Rehabilitation of
Rio Rancho Well No. 3
Challenges, Hazards and Successes

By Robert Gray, P.G., Senior Hydrogeologist
Daniel B. Stephens & Associates, Inc.
A Geo-Logic Company
Contractor: Alpha Southwest, Inc.
Rio Rancho Water System & Wells
Well 3 Construction Details

- Completed June 1965
- 12” diameter low-carbon steel blank casing to 584 ft
- 10” diam., 0.040-in slot, Johnson stainless steel wire wrap screen
- 6 screens from 584-820 ft totaling 136 ft length
- May 1967 Static WL 373 ft
- March 2017 Static WL 426 ft
- Pre-treatment capacity ~615 gpm
Well Performance Issues

• All wells experience deterioration to varying degrees as soon as they are turned on, affecting well performance and increasing operating costs
  – Increasing drawdown, declining yield
  – Reduced well efficiency
  – Screen clogging by physical blockage (fines, encrustations)
  – Insufficient well development
  – Mineral precipitation (FeO, Fe$_2$O$_3$, CaCO$_3$, MnCO$_3$)
  – Biofouling, bacterial slime
Well Performance Issues

- Silt/clay
- Sand/gravel
- Silt/clay
- Sand/gravel
- Cement seal
- Static water level
- Bentonite seal
- Filter pack
- Well screen
- Formation - Sand/gravel mixture
- Filter pack
Well Performance Issues

Silt/clay

Cement seal

Static water level

Sand/gravel

Silt/clay

Bentonite seal

Filter pack

Sand/gravel mixture

Well C

Well screen

Filter pack

Formation-Sand/gravel mixture

Fines

Fines can clog the filter pack and well screen.

High velocity flow can also mobilize aquifer fines.

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Well Performance Issues

- Silt/clay
- Sand/gravel
- Silt/clay
- Sand/gravel

Cement seal
Static water level
Bentonite seal
Filter pack

Well screen
Filter pack
Formation-Sand/gravel mixture

Encrustation
Mineral encrustation
Clean well screen

Well Performance Issues

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Well Performance Issues

- Silt/clay
- Sand/gravel
- Static water level
- Cement seal
- Bentonite seal
- Filter pack
- Well screen
- Filter pack
- Formation-Sand/gravel mixture

Bacterial slime + mineral buildup

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Pre-treatment Video

Screen 1: 584’-596’

Screen 2: 620’-634’
Pre-treatment Video

Screen 3: 654’-714’

Screen 4: 730’-746’
Pre-treatment Video

Screen 5: 776’-800’

Screen 6: 810’-820’
Diagnosis

• Moderate to extensive biofouling
• Some mineral encrustation (likely CaCO₃)
• Some mud and clay clogging screen
• Screens 1, 2 & 3 up to 75% plugged
• Portions of screens 4 & 5 up to 100% plugged
• All of screen 6 was 100% plugged
• Fairly significant discrepancies in screen depths between well diagram and video survey
  – Screens 1, 2, and 3 ~ 10 ft higher than depicted in diagram
  – Screens 4, 5, and 6 ~ 5 ft higher than depicted in diagram
  – May have resulted in erroneous screen placement against zones with high clay content
Step-Drawdown Pumping Tests

- Pre-treatment and post-treatment tests performed
- Assess well performance (specific capacity, formation head loss, well head loss, efficiency)
- Provide benchmark for comparison between pre-treatment and post-treatment performance
- 4 steps at nominal 200, 400, 600, 800 gpm, 2 hours each
- Pump = 12 stage Goulds line-shaft turbine set at 760 feet between screens 5 and 6
Well Performance

Concrete pad

Static water level

Sanitary seal

Column pipe

Bentonite

Submersible pump

Filter pack

Screen
Well Performance

- **Components of drawdown**
  - **Formation head loss** = drawdown in aquifer due to hydrogeologic conditions
  - **Well head loss** = drawdown due to water passing through the filter pack and well screen
  - **Efficiency** = Formation loss/Total drawdown

![Diagram of well performance](image)
Pretreatment Step-Drawdown Test
Pretreatment Step-Drawdown Test

- First signs of trouble
  - Protective sounding tube for transducer unable to be installed due to tight fit between 9.5-inch diameter column pipe couplings and 10-3/8 inch diameter well screen
  - Transducer and cable strapped directly to column pipe
  - Impossible to get sounder down well after pump installed (hung up at ~ 400 ft)
  - Could not communicate with transducer at time of test
  - Had to rely on airline for all water level data during test
  - When test pump pulled, found transducer cable torn and severed in 2 places; operator reported misalignment in screened section caused tight fit for column pipe
Pretreatment Step-Drawdown Test
Pretreatment Step-Drawdown Test

