Water Resources Board Meeting
September 29, 2016
1:00 PM EDT
Training Room C
300 Sower Blvd
Frankfort, Kentucky 40601

1. Call Meeting to Order and Roll Call of Board Members

2. Introduction of Guests

3. Approve Minutes of August 29, 2016

4. Presentation by Chuck Taylor, Head, Water Resources Section, Kentucky Geological Survey – Overview of Kentucky's Aquifers- The Framework for Groundwater Availability

5. Presentation by Chuck Taylor, Head, Water Resources Section, Kentucky Geological Survey – Kentucky Groundwater Data and Research Needs- the KGS Perspective

6. Presentation by Peter Goodmann, Director, DOW and Bill Caldwell, Scientist, DOW – A Kentucky Water Resources Plan

7. Action Items and Reports
   a. Projects Workgroup Report

8. Open Discussion for Board Members

9. Public Comment Period

10. Next Meeting 1:00 PM – October 31, 2016 Training Room C

Water Resources Board
Draft Meeting Minutes
September 29, 2016

Board Members in Attendance: Earl Bush (County Judge Executives); Steve Coleman (KY Farm Bureau); Lloyd Cress, Jr. (KY League of Cities); John Dix (KRWA); Peter Goodmann (Proxy, EEC, Director DOW); Kevin Jeffries (Soil and Water Conservation Districts); Tom McKee (LRC); Kevin Rogers (KY Chamber of Commerce); Lance Terrell (Proxy, KDA); Steve Workman (Proxy, UK)

Board Members Absent: Dr. Nancy Cox (UK); Ryan Quarles (Commissioner Dept. of Agriculture); Charles Snavely (EEC Secretary);

Others in Attendance: Lowell Atchley (LRC); Jory Becker (DOW); Joe Cain (KY Farm Bureau); Bill Caldwell (KDOW); Annette Dupoint-Ewing (KMUA); Carey Johnson (DOW); Samantha Kaiser (DOW); Jim Kipp (KWRRI); Gary Larimore (KRWA); Haley McCoy (EEC); Kate Shanks (KY Chamber of Commerce); Chuck Taylor (KGS)

The meeting began at 1:05 p.m.

Call Meeting to Order and Roll Call of Board Members

Peter Goodmann called the meeting to order and led the roll call of Board members.

Introduction of Guests

Guests introduced themselves.

Approve Minutes of August 29, 2016

No changes were made to the meeting minutes from August.

Presentation by Chuck Taylor, Head, Water Resources Section, Kentucky Geological Survey – *Overview of Kentucky's Aquifers- The Framework for Groundwater Availability & Priority Groundwater Data and Research Needs- KGS Perspective*

Mr. Taylor gave a Power Point presentation regarding groundwater aquifers. He discussed several different types of aquifers and how porosity and permeability factors in storage capacity and flow rate. Characteristic of an ideal aquifer include the extraction rate and quantity of water needed for use; water quality suitable for intended uses; highly porous, permeable, and mostly homogenous geological material; geographic extensiveness; good saturated thickness and below elevation for base-level drainage; and enough recharge and groundwater storage to main sustainability. Kentucky is a topographically and geologically diverse state, which makes its aquifers equally as diverse. Due to different flow rates and paths of groundwater, this affects groundwater recharge, residence time, and quality. Kentucky's six aquifer systems by physiographic region are Jackson Purchase, Western Coal Field, Ohio River Alluvium, Mississippian Plateau Karst, Inner Bluegrass Karst, and Eastern Coal Field. Many aquifers are highly productive, but water quality may not be suitable. The diversity and complexity of fractured and karst aquifers contribute to difficulty in mapping aquifers, quantifying their hydrologic properties, and assessing groundwater availability.

All groundwater data collected in Kentucky is accessible by the Groundwater Data Repository (GWDR). KGS identified four priority groundwater data and research needs: (1) Kentucky needs a statewide long-term groundwater observation network (KGON). KGS is currently working to rebuild the KGON, but long-term maintenance, expansion, or enhancement of the network and data-collection activities will require additional outside funding and partnership. (2) More quantitative data on aquifer yield and hydraulic properties. KGS has preliminary data from the Jackson Purchase Area, but additional well monitoring and data collection is needed. (3) Aquifer delineation and mapping, improved groundwater availability assessment, and resource development and management. Currently DOW and KGS are working on a proposal for a pilot-scale project for aquifers used by permitted groundwater suppliers. A publicly-accessible aquifer test archive database will be accessible in the future through a KGS website currently being built. (4) Development of improved groundwater management tools. This may involve the creation of groundwater flow models or well-hydraulic response simulation tools that can help predict groundwater availability and sustainability. This objective will depend on data from previous items discussed.

Due to time constraints, the presentation by Peter Goodmann, Director, DOW, and Bill Caldwell, Scientist, DOW– *A Kentucky Water Resources Plan* will be given at the next meeting.

Action Items and Reports

There were no additional details to discuss. The sub-committee will meet prior to the next meeting to prioritize projects.

Open Discussion for Board Members

The Board again indicated interest in a presentation on funding sources, and to discuss the differences between State Cost Share Funds (SCS) and State Revolving Funds (SRF). A member from the Army Corps of Engineers will be invited to a future meeting. During that same meeting the Board would also like to discuss jurisdiction of the waters of the Commonwealth. The Board would like to discuss how the Water Resources Development Act will affect Kentuckians if the bill passes.

Public Comment Period

No public comments were made.

Next Meeting 1:00 PM – October 31, 2016 Training Room C

The meeting adjourned at 3:22 p.m.

Water Resources Board Meeting
300 Sower Blvd, Frankfort, KY 40601
September 29, 2016

PUBLIC SIGN-IN SHEET

Name	Agency/Organization	Email Address	Phone number
JIM KIPP	KWRRI	KIPP@UKY.EDU	859-257-1832
Lowell Atchley	LRC	lowell.atchley@lrc.ky.gov	502-564-8100 x469
Rusty Cress	KCC	rusty.cress@dinsmore.com	502-352-4612
Joe Cain	KY Farm Bureau	joe.cain@kyfb.com	502-495-7738
CHUCK TAYLOR	KGS	CHARLES.TAYLOR@UKY.EDU	859.323.0532
Lance Terrell (Proxy for Ryan Quarles)	KDA	lance.terrell@ky.gov	502-604-0629
GARY LARIMORE	Ky Rural Water	g.LARIMORE@KRWA.ORG	270.843.2291
Kate Shanks	Ky Chamber	kshanks@kychamber.com	502-695-4700
Jory Becker	DOW	jory.becker@ky.gov	502 782 6887
Annette DUPONT-EWING	KMUA	ade.kmua@gmail.com	502 223-2063
Carey Johnson	DOW	carey.johnson@ky.gov	502-782-6990
Peter Goodmann	DOW	peter.goodmann@ky.gov	502-782-6956
Samantha Kaiser	DOW	samantha.kaiser@ky.gov	502 782-6995

Water Resources Board Meeting
300 Sower Blvd, Frankfort, KY 40601
September 29, 2016

BOARD MEMBER SIGN-IN SHEET

Name	Agency/Organization	Email Address	Phone number
Steve Coleman	Farm Bureau	soil1951@yahoo.com	502-223-4196
Kevin Jeffries	KACD	kevinjeff@bellsouth.net	502-553-2938
John Dix	KRWA	JOHND@WARRENWATER.COM	270-495-3491
Earl Bush	Bracken Co Judge/Exec	brackenjudge@windstream.net	606-735-2300
Gary Larimore	Ky Rural Water	glarimore@KRWA.org	270.843.2291
Rusty Cress	KLC	RCress@dinsmore.com	502-332-4612
Kevin Rogers	KY AMERICAN	KEVIN.ROGERS@AMWATER.COM	859-550-3786
Steve Workman E. Nancy Cox	UK	steve.workman@uky.edu	859-218-4879
Lance Terrell Com. Ryan Quarles	KDA	lance.terrell@ky.gov	502-6040629
Tom McKee	State Leg.	Tom.McKee@LRC.ky.gov	859-234-5879

Water Resources Board
Meeting Minutes
September 29, 2016

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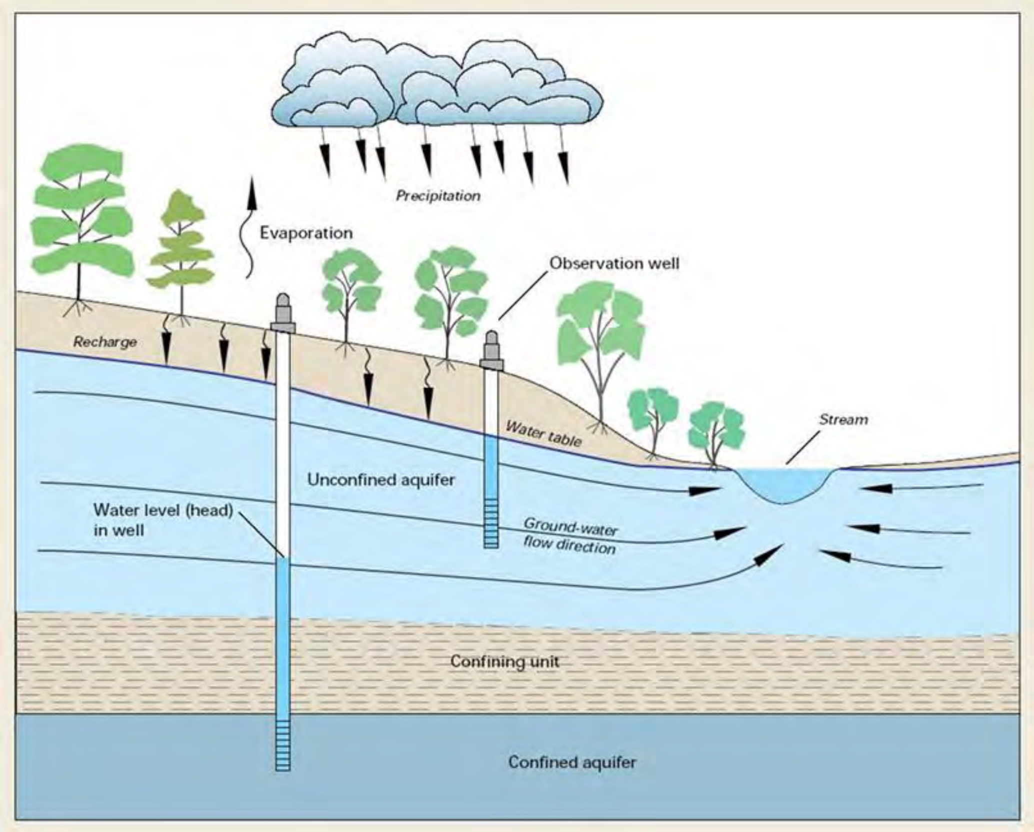
Overview of Kentucky Aquifers—Framework for Understanding Groundwater Availability & Priority Groundwater Data and Research Needs—KGS Perspective

Charles J. Taylor, Head
Water Resources Section
Kentucky Geological Survey
University of Kentucky

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.



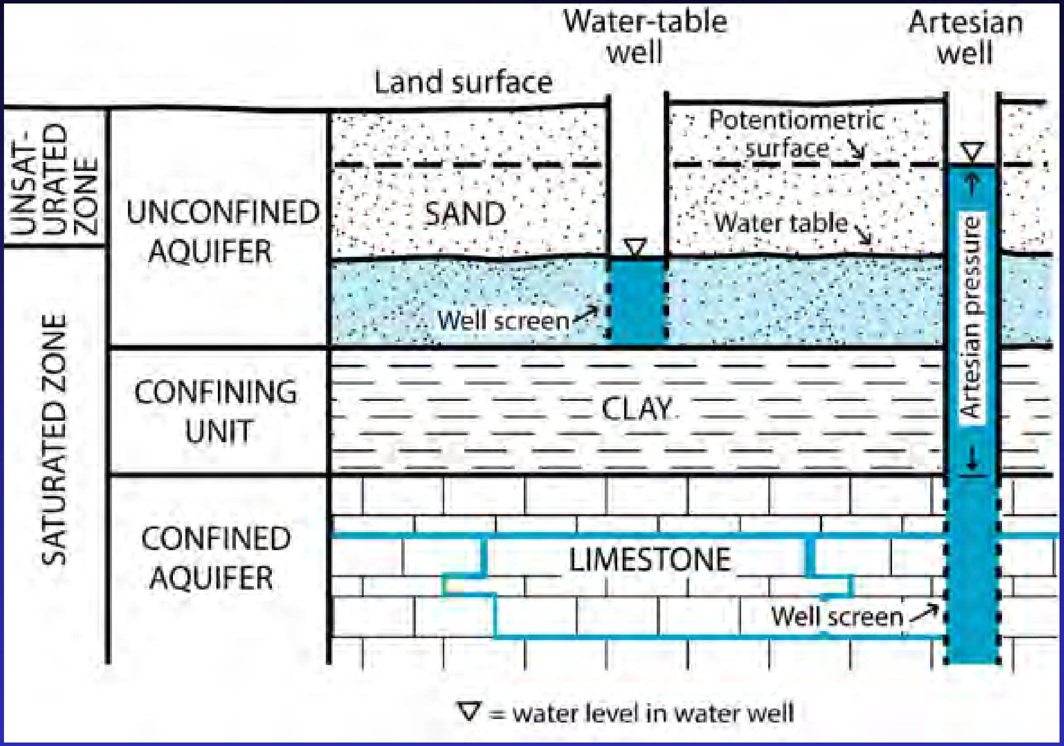
"Aquifers come in many shapes and sizes but they are really a contained underground repository of water" –Steve Phillips, USGS, Sacramento

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.**

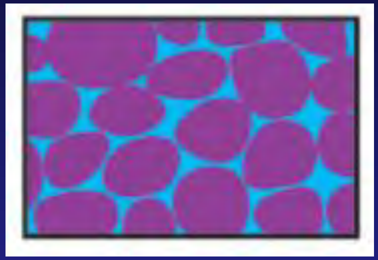
***Confined aquifer* - An aquifer bounded above and below by impermeable or lower permeability beds, with water under artesian or confining pressure (greater than atmospheric pressure).**



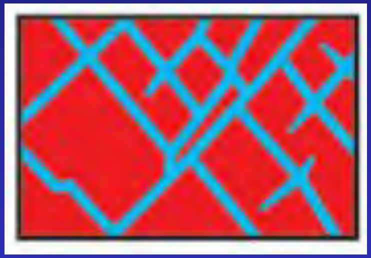
Hydraulic head—is the height that water will rise in a well due to natural conditions in the aquifer, particularly the kinetic and potential energy of groundwater at that location. Groundwater moves from areas of higher hydraulic head to areas of lower hydraulic head.

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

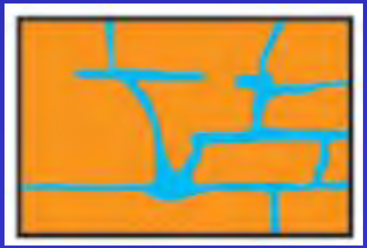
Intergranular

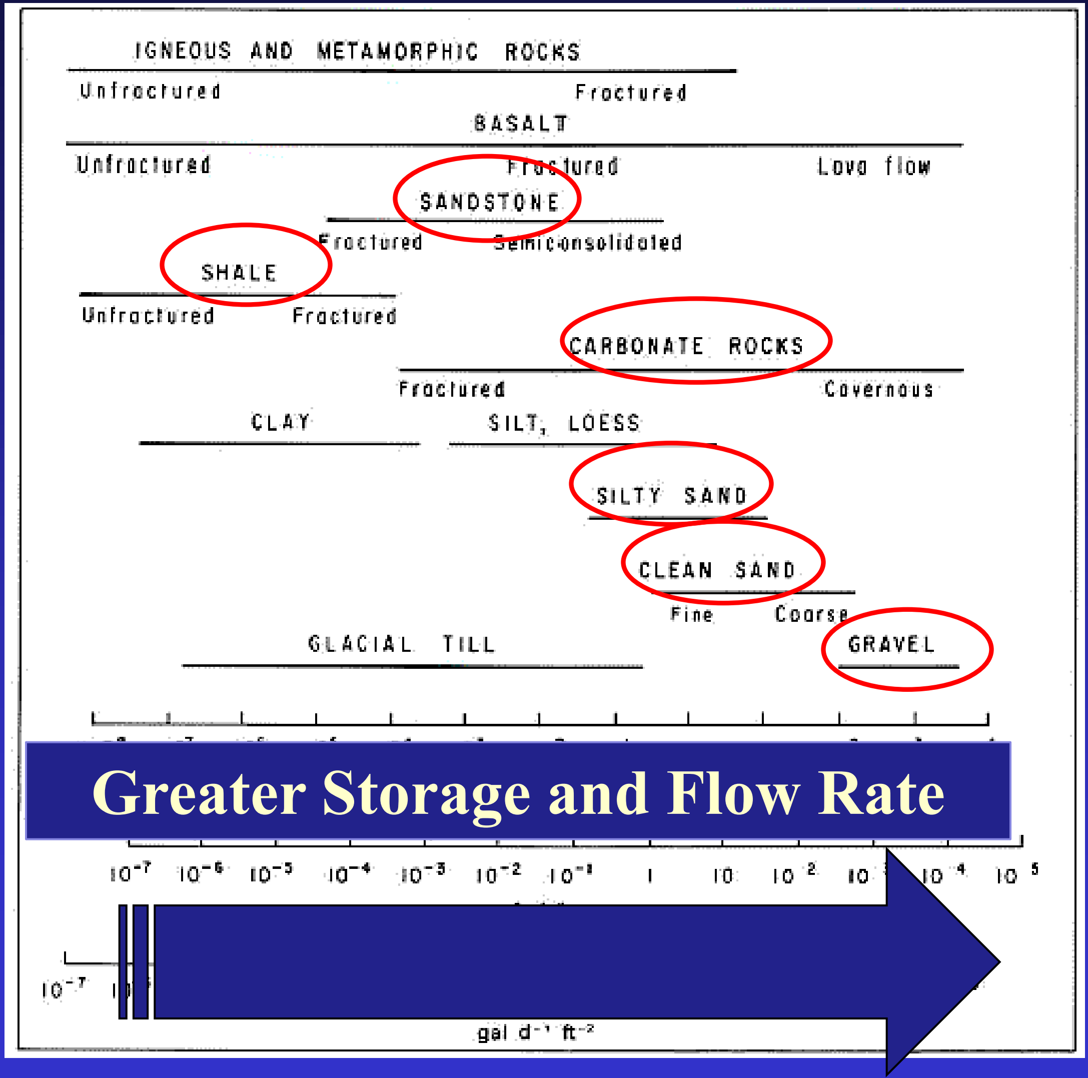


Fracture

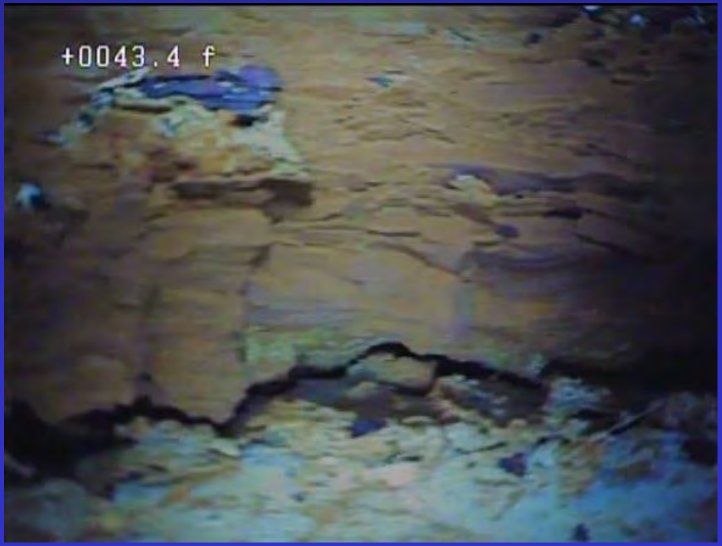


Solution (Karstic)



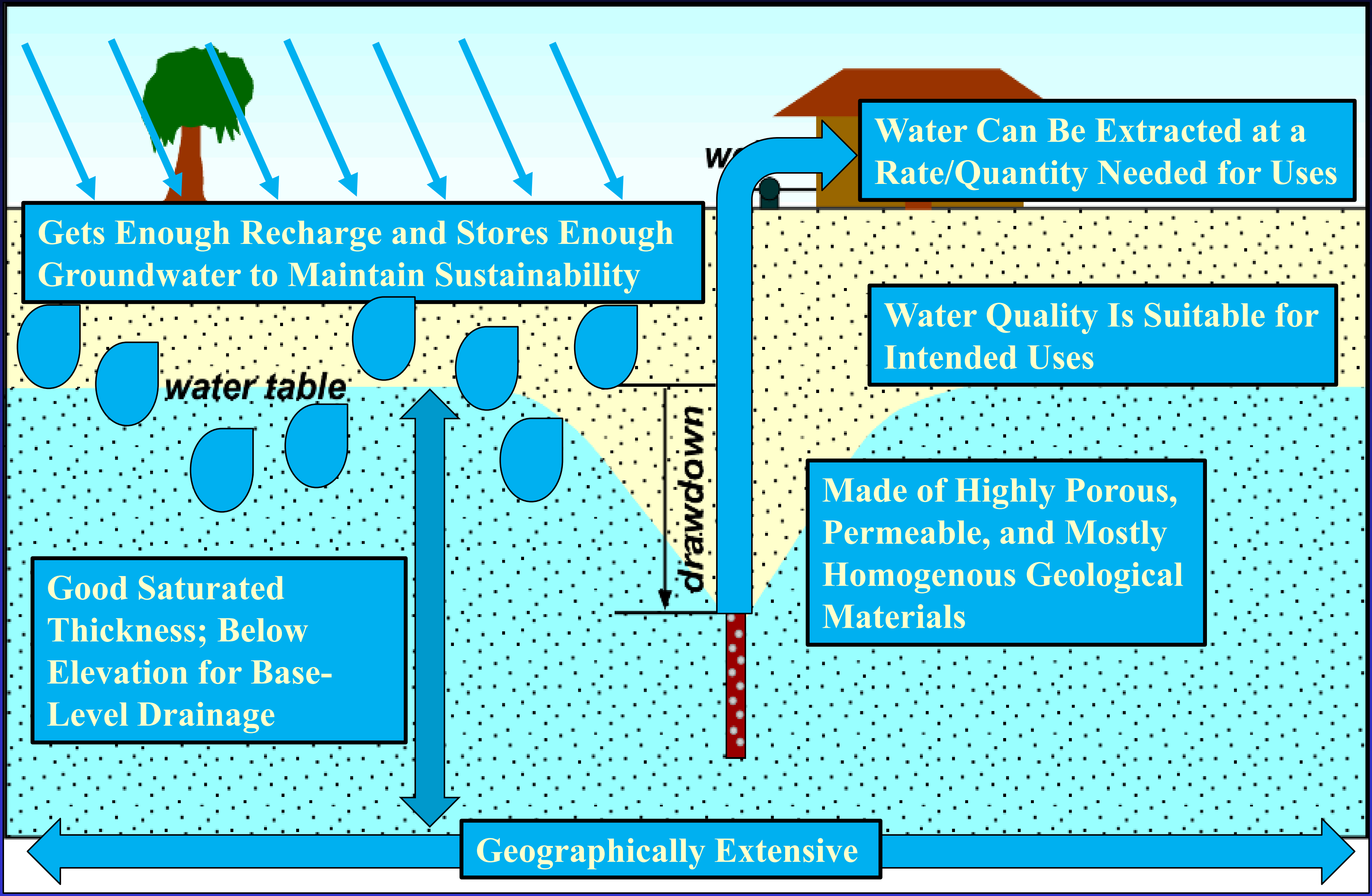


A Look At Fracture and Solution Permeability In Limestone Well in Elizabethtown, Ky

