Overview of Kentucky Aquifers—Framework for Understanding Groundwater Availability & Priority Groundwater Data and Research Needs—KGS Perspective

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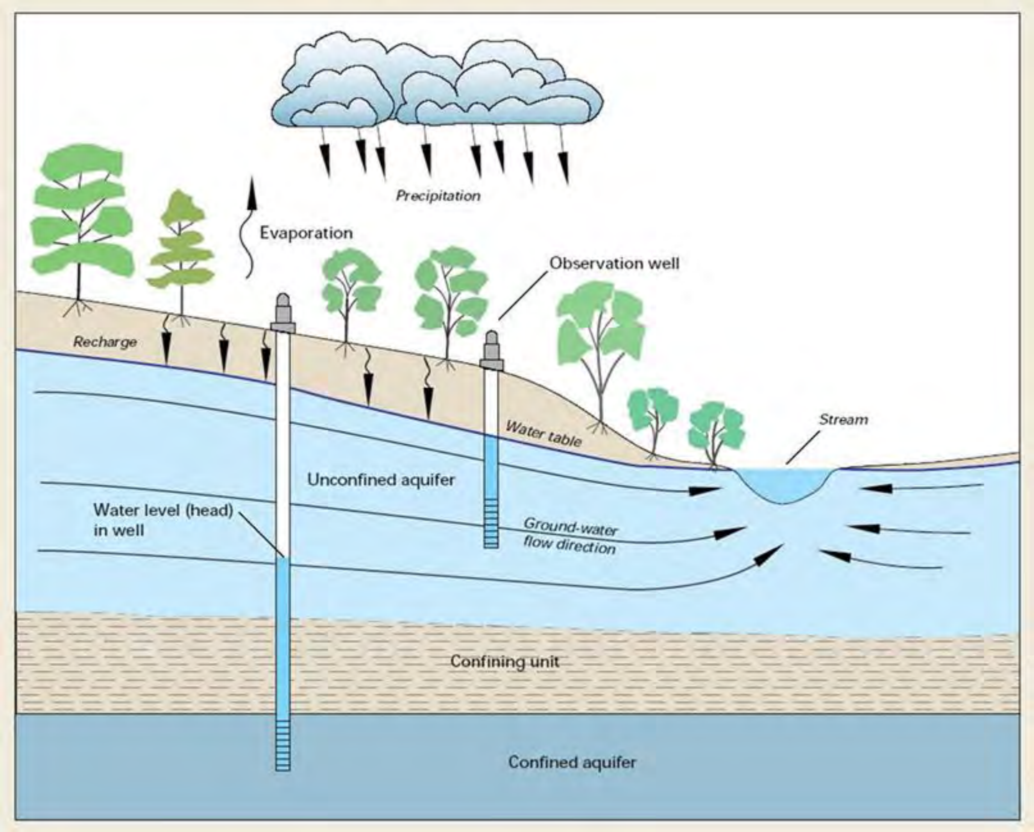
Classical Definition of An Aquifer

A geological formation that is sufficiently permeable to transmit ground water and yield economically sufficient quantities of water to wells and springs.



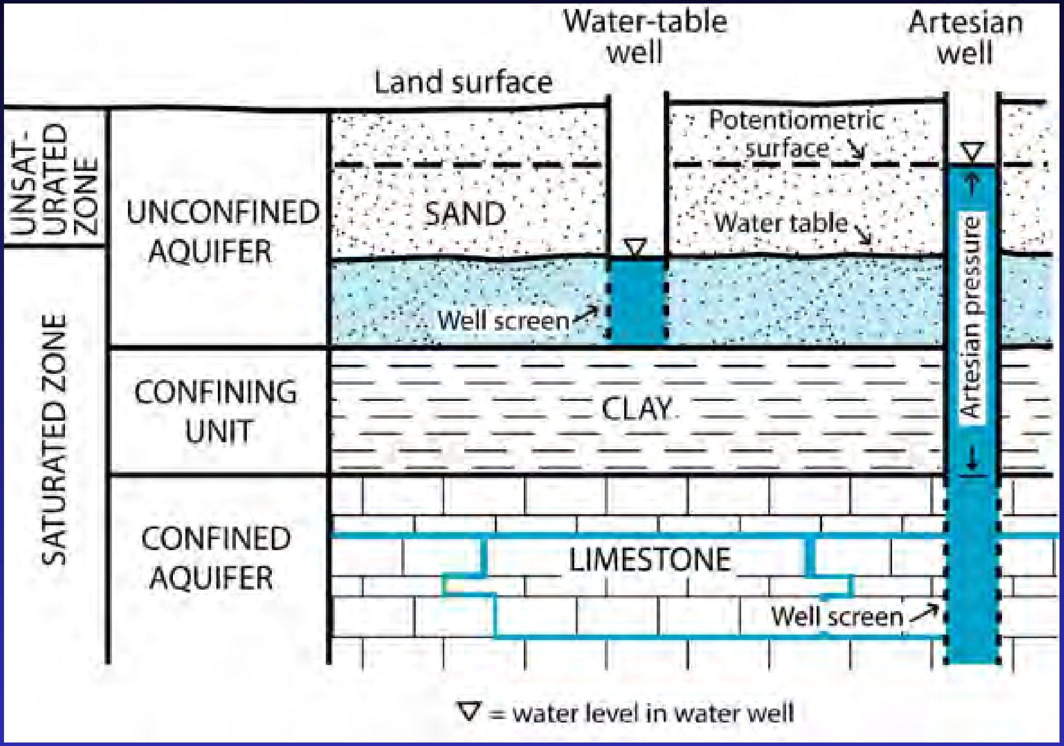
"Aquifers come in many shapes and sizes but they are really a contained underground repository of water" –Steve Phillips, USGS, Sacramento

A Few More Aquifer Definitions:

***Confining unit (Aquitard)*- A body of impermeable or distinctly less permeable material that restricts flow into or out an adjacent aquifer.**

***Unconfined aquifer* - An aquifer having a water table surface, open to atmospheric pressure.**

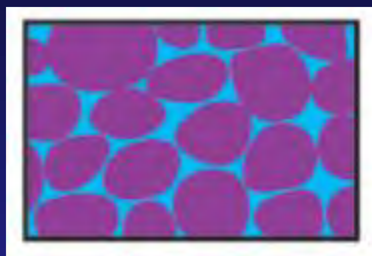
***Confined aquifer* - An aquifer bounded above and below by impermeable or lower permeability beds, with water under artesian or confining pressure (greater than atmospheric pressure).**



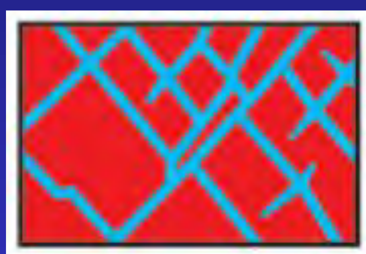
Hydraulic head—is the height that water will rise in a well due to natural conditions in the aquifer, particularly the kinetic and potential energy of groundwater at that location. Groundwater moves from areas of higher hydraulic head to areas of lower hydraulic head.

Porosity and Permeability Are the Primary Factors Controlling Groundwater Occurrence & Availability

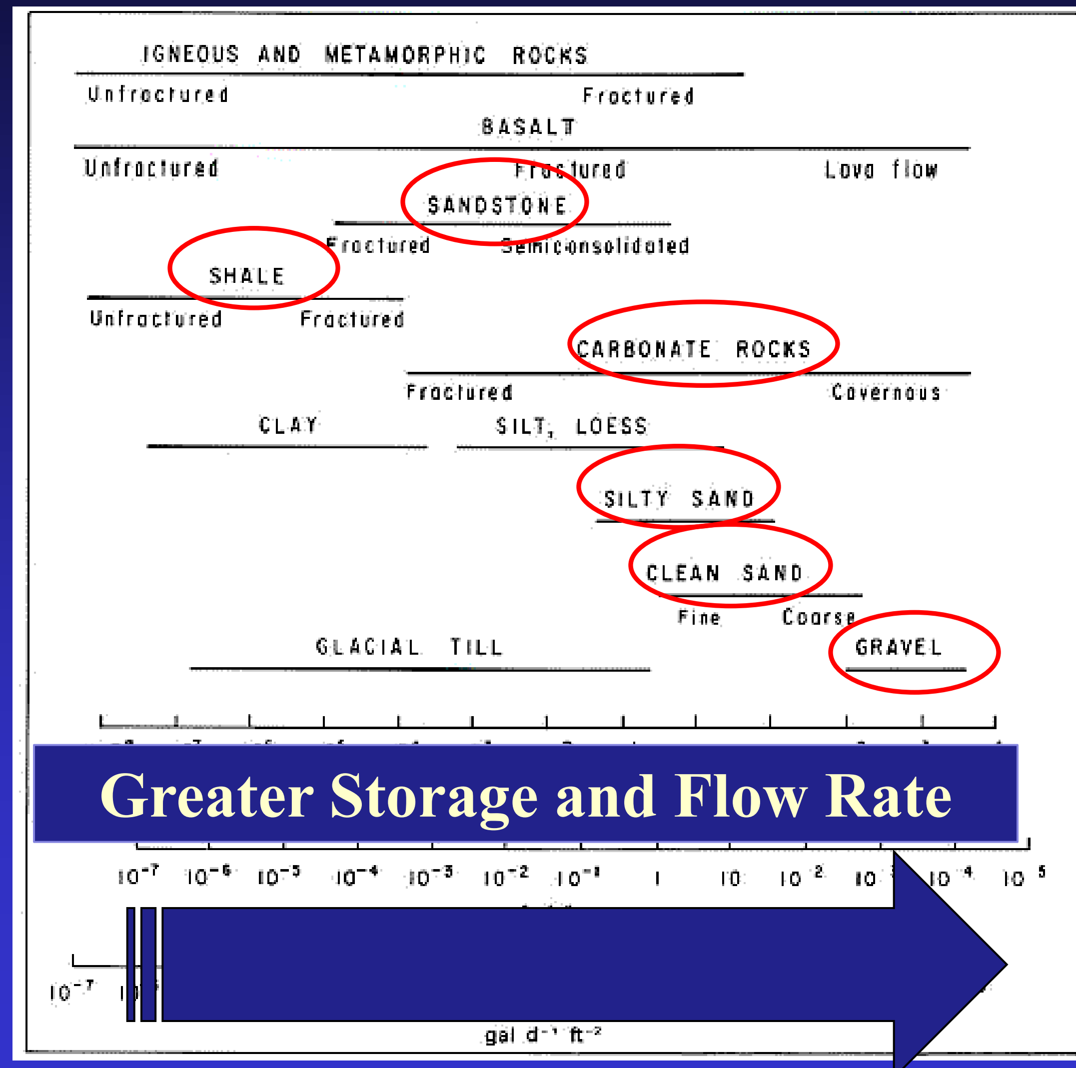
Intergranular



Fracture

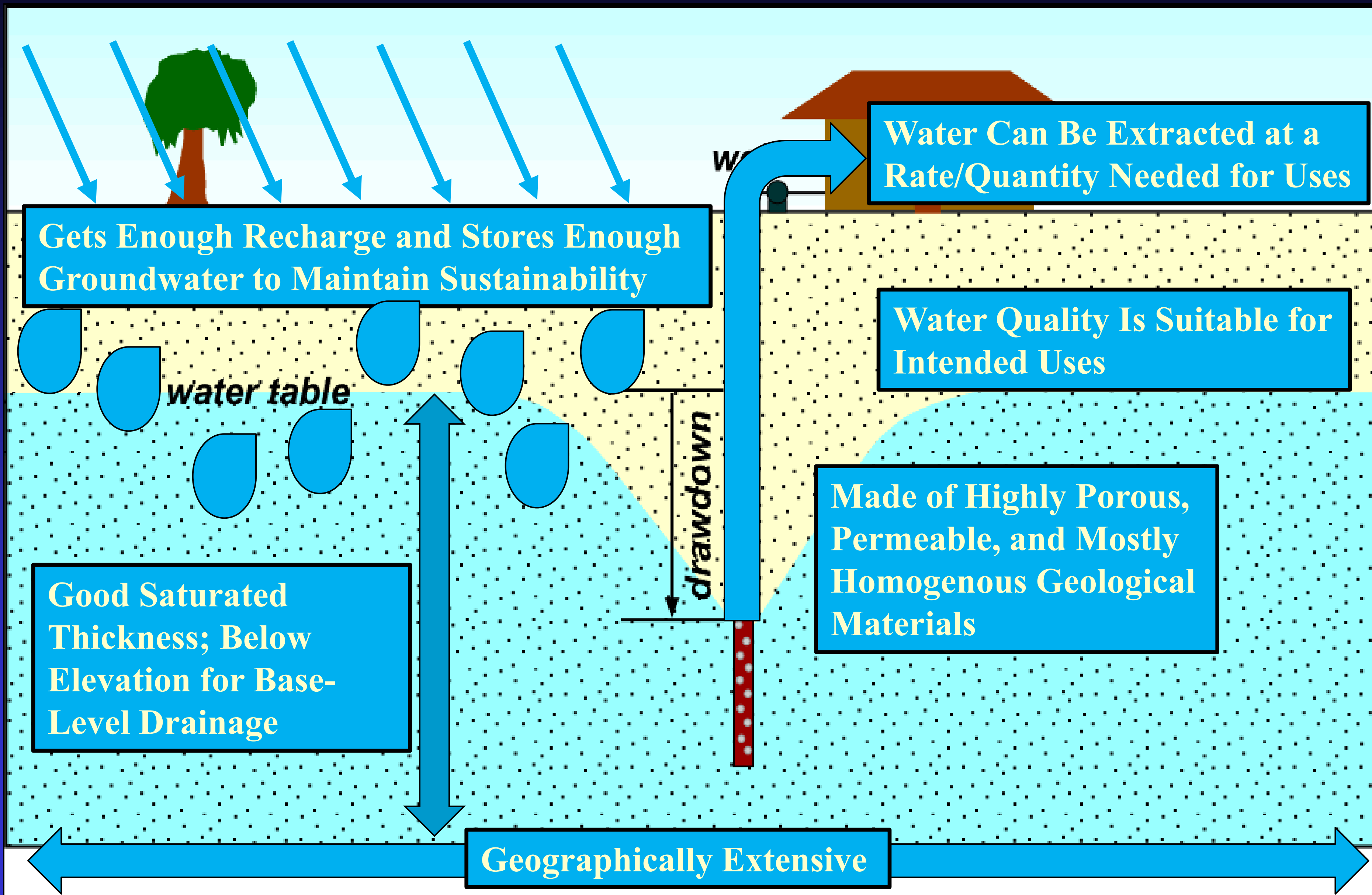


Solution (Karstic)

