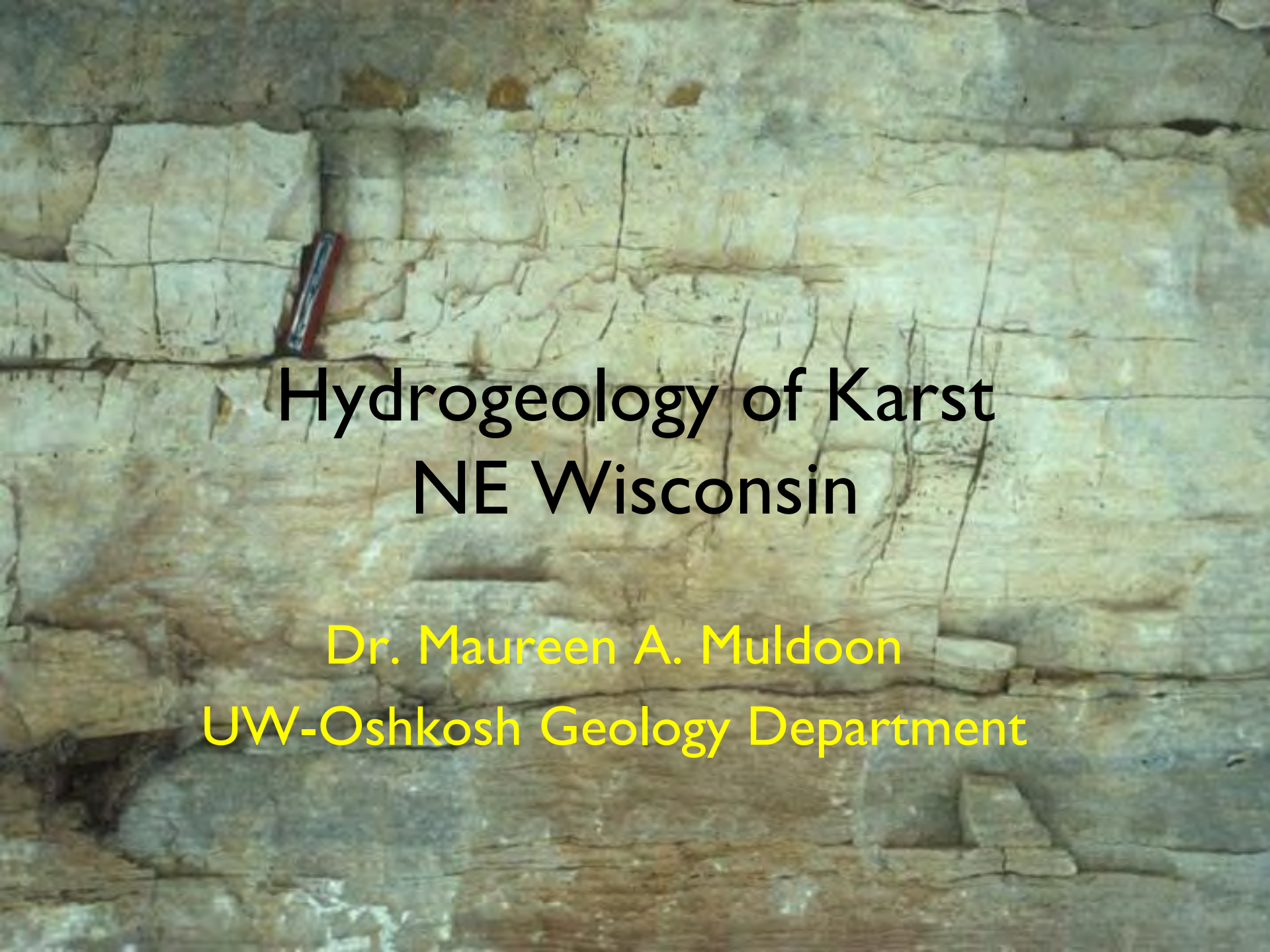


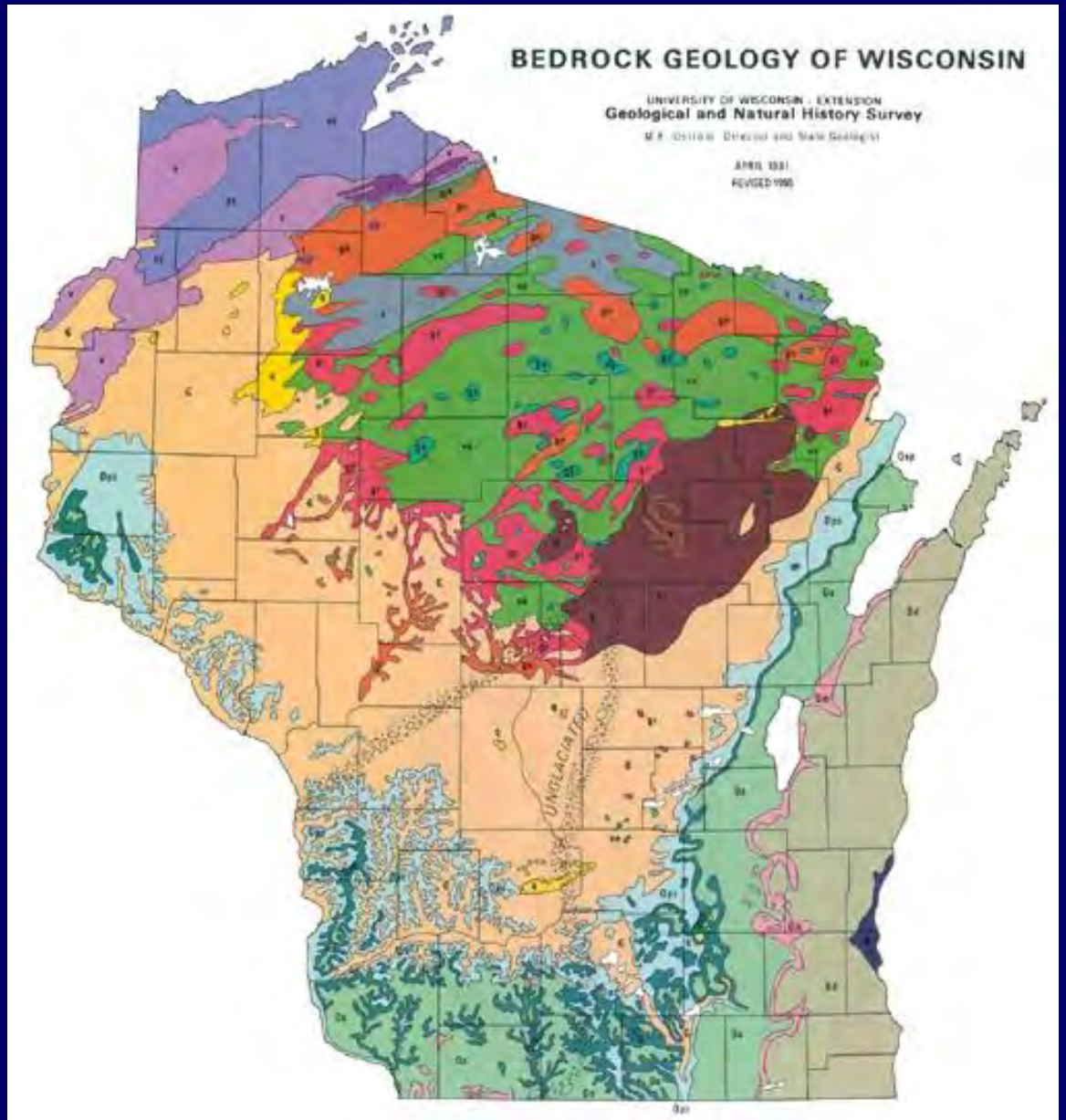
Hydrogeology of Karst NE Wisconsin

Dr. Maureen A. Muldoon
UW-Oshkosh Geology Department

Outline

- WI Bedrock
- Karst Landscapes
- Existing WQ Data
- Flow in Karst Aquifers
  - Overview of Silurian Aquifer
  - Water Level Variations
  - Water Quality Variation
  - Groundwater Velocities
- Recharge Process
- Storm Water Concerns

WI Geology



Extent of glaciation

PHANEROZOIC

DEVONIAN FORMATIONS

dolomite and shale

SILURIAN FORMATIONS

Sd dolomite

ORDOVICIAN FORMATIONS

Om Maquoketa Formation—shale and dolomite

Os Sinnipee Group—dolomite with some limestone and shale

Osj St. Peter Formation—sandstone with some limestone, shale and conglomerate

Opc Prairie du Chien Group—dolomite with some sandstone and shale

CAMBRIAN FORMATIONS

C sandstone with some dolomite and shale

PRECAMBRIAN

MIDDLE PROTEROZOIC ROCKS

Keweenawan Rocks—
ss, sandstone
v, basaltic to rhyolitic lava flows
i, gabbroic, anorthositic and granitic rocks

Wolf River Rocks—
g, rapakivi granite, granite and syenite
a, anorthosite and gabbro

LOWER PROTEROZOIC ROCKS

q quartzite

gr granite, diorite and gneiss

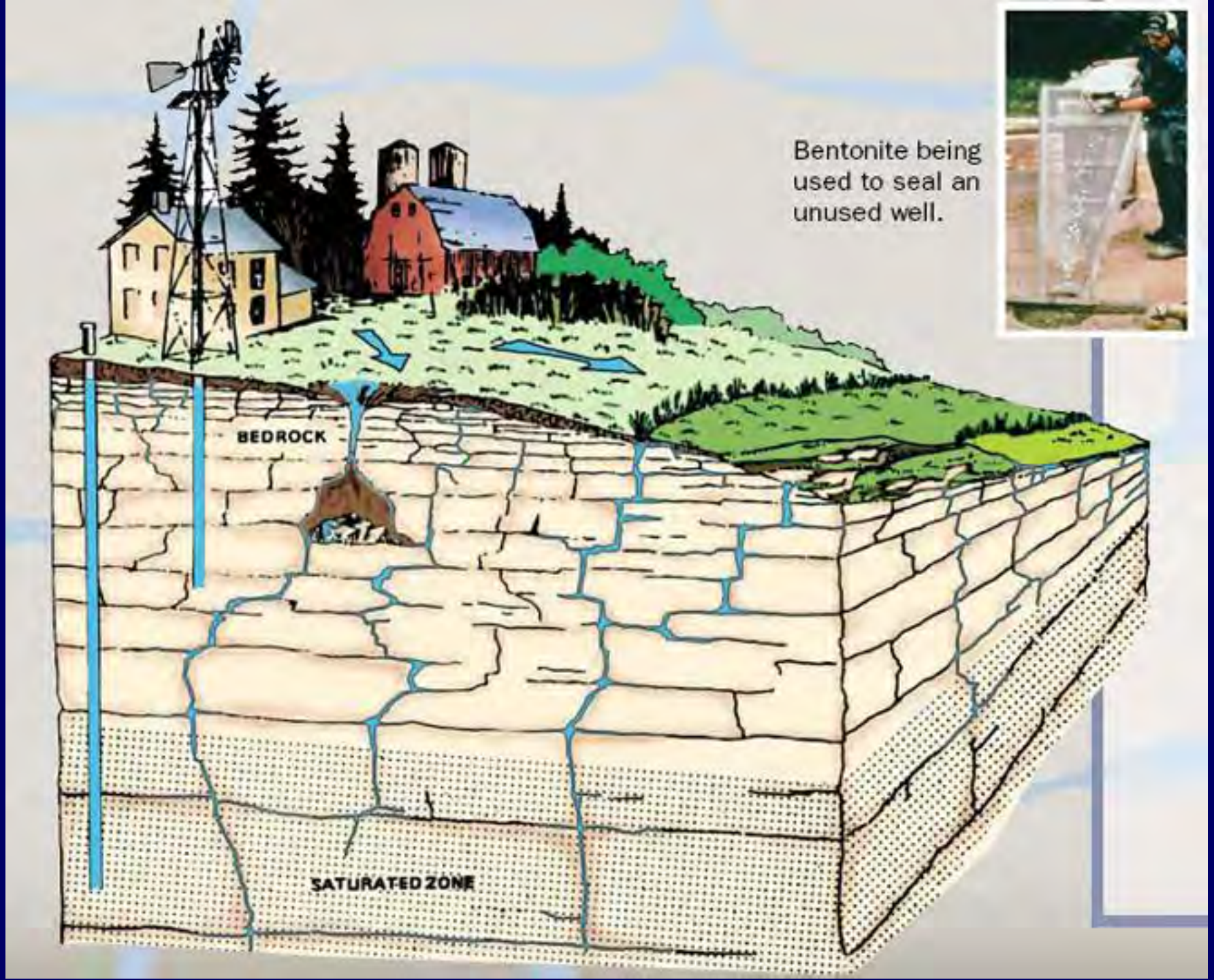
s, argillite, siltstone, quartzite, graywacke, and iron formation
vs, basaltic to rhyolitic metavolcanic rocks with some metasedimentary rocks
ga, meta-gabbro and hornblende diorite