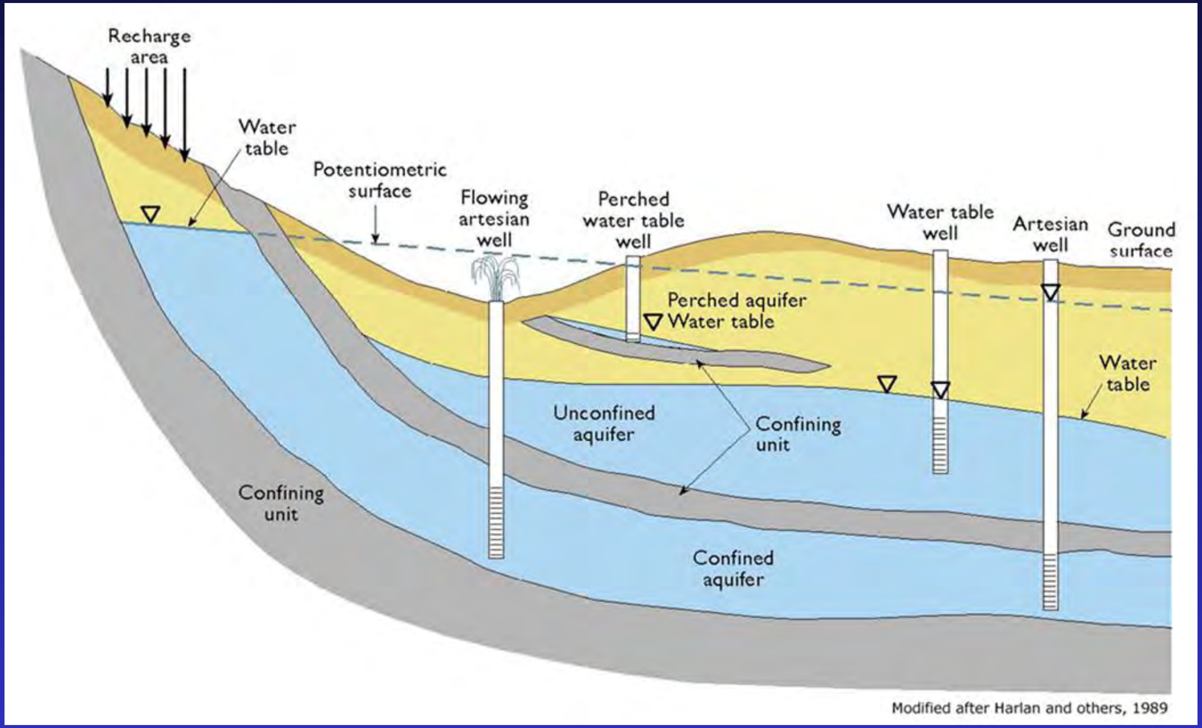


UK UNIVERSITY OF KENTUCKY
Kentucky Geological Survey

Characteristics of an "Ideal" or Good Aquifer

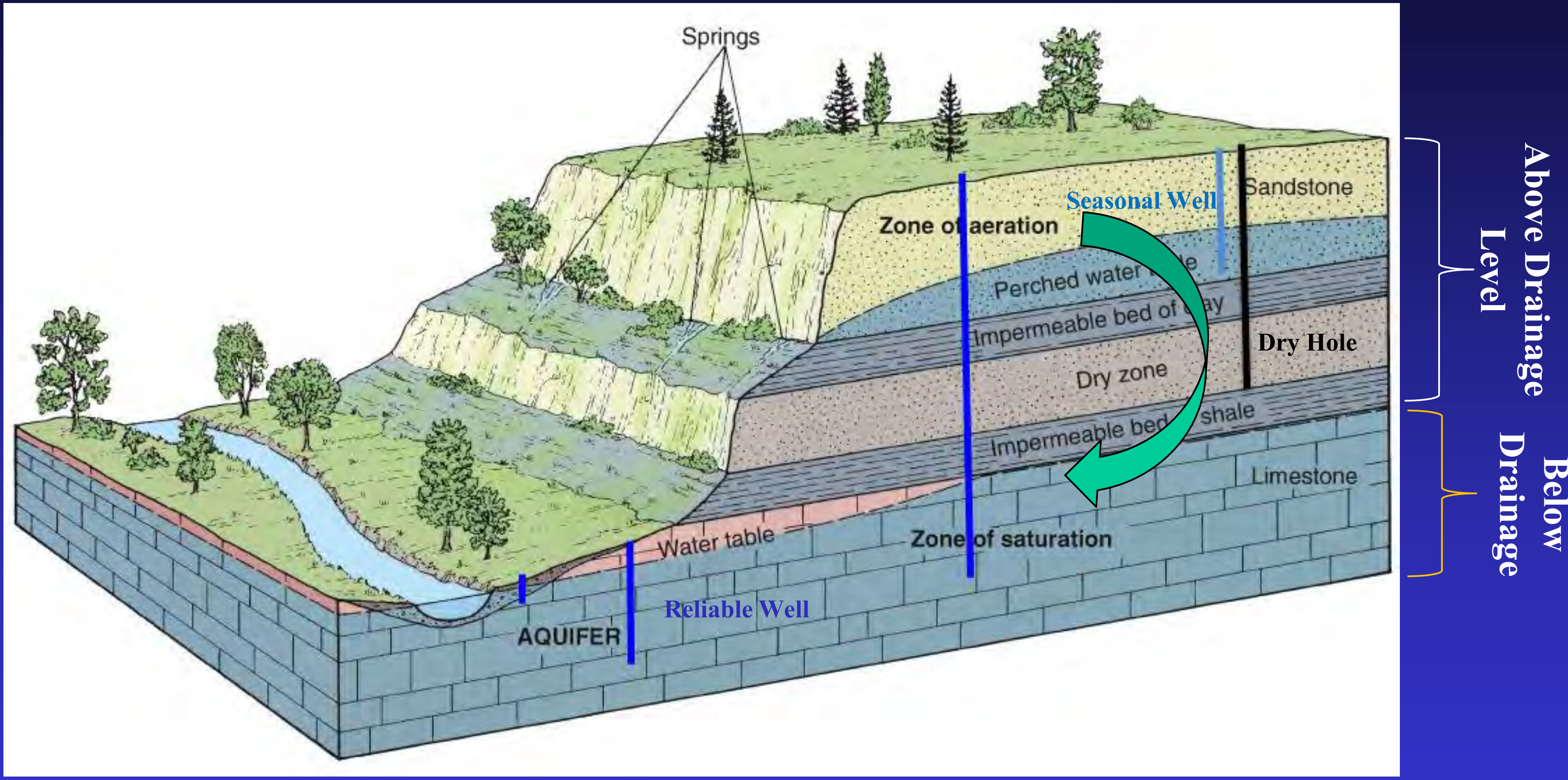


In Reality Aquifers are Zones Within Complex Groundwater Flow Systems and Characteristics Vary



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



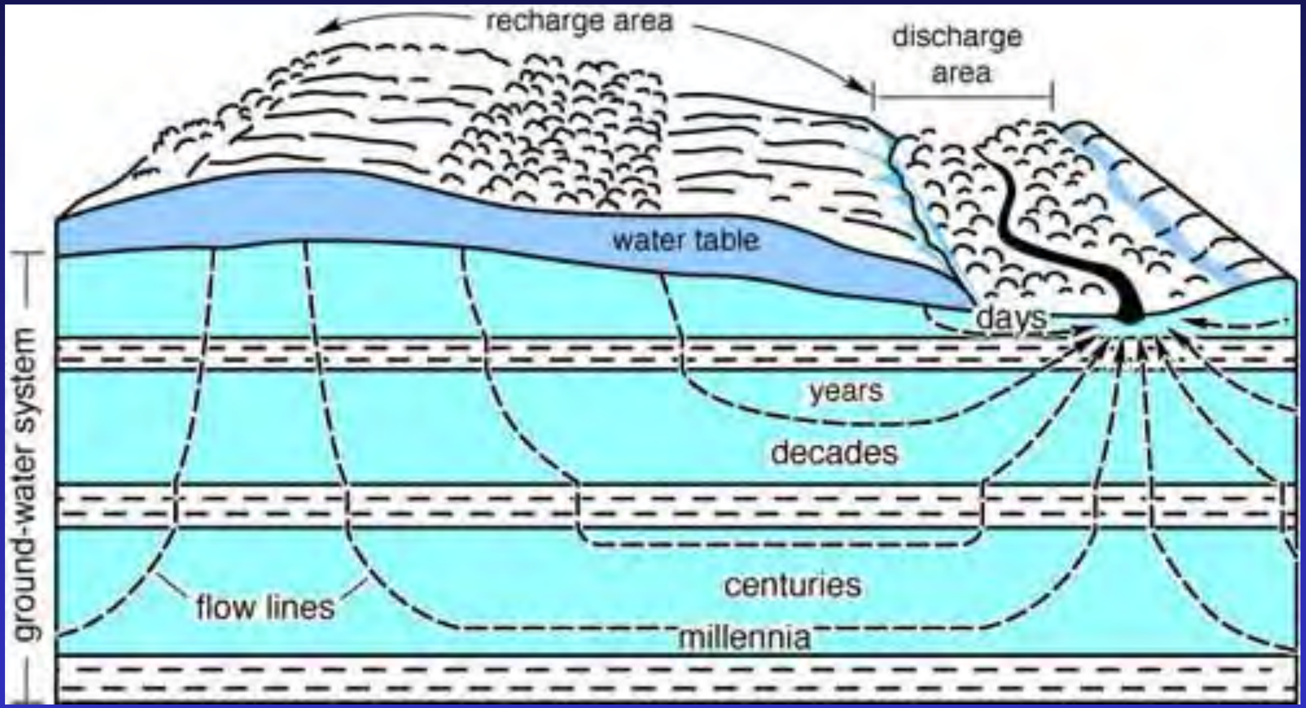
Above drainage, aquifers are more likely to be geographically and hydrologically isolated, and have limited recharge area.

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)



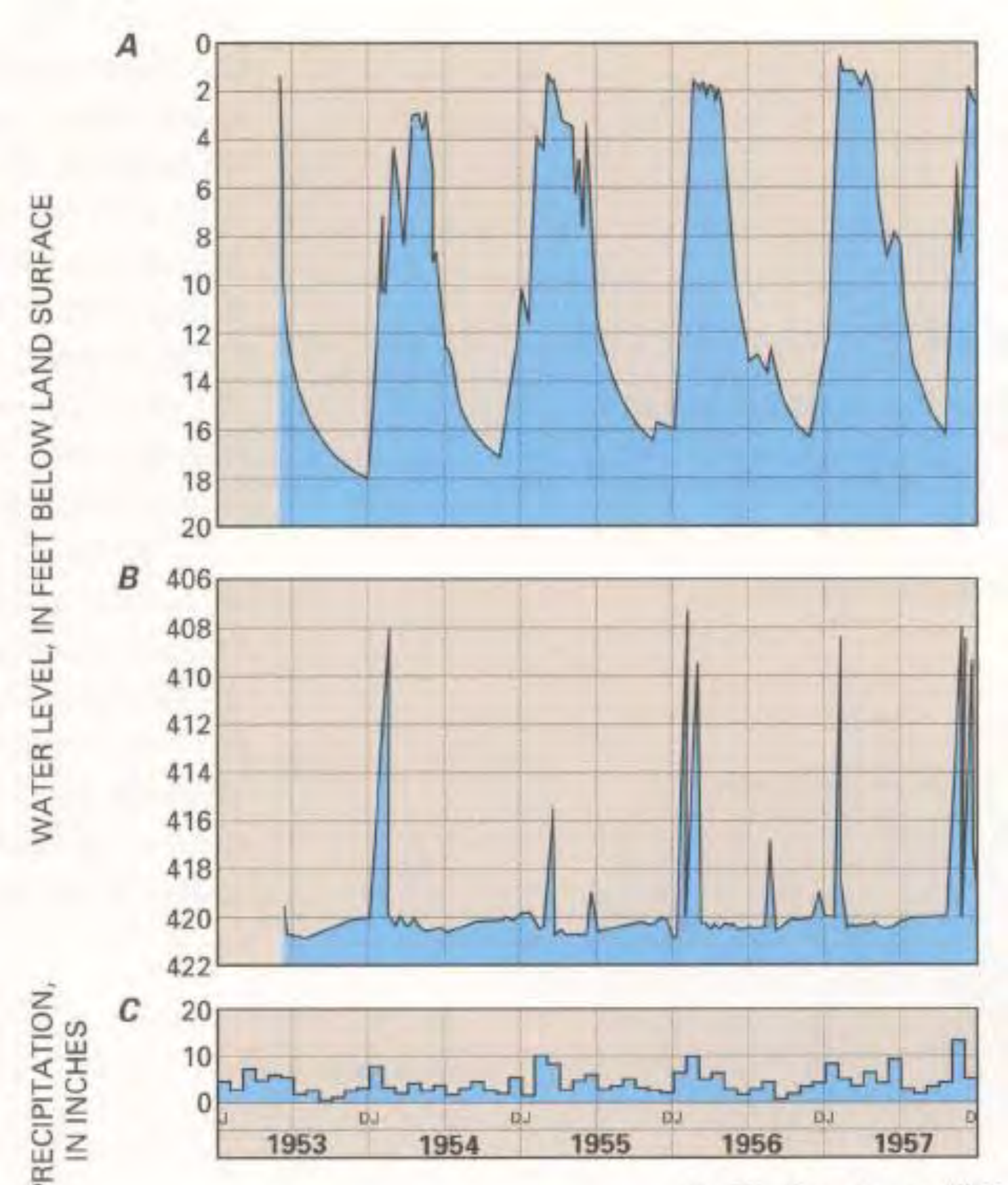
GW Flow Paths and Residence Times Also Affect Vulnerability of Aquifer (and Wells) to Contamination.

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).



Modified from Brown, 1966

Kentucky Aquifers

Kentucky is a Topographically and Geologically Diverse State.

- Aquifers are equally diverse.

Geological Materials that Serve as Aquifers include:

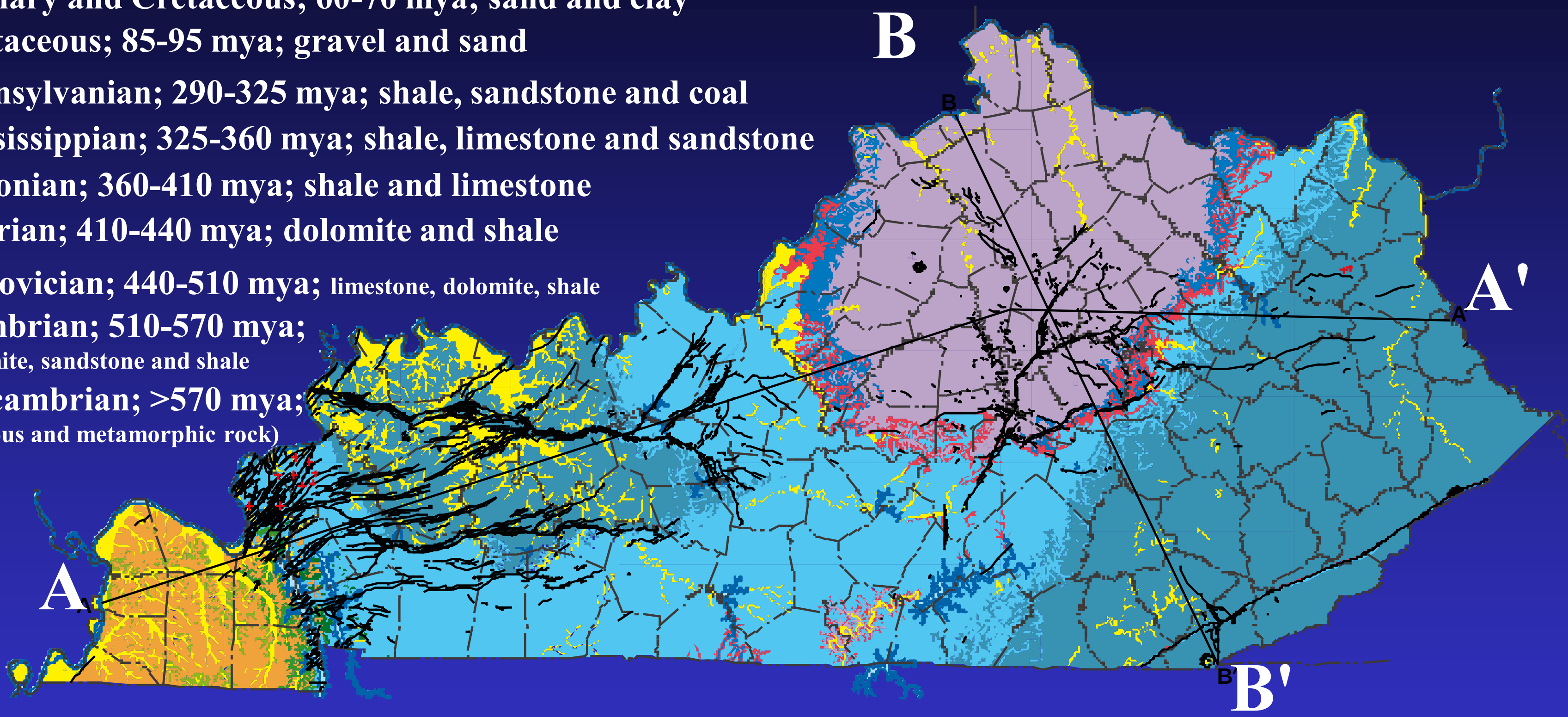
- Unconsolidated Sand and Gravel Deposits.
- Fractured Sandstones, Shales or Siltstones, and Coal.
- Fractured and Karstic Limestone and Dolostone.

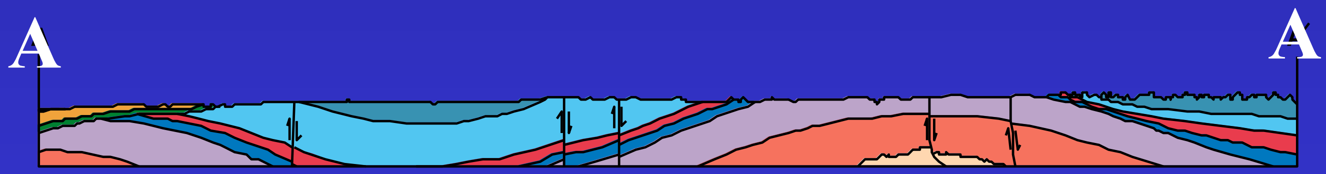
- Porosity and Permeability Varies Greatly Among these Aquifer Materials.
- Hence, Groundwater Storage, Flow, and Availability Varies Greatly Depending on the Occurrence and "Arrangements" of these Aquifer Materials.

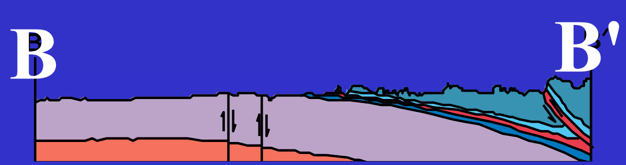
- Natural Groundwater Quality is Also Highly Variable.

Geologic Map of Kentucky

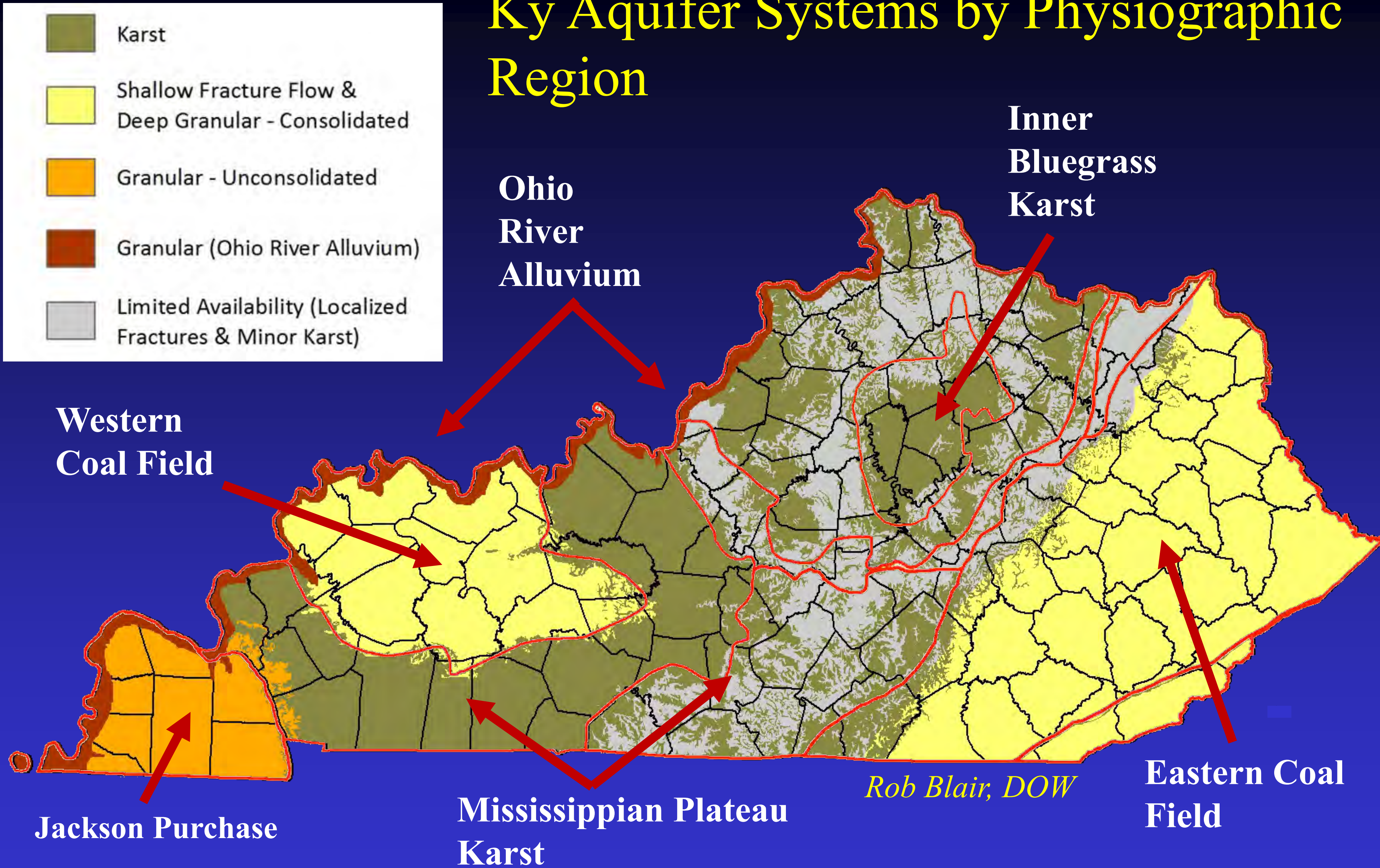
- Quaternary; 2 mya; sand, clay, gravel
- Quaternary and Tertiary; 1-5 mya; gravel and sand
- Tertiary; 30 mya; clay and sand
- Tertiary and Cretaceous; 60-70 mya; sand and clay
- Cretaceous; 85-95 mya; gravel and sand
- Pennsylvanian; 290-325 mya; shale, sandstone and coal
- Mississippian; 325-360 mya; 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)



