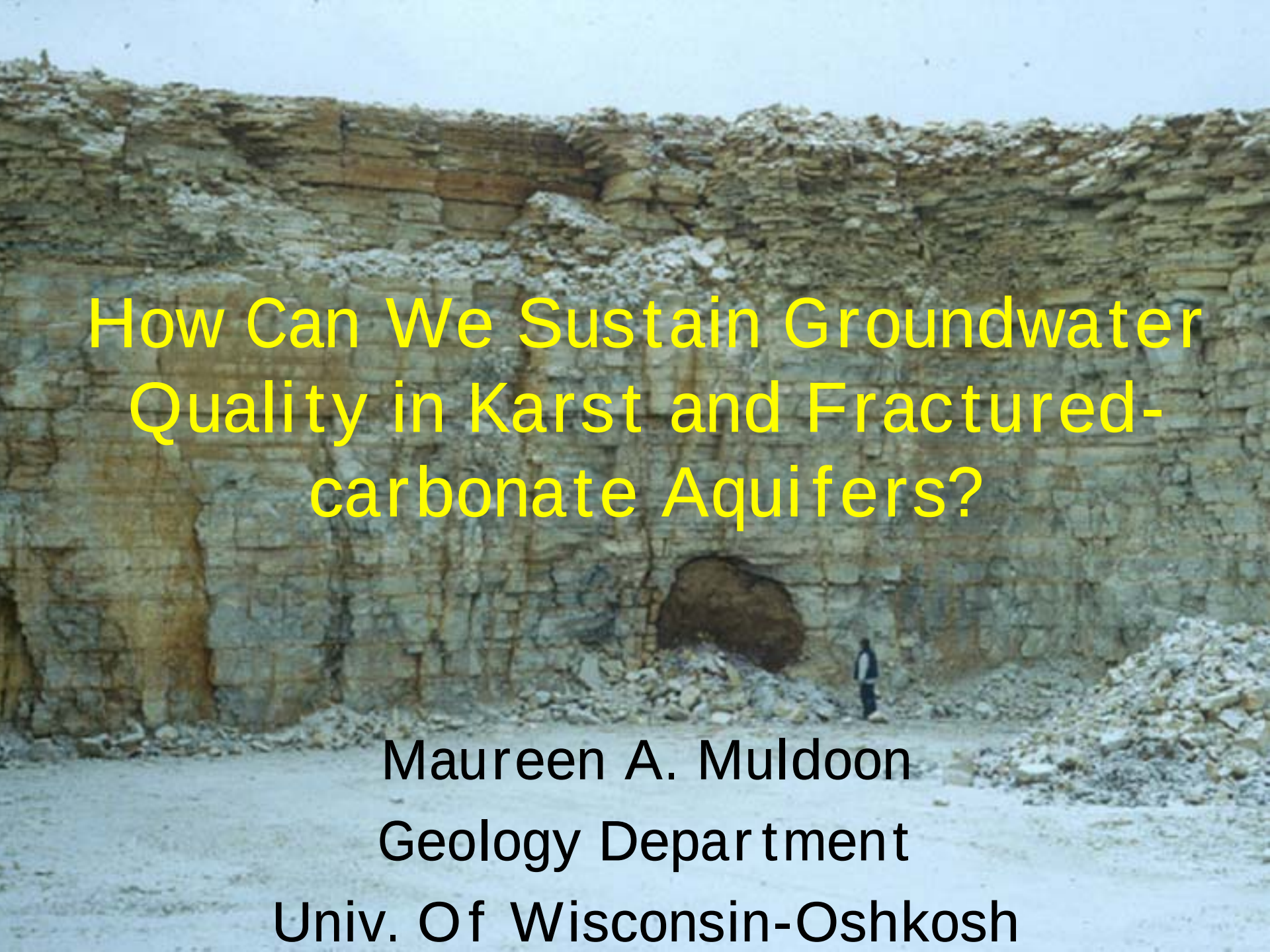


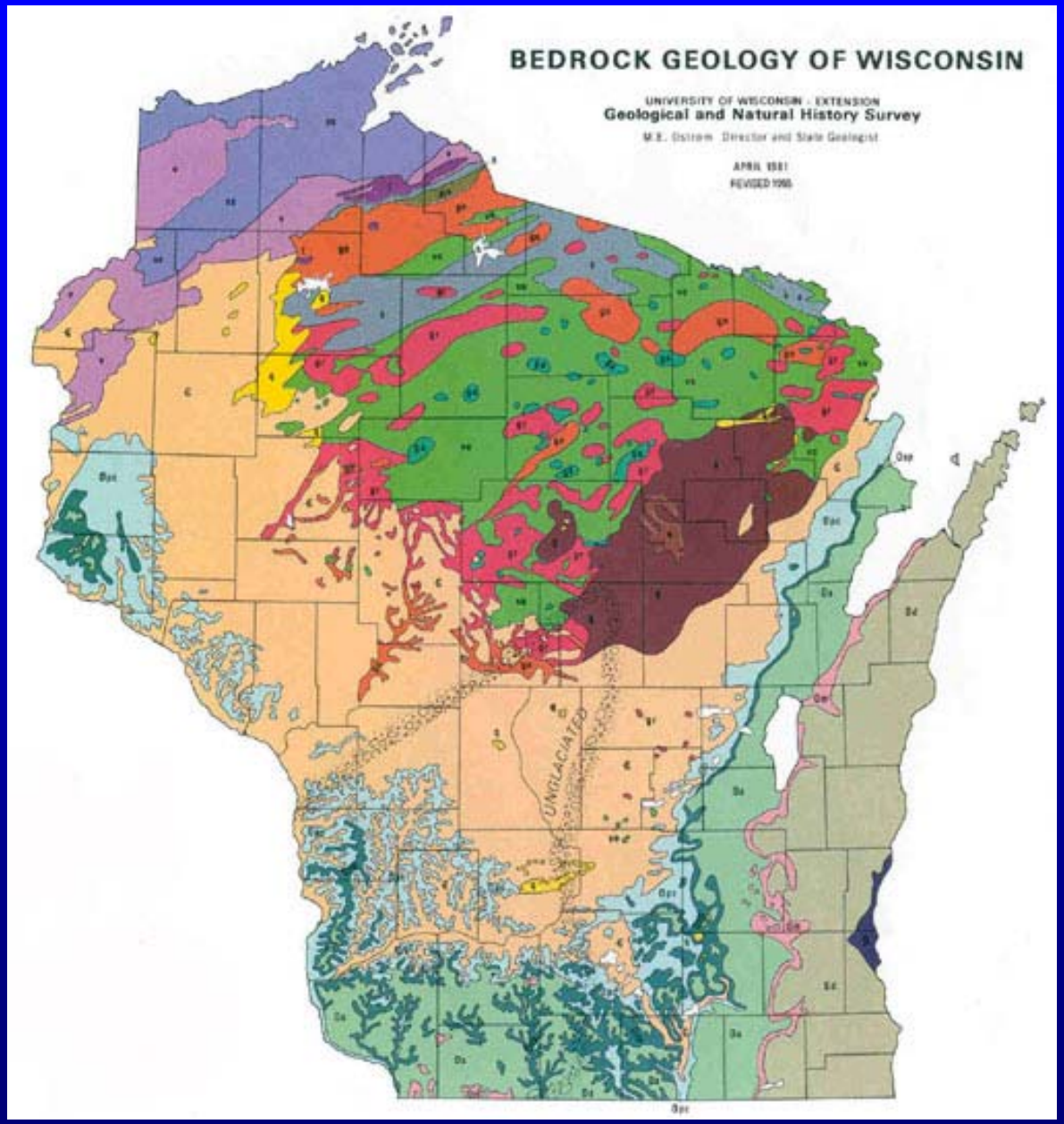
How Can We Sustain Groundwater Quality in Karst and Fractured-carbonate Aquifers?

