A Laypersons Summary of Clarke County's 6 year Ground-Water Study 2002-2008

Presented to the Clarke County Board of Supervisors

November 13, 2009

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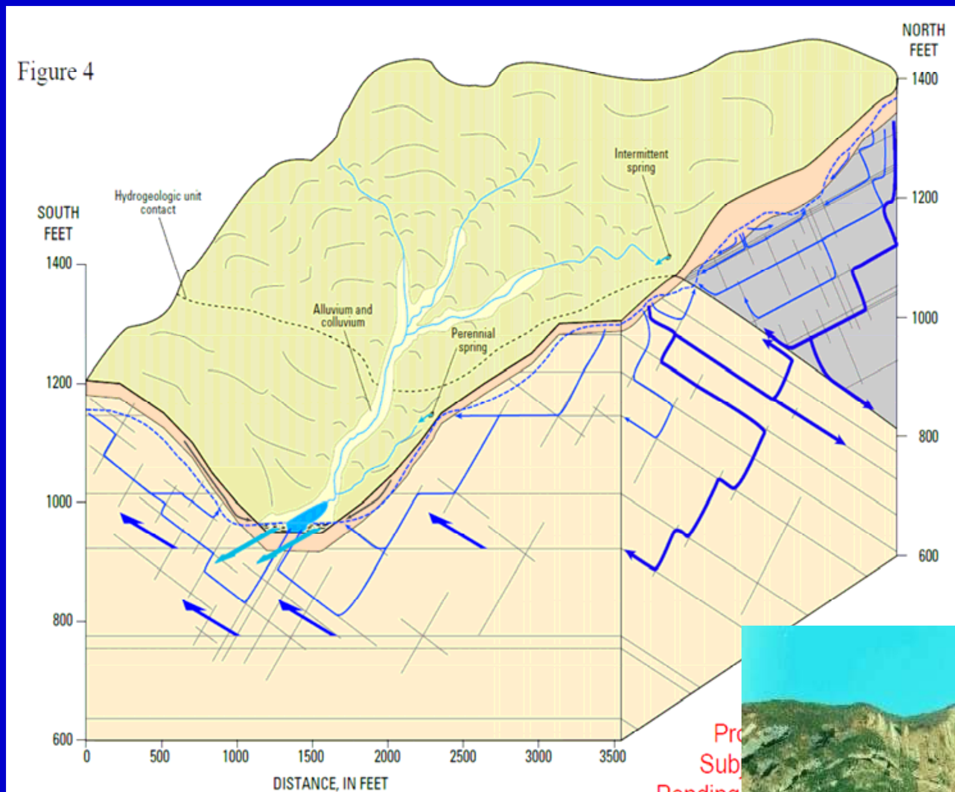
A prolonged drought between 1999 and 2002 focused attention in Clarke County, Virginia on the quantity and sustainability of the ground-water resources. A study was conducted between October 2002 and October 2008 by the U.S. Geological Survey (USGS), in cooperation with Clarke County to describe the hydrogeology and ground-water availability in the County and to establish a long-term monitoring network. This presentation attempts to summarize the findings and detail how the data can be used to protect ground-water resources and reduce future impacts of drought.

Principle questions outlined in the project proposal

- How much water is available for use?
- What are the effects of increased pumpage on ground-water levels and instream flows?
- What is the current quality of the ground-water supply and its vulnerability to contamination?

Key Site Evaluation Activities

- Geology
- Hydrology
- Age Dating
- Effective Recharge
- Water Budget



GEOLOGY

<u>What was Studied?</u>

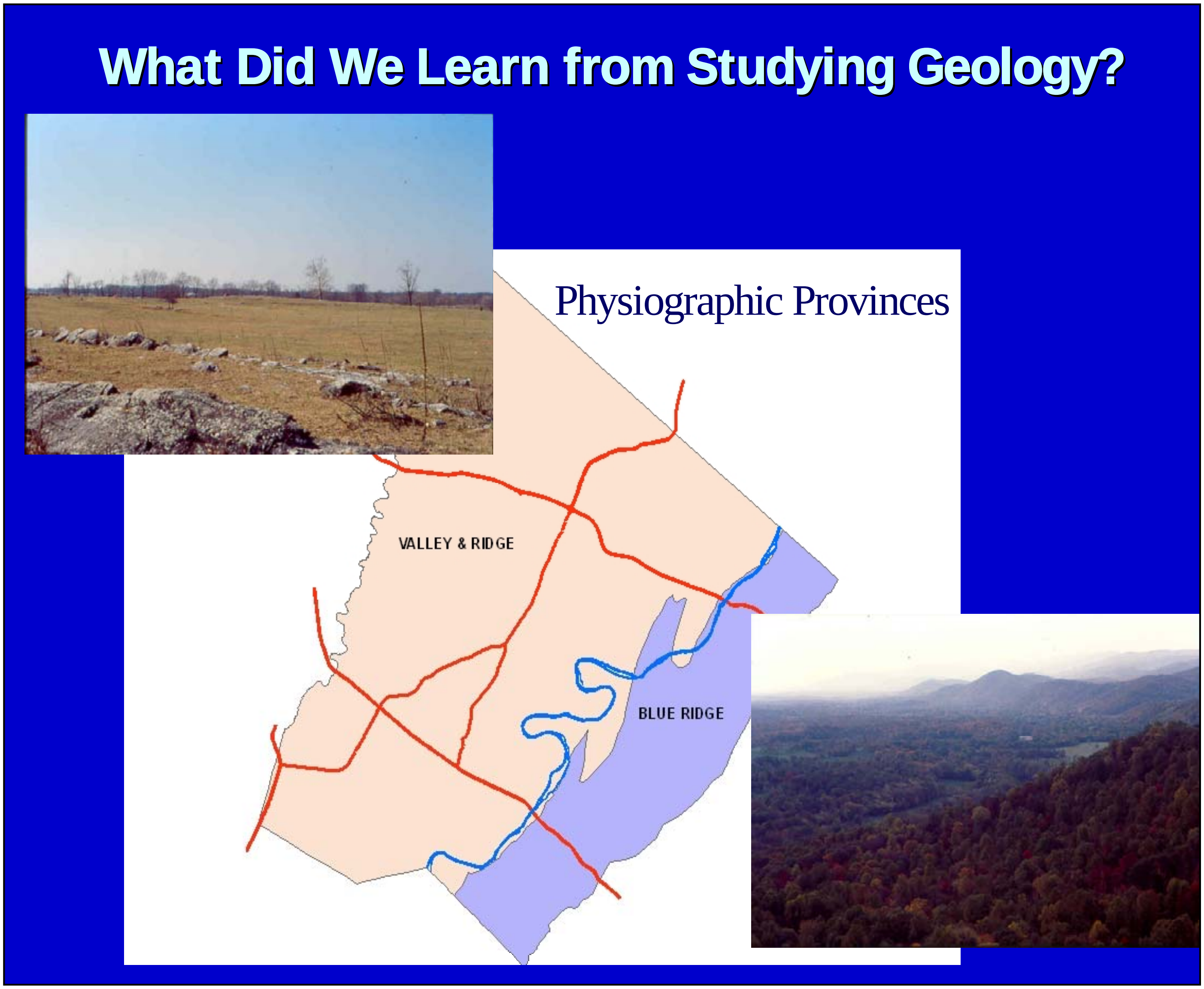
- Driller logs
- Borehole geophysical logs
- Maps

