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

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Extension

Center for Watershed Science and Education
College of Natural Resources
University of Wisconsin–Stevens Point
Lincoln Township: Background

- Silurian Dolomite bedrock Karst Aquifer
- Private Wells – Groundwater water supply
- 334 Households
- 384 Sanitary Permits (63 are holding tanks)
- 70% Agriculture; 21% Wetland; 6% Forest
- Approximately: 13,500 cows (dairy/calves/beef/heifers)
Susceptible Geology

Shallow Silurian Carbonate Bedrock in Wisconsin

Shallow Carbonate Bedrock Area (<50 feet to Silurian Dolomite): These areas have been identified to have significant vulnerability to nitrate contamination in the Northeast Wisconsin Karst Task Force Report.

Photos courtesy of Brown Co. LCD
Depth to Bedrock:
- < 5 ft (>70% of area)
- < 5 ft (35% - 70% of area)
- 5 to 50 ft
- 50 to 100 ft
- > 100 ft
Previous Sampling Data

- 2004–2014: 159 Well Water Samples (UW–Stevens Point)

- 32% Positive for Coliform Bacteria
  State Average 15%

- 20% >10 ppm nitrate
  State Average 9%

- 50% – nitrate concentrations above background/natural (2 ppm)
Nitrate-N Concentration (mg/L)*

- Less than 2
- 2 - 5
- 5 - 10
- 10 - 20
- Greater than 20

*Maximum displayed where overlapping values occur.

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.
Nitrate-N Concentration (mg/L)*
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- Greater than 20

*Maximum displayed where overlapping values occur.

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.
Coliform/E. coli
- Positive

Coliform Bacteria Only
- Negative
- Positive

Kewaunee County, Bacteria Results (2004-2014)
Objectives

1. Establish Baseline Data of the Intra-Annual Variation of Well Water Quality for 10 wells.
2. Investigate Groundwater and Land-Use Interactions in the Region
3. Recommend a Long-Term Strategy for Monitoring Lincoln Township’s Well Water
Methodology

- 10 wells
  - Preferred past Bacteria Positive &/or > 10ppm Nitrates
  - Landowner Permission
  - Variety of Well & Casing Depths

- 12 months (June 2013 – May 2014)
- Pre–Selected Dates
- All Wells Sampled by Davina Bonness (LWCD)
- Tested at UWSP WEAL Lab
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Testing Parameters

- **Total Coliform / E-Coli** (MPN cfu/100mL)
- **Nitrate–nitrogen** (mg/L)
- **Chloride** (mg/L)
- **Total Hardness** (as mg/L CaCO$_3$)
- **Alkalinity** (as mg/L CaCO$_3$)
- **Conductivity** (µs/cm)
- **pH**
Coliform bacteria

- Any present makes water unsafe
- Not harmful themselves, but may indicate pathogens (E.coli)
- Pathogens can cause gastrointestinal disease, cholera, hepatitis
- Sources:
  - Sampling error
  - Soils
  - Human and animal waste
  - Well construction faults
  - Maintenance issues
COLIFORM BACTERIA
• Detected at least once in 6 wells
• Levels were generally low
• No Wells tested Positive for E–Coli

60.2 cfu/100 mL – Well 4
43.5 – 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 Celsius.
Summary of Total Coliform / E-coli. Values represent the annual mean with standard deviation provided in parentheses.

<table>
<thead>
<tr>
<th>Well</th>
<th>Total Coliform</th>
<th>Total Coliform</th>
<th>E-Coli</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sample Periods Positive</td>
<td>MPN Cfu 100 mL&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>Sample Periods Positive</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0.9 (0.3)</td>
<td>0</td>
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<tr>
<td>2</td>
<td>0</td>
<td>ND</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>ND</td>
<td>0</td>
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<tr>
<td>4</td>
<td>6</td>
<td>6.2 (17.1)</td>
<td>0</td>
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<tr>
<td>5</td>
<td>6</td>
<td>1.7 (2.4)</td>
<td>0</td>
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<tr>
<td>6</td>
<td>0</td>
<td>ND</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>2.5 (8.1)</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>7</td>
<td>3.4 (5.1)</td>
<td>0</td>
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<tr>
<td>9</td>
<td>0</td>
<td>ND</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
<td>6.3 (13.1)</td>
<td>0</td>
</tr>
</tbody>
</table>
Bacteria Conclusion Cont.

Only one Bacteria detection over 12 months.

4, 5, 8 had detections in more than half of sampling events.

Well Construction Alone Cannot Explain CB Results, but Looking at # / Length of Fractures – more important.
Bacteria Conclusion

- Bacteria testing once/year – could be a false sense of well safety – karst geology
- Inconclusive – Source
- CB are detections were variable month–month
- Contamination period may be as little as one month or less
- REMEMBER: SAMPLE DATES PRE–SELECTED
Nitrate Nitrogen

- Greater than 10 mg/L
  *Exceeds State and Federal Limits for Drinking Water*

- Between 2 and 10 mg/L
  *Some Human Impact*

- Less than 2.0 mg/L
  *“Transitional”*

- Less than 0.2 mg/L
  *“Natural”*
NITRATE – NITROGEN

- Very Mobile in Soils / Groundwater
- Fertilizer (lawn/ag), manure, bio-solids, leaking septic tanks, septic drain fields

Wells 1, 2, 3, 7 – > 10 mg/L – all 12 Months

Well 9 – < 2 mg/L   Well 10 – < 1 mg/L
Summary for the 12 month period (annual mean with standard deviation provided in parentheses)

