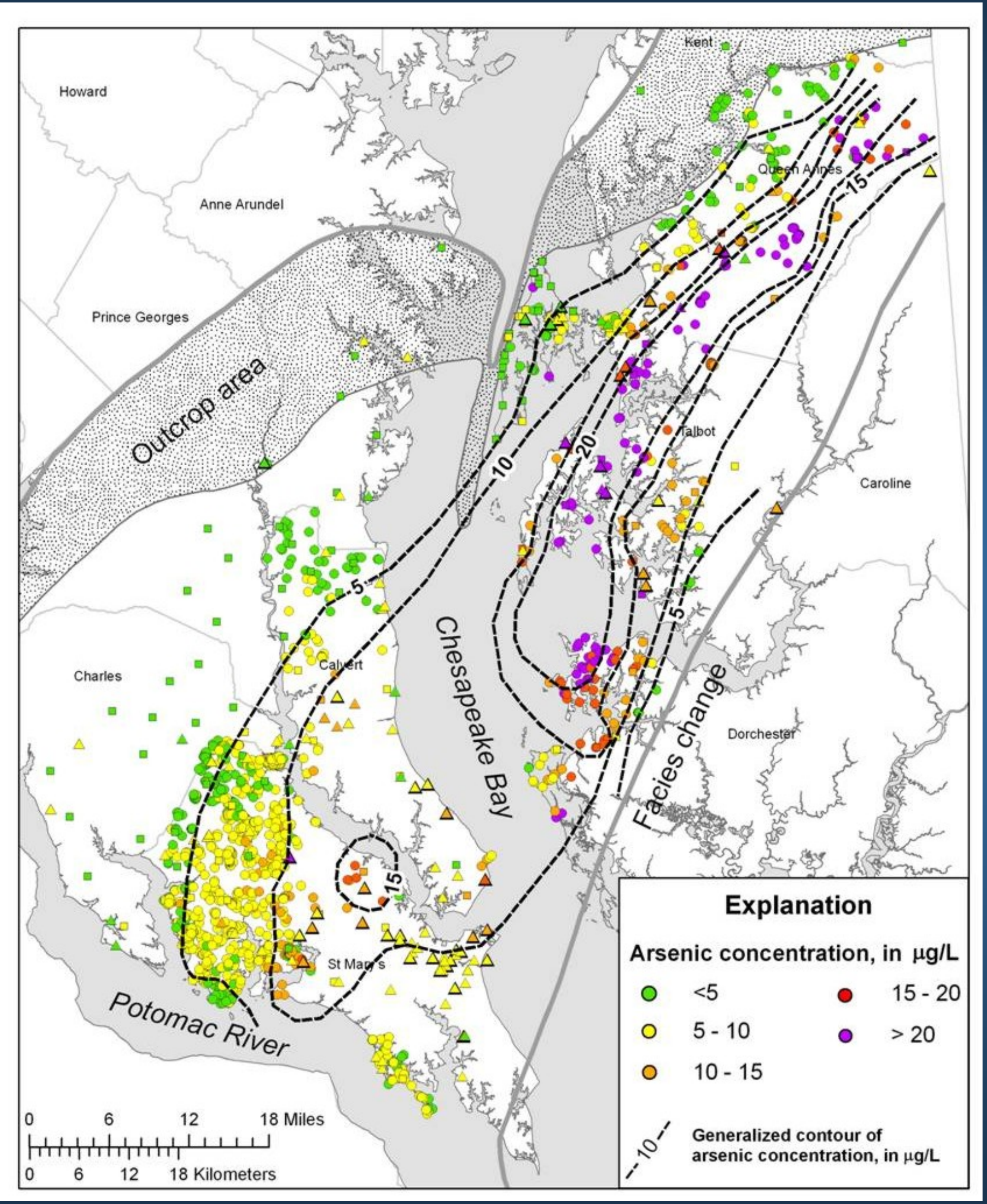
Brackish-Water Intrusion



Arsenic in Maryland Ground Water



Arsenic Concentrations in the Aquia Aquifer



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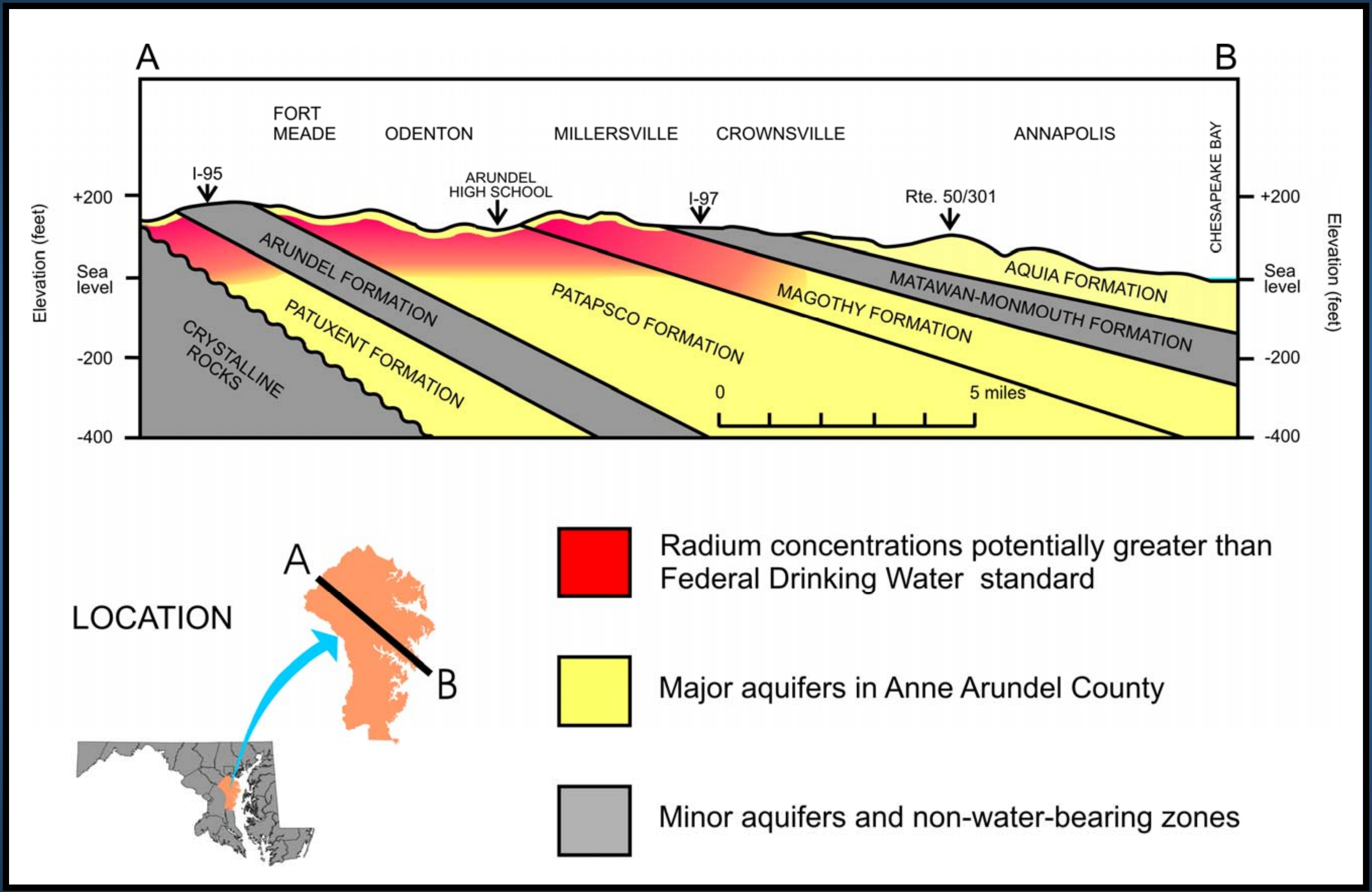
Radium in Anne Arundel County



Some Things to Keep in Mind

Outcrop areas for the aquifers we use for drinking water in Anne Arundel County are in this county.

What is applied to the ground surface could have the potential to infiltrate.

Public water supply wells in most Coastal Plain areas come from confined aquifers and it is possible to withdraw ground water at a greater rate than it can be recharged.

There are some naturally occurring and some man-induced ground water quality issues but there are solutions.

Underlying geologic materials are a parent material for most soils.

Increased impervious surface area reduces infiltration and increases runoff.

Some Things to Consider

There are actions we can take that can help maintain/conserve our ground water resources as well as our surface water resources.

For example:
Consider alternatives to impervious surface materials

In landscaping consider:

- use of plants suited to a region and specific location, which may need little or less irrigation, fertilizers, pesticides and herbicides.

- use of rain gardens and landscaping to reduce runoff

- use of rain barrels to capture roof runoff for later use for watering

Store, use and dispose of any household and yard chemicals and fertilizers appropriately

Maryland Geological Survey

www.mgs.md.gov