

Investigating Intra-Annual Variability of Well Water Quality in Lincoln Township

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Questions about land-use changes and impacts on groundwater

Recent interest in using historical private well water data to investigate whether water quality is better or worse

Well Owners Perspective:

- Is our water less safe?
 - Pathogens
 - Nitrate

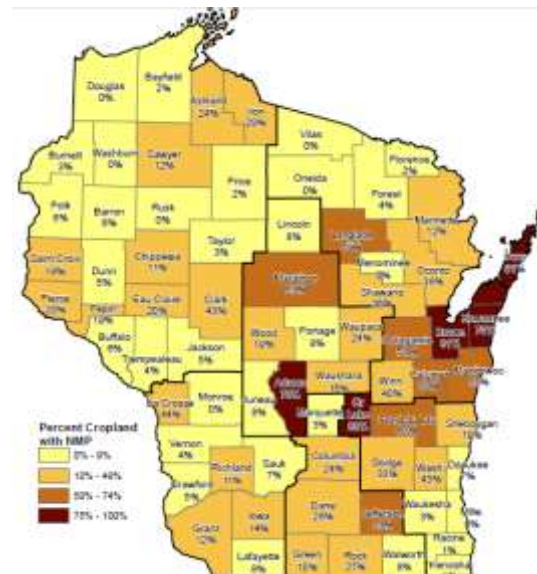
Farmer Perspective:

- Is our water better?
 - Regulations
 - Nutrient Management

% Change in Total Cattle Numbers from 1983-2012 by County



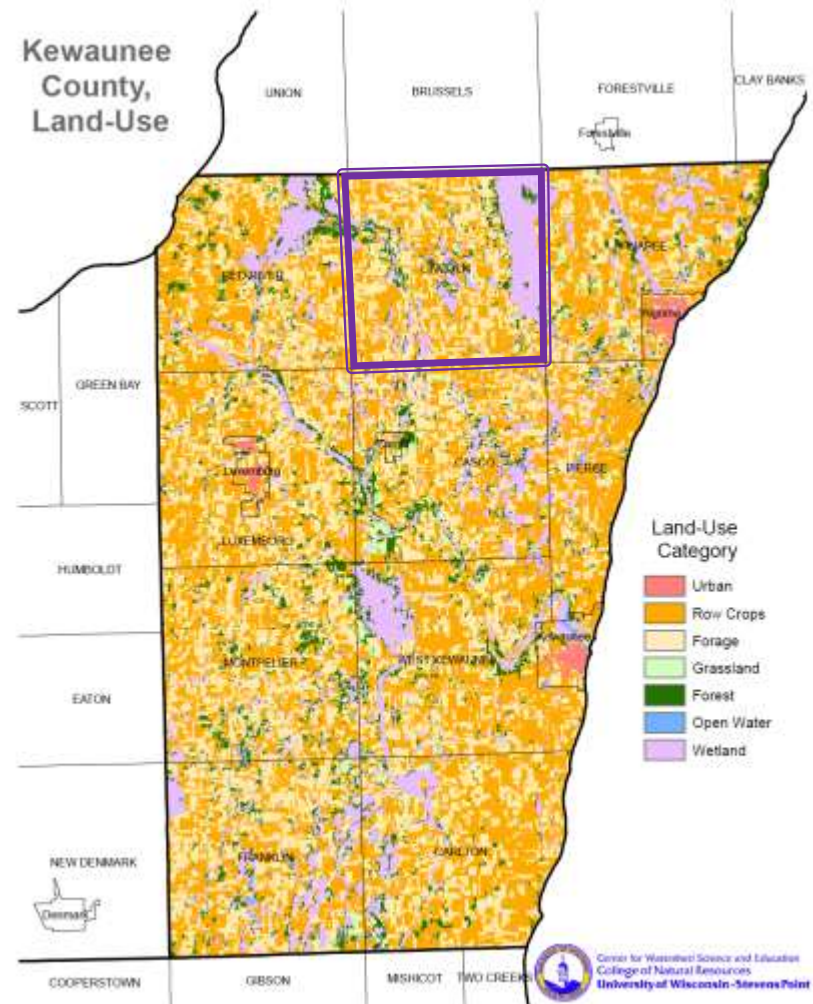
33.8% increase in cattle numbers from 1983-2012 in Kewaunee Co.

