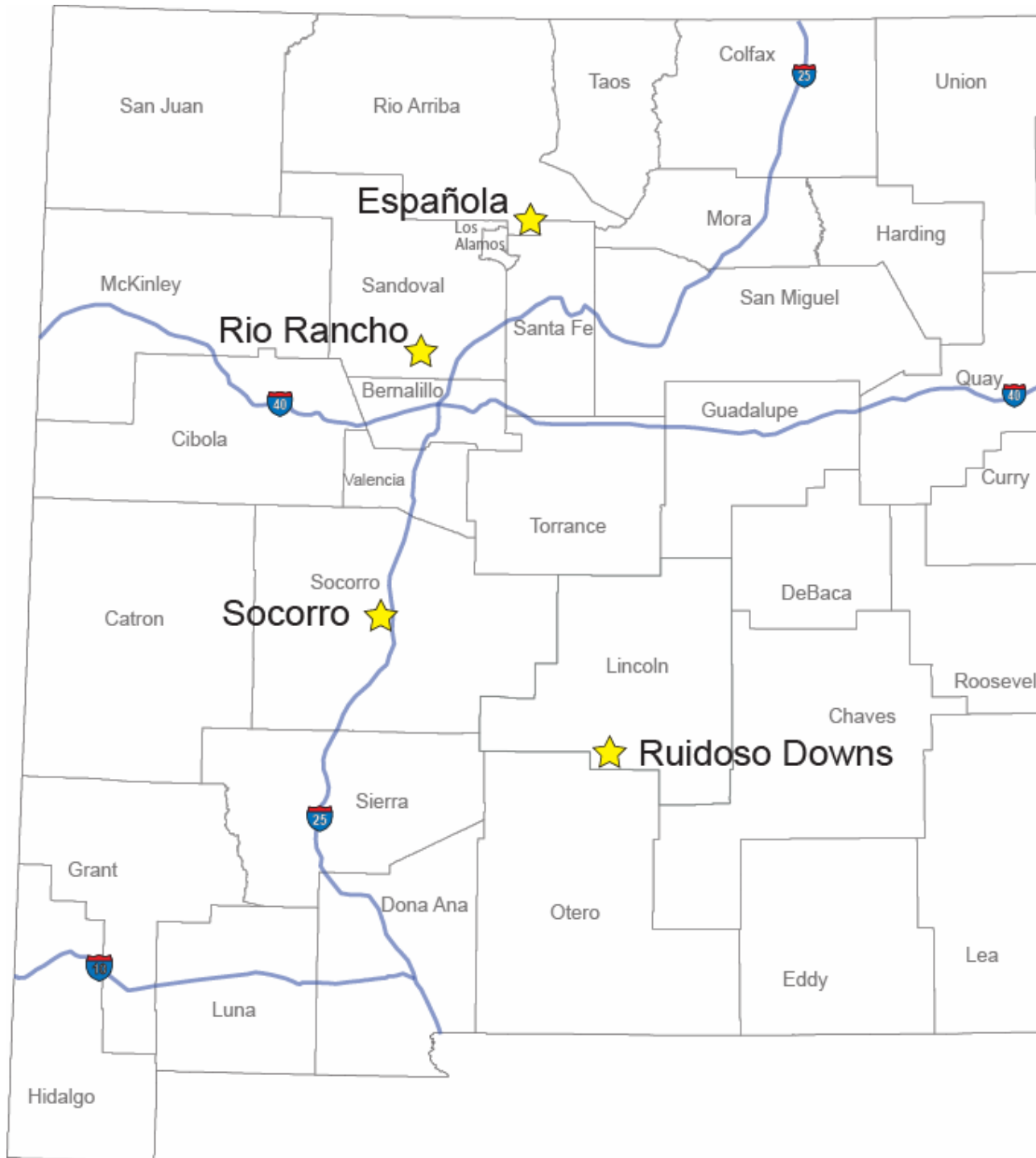


Analysis of Various Water Quality Zone Testing Methods – Case Studies and Results

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Project Locations



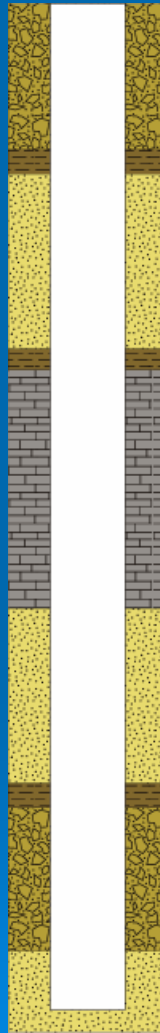
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Four Zone Sampling Methods

- Gravel Envelope
- Open hole straddle packer
- Cased hole, straddle packer
- Cased hole, production pump with spinner log and down hole sampling apparatus



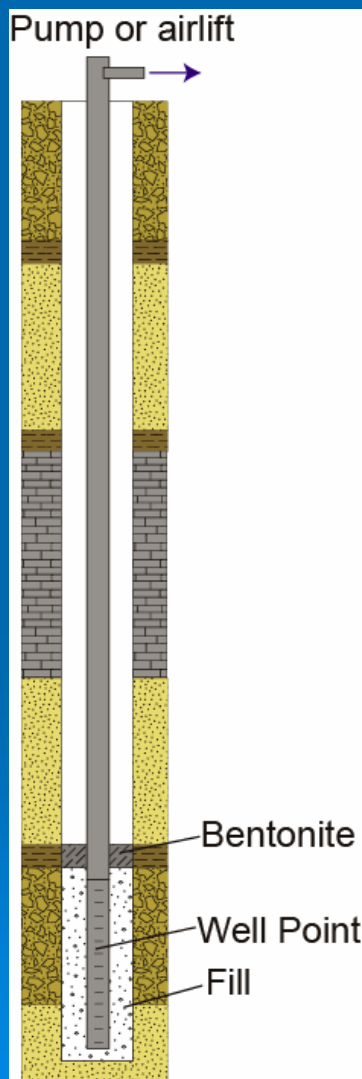
Gravel Envelope Method, Overview



- Drill to TD, log cuttings, run geophysics
- Select Zones
- Use low permeability units (shale, clay) to separate zones if possible



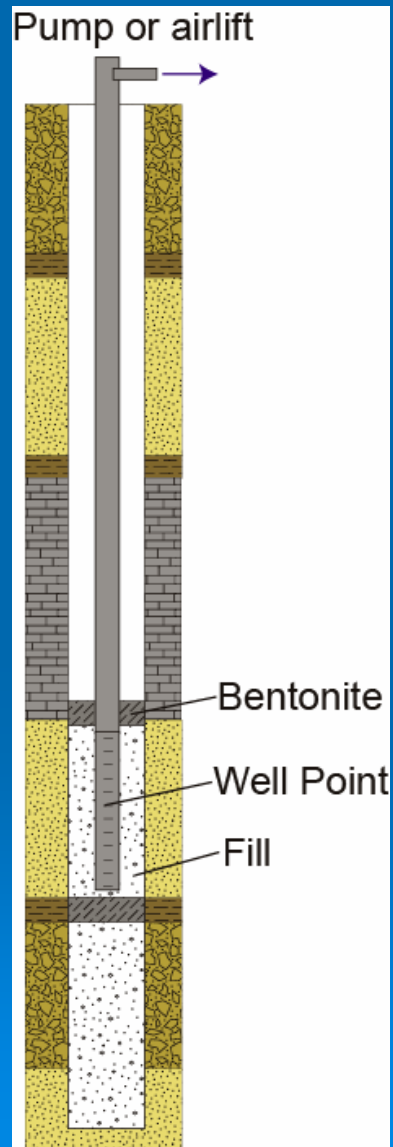
Gravel Envelope Method, Overview



- Run well point or perforated pipe to selected zone
- Backfill around screen (silica sand, pea gravel, or natural fill)
- Install Bentonite seal
- Pump or airlift until water quality stabilizes, collect sample for analysis