- 200 gpm
  \( s = 26.2 \text{ ft} \)
- 400 gpm
  \( s = 52.3 \text{ ft} \)
- 600 gpm
  \( s = 78.5 \text{ ft} \)
- 800 gpm
  \( s = 105.3 \text{ ft} \)
Pretreatment Step-Drawdown Test

Specific Capacity vs. Discharge

Specific capacity should decrease at higher pumping rates
Treatment Chemistry

• Chemicals and application volumes provided by HCT, LLC
• Products marketed to well rehabilitation industry:
  • **WaterSolv BC** - treats slime forming bacteria, polysaccharides
    – MSDS lists 30-35% peroxide, 5-10% glycolic acid
  • **Well-Klean Concentrate (WKC)** - descaler, corrosion inhibitor, catalyst, sequestrant, dispersant, chelating & wetting agent
    – MSDS lists 30-40% glycolic acid, 5-10% proprietary ingredients (likely polyacrylamides, other organic acids?)
  • **Well-Klean Pre-blend (WKP-b)** - descaler
    – 90% HCl (34% active), 10% Well-Klean Concentrate
Treatment Process

- **Pre-clean** (April 4-6) - brush, swab with WKC- H$_2$O$_2$ mix: 5 mins/10-ft interval, soak time: none, bail
- **Remediation** (April 7-11) - brush, swab with WKC- H$_2$O$_2$ mix: 5 mins/10-ft interval (blank), 15 mins/10-ft interval (screen), soak time: 36 hours
- **Descaling** (April 12-13) - brush, swab with WKP-b: 1 min/10-ft interval (blank), 5 mins/10-ft interval (screen), soak time: 24 hours
- **Neutralization** (April 14) - brush, swab with sodium bicarbonate/water mix: 3 min/10-ft interval (blank), 5 mins/10-ft interval (screen)
- **Development** by swabbing/pumping (April 18-24)
- **Development** by pumping (June 14-15)
- Implementation took 20 days through swabbing/pumping; 72 days to complete treatment field work
Treatment Process Difficulties

- WaterSolv BC used in the pre-clean and remediation steps
- Provided as 2 components due to “DOT shipping limitations and logistics”: Well-Klean Concentrate (WKC) and peroxide shipped separately & Alpha SW crew instructed to mix on site
- HCT provided multiple revised mixing volumes during project
  - Mixture specified 2/20/17 = 293 gals $\text{H}_2\text{O}_2$ (91%) + 30 gals WKC (9%)
    - pre-clean: 3.2 gals/10 ft (screen), 3.0 gals/10 ft (blank)
    - remediate: 7.8 gals/10 ft (screen), 8.4 gals/10 ft (blank)
  - Mixture specified 4/6/17 = 293 gals $\text{H}_2\text{O}_2$ (73%) + 110 gals WKC (27%)
    - pre-clean: 2.7 gals/10 ft (screen), 2.9 gals/10 ft (blank)
    - remediate: 8.5 gals/10 ft (screen), 9.1 gals/10 ft (blank)
  - Mixture specified 4/7/17 = 70 gals $\text{H}_2\text{O}_2$ (78%) + 20 gals WKC (22%)
Treatment Chemistry

- H₂O₂ = weak acid & powerful oxidizer
- In acidic solutions Fe²⁺ is oxidized to Fe³⁺
- 2 Fe²⁺(aq) + H₂O₂ + 2 H⁺(aq) → 2 Fe³⁺
- Activation energy of the reaction of H₂O₂ with iron oxide determined to be 32.8 kJ/M (Lin, Shu-Sung & Gurol, Mirat, 1998)

1 Joule = the energy transferred to an object when a force of one newton acts on that object through a distance of one meter; 1 newton of force is the force required to accelerate an object with a mass of 1 kilogram 1 meter per second per second.
Reaction of $\text{H}_2\text{O}_2$ with $\text{Fe}^{3+}$
Brush and Swab Tool
Pre-Clean/Remediate
Pre-Clean/Remediate
Pre-Clean/Remediate
Pre-Clean/Remediate Challenges & Hazards

• Have to use drill pipe because the H$_2$O$_2$-acid mixture eats up regular steel pipe
• Issues with pressure buildup
• Pressures in Well 3 reached 120 psi
• Had to bleed off pressure slowly & swab longer to calm reaction
• Alpha SW had recently performed same procedures for ABCWUA; Leyendecker #1 Well reportedly experienced pressures as high as 240 PSI causing chemicals to spout over 50 ft into the air
Pre-Clean/Remediate Challenges & Hazards

• During remediate step, ~50 ft of drill pipe connected to the 12” swab tool blew out immediately after adding chemicals at bottom of blank casing 1st thing Sat. morning
• Pipe bent over and broke off, falling on roof of adjacent building
• Remaining pipe string and swab tool fell to 1 joint off bottom
• 12” swab stuck in 10-3/8” screen
• Took 1-½ days to pull out
• Resumed swabbing blank section without rubber discs and no more H₂O₂
Descale/Development/Neutralization