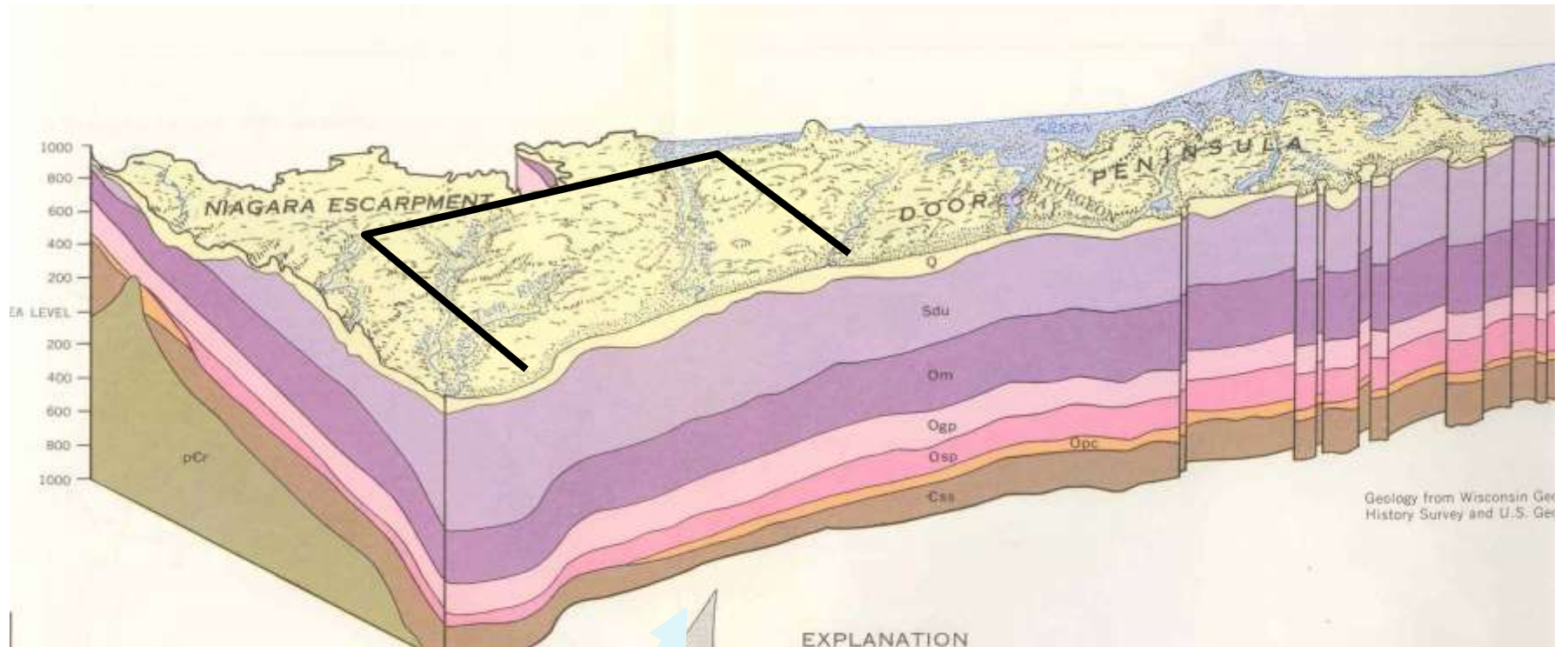


76% of cropland acres in Kewaunee Co. w/ nutrient management plans

Kewaunee County, Town of Lincoln

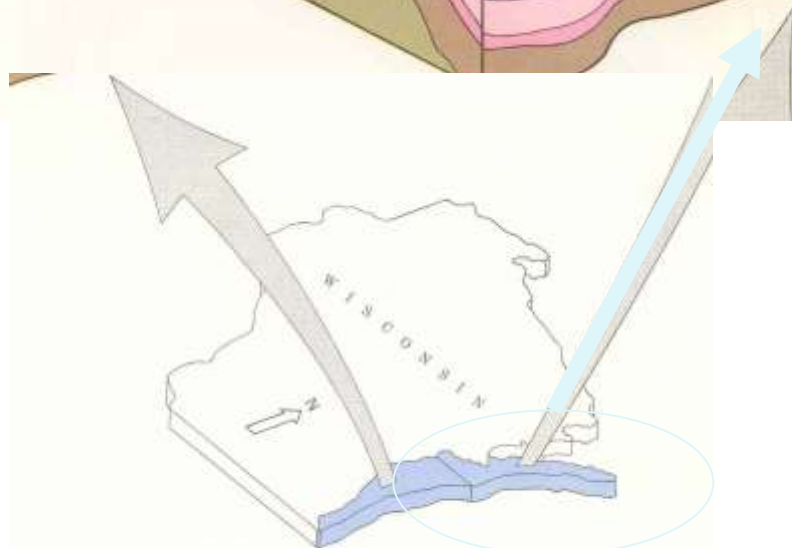
- 334 households w/private wells
- 384 Sanitary Permits
 - (63 are holding tanks)
- Land-use
 - 70% Agriculture
 - 21% Wetland
 - 6% Forest
- ~13,500 cows
 - (dairy/calves/beef/heifers)
- Significant vulnerability to contamination
 - Silurian dolomite aquifer with less than 50 ft to bedrock





Geology from Wisconsin Geology History Survey and U.S. Geology

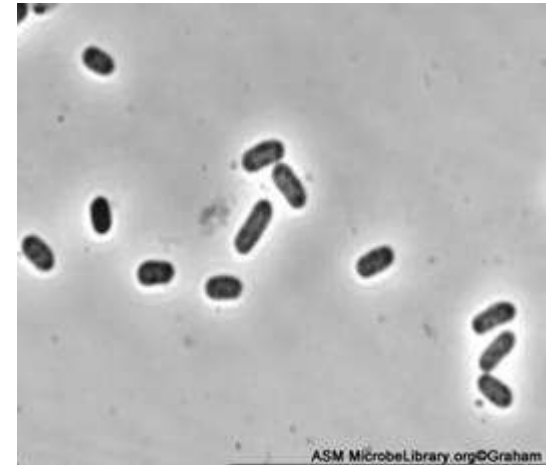
EXPLANATION



BLOCK DIAGRAM OF THE LAKE MICHIGAN BASIN

Coliform bacteria

- Generally do not cause illness, but indicate a pathway for potentially harmful microorganisms to enter your water supply.
 - Harmful bacteria and viruses can cause gastrointestinal disease, cholera, hepatitis
- Well Code: “Properly constructed well should be able to provide bacteria free water continuously without the need for treatment”
- Recommend using an alternative source of water until a test indicates your well is absent of coliform bacteria
- Sources:
 - Live in soils and on vegetation
 - Human and animal waste
 - Sampling error



Greater than or equal to 1

Present = Unsafe

Zero bacteria

Absent = Safe

If coliform bacteria was detected, we also checked for e.coli bacteria test

- Confirmation that bacteria originated from a human or animal fecal source.
- E. coli are often present with harmful bacteria, viruses and parasites that can cause serious gastrointestinal illnesses.
- Any detectable level of E.coli means your water is unsafe to drink.

Information Sources: United States Department of Health and Human Services – Centers for Disease Control and Prevention (www.cdc.gov) and United States Environmental Protection Agency (www.epa.gov)

Contaminants	Sources	Symptoms
BACTERIA		
<p><i>Escherichia coliform (E. coli)</i> <i>Salmonella</i> <i>Campylobacter</i> <i>E. coli O157</i> (Requires a special water test for detection. Causes similar, but more serious illness than other E.coli strains. Requires medical treatment.)</p> <hr/> <p><i>Leptosporidia</i></p>	<ul style="list-style-type: none"> • Infected human and animal feces • Manure • Septic systems • Sewage <hr/> <ul style="list-style-type: none"> • Urine of livestock, dogs and wildlife • Manure 	<ul style="list-style-type: none"> • Gastrointestinal illness • Low-grade fever • Begins 12 hrs - 7 days after exposure <hr/> <ul style="list-style-type: none"> • High fever, severe headache and red eyes • Gastrointestinal illness • Begins 2-28 days after exposure
MICROSCOPIC PARASITES		
<p><i>Cryptosporidia</i> <i>Giardia</i></p>	<ul style="list-style-type: none"> • Infected human and animal feces • Manure • Septic systems • Sewage 	<ul style="list-style-type: none"> • Gastrointestinal illness • Begins 2-14 days after exposure
VIRUSES		
<p>Norovirus</p>	<ul style="list-style-type: none"> • Infected human feces and vomit • Septic systems • Sewage 	<ul style="list-style-type: none"> • Gastrointestinal illness • Low-grade fever & headache • Begins 12-48 hrs after exposure
CHEMICALS		
<p>Nitrate</p> <hr/> <p>Atrazine (trade-name herbicide for control of broadleaf and grassy weeds)</p>	<ul style="list-style-type: none"> • Fertilizers • Manure • Bio-solids • Septic systems <hr/> <p>Estimated to be most heavily used herbicide in the U.S. in 1987/89, with its most extensive use for corn and soybeans in the Midwest, including WI. In 1993, it became a restricted-use herbicide nationally. U.S. EPA set a max. contaminant level (MCL) at 3 parts per billion for safe drinking water.</p>	<p>Methemoglobinemia or "Blue Baby Syndrome" – No documented cases in Door County, but elevated nitrate levels in well water may indicate risk of contamination by additional pathogens.</p> <hr/> <p>Short-term exposure above the MCL may cause: congestion of heart, lungs and kidneys; low blood pressure; muscle spasms; weight loss; damage to adrenal glands.</p> <p>Long-term exposure above MCL may cause: weight loss, cardiovascular damage, retinal and some muscle degeneration; cancer.</p>