Gravel Envelope Method, Overview



- Trip to next zone
- Add fill and bentonite
- Collect sample
- Repeat until uppermost zone is sampled

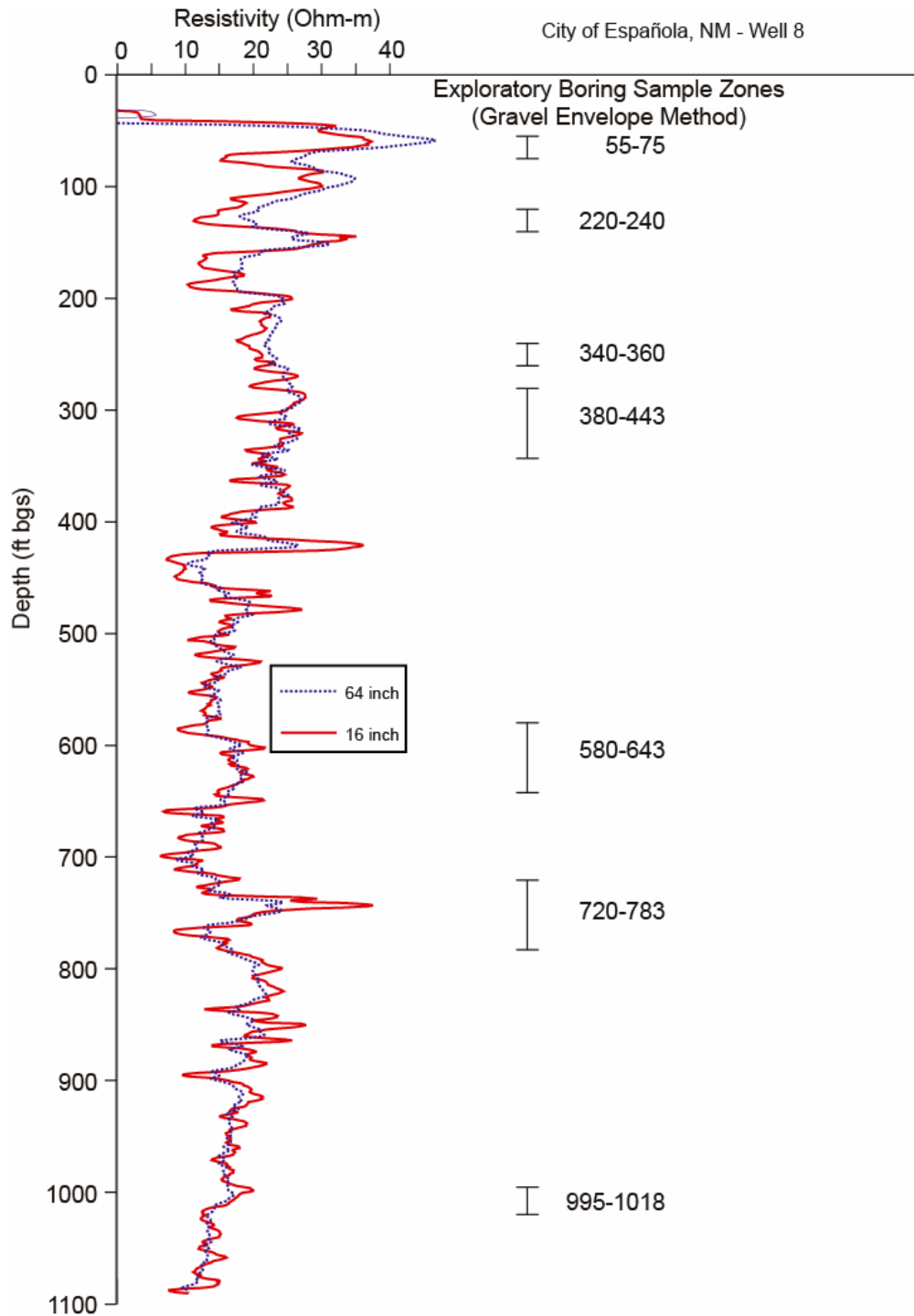


Española



- Well drilled in 2002
- Drilled in Santa Fe Group sediments within the Española Basin (Rio Grande Rift)
- Anticipated problems with nitrate, arsenic, fluoride, and radionuclides
- Tested using gravel envelope method

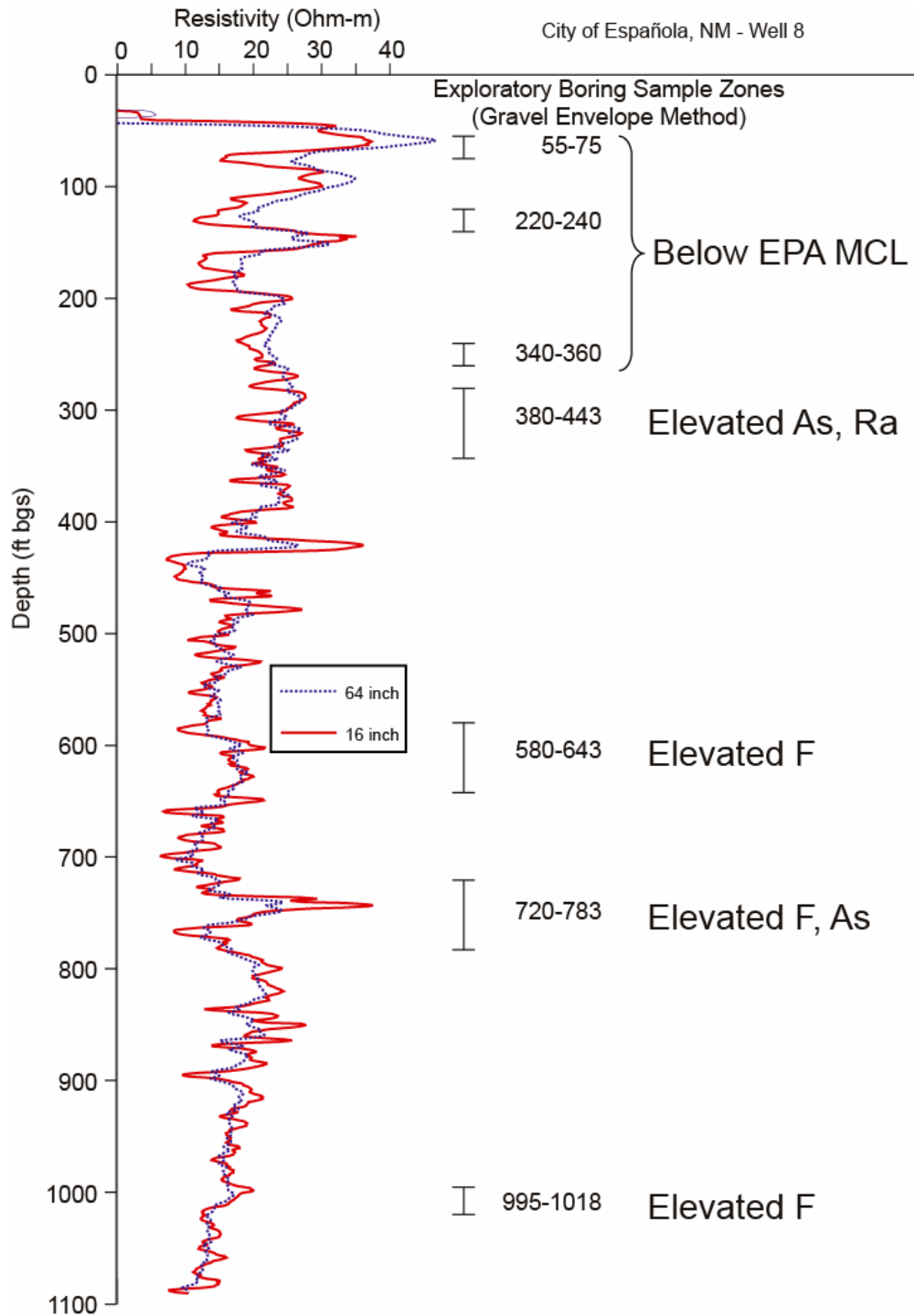




- Samples collected from seven zones
- Zones separated by clays identified in cuttings and geophysical logs (where possible)