LOWER PROTEROZOIC OR UPPER ARCHEAN ROCKS

mv, metavolcanic rocks
gn, granite, gneiss and amphibolite

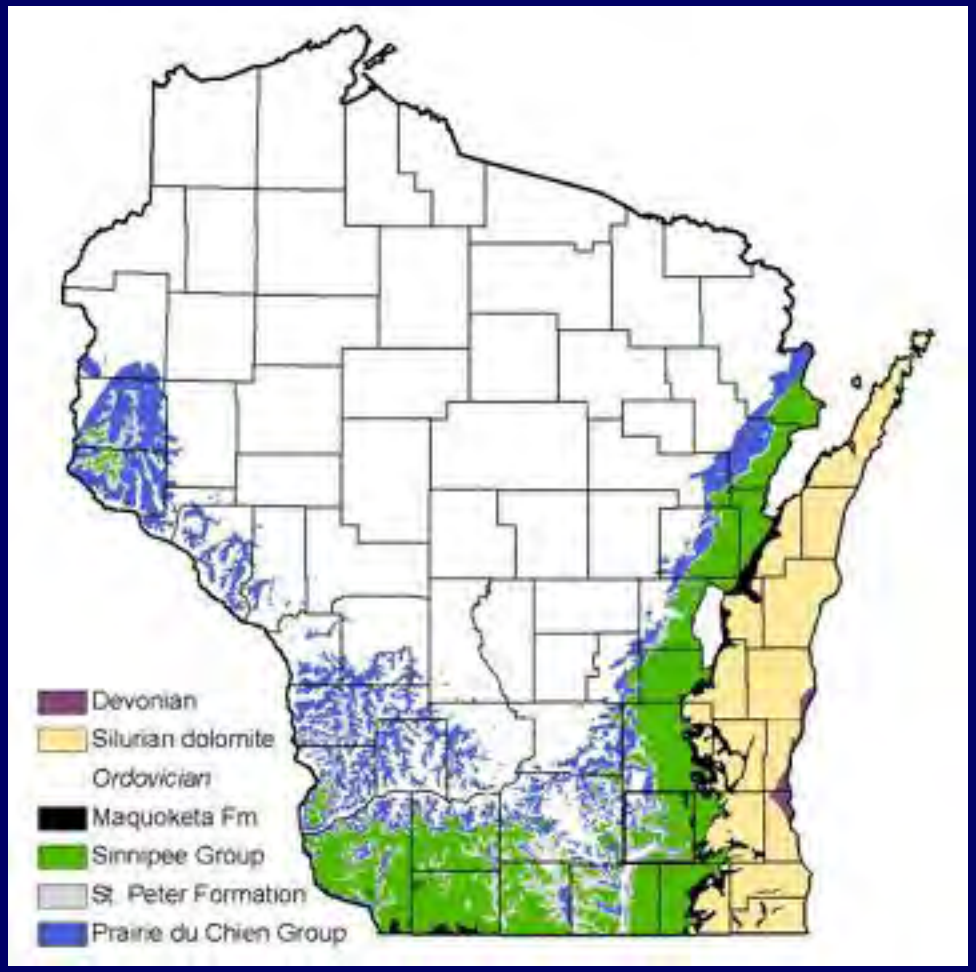
What is Karst?

- A type of topography that is formed on limestone (& dolostone) gypsum, and other rocks, primarily by dissolution, and is characterized by sinkholes, caves, and underground drainage (Glossary of Geology)
- Spectrum of landscapes -- Door Co. to tower karst of China
- Significant land area - 20% of U.S., 40% of area east of Mississippi River

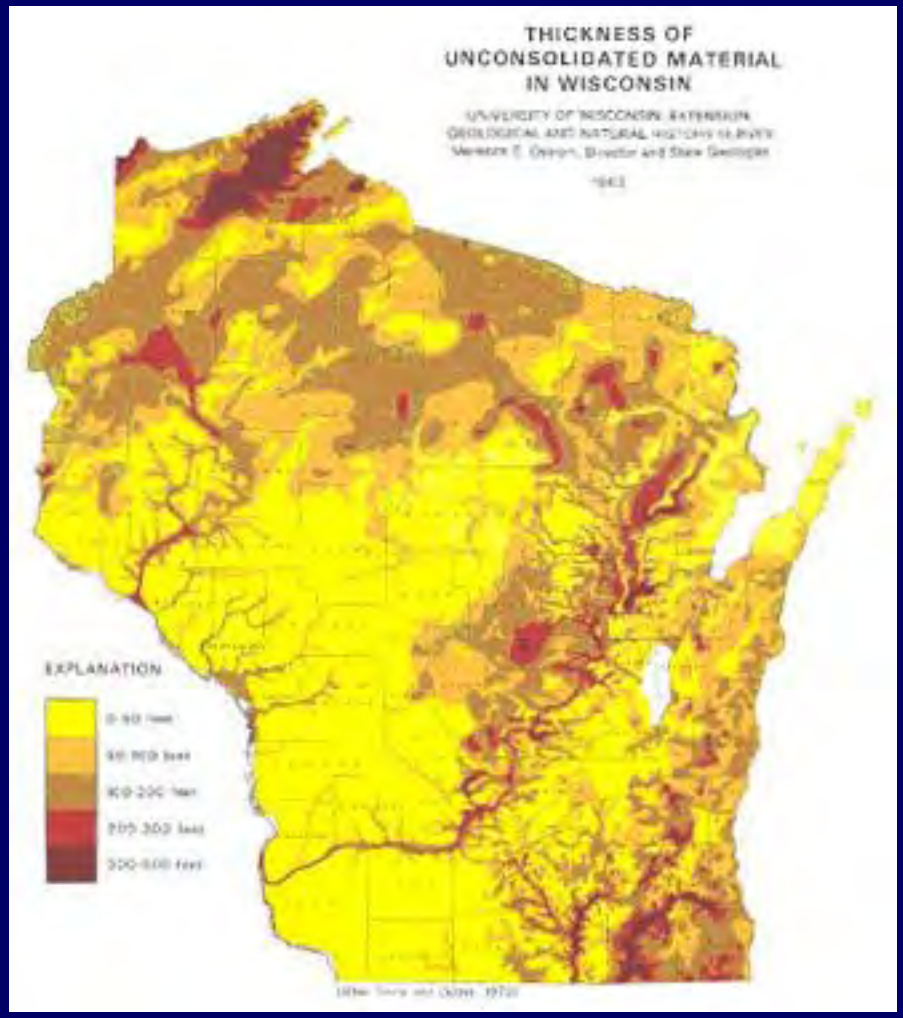


Bentonite being used to seal an unused well.