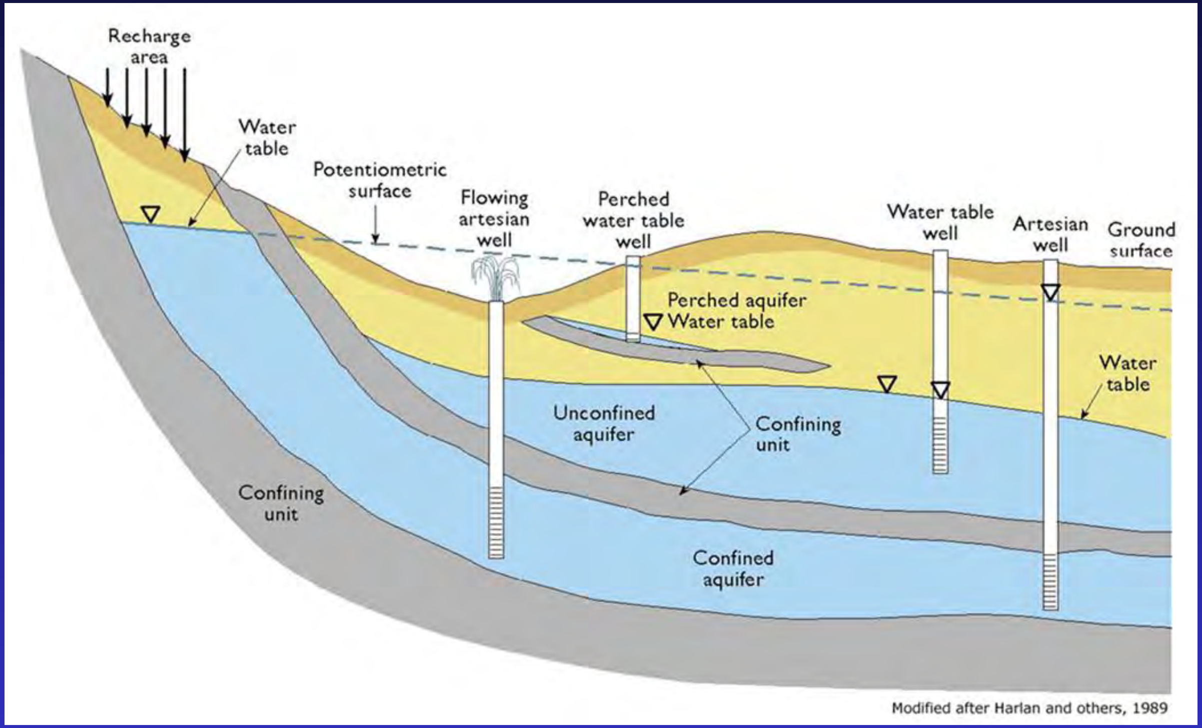


A Look At Fracture and Solution Permeability In Limestone Well in Elizabethtown, Ky

Characteristics of an "Ideal" or Good Aquifer

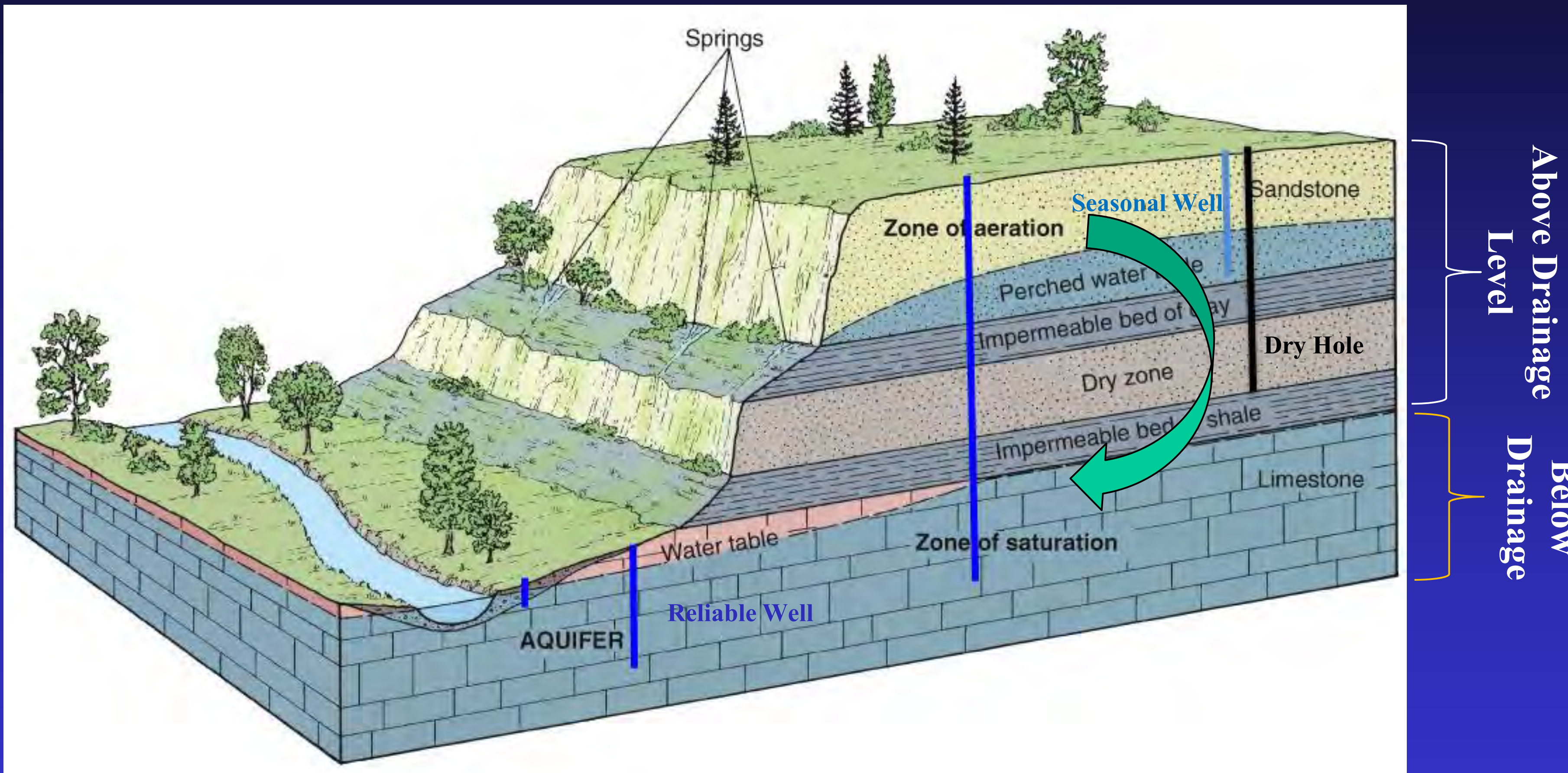


In Reality Aquifers are Zones Within Complex Groundwater Flow Systems and Characteristics Vary



Groundwater Availability depends on What Parts of the System a Well Penetrates, the Capture Zone or Contributing Area of the Well (or Spring) and What are the Local and Regional Hydrogeologic Factors That Control Groundwater Recharge, Storage, and Flow.

In Ky Layered Stratigraphy and Topography Affect Groundwater Occurrence and Availability



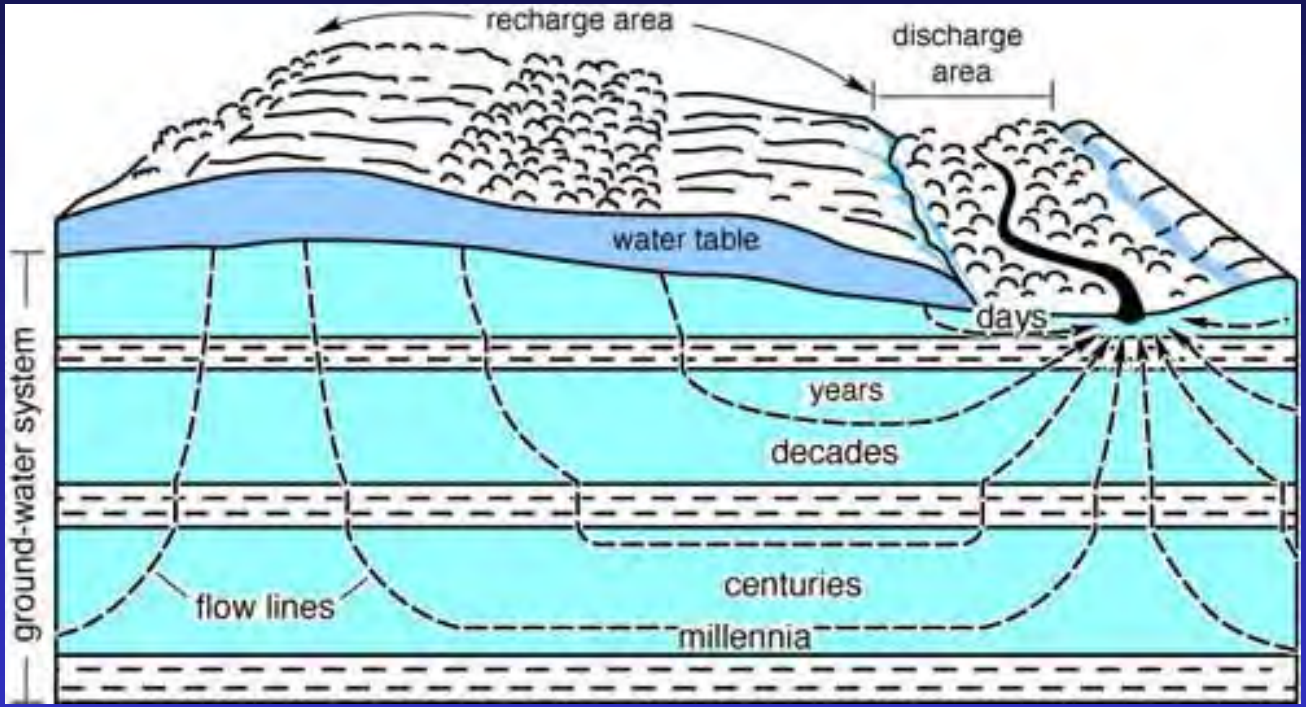
Above drainage, aquifers are more likely to be geographically and hydrologically isolated, and have limited recharge area.

Groundwater Moving at Different Rates and Along Different Flow Paths Affects Groundwater Recharge, Residence Time, and Groundwater Quality

Recharge may occur at Different Time Scales

Less Recharge is Available to Deeper Aquifers

If Withdrawal Rates are Greater than Recharge Rates, Aquifer May be Depleted (True Regardless of Depth)



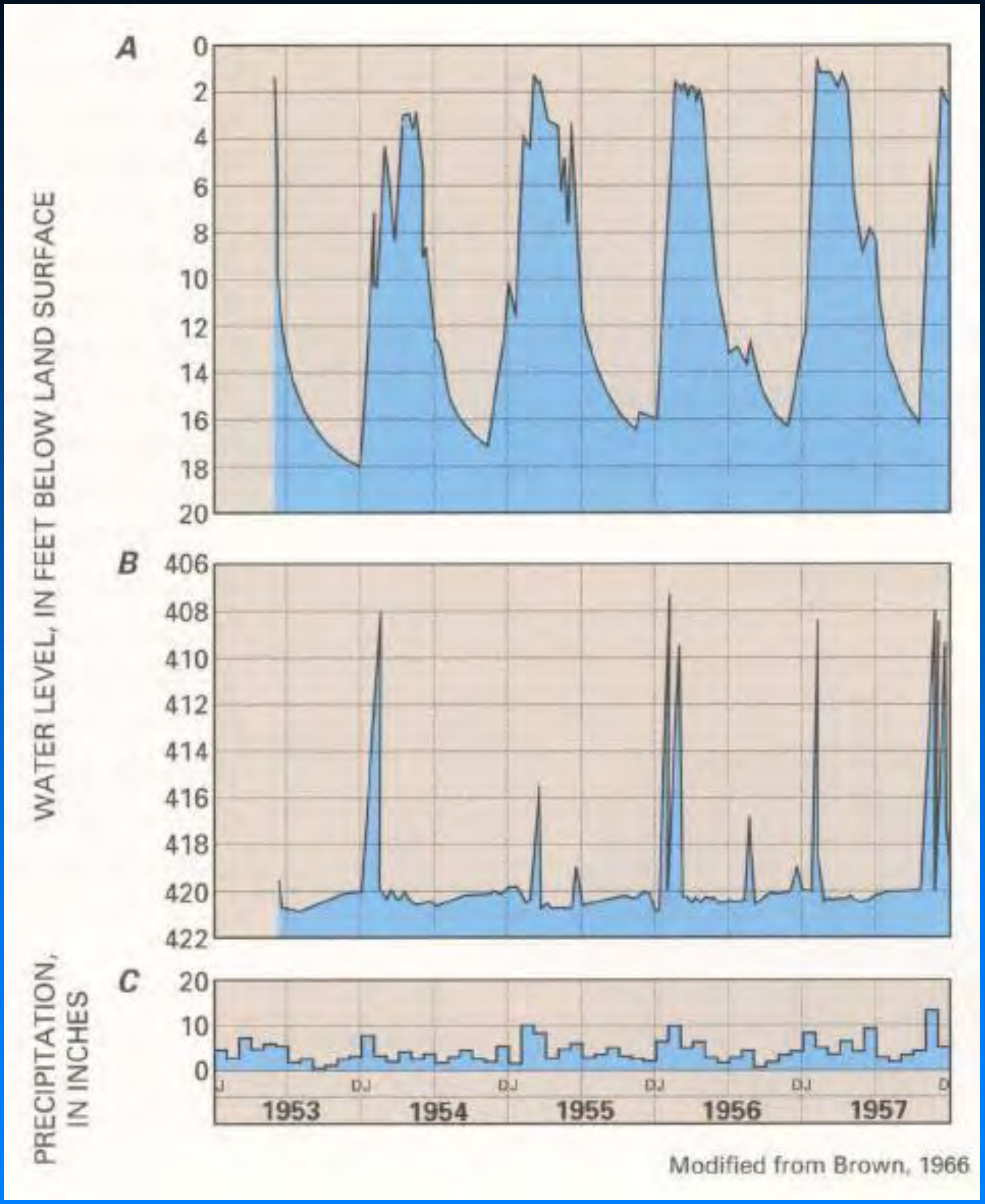
GW Flow Paths and Residence Times Also Affect Vulnerability of Aquifer (and Wells) to Contamination.

Longer time of Rock Interaction Between Water and Rock Results in Increased Dissolved Mineral Content

Water Levels and Response to Precip Recharge Varies In Wells Depending on Aquifer Hydraulic/ Hydrogeologic Conditions

A: Fractured Sandstone aquifer—rapid recharge, slower drainage.