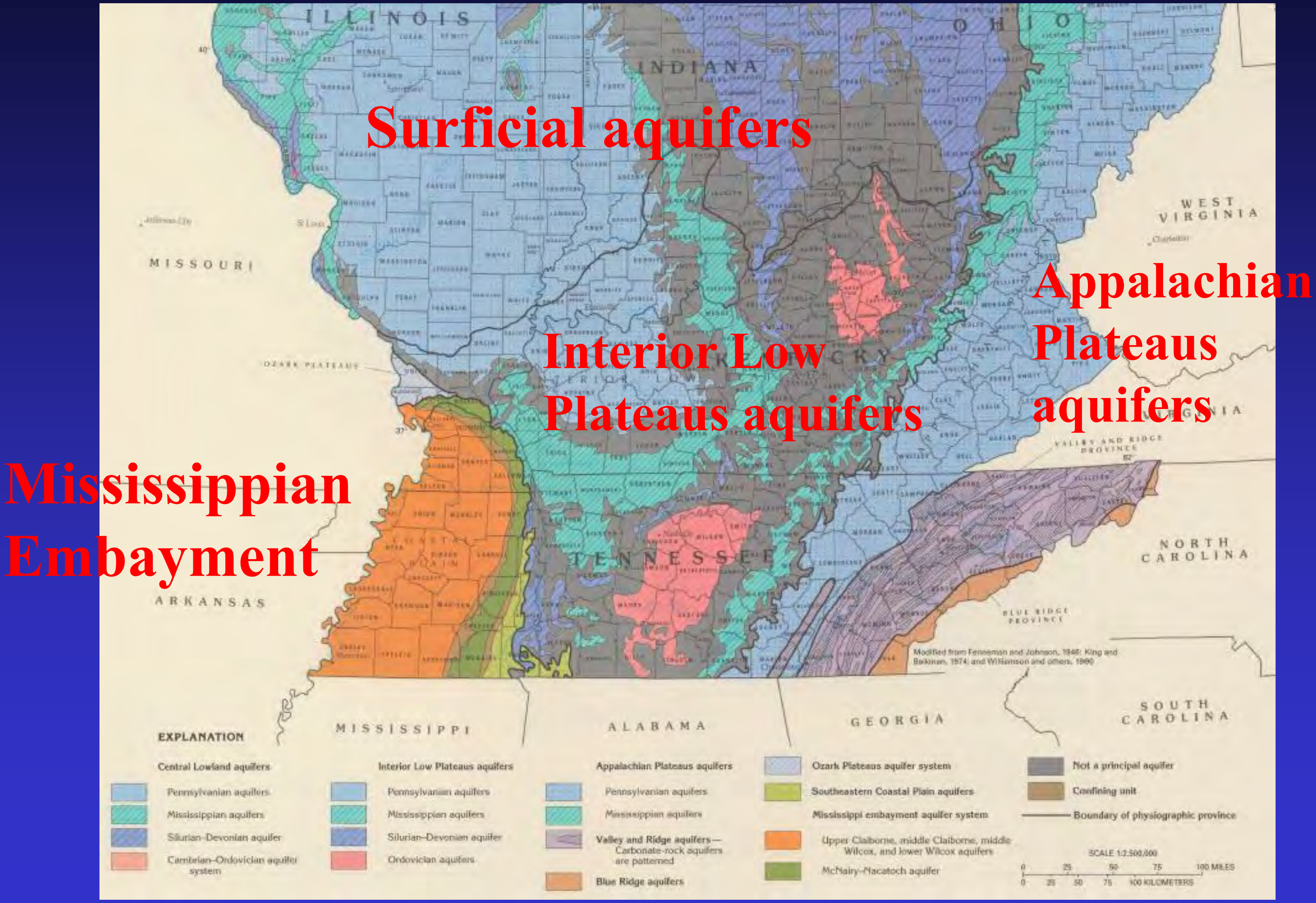




Ky Aquifer Systems by Physiographic Region

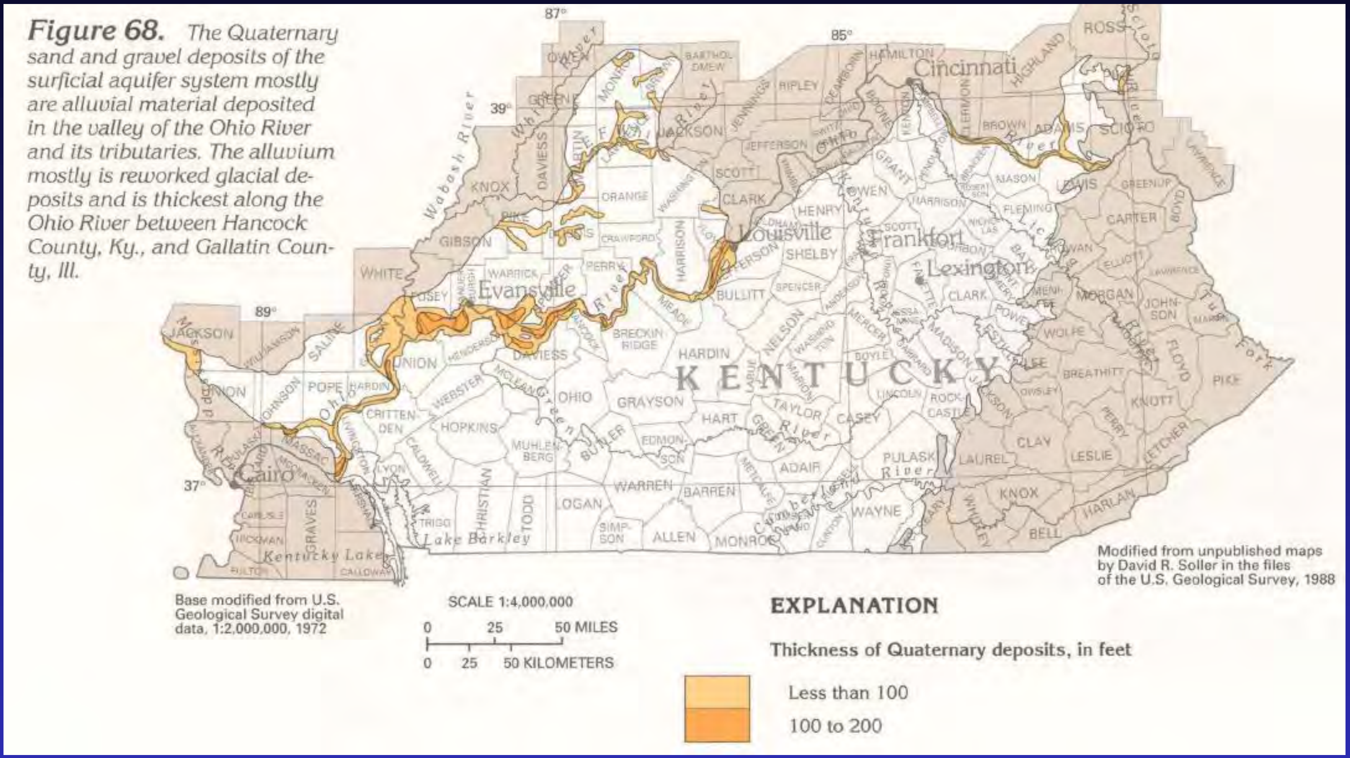


Principle Aquifers of the United States—
USGS HA 730-K Seg.10 (Lloyd and Lyke, 1995)

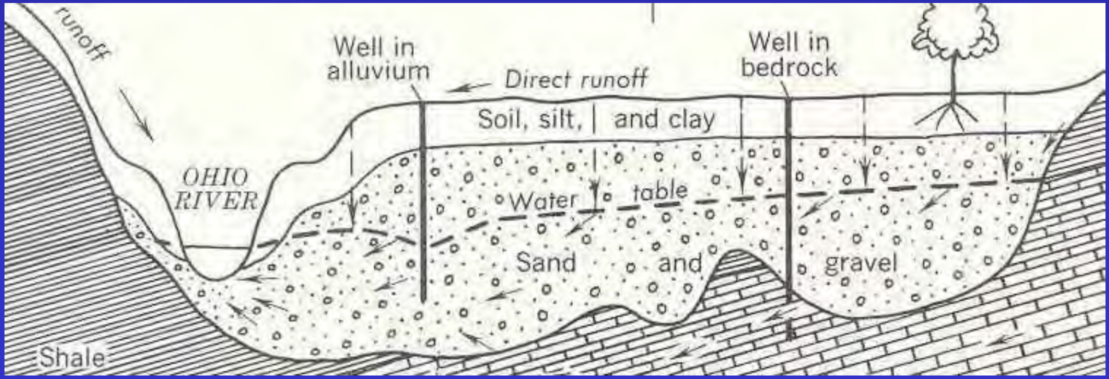


Ohio River Alluvial Aquifer

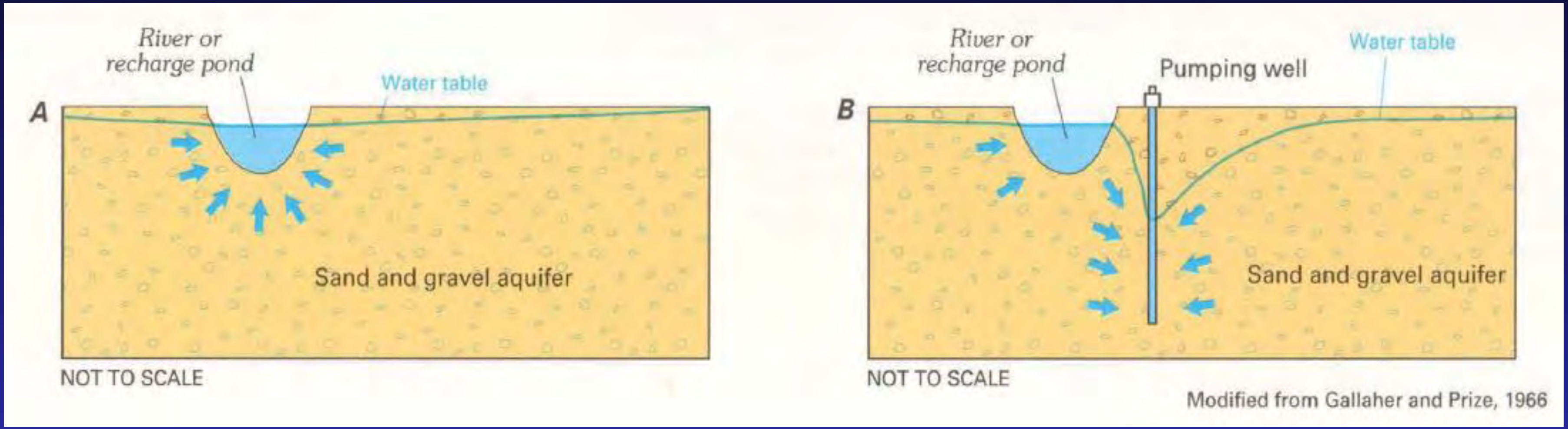
Highly productive unconsolidated sand and gravel deposits along Ohio and lower Green River.



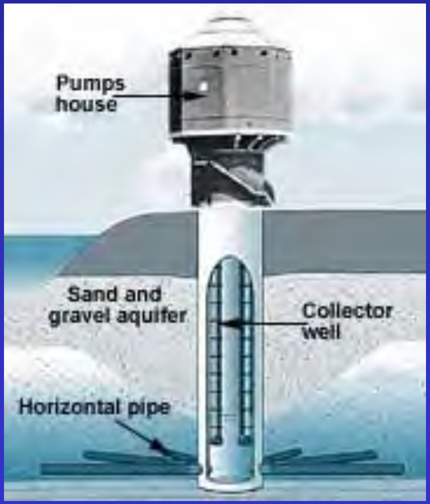
Thicker deposits of alluvium along many Ky streams serve as important local aquifers.



Riverbank Infiltration and Pumping-Induced Recharge from Streams



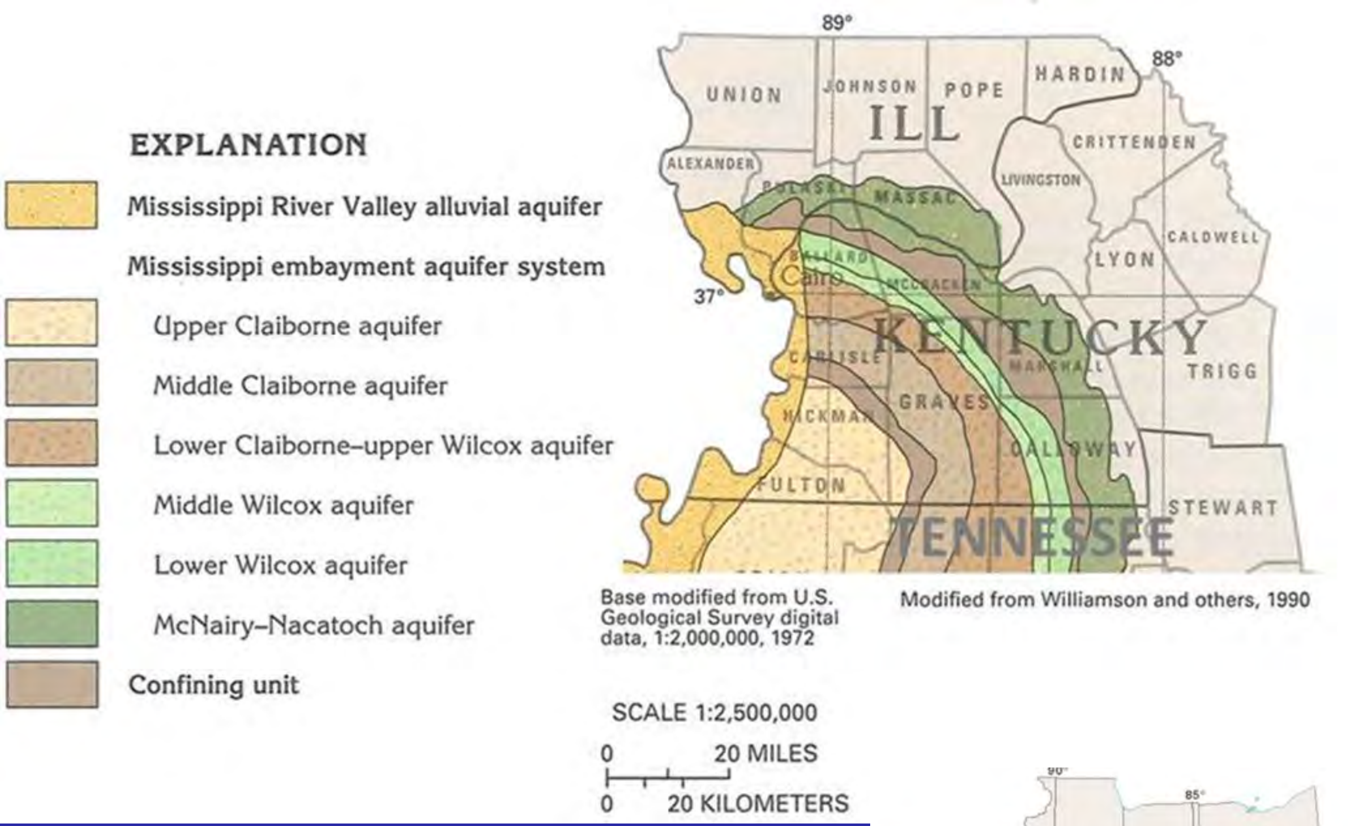
Horizontal-Collector or Ranney Well Construction



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.

SCALE 1:2,500,000

0 20 MILES

0 20 KILOMETERS

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

Modified from Williamson and others, 1990

EXPLANATION

Thickness of middle Claiborne aquifer, in feet

- Less than 200
- Greater than 200
- Aquifer absent

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.

SCALE 1:2,500,000

0 20 MILES

0 20 KILOMETERS

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

Modified from Hosman and Weiss, 1991

EXPLANATION

Thickness of McNairy–Nacatoch aquifer, in feet

- 200
- 400
- Aquifer absent

—400— Line of equal thickness of McNairy–Nacatoch aquifer—Interval 50 feet

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

Aquifer	Thickness (ft)	Hydraulic Conductivity (gpd/ft²)	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

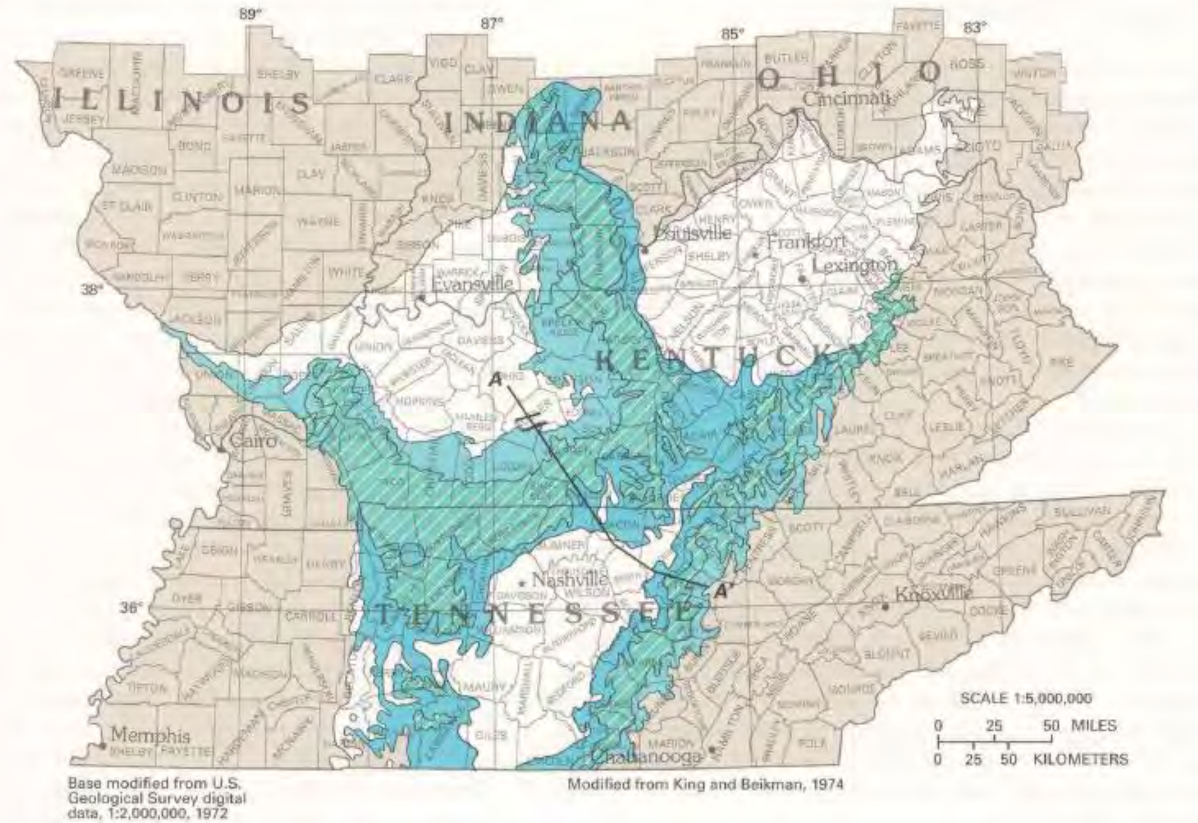


Figure 78. *Rocks of Mississippian age underlie a large part of the Interior Low Plateaus Province in Segment 10. The principal aquifers in these rocks primarily are in the Upper Mississippian limestones.*

EXPLANATION

- Mississippian aquifers
- Upper Mississippian rocks—Generally confining units but may contain local aquifers
- Lower Mississippian rocks—Generally confining units but may contain local aquifers

Cross-section of Mammoth Cave Area Limestone and Sandstone Aquifers

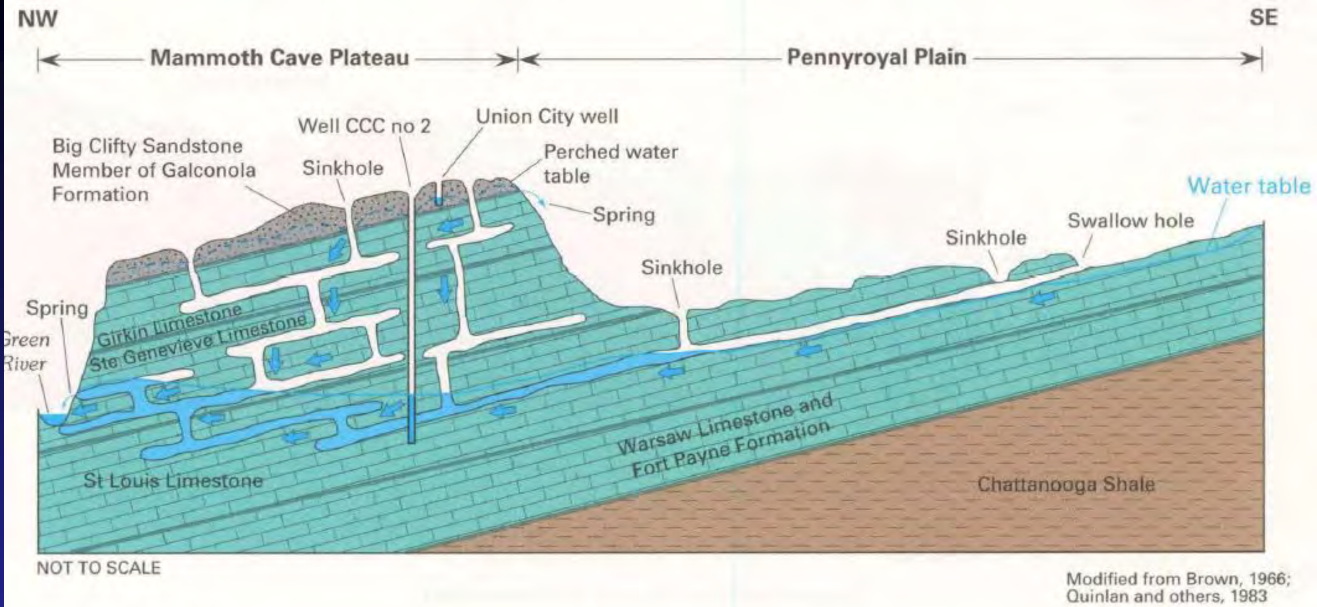
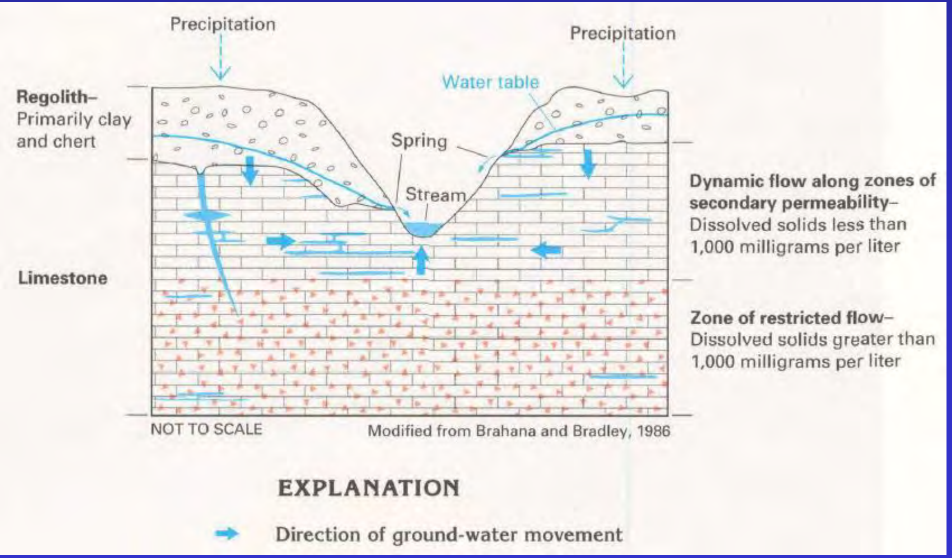
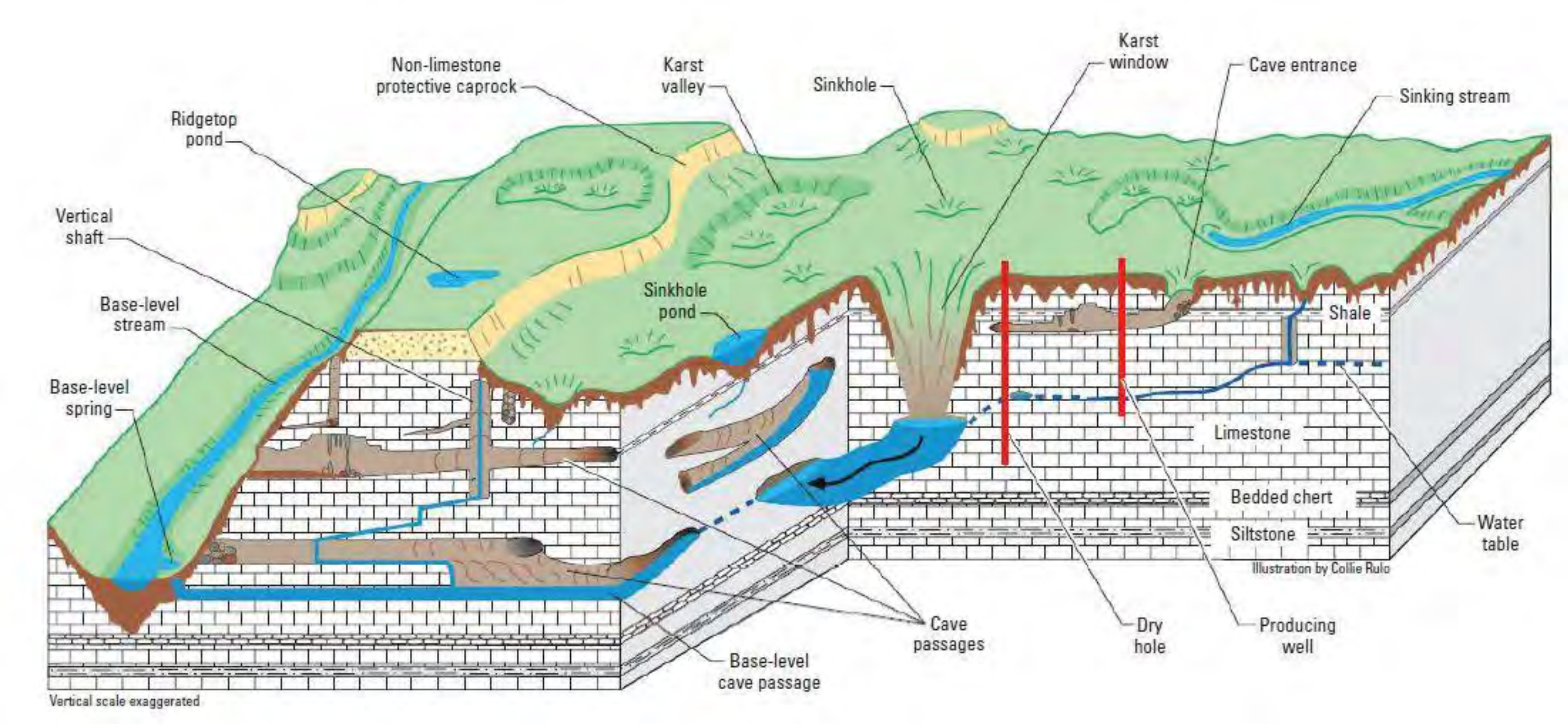


Figure 86. The Ste. Genevieve and the St. Louis Limestones that underlie the Mammoth Cave Plateau contain a well-developed network of solution openings. These openings were formed by dissolution of the limestones as ground water moved along bedding planes and fractures from recharge areas to points of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