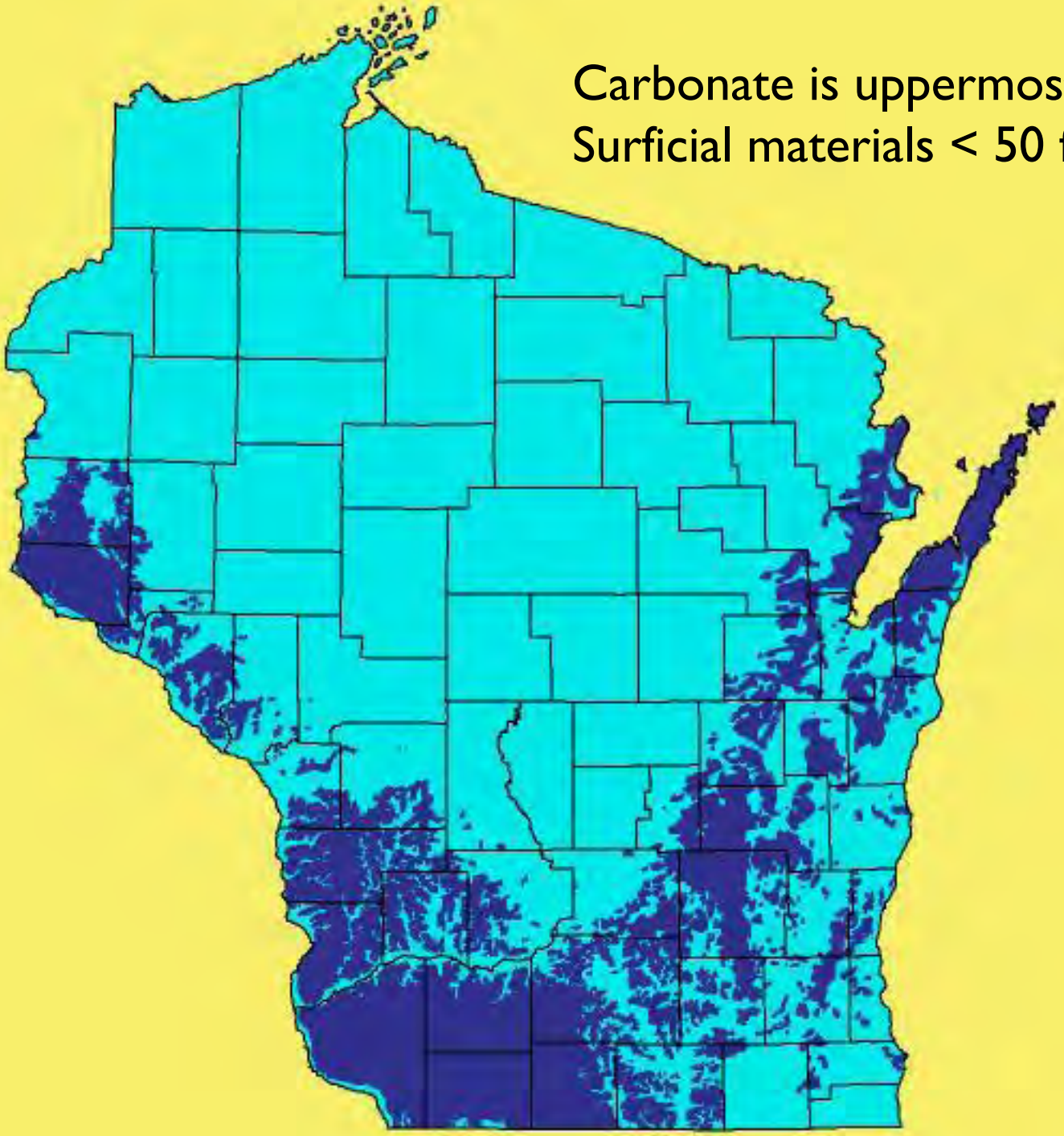
“Karst Potential” in Wisconsin



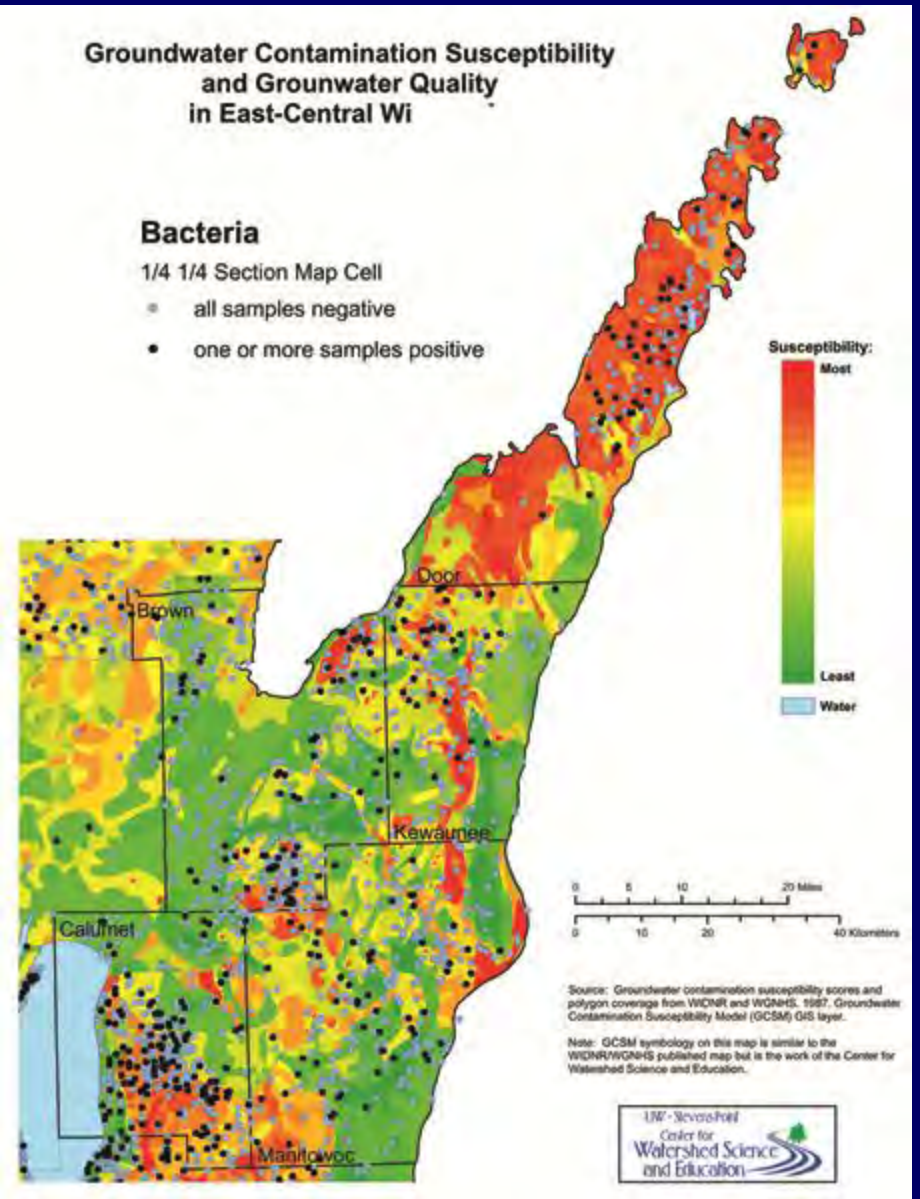
Carbonate is uppermost bedrock

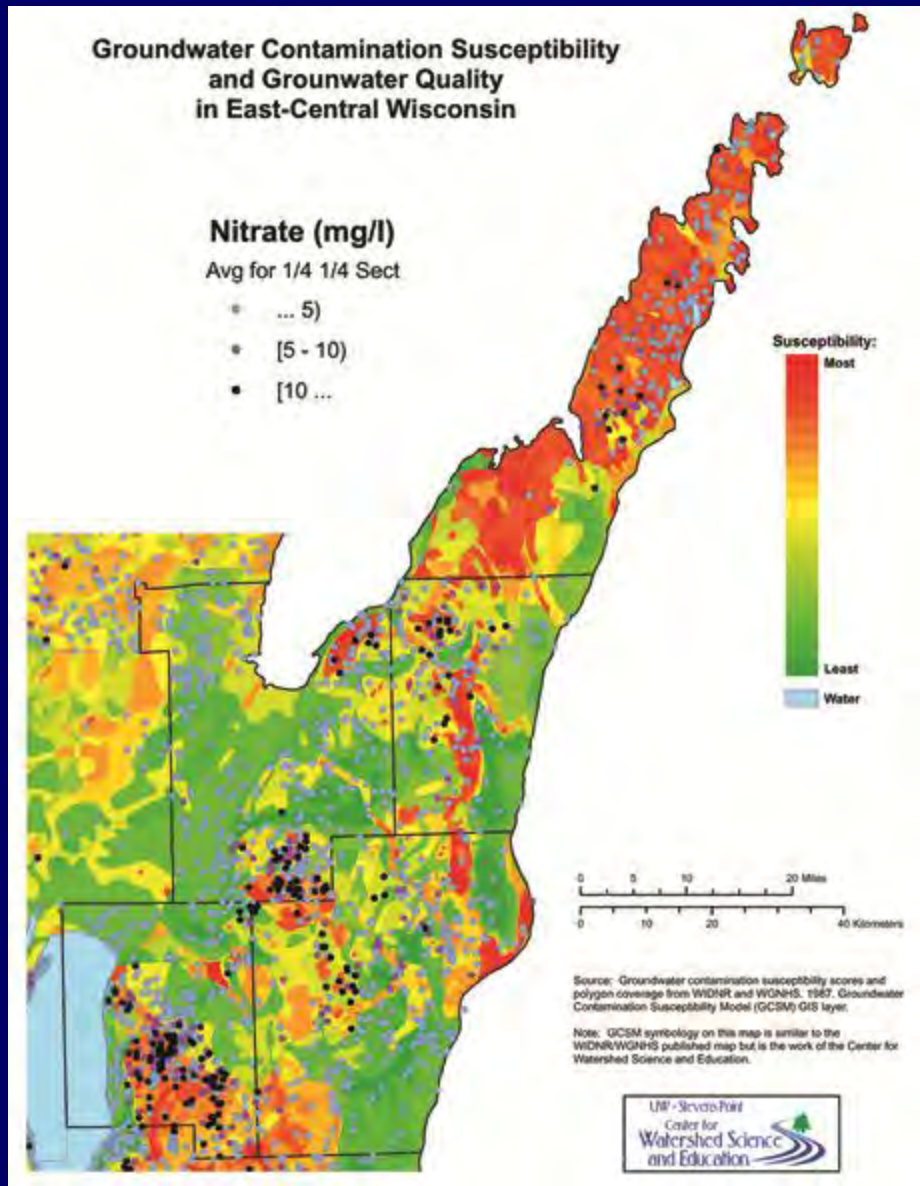


Unconsolidated
Deposits < 50 ft thick


Carbonate is uppermost bedrock
Surficial materials < 50 ft thick

Regional WQ Data





UWSP Well Water Quality Viewer

University of Wisconsin Stevens Point

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Center for Watershed Science and Education

College of Natural Resources and University of Wisconsin-Extension

- Home
- Water & Environmental Analysis Lab
- Groundwater Center
- Activities
- Reports
- WI Well Water Quality Viewer
- Student Involvement
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Well Water Quality Viewer: Private Well Data for Wisconsin

WI Well Water Quality Interactive Viewer

Use the Interactive Well Water Quality Viewer

Homeowners and local units of

Introduction

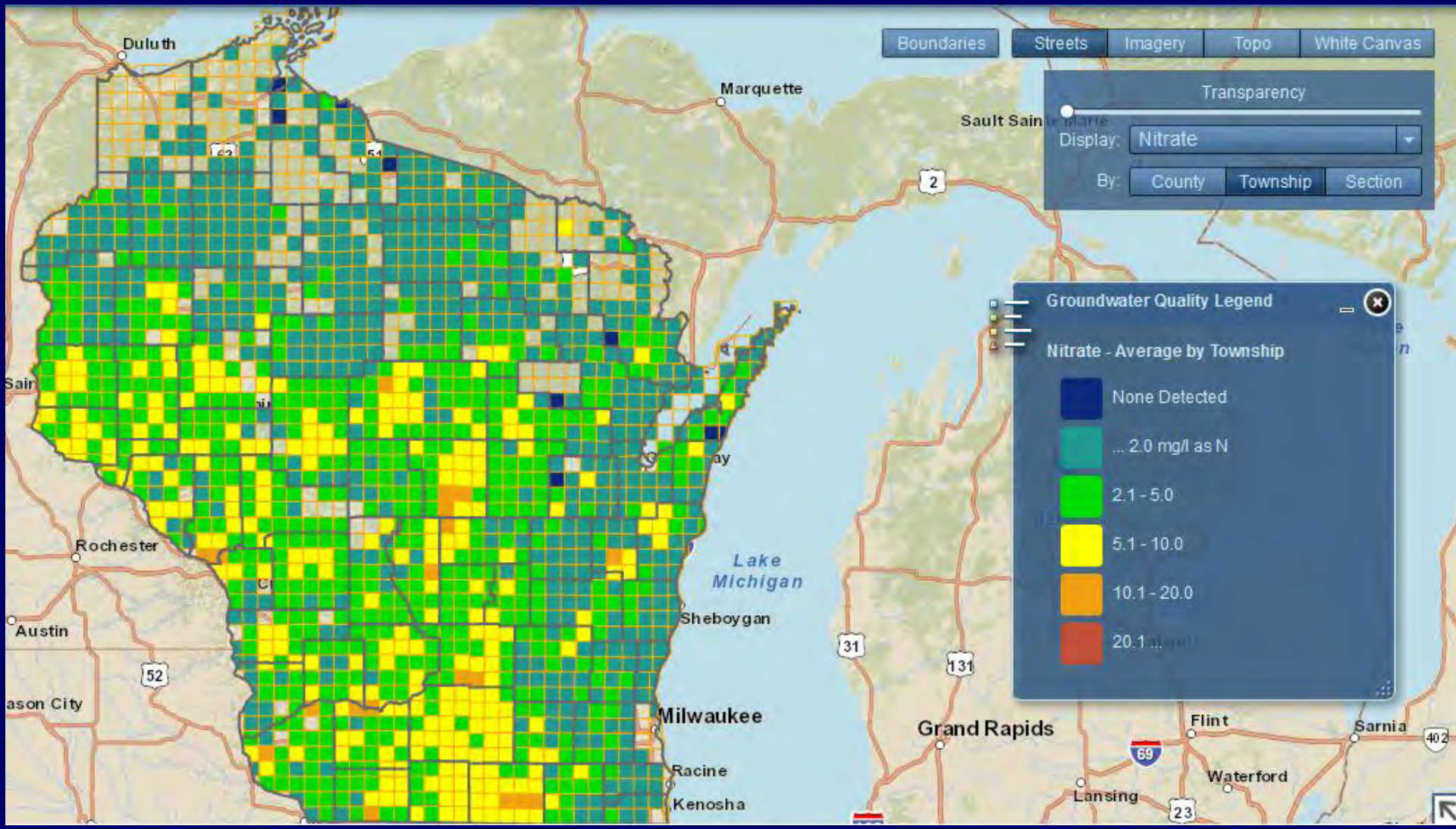
Nearly 900,000 households rely on private wells as their primary water supply. Homeowners with private wells are encouraged to have their well tested on a regular basis to determine the safety of the water supply for purposes such as drinking and cooking. While testing is the only way to determine the types and amount of contaminants in a well water system, homeowners and local officials often want to know more about water quality issues in their community.

The WI Well Water Quality Interactive Viewer was created as an educational tool to help people better understand Wisconsin's groundwater resources that many of us rely on for our drinking water.

