Senior Project: Groundwater Design
KBIC Fish Hatchery

Brendan Ruppen, Denada Planaj, Kyle Walker
Presentation Outline

- Site location
- Hatchery Background
- Problem
- Methods
- Solution
- Tests
- Results
- Conclusion
KBIC Fish Hatchery
Located NE of L’Anse, MI

Keweenaw Bay Indian Community (KBIC)
Hatchery Objective

- Restore fish populations in rivers and lakes
- Reduce water usage in hatchery facilities
- Installation of pump motor controls and monitoring system
- Community involvement and education

http://nrd.kbic-nsn.gov/stocking
Well History

Total of 5 wells - currently 3 wells pumping

<table>
<thead>
<tr>
<th>Well #</th>
<th>Date Installed</th>
<th>Depth to Screen (ft)</th>
<th>Diameter (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1992</td>
<td>236</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>1993</td>
<td>230</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>1997</td>
<td>241</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>2008</td>
<td>210</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>2015</td>
<td>228</td>
<td>6</td>
</tr>
</tbody>
</table>

Well 4 - 2018
Problem with Production Wells

- Wells are showing signs of reduced yield
- More energy required to produce equal amount of water
Troubleshooting Problem

- Pumps losing efficiency
- Aquifer getting drained dry
- Mineral buildup
- Screen getting clogged by sediments
- Biological film buildup
- Screen being wedged up into casing
- Improper screen width
Downhole Video - Well 3

- Screen: 240-278 ft.
- Well screen video log of well in 2017
- Mechanically scrubbed in February 2017
Downhole Video - Well 5

- Screen: 228-258 ft.
- Well screen video log of well in 2017
- Showing similar mineral precipitation as well 3
The Problem

- Calcite has rhombohedral appearance
- Typically formed as chemical precipitation in environments rich with calcium bicarbonate
## Chemical Report