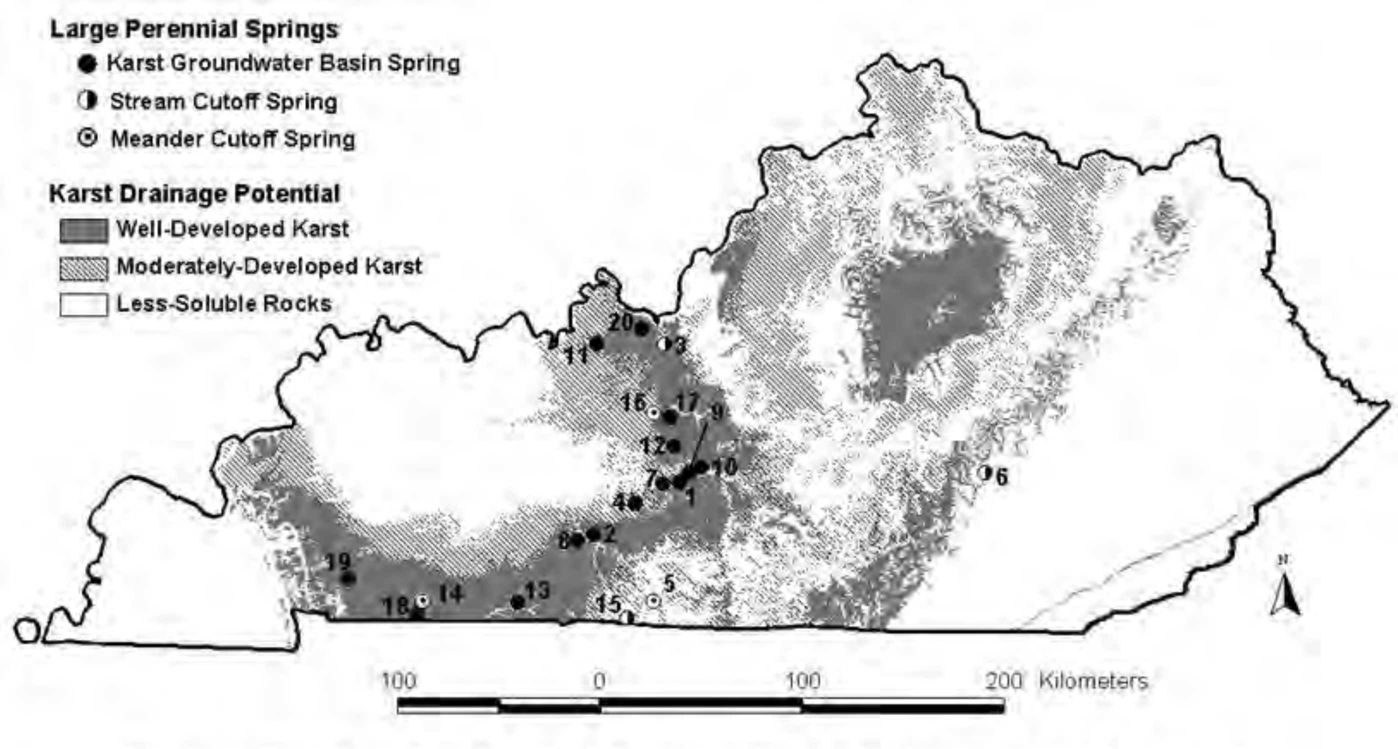


Figure 4: Distribution and rank of the twenty largest perennial springs in Kentucky

"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

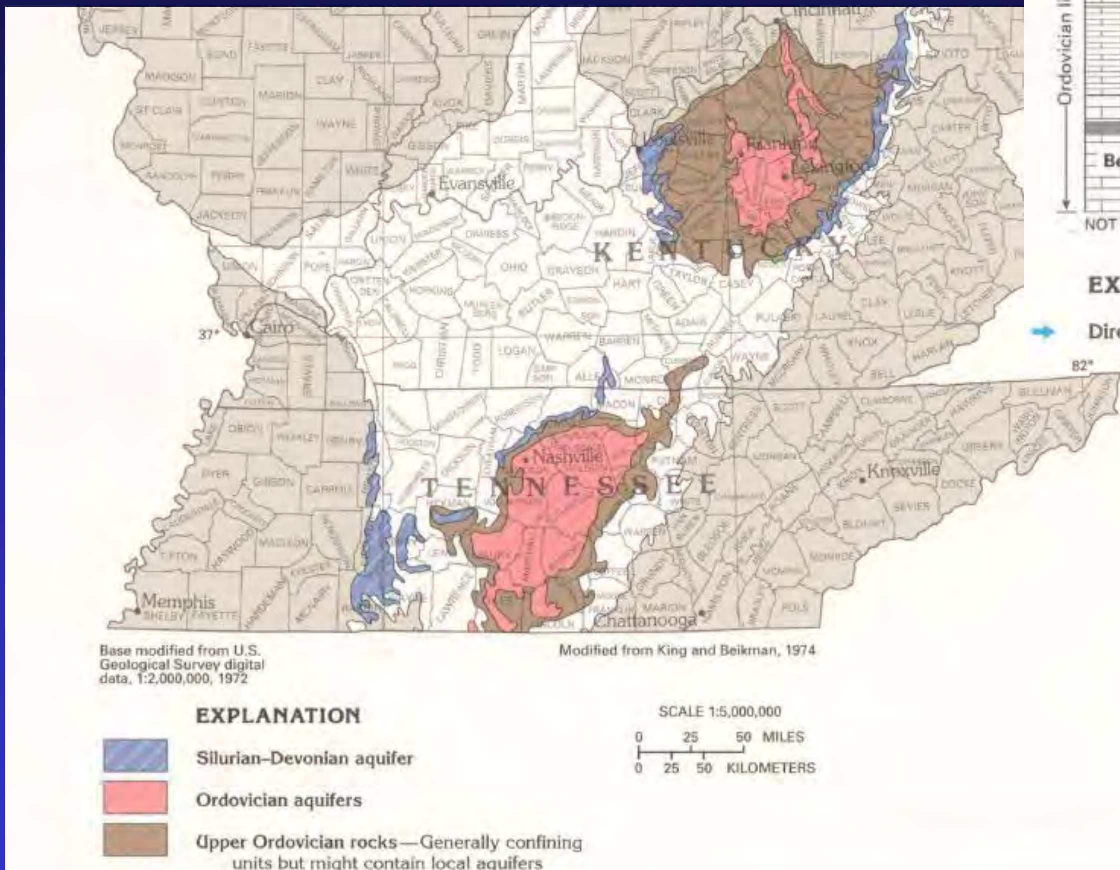
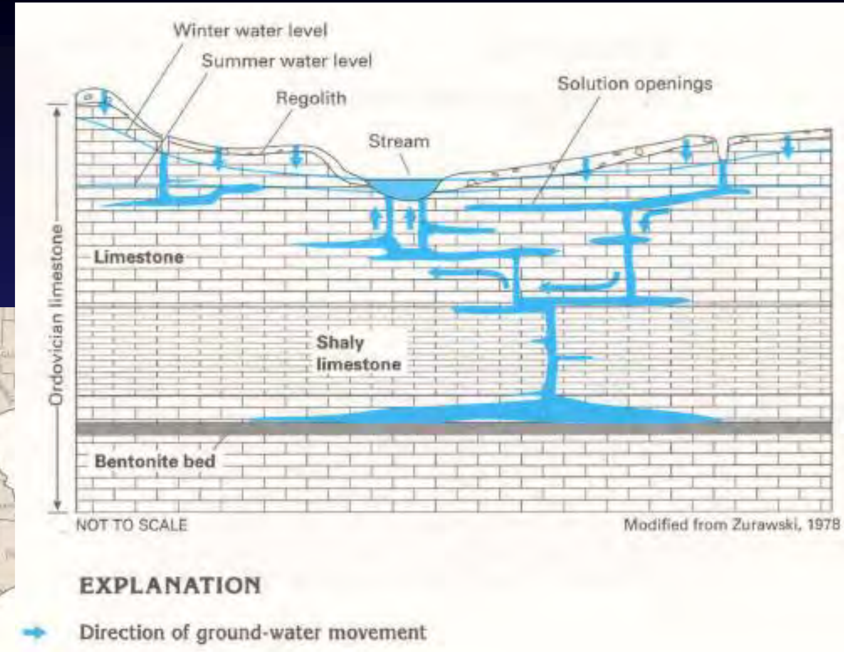


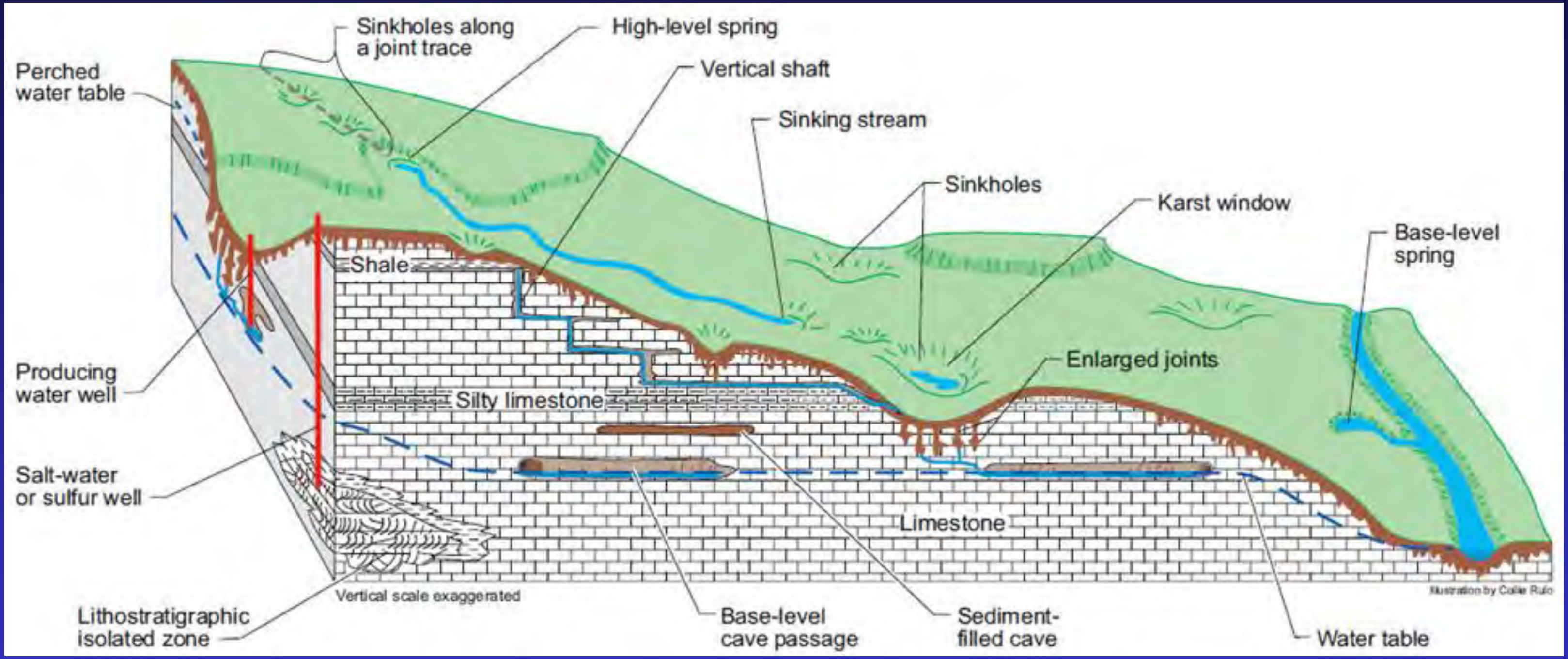
Figure 94. Aquifers in carbonate rocks of Devonian, Silurian, and Ordovician ages underlie large parts of central Kentucky and central Tennessee in the Interior Low Plateaus Province in Segment 10. Most Upper Ordovician rocks are confining units, but some locally yield small quantities of water.



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

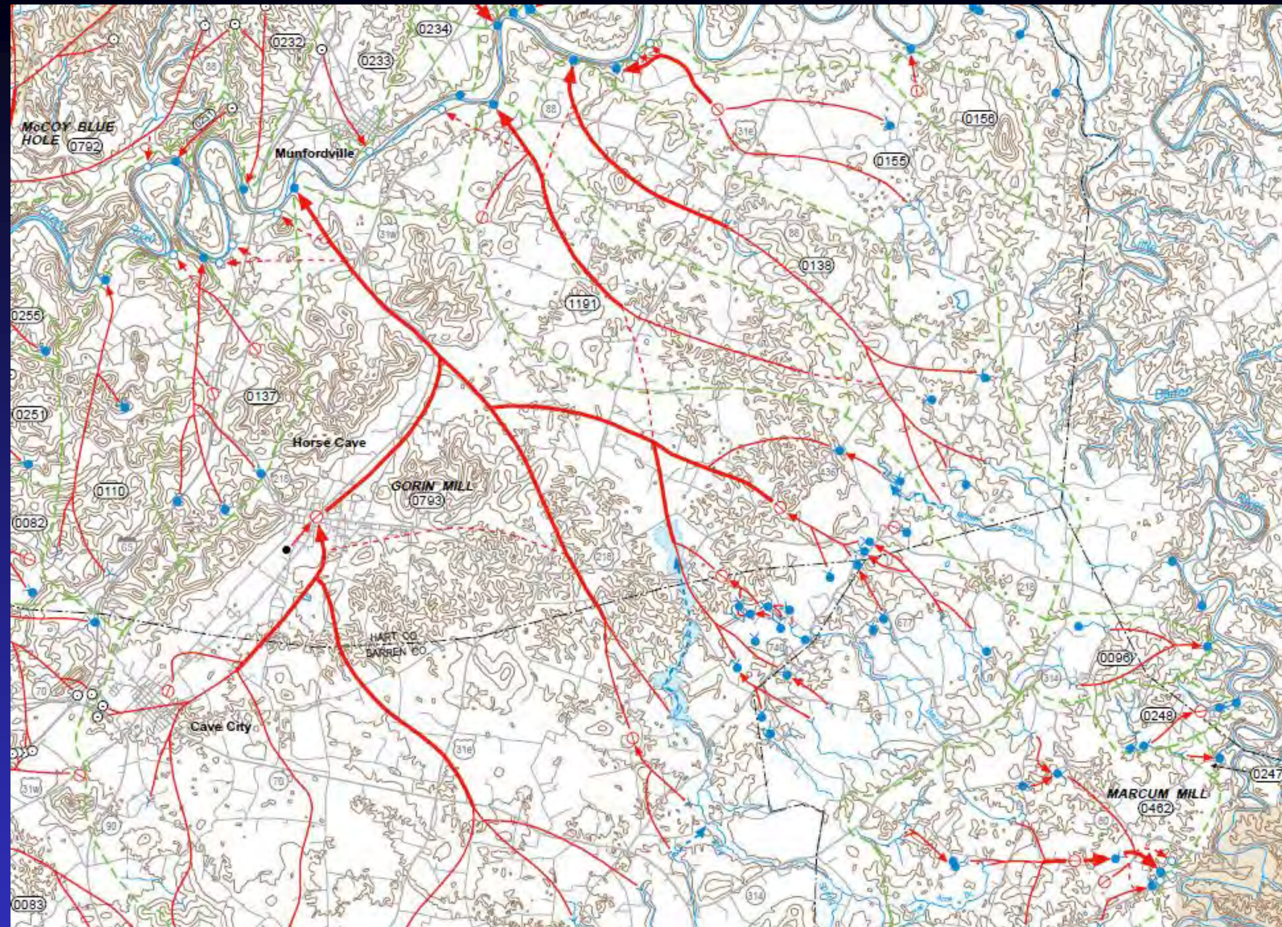
State and aquifer	Well depth below land surface (feet): Common range	Well depth below land surface (feet): May exceed
Kentucky (Ordovician limestone and dolomite)	50 to 200	300
Tennessee (Ordovician limestone and dolomite)	50 to 150	200
(Knox Group)	700 to 1,200	1,400

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).

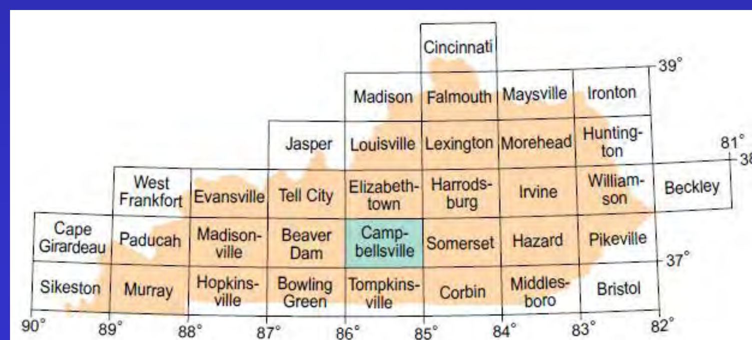
KY Karst Aquifers Are Highly Compartmentalized Into Subsurface Basins Similar to Surface Streams



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.

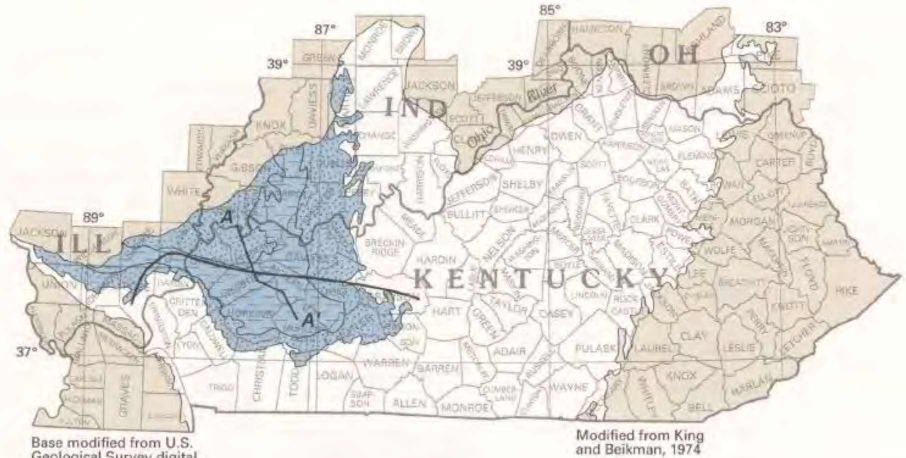
Karst Atlas maps are available for much of Kentucky and can be downloaded as .PDF files from the KGS website: http://www.uky.edu/KGS/water/research/kaatlas.htm



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

EXPLANATION

Pennsylvanian aquifers

Generally sandstone

Generally shale

Rough Creek Fault System—Approximately located

A——*A'* **Line of hydrogeologic section**

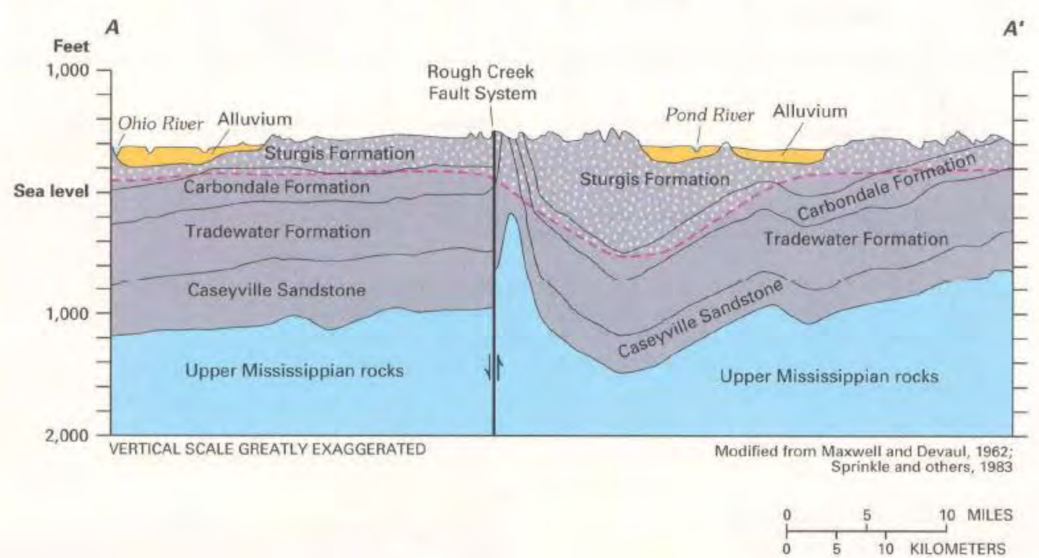


Figure 74. *Pennsylvanian rocks are offset by faults in some places and are folded in other places. The depth to water with a dissolved-solids concentration of 1,000 milligrams per liter averages less than 500 feet but can be as great as 1,000 feet. The line of the section is shown in figure 73.*

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

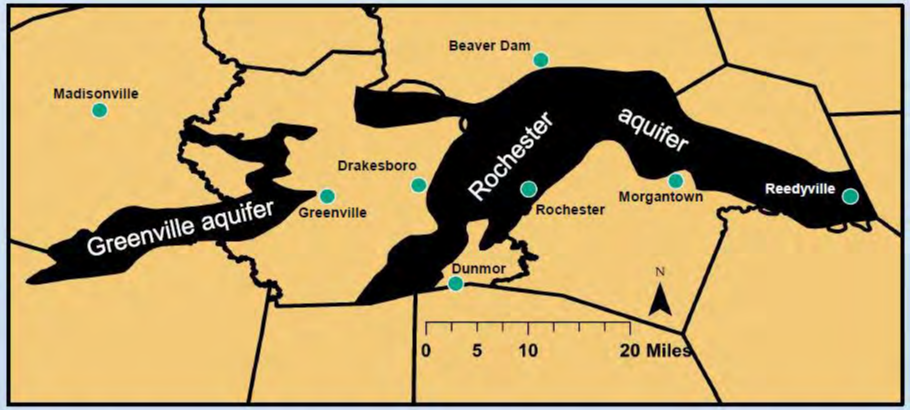
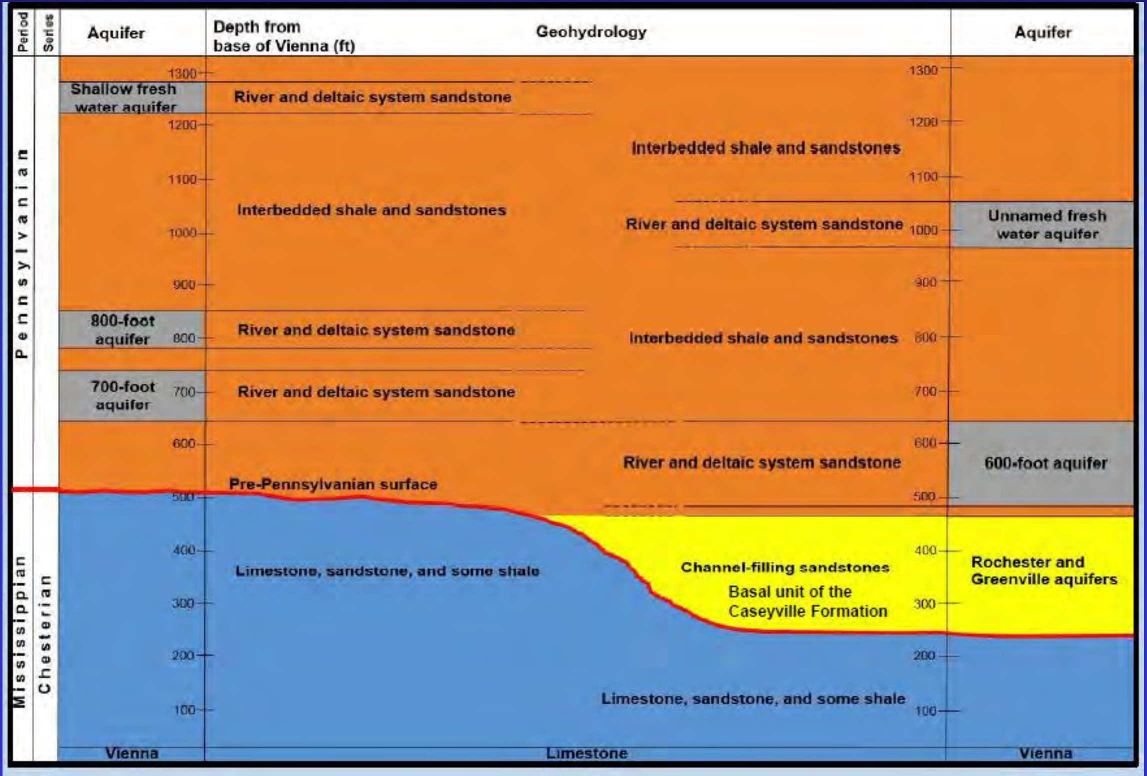


Figure 3. Distribution of the Greenville valley aquifer in relation to the Rochester valley aquifer. Modified from Davis and others (1974).