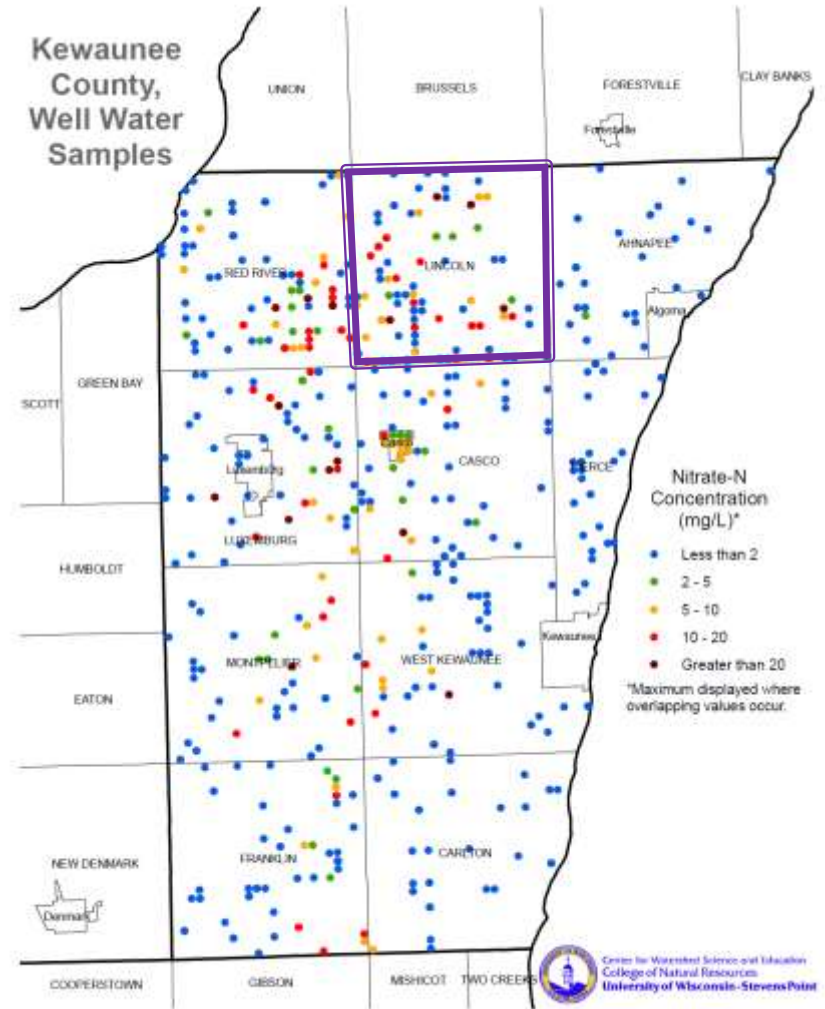
Overview of Private Well Water Quality

2005–2015 Private Well Water Data

	Town of Lincoln*	Kewaunee County	Statewide
	n = 154	n = 846	n = 31,181
Coliform Bacteria (% positive)	32	19	17
Nitrate-N (% >10 mg/L)	20	11	11

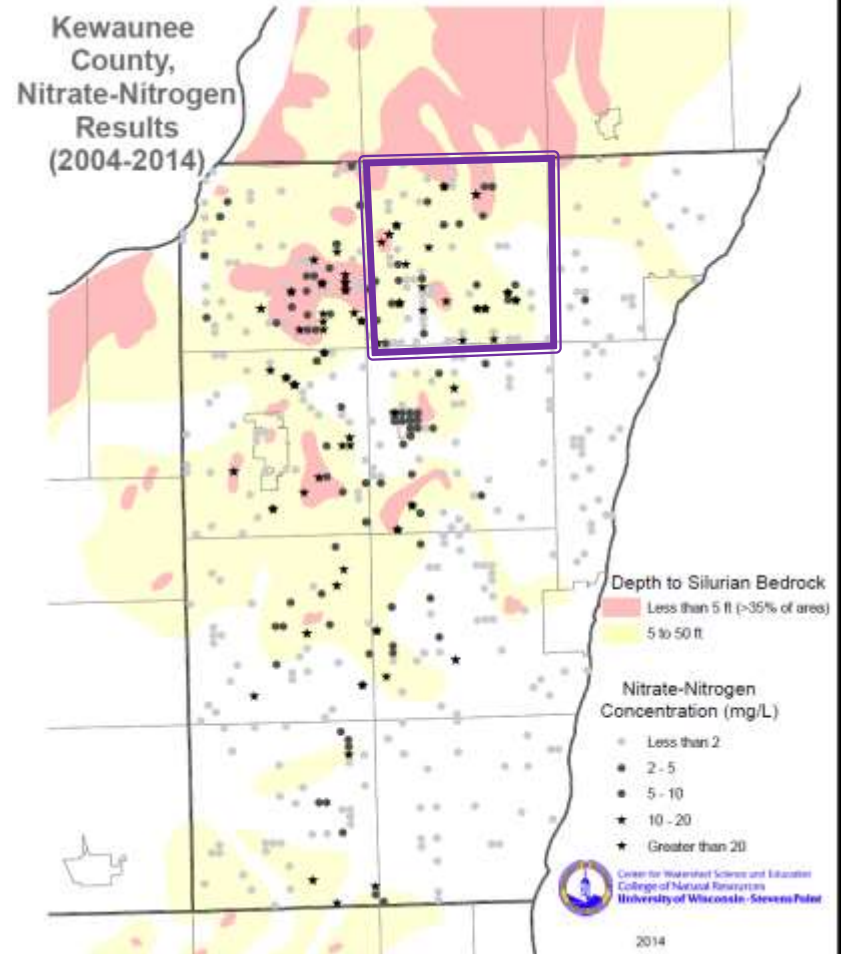
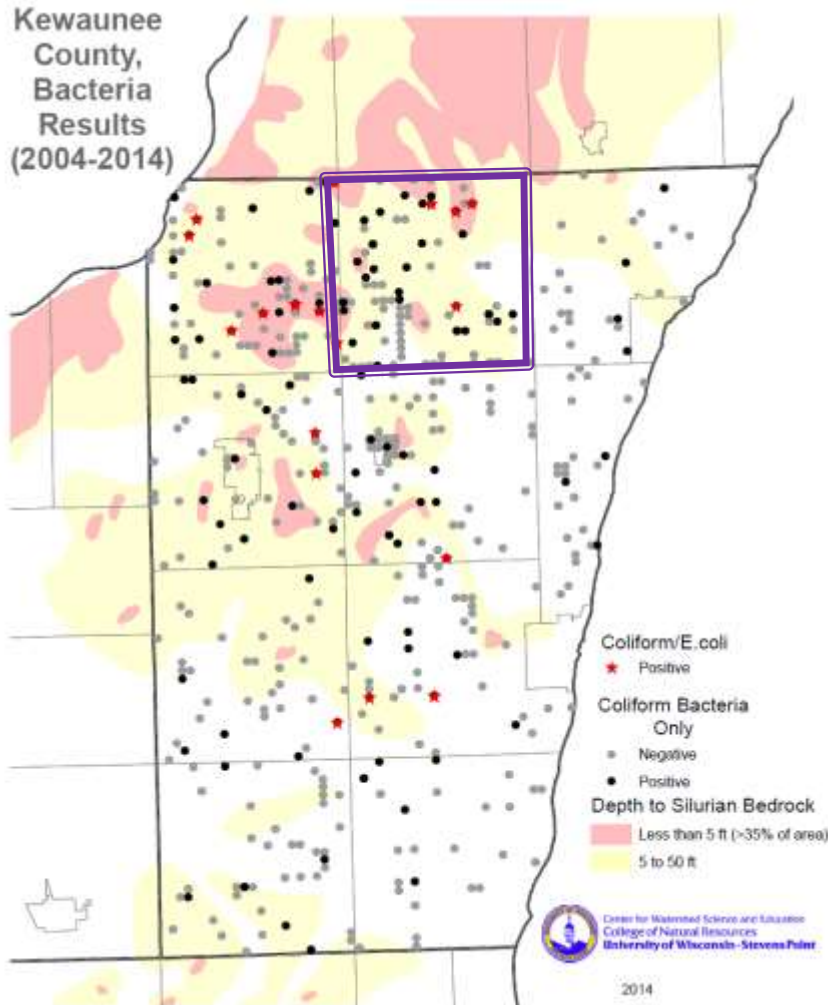
Center for Watershed Science and Education Database, 2015

**Many wells only tested once or twice – very little to compare to*



Disclaimer: This map represents data in the Center for Watershed Science and Education database for the period from 2004-2014. It does not represent all known private well tests and does not represent a scientifically conducted study.