B: Karst Limestone aquifer—rapid recharge and drainage ("flashy" response).



Kentucky Aquifers

Kentucky is a Topographically and Geologically Diverse State.

- Aquifers are equally diverse.

Geological Materials that Serve as Aquifers include:

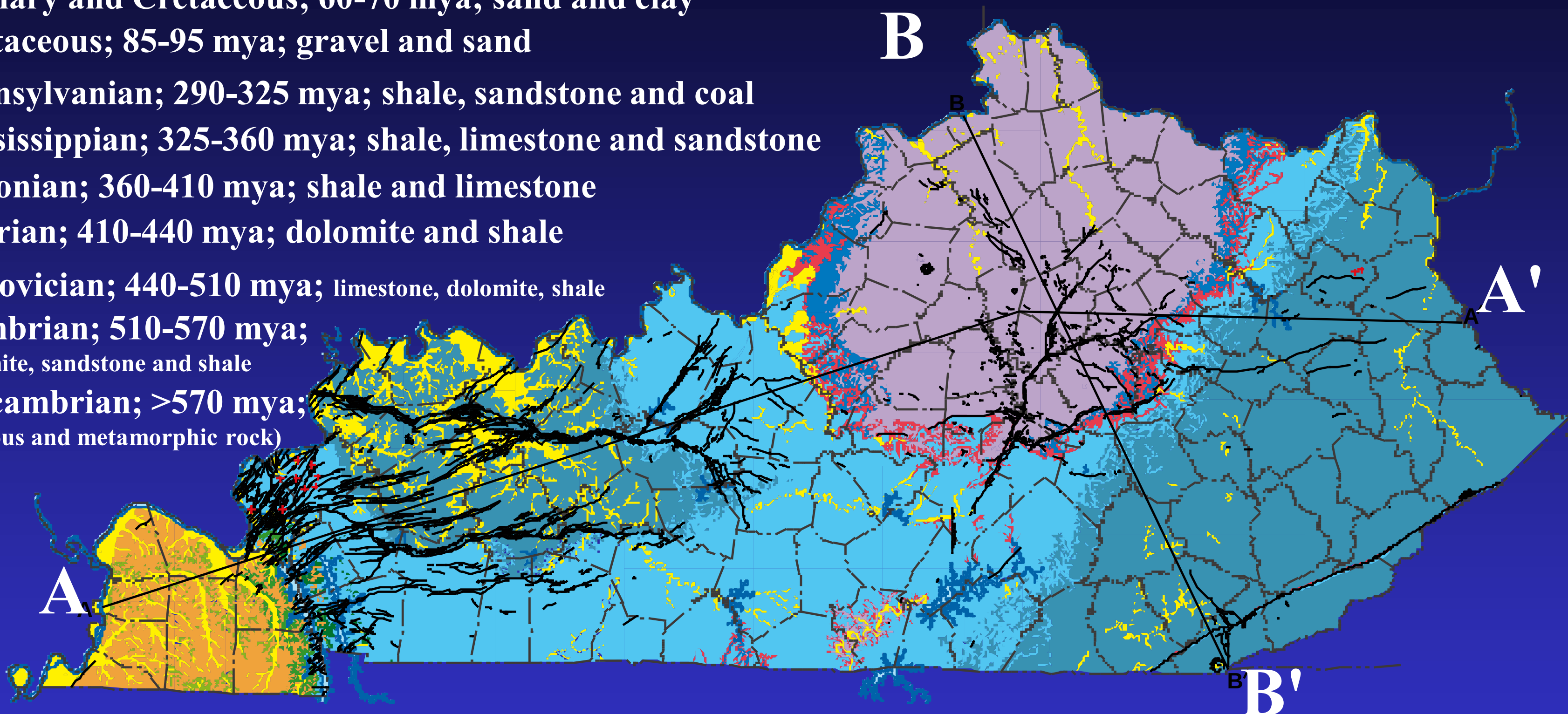
- Unconsolidated Sand and Gravel Deposits.
- Fractured Sandstones, Shales or Siltstones, and Coal.
- Fractured and Karstic Limestone and Dolostone.

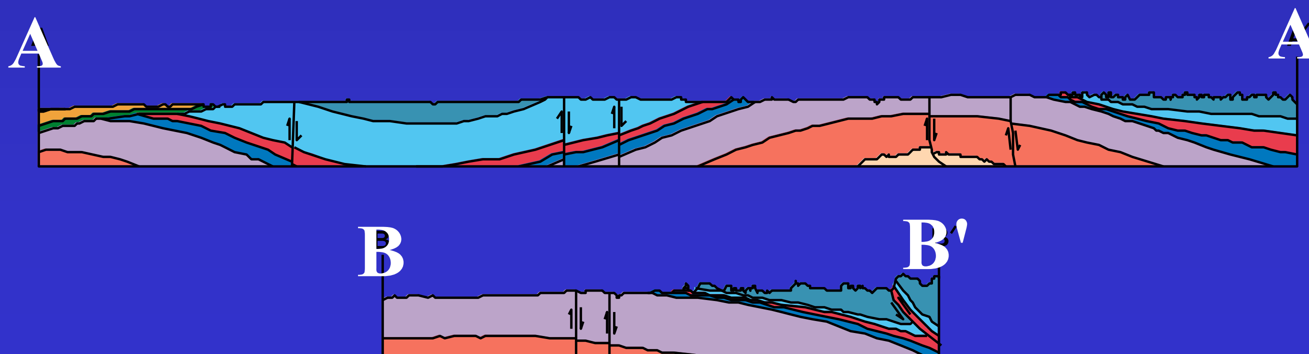
- Porosity and Permeability Varies Greatly Among these Aquifer Materials.
- Hence, Groundwater Storage, Flow, and Availability Varies Greatly Depending on the Occurrence and "Arrangements" of these Aquifer Materials.

- Natural Groundwater Quality is Also Highly Variable.

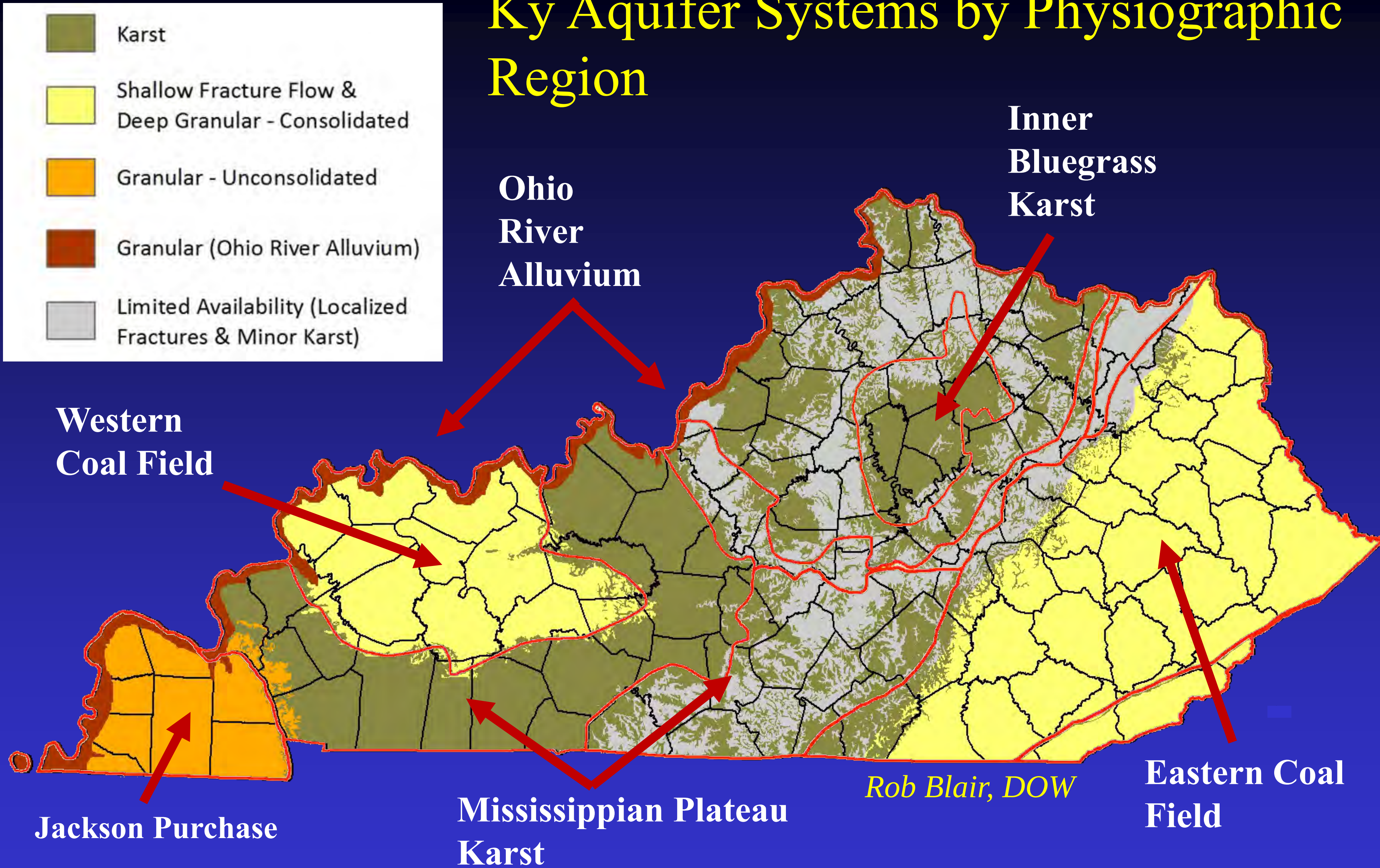
Geologic Map of Kentucky

- Quaternary; 2 mya; sand, clay, gravel
- Quaternary and Tertiary; 1-5 mya; gravel and sand
- Tertiary; 30 mya; clay and sand
- Tertiary and Cretaceous; 60-70 mya; sand and clay
- Cretaceous; 85-95 mya; gravel and sand
- Pennsylvanian; 290-325 mya; shale, sandstone and coal
- Mississippian; 325-360 mya; shale, limestone and sandstone
- Devonian; 360-410 mya; shale and limestone
- Silurian; 410-440 mya; dolomite and shale
- Ordovician; 440-510 mya; limestone, dolomite, shale
- Cambrian; 510-570 mya; dolomite, sandstone and shale
- Precambrian; >570 mya; (igneous and metamorphic rock)