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

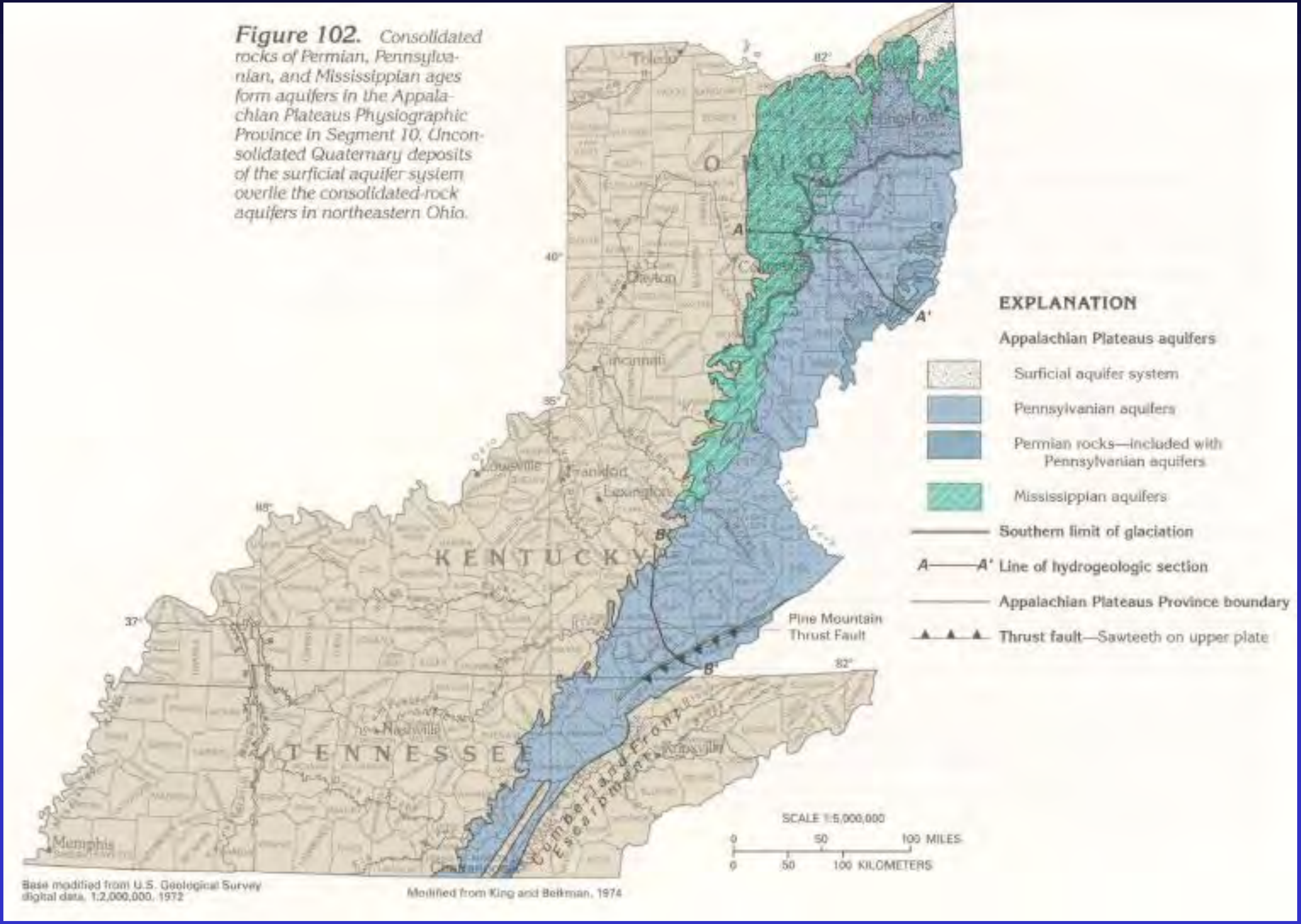
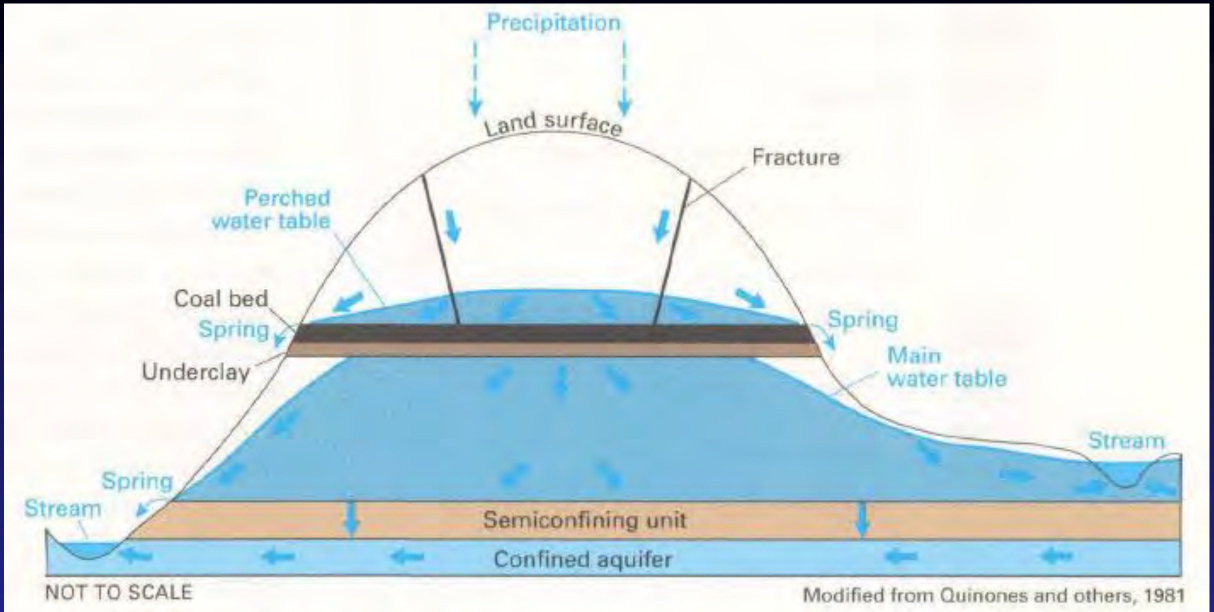


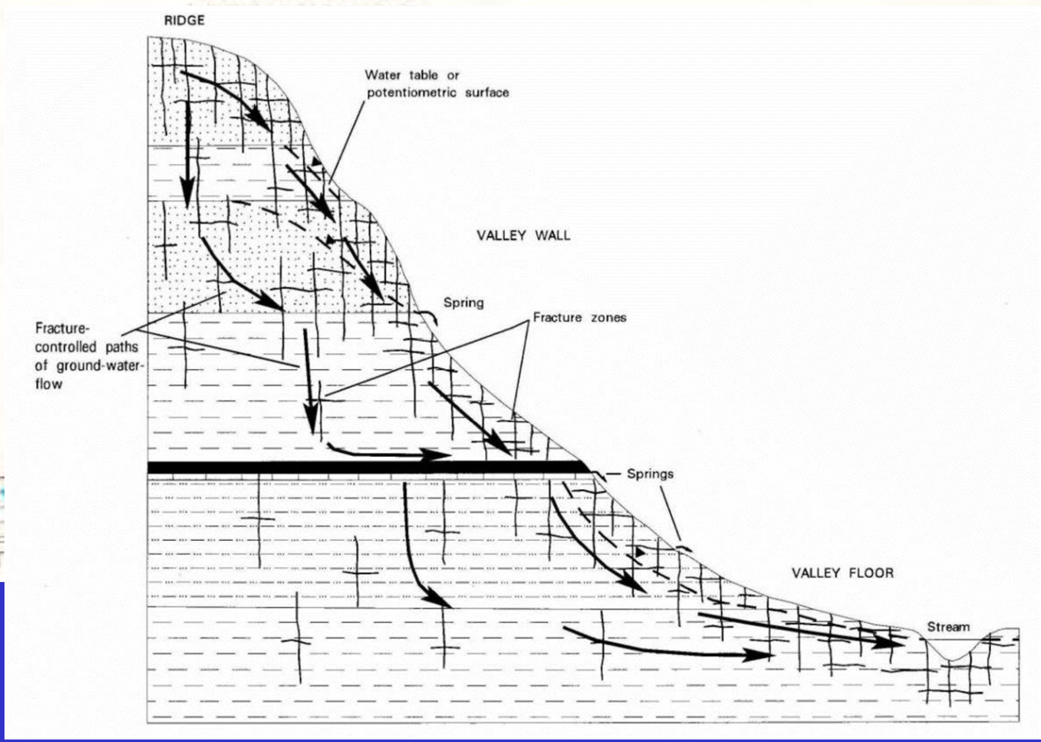
Figure 102. *Consolidated rocks of Permian, Pennsylvanian, and Mississippian ages form aquifers in the Appalachian Plateaus Physiographic Province in Segment 10. Unconsolidated Quaternary deposits of the surficial aquifer system overlie the consolidated-rock aquifers in northeastern Ohio.*

Typical Eastern Coal Field Stress-Relief Fractured Aquifer System

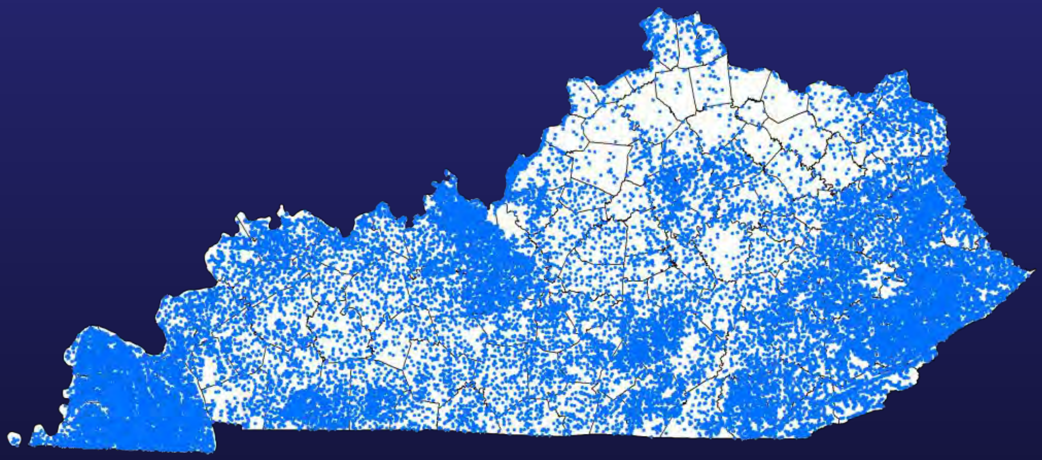
Above drainage, coal beds and fractured sandstones may be significant perched aquifers.

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

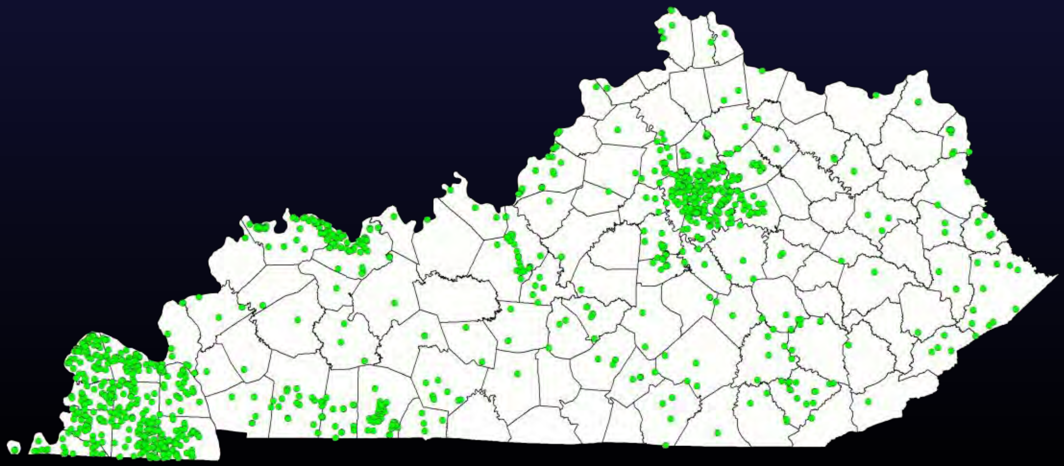




Distribution of Water Wells in Kentucky Gives Us A Clue as To Groundwater Availability and Suitability of Aquifers



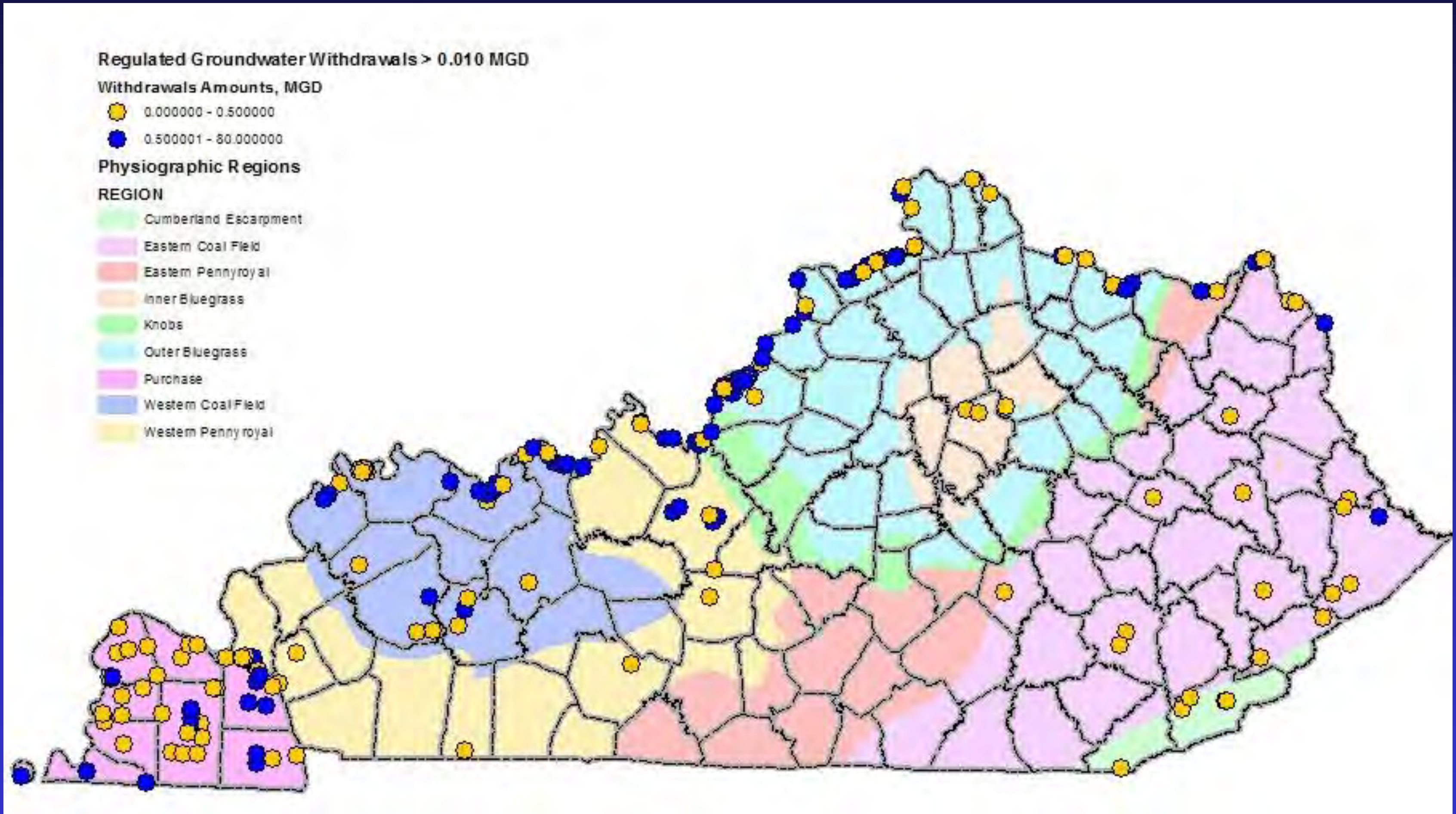
Private Water Wells in (52,000 records).



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

Part 2:
Priority Groundwater Data and Research Needs—KGS Perspective

Charles J. Taylor, Head
Water Resources Section
Kentucky Geological Survey
University of Kentucky

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KGS Role in Groundwater Monitoring and Studies

Mission:

- We are a Research and Public Service Unit within UK.
- KGS Mission is to Characterize and Provide Information about Ky's Geological, Mineral, Energy, and Water Resources.
- No Regulatory Responsibilities or Functions.

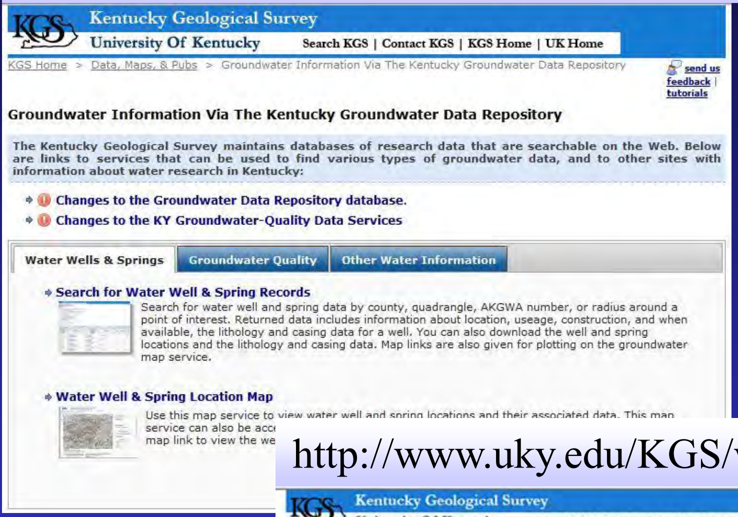
Legislative Mandates:

- KRS 151.035 "Official Repository for Groundwater Information.
- KRS 151.625 "Establishment of Long-Term Groundwater Monitoring Network".
- KRS 151.113 Kentucky Water Resources Board (source of "technical assistance").

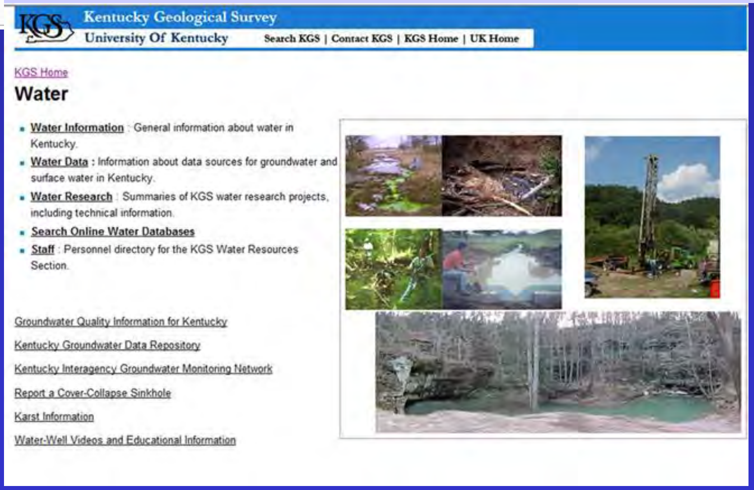
All Groundwater Data Collected In Kentucky is Stored and Accessed By the Groundwater Data Repository (GWDR).

- Initiated in 1990 by legislative mandate (KRS 151:035) and maintained by KGS.
- Currently:
  - Over 92,000 water well records.
  - Approximately 5,100 spring records.
  - About 60,000 groundwater-quality analyses.
- Over 15 contributing agencies, including KDOW, USGS, and EPA Storet.
- Largest single source of data: Kentucky certified water-well driller records from KDOW.

http://kgs.uky.edu/kgsweb/DataSearching/watersearch.asp



http://www.uky.edu/KGS/water/index.htm



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Priority Groundwater Data and Research Needs

- **Statewide Long-term Groundwater Observation Network.**

- **Aquifer Delineation and Mapping.**

- **More Quantitative Data on Aquifer Yield and Hydraulic Properties.**

- **Development of Improved Groundwater Management Tools.**

Priority Groundwater Data and Research Needs

Statewide Long-term Groundwater Observation Network

- Continuous monitoring of water levels in a suitable network of observations wells is needed to build a database capable of identifying and tracking trends in groundwater levels and assessing changes in groundwater recharge, storage, and discharge (withdrawals).
- Calculations of meaningful statistical parameters such as mean, maximum, and minimum groundwater levels will require at least 5 years of data.

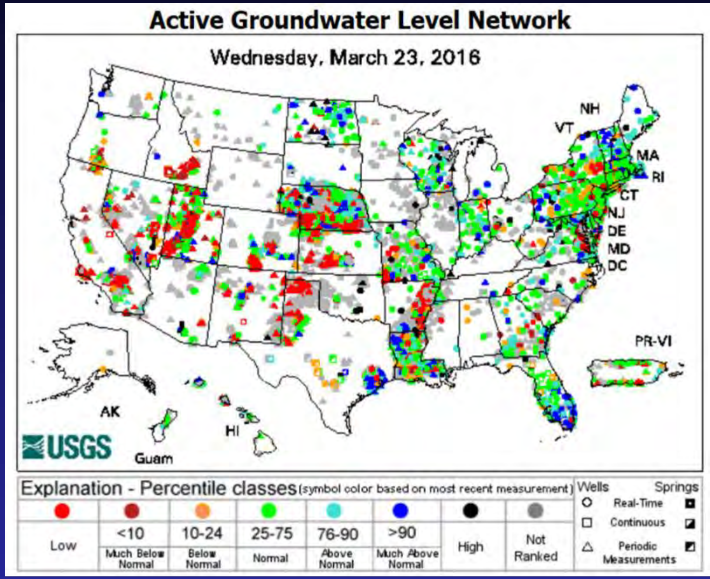
Need for a Ky Groundwater-Level Observation Network

- **Previously a statewide network of up to 64 wells was operated jointly by USGS and KGS from the mid-1950s to the early-1990s.**

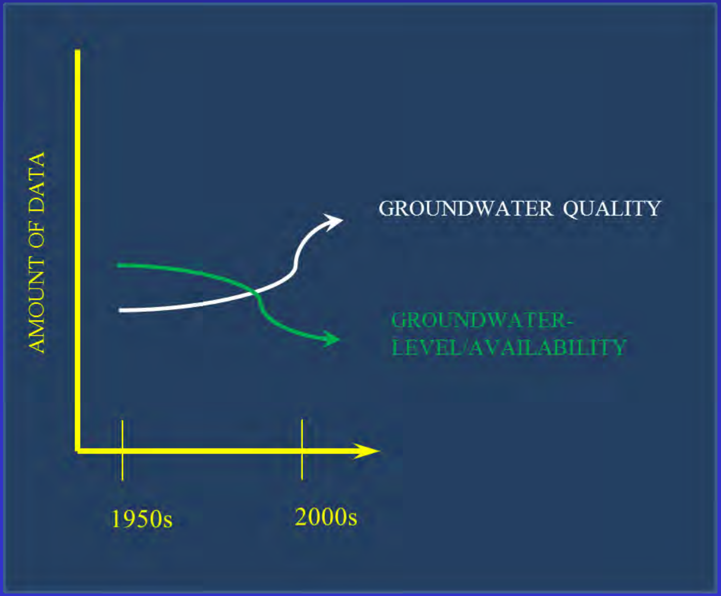
- **Continual decreases in Federal and state funding steadily eroded the network over the years, eventually leaving only one well being continuously monitored in Kentucky by USGS as part of a national groundwater network.**

- **In recent decades, comparatively more effort has been given to the collection of groundwater-quality data, largely driven by the needs of state and federal regulators.**

- **Information about current groundwater conditions is unavailable in most parts of the state, and it is not uncommon for available water-level data to be 25 years or more out-of-date.**



Source: http://groundwaterwatch.usgs.gov/



In 2015 KGS Started Work Rebuilding A Statewide Kentucky Groundwater Observation Network (KGON)

- Helps meet critical need for continuously updated groundwater-level data and re-establishment of a statewide long-term groundwater monitoring network.

- Helps fulfill KGS legislative mandate to establish a network "…for the purpose of characterizing the quality, quantity, and distribution of Kentucky's groundwater resources."

- "…in areas of demonstrated need.".

- Wells serve as fixed monitoring sites representative of specific aquifers or aquifer types (e.g. karst, fractured sedimentary rock, etc.).

- "…support research efforts that develop models for groundwater systems…", and "…to determine and monitor trends…".

Capitalization

- KGS: App. $75K one-time internal funding contributed to establish initial network of up to 15 observation wells in critical areas and cover 12 mo. operations costs (implementation during 2015-16).

- Annual O&M costs (app. $30K) are presently anticipated to be covered by KGS for first 3 years; unanticipated cost increases, funding cuts, or resource re-allocation decisions could potentially affect this.

- Long-term maintenance, expansion or enhancement of network and data-collection activities, will require additional outside funding and partnerships.

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Equipment Installation At the Network's 1st Observation Well

Monitoring a fractured-karstic limestone aquifer at Kentucky Horse Park, Scott Co.

Clockwise from upper left:

1. Preparation of anchor point (datum) for pressure transducer.
2. Measuring out transducer data cable length.
3. Inserting transducer and cable into well.
4. Final field check of transducer and telemetry equipment.