Overview of Private Well Water Quality



Water quality changes in karst

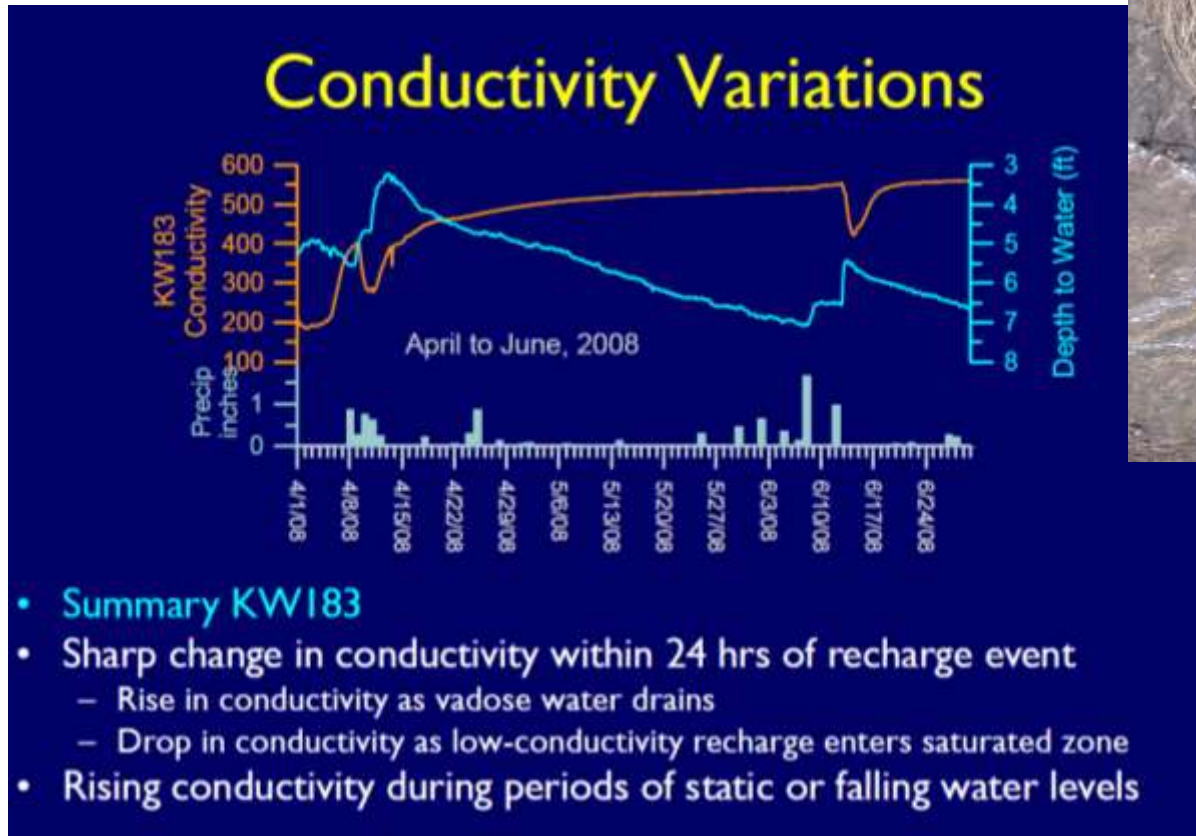


Photo credit: Brown County LCD

Muldoon, 2014

<http://www.ecwrpc.org/wp-content/uploads/2014/10/Hydrogeology-of-Karst-NE-Wisconsin-Maureen-Muldoon.pdf>

Objectives:

- ▶ **Put existing well water data into context**
 - How does water quality behave during the course of the year?
 - Recommend better testing strategies for homeowners to evaluate the safety of their water supply

- ▶ **Estimate nitrogen and pathogen sources**
 - Fertilizer Inputs
 - Manure Applications
 - Septic System Effluent

- ▶ **Recommend long-term testing strategy to town that would allow them to better assess trends or changes to groundwater**

