Complying with the Revised Total Coliform Rule and Controlling Iron Bacterial Problems

The Importance of Well Maintenance

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Subsurface Technologies Inc.
Well Problems

- Well Clogging – Lower Production
- Loss of Efficiency - More Expensive Water
- Deterioration of Water Quality – “the well is dirty”
- “Unsafe Bacterial” results
- Sand Production
- Corrosion
- Total Loss of Capital Investment
Figure 15.18. The open area of the screen and the configuration of the slot openings are important factors controlling the effectiveness of development procedures using water jetting.
Biofilm and Bacterial Accumulation

- Bacteria are involved with the oxidation and accumulation of minerals
- Biological Slime (Extra Cellular Poly Saccharides) are the easiest component to remove during rehabilitation
- Historically too much focus has been on bacteria during rehabilitation

- Well Maintenance is Less about Biofilm control and More about Deposit Management
Revised Total Coliform Rule (RTCR):

- Requires public water systems that are vulnerable to microbial contamination to identify and fix problems; and
- Establishes criteria for public water systems to qualify for and stay on reduced monitoring, which could reduce water system burden and provide incentives for better system operation.

The 1989 TCR remains effective until March 31, 2016. PWSs and primacy agencies must comply with the requirements of the RTCR beginning April 1, 2016.
As with the 1989 TCR, the RTCR will impact approximately 154,000 PWSs. These water systems serve approximately 307 million individuals.

The estimated net incremental cost of the RTCR is $14 million annually. This represents total increased costs relative to the 1989 TCR provisions. PWSs are estimated to incur approximately 90 percent of the revised rule’s net annualized present value costs.
Foundation 0'

Surface Casing Dia: 24''
Bottom of Surface Casing: 59'

Outer Casing Dia: 18''
J Slot: 448'
Inner Casing Dia: 14''

Top of Gravel: 453'

Bottom of Outer Casing: 540''

Top of Screen: 548'
Screen Dia: 14''
Screen Slot: 0.050
Screen Material: 316L SS
Gravel Size: #2

Bottom of Screen: 618'
Cellar Material: 316L SS
Bottom of Cellar: 623'

Double-Cased 14in Inner to Surf
What Happens When We Wait Too Long to Rehab?

Extensive and Hardened Mineralization!
• **Specific capacity** – the rate of pumping discharge per unit of drawdown \( \text{gpm/ft} \)

• Historically utilized as an indicator of when Rehabilitation and/or Maintenance needs to be performed
Fundamental Shift Number 1

• We historically wait way too long before performing cleaning (Rehabilitation or Maintenance) on wells

• In the Late 1990’s the reason for the timeframe between treatments (Longevity) becoming shorter and shorter was realized.

• Feedback monitoring with performance testing and water quality evaluation was not effective at determining when well maintenance needs to be performed

Time based maintenance is VERY IMPORTANT
Historical Standard Operation

Operate to Failure Compared to Proactive Aqua Gard Maintenance of Wells

- Periodic Rehabilitations
- Scheduled Treatments

Specific Capacity (GPM/ft)

Years

Rehabilitation of Well
Rehabilitation
Rehabilitation
Rehabilitation of
Longevity of Successful Treatment, factor

- During Rehabilitation, 100% of the deposited mass is often not removed therefore the original pore volume has not been achieved. Therefore it does not take as long to plug the remaining pore volume.
- Bacteria can regrow very quickly on organic material left behind after treatment.
- Key to increasing time between treatments is: EFFECTIVE DEPOSIT REMOVAL

* Most wells have excess production capacity
Sand Migration During Pumping
Water Well Plugging

Common Causes

- Mineral Encrustation
- Biofouling
- Formation Fines (Silt and Clay)
Rate of Lost Capacity or Biofouling

- Rate of deposition most significantly determined by organics, oxygen, and water chemistry

- Biological active zone often takes years to filter enough material from the groundwater
Fundamental Shift Number 2

- During the 1980’s and 1990’s much time, effort and money was devoted to trying to prevent loss of capacity or biofouling including:
  - Shock chlorination programs
  - Heat treatment on wells
  - Anoxic block technology
- The Fundamental Shift came in the late 1990’s when it became evident that prevention of deposits building up in water wells was almost impossible and the management of the deposits be removing them at the early stages was much more effective
LAYNE-WESTERN COMPANY, INC. (DELAWARE CORPORATION)
1900 SHAWNEE MISSION PARKWAY
MISSION WOODS, KS 662052001

FOR: WATER WELL TREATMENT SERVICES; NAMELY, INHIBITING AEROBIC BACTERIAL CONTAMINATION OF WATER WELLS BY CHEMICAL TREATMENT, IN CLASS 40 (U.S. CL. 106).

NO CLAIM IS MADE TO THE EXCLUSIVE RIGHT TO USE "ANOXIC" AND "SYSTEM", APART FROM THE MARK AS SHOWN.


LIZABETH MARTIN, EXAMINING ATTORNEY
Reducing Total Well Life Cycle Costs Starts with selection of Materials during construction

- Enlargement of Openings
- Sand pumping
- Need for patches
- Lost capacity due to corrosion by-products
- Pump failure
Tuberculation Scale Growth

Sulfate-reducing bacteria grows in the anaerobic environment beneath the scale nodule.