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Result</th>
<th>Units</th>
<th>Dilution</th>
<th>LOD</th>
<th>LOQ/MCL</th>
<th>Analyzed</th>
<th>Method</th>
<th>Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkalinity, tot. as CaCO₃ (unfiltered)</td>
<td>150</td>
<td>mg/L</td>
<td>1</td>
<td>2.0</td>
<td>2.0</td>
<td>10/18/17</td>
<td>EPA 200.8, Rev 5.4</td>
<td>721026460</td>
</tr>
<tr>
<td>Arsenic, tot. recoverable as As by ICP-MS</td>
<td>2.4</td>
<td>ug/L</td>
<td>1</td>
<td>0.50*</td>
<td>1.0 / 10*</td>
<td>10/17/17</td>
<td>EPA 200.8, Rev 5.4</td>
<td>721026460</td>
</tr>
<tr>
<td>Calcium, tot. recoverable as Ca by ICP-MS</td>
<td>34</td>
<td>mg/L</td>
<td>1</td>
<td>0.15*</td>
<td>0.30*</td>
<td>10/17/17</td>
<td>EPA 200.8, Rev 5.4</td>
<td>721026460</td>
</tr>
<tr>
<td>Cadmium, as Cd (unfiltered)</td>
<td>2.94</td>
<td>ug/L</td>
<td>1</td>
<td>2.9</td>
<td>5.0</td>
<td>10/17/17</td>
<td>EPA 300.0, Rev 2.1</td>
<td>721026460</td>
</tr>
<tr>
<td>Chromium, tot. recoverable as Cr by ICP</td>
<td>ND</td>
<td>ug/L</td>
<td></td>
<td></td>
<td></td>
<td>10/17/17</td>
<td>EPA 200.7, Rev 4.4</td>
<td>105330</td>
</tr>
<tr>
<td>Total Coliform Bacteria</td>
<td>Positive</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. coli</td>
<td>Negative</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copper, tot. recoverable as Cu by ICP-MS</td>
<td>ND</td>
<td>ug/L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluoride, as F (unfiltered)</td>
<td>0.23</td>
<td>mg/L</td>
<td>1</td>
<td>0.050*</td>
<td>0.10 / 4.0*</td>
<td>10/17/17</td>
<td>EPA 200.8, Rev 5.4</td>
<td>721026460</td>
</tr>
<tr>
<td>Hardness, tot. recoverable as CaCO₃ (calc/unfilt/pcm)</td>
<td>140</td>
<td>mg/L</td>
<td>1</td>
<td>1.0</td>
<td>2.0</td>
<td>10/17/17</td>
<td>EPA 200.8, Rev 5.4</td>
<td>721026460</td>
</tr>
<tr>
<td>Iron, tot. recoverable as Fe by ICP-MS</td>
<td>0.17</td>
<td>mg/L</td>
<td>1</td>
<td>0.016*</td>
<td>0.004*</td>
<td>10/17/17</td>
<td>EPA 200.8, Rev 5.4</td>
<td>721026460</td>
</tr>
<tr>
<td>Lead, tot. recoverable as Pb by ICP-MS</td>
<td>0.40</td>
<td>ug/L</td>
<td>1</td>
<td>0.30*</td>
<td>0.15*</td>
<td>10/17/17</td>
<td>EPA 200.8, Rev 5.4</td>
<td>721026460</td>
</tr>
<tr>
<td>Magnesium, tot. recoverable as Mg by ICP-MS</td>
<td>12.7</td>
<td>mg/L</td>
<td>1</td>
<td>1.0*</td>
<td>2.0 / 1300*</td>
<td>10/17/17</td>
<td>EPA 200.8, Rev 5.4</td>
<td>721026460</td>
</tr>
<tr>
<td>Manganese, tot. recoverable as Mn by ICP-MS</td>
<td>0.01</td>
<td>ug/L</td>
<td></td>
<td></td>
<td></td>
<td>10/17/17</td>
<td>EPA 200.8, Rev 5.4</td>
<td>721026460</td>
</tr>
<tr>
<td>Phosphorus, tot. as P</td>
<td>0.002</td>
<td>mg/L</td>
<td>1</td>
<td>0.0017</td>
<td>0.050*</td>
<td>10/17/17</td>
<td>4500-P-1999</td>
<td>721026460</td>
</tr>
<tr>
<td>Silica/Silicate, as SiO₂, unfiltr</td>
<td>18</td>
<td>mg/L</td>
<td>2</td>
<td>1.0</td>
<td>2.0</td>
<td>10/17/17</td>
<td>4500-SiO₂C-1997</td>
<td>721026460</td>
</tr>
<tr>
<td>Solids, tot. dis. (TDS)</td>
<td>180</td>
<td>mg/L</td>
<td>1</td>
<td>2.0</td>
<td>2.0</td>
<td>10/18/17</td>
<td>2540-C-1997</td>
<td>721026460</td>
</tr>
<tr>
<td>Solids, tot. susp. (TSS)</td>
<td>180</td>
<td>mg/L</td>
<td>1</td>
<td>1.0</td>
<td>1.0</td>
<td>10/18/17</td>
<td>2540-D-1997</td>
<td>721026460</td>
</tr>
<tr>
<td>Sulfate, as SO₄ (unfiltered)</td>
<td>3.33</td>
<td>mg/L</td>
<td>1</td>
<td>2.5</td>
<td>5.0</td>
<td>10/17/17</td>
<td>EPA 300.0, Rev 2.1</td>
<td>721026460</td>
</tr>
<tr>
<td>Uranium, tot. recoverable as U by ICP-MS</td>
<td>2.2</td>
<td>mg/L</td>
<td>1</td>
<td>0.50</td>
<td>1.0</td>
<td>10/17/17</td>
<td>EPA 200.8, Rev 5.4</td>
<td>721026460</td>
</tr>
<tr>
<td>Zinc, tot. recoverable as Zn by ICP-MS</td>
<td>ND</td>
<td>mg/L</td>
<td></td>
<td></td>
<td></td>
<td>10/17/17</td>
<td>EPA 200.8, Rev 5.4</td>
<td>721026460</td>
</tr>
<tr>
<td>Lab filtration for TDS</td>
<td>yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10/17/17</td>
<td>EPA 300.0, Rev 5.4</td>
</tr>
</tbody>
</table>