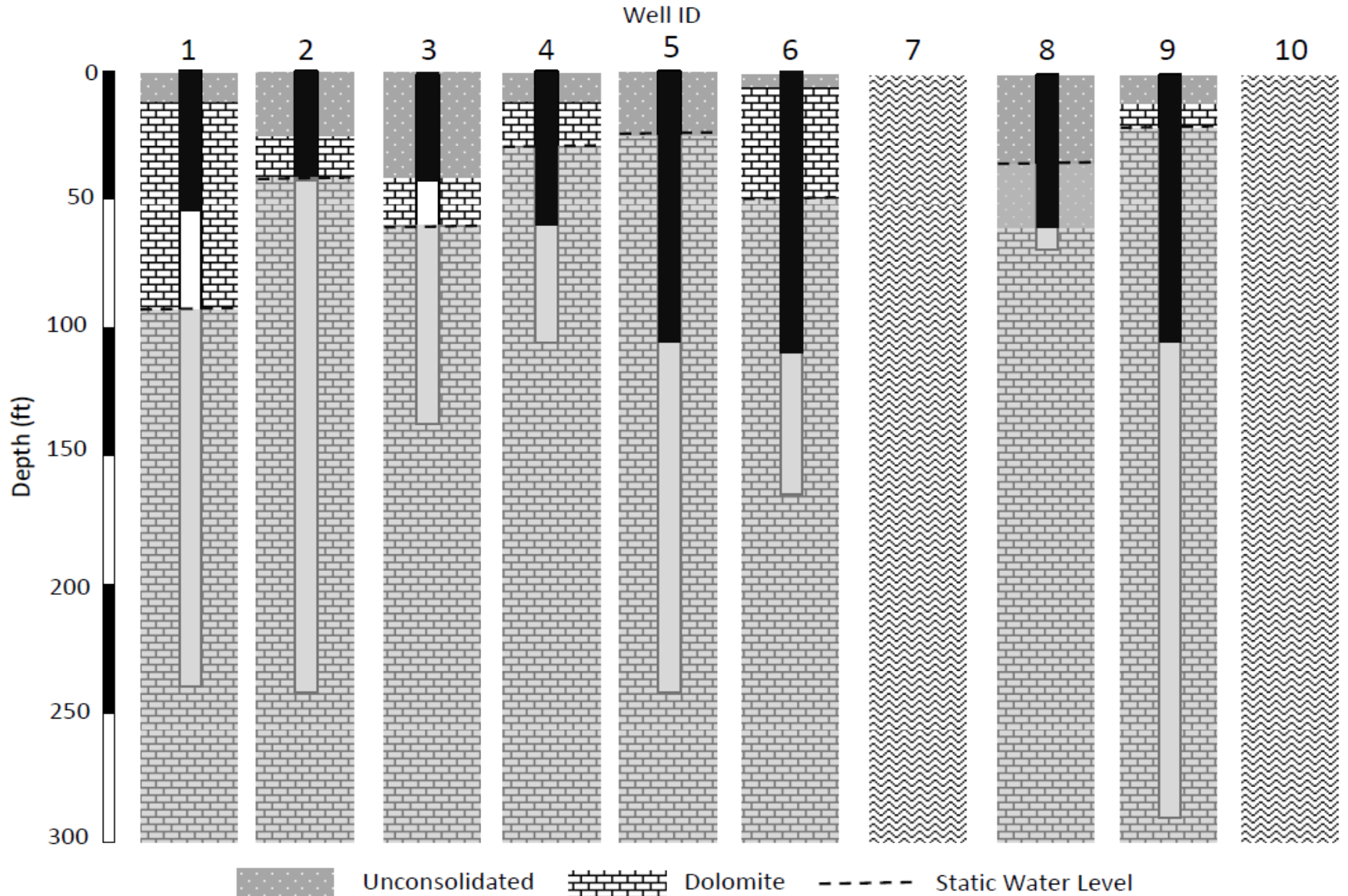
Well Selection & Sample Analysis

- **Well Selection (n=10)**
 - Preferred past bacteria positive and/or elevated nitrate–nitrogen
 - Landowner cooperation
 - Variety of well & casing depths
- **Water Samples**
 - Pre–selected sampling dates
 - (June 2013 – May 2014)
 - All wells sampled by Davina Bonness (LWCD)
 - Tested at Water and Environmental Analysis Lab (UWSP)
 - Total coliform / E. coli
 - Nitrate–nitrogen
 - Chloride
 - Total Hardness
 - Alkalinity
 - Conductivity
 - pH

Well Locations

		5			
			1		
2					
9, 10					
	3, 8		4, 6		
7					

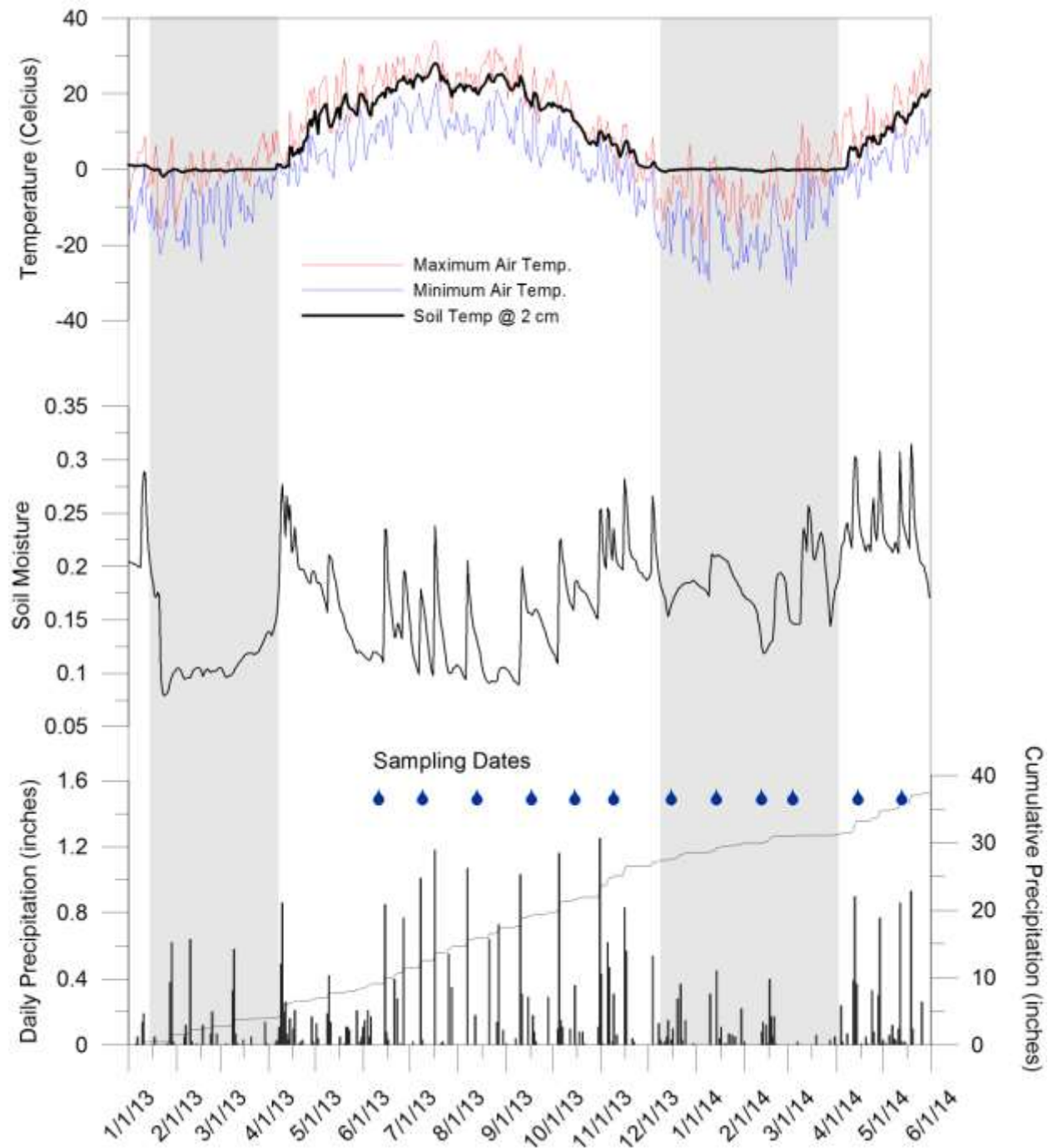
Well Construction Report Diagram



½ Mile Radius Source Assessment

<i>Well ID</i>	<i>Non-cropland (acres)</i>	<i>Non-cropland (%)</i>	<i>Total Cropland (acres)</i>	<i>Cropland (%)</i>	<i>Cropland with a Nutrient Management Plan (acres)</i>	<i>Cropland with a Nutrient Management Plan (%)</i>	<i>Fertilizer nitrogen (lbs/acre of cropland/yr)</i>	<i>Manure Nitrogen (lbs/acre of cropland/yr)</i>	<i>Total agricultural nitrogen (lbs/acre of cropland/yr)</i>	<i>Total nitrogen from agricultural sources (lbs)</i>	<i># of septic systems</i>	<i>Nitrogen from septic systems (lbs)</i>
1	134	27	368	73	295	80	31	27	58	21,432	6	150
2	314	63	188	37	178	95	31	28	59	11,073	7	175
3	181	36	321	64	321	100	26	39	65	20,881	11	275
4	117	23	385	77	385	100	16	63	78	30,130	7	175
5	132	26	370	74	370	100	13	70	83	30,684	1	25
6	107	21	395	79	395	100	29	51	79	31,383	6	150
7	127	25	375	75	185	49	26	44	69	25,916	9	225
8	293	58	209	42	191	91	13	33	47	9,762	14	350
9	45	9	457	91	337	74	38	54	92	41,943	11	275
10	134	27	368	73	368	100	33	51	83	30,706	14	350
Average	158	32	344	68	303	89	25	46	71	25,391	8.6	215