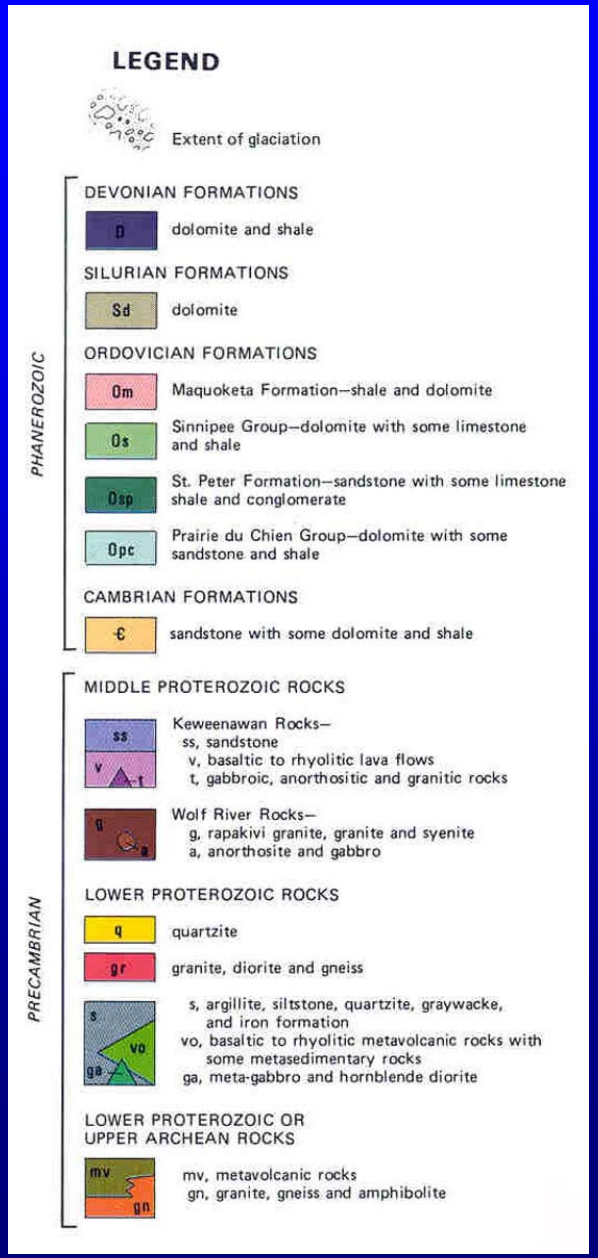
Maureen A. Muldoon
Geology Department
Univ. Of Wisconsin-Oshkosh

The Question

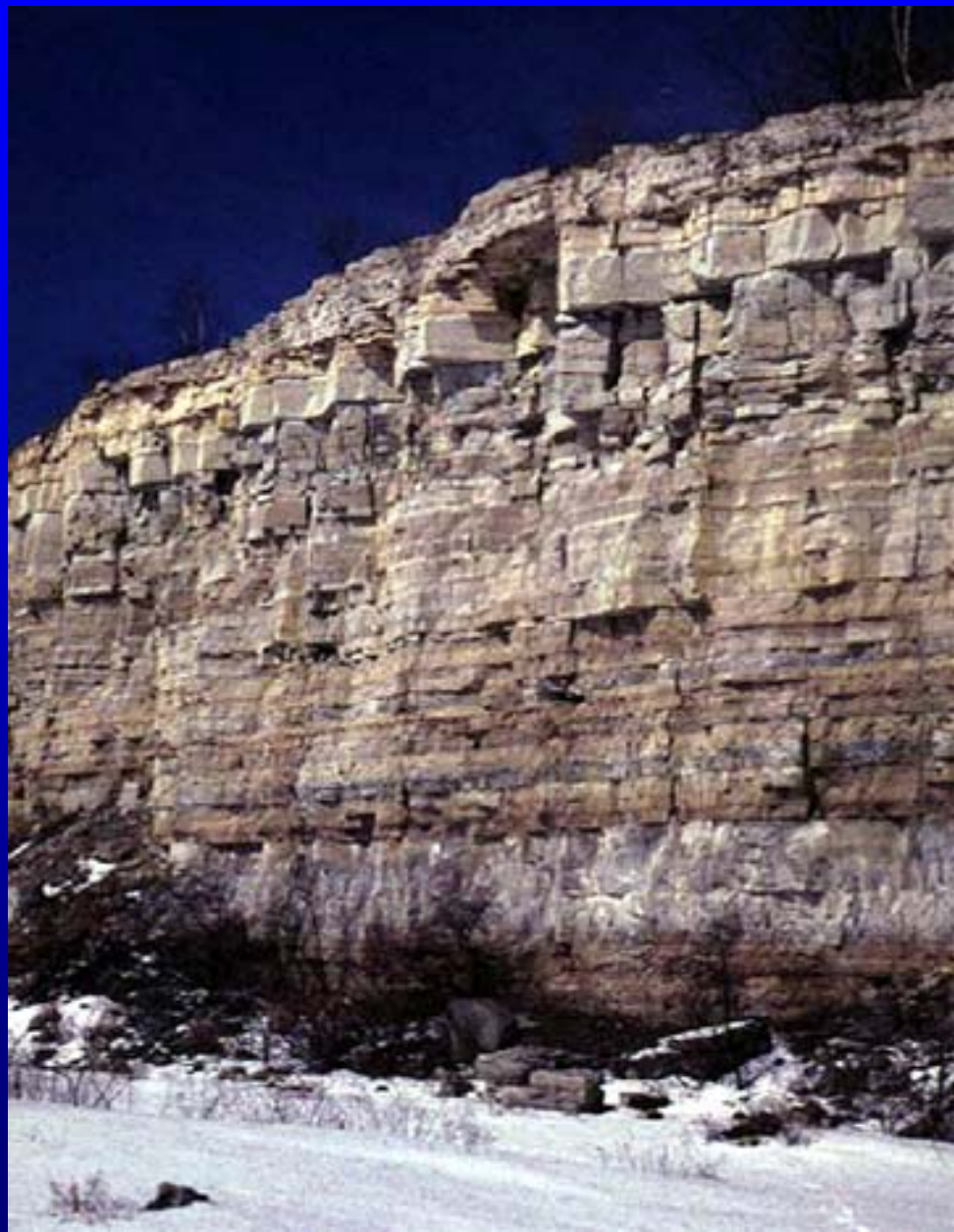
- Karst and fractured-carbonates form productive, but quite vulnerable, aquifers.
- We live, farm, and dispose of waste on top of these fragile systems.
- Can we sustain the water quality in these aquifers for current & future users?