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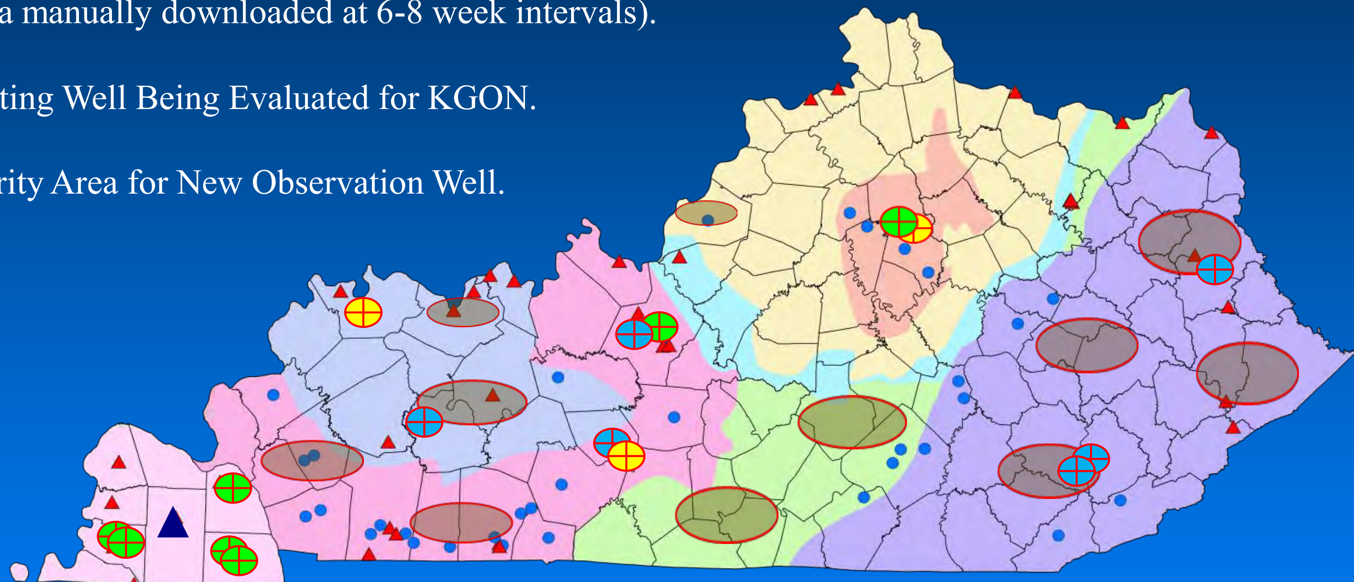
Status of KGS KY Observation Well Network (KGON) Sites As Of August 10, 2016

- Continuously-Monitored Observation Well (Data downloaded daily).
- Continuously-Monitored Observation Well (Data manually downloaded at 6-8 week intervals).
- Existing Well Being Evaluated for KGON.
- Priority Area for New Observation Well.



Map Courtesy of Rob Blair, KDOW, 2014

Groundwater Monitoring Sites Maintained By Other Agencies:

- Spring / Well — KDOW-ITAC Periodic Groundwater-Quality Sampling Sites
- USGS National Climate-Response Network Well

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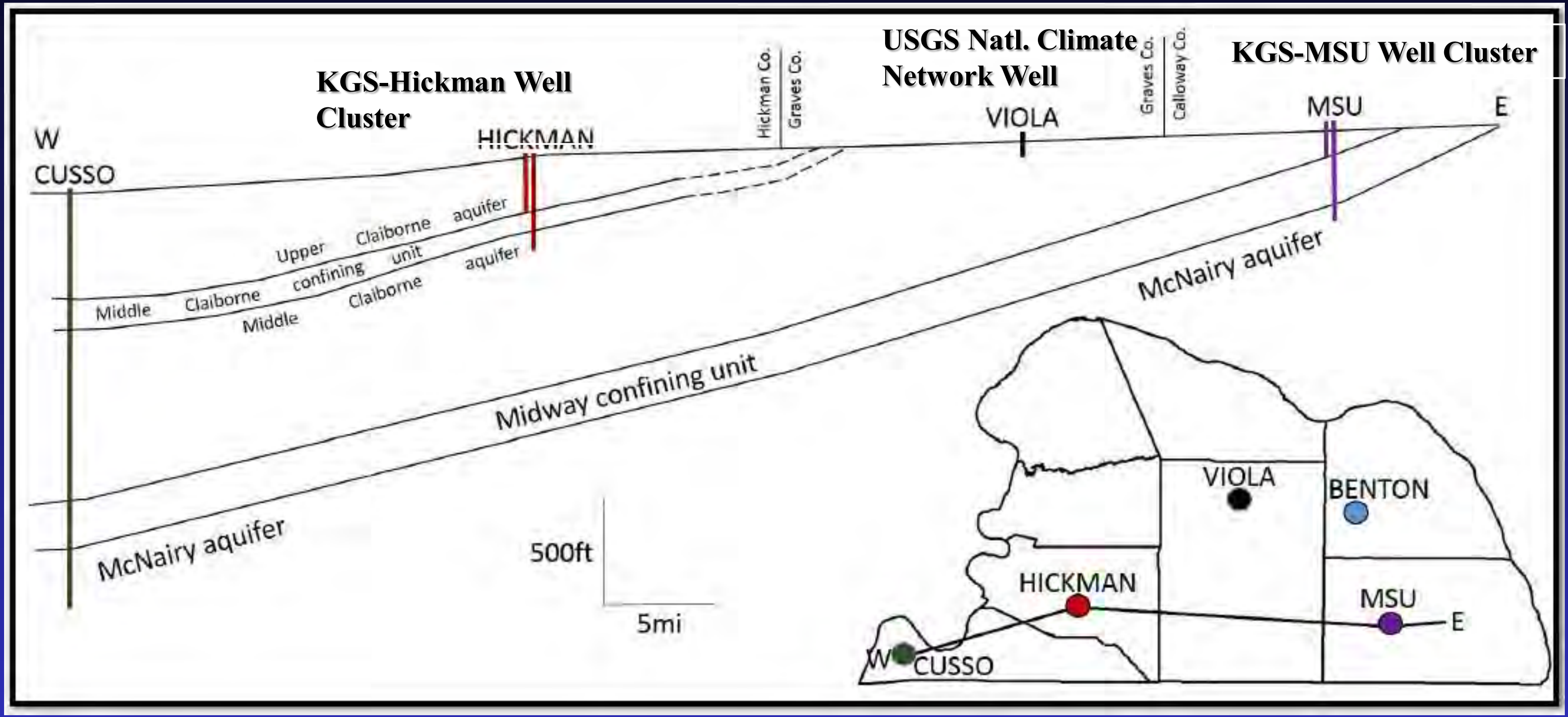
KGS Groundwater Monitoring Work in JPA



- ✓ KGS Drilled and Instrumented Two New Observation Well Clusters, and established a Third Observation Well at Benton.
- ✓ Collecting Natural Gamma Logs, and other Geophysical Data, to Improve Identification of Subsurface Aquifer Boundaries and Confining Units.
- ✓ Collected Additional GWL Measurements and Water Well Data, and Conducted Specific Capacity Tests of Irrigation Wells at Clarks River Wildlife Refuge near Benton.

KGS Hickman Co. Observation Well Cluster

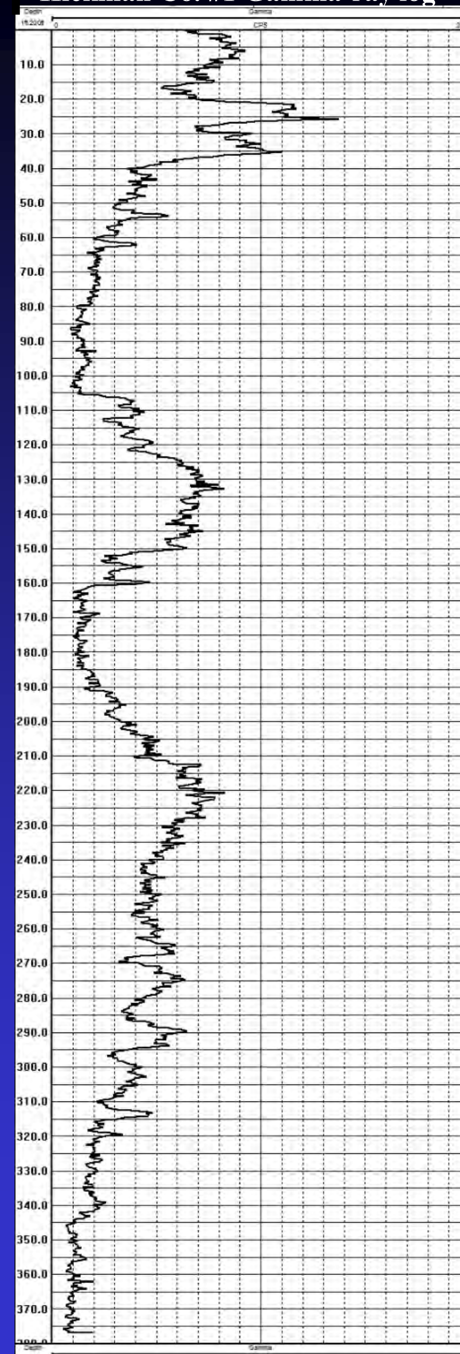
near Clinton, KY

SWL/TD:

HICKMAN #2 81/180 FBLS

HICKMAN #1 84/380 FBLS

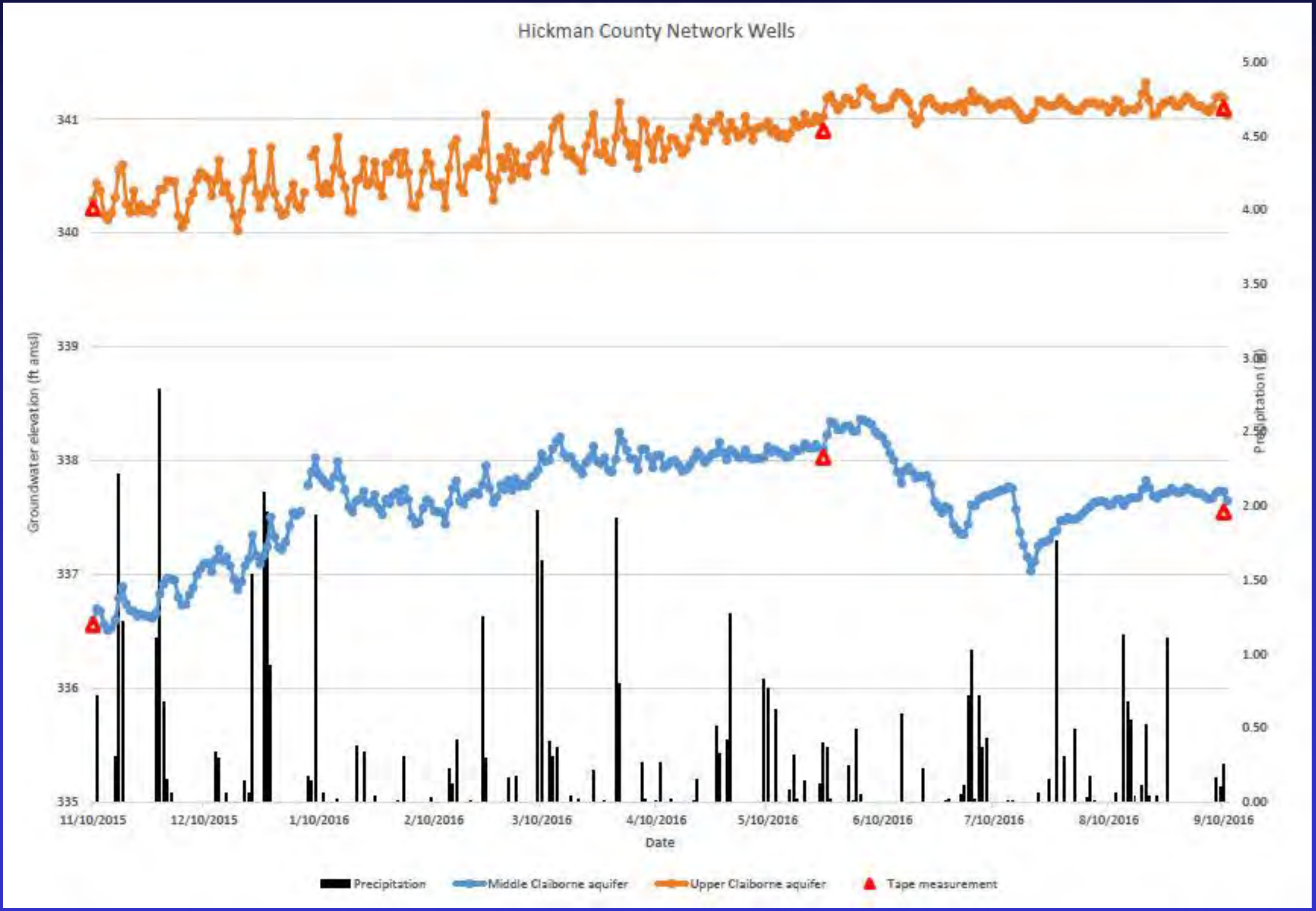
Hickman Co. #1 Gamma-ray log



Lithology	Hydrogeologic unit
Silt/clay	Soil/loess
Clay	Unnamed unit
Sand	Upper Claiborne aquifer
Clay	
Sand	
Clay	Middle Claiborne confining unit
Sand	Middle Claiborne aquifer

Location of the Hickman Observation Cluster Relative to Some High-Yield Water Wells

Preliminary
JPA Hickman Well Cluster Hydrograph Data



KGS MSU Observation Well Cluster

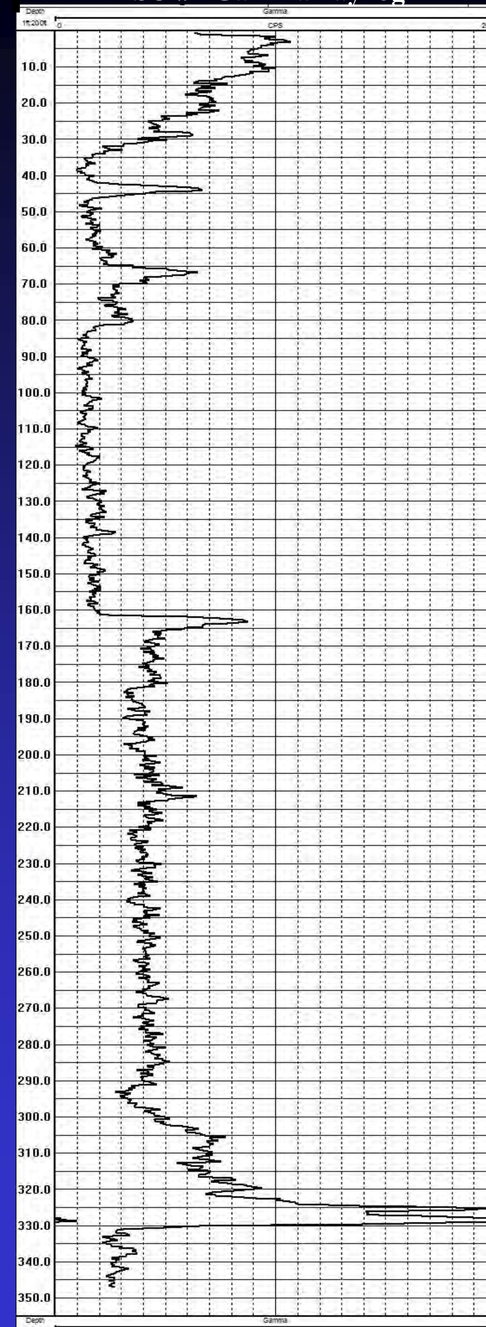
at Murray, Calloway Co., KY

SWL/TD:

MSU #2 45/150 FBLS

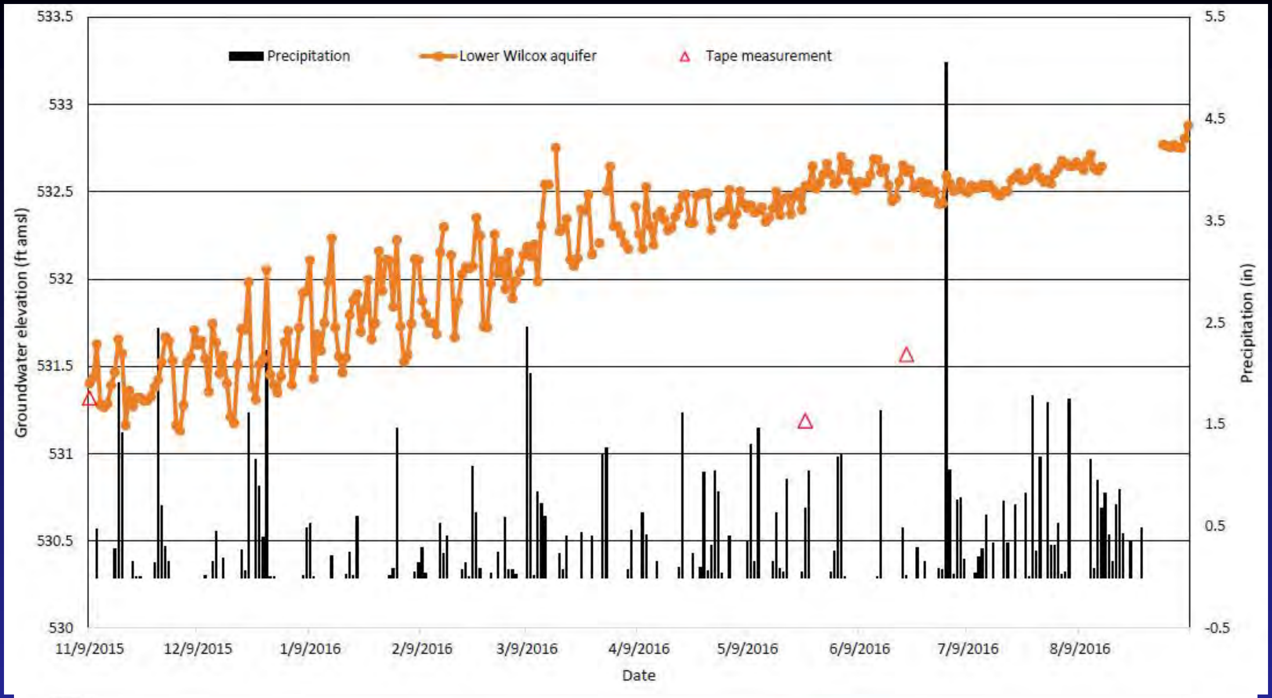
MSU #1 150/350 FBLS

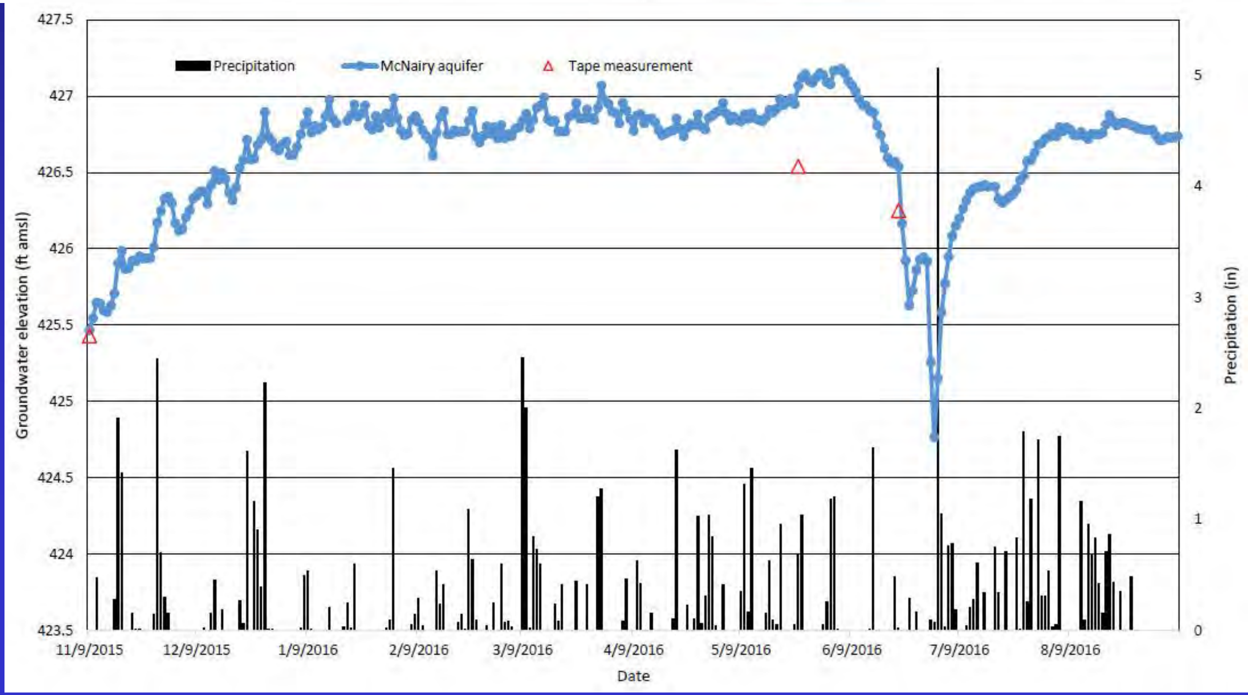
MSU #1 Gamma-ray log



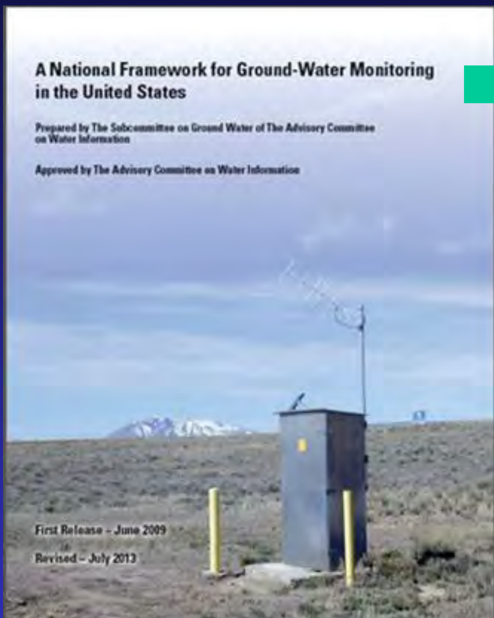
Lithology	Hydrogeologic unit
Silt/clay	Soil/loess
Clay	Unnamed units
Gravel	
Sand	Lower Wilcox aquifer
Clay	Midway confining unit
Sand	McNairy aquifer

Preliminary JPA Murray Well Cluster Hydrograph Data





KGS Using Nationally Recommended Approach to Build a Synergistic Program for Groundwater Monitoring & Assessment



Groundwater Monitoring Network (Groundwater Level and Quality Data)

Surveillance (Synoptic) Sites

For single or periodic measurement of water levels and groundwater quality at many locations (Snapshot-in- Time) data to complement Trend Sites data.

Special Studies

Targeted groundwater investigations conducted to better map and quantify aquifer properties.

Trend Sites (Continuous sites)

For continuous tracking of temporal changes (short and long term) at specially targeted locations. Subnetworks recommended for unstressed and impacted aquifers.

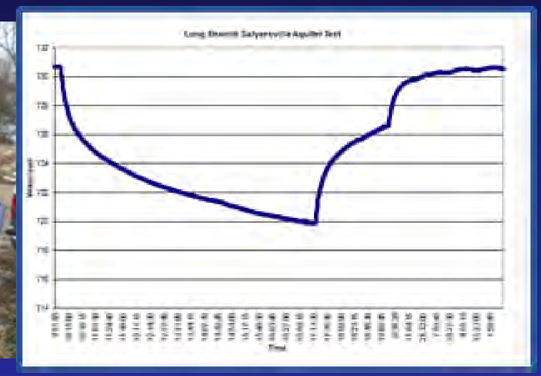
Baseline Monitoring Period of 5 years minimum recommended

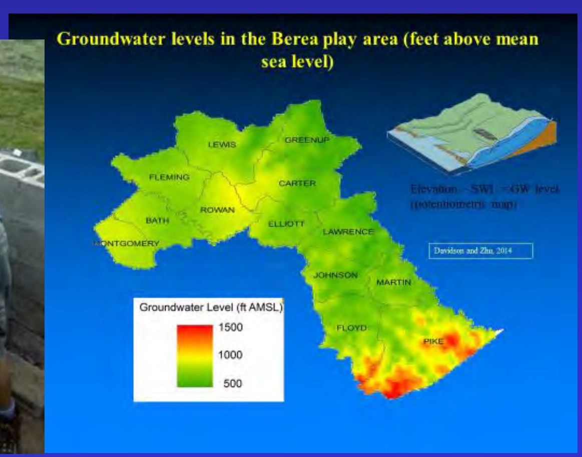
Contributors: KDOW, USGS, other UK Departments (Earth and Environmental Sciences, Agriculture) and Ky Colleges

Additional Data Collection Activities Being Conducted by KGS to Support the KY Groundwater Observation Network:

Well/borehole geophysical logging

Aquifer tests





Synoptic water-level measurements from additional wells. Limited groundwater quality sampling.