<u>Why?</u>

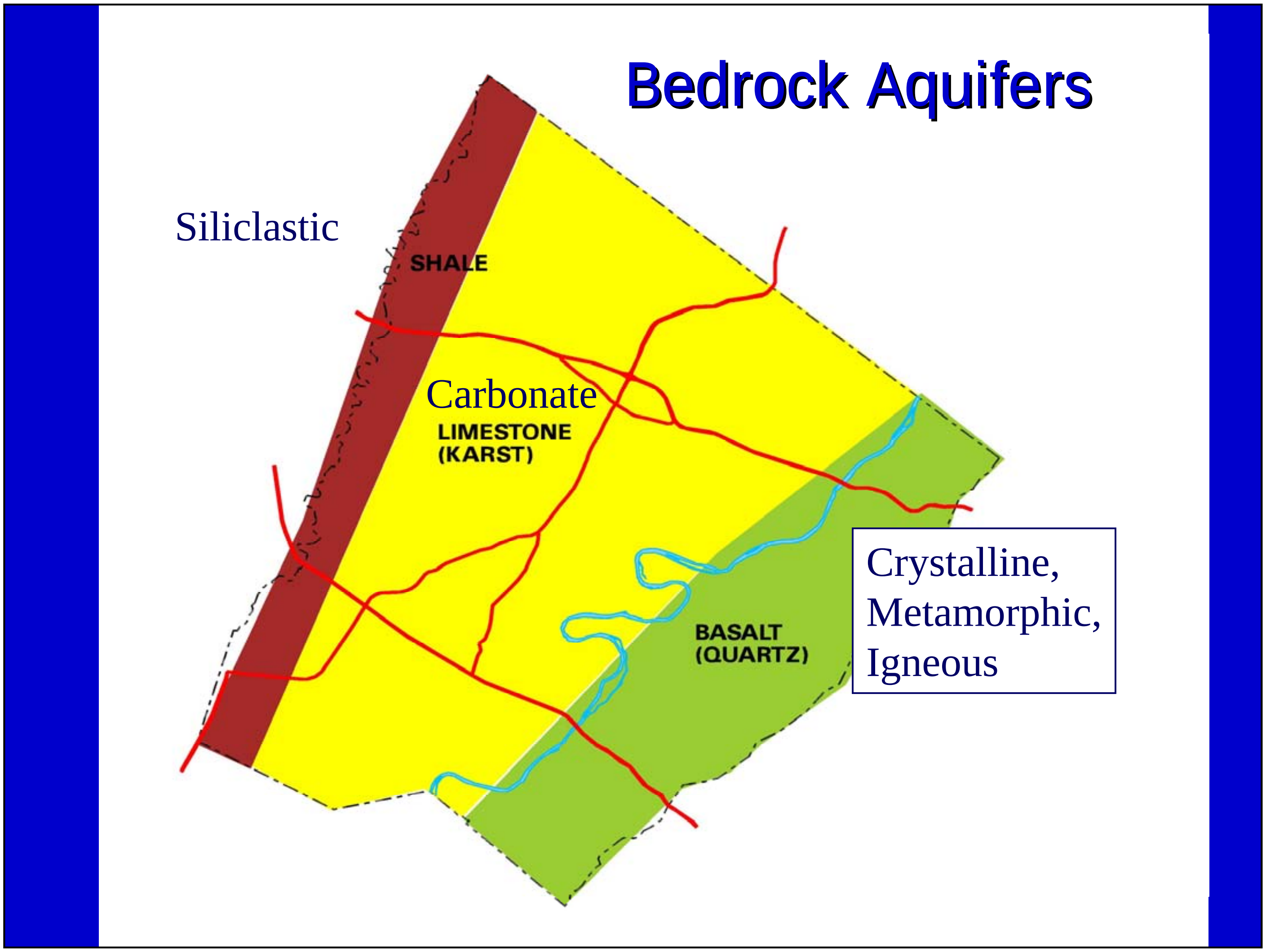
Provides an understanding of Ground-water flow

Folding of rocks affects where water is and how it moves

Understanding the occurrence, distribution, movement, and quality of ground-water rests upon understanding the geologic processes that form aquifers. The underlying rocks have different properties that affect ground-water movement. Structural properties such as fracture patterns, solubility, and the amount of folding in the rock all affect where water is and how it moves. Terms like cross-strike fault plane, bedding plane partings, strike, dip, and strike parallel faults are terms used by geologists to describe the potential flow patterns in rocks.

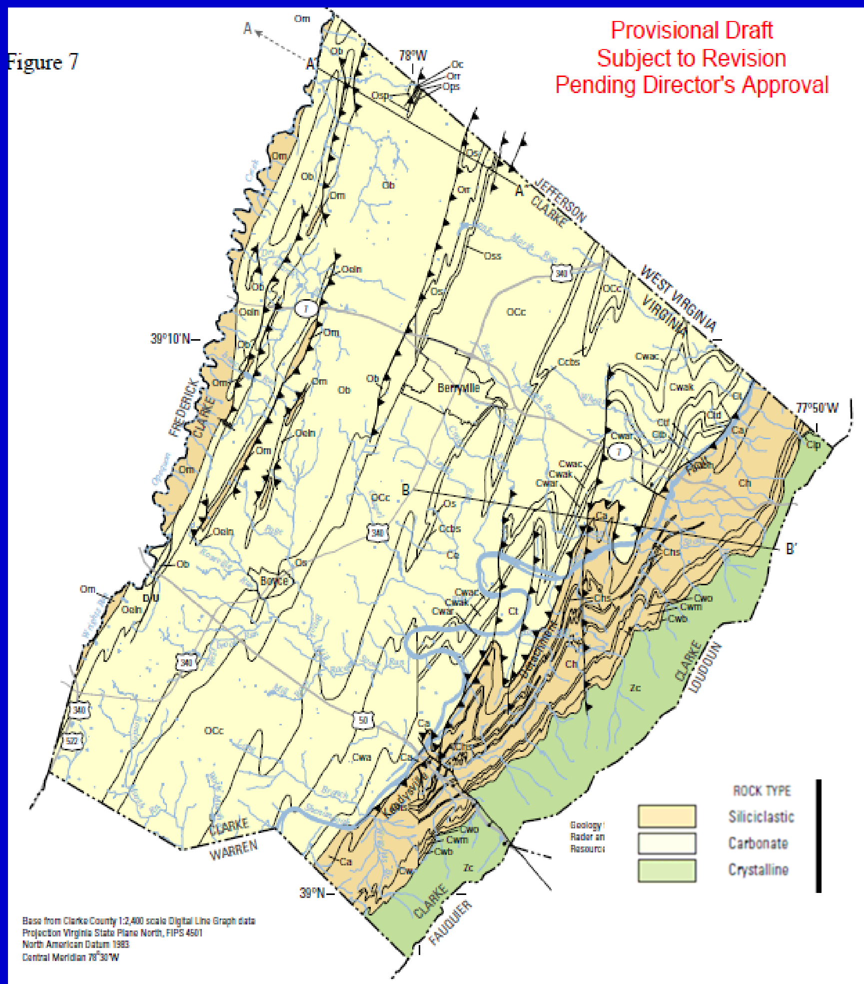


A landform describes the ruggedness of the Blue Ridge Mountains, as opposed to the relative flatness of the Shenandoah Valley.



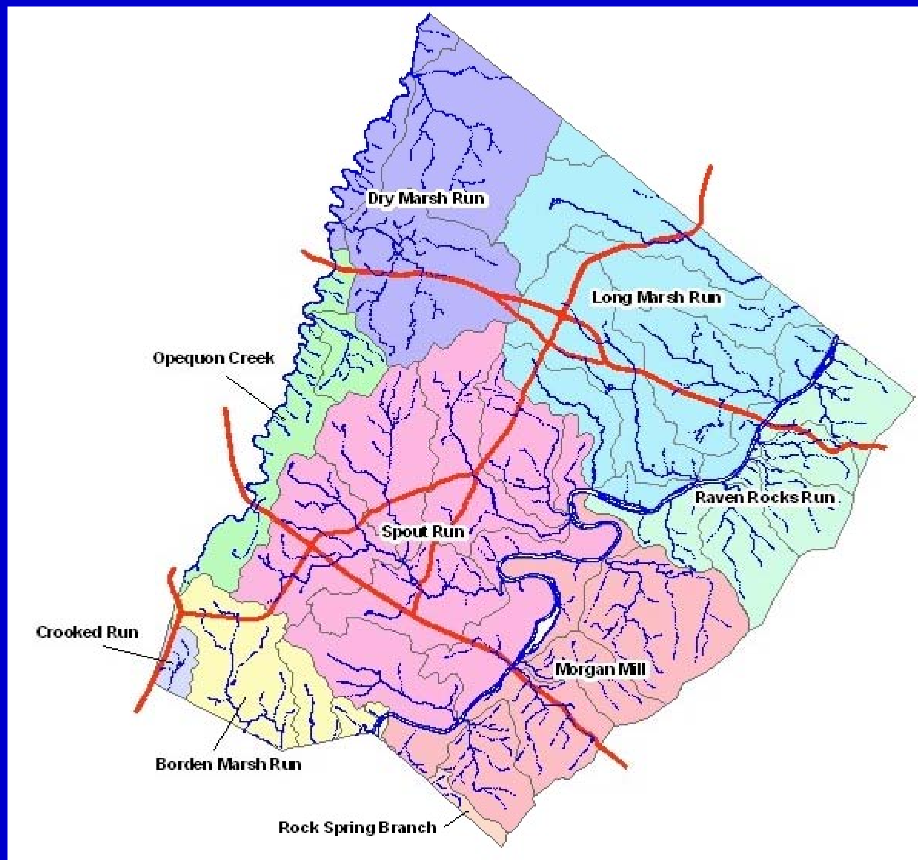
In regards to flow patters the carbonate is characterized as the karst aquifer system while the siliclastic and crystalline bedrock types are described as fractured-rock systems. Aquifers are underground geologic formations that store and yield water. In karst water moves as conduit and diffuse flow, in fractured rock the flow is mainly diffuse. The type of flow pattern is important to understand as this affects the ground-water recharge and also the susceptibility of the ground-water to contamination, i.e. how quickly does water get into and move around in the system.