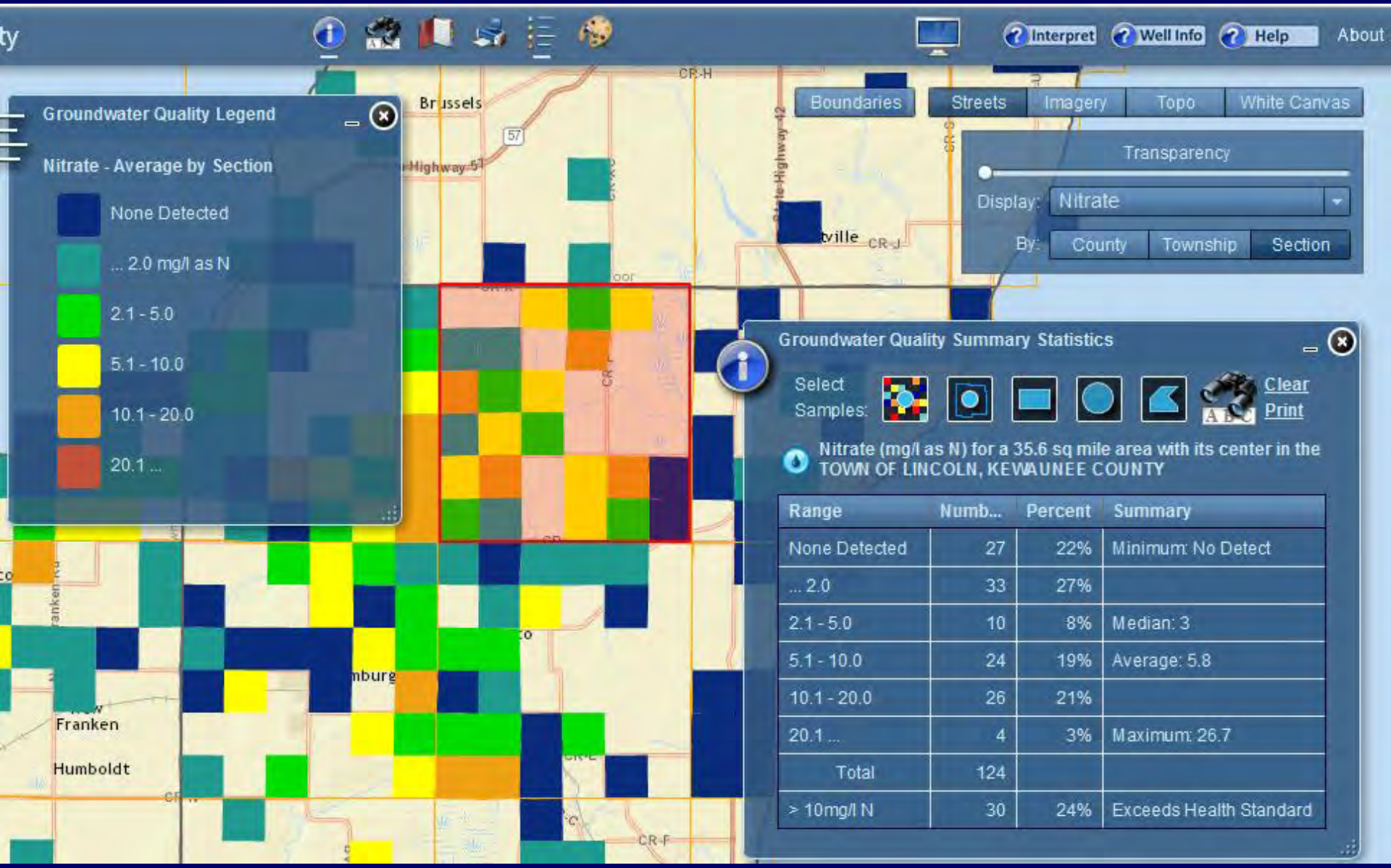
How does the viewer work?

The viewer relies mostly on voluntarily submitted well water samples from homeowners and other well water data collected by state agencies over the past 25 years. It would not have been made possible without the many well owners who took the initiative to have their wells tested.

UWSP Well Water Quality Viewer



UWSP Well Water Quality Viewer



Range	Numb...	Percent	Summary
None Detected	27	22%	Minimum: No Detect
... 2.0	33	27%	
2.1 - 5.0	10	8%	Median: 3
5.1 - 10.0	24	19%	Average: 5.8
10.1 - 20.0	26	21%	
20.1 ...	4	3%	Maximum: 26.7
Total	124		
> 10mg/l N	30	24%	Exceeds Health Standard

- Well was drilled in June of '96
- 123 ft deep, cased to 63ft
- Has been bleached seven times
- Tested over a dozen times in the past six years
- Persistent bacteria problems
- Nitrate level has fluctuated from high teens to 39 ppm.

Manure-tainted wells, replaced

Since 2006, the state has compensated the owners of 66 wells that were found to be contaminated with livestock manure.

County	Town	
Brown	Cooperstown	4
	Morrison (Village of W.	24
Calumet	Brotherton	2
	Kloten	5
Dane	Waunakee	2
Dodge	Brownsville	7
	Lomira	1
	Lowell	1
Door	Valmy	1
Fond du Lac	Byron	4
	Ripon	1
Green Lake	(left blank)	2
	Monroe	1
Iowa	Mineral Point	1
Jefferson	(left blank)	1
Manitowoc	Cato	1

http://wisconsinwatch.org/2014/08/in-states-karst-area-even-good-farming-may-pollute-groundwater/

Silurian Dolomite Aquifer

Silurian Dolomite Aquifer

Silurian Dolomite Aquifer

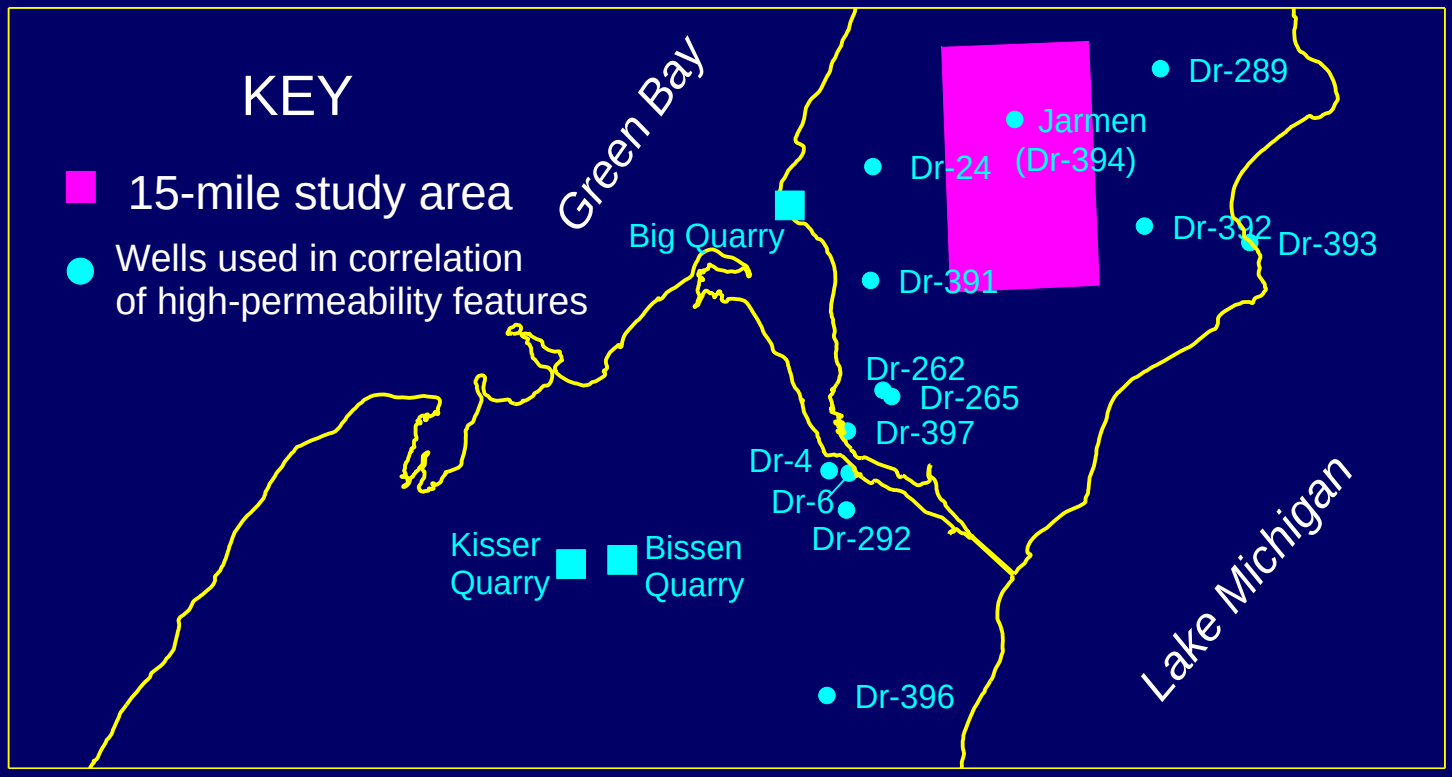
- Calumet and Brown Counties

Silurian Dolomite Aquifer

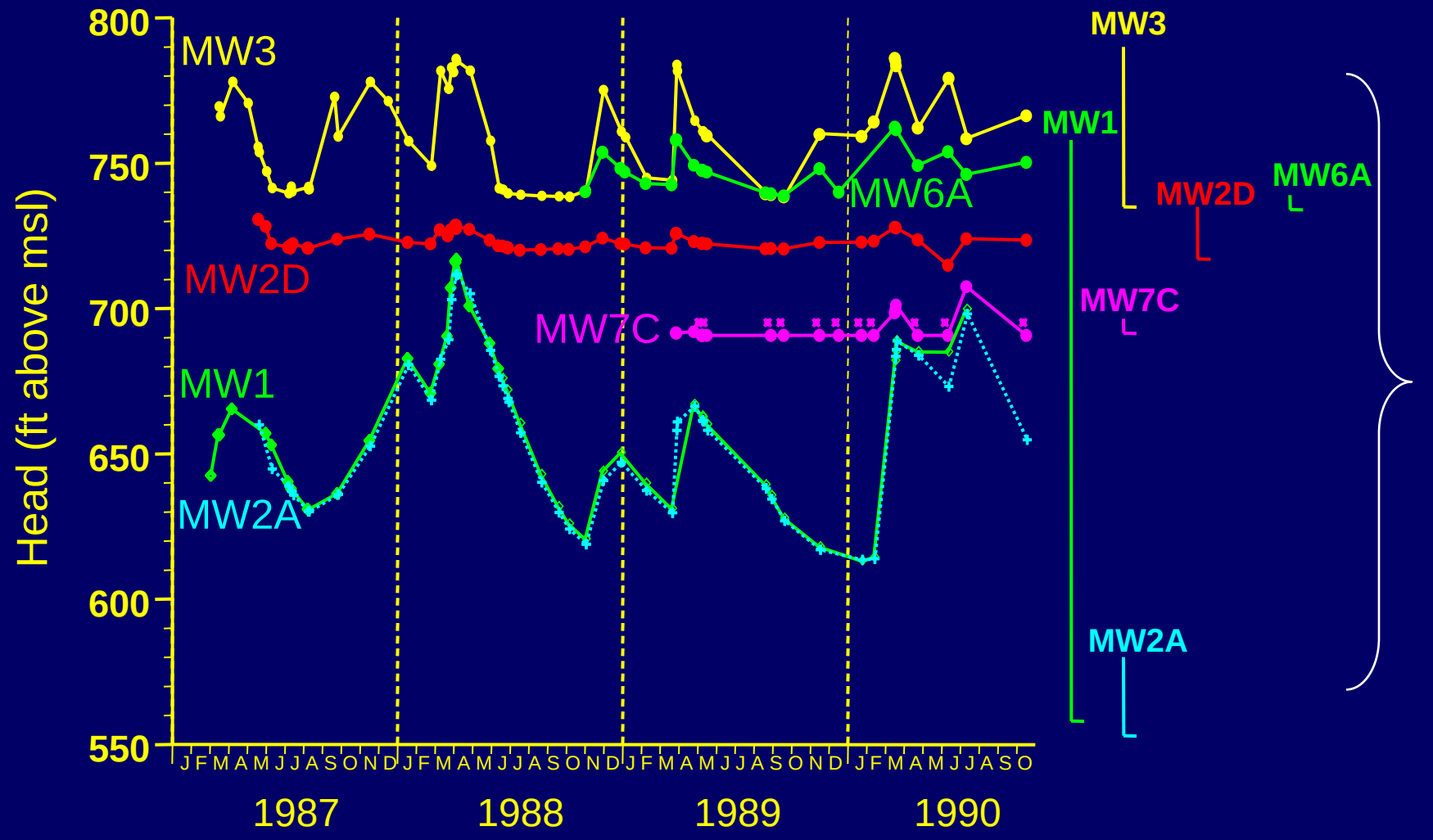
- Rapid downward flow in vertical fracture network
- Rapid lateral flow along bedding-plane parallel fractures
- Little to no attenuation of contaminants within the aquifer