Values in brackets represent results greater than or equal to the LOD but less than the LOQ and are within a region of "Less-Certain Quantitation". Results greater than or equal to the LOQ are considered to be in the region of "Certain Quantitation". LOD and/or LOQ tagged with an asterisk(*) are considered Reporting Limits. All LOD/LOQs adjusted to reflect dilution and/or solids content. ND = Not Detected (< LOD) LOD = Limit of Detection LOQ = Limit of Quantitation NA = Not Applicable

DWB = Dry Weight Basis %DWB = (mg/kg DWB) / 100000 1000 ug/L = 1 mg/L MCL = Maximum Contaminant Levels for Drinking Water Samples. Shaded results indicate >MCL.

Authorized by: R. T. Krueger President

Reviewed by:
Specific Capacity

- Specific capacity is the relationship between the pumping rate (gpm) and drawdown (ft), useful in comparing the efficiency of a well over time.
- Specific capacity of each well was calculated using the SCADA (supervisory control and data acquisition) which offers pumping rates and drawdown levels of the wells dating back to December 2016.
Well 3 Specific Capacity (SCADA)
Well 4 Specific Capacity (SCADA)
Well 5 Specific Capacity (SCADA)
## Power Efficiency

### Jan-18

<table>
<thead>
<tr>
<th>Well</th>
<th>Pumping Rate (gpm)</th>
<th>Drawdown (ft)</th>
<th>Lift (ft)</th>
<th>TDH (ft)</th>
<th>Calculated Output (hp)</th>
<th>Calculated Output (kW)</th>
<th>SCADA Input (kW)</th>
<th>Efficiency %</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>45</td>
<td>83</td>
<td>15.81</td>
<td>98.81</td>
<td>1.1</td>
<td>0.8</td>
<td>4.6</td>
<td>18.2</td>
</tr>
<tr>
<td>4</td>
<td>140</td>
<td>87</td>
<td>17.84</td>
<td>104.84</td>
<td>3.7</td>
<td>2.8</td>
<td>6.7</td>
<td>41.3</td>
</tr>
<tr>
<td>5</td>
<td>220</td>
<td>61</td>
<td>15.81</td>
<td>76.81</td>
<td>4.3</td>
<td>3.2</td>
<td>3.5</td>
<td>90.9</td>
</tr>
</tbody>
</table>

### Feb-18

<table>
<thead>
<tr>
<th>Well</th>
<th>Pumping Rate (gpm)</th>
<th>Drawdown (ft)</th>
<th>Lift (ft)</th>
<th>TDH (ft)</th>
<th>Calculated Output (hp)</th>
<th>Calculated Output (kW)</th>
<th>SCADA Input (kW)</th>
<th>Efficiency %</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>45</td>
<td>90</td>
<td>15.81</td>
<td>105.81</td>
<td>1.2</td>
<td>0.9</td>
<td>5.0</td>
<td>17.9</td>
</tr>
<tr>
<td>4</td>
<td>190</td>
<td>104</td>
<td>17.84</td>
<td>121.84</td>
<td>5.8</td>
<td>4.4</td>
<td>9.5</td>
<td>45.9</td>
</tr>
<tr>
<td>5</td>
<td>217</td>
<td>68</td>
<td>15.81</td>
<td>83.81</td>
<td>4.6</td>
<td>3.4</td>
<td>4.0</td>
<td>85.6</td>
</tr>
</tbody>
</table>