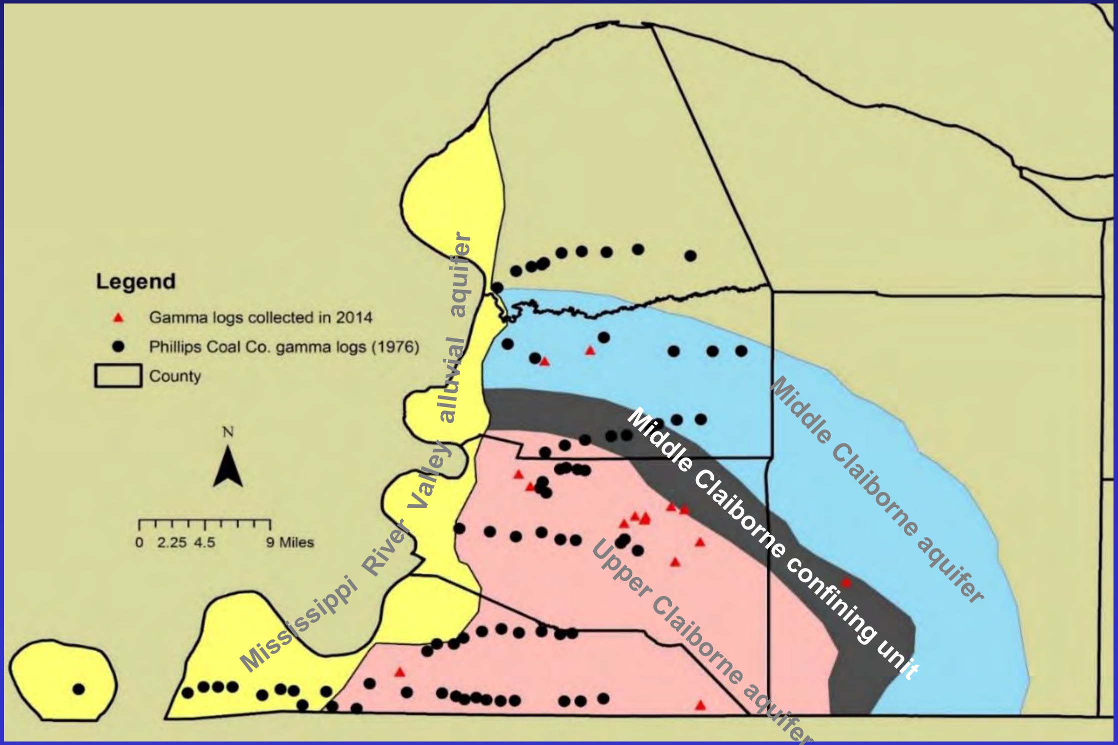
Priority Groundwater Data and Research Needs

Aquifer Delineation and Mapping

- Needed for Improved Groundwater Availability Assessment, and Resource Development and Management.
- Involves Collecting and Synthesizing Data From Multiple Sources including Geological Mapping Data (Stratigraphy and Structure), Geophysical Logs and Well Construction Records Obtained for Water, Oil, and Gas Wells.
- Also Requires Data on Aquifer Hydraulic Properties Obtained from Well Tests.
- KDOW & KGS Working in Collaboration on Proposal for Pilot-Scale Project for Aquifers Used by Permitted Groundwater Suppliers (funding opportunity through USGS National Water Use Program).

Present Aquifer Delineation Activity in western Jackson Purchase Area—

- **Water well inventory and gamma-ray logging of selected irrigation and domestic wells.**
- **Digitizing scanned gamma-ray logs from Phillips Coal Company boreholes (ca. 1976).**



Modified from Lloyd and Lyke, 1995

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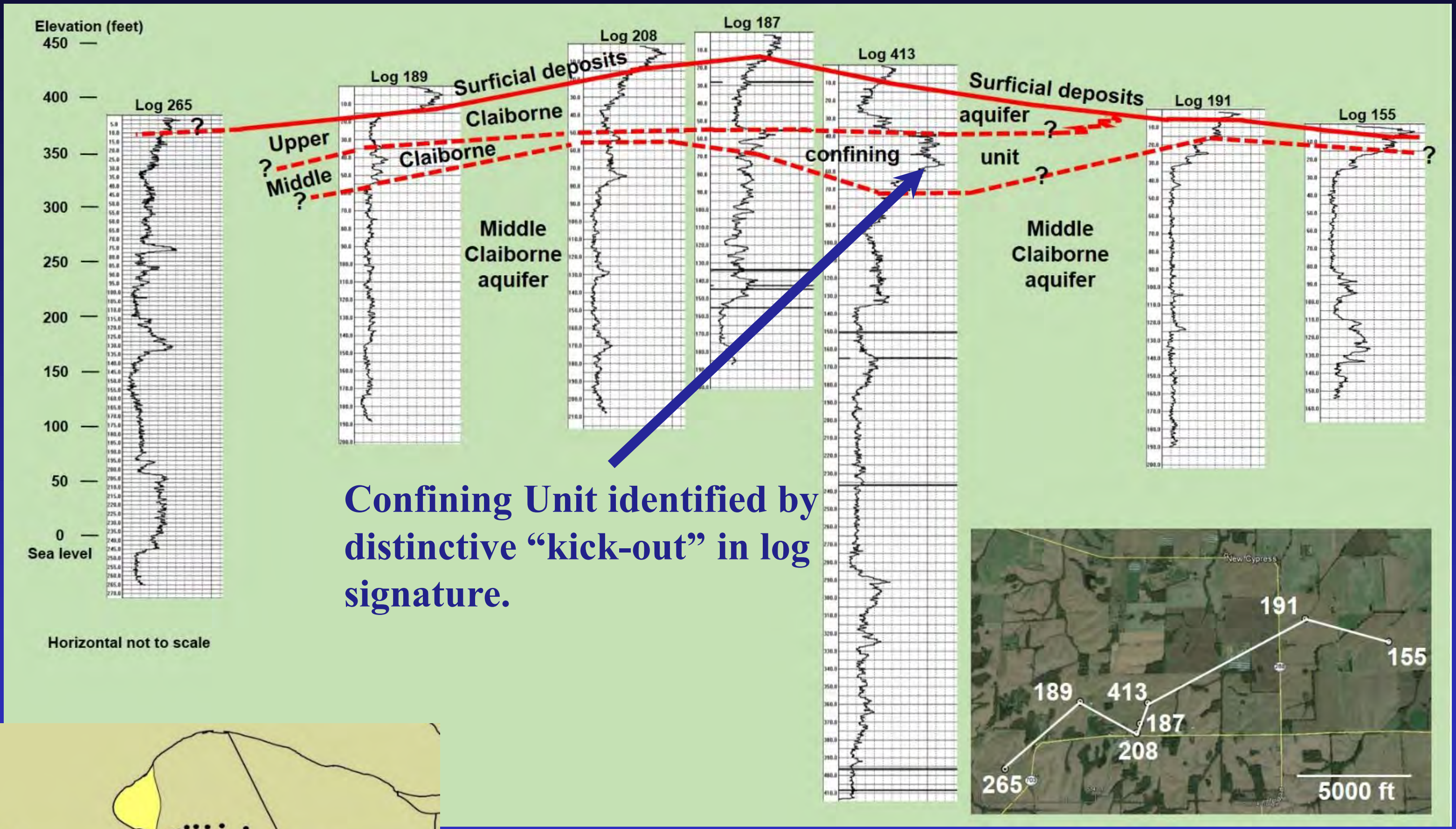
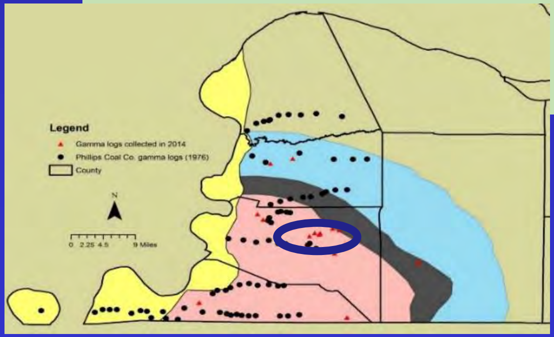
Gamma-Ray Logs of JPA Wells Raise Questions about Variations in Extent and Thickness of Aquifer Zones and Confining Units



Confining Unit identified by distinctive "kick-out" in log signature.



These Questions May Have Important Implications for Groundwater Monitoring and Groundwater and Surface Water Resources Management in the Area.

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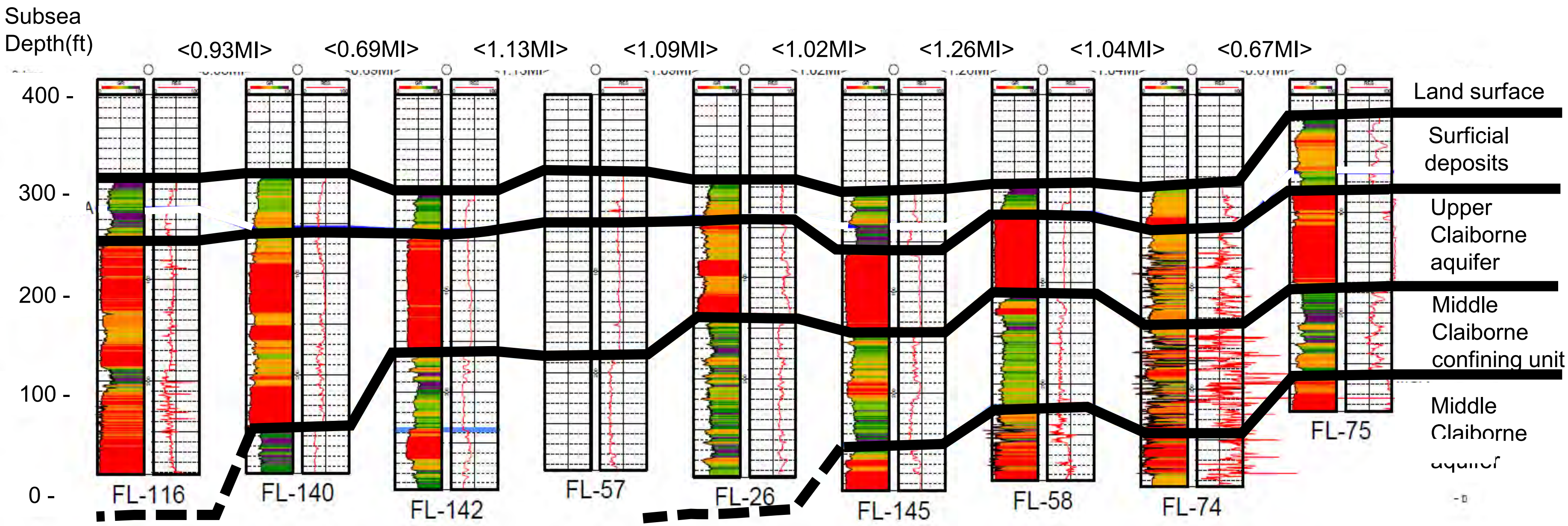
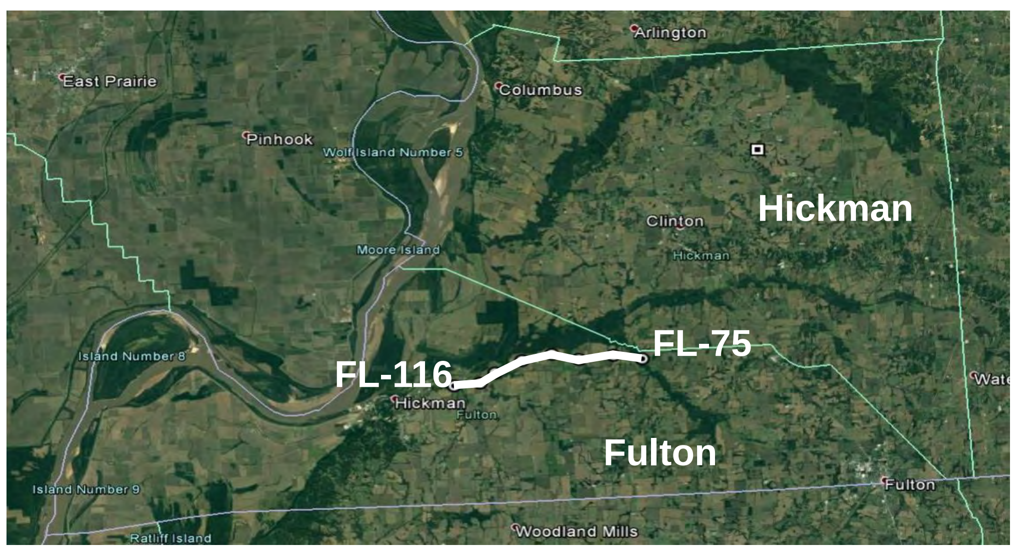
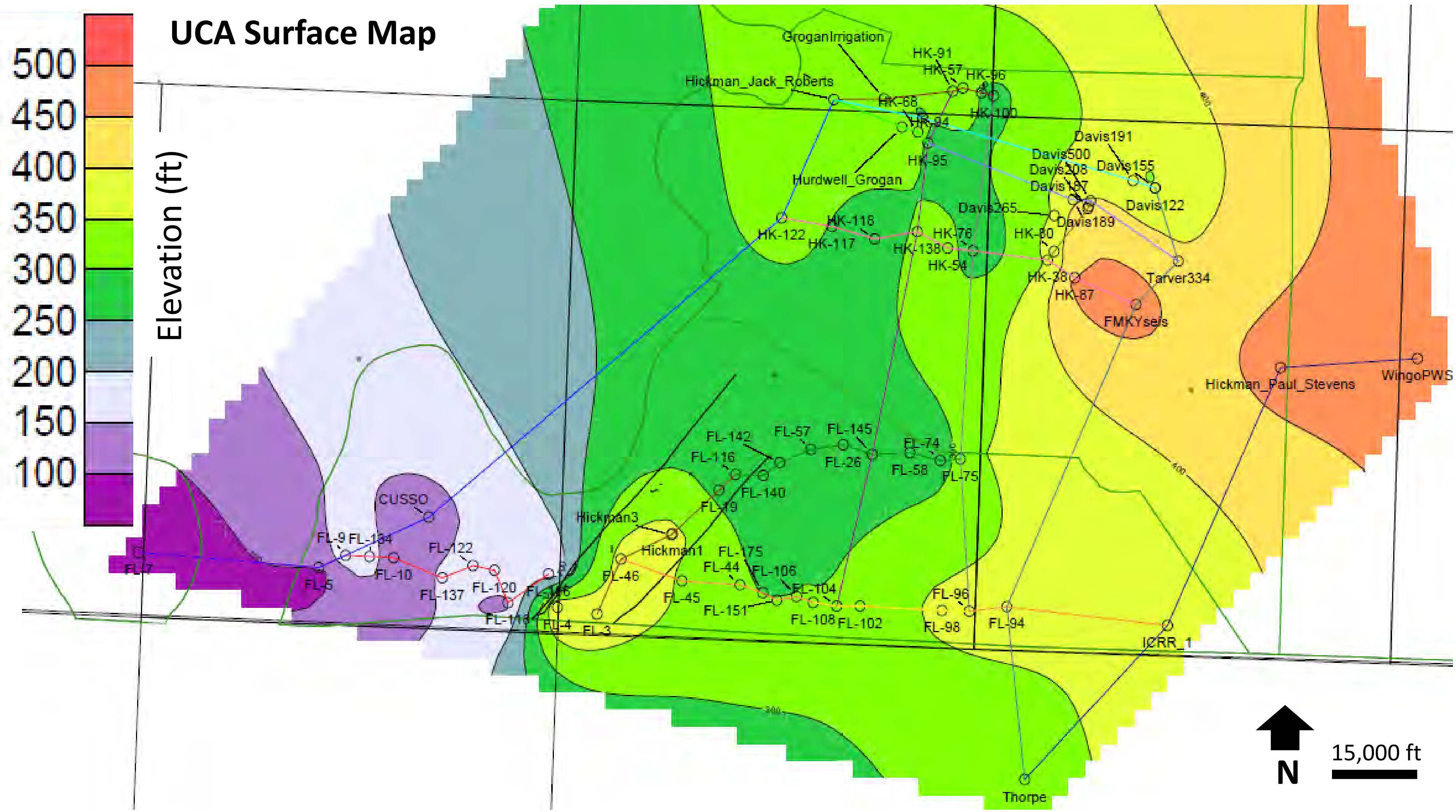
Example Hydrostratigraphic Cross Section

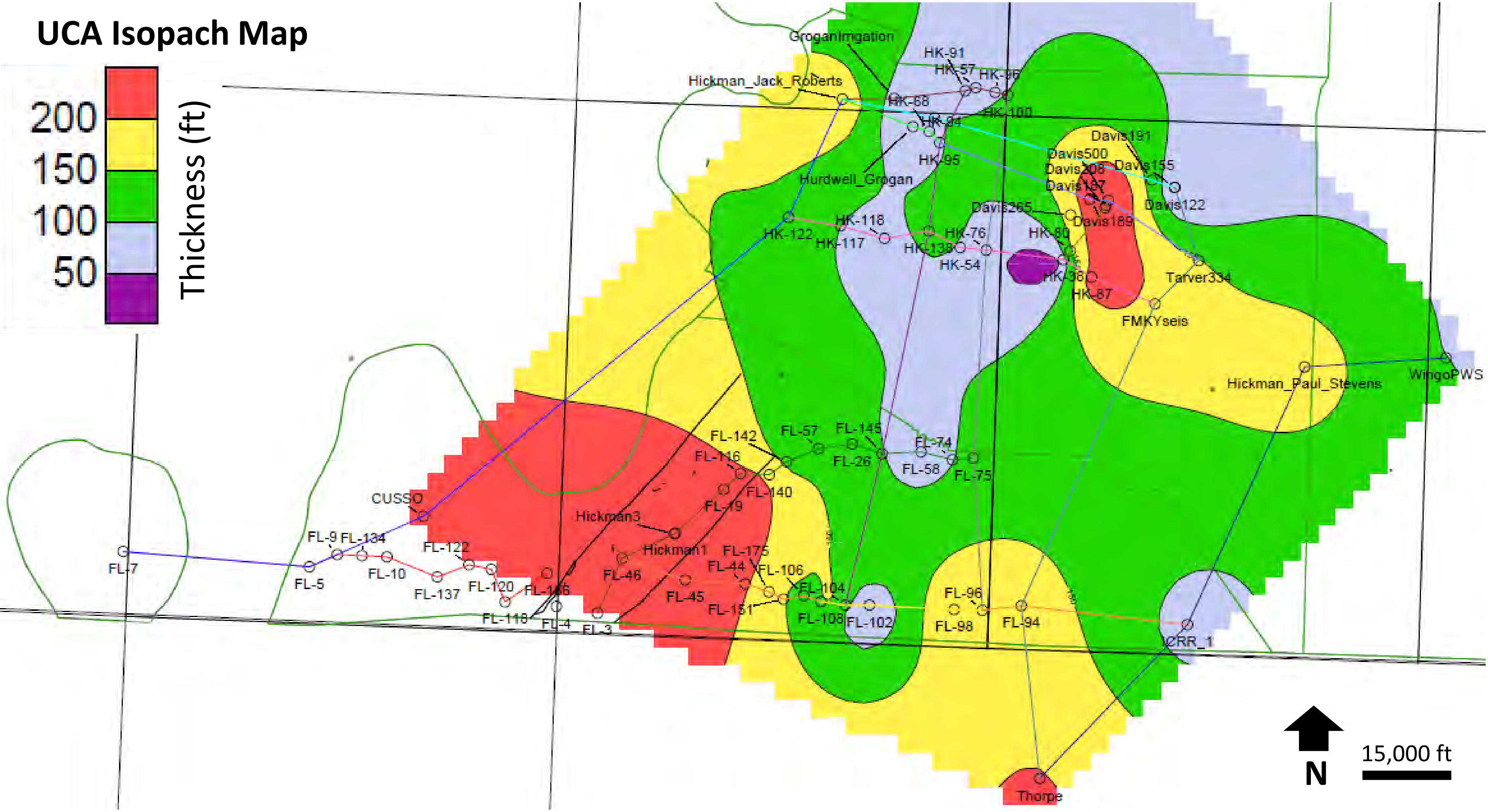




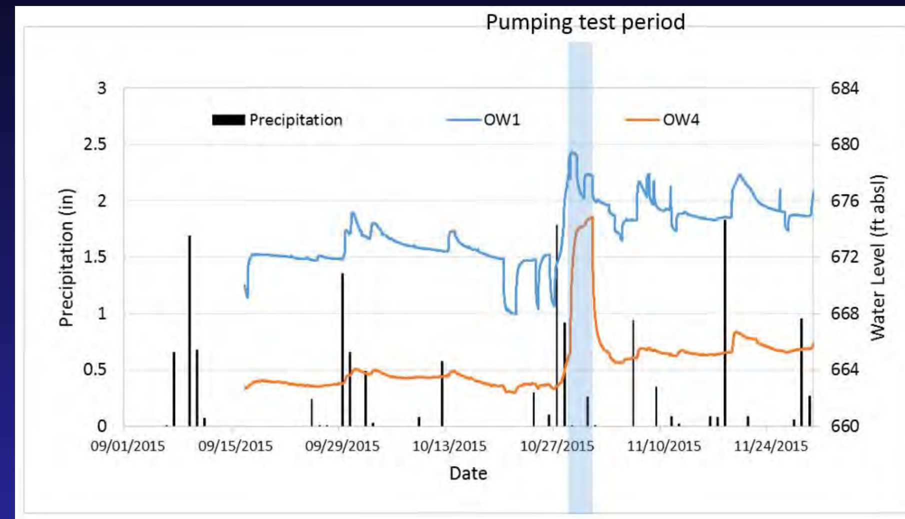
Upper Claiborne Aquifer Surface Map

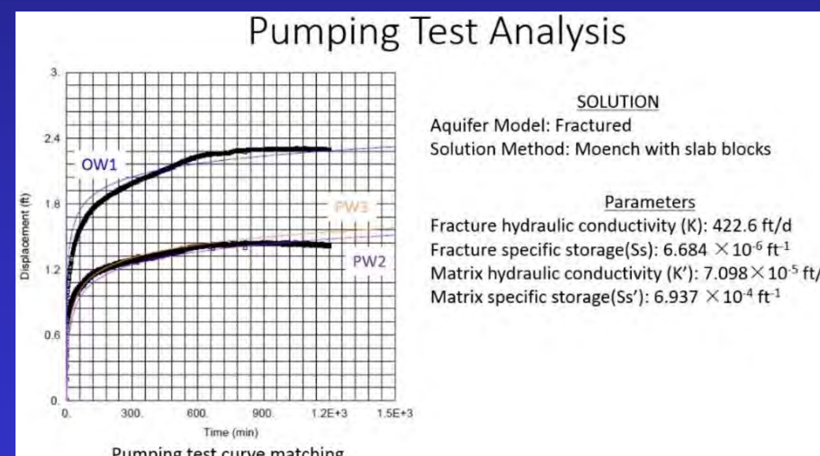


Upper Claiborne Aquifer Thickness Map



More Quantitative Data on Aquifer Yield and Hydraulic Properties—Example: Elizabethtown municipal well field





KGS is actively working with KY Rural Water and others to identify water wells for testing.