Iron-related bacteria grows in the aerobic environment on the casing surface. No oxygen beneath the scale nodule, due to metabolic activity.
Mineral Encrustation

Fe^{++} → Fe^{+++}
(Ferrous)   (Ferric)

Red or Brown Deposits
Mineral Encrustation

$\text{Mn}^{++} \rightarrow \text{Mn}^{++++}$

(Mangannous) \quad (Mangannic)

Brown and Black Deposits
Mineral Encrustations

\[
\begin{align*}
\text{CaHCO}_3 & \rightarrow \text{CO}_2 \\
\text{MgHCO}_3^+ & \rightarrow \text{CO}_2 \\
\text{CaCO}_3 & \rightarrow \text{MgCO}_3 \\
\end{align*}
\]

White or Yellow Deposits
Biological Accumulation of Minerals

Slime-Forming Bacteria

ECPS (Slime)

CaCO$_2$, MgCO$_2$, FeOH, FeO, SIO$_2$, MnOH
Subsurface Microbiology

- Indigenous populations typically contain $10^8$ to $10^9$ bacterial cells per gram
- Approximately 90% are attached and form biofilms
- Depth has no influence
- Culturable vs. nonculturable are 4 to 5 orders of magnitude higher numbers
- 95% of the isolates are aerobic
- 95% of the isolates are chemoorganoheterotrophs
- 4,500 different types of bacteria have been isolated from 60 samples in 4 wells
Unsafe Bacterial Samples

- Total coliforms
- Fecal coliforms
- TNTC (to numerous to count)
- Overgrown (Atypical)
- Complying With the Revised Total Coliform Rule (RTCR)

- Surface Water Infiltration
- Sampling Techniques
- Earthquake

- Natural Indigenous Bacteria
  - *Enterobacter* sp.
  - *Citrobacter* sp.
  - *Klebsiella* sp.
  - *Aeromonas hydrophila*
The Single Most Important Factor
Well Hydraulics

- Production profiles change as wells age
- Water quality changes can result from changes in the production profile
- Well hydraulics influence the effectiveness of well rehabilitation
- Excess production capacity exists in many wells
- If a well is significantly clogged the pump needs to be pulled.
Flow Rate Before and After

**BEFORE**
- Total Flow 3000 gpm
  - 600 gpm
  - 568 gpm
  - 793 gpm
  - 481 gpm
  - 314 gpm
  - 244 gpm

**AFTER**
- Total Flow 3000 gpm
  - 1,074 (+79%)
  - 1,002 (+76%)
  - 267 (-64%)
  - 150 (-69%)
  - 194 (-38%)
  - 313 (+28%)
Rehabilitation Treatments

- Can involve many different strategies
- Must achieve effective deposit removal
- Must be custom tailored, based upon cause of problem, well construction details, and type of formation
- Must have penetration into the surrounding formation
- Must have good agitation

✓ Pretreatment
✓ Various Treatment Applications
✓ Development or Redevelopment

Note: You get what you pay for:
Steps for Effective Rehabilitation

- Site Visit/ Site Evaluation
- Pre-Rehabilitation Pump Test
- Pull pumping equipment
- Video inspection
- Wire Brushing
- Main Energy Application (Chemical, Carbon Dioxide)
- Post Development
- Video Inspection
- Install pumping equipment
- Post Rehabilitation Pump Test
Pull Pumping Equipment
Pre Treatment Video Inspection
Percussive Explosives

a) Ability to remove hard encrusted materials on the inside of the casing

b) Some fracturing of cemented gravel pack and formation material

c) Extremely aggressive in nature

d) Short term fix
Solution: Chemical Treatment
Site-Specific Customization and Chemical Treatment Considerations

- Volume
- Concentration
- Sequence
- Combination
- Above-ground premixing
AquaFreed

- Effective Rehabilitation Technology
- Environmentally Safe
- More Than 8000 wells treated worldwide
- Excellent Penetration
- Excellent at Removal of Plugging Deposits
Sealing the Well for Aqua Freed Treatment
FIRST STAGE:
Seal off the well and inject CO\textsubscript{2} in the gaseous state.
SECOND STAGE:

\[ \text{CO}_2 \text{ injection in liquid state at controlled pressures.} \]
Aqua Freed Vs. Nitrogen Shock (percussive technology)  
2011 Comparative Analysis

14 wells rehabilitated  
7 wells using Aqua Freed vs. 7 wells using Nitrogen Shock Wave

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<thead>
<tr>
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<th>Avg. increase in Efficiency</th>
<th>Average Increase in GPM</th>
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<tbody>
<tr>
<td>Aqua Freed®</td>
<td>363%</td>
<td>76.2%</td>
</tr>
<tr>
<td>Nitrogen Shock Wave</td>
<td>36.4%</td>
<td>24.6%</td>
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Air Line

Perforated Pipe

Drill Pipe

Swab Flanges

Airlift Swabbing Tool
Post Treatment Video Inspection
Aqua Gard™

- Aqua Gard Well Maintenance is installed when pumping equipment is installed
- In well maintenance device
- Very cost effective
- Allows wells to be effectively maintained without pulling the pump
- Allows effective energy to be delivered into a well

Reactive  Proactive
Applications

New Wells
Retrofitting existing wells after rehabilitation
ASR wells
Injection wells
Recovery wells
Powesheik Rural Water
Pumping Cost Reduction Associated With Aqua Gard Well Maintenance

Cost Per MG in 2002 KW/h Rate

Year

2002 2003 2004 2005 2006 2007 2008 2009

$87.13 $88.03 $88.87 $86.83 $85.92 $86.41 $82.30 $82.77

4 wells Equipped

4 wells Equipped

4 wells Equipped
Summary

- 100% Environmentally Sound
- Maximize Well Production
- Maximize Pumping Efficiency
- Lower Pumping Energy Costs
- Lower Maintenance Cost
- Improve Raw Water Quality
- Comply with RTCR
- Fixed Budget Pricing
Questions

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