### Mar-18

<table>
<thead>
<tr>
<th>Well</th>
<th>Pumping Rate (gpm)</th>
<th>Drawdown (ft)</th>
<th>Lift (ft)</th>
<th>TDH (ft)</th>
<th>Calculated Output (hp)</th>
<th>Calculated Output (kW)</th>
<th>SCADA Input (kW)</th>
<th>Efficiency %</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>46</td>
<td>93</td>
<td>15.81</td>
<td>108.81</td>
<td>1.3</td>
<td>0.9</td>
<td>5.2</td>
<td>18.1</td>
</tr>
<tr>
<td>4</td>
<td>190</td>
<td>107</td>
<td>17.84</td>
<td>124.84</td>
<td>6.0</td>
<td>4.5</td>
<td>10.1</td>
<td>44.2</td>
</tr>
<tr>
<td>5</td>
<td>220</td>
<td>71</td>
<td>15.81</td>
<td>86.81</td>
<td>4.8</td>
<td>3.6</td>
<td>4.1</td>
<td>87.7</td>
</tr>
</tbody>
</table>
Solution to Reduced Yield

- Mechanical scrubbing

- Use acid to treat the mineral buildup
  - Kleiman uses a liquid descaler from Cotey Chemical

- 36 hours in the well, agitated every few hours
Complications with the Acid Method

- Liquid descaler captured by neighboring wells
  - Fish could be harmed or killed by liquid descaler

- Water demand and constant pumping

- Liquid descaler could runoff into Lake Superior
AQTESOLV - Hydraulic Conductivity

![Graph showing hydraulic conductivity data](image)

### Table: Hydraulic Conductivity

<table>
<thead>
<tr>
<th>Well</th>
<th>T (ft^2/min)</th>
<th>Thickness, b (ft)</th>
<th>K (ft/min)</th>
<th>K (ft/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>1.181</td>
<td>40</td>
<td>0.0295</td>
<td>42.5</td>
</tr>
<tr>
<td>4</td>
<td>1.478</td>
<td>40</td>
<td>0.0370</td>
<td>53.2</td>
</tr>
<tr>
<td>5</td>
<td>0.9534</td>
<td>30</td>
<td>0.0318</td>
<td>45.8</td>
</tr>
</tbody>
</table>

**Hydraulic Conductivity**

\[ K = \frac{T}{b} \]
Hazen Method - Hydraulic Conductivity

Well 3 Screen Hydraulic Conductivity Variations

Average $K$ 85.4 ft/day

$$K = A(B)^2 \tau d_e^2$$

$B = 400 + 40(n - 26)$

$\tau = 0.7 + 0.03 T_{\text{water, } ^\circ C}$

Hazen Method (Kasenow 2002 eq.)
Various Hydraulic Conductivity Values for Modeling

<table>
<thead>
<tr>
<th>Well</th>
<th>T (ft^2/min)</th>
<th>Thickness, b (ft)</th>
<th>K (ft/min)</th>
<th>K (ft/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>1.181</td>
<td>40</td>
<td>0.0295</td>
<td>42.5</td>
</tr>
<tr>
<td>4</td>
<td>1.478</td>
<td>40</td>
<td>0.0370</td>
<td>53.2</td>
</tr>
<tr>
<td>5</td>
<td>0.9534</td>
<td>30</td>
<td>0.0318</td>
<td>45.8</td>
</tr>
</tbody>
</table>

Average K 85.4 ft/day

GMS model of tracer test on well 3 with various hydraulic conductivity and porosity values.
GMS Groundwater and Particle Modeling
Well 3 GMS Model