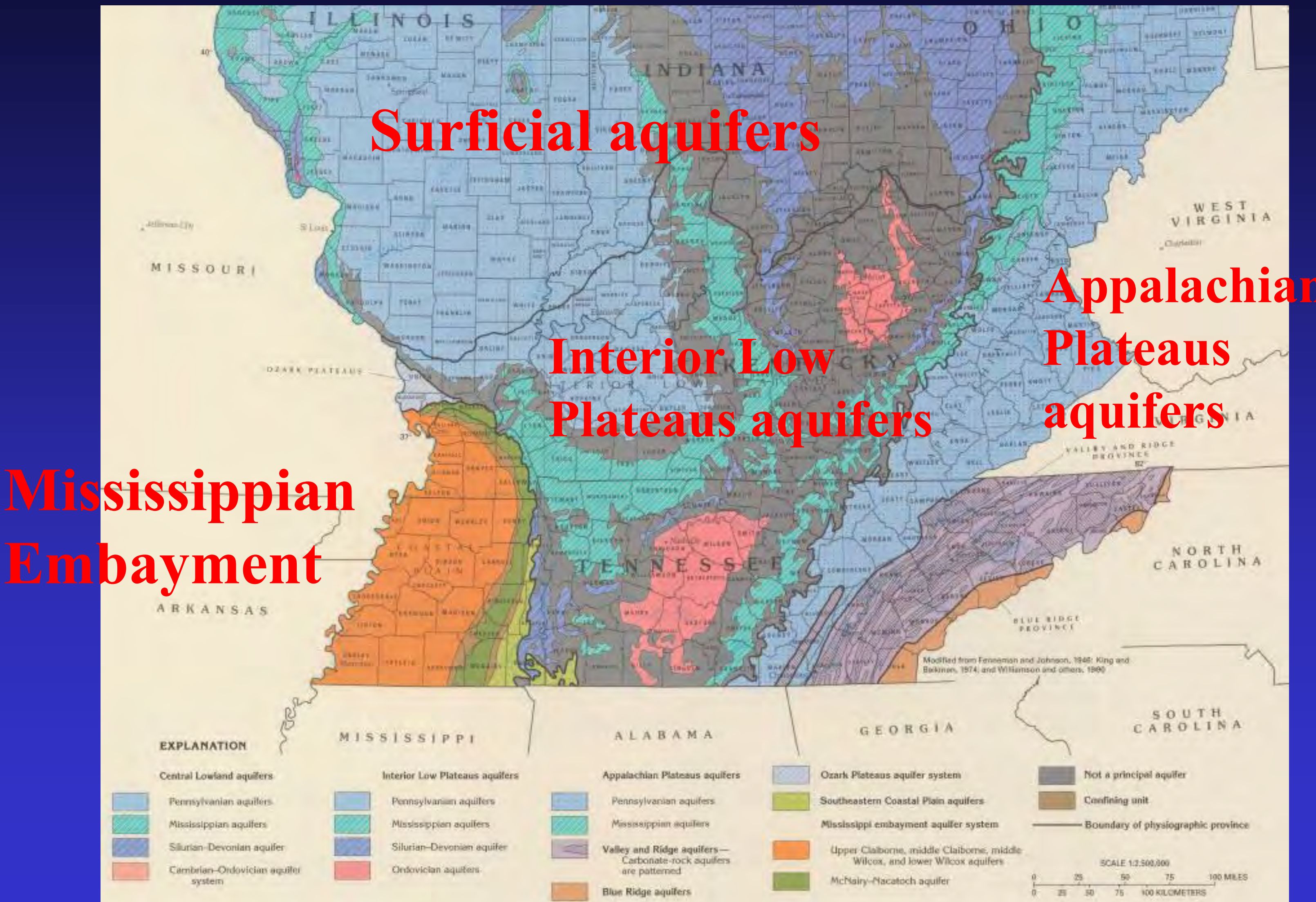




Ky Aquifer Systems by Physiographic Region

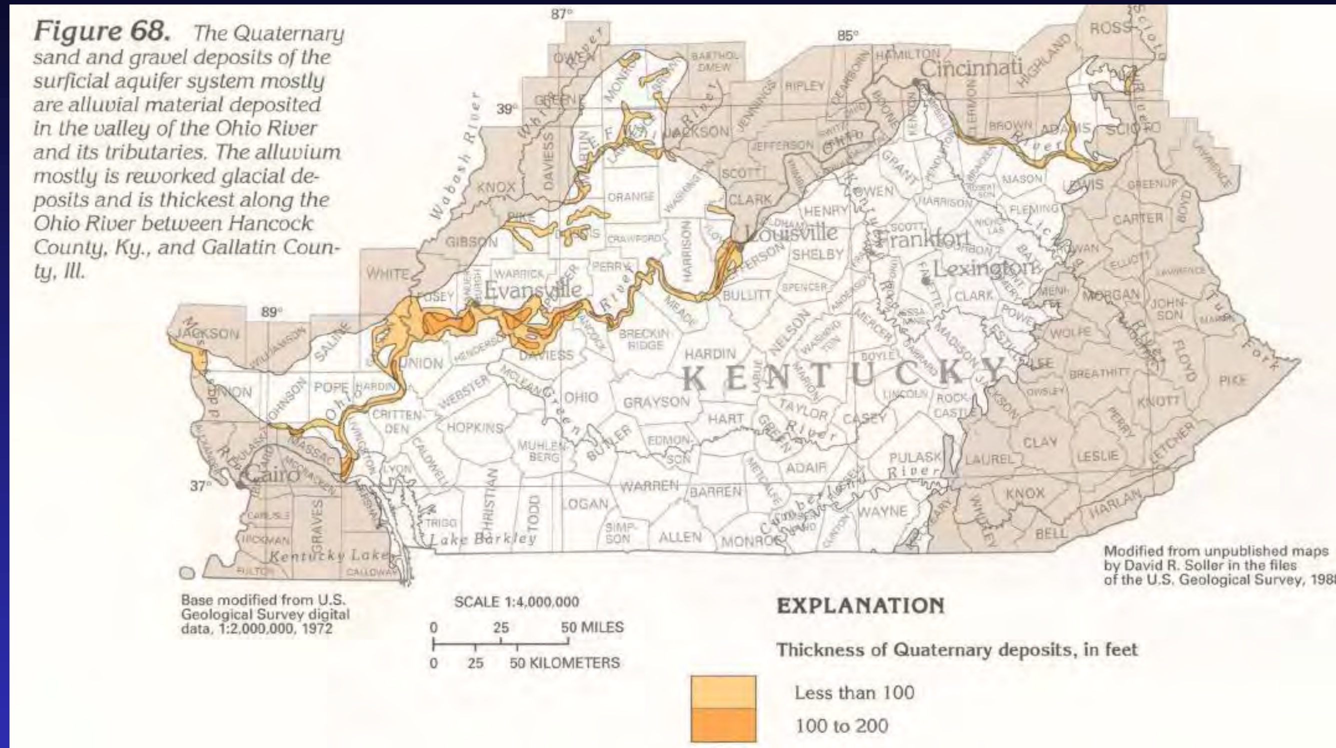


Principle Aquifers of the United States—
USGS HA 730-K Seg.10 (Lloyd and Lyke, 1995)

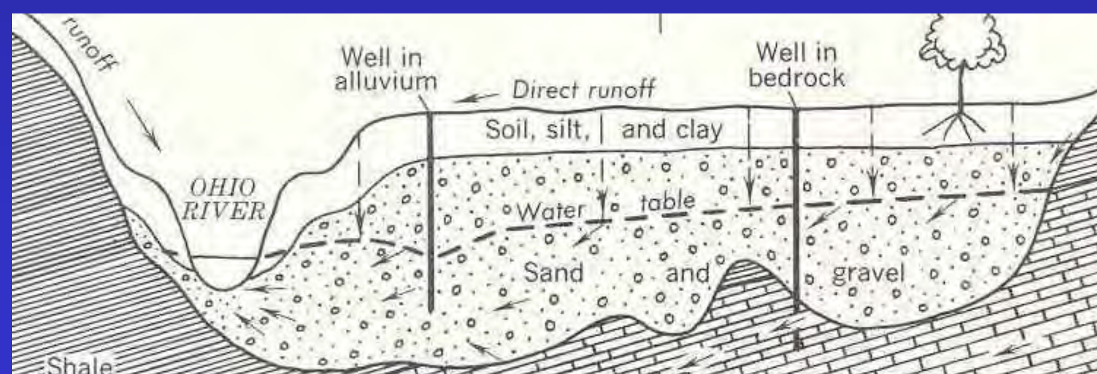


Ohio River Alluvial Aquifer

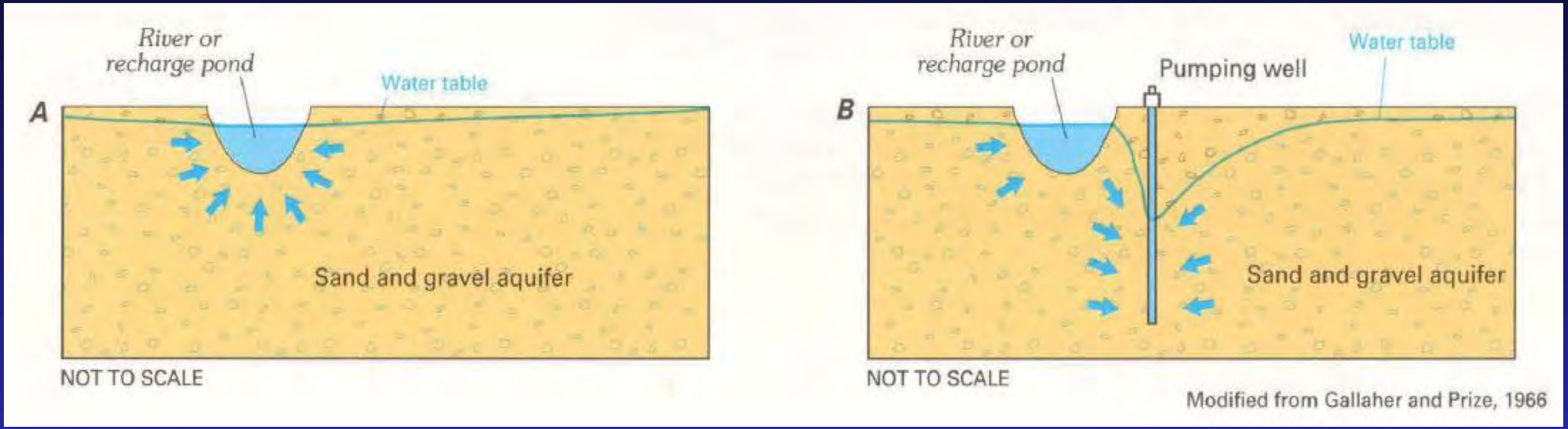
Highly productive unconsolidated sand and gravel deposits along Ohio and lower Green River.



Thicker deposits of alluvium along many Ky streams serve as important local aquifers.



Riverbank Infiltration and Pumping-Induced Recharge from Streams

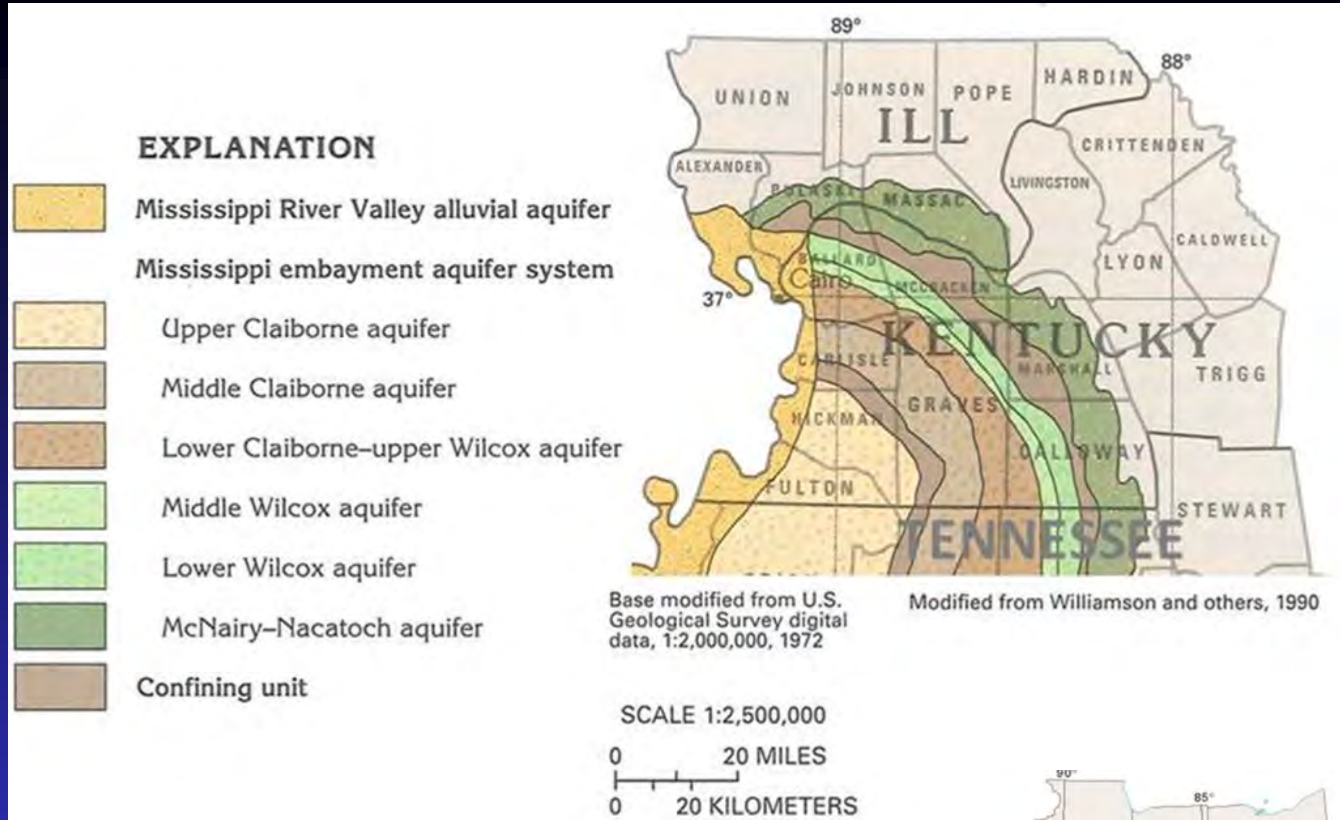


Horizontal-Collector or Ranney Well Construction

Louisville Water Company Pilot-Scale Horizontal Collector Well

Jackson Purchase

Mississippian Embayment aquifer system



Highly Productive Layered Aquifer System of Semi-Consolidated Sands and Alternating Clayey Confining Layers.

Part of Much Larger Mississippian Embayment Regional Aquifer System (MERAS)

Two of the Major Aquifer Zones in the JPA

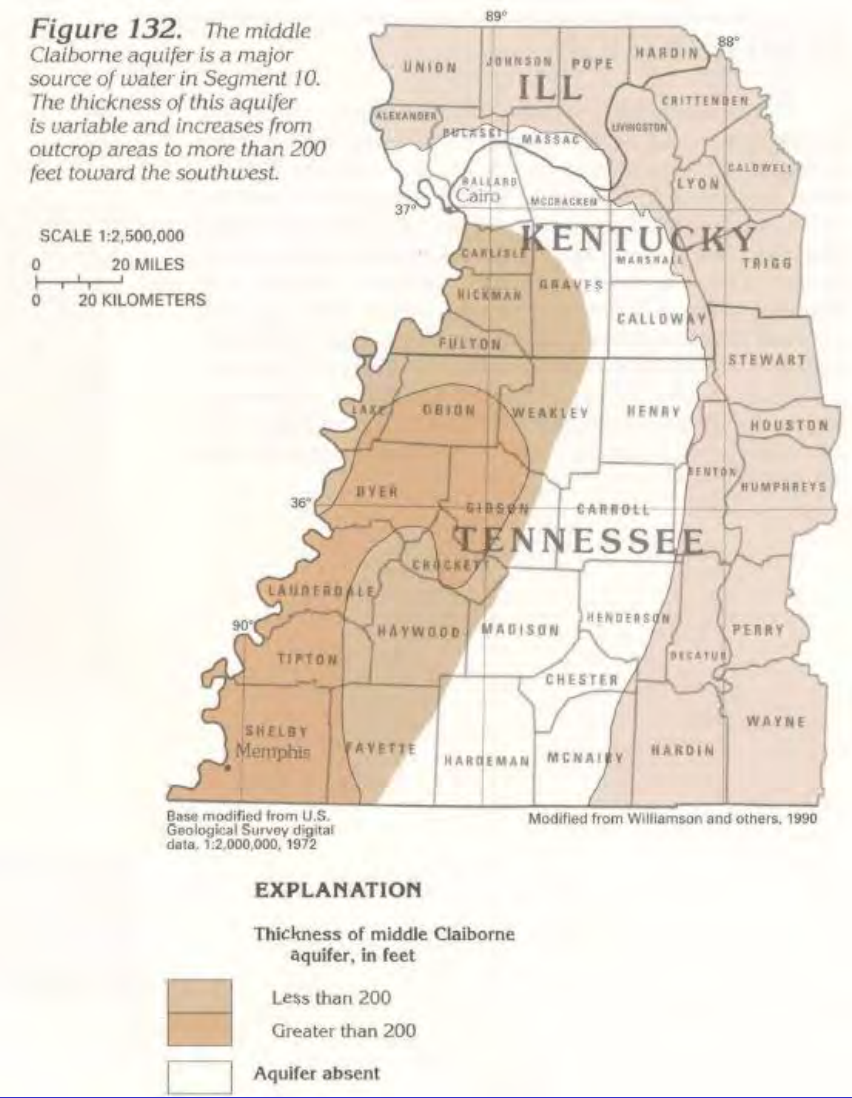


Figure 132. The middle Claiborne aquifer is a major source of water in Segment 10. The thickness of this aquifer is variable and increases from outcrop areas to more than 200 feet toward the southwest.