Bedrock Geology

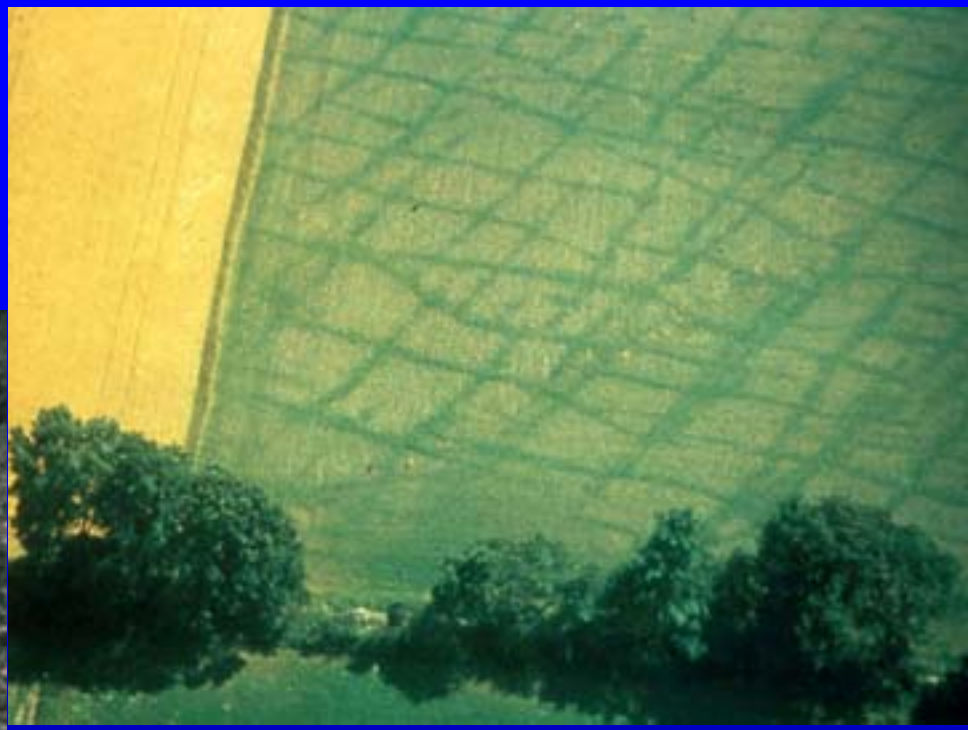




Silurian Dolomite Aquifer



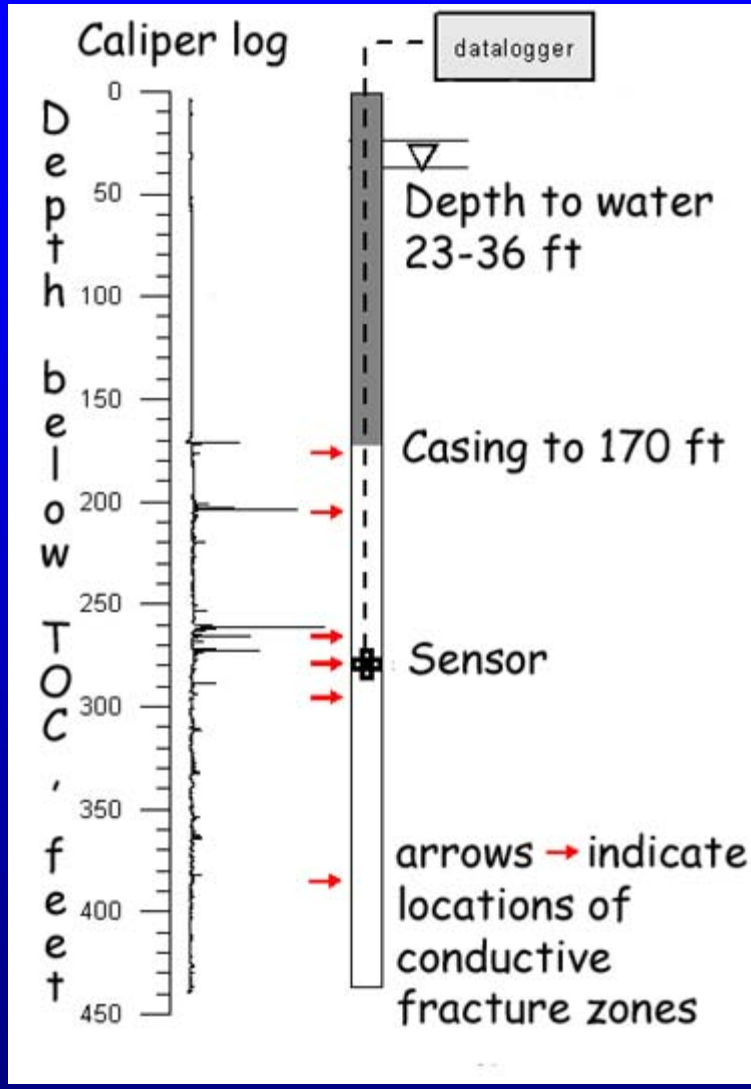
Silurian Dolomite Aquifer

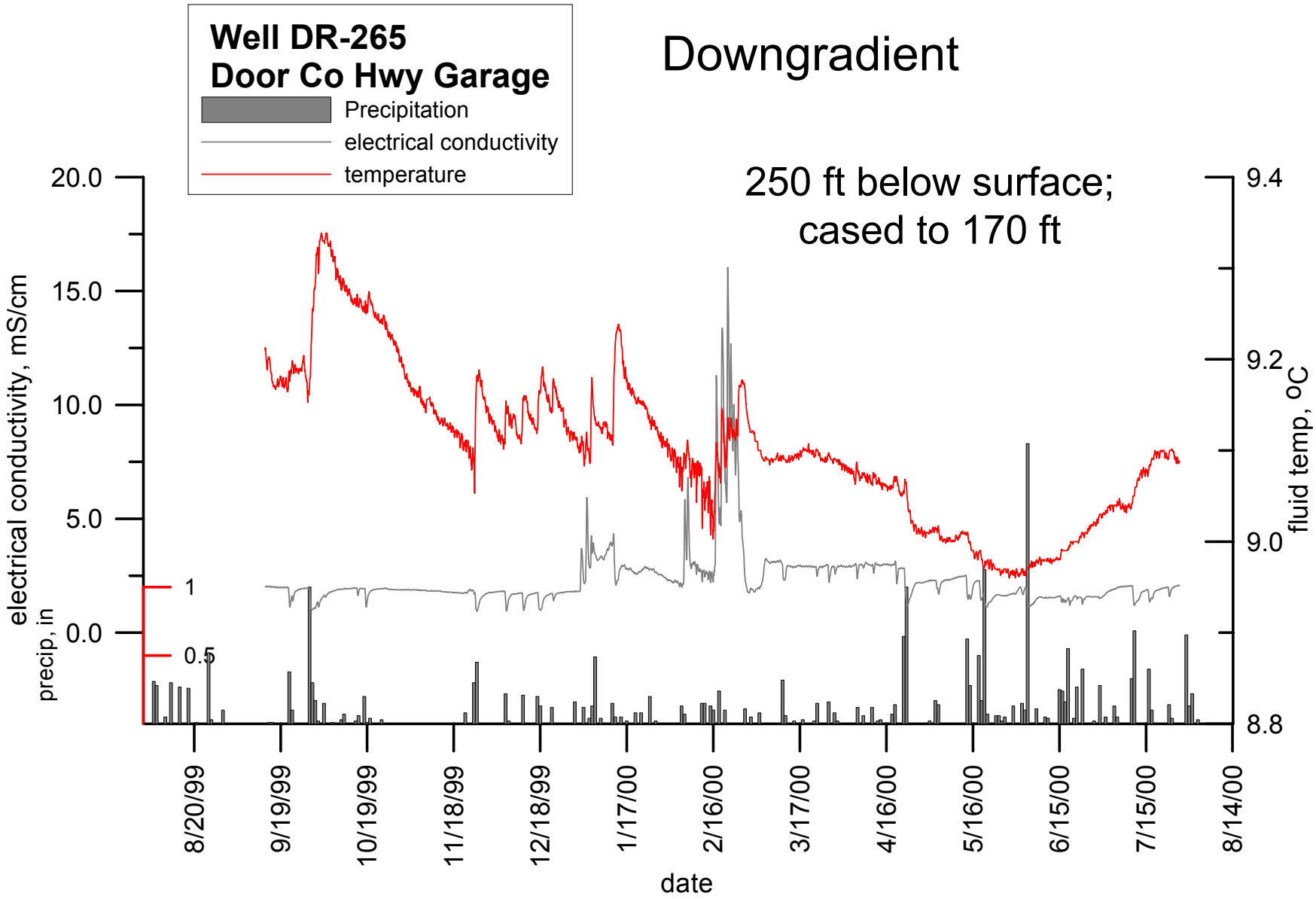


Silurian Dolomite Aquifer

- Rapid downward flow in vertical fracture network
- Rapid lateral flow along bedding-plane parallel fractures
- Some of these flow zones are laterally continuous at the scale of kilometers