- Well 3 tracer
- Particle travel distance over 3 days
Well 3 GMS Model

- Recovery time: 19.5 hours
- Pumping rate: 60 gpm
Well 3 GMS Model

- Minimum recovery time: 2.5 days
- Pumping rate: 26 gpm
Well 4 GMS Model

- Well 4 tracer
- Particle travel distance over 3 days
Well 4 GMS Model

- Recovery time: 15 min
- Pumping rate: 200 gpm
GMS Drawdown Check

- Validate the model

<table>
<thead>
<tr>
<th>Well #</th>
<th>Observed</th>
<th>Correction</th>
<th>Corrected</th>
<th>Error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W3</td>
<td>45.7</td>
<td>0.078</td>
<td>44.3</td>
<td>3.2</td>
</tr>
<tr>
<td>W4</td>
<td>38.4</td>
<td>0.063</td>
<td>34.9</td>
<td>10.0</td>
</tr>
<tr>
<td>W5</td>
<td>24.1</td>
<td>0.112</td>
<td>23.8</td>
<td>1.3</td>
</tr>
</tbody>
</table>

- Well 3 is most susceptible
Tracer Test

- Reason for performing test
- CaCl2 salt tracer
- Electrical conductivity
- MSDS sheet

https://sciencing.com/salt-water-can-conduct-electricity-5245694.html
Clean Water Test

- Test equipment
- Dry run of process
  - Pumping rates
  - Water tanks
  - Water sampling
  - Cleanout pump
Slug Salt Tracer Test

- “Slug” injection
- 12.12 lb of CaCl2 in 2750 L
- 36 hours in well
- Water sampling every hour leading up to the pump out
- Pumped out using clean out valve

\[
\frac{2000 \text{ mg}}{1 \text{ L}} = \frac{x}{V_{\text{well}}}
\]
Procedure: Water Tanks

- Total of 726 gallons
- 288 gallon holding tank
Procedure: Mixing Solution

- 5 batches
- Concentrated solution
Well Casing

- Pump left in
- 25 gpm pump
Procedure: Water Testing and Pump Out

- Peacock valves installed for water sampling
- Release valve
## Equipment

**Vernier Conductivity Probe**

### Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low range</strong></td>
<td>0 to 200 μS/cm (0 to 100 mg/L TDS)</td>
</tr>
<tr>
<td><strong>Mid range</strong></td>
<td>0 to 2000 μS/cm (0 to 1000 mg/L TDS)</td>
</tr>
<tr>
<td><strong>High range</strong></td>
<td>0 to 20,000 μS/cm (0 to 10,000 mg/L TDS)</td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>ABS body, parallel graphite electrodes</td>
</tr>
<tr>
<td><strong>Response time</strong></td>
<td>98% of final reading in 5 seconds</td>
</tr>
<tr>
<td><strong>Temperature compensation</strong></td>
<td>Automatic from 5 to 35°C</td>
</tr>
<tr>
<td><strong>Temperature range</strong></td>
<td>0 to 80°C</td>
</tr>
<tr>
<td><strong>Accuracy using factory calibration</strong></td>
<td>±8% of full-scale reading for low range</td>
</tr>
<tr>
<td></td>
<td>±3% of full-scale reading for mid range</td>
</tr>
<tr>
<td></td>
<td>±4% of full-scale reading for high range</td>
</tr>
<tr>
<td><strong>Accuracy using custom calibration</strong></td>
<td>±2% of full-scale reading for each range</td>
</tr>
<tr>
<td><strong>Shaft diameter</strong></td>
<td>12 mm OD</td>
</tr>
</tbody>
</table>

Equipment

HOBO Data Logger

Memory: 18,500 temperature and conductivity measurements when using one conductivity range; 14,400 sets of measurements when using both conductivity ranges (64kbytes)
Sample rate: 1 second to 18 hrs, fixed or multiple-rate sampling with up to 8 user-defined sampling intervals
Battery life: 3 years (@ 1 min logging)
Maximum depth: 70 m (226')
Operating range: -2 to 36°C (28° to 97°F) - non freezing
Weight: 193 gm (6.82 ounces). buoyancy in freshwater: -59.8 gm (-2.11 ounces)
Size: 3.16 cm diameter x 16.5 cm, with 6.3 mm mounting hole (1.25" diameter x 0.5", ¼" hole)
Calibrated range: Conductivity: Low Range: 0 to 1,000 μS/cm; Full Range: 0 to 10,000 μS/cm - Temperature: 5 to 35C (41 to 95F)
Accuracy: Conductivity: 3% of reading, or 5 μS/cm, whichever is greater / Temperature: 0.1C (0.2°F)
Resolution: Conductivity: 1 μS/cm - Temperature: 0.01°C (0.02°F)
Response time: 1 second to 90% of change