Geologic Formations

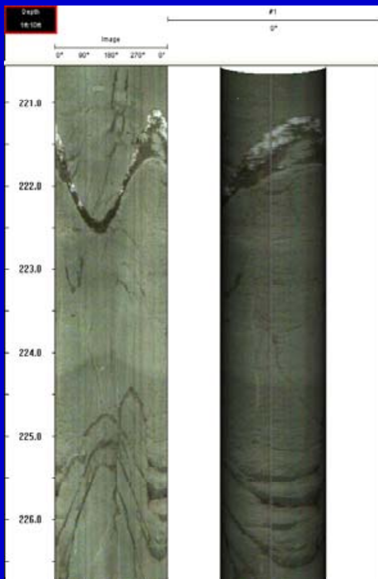


Within these bedrock aquifers there features called formations that contain a variety of related or interlayered rock types, and in these cases the word ‘formation’ is used instead of a single rock type. For example, the Martinsburg Formation consists of beds of shale, siltstone, and sandstone. Formations are features that commonly occur together or have similar characteristics and distribution are lumped together by geologists.

Ground-water Management Areas



Ground-water management area designations group geologic formations with similar hydrologic features. These areas will be the basis for land use planning applications.



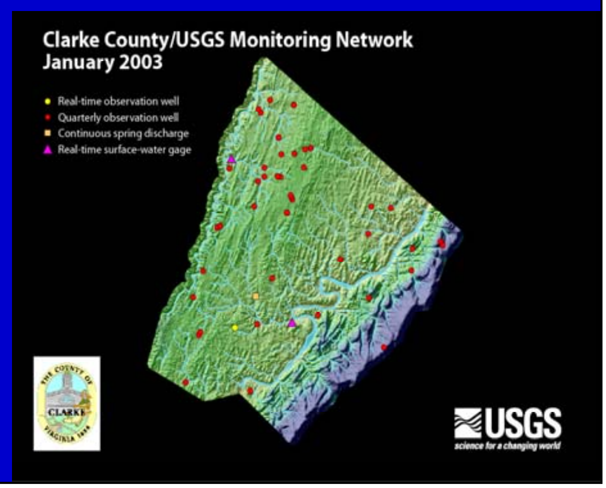
Hydrology (part 1)

What was Studied

Long-term Monitoring Network - Wells

- Water level measurements (quarterly and continuous)
- Depth, yield, depth to bedrock, depth of water bearing zones from driller logs (GW2) (N=1800)

Why?
By analyzing the data, distinctive ground water characteristics within geologic formations can be identified.



Hydrology is the study of the movement, distribution, and quality of water. Information about the hydrology in Clarke County was obtained by analyzing well driller logs and by collecting data using the long-term monitoring network. The long-term monitoring network consists of 40 wells, 23 springs. 2 stream gages.

Hydrology (Part 2)

What was Studied

Long-term Monitoring Network

Springs & Streams (2 stream gages)

a. discharge
b. temperature
c. water quality properties (chemistry)

Why?

A key component to developing water budgets. How much of stream flow is ground-water.

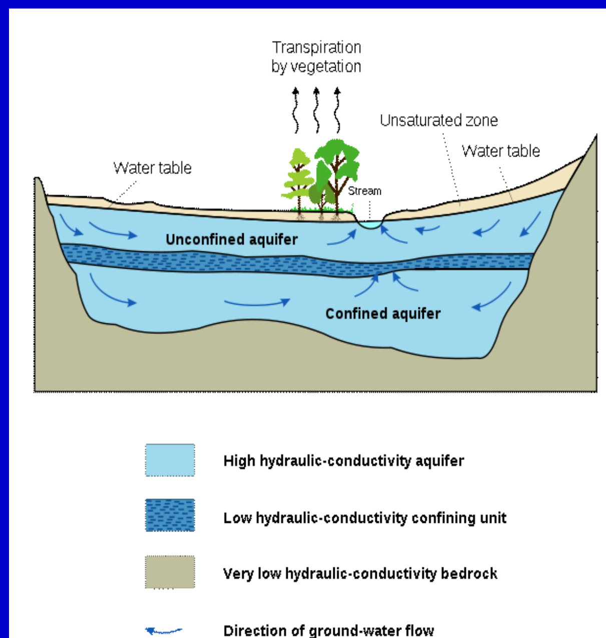
Hydrogeologic Units

<u>What Did We Learn?</u>

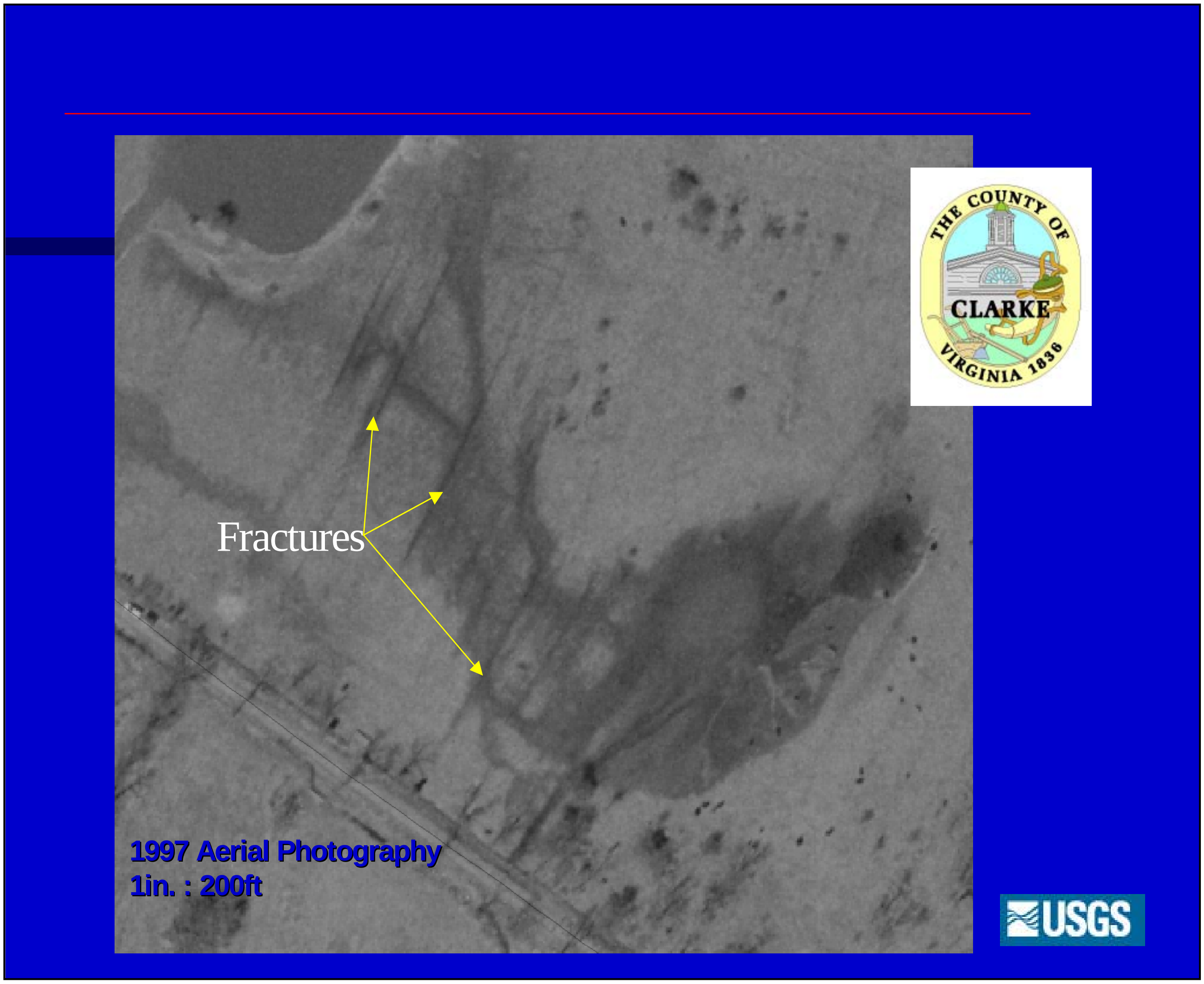
<u>Aquifer Properties – County-wide</u>

Unconfined

Ground-water movement is controlled by topography, it is not under pressure, gravity pulls it, it is locally recharged, and easily contaminated.



In both the Blue Ridge and Valley provinces ground-water is described as unconfined. Unconfined aquifers are sometimes also called water table or phreatic aquifers, because their upper boundary is the water table.