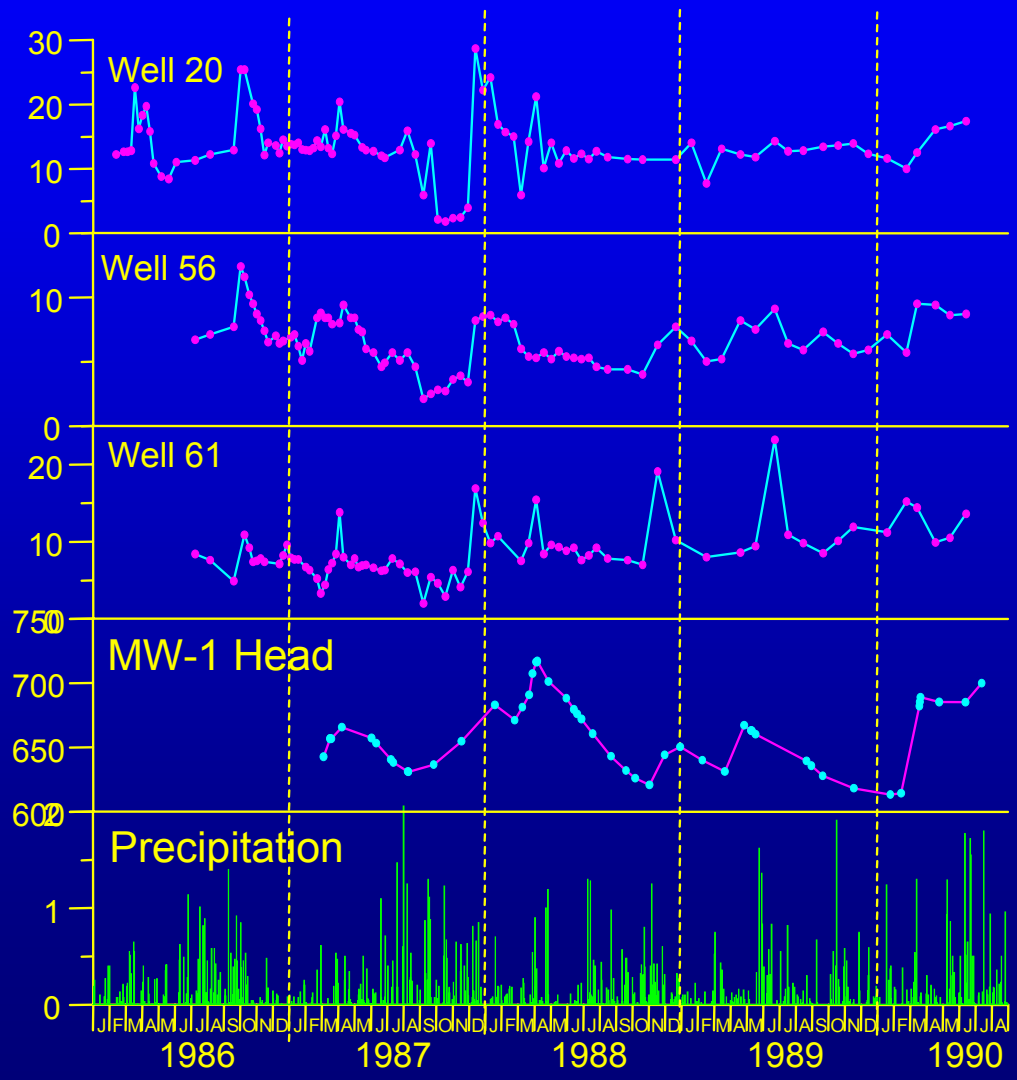
✚ locations of wells and rain gauge used in this study
● other municipal wells

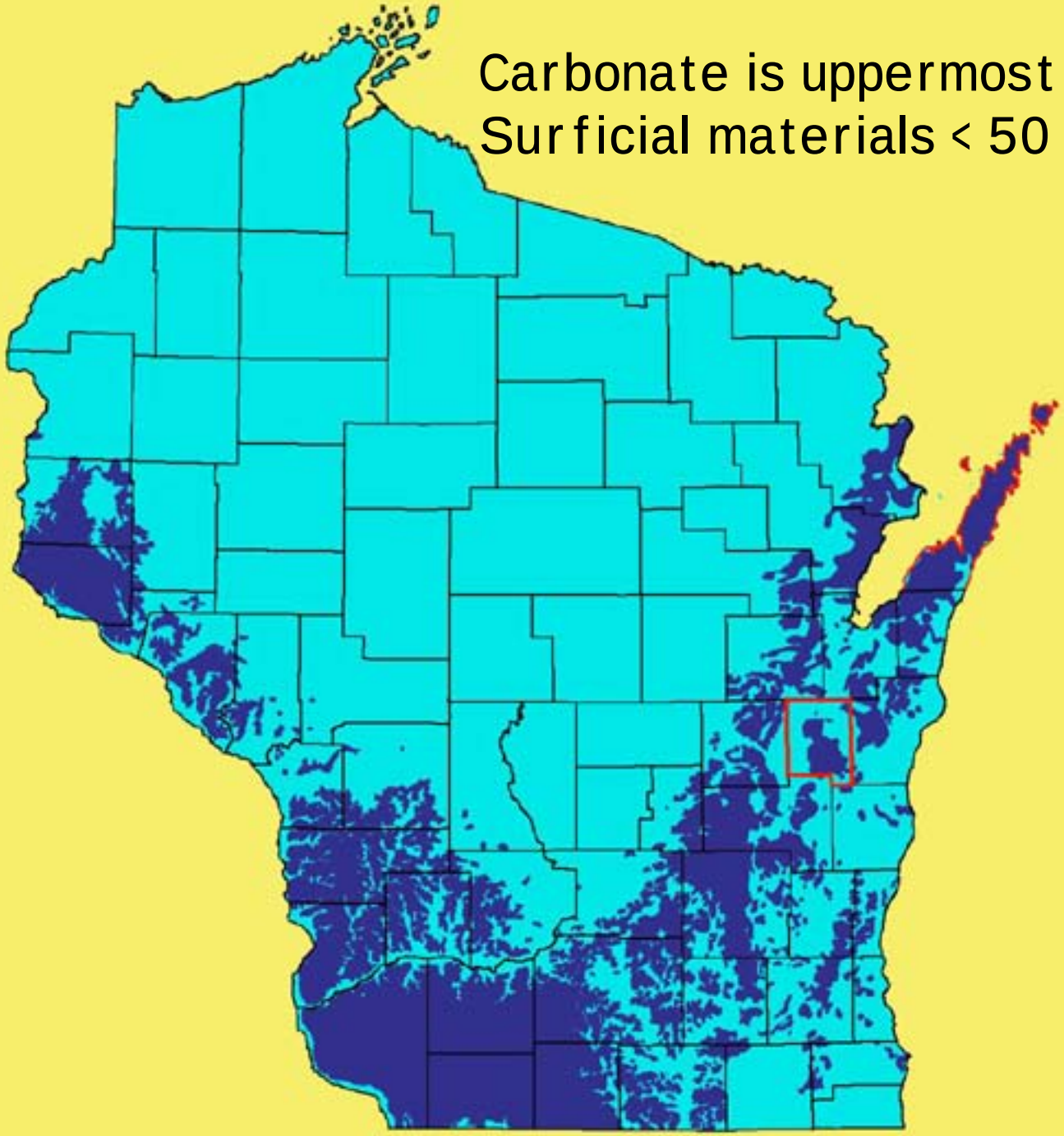



Well DR-265
Door Co Hwy Garage
Precipitation
electrical conductivity
temperature
Downgradient
250 ft below surface;
cased to 170 ft
electrical conductivity, mS/cm
precip, in
fluid temp, oC
20.0
15.0
10.0
5.0
0.0
1
0.5
9.4
9.2
9.0
8.8
8/20/99
9/19/99
10/19/99
11/18/99
12/18/99
1/17/00
2/16/00
3/17/00
4/16/00
5/16/00
6/15/00
7/15/00
8/14/00
date