Climate & Soil Data

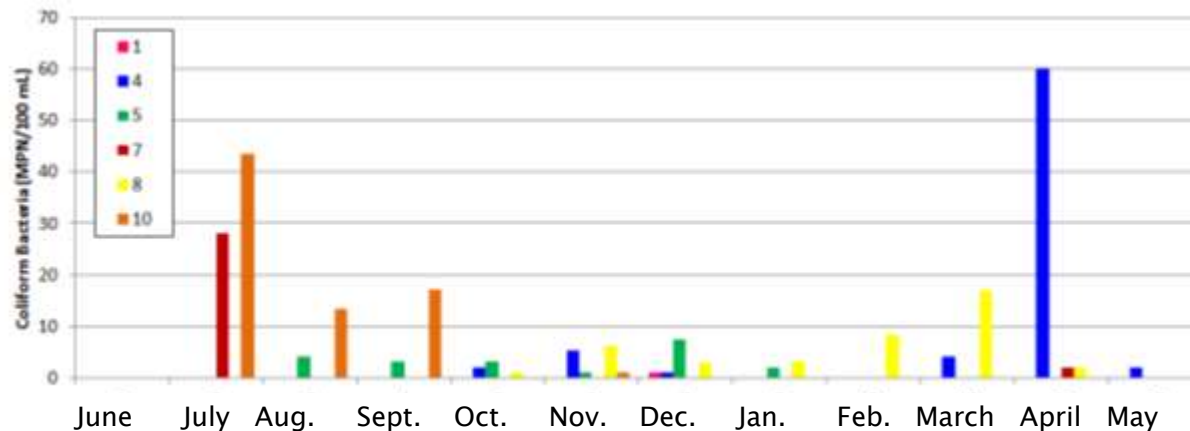


Weather Data:
Roethle Orchards, Casco, WI
Michigan State University Extension

Coliform and *E.coli* bacteria results

- Detected at least once in 6 wells
- Levels were generally low
- No Wells tested positive for *E.coli*
- Wells went from positive to negative without disinfection

Well	Total Coliform		E-Coli
	Sample Periods Positive	MPN Cfu 100 mL ⁻¹	Sample Periods Positive
1	1	0.9 (0.3)	0
2	0	ND	0
3	0	ND	0
4	6	6.2 (17.1)	0
5	6	1.7 (2.4)	0
6	0	ND	0
7	2	2.5 (8.1)	0
8	7	3.4 (5.1)	0
9	0	ND	0
10	4	6.3 (13.1)	0



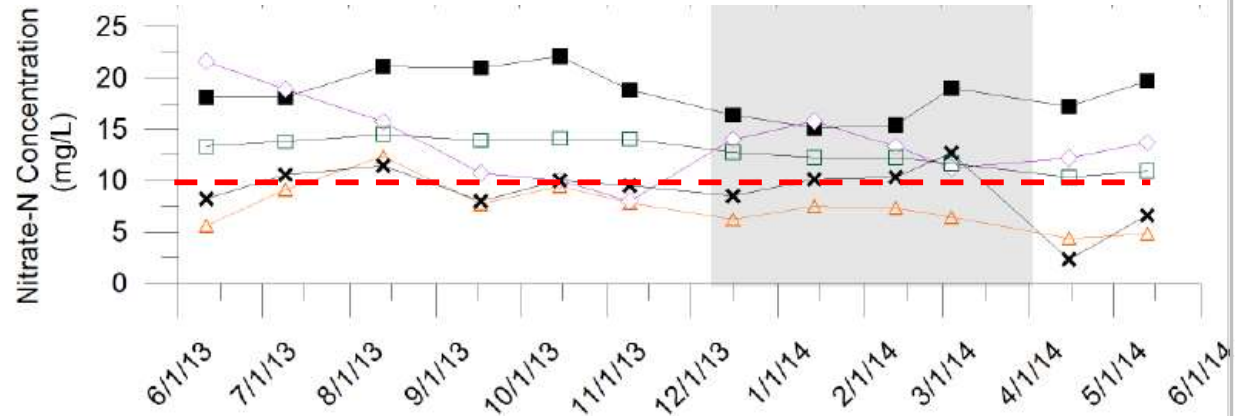
Bacteria Conclusions

- ▶ In Town of Lincoln:
 - An absent bacteria test likely providing false representation of year-round bacteriological safety for many homes
 - Likely underestimating number of wells with fecal contamination (Braatz, 2004)
 - Timing of sampling matters
 - Grab samples limited in ability to assess magnitude of bacterial contamination from rapid recharge
 - New techniques needed to assess severity of bacterial contamination during and after rapid recharge events

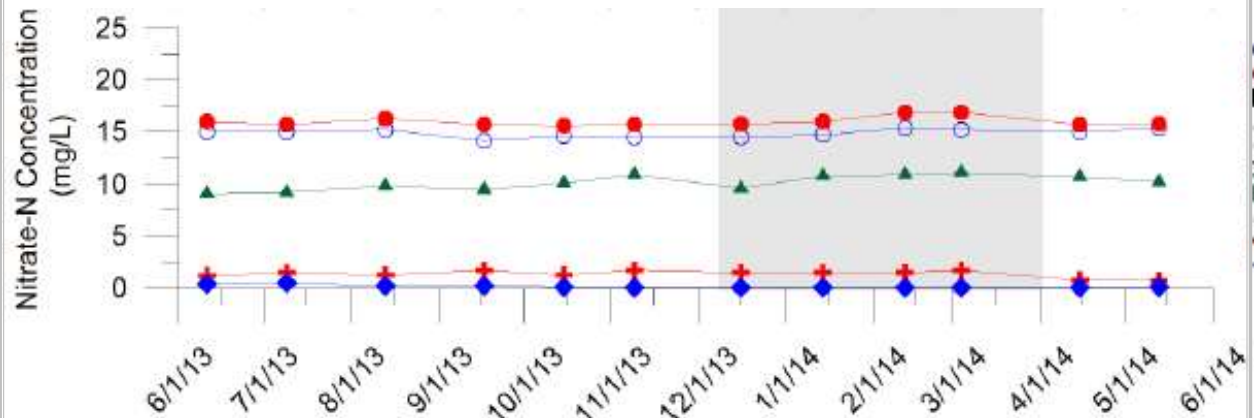
Monthly Nitrate Results

Well	Nitrate-Nitrogen mg L ⁻¹
1	14.9 (0.4)
2	16.0 (0.5)
3	18.5 (2.2)
4	7.4 (2.2)
5	13.8 (3.8)
6	9.0 (2.7)
7	12.8 (1.4)
8	10.2 (0.7)
9	1.4 (0.3)
10	0.2 (0.2)