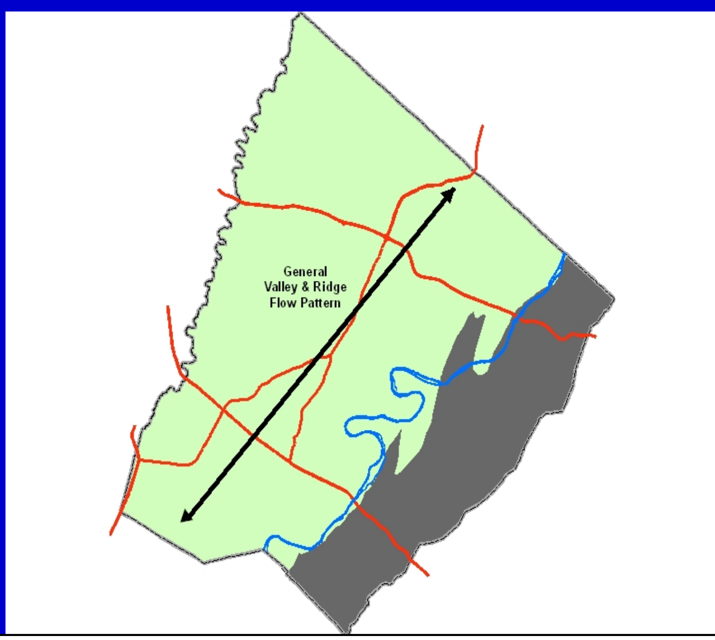


1997 Aerial photo describes unconfined nature of aquifers in Clarke County. Taken during a wet year, fracture patterns are readily visible.

Hydrogeologic Units

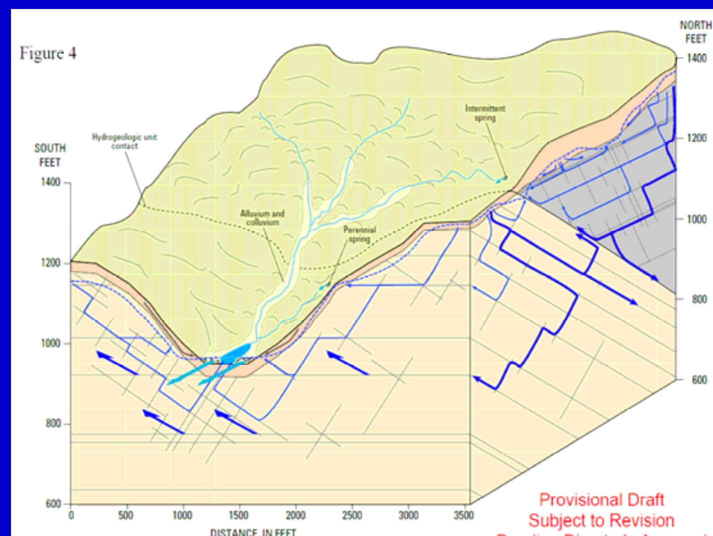
What Did We Learn?

Flow patterns
Generally follow topography and are controlled by the geologic structure



Mountain

mimics the land surface



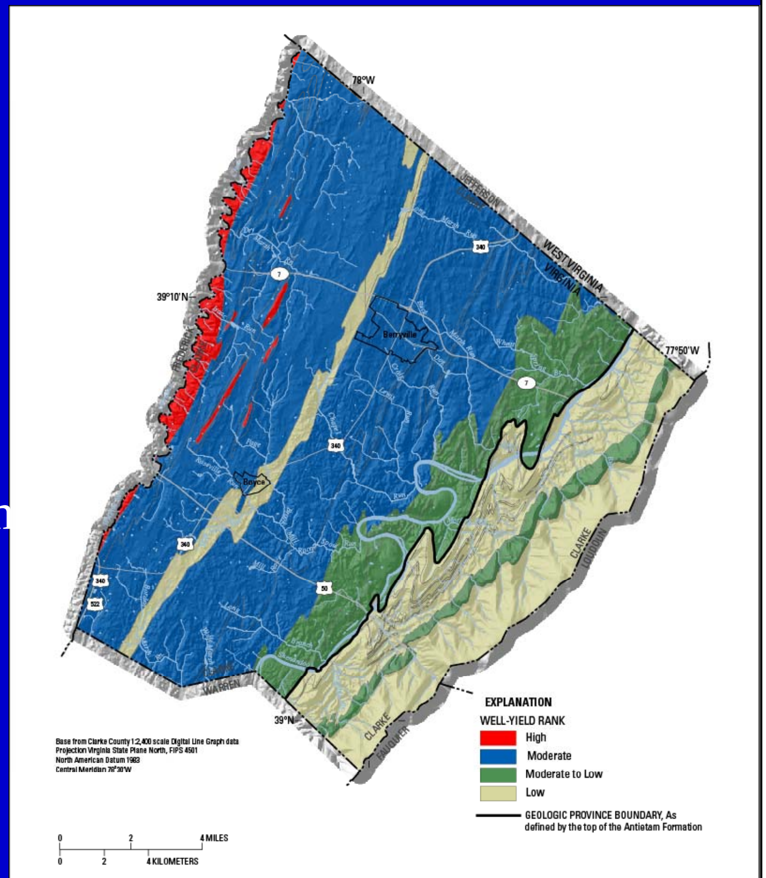
Valley

elevated areas to the northeast or south west

Hydrogeologic Units

<u>What Did We Learn?</u>

<u>Average Well Yields (General)</u>
Based on formations
High > 35 gpm
Moderate > 27 and < 35 gpm
Low-Moderate > 20 and < 25 gpm
Low < 20 gpm



Understanding where water is plentiful provides land use planners with a tool to help direct large water using industry to appropriate locations.

Well Yields in Clarke County, Va.

(>50 gal/min) (<5 gal/min)

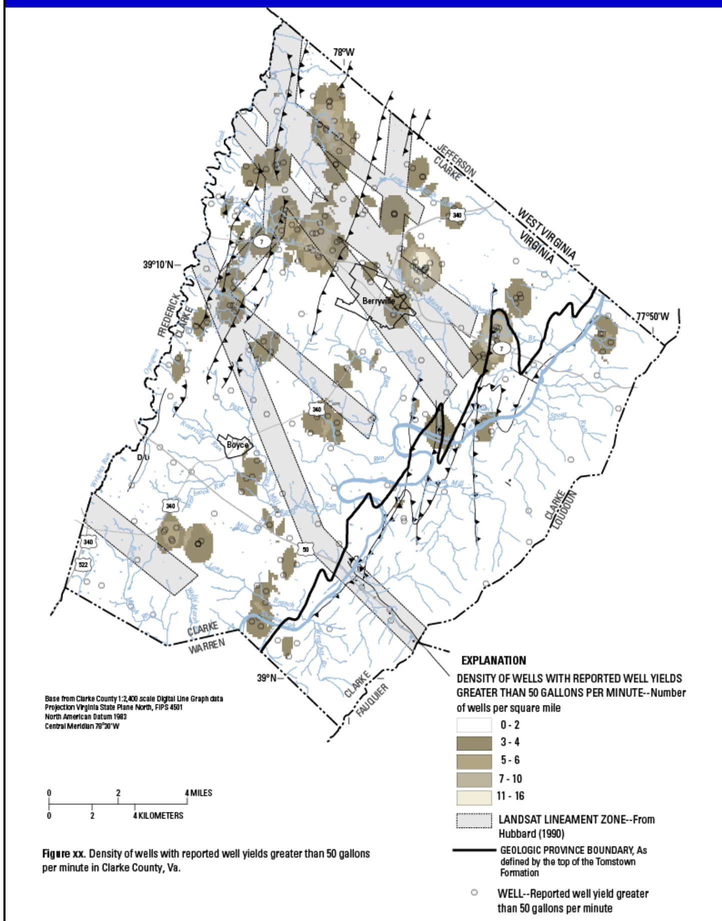


Figure xx. Density of wells with reported well yields greater than 50 gallons per minute in Clarke County, Va.