Bedding-plane Fractures

Location Slide

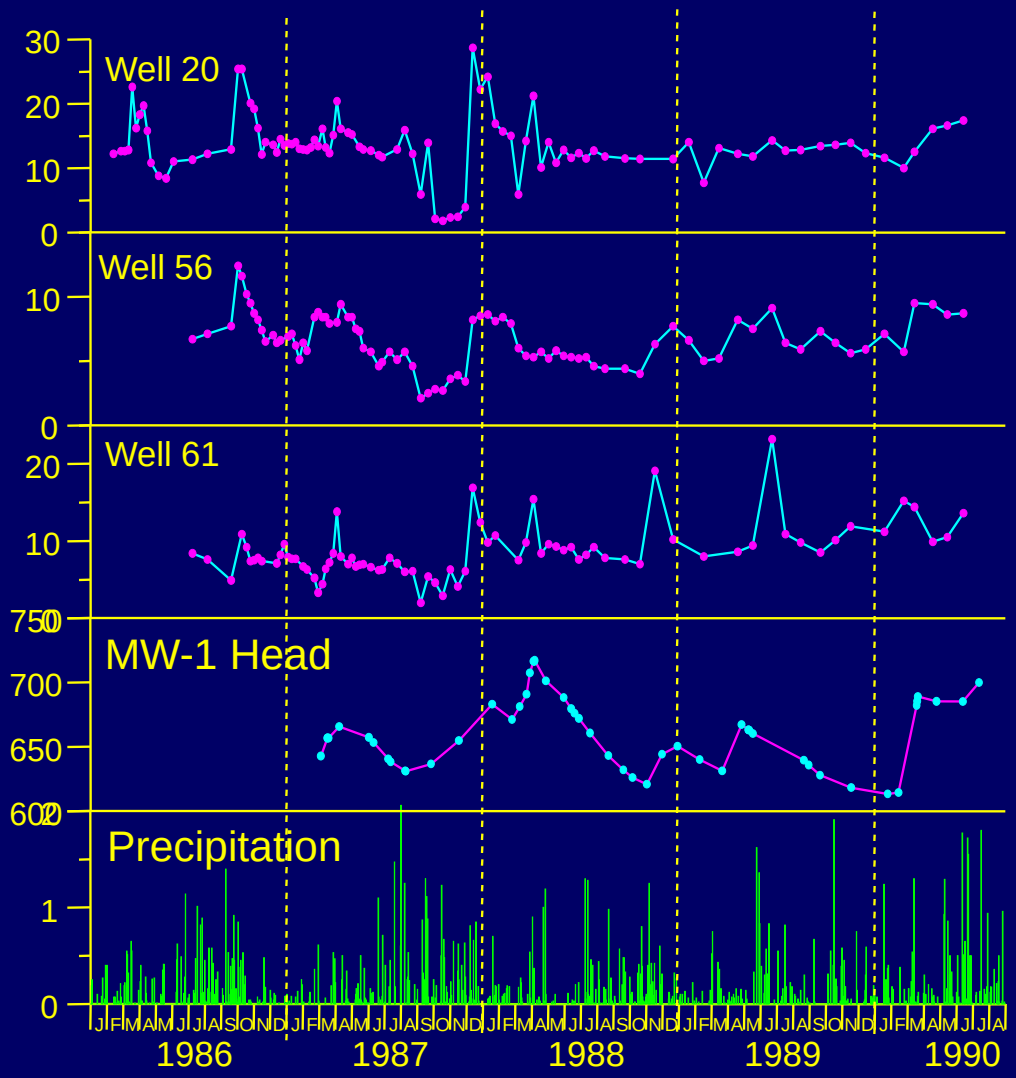


Water levels and fluctuations at a piezometer nest in fractured dolomite



Note the large variations in water levels (up to ~90 ft)
(from Bradbury and Muldoon, 1992)

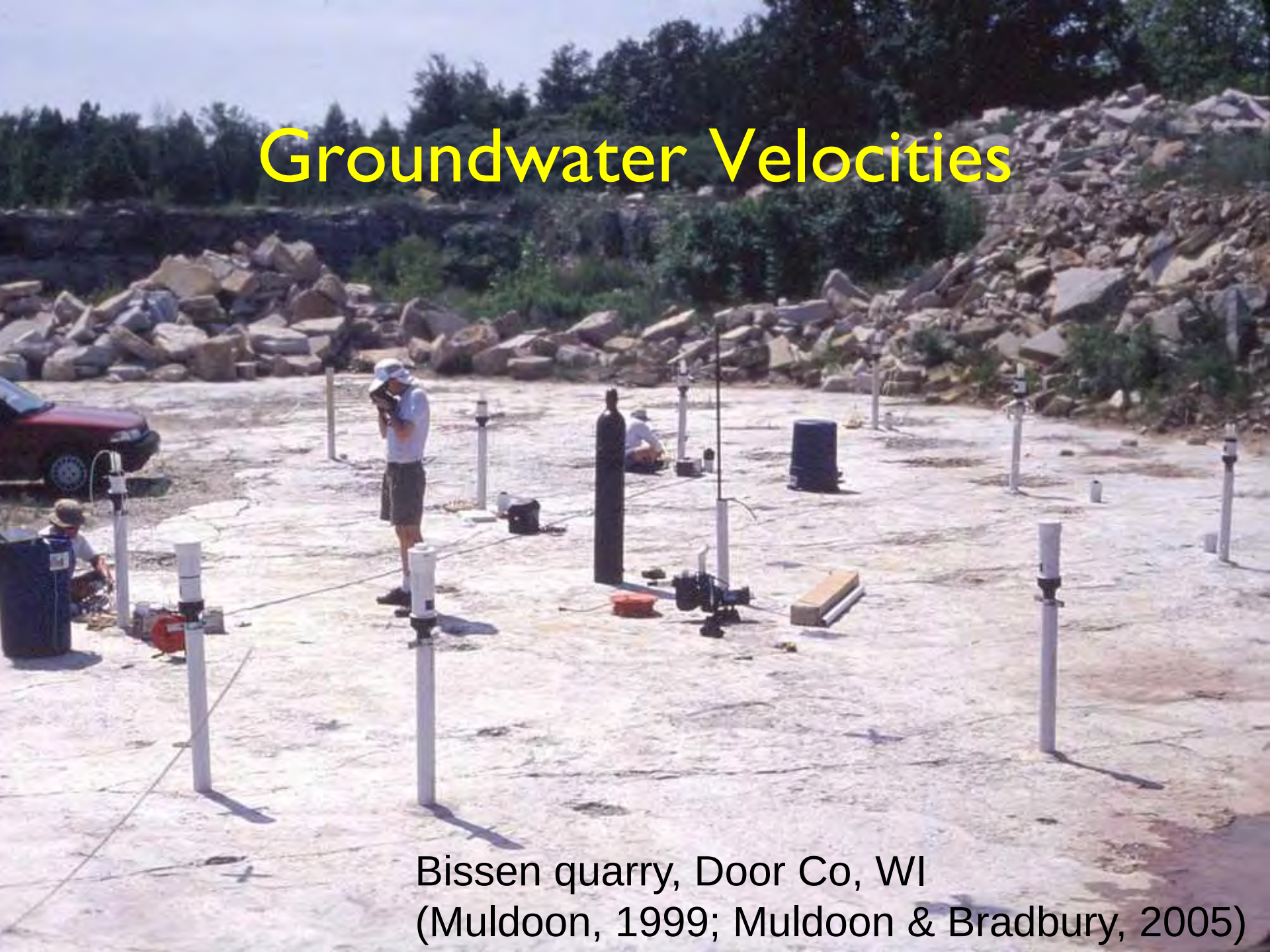
Water Quality Variation



- NO_3-N values from three domestic wells completed in the Silurian dolomite (miles apart)
- Similar response indicates a non-point or diffuse source rather than point source of contamination

(from Bradbury and Muldoon, 1992)

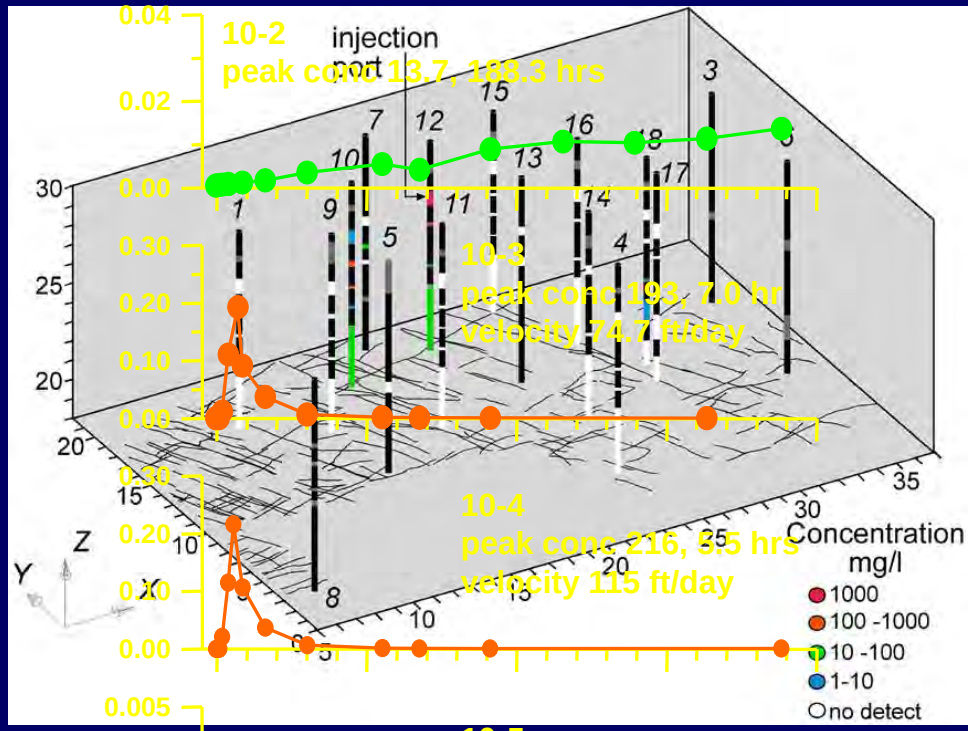
Groundwater Velocities

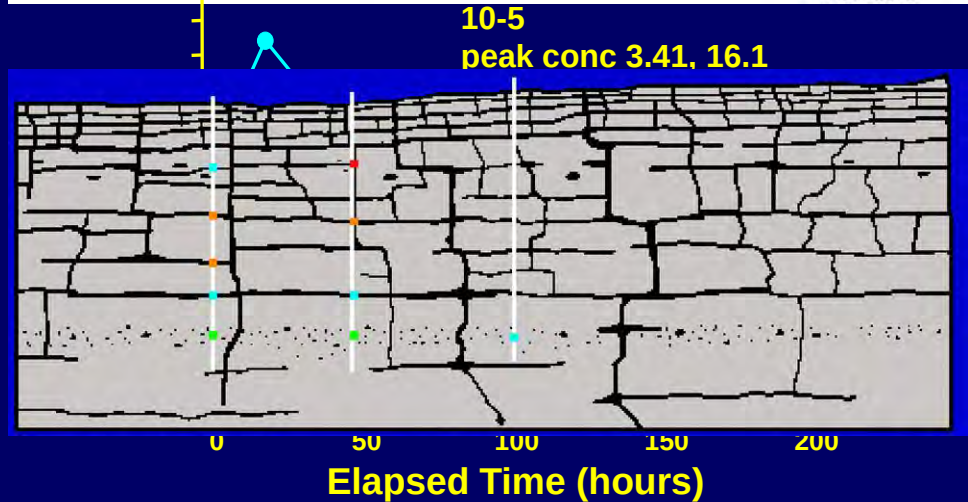


Bissen quarry, Door Co, WI
(Muldoon, 1999; Muldoon & Bradbury, 2005)