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Results

- Production well completed to 450 ft
- All constituents within EPA primary standards
- Fluoride (3.3 mg/l) exceeds secondary standard of 2.0 mg/l
- Produces 275 gpm



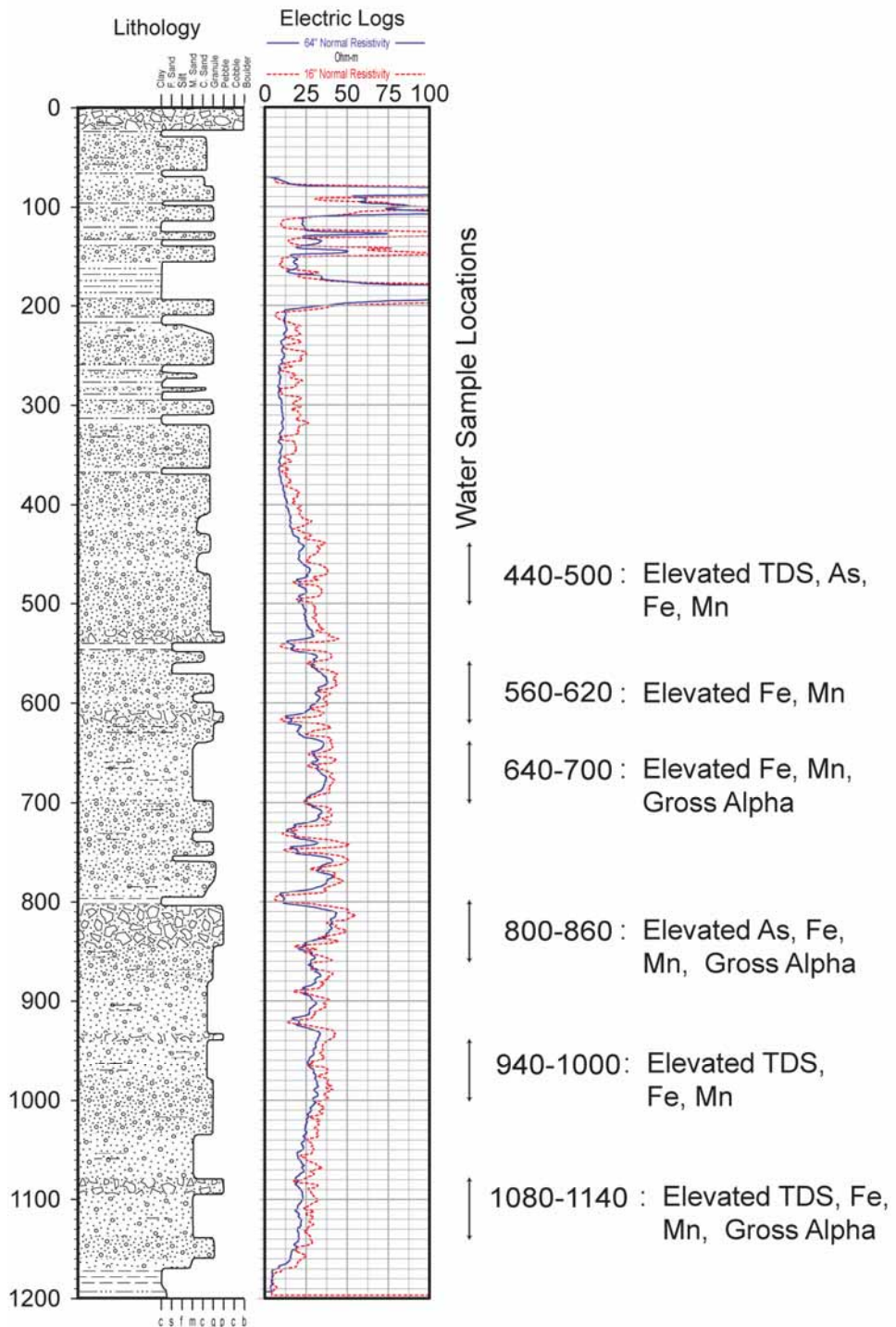
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Socorro

- Test well drilled in 2004
- Drilled in Santa Fe Group sediments within the Socorro Basin (Rio Grande Rift)
- Anticipated problems with TDS, arsenic, iron, manganese and radionuclides
- Tested using gravel envelope method



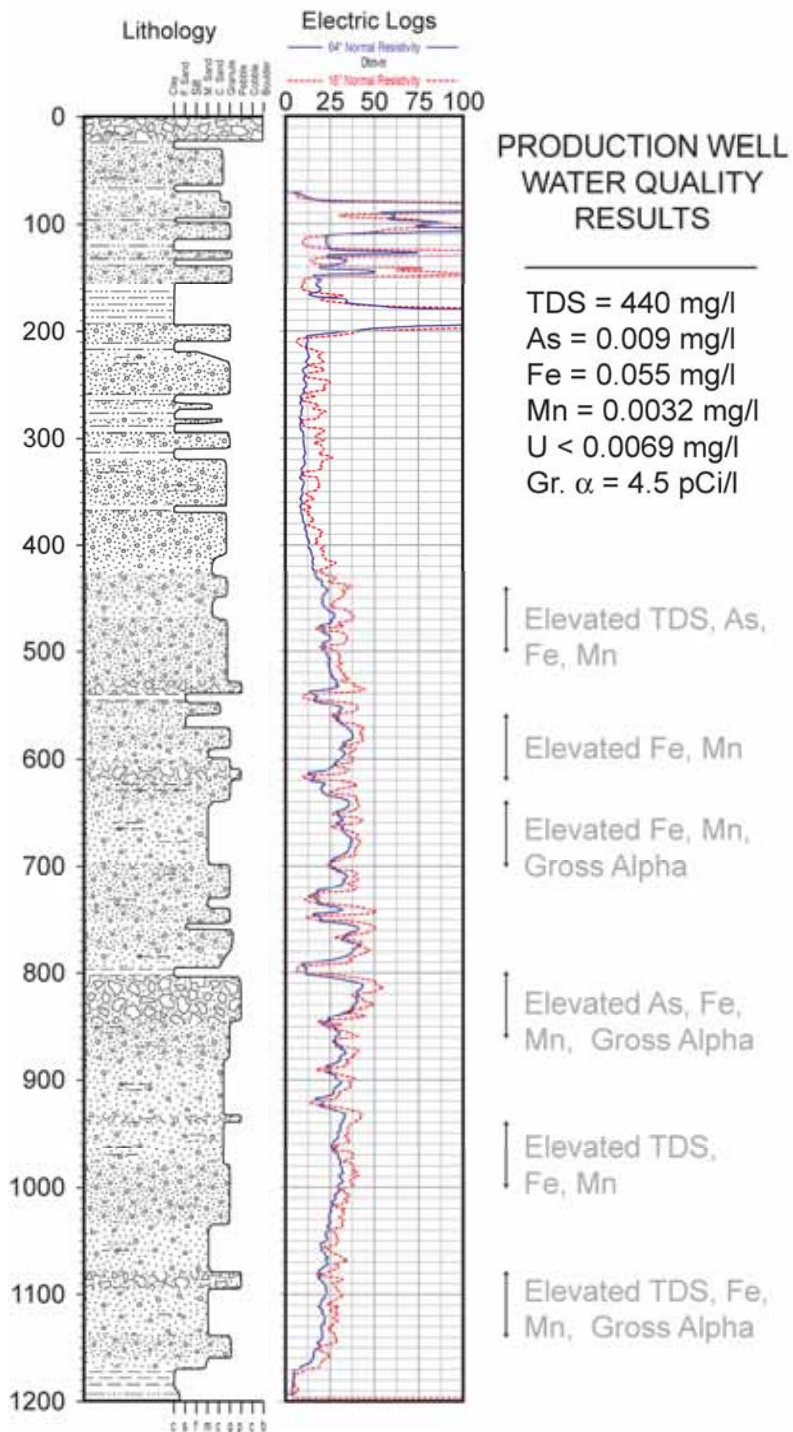


Results

- All zones had two or more constituents above EPA primary or secondary standards
- Designed production well to minimize TDS, allowing easier treatment of other constituents
- But.....



