“What Makes A Good Seal?- beyond the grout study”

State of Nebraska Dept. of Health and Human Services, Dept. of Environmental Quality, University of NE., Water Well Contractors and Licensing Board.
To address the issue of inadequate ground water protection in water wells constructed prior to the adoption of standards October 1, 1988 as revealed by the grout study.

Mission Statement;

“The goal of the Nebraska Annular Seal Task Force is to study methods that can be utilized to introduce an annular seal in existing water wells in order to protect our groundwater resources by inhibiting preferential movement of fluids through the annular space of wells”.
Facts about Nebraska

Population ~ 1.7 million
Relies on Ground Water for 1.2 million people
2/3 Located eastern 1/4th of NE
Economy- Agriculture based
   Industry- Manufacturing
3.2 billion in income
40% cattle and calves
31% corn
14.7% soybeans
4.3% hogs

Natural Resources-

Ground Water
Lake surface area larger than Superior, Michigan, Huron combined.

Grains
97,000 + Irrig. Wells- 93 counties
40% of crop land irrigated

Livestock
2 million head of cattle* 2008 USDA
Ground water use- Nebraska

Irrigation- 92% - 7.5 b-gpd
Domestic- 5% - 382m-gpd
Livestock- 1.6% - 110m-gpd
Industry- 0.1% - 11m-gpd

Ground Water pollution concerns:
• Chemicals
• Bacteria- pathogens
Active Irrigation Wells

1900-1930 ---150
1930-1956---9239
1956-1976---34,491 * Pre-Plastic Pipe
1976-1989---22,204 * Pre-Construction Stds.
1989-2013---27,021 * After Standards

• Total active irrigation wells---93,105
• Total before standards-------66,084---70%
• Total before PVC-------------43,880---47%
Irrigation well construction prior to 1970’s

Predominately concrete tile or cement asbestos “transite” casing

Concrete tile normally;
- 30” in length strung on a cable or pop riveted straps for connection
- 24” OD
- 2.5” wall thickness
- Gravel packed from TD to surface
- Clay pack or concrete surface pad

Cement asbestos “Transite” casing
- 13’ in length banded to together with a notch and groove design
- ¾” wall thickness
- 18” OD
- Gravel Pack from TD to surface
- Clay pack or concrete surface pad
Annular Space Research Model
A fully gravel packed annular space;

1. Allows flow though the Annular space vertically as well as horizontally
   1. Down gradient travel more rapid than previously thought

2. In areas of perched water tables
   • comingling of the groundwater occurs even when the well is not active
   • can promote mineralization that affects well performance and longevity
   • can contaminate water quality in multiple aquifers within the same borehole
   
Promoting premature well failure / pump inefficiency

   • mineralization of screened openings
   • Enhancing biofilm growth (Iron Bacti-Psuedomonas)
Prototype

16” irrigation well

- Unused since 1994
- Owner drills replacement n 2013
- Donates old well to research
- Try to rehab for future use
- Decommission when done
- Total depth 223’
- SWL 97’-(120’) in 1975
- Yield-800 GPM

Perched water
12-20’ BGS
Transite casing
13’ joints
cascading water
Well before brushing
Brushing and Airlift development

Before Brushing

After brushing
Full diameter brush
Transite- 1st Joint
Transite 3rd Joint
## Water Quality before and after