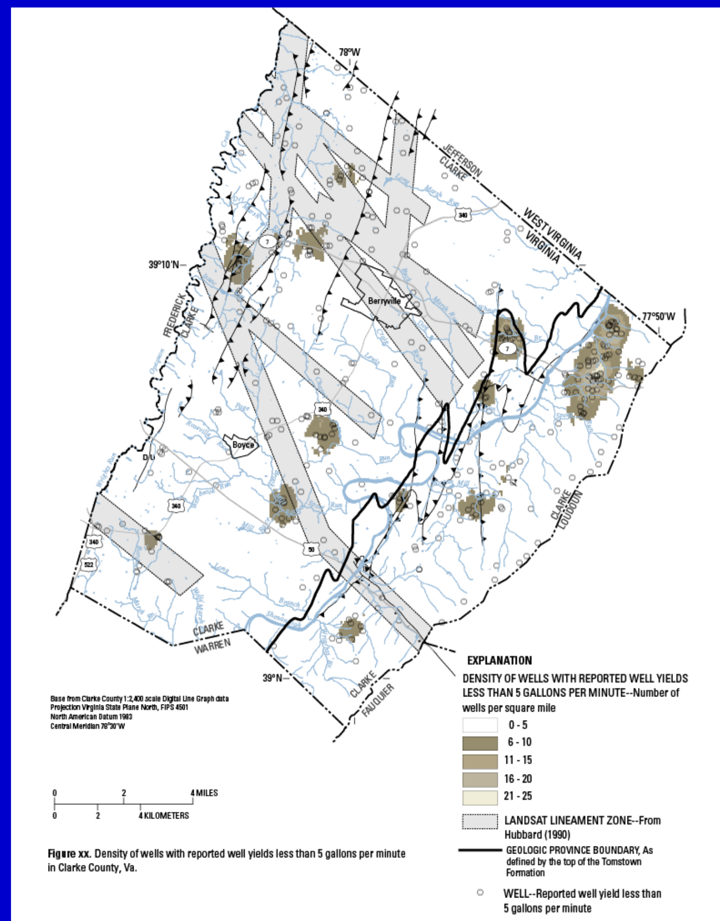


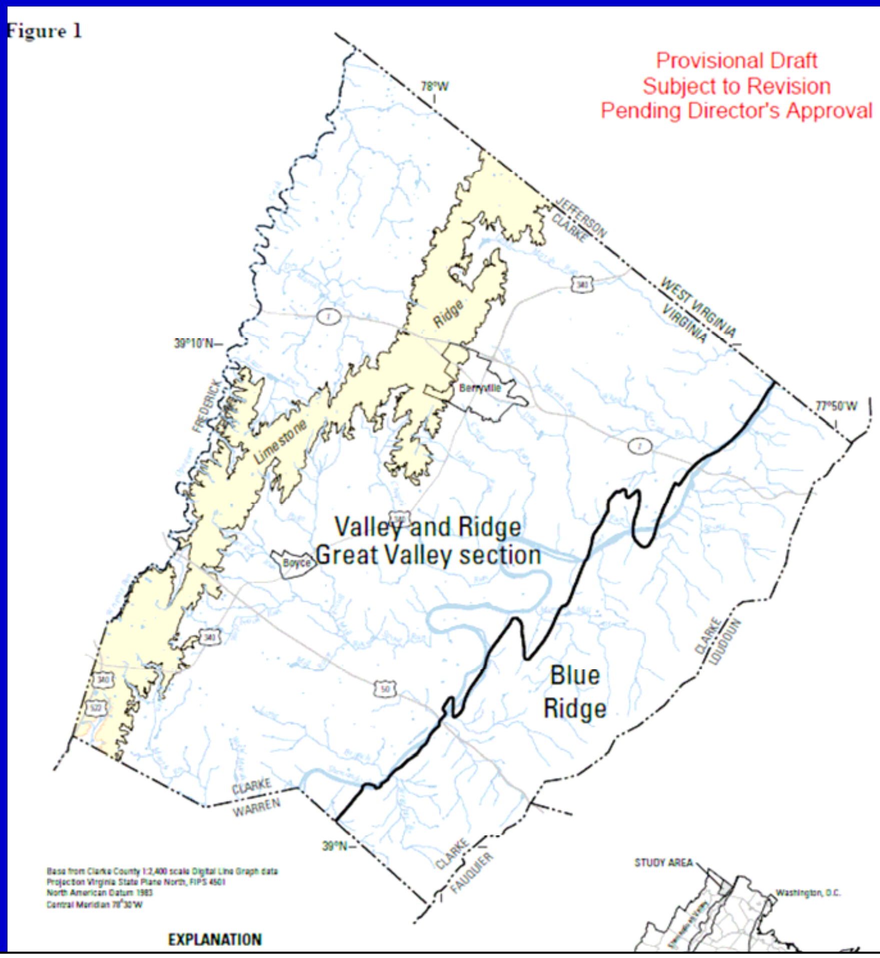
Figure xx. Density of wells with reported well yields less than 5 gallons per minute in Clarke County, Va.

High yielding wells generally tend to cluster along faults, within lineament zones

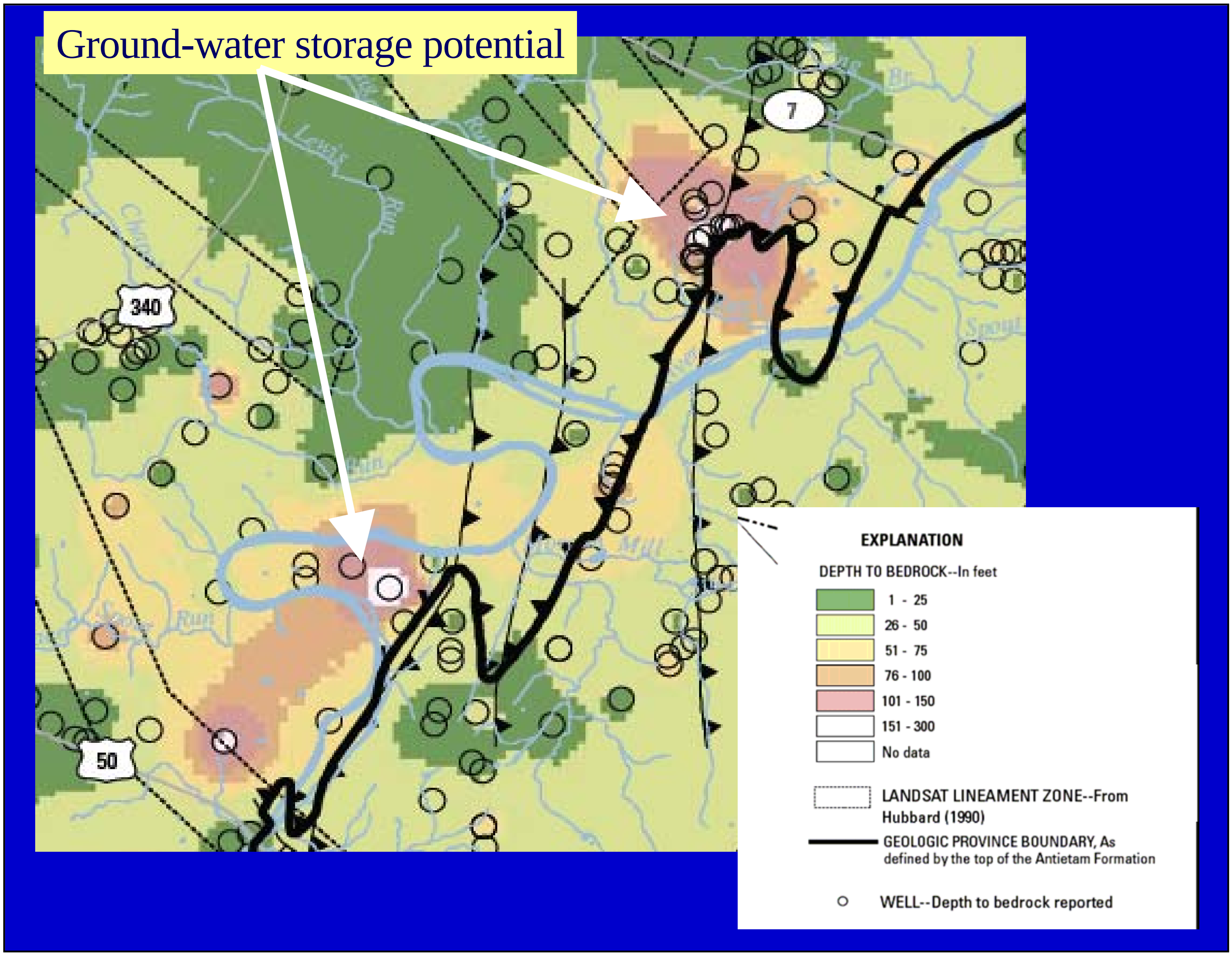
Grey bands indicate lineament zone locations.

Limestone Ridge

Recharge Area



The drainage divide between the Opequon and the Shenandoah basins occurs along an area above the 630’ contour line. This “Limestone Ridge” is important for groundwater recharge. Preventing large amounts of impervious surface in this area will help to insure the maximum amount of recharge is available in any given year.



Areas with thick sequence of regolith (the layer of loose rock resting on bedrock, constituting the surface of most land) may have considerable groundwater storage potential (Waynesboro Formation) The difference in storage potential is due to the media. The regolith is unconsolidated porous media (imagine a sponge), whereas in the bedrock, water is stored in the fractures and conduits.