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Results/Interp.

- In production well, all constituents are below primary and secondary standards
- Produces in excess of 3200 gpm
- Blending of zones resulted in lower TDS, As, and Gross Alpha
- Pipe dope or the pipe itself contributed Fe and Mn???



Gravel envelope method: Conclusions

- Gravel envelope method using drill string not recommended if iron/manganese are constituents of concern
- Gives a good accounting of concentrations in zones sampled, but cannot provide a good estimate of production from zones
- Mixing proportions cannot be determined accurately without production information
- For best results, zones need to be large enough and cover enough of the aquifer to adequately characterize water quality
- Can get unexpected results, but overall quality is better when poor quality zones are identified and sealed off



Gravel envelope method: Other considerations

- Relatively inexpensive
- If water quality is all poor, can abandon hole with minimal capital loss
- Must ream hole or drill adjacent hole if casing is to be installed
- Ideal for poorly consolidated sediments where it is impractical (imprudent) to run packer assemblies and cost limitations prevent running casing in test well



Open Hole Straddle Packer

- Only suitable in hard rock/well lithified sedimentary rock settings
- Ideal in settings with good low-permeability interbeds to separate zones
- Allows well to be designed and installed with only one additional reaming pass



Methodology

- Run two packers separated by perforated pipe
- Start at bottom of hole, work up to top of hole, may have to trip pipe to change spacing
- Pump placed above packers
- Air line for each packer to inflate/monitor pressure
- Inflate packers (adjacent to low permeability units), pump until field parameters (T, pH, conductivity) stabilize
- Collect sample for lab analysis
- Repeat in each overlying zone



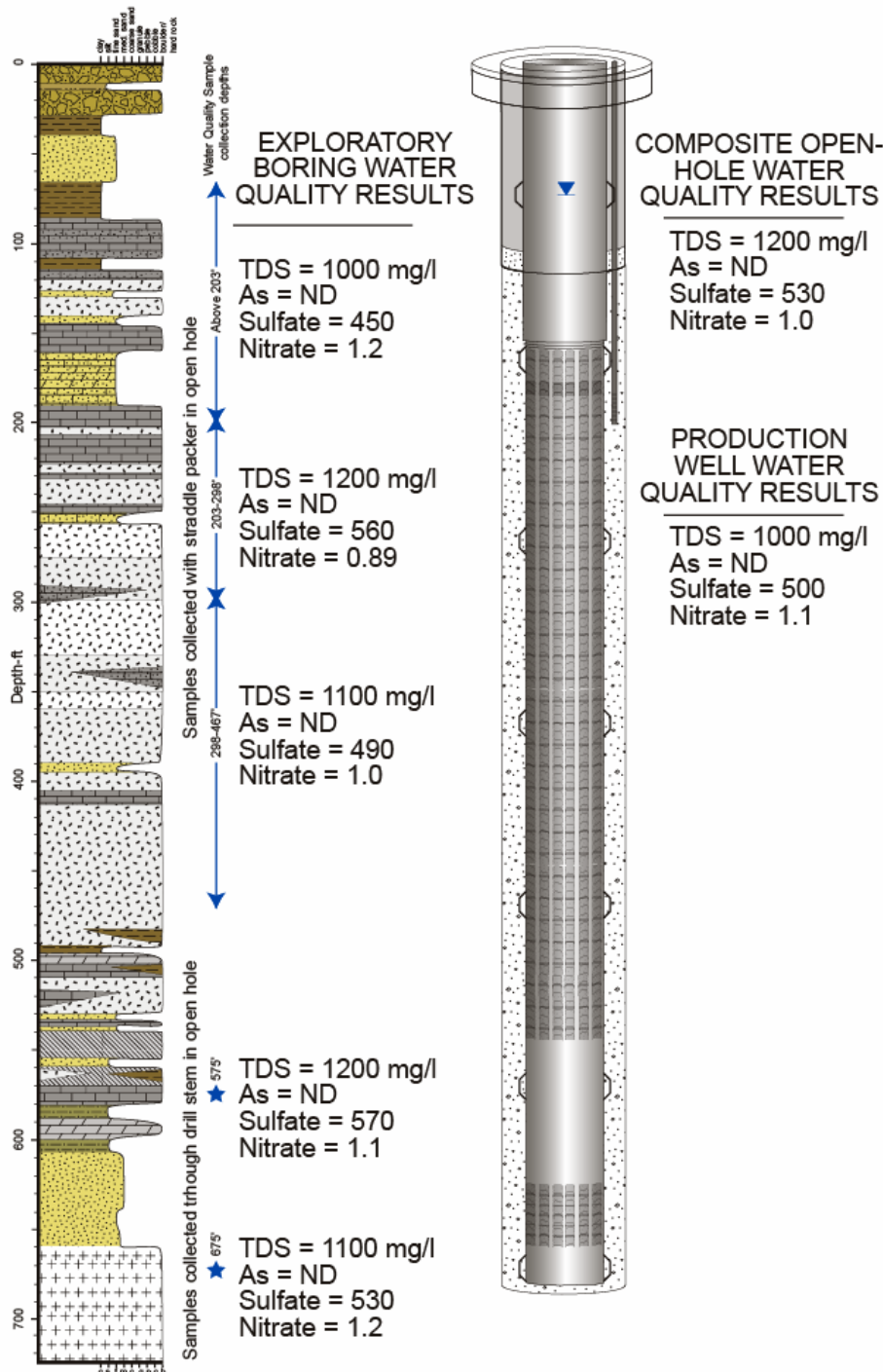
Ruidoso Downs

- 720 ft deep test well
- Well lithified but highly fractured Permian sandstone, limestone, shale, and evaporites, intruded by diorite sills
- TD in Precambrian granite
- Primary concerns were TDS, sulfate, arsenic, nitrate



