Determining the Sources of Water for Conduit “Sandboil” Springs

Nachusa Grasslands, Franklin Grove

Clint Bailey
Hydrologist
U.S. Geological Survey, IL WSC
DeKalb, IL
Nachusa Grasslands

- Fen Spring Site
- Big Woods Unit
- Residential Wells
  - 6 Residential wells bordering the sites
  - Screened in St. Peters sandstone, Prairie du Chien Limestone, or a mixture of both
Major Structural Features & Bedrock Topography

Study Area

Modified from Beck USGS, 1965.

500 foot Contour Int.
Sandboil Controversy
Objectives

- The purpose of this research was to determine the source of water generating the Nachusa Sandboil springs, by utilizing geochemical and stable isotope groundwater and surface water analyses.

- Project Goals:
  1. Elucidate the subsurface geology influencing the hydrogeologic system (s).
  2. Characterize the geochemistry and stable isotopes of the surface water, sandstone conduits, and groundwater.
  3. Determine the main hydrologic influence of the springs, and any mixing between hydrologic systems.
Hypothesis

- It was my hypothesis that the source of the sandboil springs originated from the upwelling of water from a deeper aquifer system, which flows through a fracture/conduit controlled subsurface within the St. Peter Sandstone Bedrock.
Methodologies

- **Field Methods**
  1. Geophysics and Lithologic Core Analysis
  2. Water Sampling
  3. Water Quality Analysis

- **Laboratory analytical methods**
  4. Geochemical Analysis
  5. Stable Isotope Analysis
Field Methods

1a). Geophysics

- Resistivity Soundings
- Seismic Refraction
- Electromagnetic (EM)
- Ground Penetrating Radar (GPR)
Survey Lines at the Fen
1b). Well Installation & Coring

- 4-¾” diameter shallow piezometers
  - 5-10 feet deep
  - Screened in soil & Sandy or Limestone residuum
- 2 -1.5” diameter deep monitoring wells into St. Peter
- Cores collected and characterized from each site
  - Particle Size analysis
  - Field texturing and description
Field Methods

2a). Surface Water Sampling

- Collected separate samples for bicarbonate, stable hydrogen and oxygen isotopes, major anions, and major cations

2b). Monitoring Well Sampling

2c. Residential Well Sampling

- Collected separate samples for bicarbonate, stable hydrogen and oxygen isotopes, major anions, and major cations
3). Water Geochemistry

## Major Cations
- ICP/MS Thermo Element 2
- Samples analyzed for Sr88, Ca44, Fe56, Na23, Mg24, K39.
- Followed EPA method 200.7
- Samples preserved with a 1% dilution of 70% nitric acid
- Samples Run both pure and diluted 1:100

## Major Anions
- DIONEX
  - Samples analyzed for F\textsuperscript{−}, Cl\textsuperscript{−}, NO\textsubscript{2}\textsuperscript{−}, NO\textsubscript{3}\textsuperscript{−}, Br\textsuperscript{−}, SO\textsubscript{4}\textsuperscript{2−}, P0\textsubscript{4}\textsuperscript{3−}
  - Followed EPA method 300.0
- Bicarbonate HCO\textsubscript{3}−
  - HACH DR5000
    - TNT Total Alkalinity Test Kit
    - pH of samples is low enough that Alkalinity = Bicarbonate
  - S&F Analytical
    - 1 control set of samples sent to certified laboratory for titration
4). Stable Isotopes

Hydrogen

- δ²H vSMOW
- Thermo THC/EA (Thermally coupled elemental Analyzer)
- Thermo MAT 253

Oxygen

- δ¹⁸O vSMOW
- Gas Bench
- Thermo MAT 253
RESULTS
Subsurface
Geophysics: Resistivity Results

Depth (meters)

Resistivity (Ohm-m)