### Before Cleaning

**TOM CHRISTOPHERSON**<br>301 CENTENNIAL MALL SOUTH<br>PO BOX 95026<br>LINCOLN, NE 68509

**ANALYTICAL RESULTS QUALIFIERS**

**Profile:** CHRISTOPHERSON, TOM SHANAHAN WELL PR

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Results</th>
<th>Units</th>
<th>Qual</th>
<th>Report Limit</th>
<th>MCL</th>
<th>Analyzed By</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analytical Method: EPA 353.2-Nitrate (Nitrate + Nitrite (As N))</td>
<td>10.3</td>
<td>mg/L</td>
<td>0.05</td>
<td>10</td>
<td>7/3/2013 KLH</td>
<td></td>
</tr>
<tr>
<td>Analytical Method: SM 3111B - Minerals by AA</td>
<td>39.6</td>
<td>mg/L</td>
<td>0.15</td>
<td>50</td>
<td>5/16/2013 AMU</td>
<td></td>
</tr>
<tr>
<td>Analytical Method: SM 4500 SO4-E - Sulfate</td>
<td>27.8</td>
<td>mg/L</td>
<td>0.15</td>
<td>50</td>
<td>5/16/2013 AMU</td>
<td></td>
</tr>
<tr>
<td>Analytical Method: SM 9223B - Coliform</td>
<td>10</td>
<td>MPN/100 mL</td>
<td>0</td>
<td>5/15/2013 TSW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analytical Method: ALK, SM2320B</td>
<td>20</td>
<td>mg/L</td>
<td>0.15</td>
<td>50</td>
<td>5/16/2013 AMU</td>
<td></td>
</tr>
<tr>
<td>Analytical Method: TDS, SM 2540C</td>
<td>5</td>
<td>mg/L</td>
<td>0.2</td>
<td>5/3/2013 KLM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analytical Method: SM 4500F-C, Fluoride</td>
<td>0.520</td>
<td>mg/L</td>
<td>0.2</td>
<td>5/3/2013 KLM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analytical Method: EPA 150.1, pH</td>
<td>7.14</td>
<td>pH unit</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analytical Method: SM 325.2 - Chloride</td>
<td>7.55</td>
<td>mg/L</td>
<td>1</td>
<td>5/3/2013 KLM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analytical Method: SM 2340C - Total Hardness</td>
<td>4.14</td>
<td>mg/L</td>
<td>4</td>
<td>5/3/2013 KLM</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Remarks:** See reverse side of report for description of acronyms and data qualifiers. For inquiries on result interpretation call: (402) 471-6435.

### After Cleaning

**TOM CHRISTOPHERSON**<br>301 CENTENNIAL MALL SOUTH<br>PO BOX 95026<br>LINCOLN, NE 68509

**ANALYTICAL RESULTS QUALIFIERS**

**Profile:** CHRISTOPHERSON, TOM SHANAHAN WELL PR

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Results</th>
<th>Units</th>
<th>Qual</th>
<th>Report Limit</th>
<th>MCL</th>
<th>Analyzed By</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analytical Method: EPA 353.2-Nitrate (Nitrate + Nitrite (As N))</td>
<td>0.354</td>
<td>mg/L</td>
<td>0.05</td>
<td>10</td>
<td>7/3/2013 KLH</td>
<td></td>
</tr>
<tr>
<td>Analytical Method: SM 3111B - Minerals by AA</td>
<td>76</td>
<td>mg/L</td>
<td>0.15</td>
<td>50</td>
<td>7/3/2013 AMU</td>
<td></td>
</tr>
<tr>
<td>Analytical Method: SM 4500 SO4-E - Sulfate</td>
<td>23.3</td>
<td>mg/L</td>
<td>0.15</td>
<td>50</td>
<td>7/3/2013 AMU</td>
<td></td>
</tr>
<tr>
<td>Analytical Method: SM 9223B - Coliform</td>
<td>145</td>
<td>MPN/100 mL</td>
<td>0</td>
<td>6/29/2013 TSW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analytical Method: ALK, SM2320B</td>
<td>20</td>
<td>mg/L</td>
<td>0.15</td>
<td>50</td>
<td>6/29/2013 AMU</td>
<td></td>
</tr>
<tr>
<td>Analytical Method: TDS, SM 2540C</td>
<td>7.7</td>
<td>mg/L</td>
<td>0.15</td>
<td>50</td>
<td>7/3/2013 AMU</td>
<td></td>
</tr>
<tr>
<td>Analytical Method: SM 4500F-C, Fluoride</td>
<td>4.600</td>
<td>mg/L</td>
<td>0.2</td>
<td>4</td>
<td>7/2/2013 KLM</td>
<td></td>
</tr>
<tr>
<td>Analytical Method: EPA 150.1, pH</td>
<td>7.67</td>
<td>pH unit</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analytical Method: SM 325.2 - Chloride</td>
<td>4.98</td>
<td>mg/L</td>
<td>1</td>
<td>7/1/2013 MAY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analytical Method: SM 2340C - Total Hardness</td>
<td>200</td>
<td>mg/L</td>
<td>4</td>
<td>7/1/2013 SKH</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Remarks:** See reverse side of report for description of acronyms and data qualifiers. For inquiries on result interpretation call: (402) 471-6435.
Retrofit Design

The Challenge;
Install a sufficient volume of grout material without destroying the well to;

• to provide groundwater protection by;
• preventing the comingling of waters through the annular space gravel pack and;
• retain the functional use of the well.