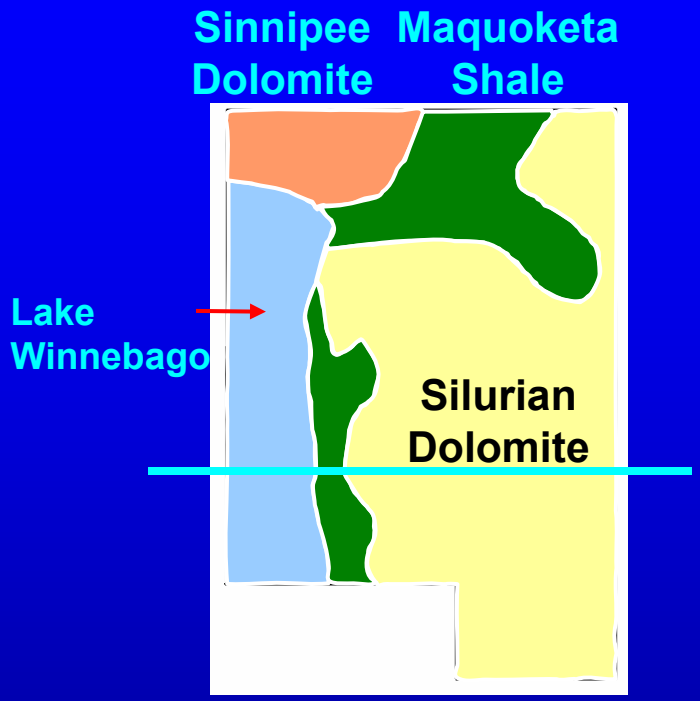
Water Quality Variation

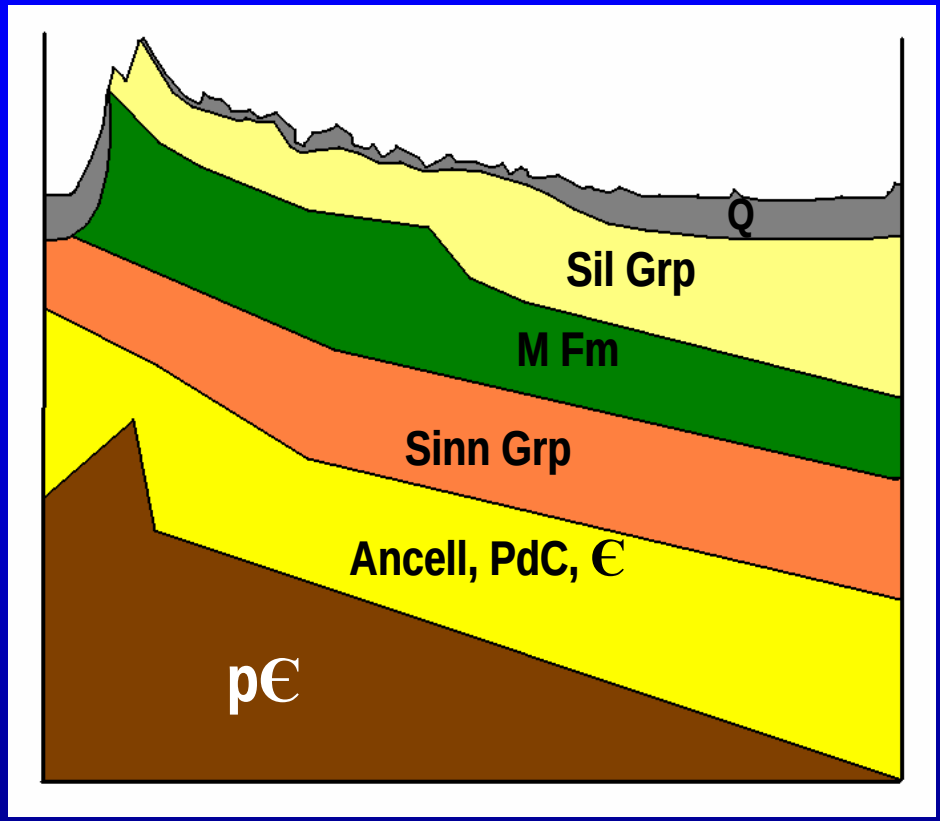
- NO_3-N values from three domestic wells completed in the Silurian dolomite
- Similarity of response in wells located miles apart suggests a diffuse rather than point source of contamination




Carbonate is uppermost bedrock
Surficial materials < 50 ft thick

Case Study 1: Calumet County





Q – Quaternary Glacial Deposits

Sil Grp – Silurian Dolomite

M Fm – Maquoketa Formation

Sinn Grp – Sinnipee Dolomite

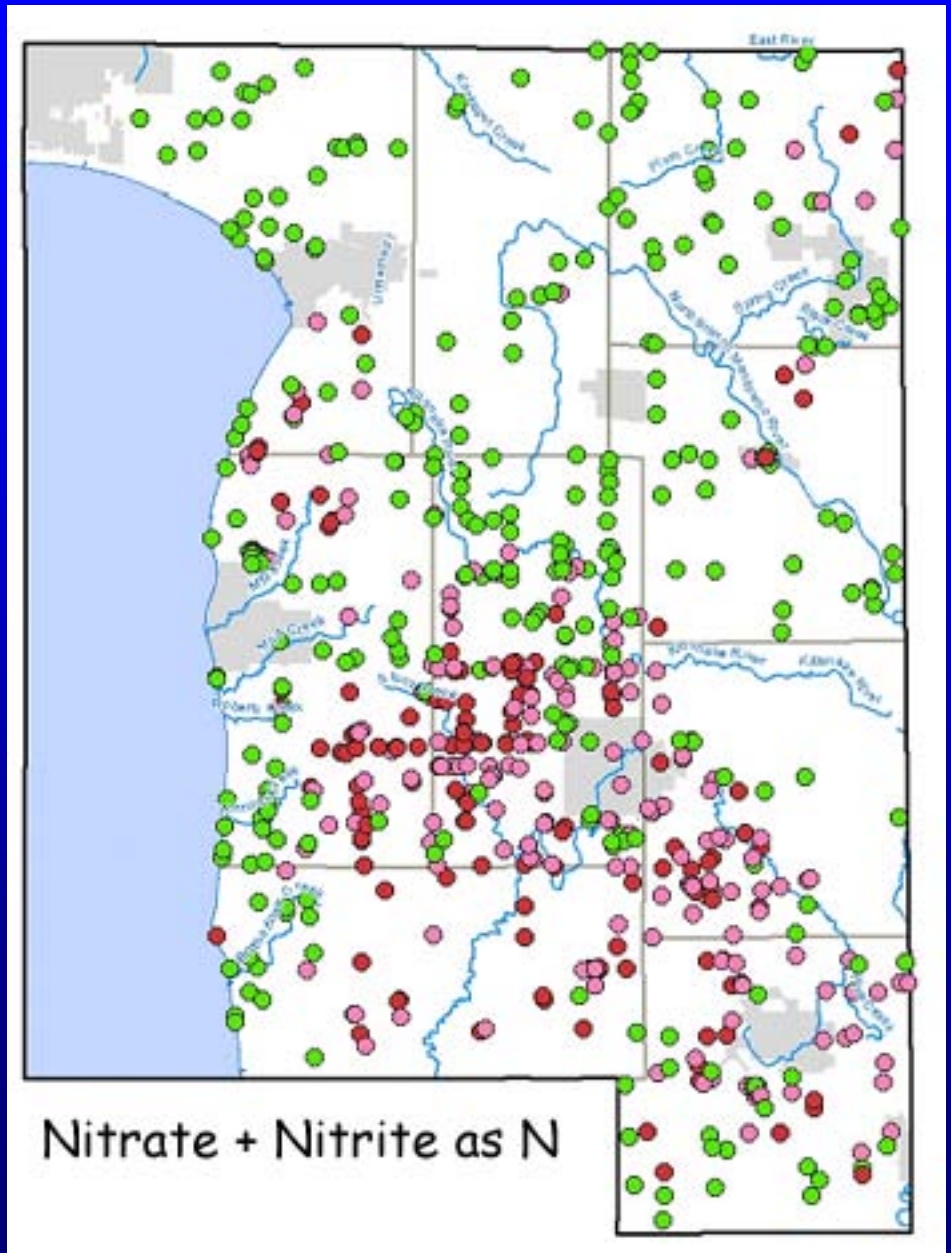
Ancell, Prairie du Chein, Undifferentiated Cambrian Formations (Sandstone & Dolomite)