Groundwater Velocities

- Bissen Tracer Tests
  - Calculated velocities using peak arrival times
  - Mix of fracture and matrix velocities
  - Range 0.47 - 118.3 m/day
  - Mean 12.7 m/day
  - Median 5.9 m/day
- Inadvertent Tracer Tests
  - 100's m/day





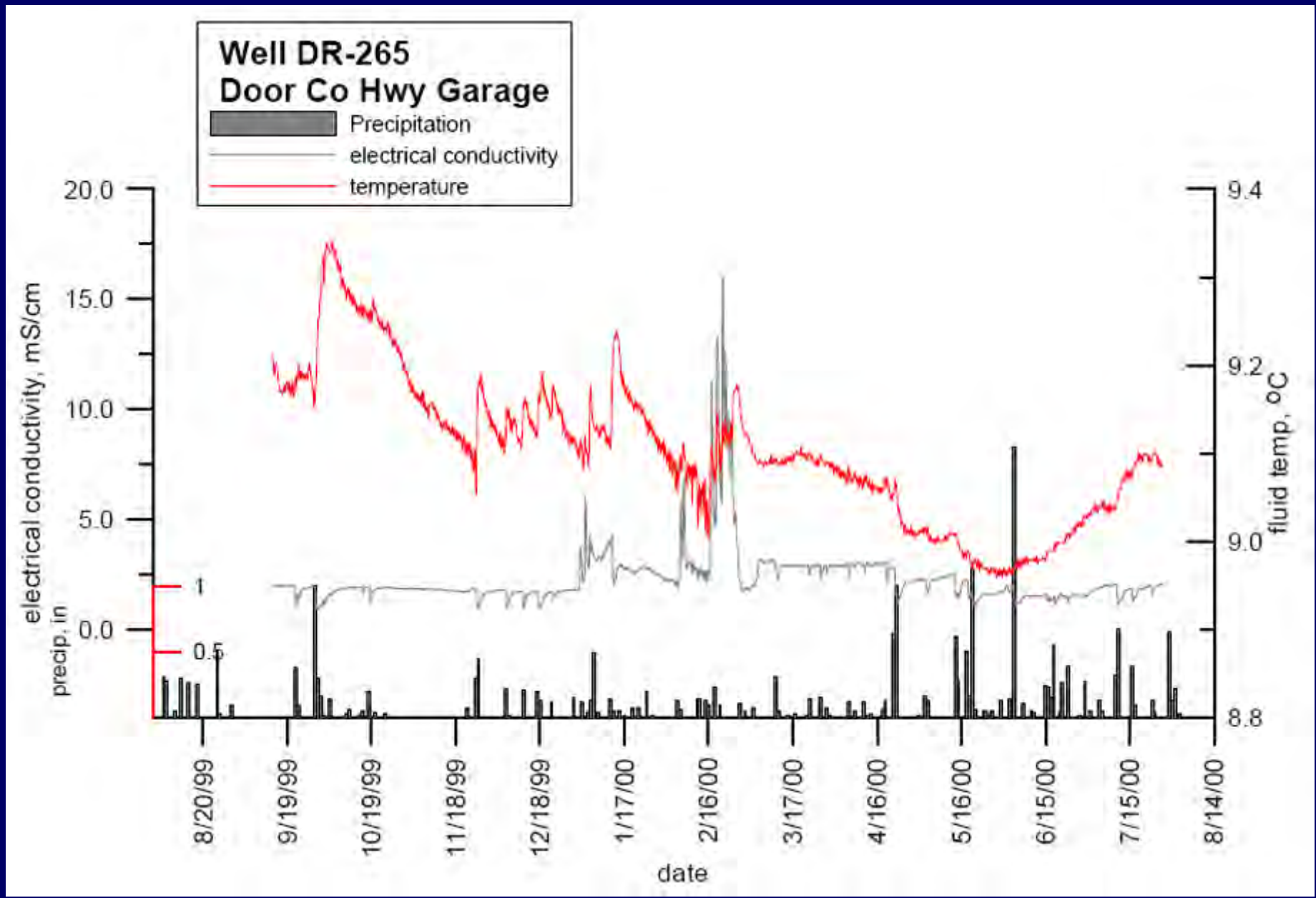
Flow Characteristics of Karst Aquifers

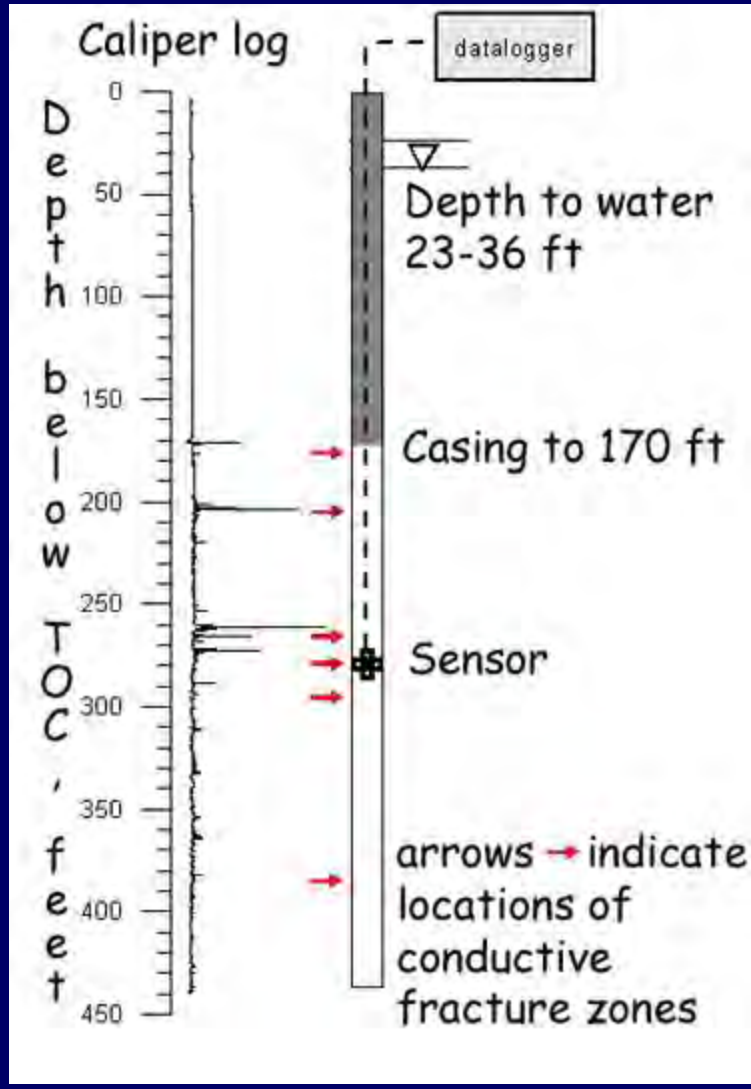
- Dense and ubiquitous fracture network
  - little surface runoff
  - water easily infiltrates to subsurface
- Recharge
  - exceedingly rapid
  - carries surface contaminants to the water table
- Flow within the aquifer occurs primarily along bedding plane fractures
  - Little to no attenuation of contaminants within the aquifer
- Flow rates vary from 10's to 100's of ft/day

Surficial Sediments

- Holy Hill Fm
  - Yellowish brown to brown, sandy till (50 to 80% sand) with associated lake and stream sediment
- Kewaunee Fm
  - Brown to reddish brown calcareous till with associated lake and stream sediment
  - Sand content varies for different members, but generally till is sandy silt