- Descale treatment with HCl mixture completed without incident
- Pumping/swabbing development proceeded for minimum 2 hrs 15 mins for each 30-ft screen segment
- pH at beginning of pumping/swabbing ~5.9
- Discharge recirculated while pH was lower than 6.9
- Continued to add NaHCO₃ to raise pH while swabbing
- Once pH reached 6.9, discharged into drain
Development/Neutralization
Development/Neutralization
Final Steps

• Pumping development conducted for ~14 hrs on 6/14 and 6/15
• Gradually increased pumping rates with periodic surging, got up to 770 gpm
• At conclusion of pumping, specific capacity reached 8.9 gpm/ft, 7.8 pH
• Post-treatment step-test ran on 6/20
• Four 2-hour steps at 200, 400, 600 and 800 gpm
• Post-treatment video survey
Step-Drawdown Test Results

Pre-Treatment/Post-Treatment Drawdown Hydrographs

Elapsed Time (minutes)

Pre-Treatment Drawdown (ft)
Post-Treatment Drawdown (ft)
Step-Drawdown Test Results

Pre-Treatment & Post-Treatment Specific Capacity vs. Discharge Comparison

\[ y = -0.0010700x + 8.5756417 \]
\[ R^2 = 0.9374250 \]

Discharge Rate (gpm)

Specific Capacity (gpm/ft)

- Pre-treatment
- Post-treatment
- Linear (Post-treatment)
Step-Drawdown Test Results

Pre-Treatment/Post-Treatment Head Loss Comparison

<table>
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<tr>
<th>Drawdown (ft)</th>
<th>Q (gpm)</th>
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<tr>
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<td>90</td>
<td>900</td>
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<td>100</td>
<td>1000</td>
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</tbody>
</table>

- Pre-Treatment Well Loss
- Post-Treatment Well Loss
- Pre-Treatment Formation Loss
- Post-Treatment Formation Loss
- Pre-Treatment Total Drawdown
- Post-Treatment Total Drawdown
Step-Drawdown Test Results

Pre-Treatment/Post-Treatment Efficiency Comparison

- Pre-Treatment Efficiency
- Post-Treatment Efficiency
Post-treatment Video

Screen 1: 584’-596’

Screen 2: 620’-634’
Post-treatment Video

Screen 3: 654’-714’
Screen 4: 730’-746’
Post-treatment Video

Screen 5: 776’-800’

Screen 6: 810’-820’
## Pre-treatment and Post-treatment Screen Conditions

<table>
<thead>
<tr>
<th>Screen</th>
<th>Pre-treatment</th>
<th>Post-treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Depth From (ft btoc)</td>
<td>Depth To (ft btoc)</td>
</tr>
<tr>
<td>Screen #1</td>
<td>574</td>
<td>586</td>
</tr>
<tr>
<td>Screen #2</td>
<td>611</td>
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<td>Screen #5</td>
<td>771</td>
<td>795</td>
</tr>
<tr>
<td>Screen #6</td>
<td>806</td>
<td>813*</td>
</tr>
</tbody>
</table>

*Top of fill Screen 5-6

Weighted average:
- Screens 1-4: 53
- Screens 5-6: 89
- Top of fill Screens: 17

*Top of fill
Conclusions

• Use of HCT’s chemicals is extremely hazardous
• Precautions must be taken to mitigate high pressure buildup and avoid contact with hazardous chemicals
• HCT seems to lack a rigorous QA/QC process to assure that chemical volumes are accurate and based on actual well conditions
  – Multiple revisions of mixing instructions during project were confusing to field crew
  – Designated application volumes difficult to measure accurately (volumes derived by tape measure on side of 300 gallon tote)
Conclusions

• Significant improvements in the amount of clogging were seen in screens 1, 3, and 4
• Screens 5 and 6 saw reduced levels of improvement, likely due to apparent lack of flow in this part of the well
• The well now has a high level of efficiency (91 percent at 600 gpm) and could be operated at rates of 800 to 1,000 gpm with efficiency levels of about 85 to 88 percent
• Available data indicates a modest improvement in specific capacity and drawdown
• Specific capacity decline between development and step test and amount of sediment bailed indicates that the well is making sand
Conclusions

• Despite challenges and hazards the project was largely successful in cleaning up bacterial slime and mineral encrustations in upper screens
• Clogging of lower screens persists due to lack of flow
• Despite blowout and jamming of oversize swab into screens, there was no damage to the well
• No one was injured!!
• Well 3 should continue providing good production capacity for many years but will likely require periodic maintenance due to sanding issue
Questions?