<table>
<thead>
<tr>
<th>Well</th>
<th>Nitrate (mg L⁻¹)</th>
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<tbody>
<tr>
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<td>14.9 (0.4)</td>
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<tr>
<td>2</td>
<td>16.0 (0.5)</td>
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<tr>
<td>3</td>
<td>18.5 (2.2)</td>
</tr>
<tr>
<td>4</td>
<td>7.4 (2.2)</td>
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<tr>
<td>5</td>
<td>13.8 (3.8)</td>
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<tr>
<td>6</td>
<td>9.0 (2.7)</td>
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<td>7</td>
<td>12.8 (1.4)</td>
</tr>
<tr>
<td>8</td>
<td>10.2 (0.7)</td>
</tr>
<tr>
<td>9</td>
<td>1.4 (0.3)</td>
</tr>
<tr>
<td>10</td>
<td>0.2 (0.2)</td>
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</tbody>
</table>

Standard Deviation > 1.0 mg/L
Greater Degree of Intra-Annual Variability

Had max N above 10 mg/L and one/more months less than standard
<table>
<thead>
<tr>
<th>Well ID</th>
<th>Non-cropland (acres)</th>
<th>Non-cropland (%)</th>
<th>Total Cropland (acres)</th>
<th>Cropland (%)</th>
<th>Cropland with a Nutrient Management Plan (acres)</th>
<th>Cropland with a Nutrient Management Plan (%)</th>
<th>Fertilizer nitrogen (lbs/acre of cropland/yr)</th>
<th>Manure Nitrogen (lbs/acre of cropland/yr)</th>
<th>Total agricultural nitrogen (lbs/acre of cropland/yr)</th>
<th>Total nitrogen from agricultural sources (lbs)</th>
<th># of septic systems</th>
<th>Nitrogen from septic systems (lbs)</th>
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<td>1</td>
<td>134</td>
<td>27</td>
<td>368</td>
<td>73</td>
<td>295</td>
<td>80</td>
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<td>73</td>
<td>368</td>
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<td>27</td>
<td>58</td>
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<td>51</td>
<td>83</td>
<td>30,706</td>
<td>14</td>
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<tr>
<td>Average</td>
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<td>32</td>
<td>344</td>
<td>68</td>
<td>303</td>
<td>46</td>
<td>71</td>
<td>25,391</td>
<td>8.6</td>
<td>215</td>
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This **HALF MILE RADIUS** assessment is **NOT AN ACCURATE REPRESENTATION OF THE ACTUAL RECHARGE AREA** of the **10 Wells** **BUT assists in quantifying general land-uses.**

DISCLAIMER: Average nitrate concentrations were not correlated to local geology, well construction, or source assessment.
THEREFORE:

89% cropland under Nutrient Management Plans…..

–We can conclude that the elevated nitrates are a result of acceptable agricultural management practices and not the result of gross mismanagement or negligence.
If the Goal is Long-Term Reduction of Nitrates in Groundwater:

Then

Need to reduce nitrogen inputs beyond the current source, rate and timing risk management strategies outlined in existing nutrient management plans
Nitrate Conclusions

Given Large Variability in Nitrate Concentrations:

Anyone with a nitrate test above 2 mg/L and less than 10 mg/L and is concerned about drinking water above 10 mg/L

Should consider testing more frequently than once/year.
Water Quality Correlations

1. Indication of changes in water quality
2. Increase understanding of groundwater movement
Water Quality Correlations – Nitrogen & Chloride

Wells: 3, 4, 6, 7, 8, 10

Chloride Concentration (mg/L)

Nitrate-N Concentration (mg/L)

Well #1
Well #2
Well #3
Well #4
Well #5
Well #6
Well #7
Well #8
Well #9
Well #10

Dates:
- 6/1/13
- 7/1/13
- 8/1/13
- 9/1/13
- 10/1/13
- 11/1/13
- 12/1/13
- 1/1/14
- 2/1/14
- 3/1/14
- 4/1/14
- 5/1/14
- 6/1/14
Conductivity

- Measure of total ions
- Usually responds to rapid influx of surface water
- Can be used to indicate presence of contaminants
- Should be 2x the hardness

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 Celsius.
Intra–Annual Variability & Long–Term Monitoring

- Groundwater quality is better, worse, or staying the same?

**Standard Deviation:**
- Measure of the average distance of values from the mean
- Standard way to measure and express variability.
Spring Groundwater Recharge

Max soil temp less than 0 degrees C

Figure 5. Sample mean of the ten sites for each sampling period. Standard deviation indicated by error bars.
Seasonal variability related to the Contamination source
Land–Use Changes
Annual Climatic Variability

Because Greater Variability – Need to Test more Often if Nitrates > 2 mg/L
Implications for Long-Term Monitoring

- Aquifer most stable during frozen soil conditions (little recharge occurring)
- Most variable – Following snow-melt and spring recharge season
- Gradual decrease during summer/fall – gradual stabilization .. Little/no recharge

THEREFORE
Sampling wells when the aquifer is most stable – best potential to detect trends/changes in groundwater overtime.
Recommendations

- Sample 25 wells bi-annually
  - **January**: when wells are under relatively stable aquifer conditions
  - **June**: to assess groundwater conditions following the spring groundwater recharge period and characterize variability (ex. well, annual, climatic, land-use, etc.)
- Test wells for nitrate, chloride and alkalinity
- Long term sampling of at least 10 years.
Questions

Funded by:

Lincoln Township
AND
Lakeshore Natural Resources Partnership