Recharge in Areas of Thin Soils

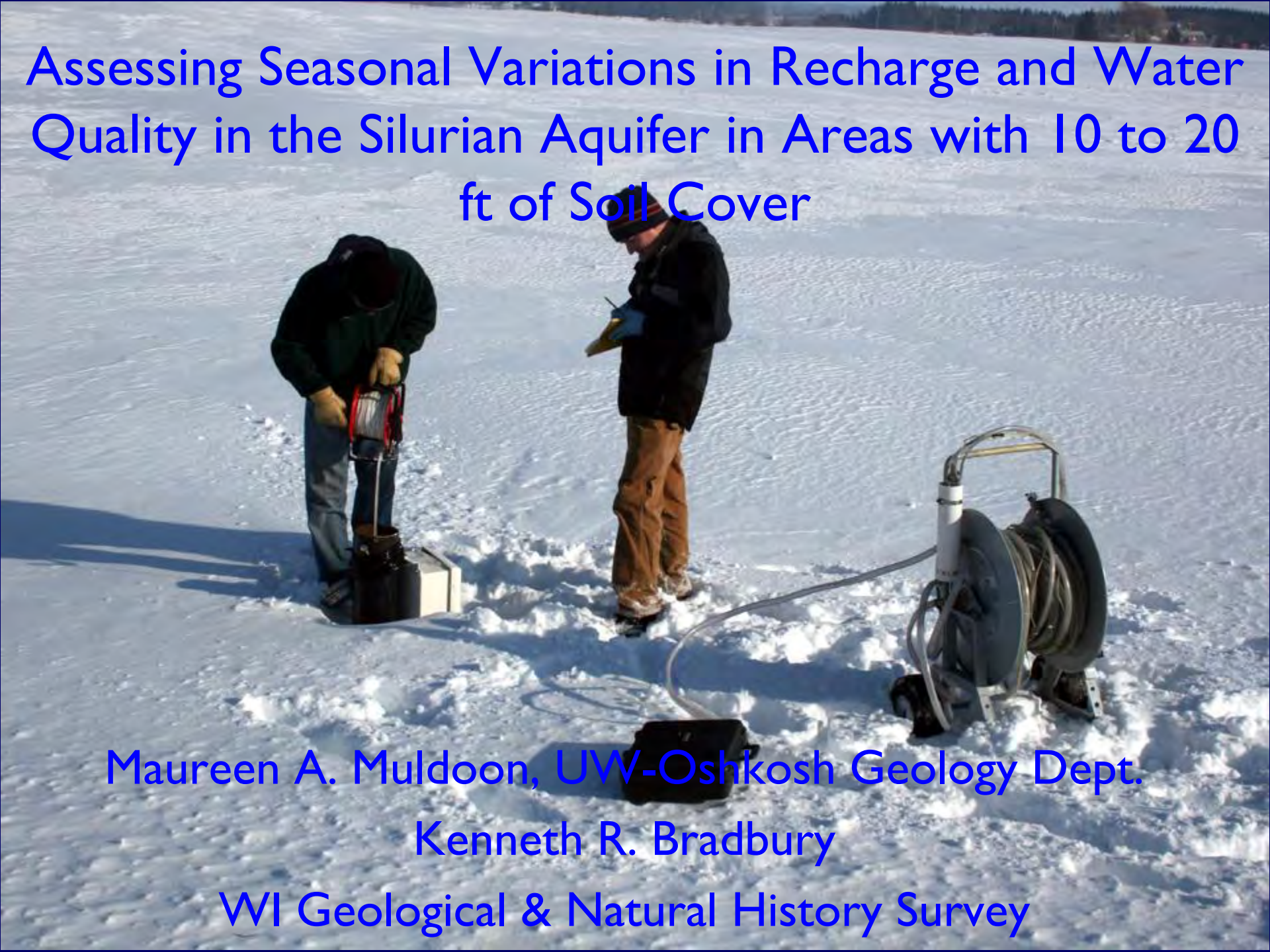




✚ locations of wells and rain gauge used in this study

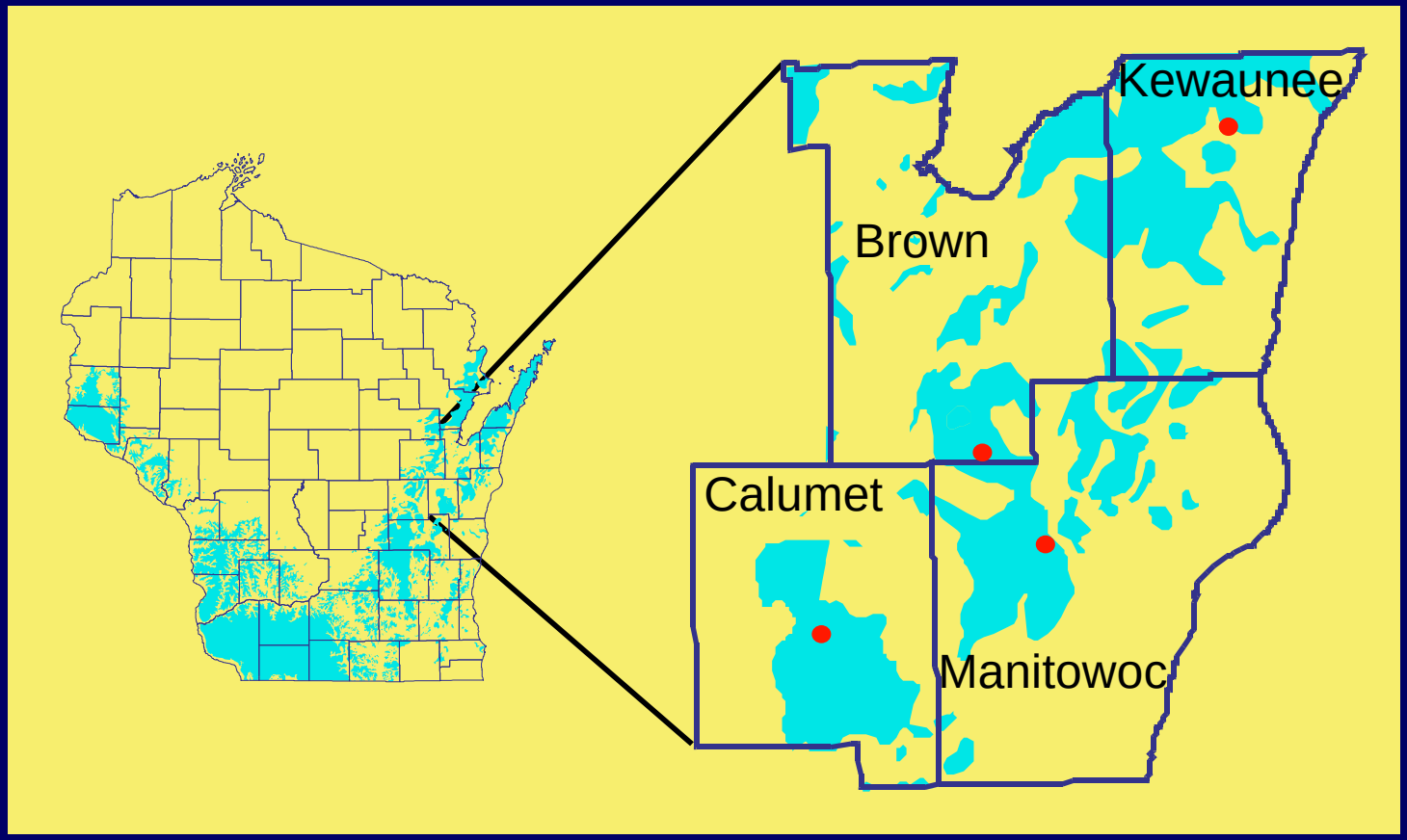
● other municipal wells

Assessing Seasonal Variations in Recharge and Water Quality in the Silurian Aquifer in Areas with 10 to 20 ft of Soil Cover



Maureen A. Muldoon, UW-Oshkosh Geology Dept.
Kenneth R. Bradbury
WI Geological & Natural History Survey

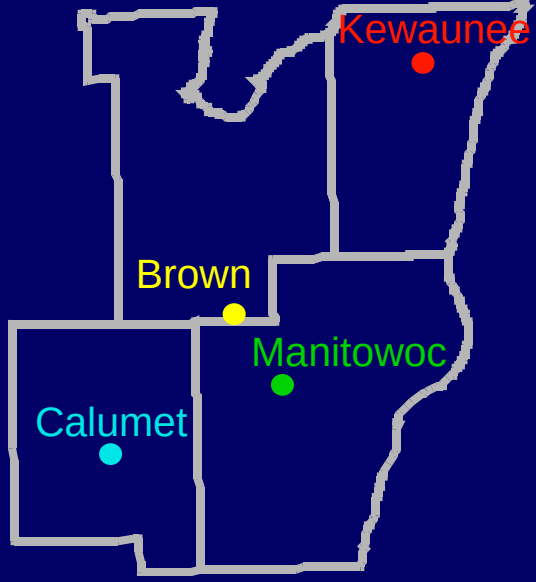
Site Selection



- Depth to rock ~10 to 20 ft
- Depth to water <50 feet
- Downgradient of agricultural fields

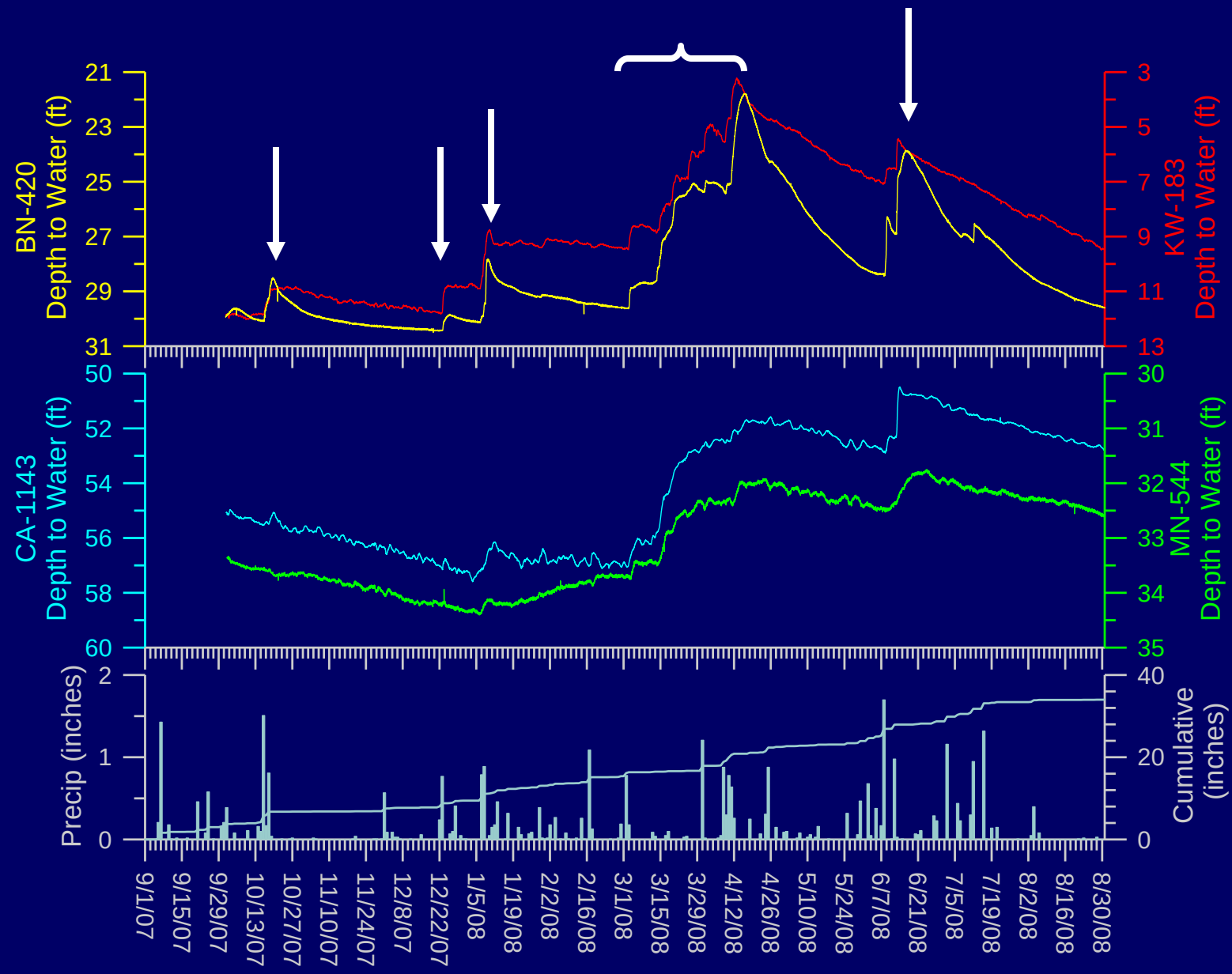
Well Characteristics

- Completed geophysical logs to identify high-permeability bedding plane fractures