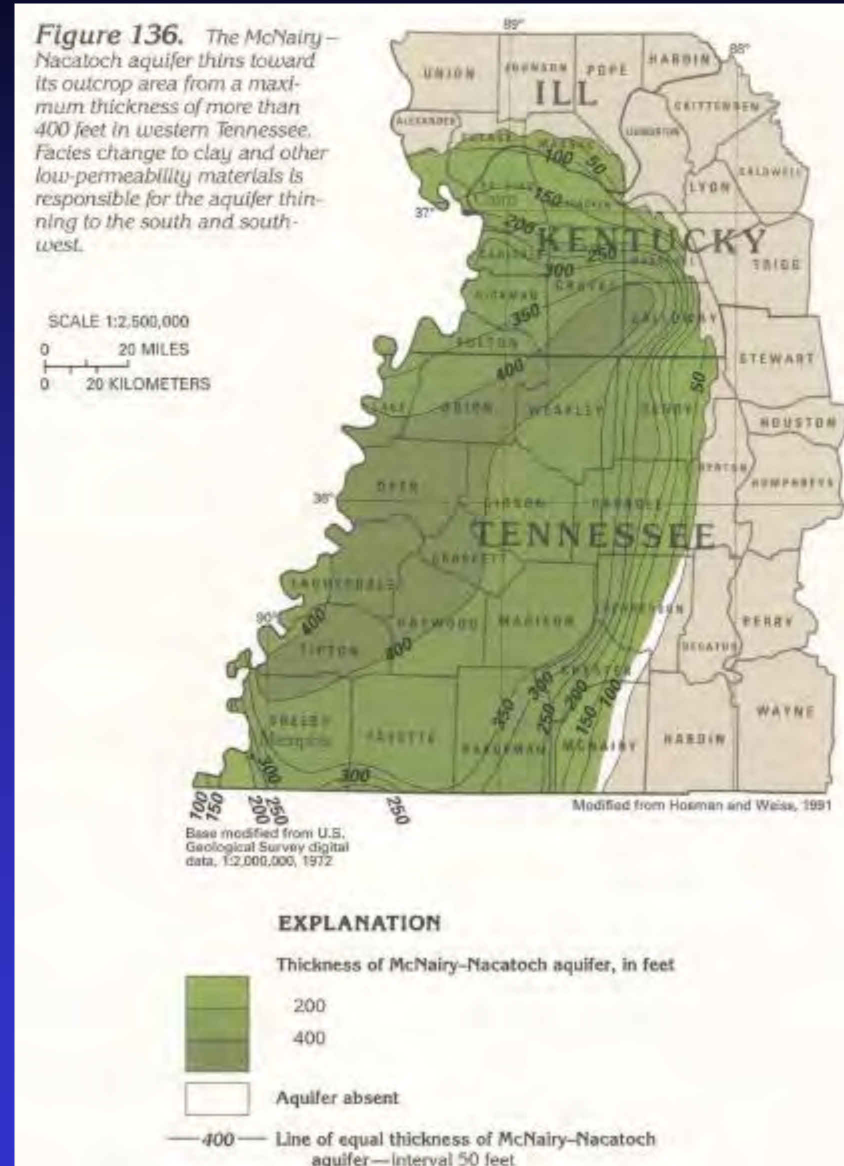


Figure 136. The McNairy–Nacatoch aquifer thins toward its outcrop area from a maximum thickness of more than 400 feet in western Tennessee. Facies change to clay and other low-permeability materials is responsible for the aquifer thinning to the south and southwest.

Purchase Area Aquifers Are Among State's Most Productive and Are of Interest for High-Yield Irrigation Wells

Aquifer	Thickness (ft)	Hydraulic Conductivity (gpd/ft^2)	Transmissivity (gpd/ft)	Specific Capacity (gpm/ft)	Well Yields (gpm)
Mississippi River Valley Alluvial Aquifer	0-100[1] 0-200[2]	2,000[6]	170,000[6]		> 1000[2,3]
Upper Claiborne Aquifer	0-300[1]				≤ 300[2]
Middle Claiborne Aquifer	0-200[1] 0-400[2]	2,000[5]	300,000[5]	54[5]	> 1000[2,3]
Lower Claiborne-Upper Wilcox Aquifer	0-400[1]				
Middle Wilcox Aquifer	0-200[1]				< 100[2]
Lower Wilcox Aquifer	0-200[1]			12[5]	< 100[2]
McNairy-Nacatoch Aquifer	0-400[1]		32,000[4]	1-27[4]	> 1000[2,3]

[1]Lloyd and Lyke, 1995
[2]Davis and others, 1971
[3]Davis and others, 1973
[4]Boswell and others, 1965
[5]Hosman and others, 1968
[6]Boswell and others, 1968 (Data used from Dyer, Tennessee.)

Interior Low Plateaus Mississippian aquifers

Karst limestone aquifers, capped in places with fractured sandstones.

Table 1. *Yields of wells completed in the Mississippian aquifers commonly range from 2 to 50 gallons per minute and locally exceed 1,000 gallons per minute*

[Data source: U.S. Geological Survey, 1985]

State	Yield of wells completed in Mississippian aquifers (gallons per minute)	
	Common range	May exceed
Illinois	5 to 25	1,000
Indiana	2 to 25	100
Kentucky	2 to 10	500
Tennessee	5 to 50	400

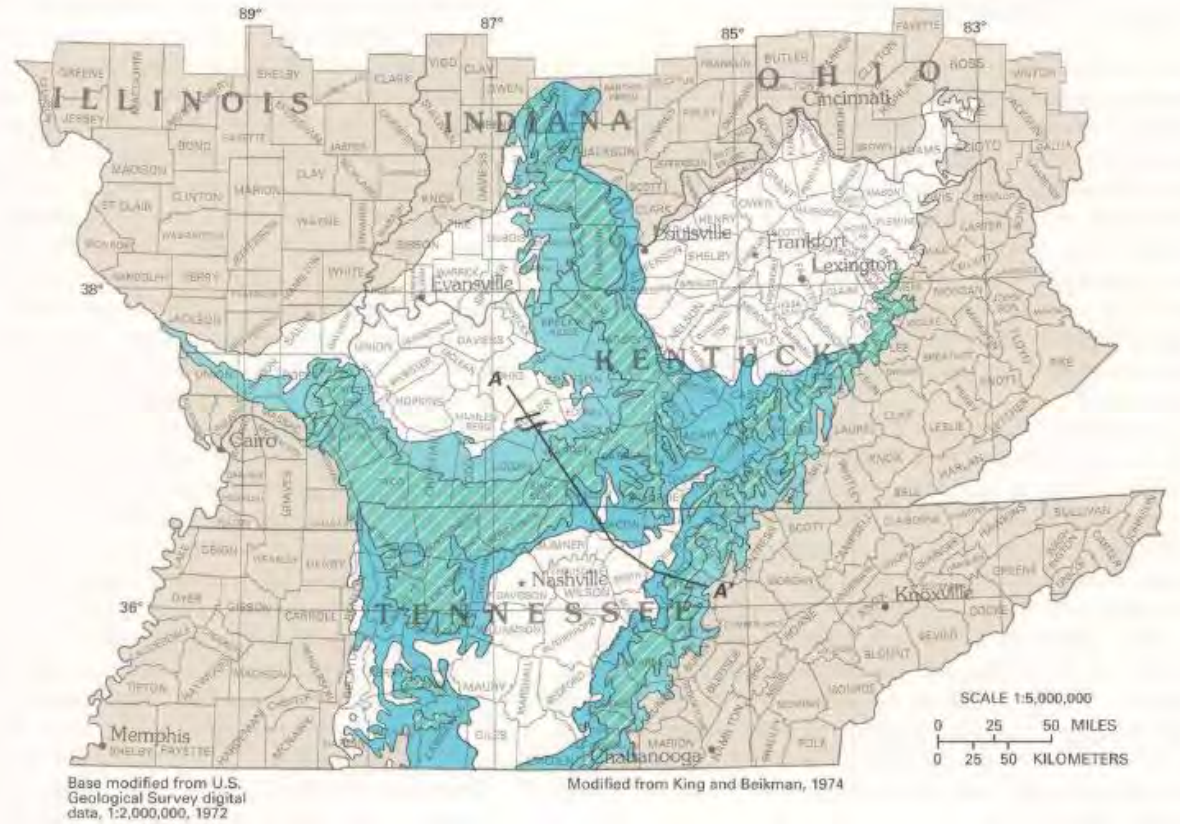


Figure 78. *Rocks of Mississippian age underlie a large part of the Interior Low Plateaus Province in Segment 10. The principal aquifers in these rocks primarily are in the Upper Mississippian limestones.*

EXPLANATION

Cross-section of Mammoth Cave Area Limestone and Sandstone Aquifers

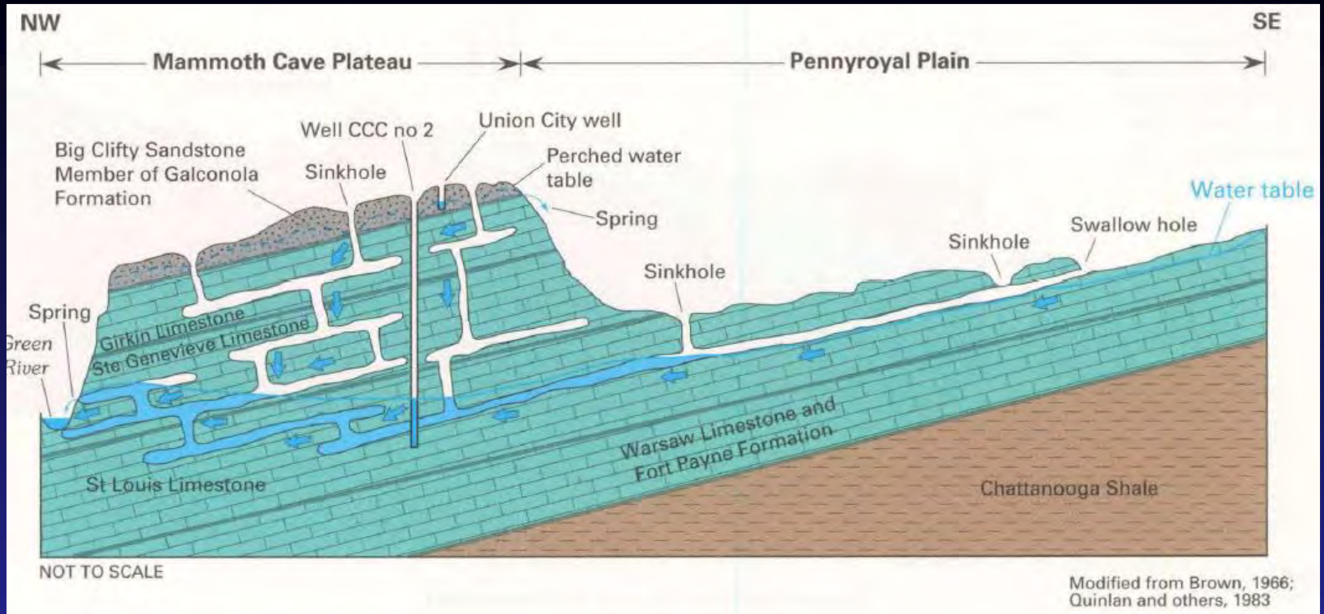
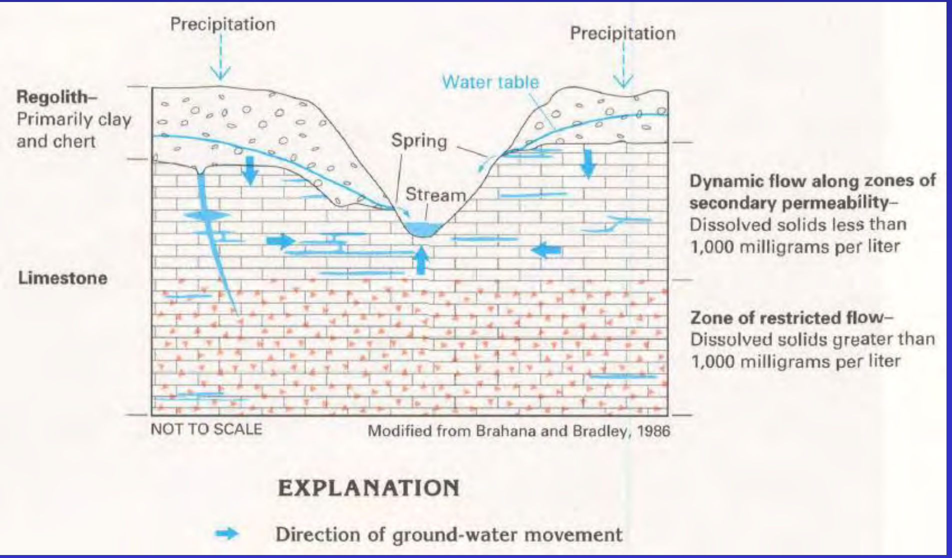
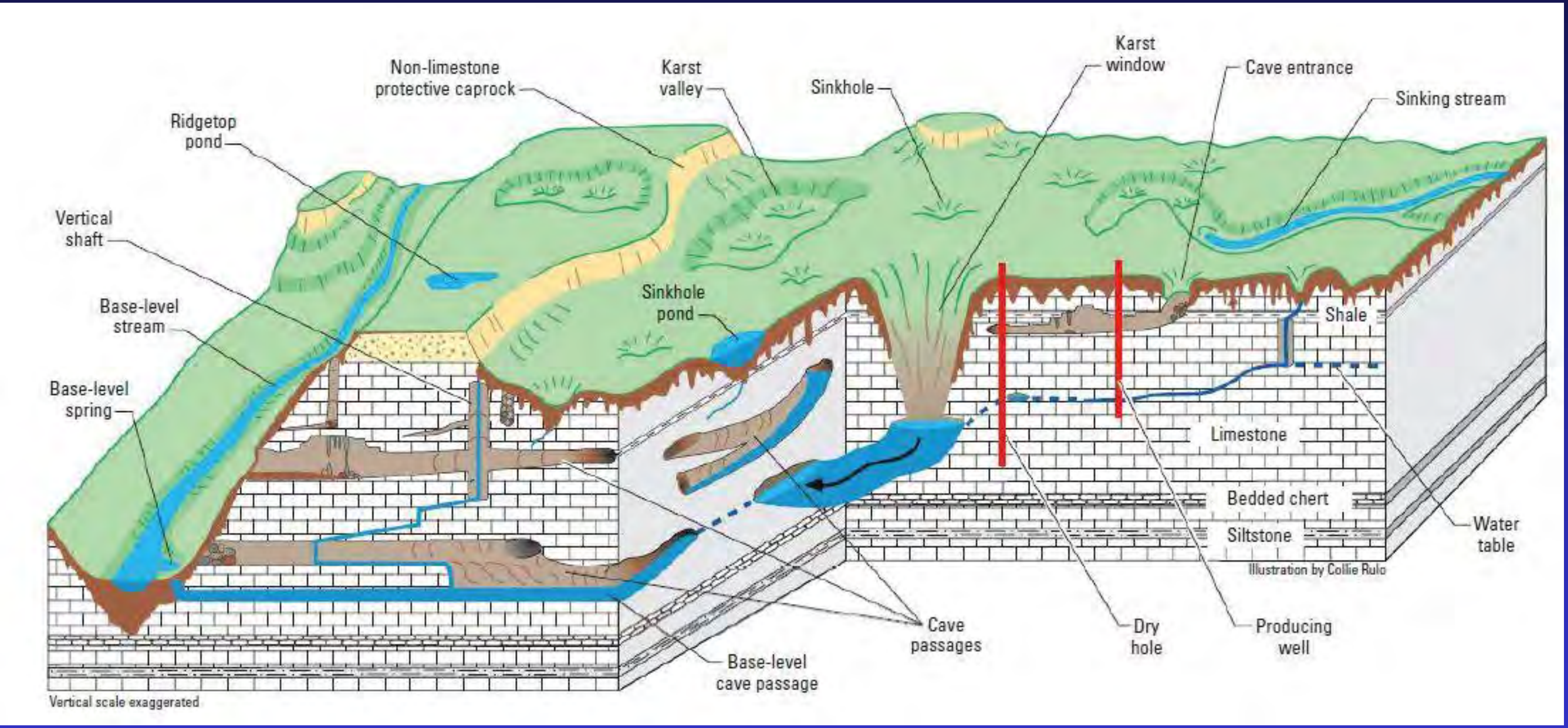


Figure 86. *The Ste. Genevieve and the St. Louis Limestones that underlie the Mammoth Cave Plateau contain a well-developed network of solution openings. These openings were formed by dissolution of the limestones as ground water moved along bedding planes and fractures from recharge areas to points of discharge.*

Right: Diagram to illustrate change in depth of fresh water circulation and water quality in limestone bedrock.