Age Dating

<u>Why was this Studied?</u>

The age of water provides an understanding of how ground-water is recharged and the potential for contamination. 15 springs in Valley were sampled.

<u>What did we learn?</u>

- The County has primarily young water - 75% less than 10 years.
- A high percentage of young water indicates piston or plug flow.
- This type of flow pattern describes rapid recharge at the upper elevations that pushes water through the system to the lower reaches such that the oldest water is discharged.
- Rapid recharge also indicates that contamination can occur rapidly as well.

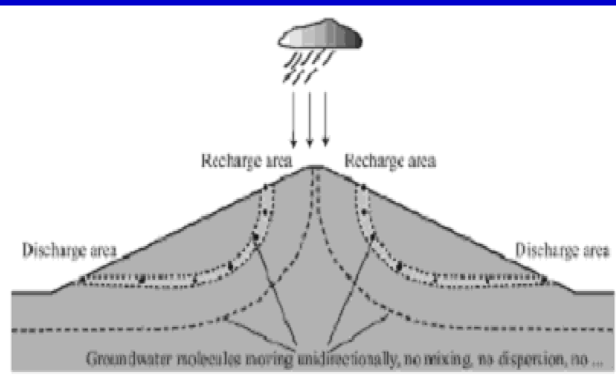
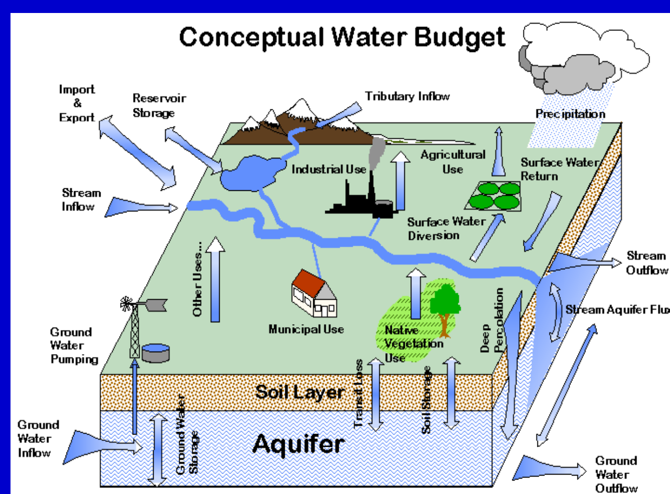


Figure 1.7 Piston-flow theory. Groundwater molecules migrate as isolated packets. Age of groundwater molecule in such a system is called the piston-flow age.

Ground-Water Availability Bringing it all together

Two main components:
- Water Budgets
- Effective Recharge

Water Budget



<u>Components</u>
- Precipitation
- Mean streamflow and mean base-flow data
- Evapotranspiration (ET),
- Changes in ground-water storage from water level data,
- Estimates of specific yield and withdrawal data.

Water budgets estimate the amount of water entering and leaving the system plus or minus storage over a specific period of time, providing information on the amount of water stored in the system that is available for use.

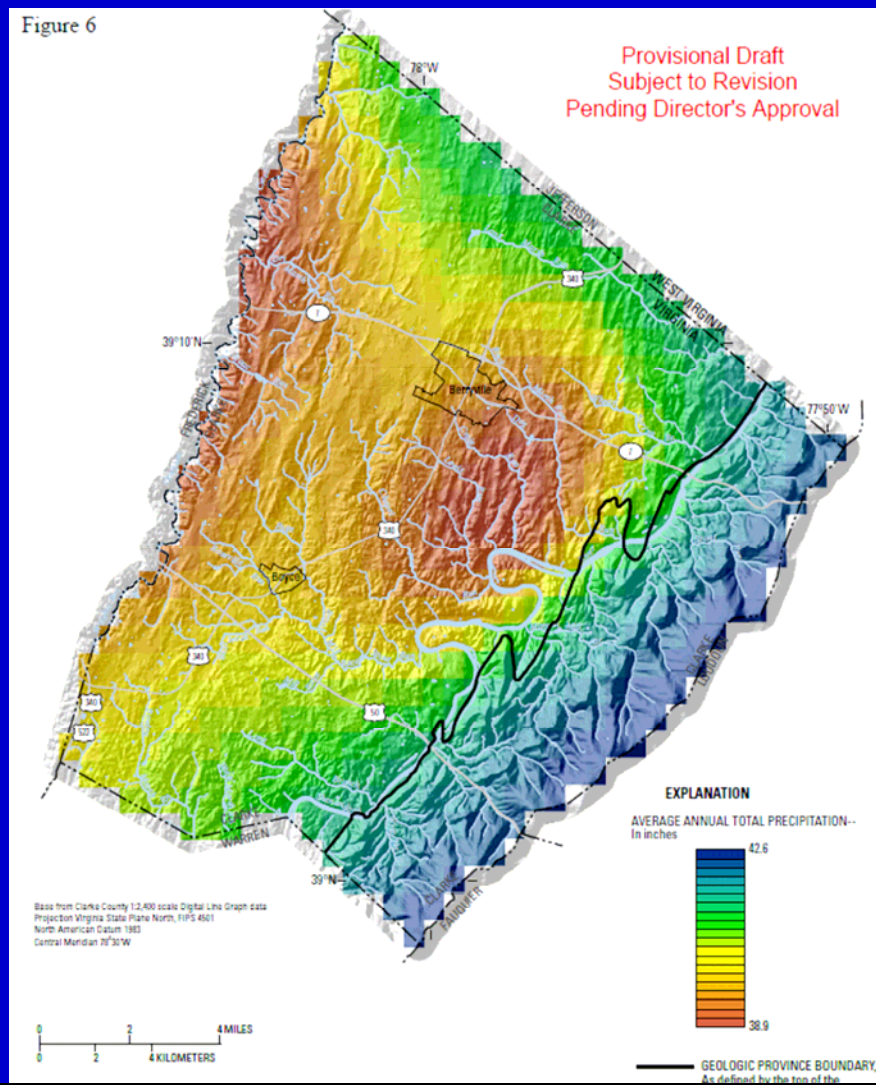
Component of Water Budget

Rainfall

1 inch of rain

falling on 1 sq. mile

= 17.4 million gallons



Effective Recharge

The amount of precipitation that reaches the water table:

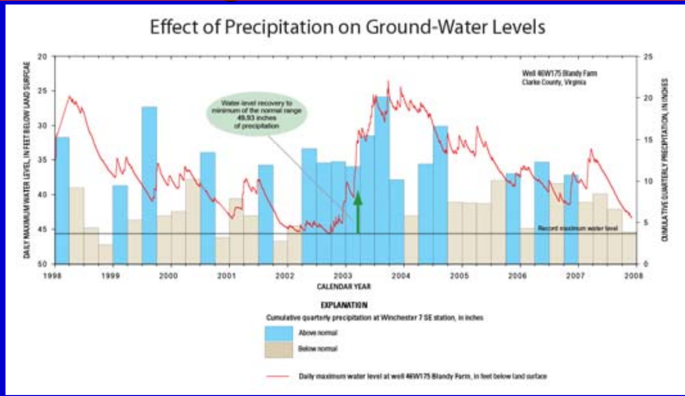
Most of this recharge water eventually discharges to streams.

A technique called hydrograph separation separates the ground-water discharge (stream base flow) from surface-runoff components of stream flow

- On average approximately 30% of precipitation reaches the water table as effective runoff;
- Below average recharge causes water level declines,
- Effective recharge increases as precipitation increases but when it occurs (Nov-Apr) and amount of snow dramatically impacts amount of recharge.

Ground-water flow systems in Clarke County are extremely vulnerable to climatic conditions. Below average recharge causes water level declines, effective recharge increases as precipitation increases but lack on snow during critical recharge periods (Nov-Apr) dramatically impacts amount of recharge.