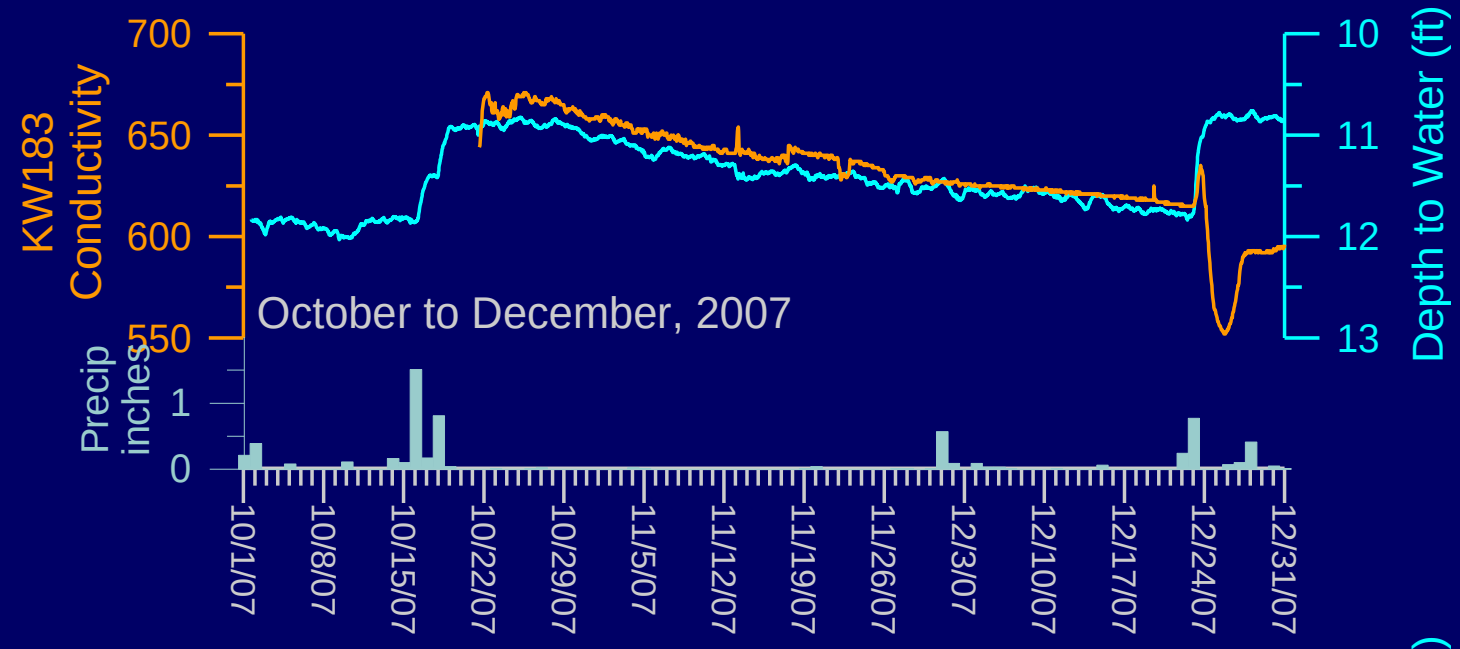


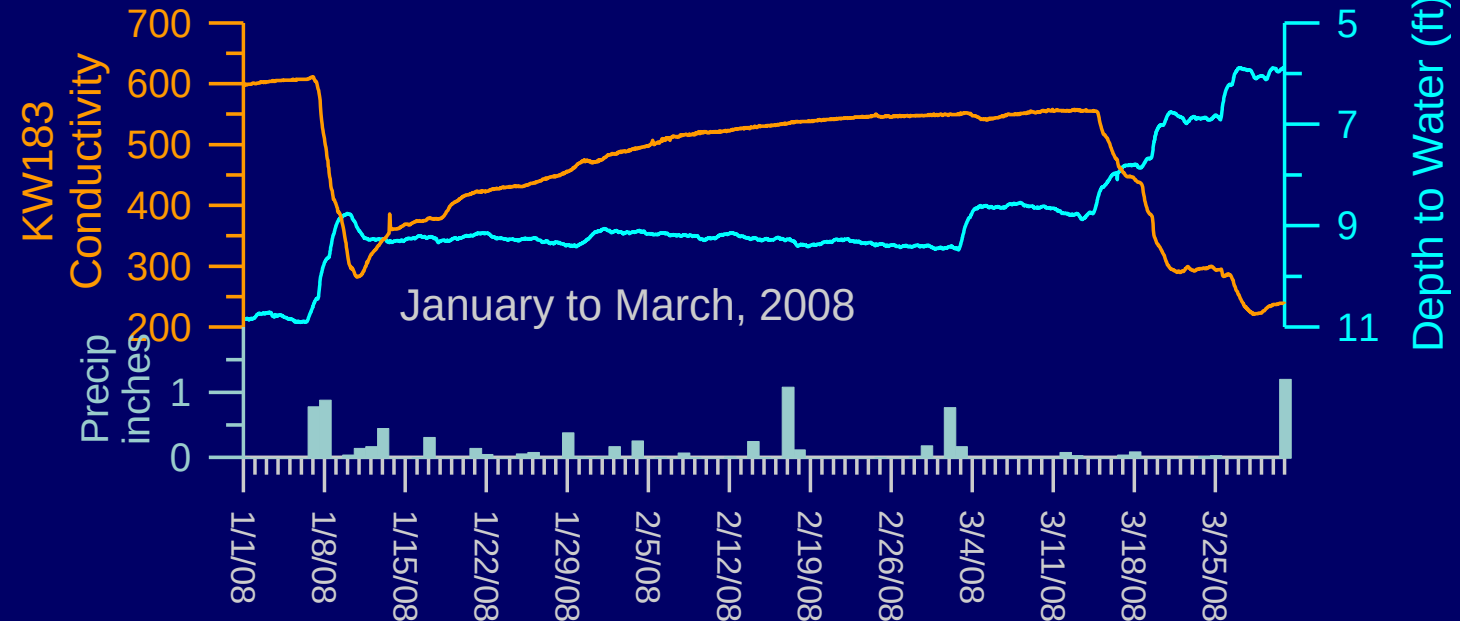
Well	County	Soil thickness	Well Depth
BN420	Brown	10	40.4
CA1143	Calumet	18	81
KW183	Kewaunee	7	33
MN544	Manitowoc	18	57.6

Water-Level Variations

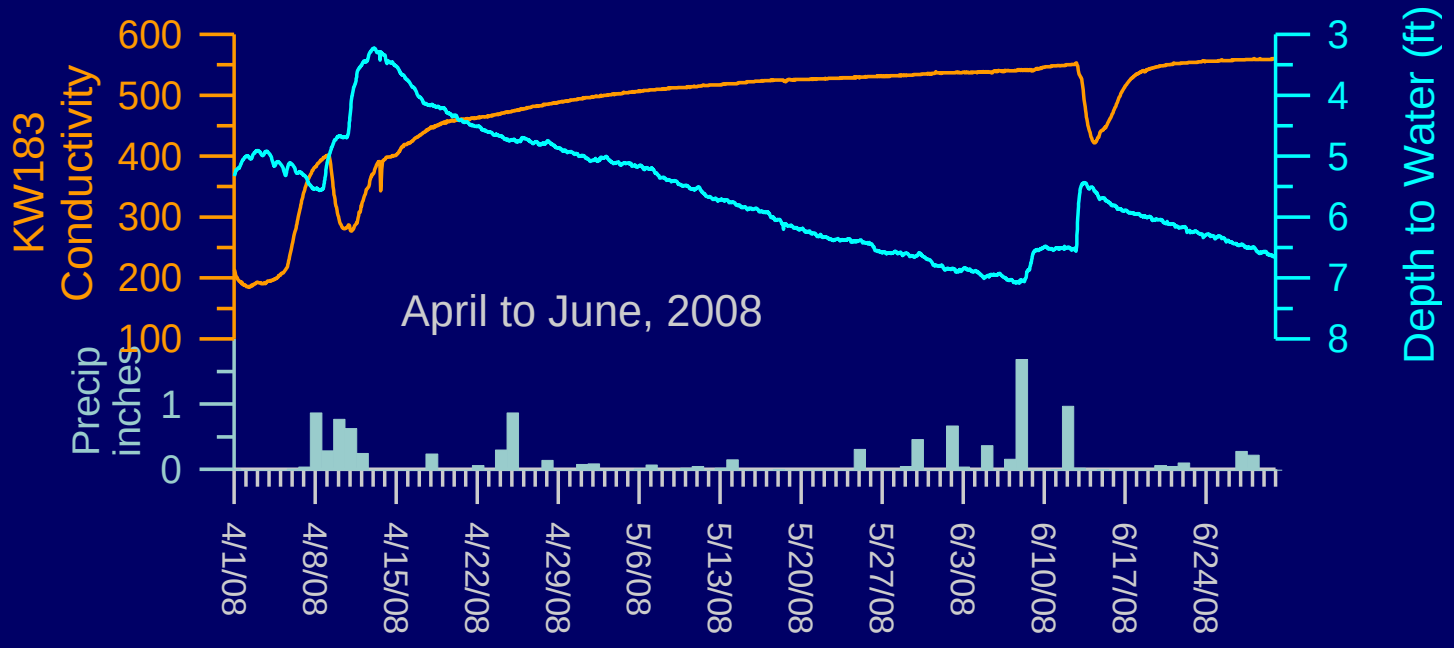


Conductivity Variations



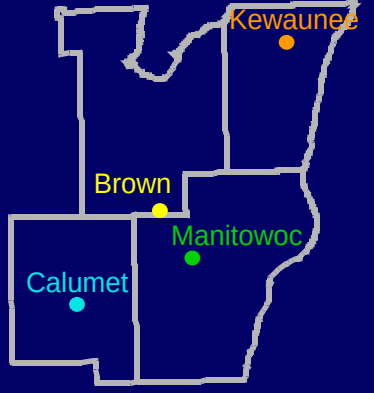


Conductivity Variations



- Summary KW183
- Sharp change in conductivity within 24 hrs of recharge event
  - Rise in conductivity as vadose water drains
  - Drop in conductivity as low-conductivity recharge enters saturated zone
- Rising conductivity during periods of static or falling water levels

Conductivity Variations



Well	Avg DTW	Sensor Depth	Cond Min	Cond Max	Cond Range	WL Range
BN420	28.06	34	719	937	218	8.71
KW183	8.52	21	185	671	486	8.80
CA1143	54.21	60	480	817	337	7.10
MN544	33.06	41	573	679	100	2.65

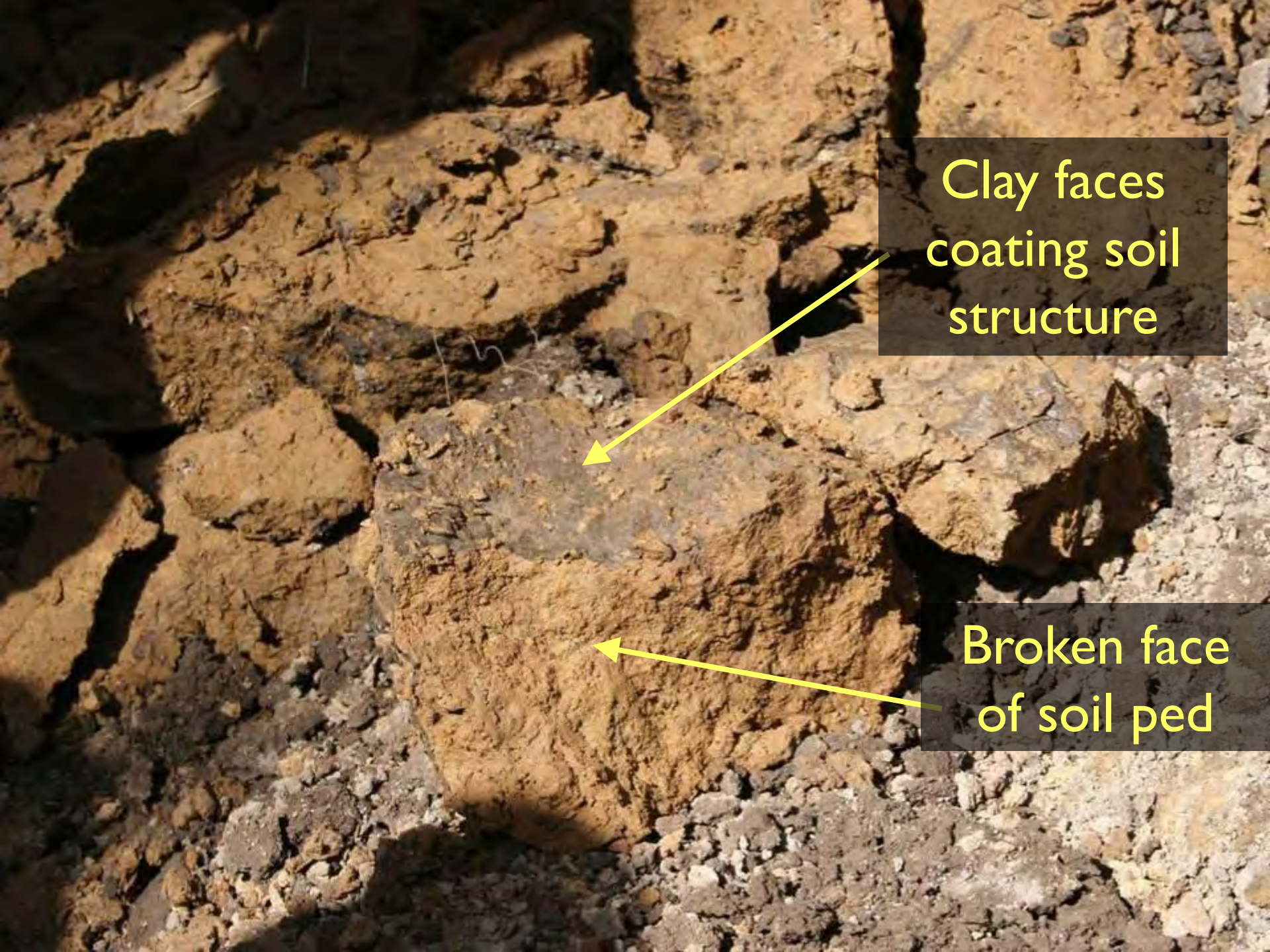
- Three wells show rapid drops in fluid conductivity in response to recharge events
  - Within 24 of major precipitation and/or melt events
  - Within a few days of more gradual recharge events (spring melt)

Implications for Management

- *"Resource mangers should consider the timing of recharge events when developing best management practices for the application of animal wastes and sewage sludge. The fact that recharge water reaches the saturated zone very rapidly and that significant recharge occurs from December to April suggests that manure and sewerage sludge applied during the winter months has the potential to carry pathogens to the aquifer very rapidly."*

Recharge & GW Vulnerability

- Studies in NE WI demonstrate that recharge reaches the aquifer within 1 to 2 days, with sediment thicknesses up to 18 ft
- Dodge County: Manure through 15+ feet of clay via cracks and pathways
- Review of midwestern and national literature suggests that clayey materials frequently contain fractures and macropores to significant depths


Clay faces coating soil structure
Broken face of soil ped

Storm Water Concerns

- Hydrogeology of the Silurian aquifer is well understood
- Geologic setting makes this area especially vulnerable to groundwater contamination from activities at land surface
- Storm water (urban or rural) carries dissolved constituents that we really don't want in our drinking-water aquifers
- Altering drainage patterns or ponding water in new areas can lead to unintended consequences in karst areas