EXPLORATORY BORING

PRODUCTION WELL



Issues / Solutions

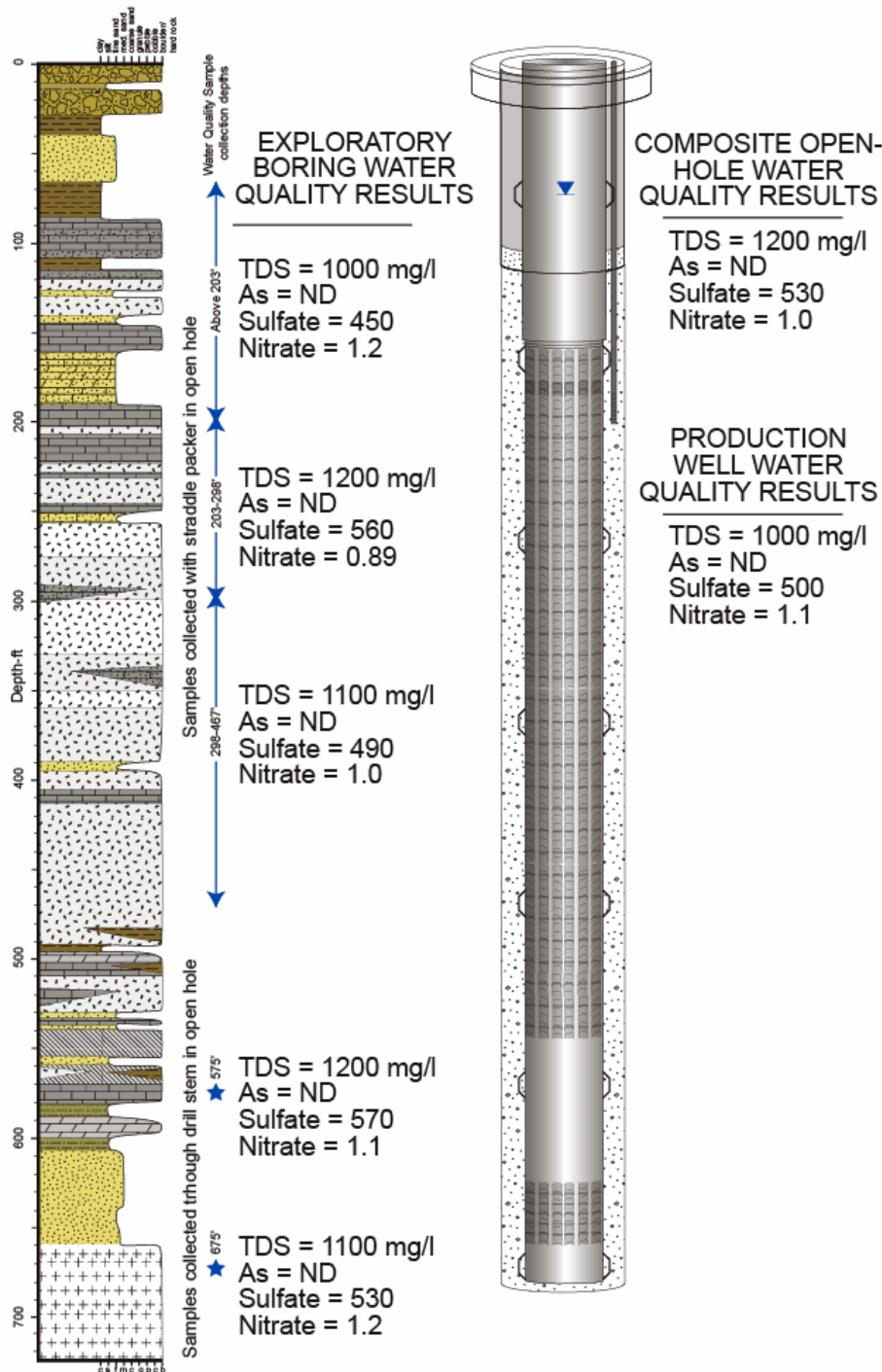
- 7 7/8" hole couldn't be advanced below 467 ft
- Collected 3 samples above 467 ft with straddle packer
- Drilled 17 7/8" hole reverse circulation to TD
- Collected 2 samples through the drill string below 467 ft
- Installed test pump in open hole, 300 gpm for 500 min, collected composite sample



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EXPLORATORY BORING

PRODUCTION WELL



Results

- Water quality relatively uniform throughout
- Blanked off High TDS/sulfate (gypsum rich) interval, resulting in improved overall water quality



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Cased Hole Straddle Packer

- Suitable for any geologic setting
- Most effective in settings with good low-permeability interbeds to separate zones
- Proper well design and construction are critical for success



Methodology

- Drill test boring
- Select zones for sampling based on lithologic and geophysical logs
- Complete well with annular seals above and below each screened interval
- Develop entire well until water is clean
- Collect samples from each zone using straddle packer assembly



Rio Rancho

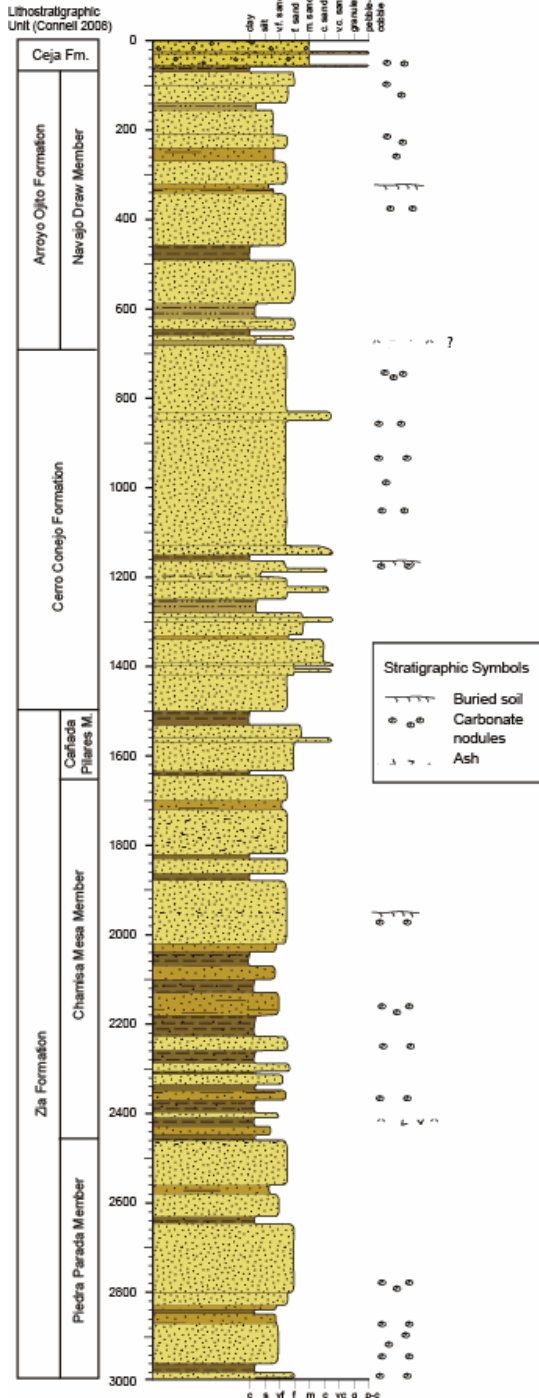


- 2990 ft deep test well
- Poorly to moderately lithified sand, silt, and clay
- Primary concerns were TDS and arsenic

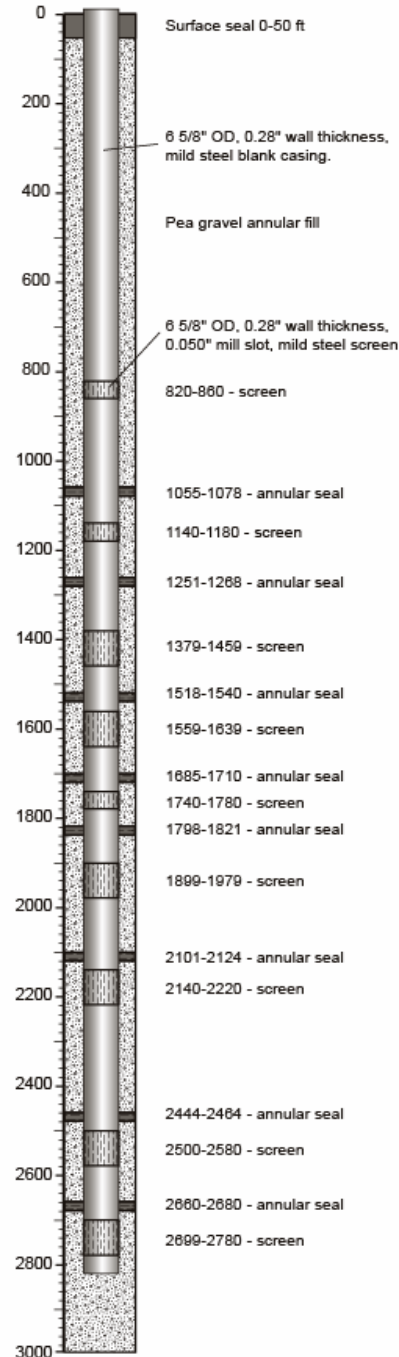


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Rio Rancho Well 23 Lithologic Log