Water Budgets



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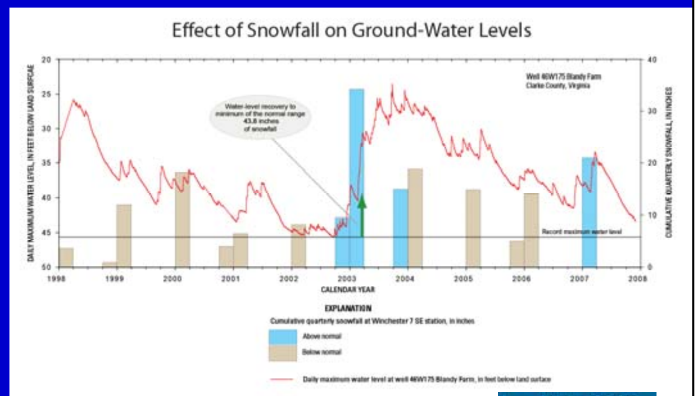
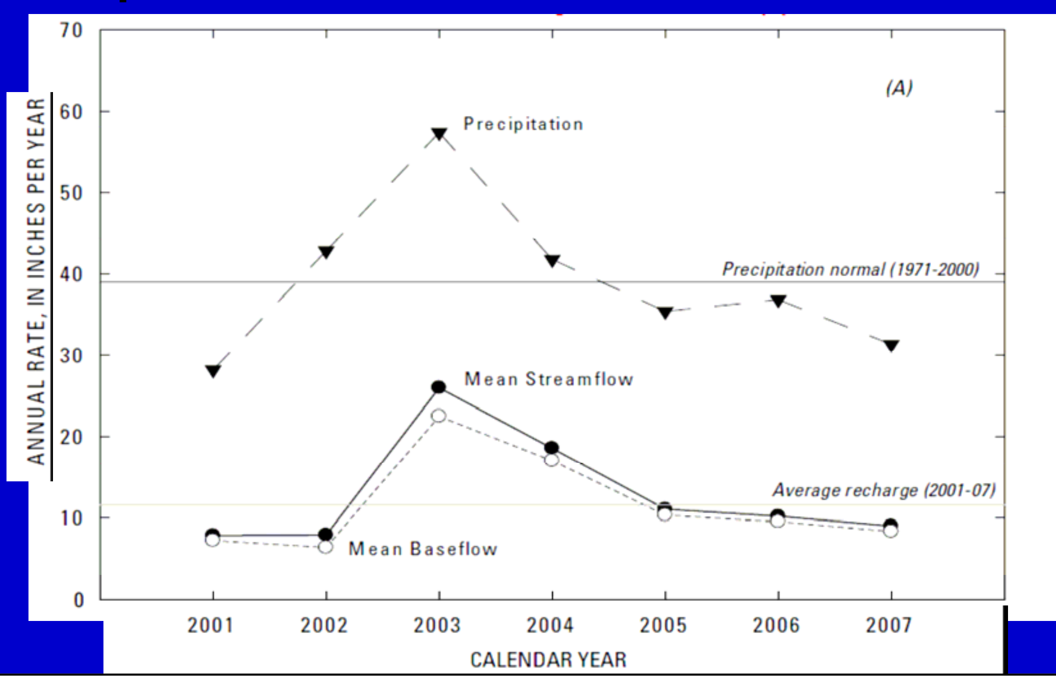


USGS

Hydrographs are charts that display the change of a hydrologic variable over time.

Surface Water Response to Precipitation



Another example showing the dependence of stream flow on precipitation

Base Stream Flow

What did we learn?

- Effective recharge is most important parameter
- Dry Marsh Run effective recharge averaged 9.47 in/yr. Baseflow of streams is 81-93% ground-water.
- Spout Run Basin effective recharge averaged 9.7 in/yr. The baseflow 80-97% mean streamflow.

Ground-water is dominant source of stream flow

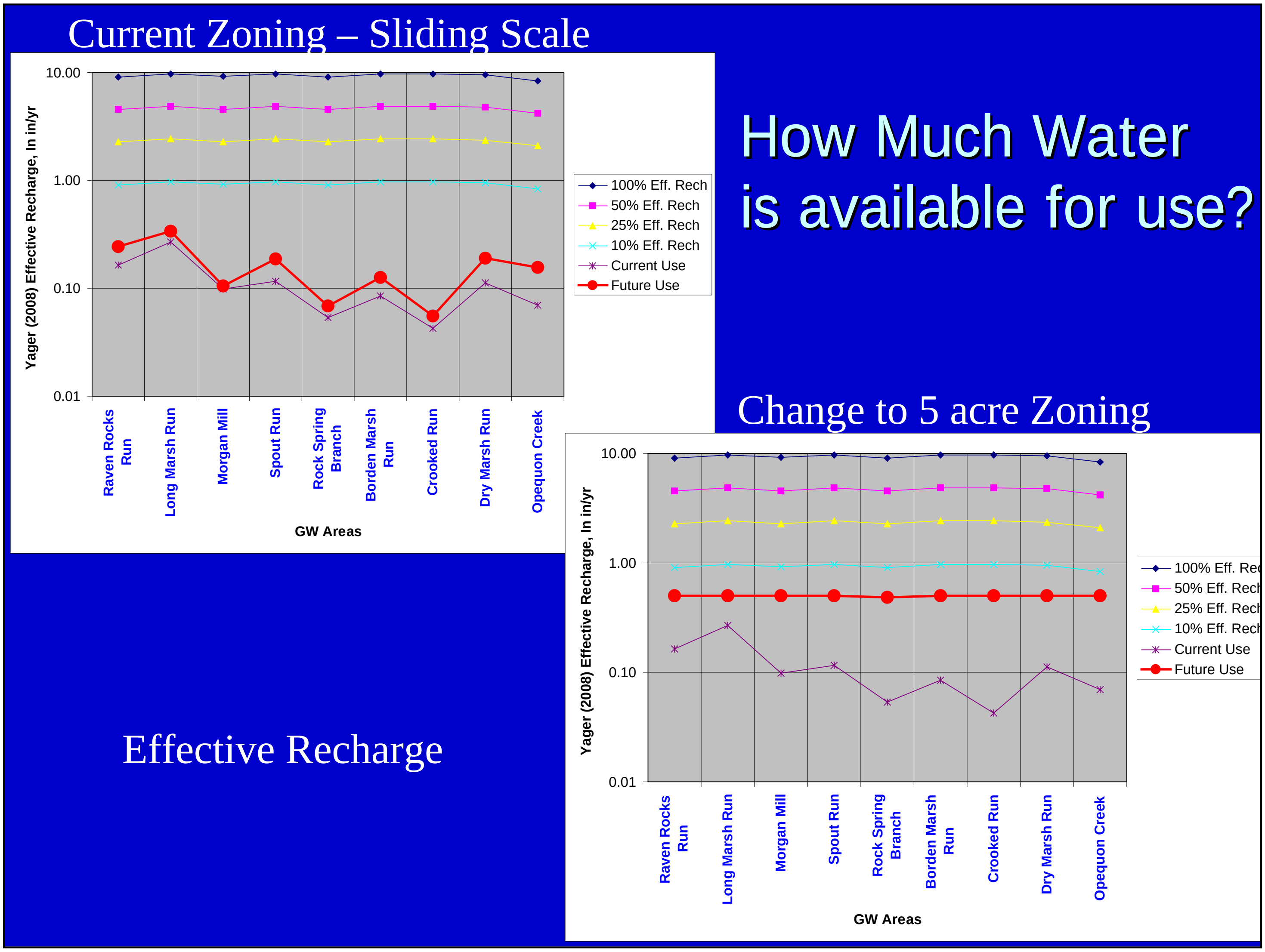
Probably the most important concept for land use planners to understand. This gets to the point of how much water is available for use. If we know 30% of precipitation is effective recharge and the above data indicates that this is equivalent to roughly 9.5”/year then we know we need to get at least 30” per year in precipitation (with a large amount of that during the recharge period Nov-Mar). If we do not get that amount of precipitation we begin to have less ground-water available for use.

Calculating Impact of Drought

How Much Water is Available for Use

Groundwater area Name	Area (square miles)	Eff. Rech Yager (2008) (in/yr)	Water Use: current # households	buildout # households	current water use* gal/d	future water use* gal/d
Raven Rocks Run	17.1	9.08	718	1056	133,548	196,416
Long Marsh Run	39.7	9.70	2737	3419	509,082	635,934
Morgan Mill	24.9	9.14	624	669	116,064	124,434
Spout Run	47.8	9.70	1423	2297	264,678	427,242
Rock Spring Branch	0.8	9.13	11	14	2,046	2,604
Borden Marsh Run	9.9	9.72	215	317	39,990	58,962
Crooked Run	1.2	9.72	13	17	2,418	3,162
Dry Marsh Run	25.8	9.47	739	1244	137,454	231,384
Opequon Creek	8.7	8.35	155	349	28,830	64,914

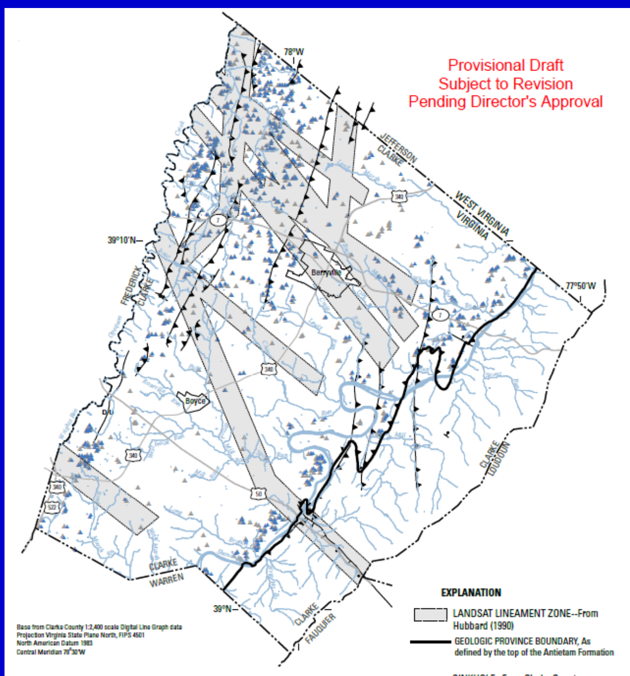
The first 3 columns of this spreadsheet detail the effective recharge per groundwater management area. The next 4 columns provide an estimation of the amount of water being used currently and then future water use at full buildout under current low density zoning.