Standard Deviation > 1 mg/L

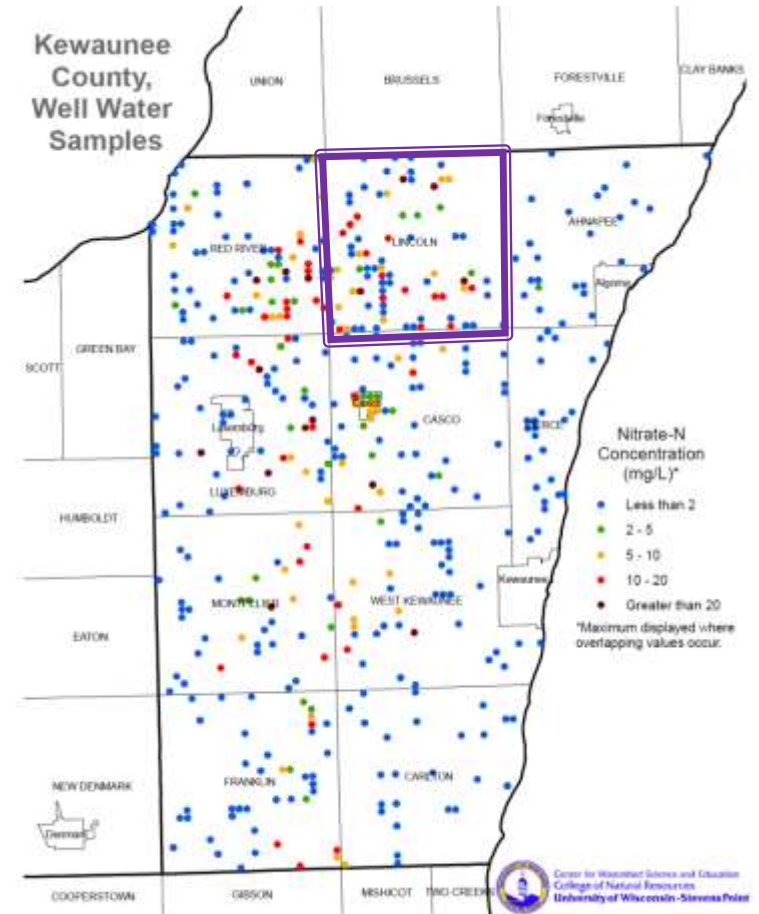


Standard Deviation < 1 mg/L



Nitrate Conclusions

- ▶ If nitrate concentration $2 \text{ mg/L} < \text{nitrate-N} < 10 \text{ mg/L}$
 - Consider testing quarterly if concerned about drinking water over the standard
- ▶ Routine long-term sampling should be capable of overcoming variability and confirming the presence or absence of trends



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Spring Groundwater Recharge

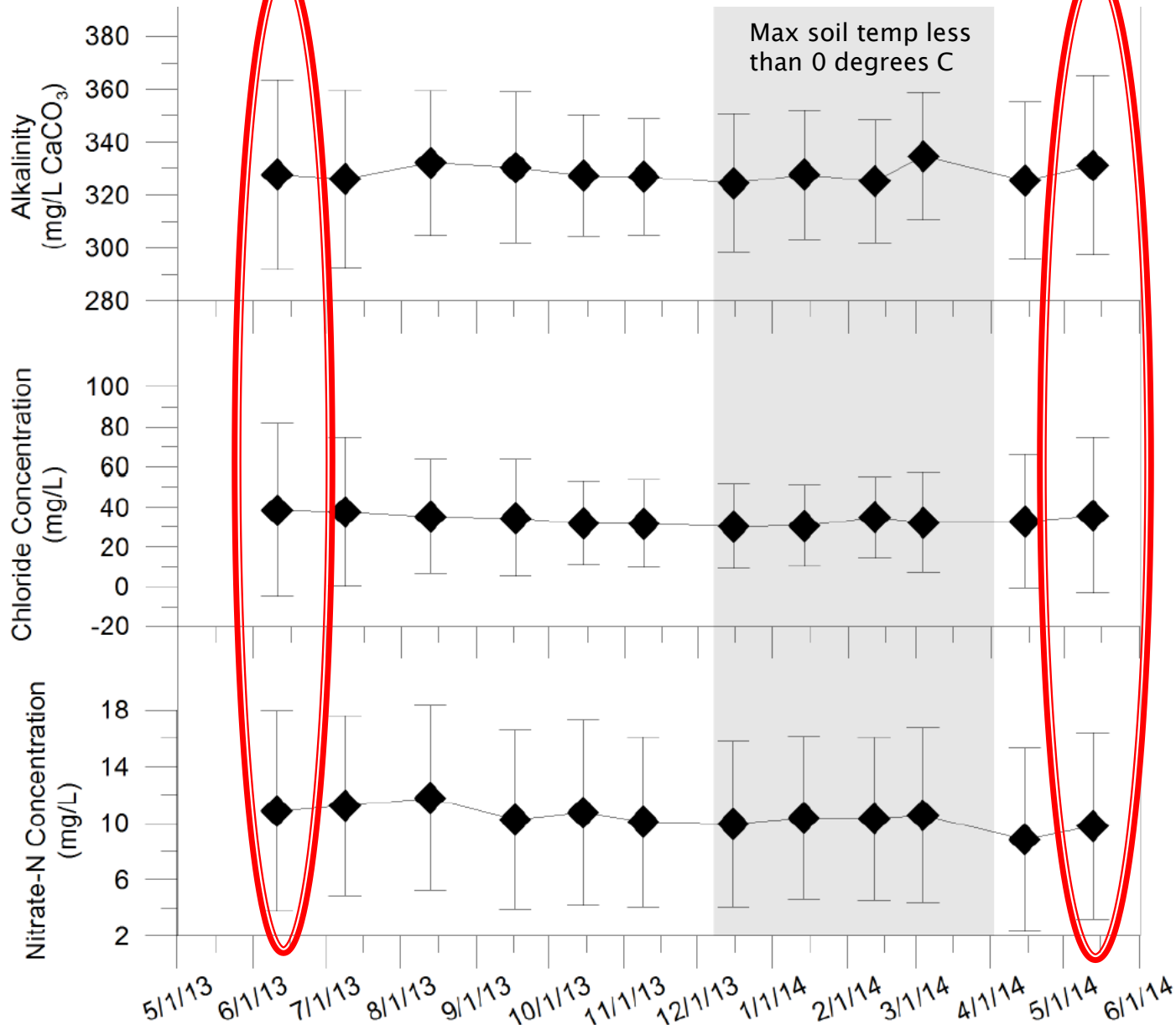


Figure 5. Sample mean of the ten sites for each sampling period. Standard deviation indicated by error bars.

Conductivity

- Measure of total ions dissolved in solution
- May respond to rapid influx of surface water

- Well #1
- Well #2
- Well #3
- △ Well #4
- ◇ Well #5
- ✕ Well #6
- Well #7
- ▲ Well #8
- ⊕ Well #9
- ◆ Well #10