Rio Rancho Well 23 exploratory well completion schematic

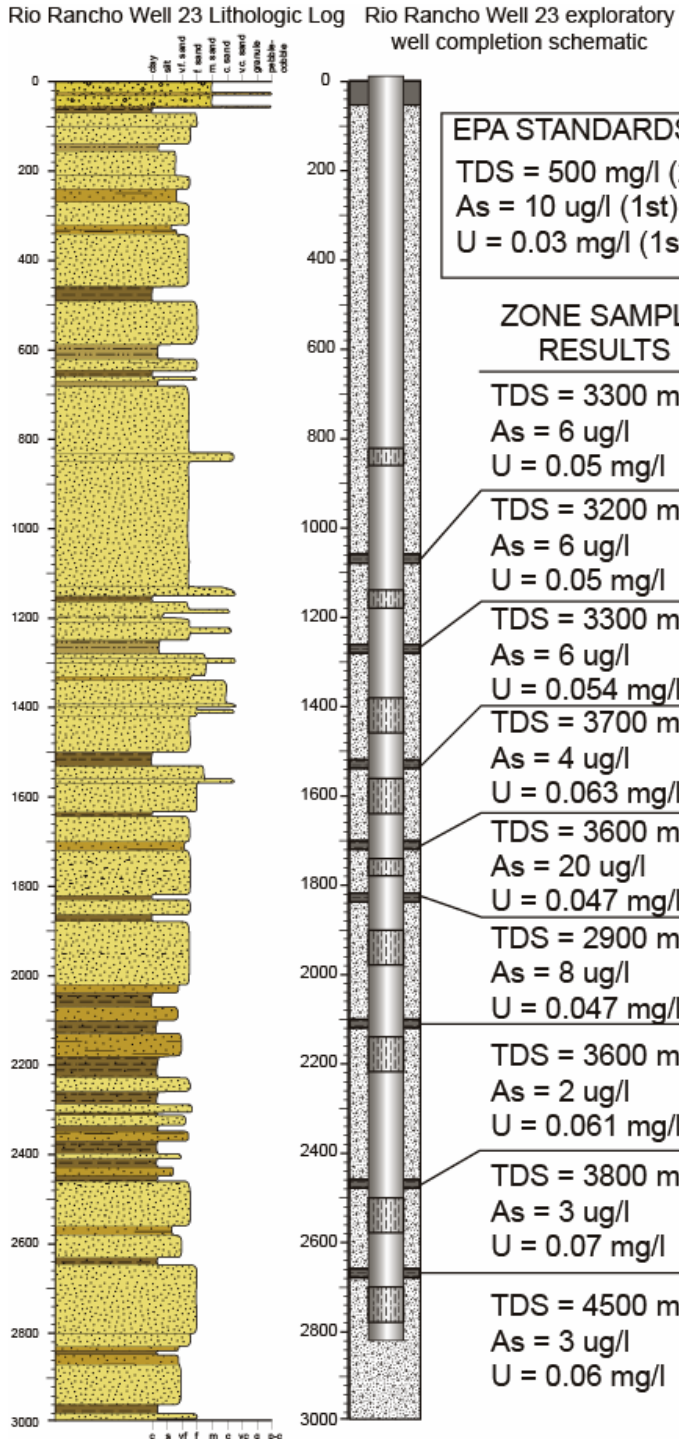


Design, Completion, & Sampling

- 9 zones selected
- None below 2800 ft based on geophysics
- Annular seals installed
- Well was developed on 12 hr/day schedule
- 5 days elapsed between development and start of sampling
- Samples collected over 4 days
- Sand produced in all zones



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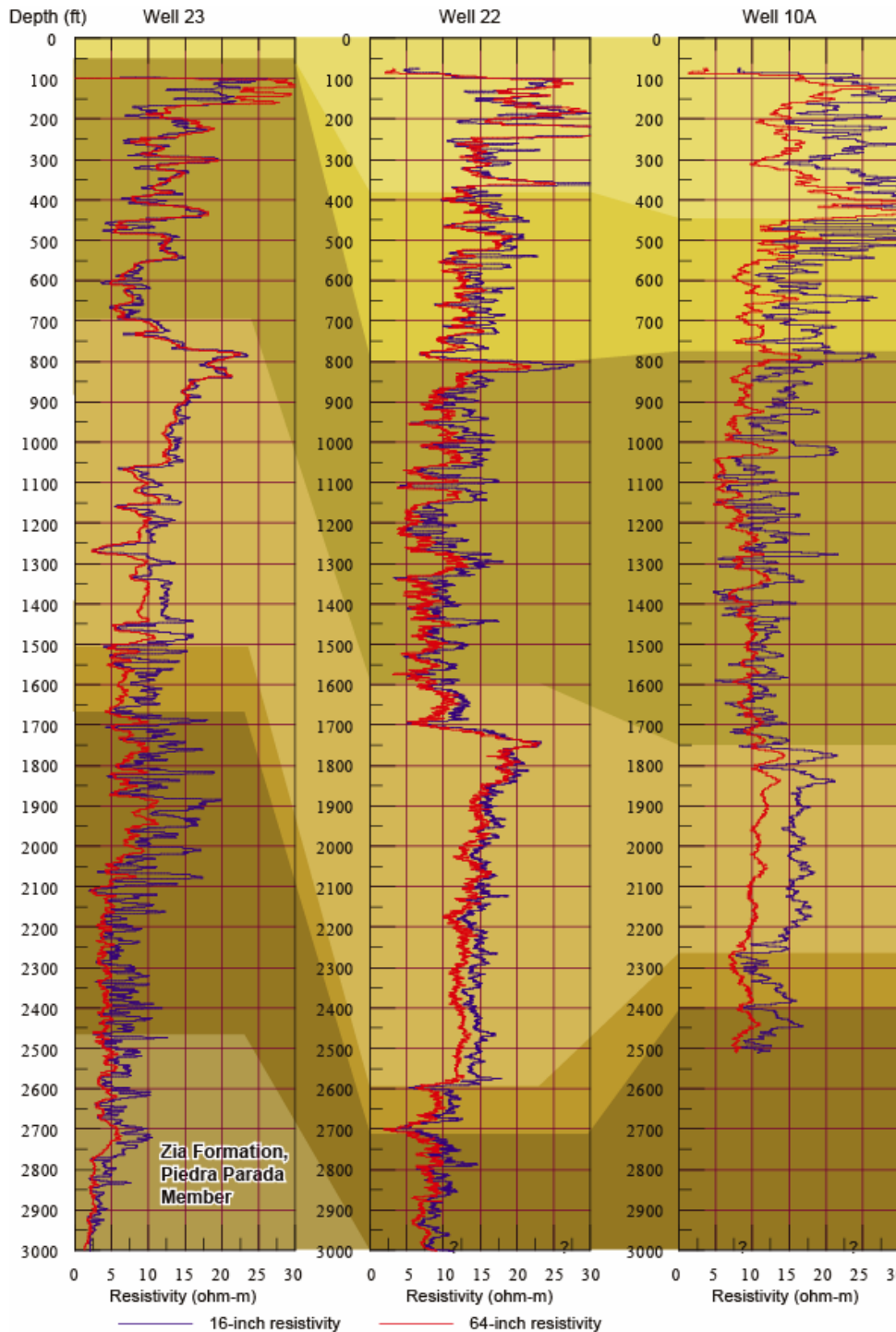


Preliminary Results

- All zones exceed EPA standards for TDS, U
- One zone exceeded EPA standard for As
- Very different water quality from other similar wells in area