http://www.onsetcomp.com/products/data-loggers/u24-00
Calibration Curve: Clean Water vs. Hatchery Water

Calibration Curve Using Hatchery Sample (minus background)

\[
y = 0.5858x + 3.6442 \\
R^2 = 0.9878
\]

Conductivity (minus water background conductivity)

\[
y = 0.5671x - 0.7578 \\
R^2 = 0.9995
\]
Background Conductivity on the Site

HOBO probe in fish tank 1.

<table>
<thead>
<tr>
<th>Hobo data average</th>
<th>303.26 microS/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verner data average</td>
<td>367.49 microS/cm</td>
</tr>
</tbody>
</table>
Background Conductivity on the Site

During Tracer Test

\[ y = 11.072x - 477770 \]
\[ R^2 = 0.1879 \]

\[ y = 11.42x - 492862 \]
\[ R^2 = 0.0428 \]
HOBO Data Post Tracer Test
HOBO Data Post Tracer Test
Salt Volume Removed from Well

- How solution was removed/measured
- Volume under curve was calculated using excel
- 9.83Lb removed = 81%
- Remaining salt?
Differences Between Tests

- Pumping rates will be lower during the acid treatment
- The total volume of water used was higher during the tracer test
- Method for adding the solution to the well
- Agitation of acid solution and added volume
Concerns & Possible Issues

- Highly permeable layer
- Well mechanic preference
- Assumed values
- As the acid treatment occurs
- Inaccuracy of groundwater model
Final Thought on Acid Treatment
Summary

- Calcium buildup causing decreased in yield
- Specific capacity and power efficiency
- Calculating the groundwater parameters and using them to model
- Clean water test and tracer test
- Results from the tracer test
- Recommendation
Appendix
Well 3, 4, & 5 History

4) **Well 3** - Installed 1997
   a) 8 inch well- no well log- 1997 completed, 278 ft depth, screen 240-278 ft bgs, 4” drop pipe to 160 ft depth
   b) Step Drawdown Test performed July 1997, specific capacity 4.3 gpm/ft (Bittner Eng. report to Mike Donofrio, 25 July 1997)
   c) This is the pump that is only producing 50 gpm now and that may need a new screen with redevelopment. The pump is 15 hp grundfos submersible, same as the one in well 4.
   d) I spoke with both Curt and Buck Larson and they were recommending acid treatment for screen encrustation. They haven’t used other methods and with all of these wells being in the same aquifer, it was advisable to use acid.
   e) Well screen video log 2017
   f) Well screen mechanically scrubbed February 2017

5) **Well 4** - Installed 2008
   a) 8 inch well- well log- 2008 completed, 248 ft depth, screen 210-248 ft bgs, 4” drop pipe 168 ft depth
   c) Production has decreased over time and I’d like an estimate on doing maintenance work- air surging, high pressure jetting, freezing, chemical....It has been running since 2008. The pump is a 15 hp.
   d) Well screen video log October 2017
   e) Well screen mechanically scrubbed October 2017

6) **Well 5** - Installed November 2011
   a) 6 inch well-well log- 2011 completed- 258 ft deep, screen 228-258 ft bgs, 3” drop pipe 160 ft depth
   b) Constant Rate Interference Test Conducted in December 2011, specific capacity 4.8 gpm/ft
   c) Former monitoring well this has been changed to a production well this year and was just started last month. It has a 10 hp- 6 inch franklin motor, 460 volt, 3 phase.