0 10 100 1000

Peaty Soil Layer

Poorly Cemented Sandstone Residuum

Sandstone Bedrock
# Particle Size Analysis (PSA)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Sand (mm)</th>
<th>Wentworth Geometric Progression</th>
<th>USDA</th>
<th>Clay</th>
<th>EUA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VCS</td>
<td>CS</td>
<td>MS</td>
<td>FS</td>
<td>VFS</td>
</tr>
<tr>
<td>MW6 (0'-1')</td>
<td>0.4</td>
<td>5.5</td>
<td>23.0</td>
<td>25.3</td>
<td>3.7</td>
</tr>
<tr>
<td>MW6 (1.9'-2.4')</td>
<td>2.1</td>
<td>4.9</td>
<td>20.0</td>
<td>25.9</td>
<td>3.6</td>
</tr>
<tr>
<td>MW6 (2.4'-3.9')</td>
<td>0.0</td>
<td>0.9</td>
<td>6.0</td>
<td>9.5</td>
<td>2.4</td>
</tr>
<tr>
<td>MW6 (3.9'-8.7')</td>
<td>0.2</td>
<td>5.8</td>
<td>44.2</td>
<td>34.8</td>
<td>1.3</td>
</tr>
<tr>
<td>MW6 (8.7'-11.5')</td>
<td>0.0</td>
<td>0.7</td>
<td>55.5</td>
<td>38.0</td>
<td>2.0</td>
</tr>
<tr>
<td>MW6 (15.5'-19.5')</td>
<td>0.1</td>
<td>8.5</td>
<td>45.9</td>
<td>36.9</td>
<td>2.3</td>
</tr>
<tr>
<td>MW6 (19.5'-23.5')</td>
<td>0.0</td>
<td>3.7</td>
<td>58.6</td>
<td>34.9</td>
<td>0.6</td>
</tr>
<tr>
<td>MW6 (23.5'-27.5')</td>
<td>0.2</td>
<td>11.5</td>
<td>63.1</td>
<td>21.5</td>
<td>0.5</td>
</tr>
<tr>
<td>MW6 (27.5'-31.5')</td>
<td>0.0</td>
<td>6.3</td>
<td>47.1</td>
<td>41.7</td>
<td>1.3</td>
</tr>
<tr>
<td>C2 (5.3'-7.5')</td>
<td>1.1</td>
<td>9.4</td>
<td>38.7</td>
<td>41.0</td>
<td>4.7</td>
</tr>
<tr>
<td>C2 (17.5'-18.3')</td>
<td>0.0</td>
<td>9.0</td>
<td>39.1</td>
<td>49.3</td>
<td>0.4</td>
</tr>
<tr>
<td>C2 (18.3'-18.8')</td>
<td>2.5</td>
<td>10.1</td>
<td>44.3</td>
<td>36.7</td>
<td>0.5</td>
</tr>
<tr>
<td>C1 (Grab *7.5')</td>
<td>0.9</td>
<td>16.8</td>
<td>70.3</td>
<td>8.5</td>
<td>0.0</td>
</tr>
<tr>
<td>C1 (Grab *11.5')</td>
<td>50.3</td>
<td>21.3</td>
<td>8.6</td>
<td>4.7</td>
<td>0.0</td>
</tr>
<tr>
<td>NG3 (Grab Sample)</td>
<td>1.1</td>
<td>22.9</td>
<td>69.2</td>
<td>3.7</td>
<td>0.0</td>
</tr>
<tr>
<td>NG5 (Grab Sample)</td>
<td>2.6</td>
<td>47.3</td>
<td>43.9</td>
<td>4.2</td>
<td>0.0</td>
</tr>
<tr>
<td>NG6 (Grab Sample)</td>
<td>0.0</td>
<td>4.4</td>
<td>36.4</td>
<td>55.2</td>
<td>0.9</td>
</tr>
</tbody>
</table>

**Note:**
- **Heaving Sand/Gravel Anomaly**
- **Sandboils**
- **St. Peter Sandstone**
Water Quality
EPA MCL 44ppm

Nitrate ppm

“Sandboils” Springs
Southern & Northern Residential Wells
Shallow Piezometers
Monitoring Wells
Wade Creek
Iron Springs
Geochemistry & Groundwater Evolution
“Sandboil” Sites
Northern Residential Wells
Stable Isotope Results
Nachusa Conceptual Subsurface Model
Conclusions

- Subsurface geology is heterogeneous with high spatial variation.
- Subsurface geology most likely Ancell group of the St. Peter and overlying Shakopee-New Richmond Limestone formations of the Prairie du Chien Group.
- Two Separate Groundwater Hydrogeologic systems.
- Sandboil springs are groundwater controlled.
- Groundwater source of the sandboil springs is directly connected to surface water.
- Homogeneity in Fen sampling sites suggests upwelling from Prairie du Chien through broken limestone and sandstone conduits.
THANK YOU
<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>SERIES</th>
<th>MEGA-GROUP</th>
<th>GROUP</th>
<th>FORMATION</th>
<th>GRAPHIC COLUMN</th>
<th>THICKNESS (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary</td>
<td>Niagara</td>
<td>Champlainian</td>
<td>Hunton</td>
<td>Racine</td>
<td></td>
<td>0-500</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Joliet-Kankakee</td>
<td></td>
<td>260-460</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Elwood</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Neda</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silurian</td>
<td>Canadian</td>
<td>Ordovician</td>
<td>Maquoketa</td>
<td>100-250</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Galena</td>
<td>230-380</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Platteville</td>
<td>70-230</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nachusa</td>
<td>60-520</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Glenwood</td>
<td>150-220</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>St. Peter</td>
<td>80-375</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kress Mbr.</td>
<td>1400-3600</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Oneonta</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Eminence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Potosi</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Franconia</td>
<td>35-160</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ironon-Galesville</td>
<td>150-220</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Eau Claire</td>
<td>350-450</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mt. Simon</td>
<td>1400-3600</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cambrian</td>
<td>Croixian</td>
<td></td>
<td>Knox</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Potsdam</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Cambrian</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Modified from Kolata ISGS 1978

### General Stratigraphic Column of Northwestern II.

- **Glacial Drift**
  - Limestone
  - Cherty
  - Sandy
  - Shaley
- **Dolomite**
  - Same Variations
- **Sandstone**
  - Silty
  - Silty/Shaley
  - Dolomitic
- **Shale**
  - Clay Shale
  - Silty/Shaley
  - Sandy
  - Calcareous
  - Dolomitic