Hydrogeologic Setting and Features Typical of Mississippian Low Plateau Karst



Mississippian Karst Notable for Large Springs

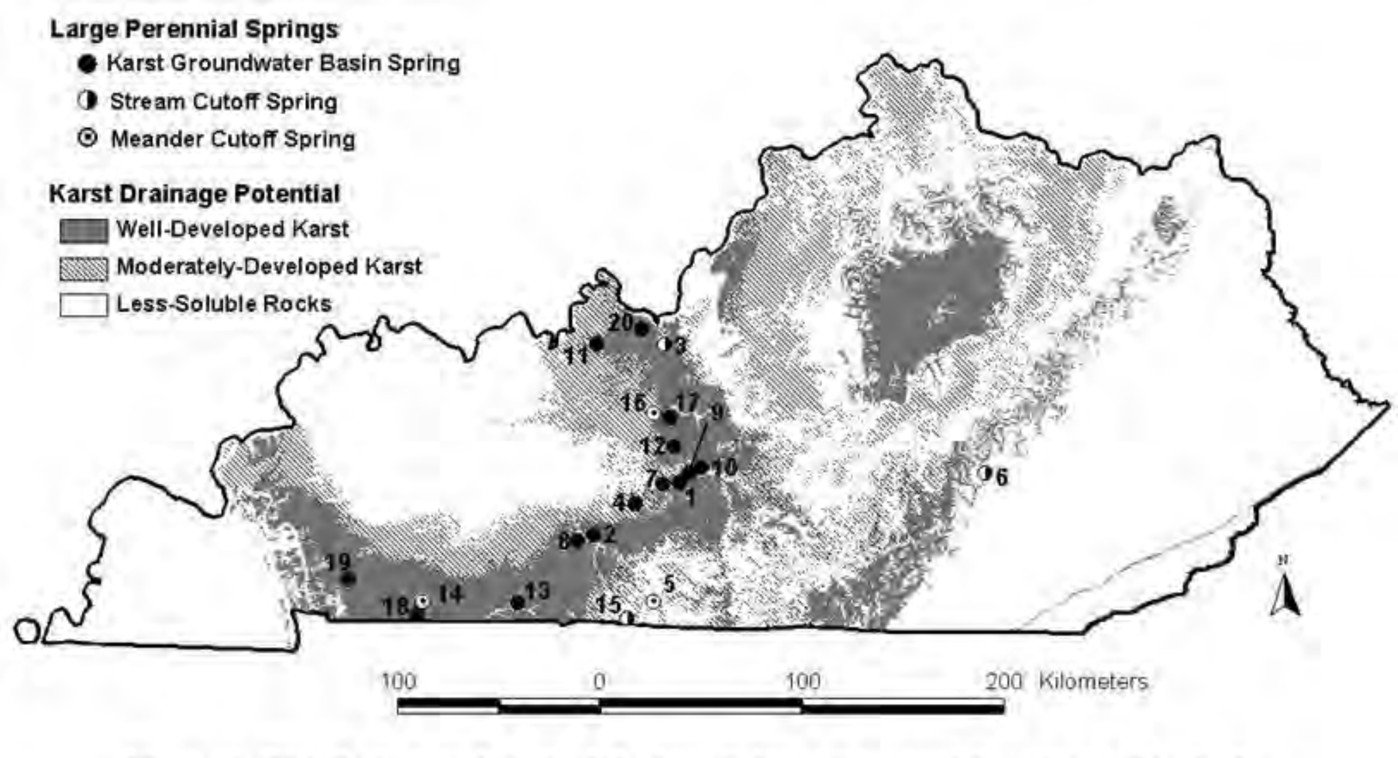


Figure 4: Distribution and rank of the twenty largest perennial springs in Kentucky

"Spring flows were ranked by minimum annual discharge, which ranged from 0.15-0.68 m^3/s." (2,378 – 10,780 gpm)

--Ray and Blair, 2005

Interior Low Plateaus Ordovician-Silurian-Devonian aquifers

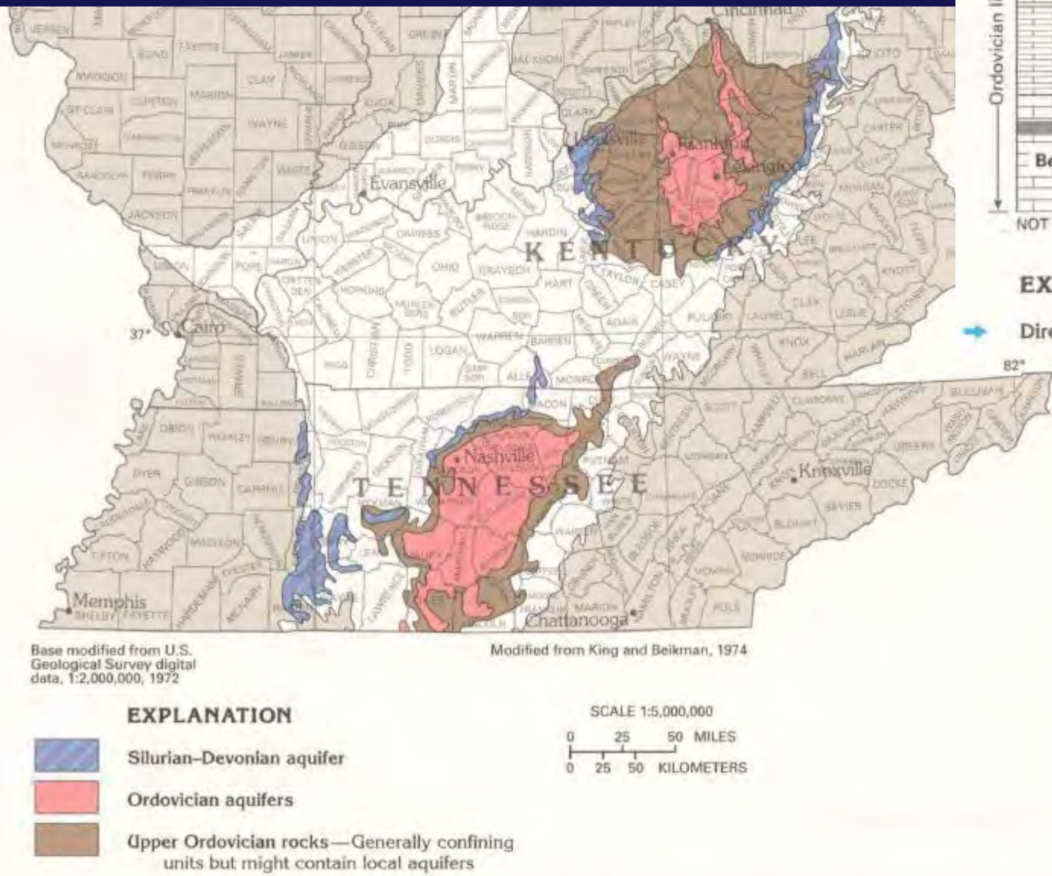
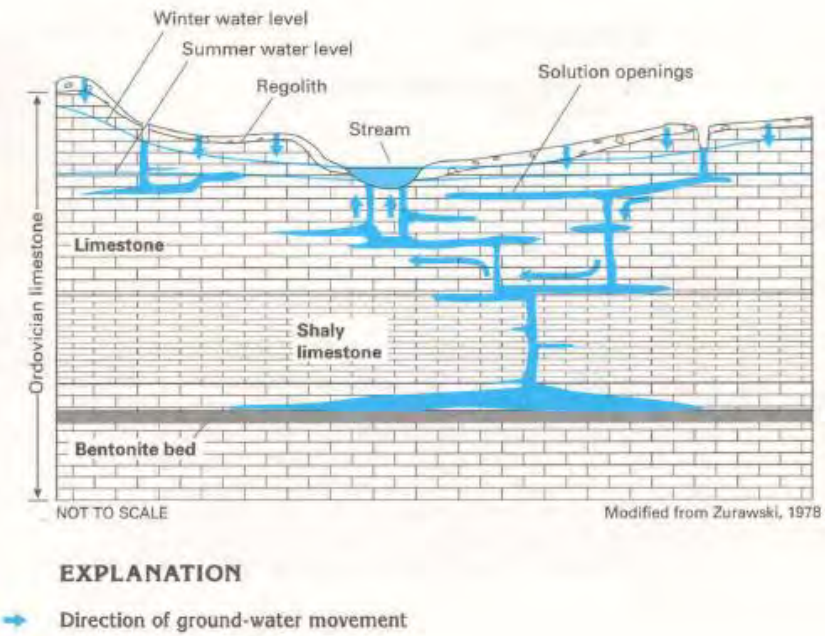


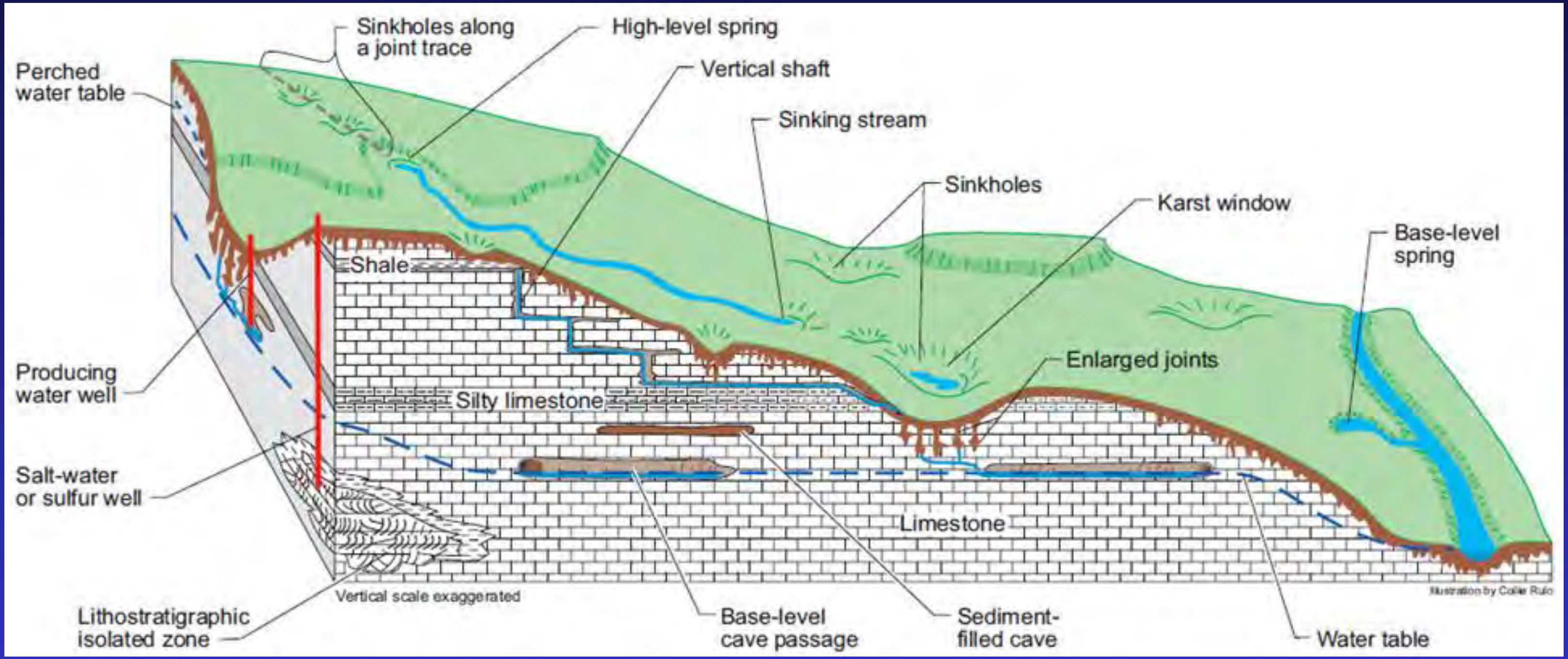
Figure 94. *Aquifers in carbonate rocks of Devonian, Silurian, and Ordovician ages underlie large parts of central Kentucky and central Tennessee in the Interior Low Plateaus Province in Segment 10. Most Upper Ordovician rocks are confining units, but some locally yield small quantities of water.*



[Data source: U.S. Geological Survey, 1985]