pЄ – PreCambrian Bedrock

Gotkowitz & Gaffield, 2004 Draft

Nitrate Sampling

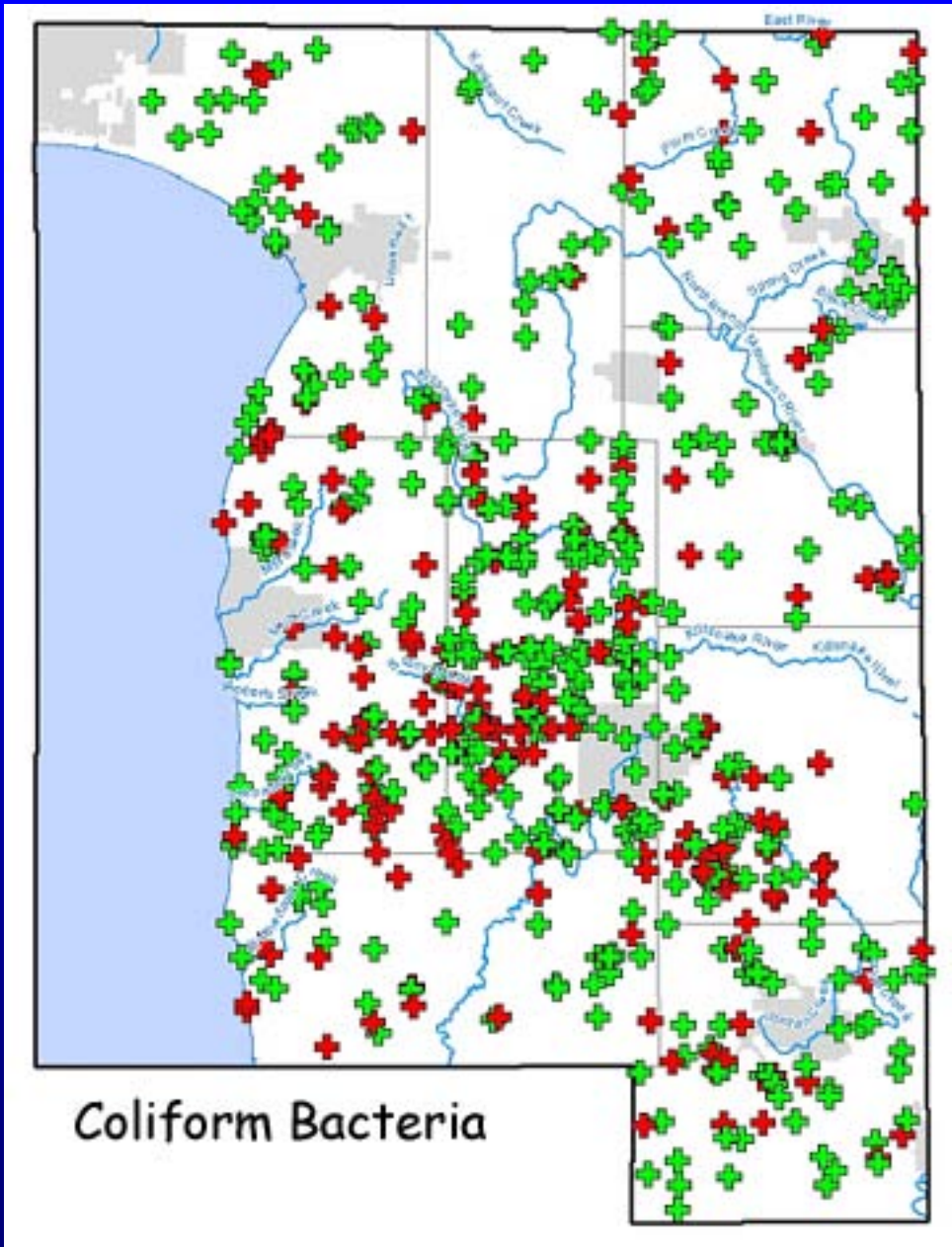
- 2002-2004 Test results
- 45% < 2 ppm
- 29% 2 – 10 ppm
- 26% > 10 ppm



Data and maps provided by
Katie Hemauer
Calumet County
Land & Water Conservation Dept

Coliform Bacteria

- 2002-2004 Test results
- 35% of wells tested positive for coliform bacteria



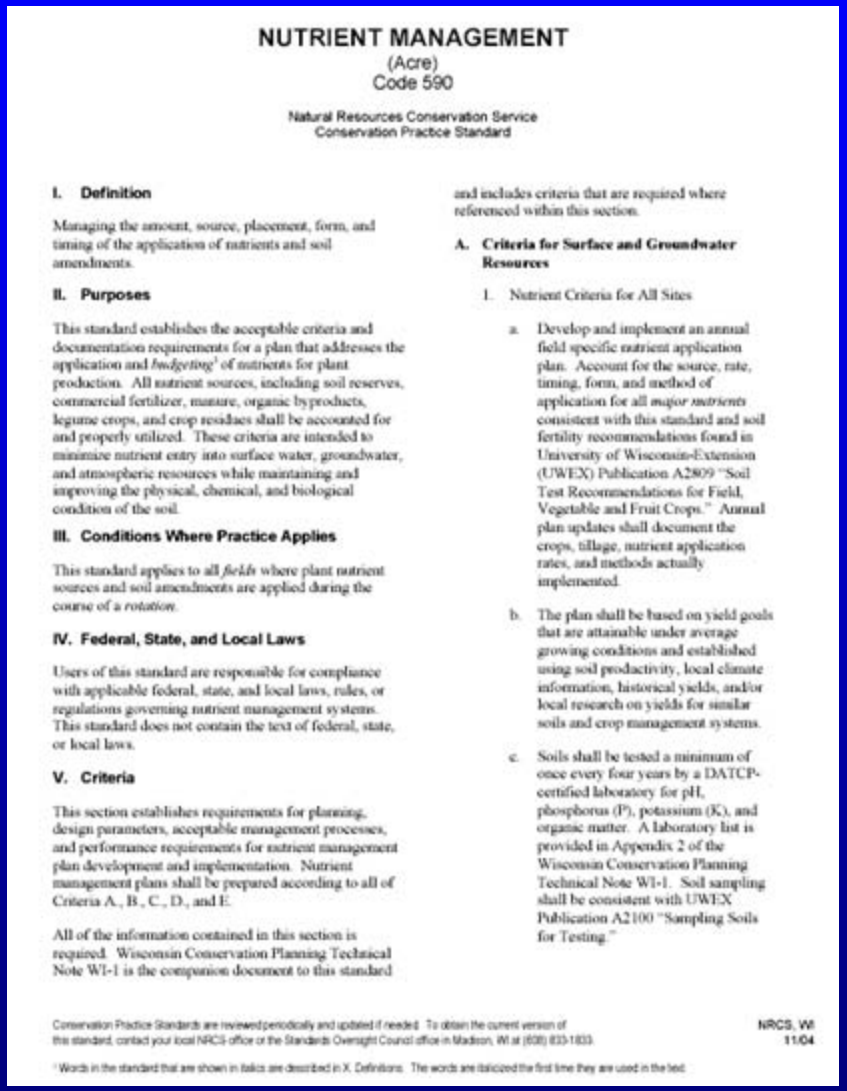
Data and maps provided by
Katie Hemauer
Calumet County
Land & Water Conservation Dept

Calumet Co GW Summit

- County personnel invited approximately 25 folks with expertise in nutrient management, soils, geology & hydrogeology to attend a summit in early April
- Wanted an answer to the question “How do we farm these areas and not degrade groundwater quality?”

NRCS Nutrient Management Standards

- Addresses the application and budgeting of nutrients for plant production
- All nutrient sources shall be properly credited & utilized
- Goal is to not apply in excess of crop needs



NUTRIENT MANAGEMENT
(Acre)
Code 590

Natural Resources Conservation Service
Conservation Practice Standard

I. Definition

Managing the amount, source, placement, form, and timing of the application of nutrients and soil amendments.

II. Purposes

This standard establishes the acceptable criteria and documentation requirements for a plan that addresses the application and *budgeting*[1] of nutrients for plant production. All nutrient sources, including soil reserves, commercial fertilizer, manure, organic byproducts, legume crops, and crop residues shall be accounted for and properly utilized. These criteria are intended to minimize nutrient entry into surface water, groundwater, and atmospheric resources while maintaining and improving the physical, chemical, and biological condition of the soil.

III. Conditions Where Practice Applies

This standard applies to all *fields* where plant nutrient sources and soil amendments are applied during the course of a *rotation*.

IV. Federal, State, and Local Laws

Users of this standard are responsible for compliance with applicable federal, state, and local laws, rules, or regulations governing nutrient management systems. This standard does not contain the text of federal, state, or local laws.