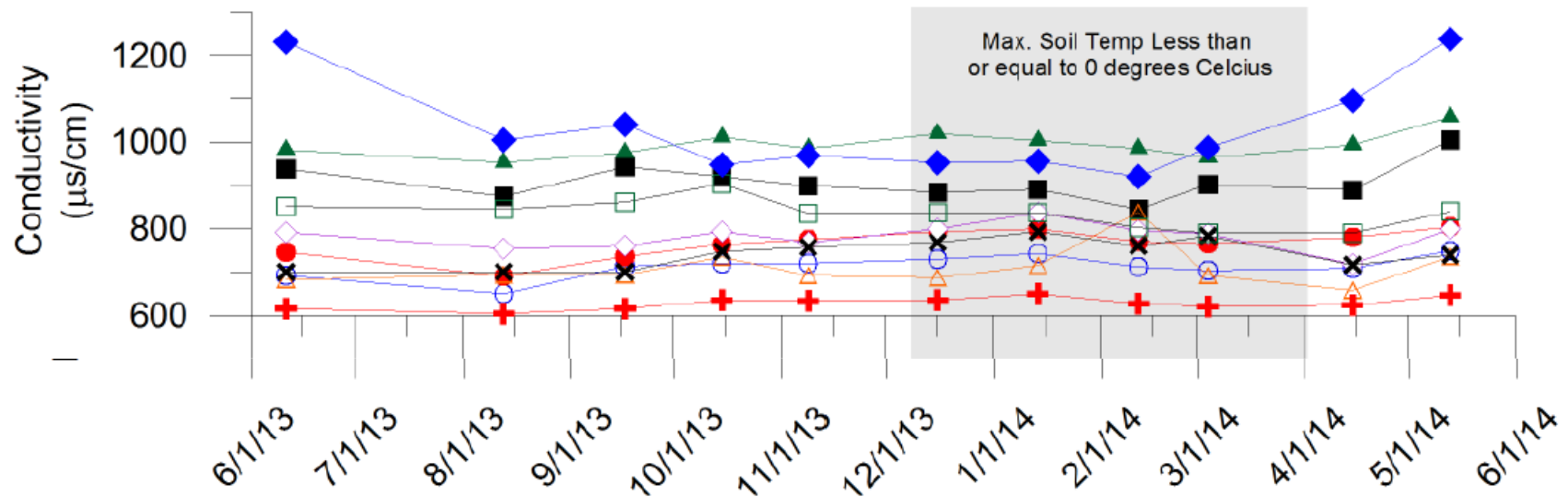
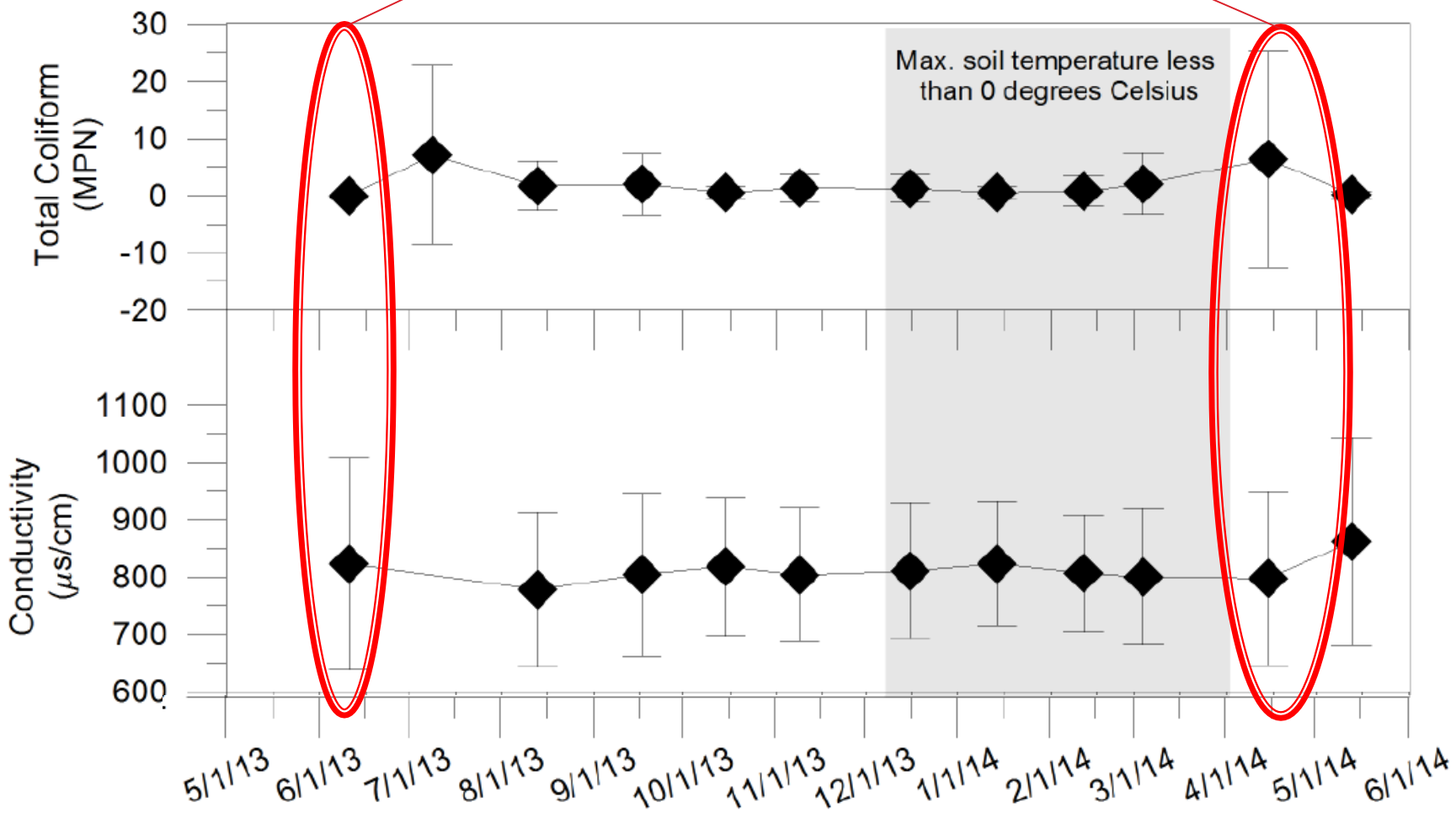


Figure 4. Monthly sample result for each of the 10 wells sampled. Shaded region represents period when maximum soil temperature at 2 cm was less than or equal to 0 degrees Celcius.

Spring Groundwater Recharge



Future Monitoring Recommendations for Town

- ▶ Sample 25 wells bi-annually for at least 10 years
 - January when water quality appears relatively stable
 - June to assess groundwater conditions following the spring groundwater recharge period
- ▶ Test wells for nitrate, chloride and alkalinity
- ▶ Stresses the need for improved bacteria and pathogen testing
 - Encourage town to seek grants or partner with researchers that can better assess source and severity of bacteria and pathogen contamination

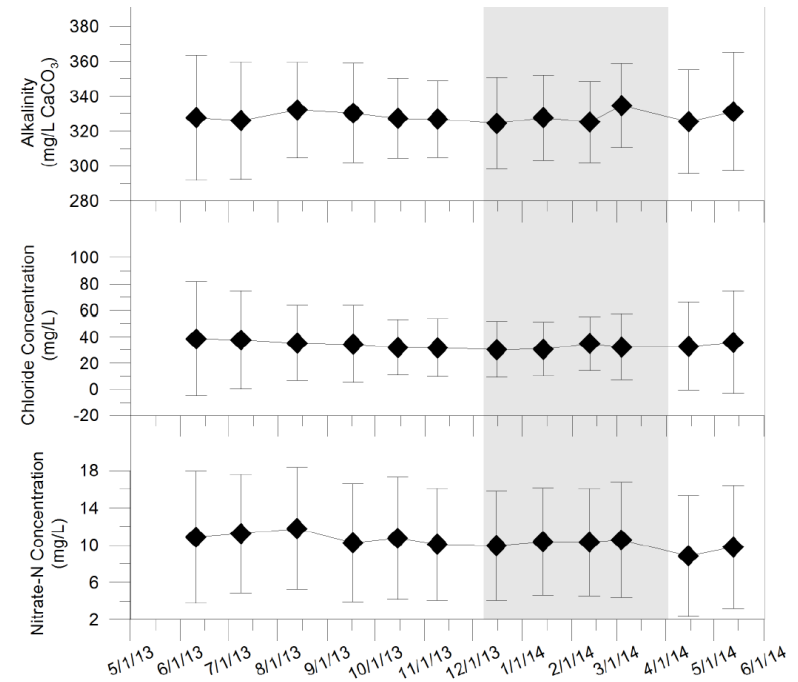


Figure 5. Sample mean of the ten sites for each sampling period. Standard deviation indicated by error bars.

Questions

Water Testing Funded by:

Lincoln Township

AND

Lakeshore Natural Resources Partnership