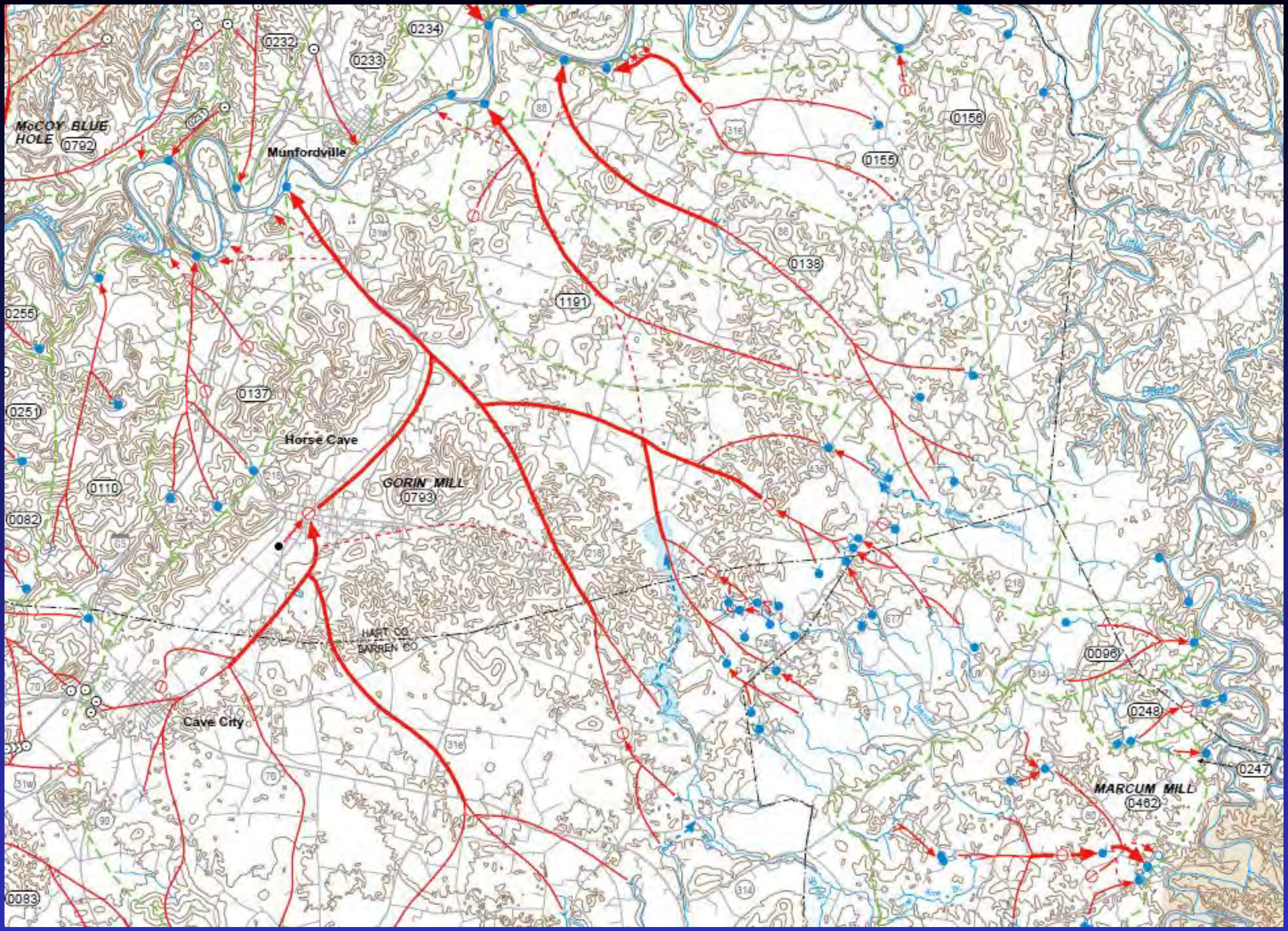
State and aquifer	Well depth below land surface (feet) Common range	May exceed
Kentucky (Ordovician limestone and dolomite)	50 to 200	300
Tennessee (Ordovician limestone and dolomite)	50 to 150	200
(Knox Group)	700 to 1,200	1,400

Hydrogeologic Features of Inner Bluegrass Karst



For comparison with Mississippian karst, springs in the IBK typically range about 0.02 - 0.33 m^3/s (269-5,386 gpm).

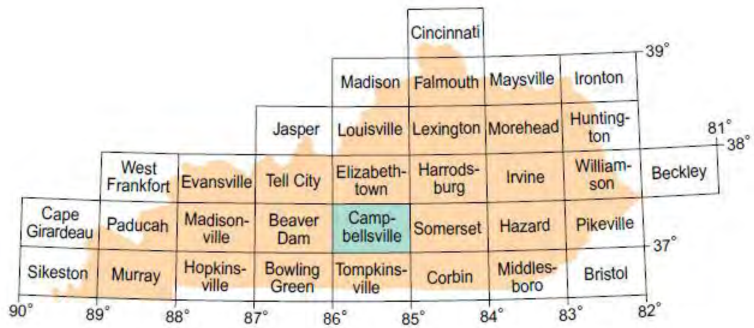
KY Karst Aquifers Are Highly Compartmentalized Into Subsurface Basins Similar to Surface Streams



Portion of the Campbellsville 30x60' quadrangle karst atlas map showing multiple karst basins.

Dye-tracer tests are used to delineate subsurface flow paths and basin boundaries.

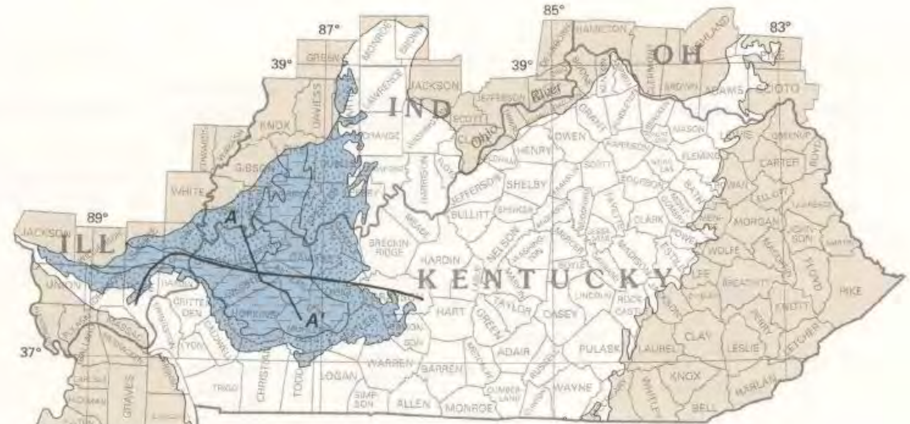
Karst Atlas maps are available for much of Kentucky and can be downloaded as .PDF files from the KGS website: http://www.uky.edu/KGS/water/research/kaatlas.htm



Locations of the 1:100,000-scale quadrangle maps covering Kentucky.
This map, the Campbellsville quadrangle, is highlighted in green.

Pennsylvanian Clastic Aquifers—Western Coal Field

Figure 73. Sandstones that form the principal aquifers in the Pennsylvanian rocks underlie northwestern Kentucky and adjacent parts of Indiana and Illinois.



SCALE 1:5,000,000
0 25 50 MILES
0 25 50 KILOMETERS

Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1972

Modified from King and Beikman, 1974

EXPLANATION

Pennsylvanian aquifers

- Generally sandstone
- Generally shale

Rough Creek Fault System—Approximately located

A——A' Line of hydrogeologic section

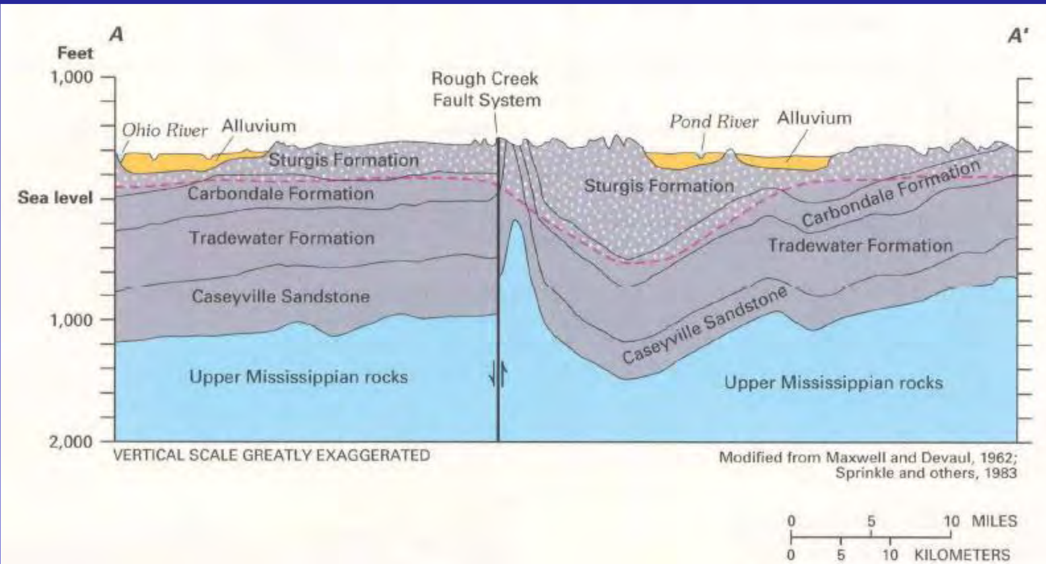


Figure 74. Pennsylvanian rocks are offset by faults in some places and are folded in other places. The depth to water with a dissolved-solids concentration of 1,000 milligrams per liter averages less than 500 feet but can be as great as 1,000 feet. The line of the section is shown in figure 73.

EXPLANATION

- Pennsylvanian rocks that contain freshwater
- Estimated line of dissolved-solids concentration equal to 1,000 milligrams per liter
- Fault—Arrows show relative vertical movement

Pennsylvanian Channel Sandstone aquifers in WKy Coal Field

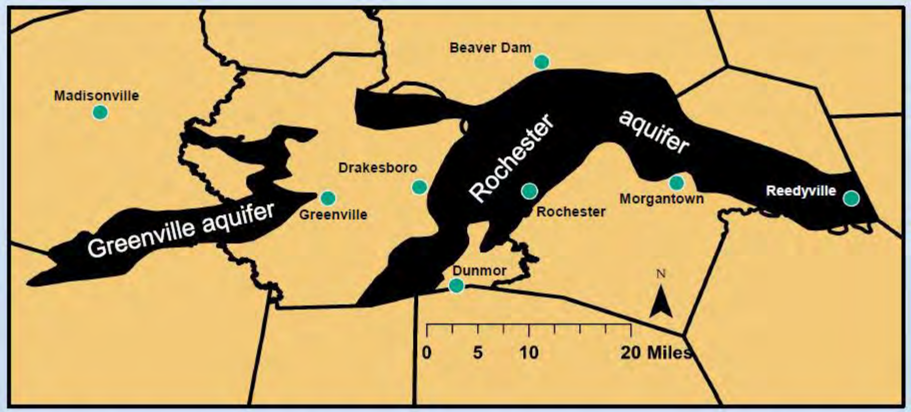
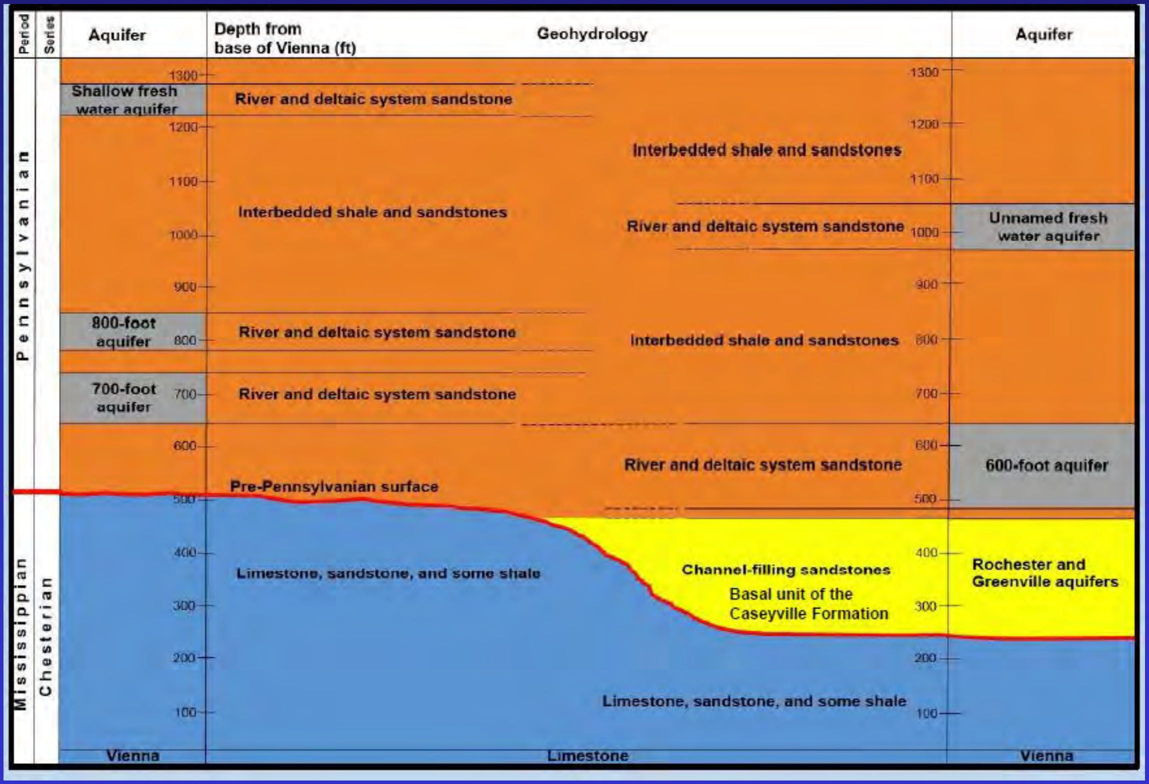
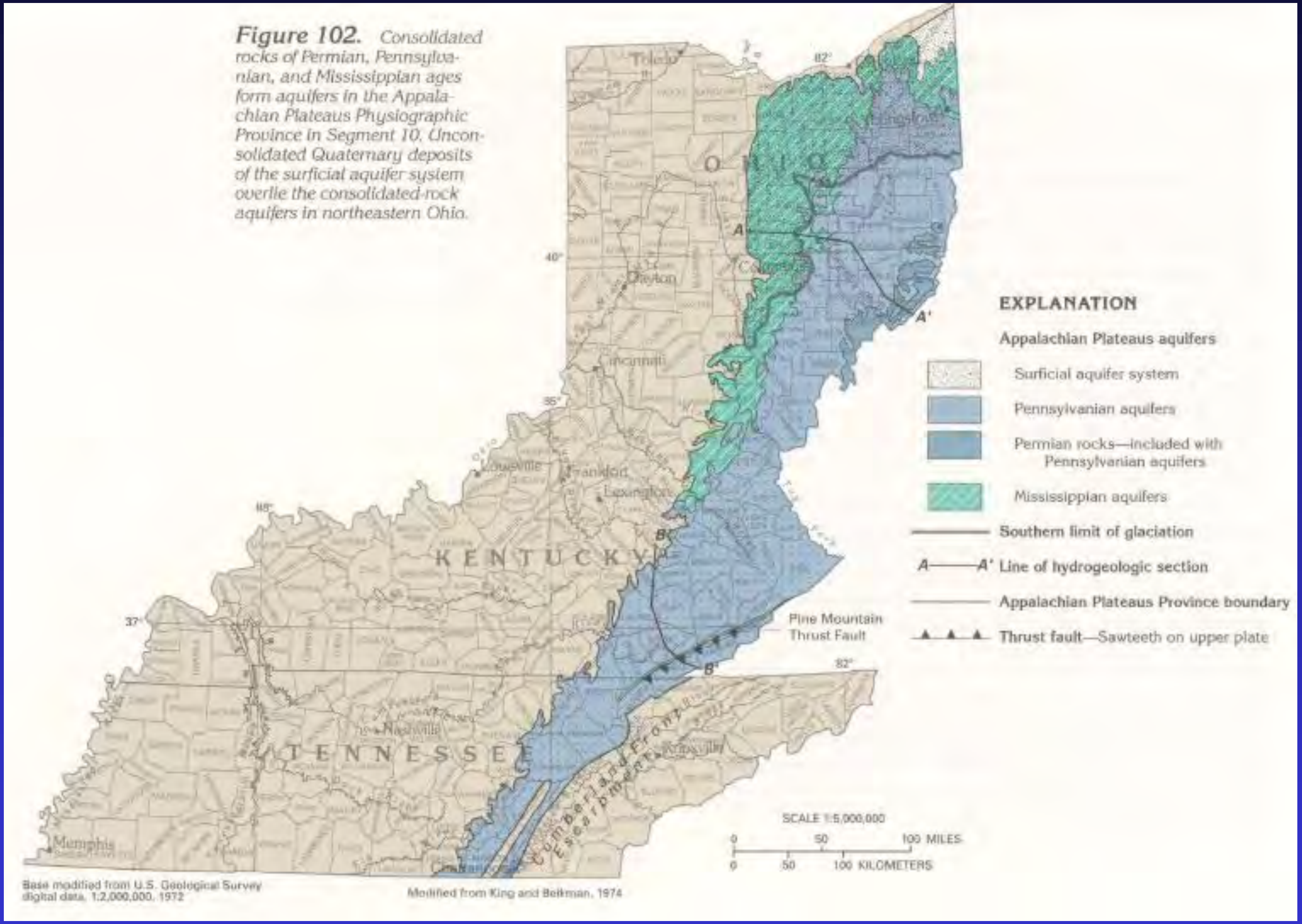