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Interpretation

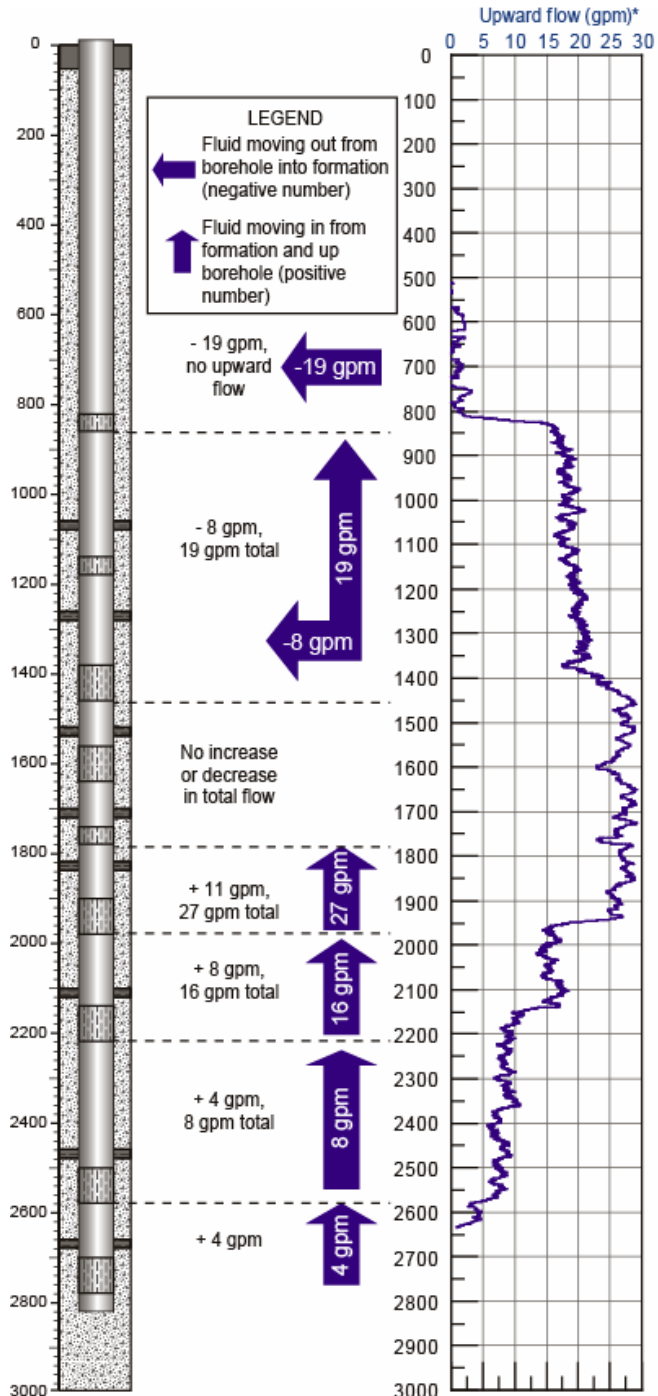
- Well 23 penetrates deeper section than other deep wells
- Deepest zone had worst water quality
- Could significant upward flow from deep zone be skewing water quality in upper zones?



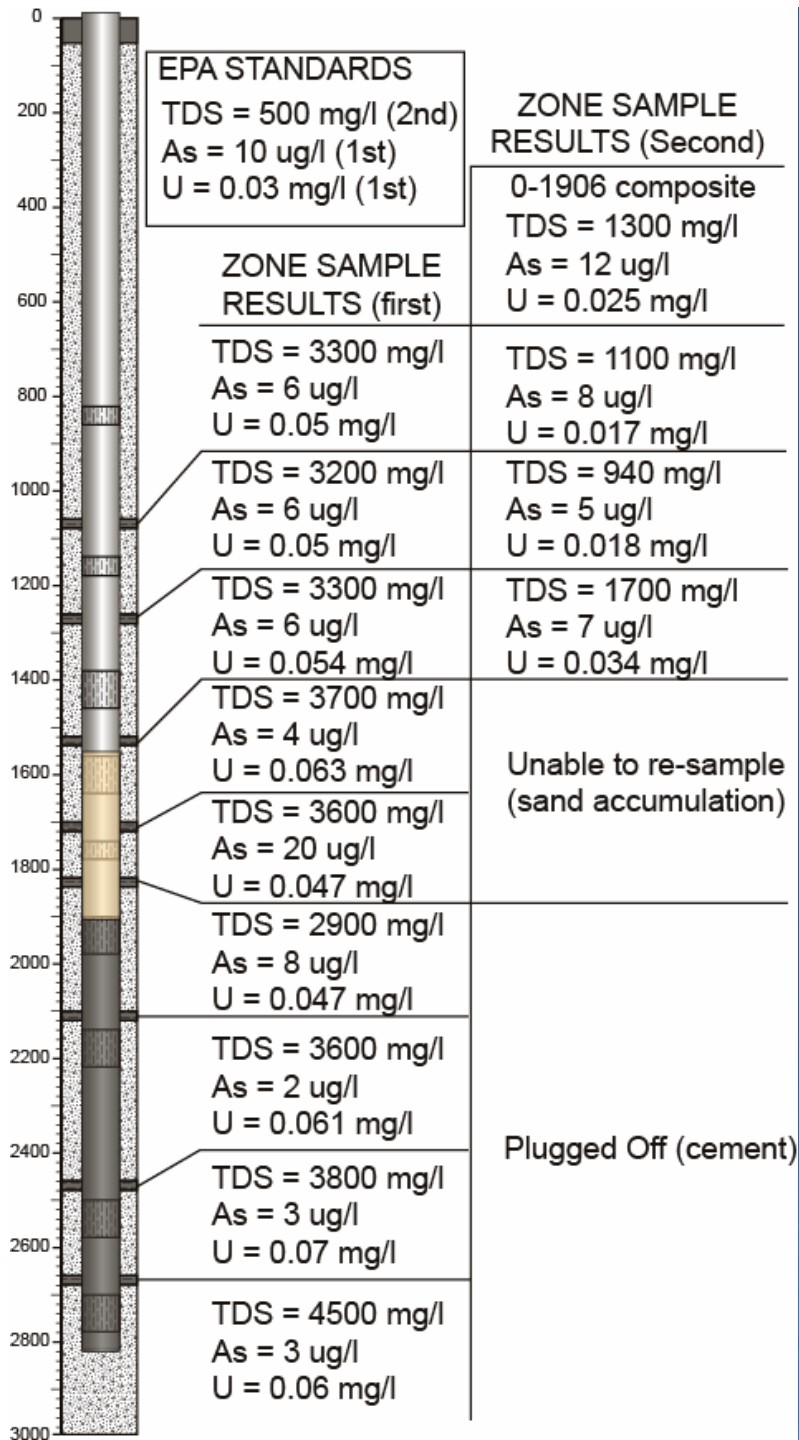
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Investigation

- Ran static spinner log in well
- Significant upward flow from deep zones
- Delay in sample collection allowed poor quality water to flow into upper intervals, resulting in bad sample data.