The Answer;
Utilize the properties of grout materials;

• By pressure grouting from the inside of the casing out to the borehole wall or;
• install grouting pipe in the annular space and pressure grout on the outside of the casing forcing the cement into the gravel pack to the borehole wall.
Borehole Schematic

Figure 1a Configuration of Annular Space Installations, Plan View
Side View Schematic

- **Sight Glasses (80-ft Max Depth)**
- **Dye Injection Tubes (15-16-ft deep and 5-10 ft above TBD Joint)**
- **Annular Space Clay Fill**
- **Grout Injection Tubes (22-ft Max Depth)**
- **Proposed Annular Seals (Minimum 5-foot thickness)**
- **Transite Casing 13-foot lengths**

**TBD = To Be Determined**
On-site Monitoring wells

Well #1
- 20’ TD
- SWL-7’
- Nitrates-15 PPM
- H2O temp 48°
- Well #2
- 97’ TD
- SWL-76’
- Nitrate .8-PPM
- H2O temp- 50°
- Well #3
- 218 TD
- SWL-104’
- Nitrates-.9-PPM
- H2O temp- 52°

Key findings
- Different Hydrostatic heads cause down gradient flow...
- Different H2O temp creates convection current increasing down gradient flow...
- 24/7 -365 days
Sight Glass inspection

2013:08:09 20:46:55

001 cnt per ft
0280.0ft

CAL Reel Clear
Microfine Cement

COLOR
Concrete gray

USES
• Stabilizing weak soils
• Sealing seepage in mines, dams and tunnels
• Low permeability grout curtaining
• Hazardous waste containment
• Oil well squeeze-cementing
Cemented
Cemented Joint
Cutting Transite Casing
Grout and Gravel pack-Existing Well
Grout Subsidence
Cement Seal Failure
Bentonite Seal - vent
Final Seal-Bentonite
Dye Testing
Lessons Learned

When pressure grouting the annular space;
  Lowest interval to the upper limit
Flooded annular space can be difficult
  Grouts need to be matched for conditions
Accurate test holes are a must.
1. Better understanding of the unsaturated zone physical properties
   1. More attention to unsaturated zone geology while drilling the borehole
      - Logging every change no matter where it occurs
      - Know the descriptive language for identifying formations
      - E-logging
      - Geo-probe

Highest degree of record
Well Reconstuction/Decom Project

- Methods of Decommissioning- retro-fitting grout cleaning and Shot detonator-used in California since 2006
- Needs to be studied on a wide scale
  - DHHS- Grant from NE Environmental Trust
    - 2 years-715K
    - 6 NRDs
      - LENRD
      - LPNNRD
      - LPSNRD
      - UBBNRD
      - LBBNRD
      - LBNRD
- Minimum of 2 wells to decom in or close to well head protection area -PWS
The village constructed a new water well to replace an older well (1929)

Challenge – decommission the old steel well by detonation leaving the well house intact.

Licensed contractor

Well 189 feet deep

Clay unit from 0-120’ below grade

Goal is 10 foot grout seal adjacent to clay layer 110-120’ below grade
Pumping cement
Detonation
Previously abandoned well
Results

Before rehab;
Water Quality results from PWS well 2 block away;
8.5-9 PPM nitrates

After rehab;
First sample taken
Nitrate 4.56 PPM
Closed loop rehab

NE Games and Parks

- Lake McConaughy visitors center
- Well drillers Assoc. installed 16 loops in 2000 for the HVAC system
- Loop failures begin in 2001
- NGTF installs study wells in 2003
  - Discovers grout vanished in the borehole
  - July 2013 Program studies if sand grout can be re-installed in study loop
- 1300 lbs of sand installed in 3 - 180’ deep loop wells
- Immediate improvement in heat transfer
What Makes a Good Seal?

• Match the grout material with the borehole material properties.
• Grouts should be flexible, dynamic, and compatible with casing material (may need composite materials).
• Avoid compromising the grout material by using the right technique for placement.
• Grout column, including annulus between seals must be less permeable than surrounding material in order to divert to the natural filtration.
The end results will provide answers to NRD’s, PWS, GW Irrigation users, water well contractors with information for:

- Providing protection for public health
- Prevent further degradation of the Ground Water
- Developing Best Management Practices (BMP) for areas susceptible to GW pollution
- Restoring the natural protection provided by sealing of the annular space
Brighter future
for Nebraska GW users
Contact Information

tom.christopherson@nebraska.gov

Office Phone 402-471-0598

P.O. Box 95026
Lincoln, NE 68509=5026

Web site-
dhhs.ne.gov/publichealth/Pages/enh_wwsindex.aspx

Thank-you SEDC