Figure 3. Distribution of the Greenville valley aquifer in relation to the Rochester valley aquifer. Modified from Davis and others (1974).



Generalized stratigraphic column showing relation of channel sandstone aquifers to other bedrock units. (Modified from Davis and others, 1974) (Illustrations courtesy of Glynn Beck, KGS).

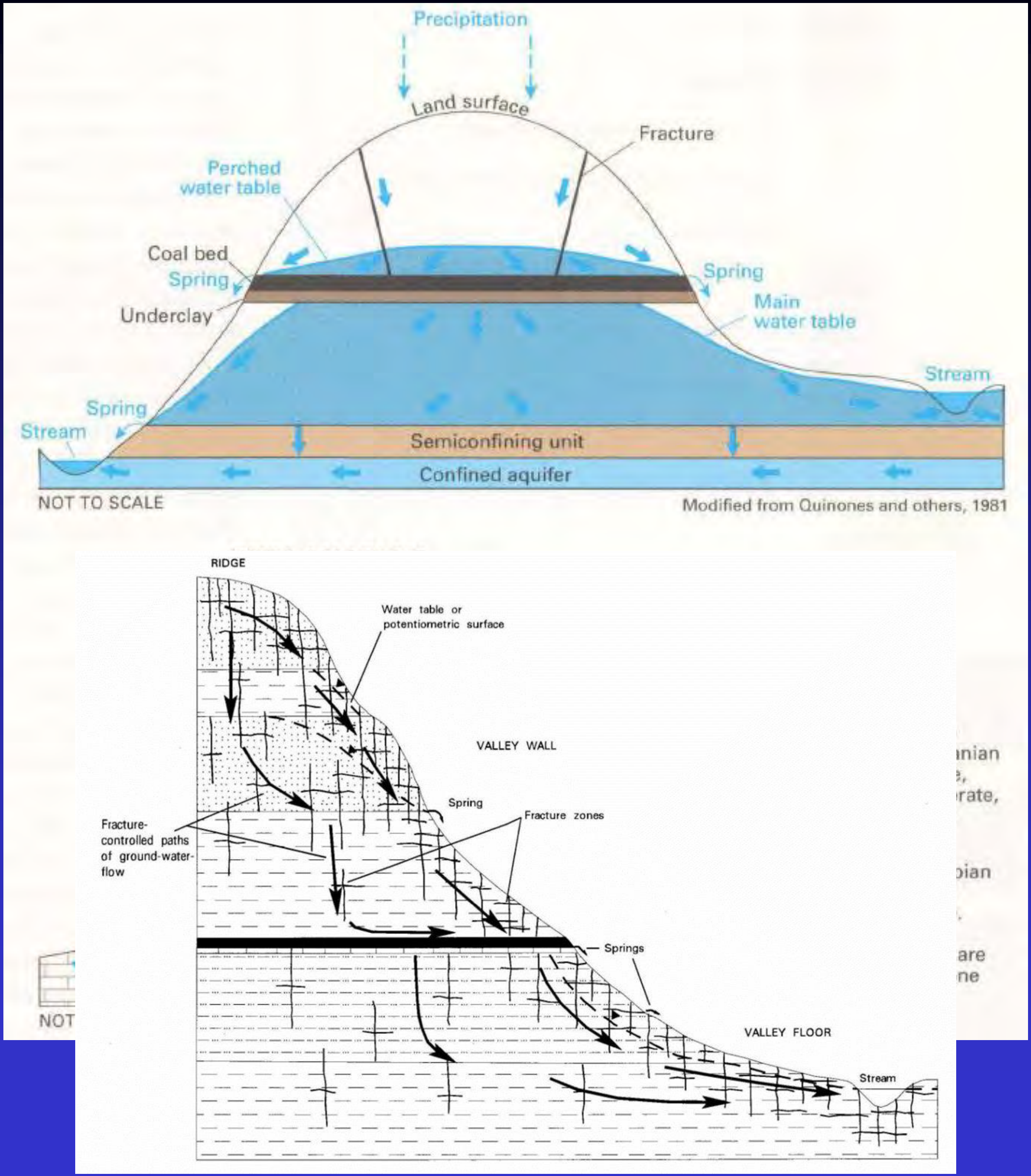
Appalachian Plateaus—Eastern Coal Field



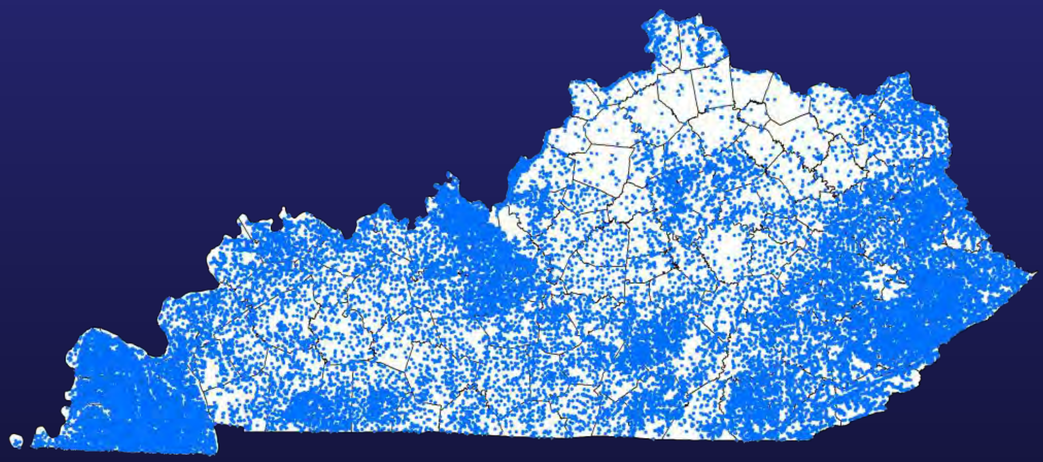
Typical Eastern Coal Field Stress-Relief Fractured Aquifer System

Above drainage, coal beds and fractured sandstones may be significant perched aquifers.

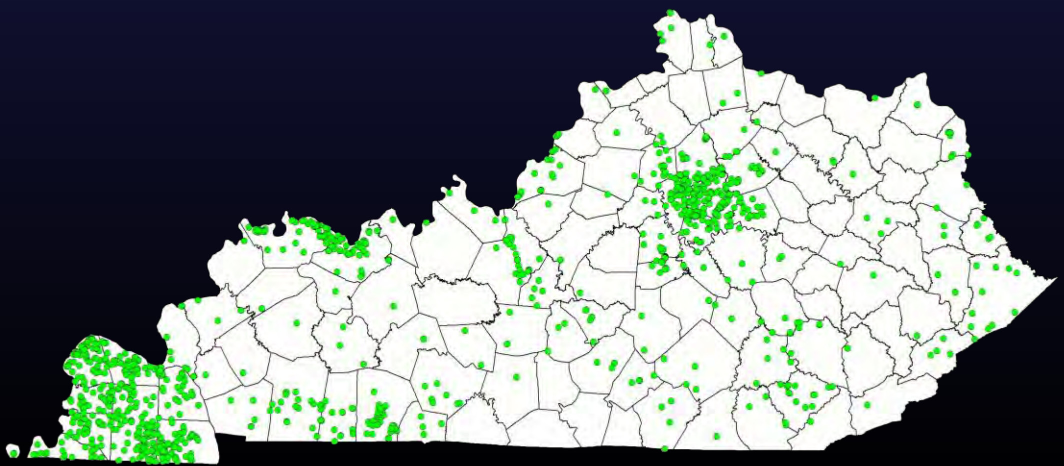
Fractures and interlayered rocks of varying permeability control downward migration of groundwater.



Distribution of Water Wells in Kentucky Gives Us A Clue as To Groundwater Availability and Suitability of Aquifers



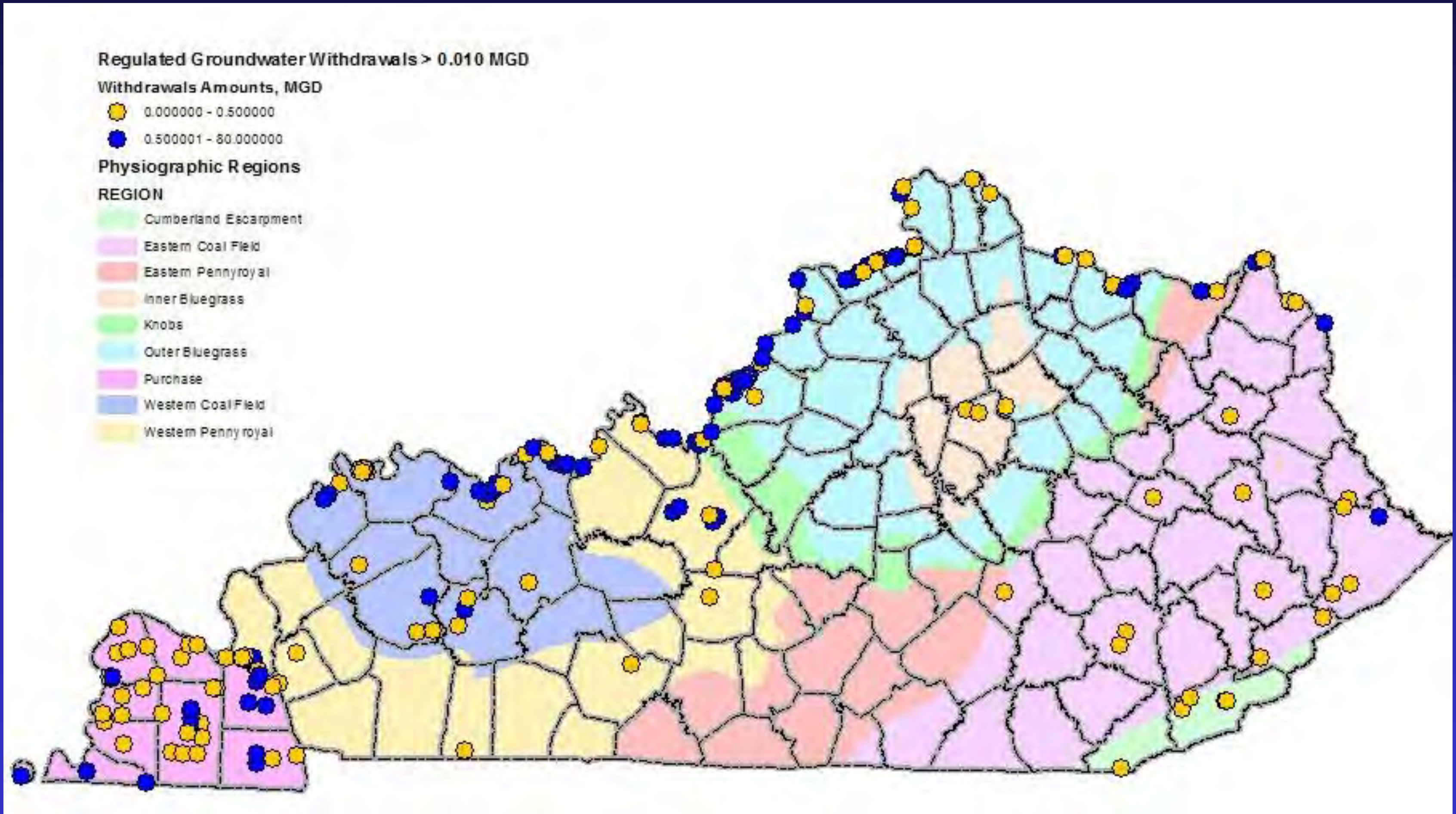
Private Water Wells in (52,000 records).



Irrigation Wells in (1,300 records).

Sources: KGS Groundwater Data Repository; KDOW Certified Water Well Drillers Well Construction Records

Distribution and Withdrawals from Public Groundwater Suppliers



Courtesy of Bill Caldwell, KDOW

Summary

- Kentucky is a topographically and geologically diverse state.
- Consequently, our aquifers and their hydrologic characteristics are equally diverse.
- Groundwater is available in almost all of the state—depending on requirements/plans for use.
- The most productive granular aquifers are located in thicker and more permeable sand and gravel deposits along the Ohio River and in JPA-Mississippian Embayment.
- The most productive consolidated (bedrock) aquifers are located in the Mississippian karst.
- However, highly productive wells can be obtained in many bedrock aquifers depending on local hydrogeologic conditions and fracture or karst permeability.
- The diversity in aquifer types and the dominance of complex fractured/karst aquifers contributes to difficulty in mapping aquifers, quantifying their hydrologic properties, and assessing groundwater availability in many parts of the state.

Questions and Comments