V. Criteria

This section establishes requirements for planning, design parameters, acceptable management processes, and performance requirements for nutrient management plan development and implementation. Nutrient management plans shall be prepared according to all of Criteria A., B., C., D., and E.

All of the information contained in this section is required. Wisconsin Conservation Planning Technical Note WI-1 is the companion document to this standard and includes criteria that are required where referenced within this section.

A. Criteria for Surface and Groundwater Resources

1. Nutrient Criteria for All Sites

   a. Develop and implement an annual field specific nutrient application plan. Account for the source, rate, timing, form, and method of application for all *major nutrients* consistent with this standard and soil fertility recommendations found in University of Wisconsin-Extension (UWEX) Publication A2809 "Soil Test Recommendations for Field, Vegetable and Fruit Crops." Annual plan updates shall document the crops, tillage, nutrient application rates, and methods actually implemented.

   b. The plan shall be based on yield goals that are attainable under average growing conditions and established using soil productivity, local climate information, historical yields, and/or local research on yields for similar soils and crop management systems.

   c. Soils shall be tested a minimum of once every four years by a DATCP-certified laboratory for pH, phosphorus (P), potassium (K), and organic matter. A laboratory list is provided in Appendix 2 of the Wisconsin Conservation Planning Technical Note WI-1. Soil sampling shall be consistent with UWEX Publication A2100 "Sampling Soils for Testing."

Conservation Practice Standards are reviewed periodically and updated if needed. To obtain the current version of this standard, contact your local NRCS office or the Standards Oversight Council office in Madison, WI at (608) 833-1833.

NRCS, WI
11/04

[1] Words in the standard that are shown in italics are described in X. Definitions. The words are italicized the first time they are used in the text.

http://www.datcp.state.wi.us/arm/agriculture/land-water/conservation/nutrient-mngmt/pdf/590_Proposed_Final_Draft.pdf

NRCS Nutrient Management Standards

- Specific prohibitions for karst and fractured rock areas

> **Nutrients shall not be spread on the following features** *the location of which are known or should have been known to the planner:*
>
> Surface water, established concentrated flow channels or permanent *non-harvested* vegetative buffers, non-farmed wetlands, sinkholes, nonmetallic mines, or *50 feet from drinking water wells.*
>
> Areas contributing runoff within 200 feet up slope of direct conduits to groundwater such as a well, sinkhole, fractured bedrock at the surface, tile inlet or nonmetallic mine, unless the nutrients are effectively incorporated within 72 hours.

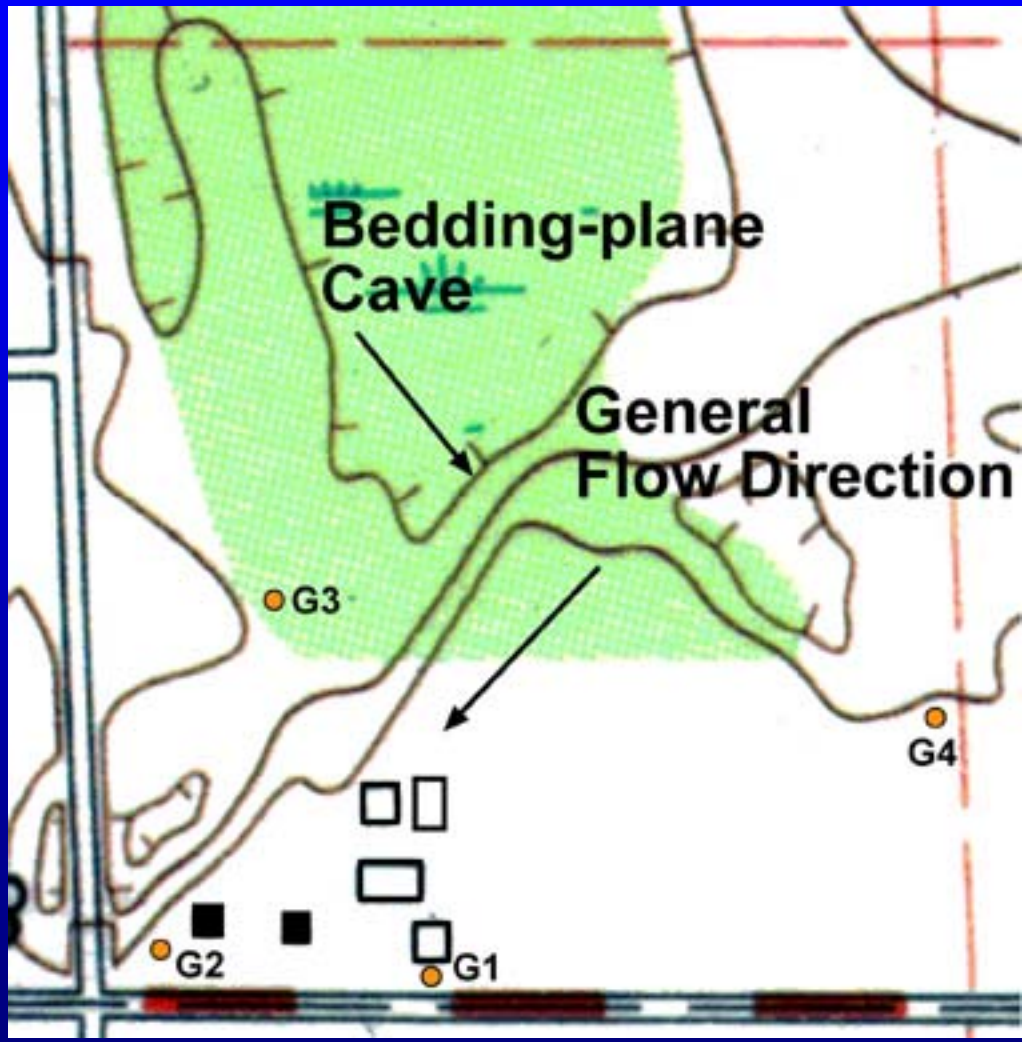
- Recommendations for karst and fractured rock areas
  - Have 6-month storage capacity for manure
  - Apply manure and incorporate into soil twice yearly
  - Credit manure application in nutrient management plan
- Will it help?

Barnyard Monitoring

- Project was designed to monitor groundwater quality at two barnyards before and after the introduction of Best Management Practices

Barnyard Monitoring

- Installed 2 to 3 piezometers/hole
- Monitored 1-yr prior to initiation of BMPs and 2 yr after
- Measured nitrate-N at >300 mg/l in water flowing into bedding plane cave
- Never detected nitrate-N (or other forms of N) > 4 mg/l in wells