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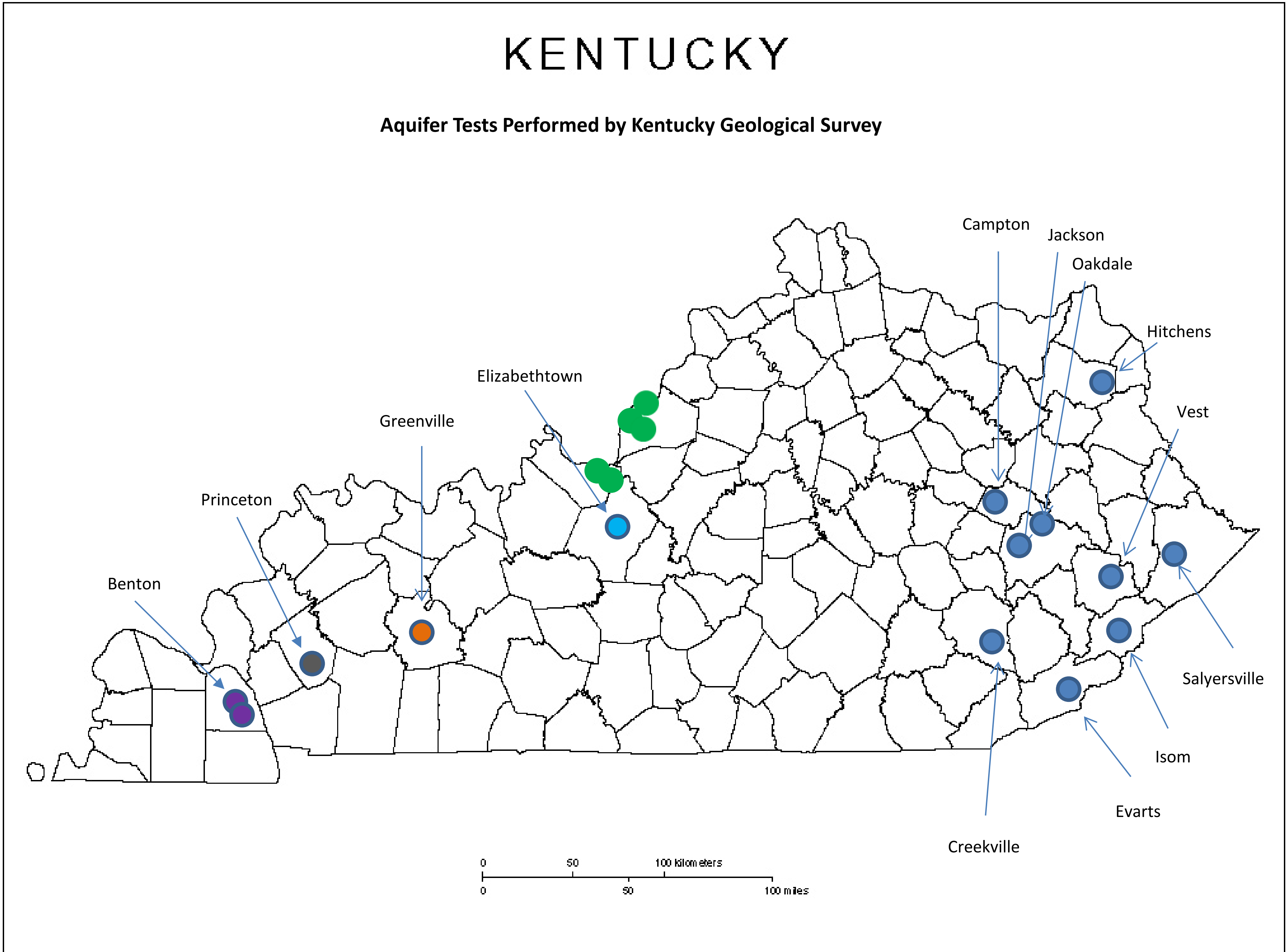

KENTUCKY
Aquifer Tests Performed by Kentucky Geological Survey
Campton
Jackson
Oakdale
Hitchens
Vest
Elizabethtown
Greenville
Princeton
Benton
Salyersville
Isom
Evarts
Creekville
0
50
100 kilometers
0
50
100 miles

KGS Is Creating an Public-Accessible Aquifer Test Archive and Webpage Site

Campton, Wolfe Co.

New Plant Well (Brewer Trail Road)
December 19, 2009

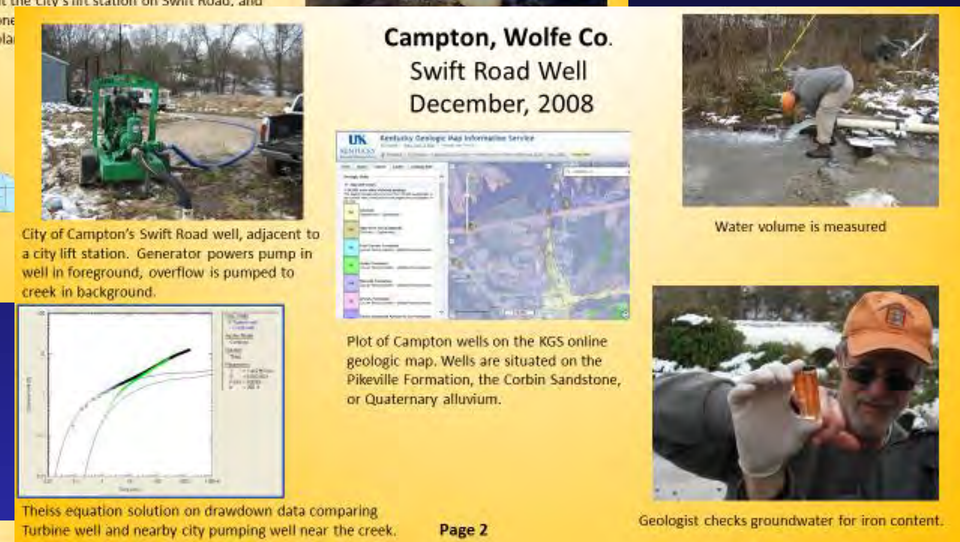
BACKGROUND

The City of Campton had been looking for an additional groundwater supply well to supplement water production drawn from nearby Campton Lake. KGS was asked in 2006 to assist in performing aquifer tests on three wells: one by the old water plant, one at the city's lift station on Swift Road, and one

pla

Site of well near location of proposed Campton Water Plant.

Well sites on a 7.5-minute topograph base of the Campton quadrangle.



Campton, Wolfe Co.

Swift Road Well
December, 2008

City of Campton's Swift Road well, adjacent to a city lift station. Generator powers pump in well in foreground, overflow is pumped to creek in background.

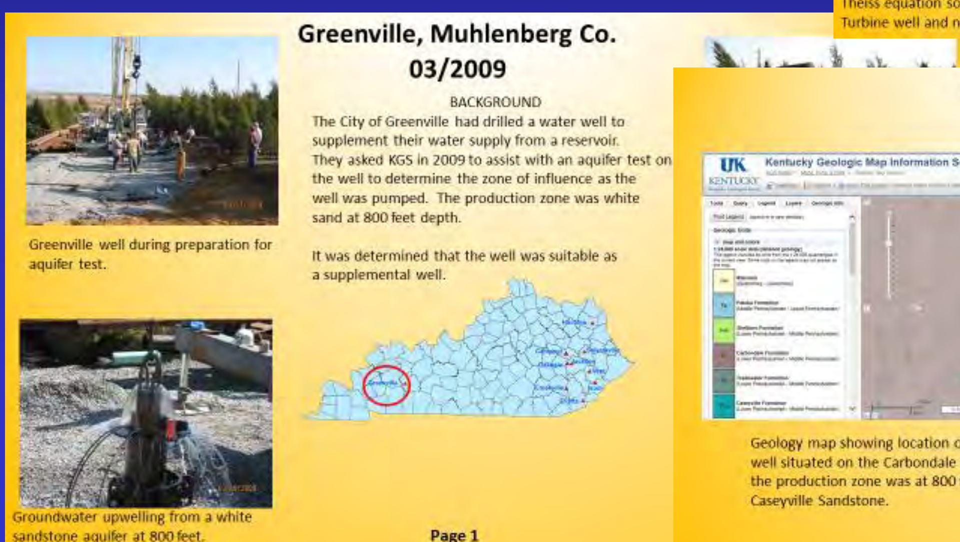
Plot of Campton wells on the KGS online geologic map. Wells are situated on the Pikeville Formation, the Corbin Sandstone, or Quaternary alluvium.

Water volume is measured

Theiss equation solution on drawdown data comparing Turbine well and nearby city pumping well near the creek.

Geologist checks groundwater for iron content.

Page 2



Greenville, Muhlenberg Co.

03/2009

BACKGROUND

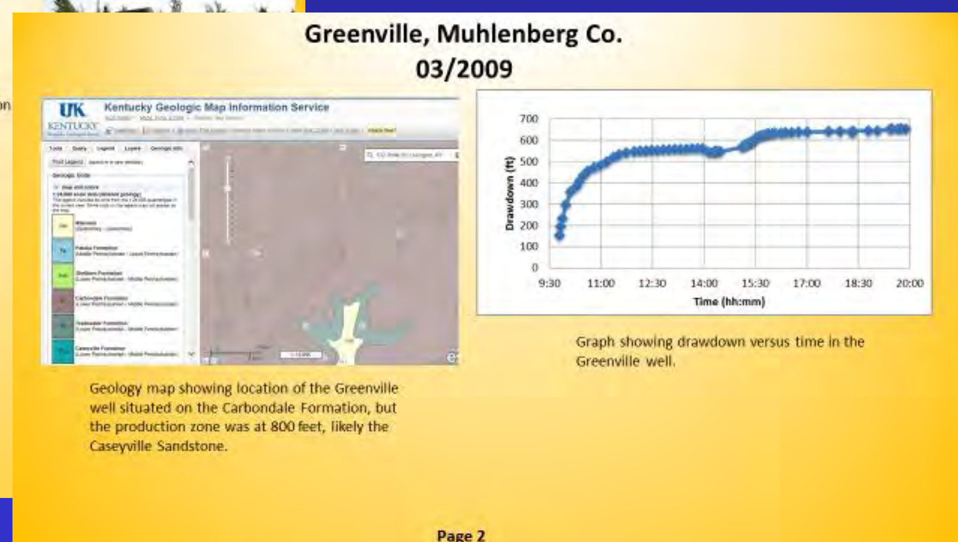
The City of Greenville had drilled a water well to supplement their water supply from a reservoir. They asked KGS in 2009 to assist with an aquifer test on the well to determine the zone of influence as the well was pumped. The production zone was white sand at 800 feet depth.

It was determined that the well was suitable as a supplemental well.

Greenville well during preparation for aquifer test.

Groundwater upwelling from a white sandstone aquifer at 800 feet.

Page 1



Greenville, Muhlenberg Co.

03/2009

Geology map showing location of the Greenville well situated on the Carbondale Formation, but the production zone was at 800 feet, likely the Caseyville Sandstone.

Graph showing drawdown versus time in the Greenville well.

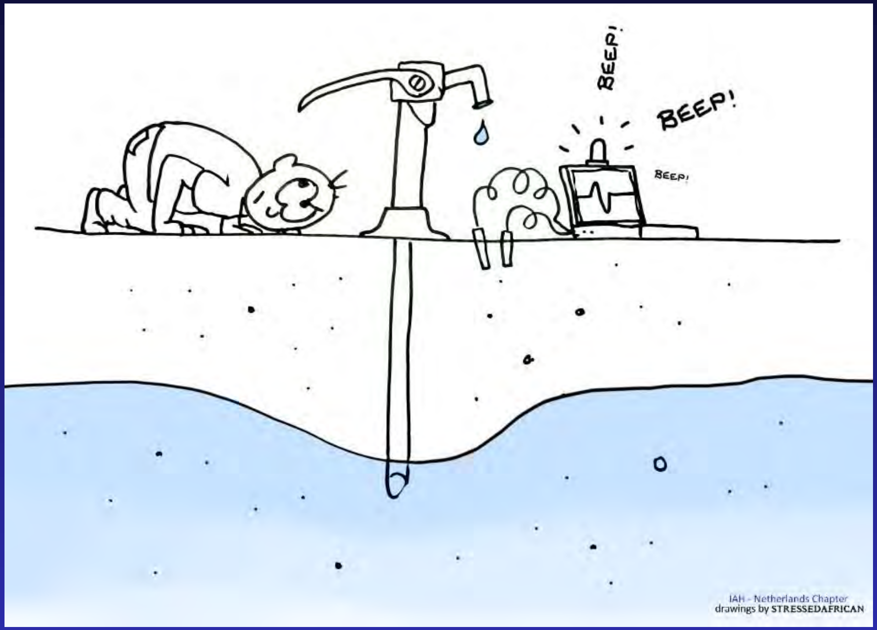
Page 2

Priority Groundwater Data and Research Needs

Development of Improved Groundwater Management Tools

- To Be Determined
- May Involve Creation of Groundwater Flow Models or Well-Hydraulic Response Simulation Tools that Can Help Predict Groundwater Availability and Sustainability.
- This Objective Requires Access to Sufficient High-Quality Hydrogeological Data, and Proper Conceptualization of the Aquifer. Therefore Its Eventual Realization Depends on the Previous Priority Items We've Discussed.

Questions and Discussion



For More Information Contact:
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Phone: 859-323-0523

Looking Ahead to a Kentucky Water Resources Plan

Water Resources Board

October 31, 2016

Department for Environmental Protection
Energy and Environment Cabinet

To Protect and Enhance Kentucky's Environment

Kentucky
UNBRIDLED SPIRIT ™

KENTUCKY FARM BUREAU

WATER MANAGEMENT
WORKING GROUP

https://www.kyfb.com/federation/water/resources/

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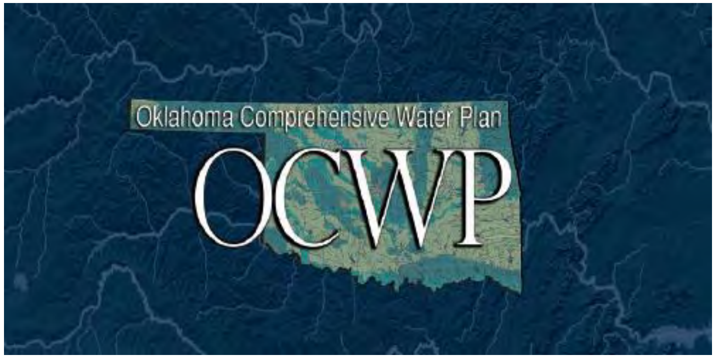
“A GOAL WITHOUT A PLAN IS A WISH”

Anonymous Radio Personality

The AWP brings data, science, and public input together to define water demands, water supplies, issues and potential solutions to meet our future needs.



States' plans are unique but share common features that are the foundation for water planning.

Georgia's
State Water Plan

The Georgia Comprehensive State-wide Water Management Plan (State Water Plan) was adopted by the General Assembly in 2008. The State Water Plan provides for Resource Assessments, Forecasting, and Regional Water Planning.

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CORE ELEMENTS OF A WATER PLAN PROCESS

WATER AVAILABILITY

DEMAND FORECASTING

GAP ANALYSIS

TECHNICAL RESULTS AND FINDINGS

ISSUES AND POLICY RECOMMENDATIONS

PLAN IMPLEMENTATION

**STAKEHOLDER-DRIVEN

**REGIONAL PERSPECTIVES AND PRIORITIES

**INCREMENTAL DEVELOPMENT

Water Supply and Infrastructure

Water Quality

Watershed Management

Wastewater Infrastructure

Drinking Water Action Plans
AG Water Quality Plans
Source Water Protection Plans
Drought Response Plan

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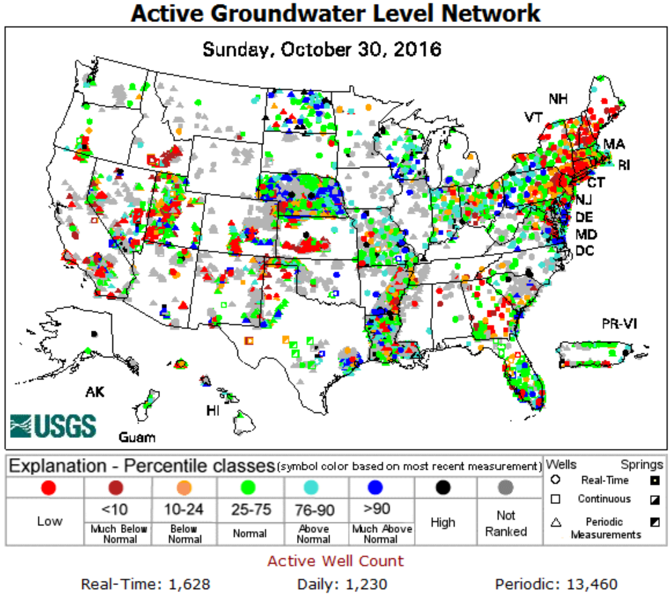

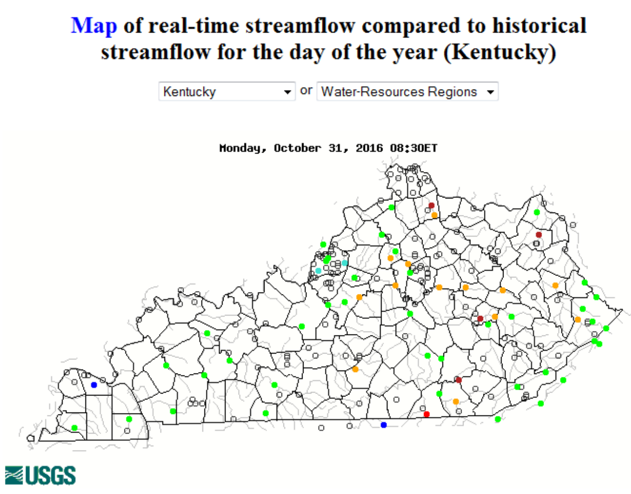

I. WATER AVAILABILITY

Regional Water Inventories

Annual and Seasonal “Surplus/Deficit”

- Existing withdrawal demand
- Instream Flow demands

TECHNICAL DATA AND STUDIES

II. DEMAND FORECASTING

Population-driven Demands

Agricultural Demands

Energy Sector Demands

Industrial Demands

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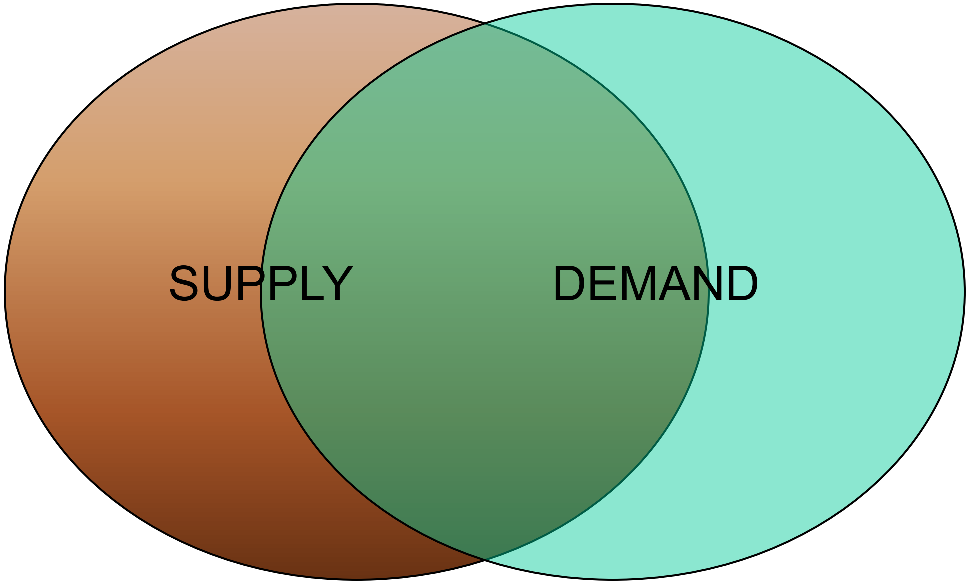
TECHNICAL DATA AND STUDIES



GAP ANALYSIS

Where does available supply not meet current demand?

Where will available supply not meet future demand?

Why does the GAP exist?

What are potential solutions?

"HOT SPOT" ANALYSIS

Which GAPS are most critical?

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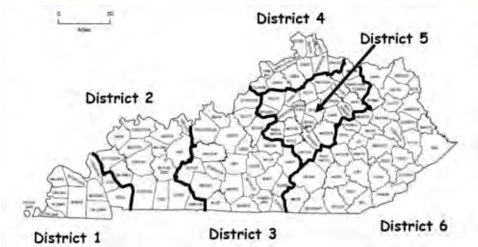
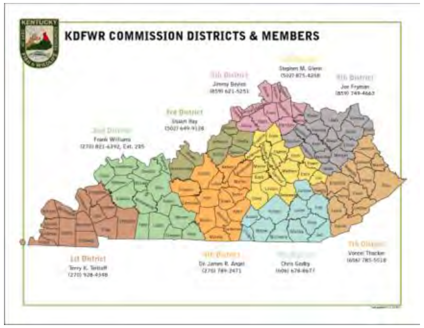
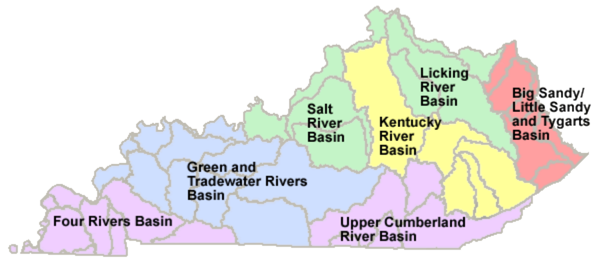
PLAN DEVELOPMENT





REGIONAL FOCUS



STAKEHOLDER DRIVEN

What issues are seen as priorities at the local/regional level?

What needs to be in the plan?

**Inform the development of a statewide water resources plan.

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PLAN DEVELOPMENT AND IMPLEMENTATION

TECHNICAL RESULTS AND FINDINGS

REGIONAL ISSUES AND PRIORITIES

STATEWIDE PRIORITIZATION OF ISSUES

POLICY/PROJECT RECOMMENDATIONS

PLAN DEVELOPMENT AND FEEDBACK

PLAN IMPLEMENTATION

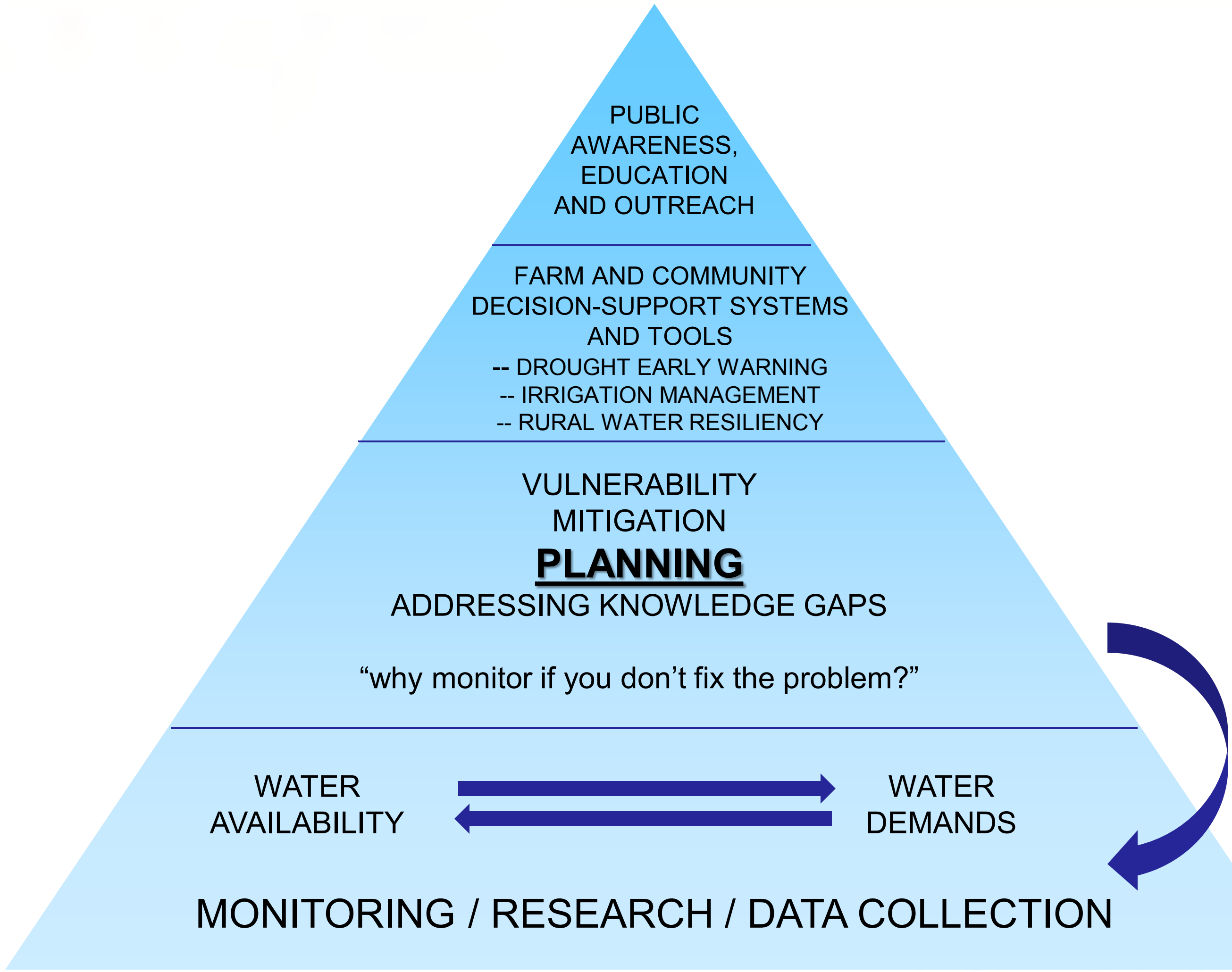
PLAN DEVELOPMENT AND IMPLEMENTATION

Appoint two working committees

- **Technical Data Committee**

- **Plan Development Roadmap Committee**

Water Resources Development
What do we need to know?



Applicant: Kentucky Climate Center, WKU

WKU-1: The Kentucky Mesonet Station Acquisition and Installation

WKU-2: Kentucky Mesonet Soil Monitoring

WKU-3: Kentucky Mesonet Precipitation Monitoring

WKU-4: Summaries, Forecasts and Outlooks

Applicant: US Geological Survey

USGS-1: Agricultural and Drought Data Management and Integration Application

USGS-2: Streamflow Gaging Stations in Critical Areas with Existing Data Gaps

USGS-3: Water Quality Monitoring Stations to Better Quantify Nutrient Loading

Applicant: Kentucky Geological Survey

KGS-1: Kentucky Groundwater Observation Network

KGS-2: A Groundwater Withdrawal Assessment Tool for the Jackson Purchase Region

Applicant: Dr. Steve Higgins/University of Kentucky

UK-1: Stormwater Management, Water Harvesting and the LEAF Program