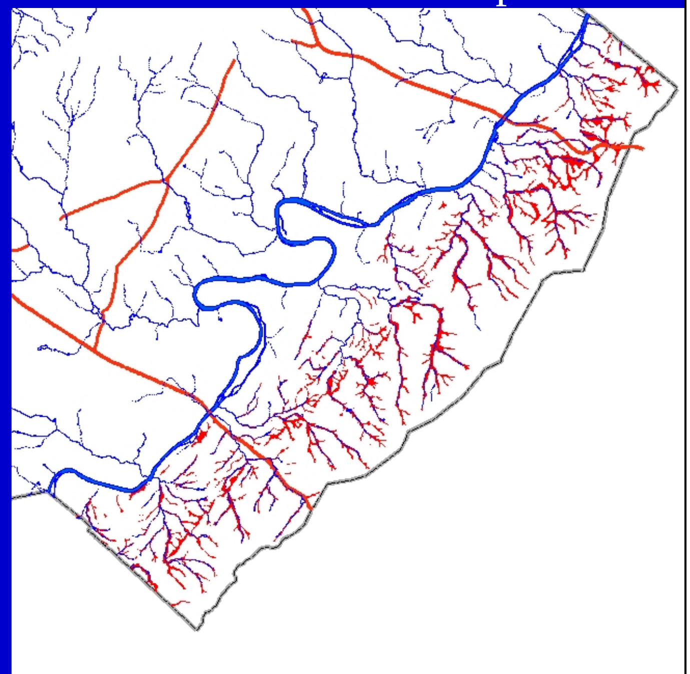
At current zoning, water use is reasonably below even very low (10%) effective recharge levels, however should zoning change or demand for ground-water increase, water shortages will occur during drought periods. Assumes full buildout and total consumptive use, I.e no water put back into the system from septic systems. Impact of reduced effective recharge will be felt in upper reached first, dry stream segments, wells, reduced dilution of contaminants

Water Contamination

Sinkholes



Alluvial & Colluvial Deposits



Don’t site potential contamination sources in areas near stream valleys with alluvial and colluvial deposits.

How Much Did it Cost

Six-Year Ground-water Study 2002-2008				
			Funding	
		Budget	Clarke Co.	USGS
FY 2003		$171,800	$104,000	$67,800
FY 2004		$177,700	$107,000	$70,700
FY 2005		$184,000	$111,000	$73,000
FY 2006		$190,000	$115,000	$75,000
FY 2007		$159,000	$100,000	$59,000
FY 2008		$123,000	$82,000	$41,000
	Total	$1,005,500	$619,000	$386,500

The USGS provided funds to match Clarke County's local government funding at approximately 40%

Annual Operating Expense to Continue Real-time Monitoring – 5 sites

FY 2010 BUDGET			FY 2010 FUNDING	
Category	Cost		Funding Totals	
Salary and Benefits	25,200		Clarke County	37,544
Real-Time Networks	37,544		USGS Coop	30,000
Travel and Vehicles	4,800		Total	$67, 544
Total	$67,544			

Clarke County, Virginia				
U.S. Geological Survey				
FY 2009 Minimum Budget - Local Government				Annual
	Collection	Cooperator	Other	Operating
Station Name	Type	Total	Funding (DEQ)	Cost
DRY MARSH RUN NEAR BERRYVILLE, VA	Discharge	$13,520	$0	$13,520
SPOUT RUN AT RT 621 NEAR MILLWOOD, VA	Discharge	$13,520	$0	$13,520
46W175 (Blandy)	Water level	$1,144	$3,536	$4,680
46X125 (Park well)	Water level	$4,680	$0	$4,680
48X 20 (Rockwood Ridge)	Water level	$4,680	$0	$4,680
Total		$37,544	$3,536	$41,080

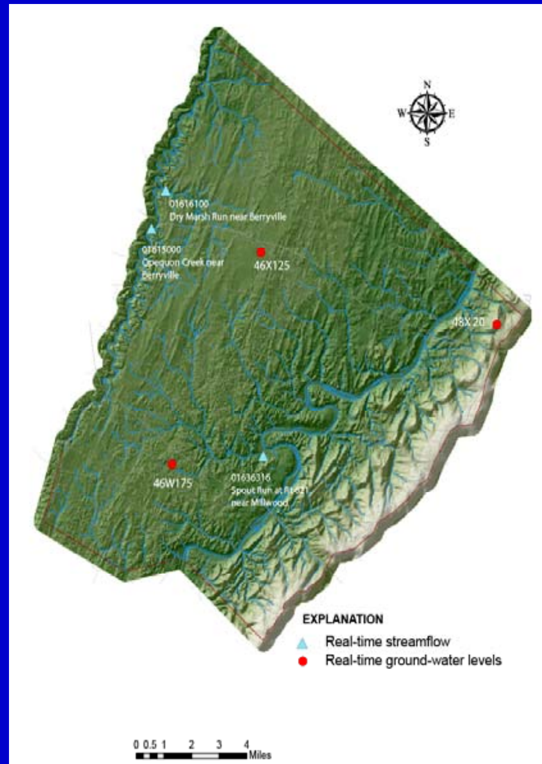


Figure 1.--Location of real-time monitoring sites in Clarke County, Va.

The USGS provided funds to match Clarke County's local government funding at approximately 44%

Continued monitoring of these gages is critical to accurately evaluating ground and surface water levels.

Management Implications

- Protect Recharge Area
- Drought Detection System
- Establish Ground-water Management Areas
- Tools to evaluate impact of water withdrawals
- Establish minimum well depths and yields to reduce potential for well failure during drought

Drought Impacts

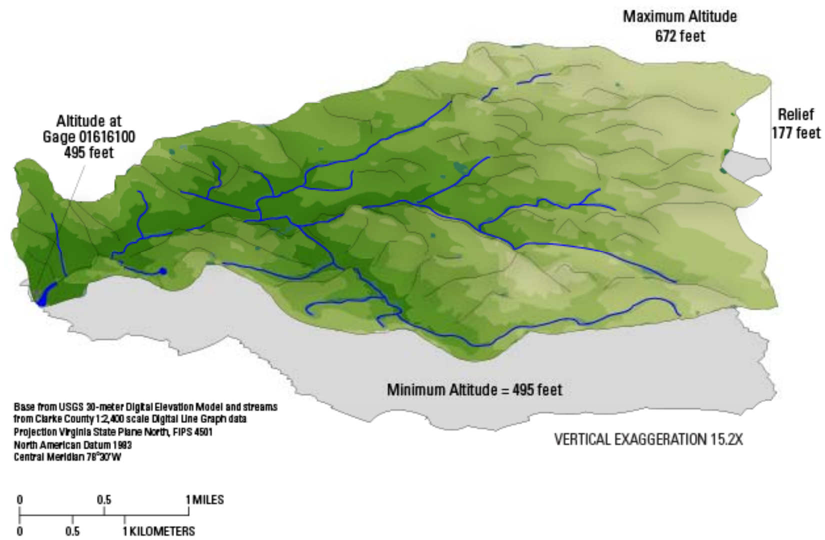


Figure xx. Schematic showing watershed volume above the altitude of streamflow gaging station 01616100 Dry Marsh Run near Berryville in Clarke County, Va.

Planning Tool: Establish minimum well depths based on topography. In the Valley, Clarke County's ground-water system fills up from lowest to highest relief. The overall relief being 177 feet. Establishing minimum well depths of 200 feet may help reduce dry wells during drought periods.

Summary

As a result of this study the County now has data to evaluate its ground-water resources:

- Actual values that detail when low groundwater recharge levels will begin to impact streams and aquatic systems.
- How changes in zoning and landuse may impact ground-water resources.
- How ground-water volume is distributed in the County
- Where contamination is more likely to occur
- Where recharge occurs

Continued minimum monitoring of established real-time gage stations and wells would only add to this body of knowledge and allow for refinement of management strategies.

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