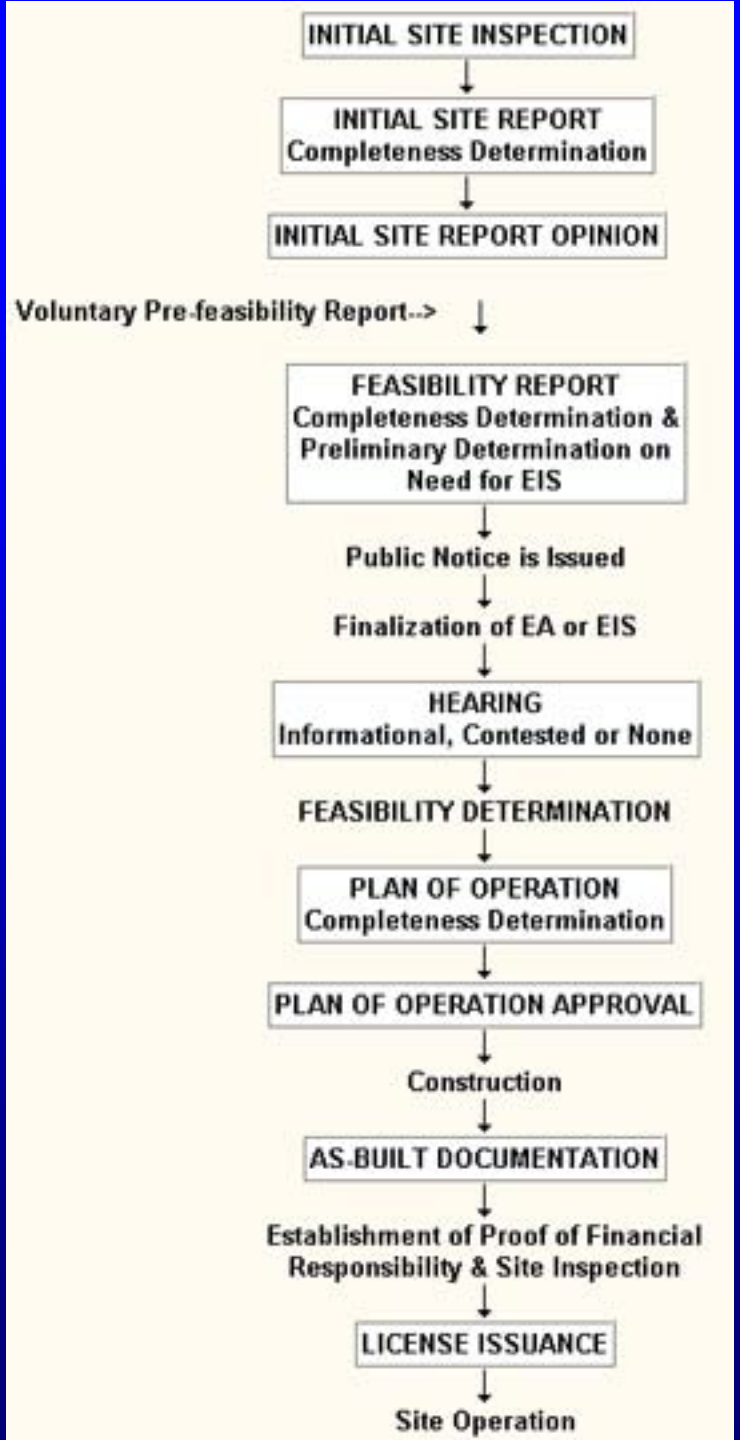
Case Study 2: Landfill Expansion

- An existing landfill in Manitowoc County is reaching capacity and is looking to expand.
- Site geology consists of approximately 50 - 90 ft of glacial sediment (tills & outwash) over Silurian dolomite.
- In portions of the proposed expansion the water-table lies within the dolomite.
- DNR is concerned about the ability to effectively monitor and remediate the site.
- The landfill owner and their consultants feel that the site characterization was conducted according to code and should be adequate.

Case Study 2

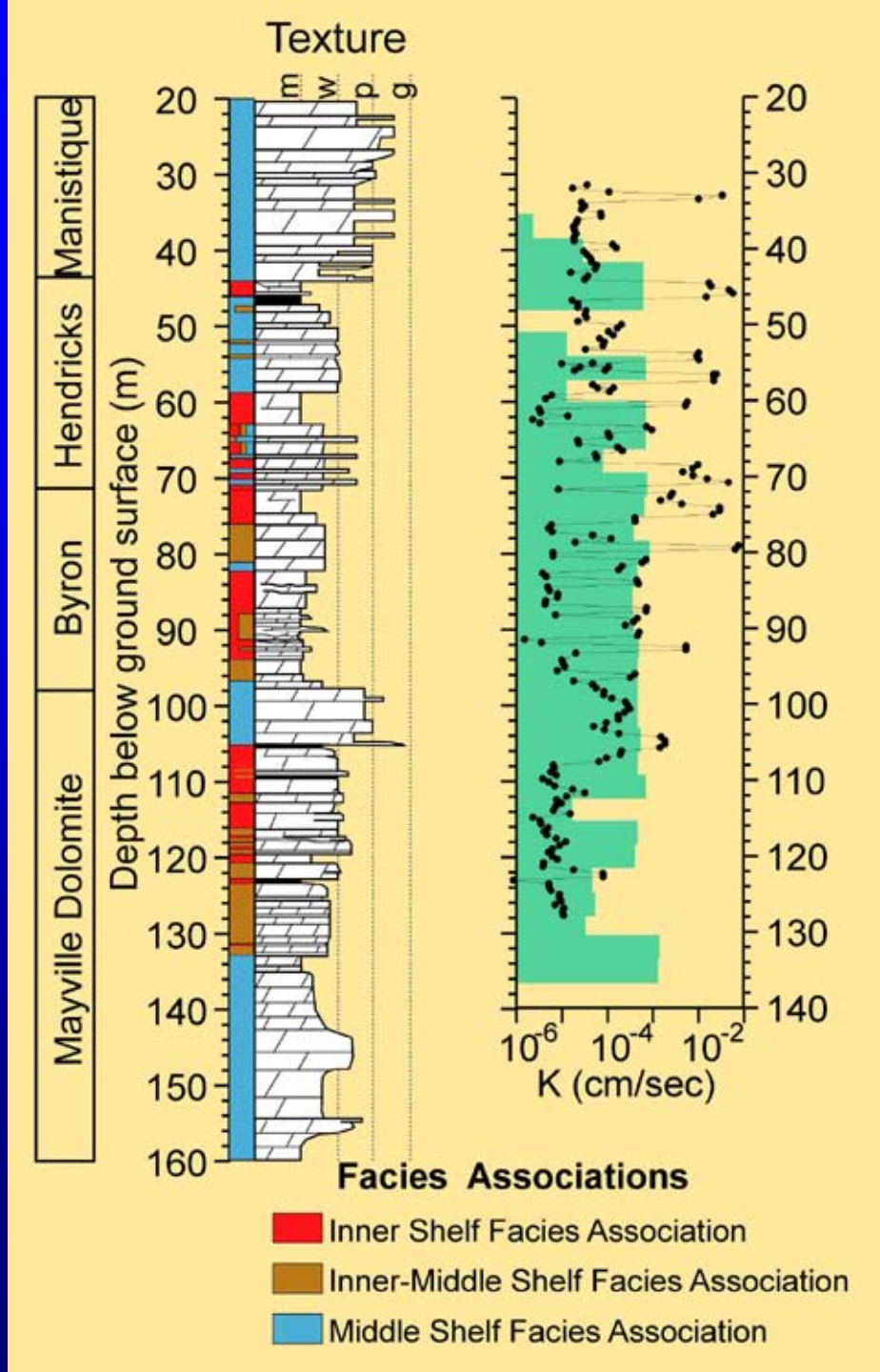
- The landfill siting process is WI is very proscribed.
- The current code specifies the data that should be included in the various required reports.
- There are no specifications or guidelines that require fractured rock sites to be characterized any differently than porous medium sites.

http://www.dnr.state.wi.us/org/aw/wm/solid/landfill/siting.htm



Site Characterization

- The site conceptual model guides characterization
  - Continuum
  - Discrete fracture
- These data illustrate the effect of test scale on measured hydraulic conductivity values
- Data were collected from the same corehole

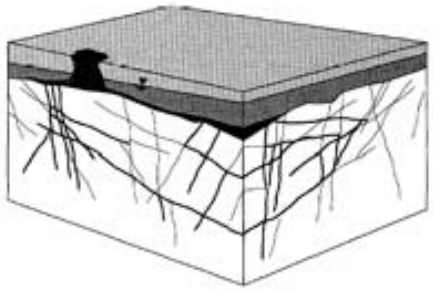


Case Study 2: Landfill Expansion

Ernest Orlando Lawrence
Berkeley National Laboratory

LBL-38142/ UC-800

Hydrogeologic Characterization of Fractured Rock Formations: A Guide for Groundwater Remediators



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October 1995

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http://www-library.lbl.gov/docs/LBL/381/42/PDF/LBL-38142.pdf

United States Environmental Protection Agency | Solid Waste and Emergency Response (5102G) | EPA542-R-01-010 July 2001 www.epa.gov/tio www.cluin.org

EPA

The State-of-the Practice of Characterization and Remediation of Contaminated Ground Water at Fractured Rock Sites

http://www.epa.gov/tio/download/misc/fracrock_state.pdf

Summary

- Existing water quality data indicate that the Silurian dolomite aquifer is quite vulnerable to contamination (evens in areas with 10's of ft of surficial sediment).
- We are just beginning to develop agricultural BMPs for these settings and we have few to no data on their effectiveness. Obtaining such data would be costly.
- While there are some guidelines for the characterization of fractured rock sites, the "state of the practice" for many (not all) sites is to treat them as porous media sites.