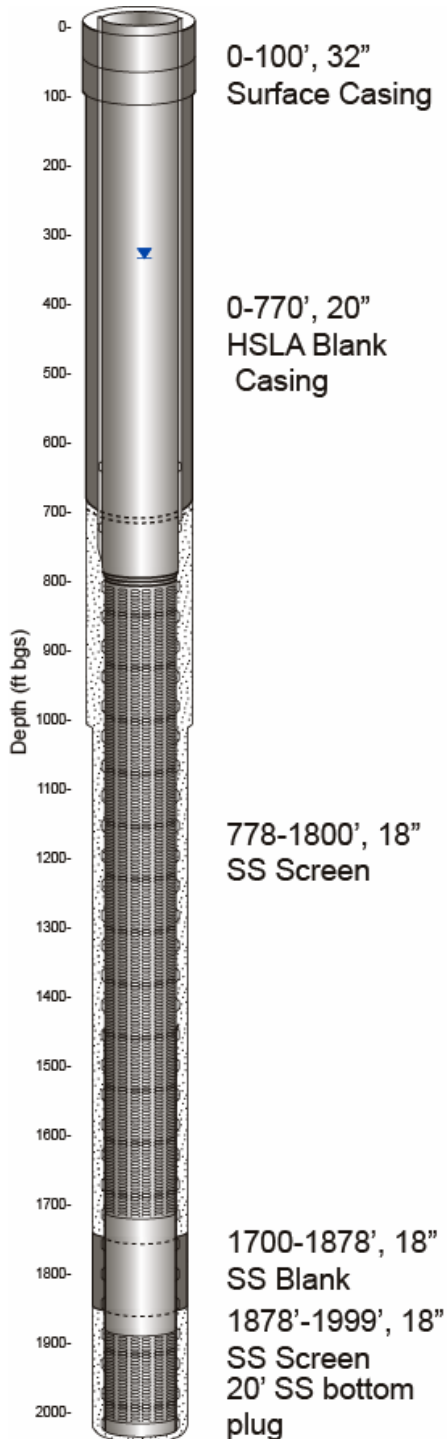
*GPM is approximate; see discussion in text of flow calculation from spinner log



Re-Sample

- Plugged well back to 1900 ft
- Airlifted until water stabilized (137 hours), Cond. decreased from 4070 μS to 1752 μS
- Collected composite sample at end of airlifting



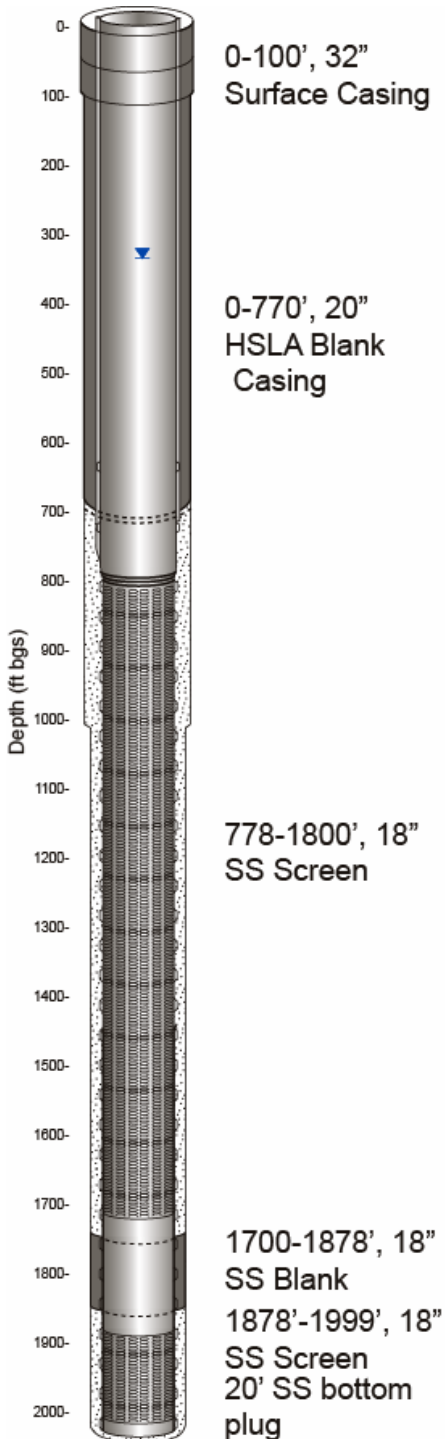


Production Well Design

- Screen upper zones of 'known' water quality
- Blank off 1700-1878' based on preliminary high As sample
- Screen 1878-1999' based on geophysical logs, need for production



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Production Testing

- Seven day test at 3008 gpm, 173 ft of drawdown ($Q/s=17.4$ gpm/ft)
- TDS = 1400 mg/l
- As ranged from 11.9 to 12.7 mg/l
- $U = 0.0232$ mg/l



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Rio Rancho - Continued

- Production well design significantly reduced both TDS and U. However....
- Reducing TDS from 1400 to 1250 and reducing As could save City up to \$5M over 20 years
- Conducted dynamic sampling in Well 23 production well

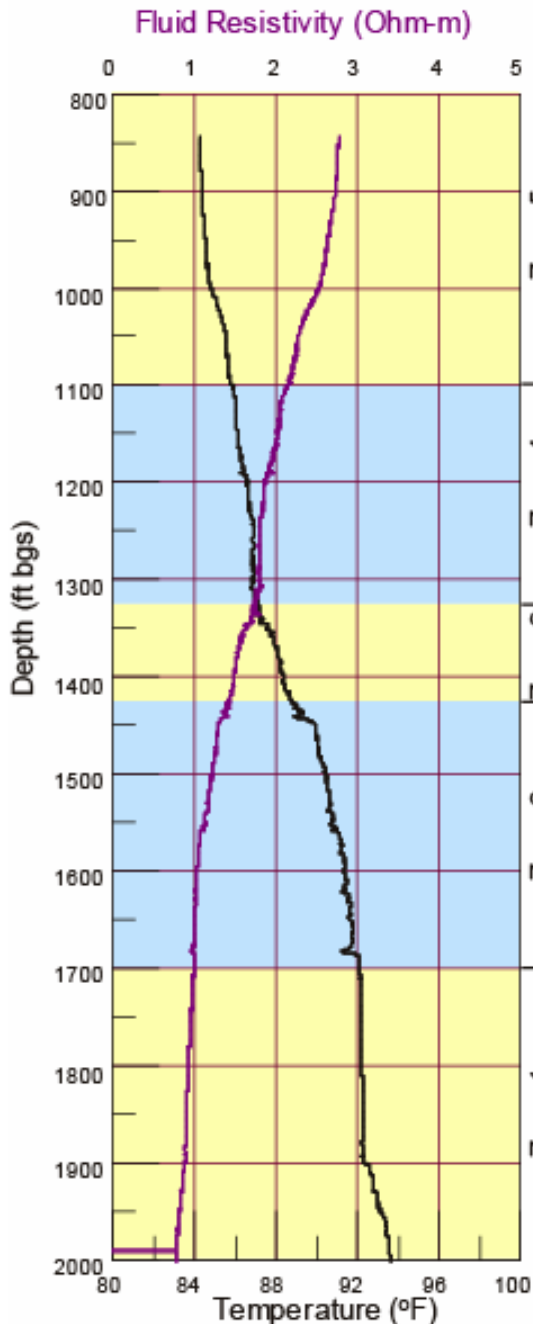


Cased hole, production pump with spinner log and down hole sampling apparatus

- Run dynamic spinner log in well while pumping at anticipated production rate
- Collect samples from down hole with automated sampling unit
- Do mass balance calculations to determine final concentrations in production well



Fluid Resistivity and Temperature Logs



Spinner Log Interpretation

Values reported are reported for each zone based on mass balance calculations

Zone 5
Flow = 674 gpm, TDS = 524 mg/l,
As = 0.028 mg/l, U = 0.0155 mg/l

Zone 4
Flow = 887 gpm, TDS = 1229 mg/l
As = -0.007 mg/l*, U = 0.0261 mg/l
*Anomalous arsenic data - possibly the result of a problem with the sampling apparatus

Zone 3
Flow = 798 gpm, TDS = 1887 mg/l
As = 0.017 mg/l, U = 0.0405 mg/l

Zone 2
Flow = 159 gpm, TDS = 2729 mg/l
As = 0.029 mg/l, U = 0.0399 mg/l

Zone 1
Flow = 360 gpm, TDS = 2110 mg/l
As = 0.019 mg/l, U = 0.0438 mg/l

Results

- 5 zones identified from T/Fr logs
- Samples collected from each zone
- Mass balance used to determine zonal contribution to well



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Results - Continued

- Mass balance calculations indicated plugging well back to 1475 ft would improve water quality
- City chose to plug the well to reduce treatment costs

Constituent	Predicted Value	Final Value in Plugged Well
Discharge	2360 gpm	2440 gpm
TDS	1250 mg/l	1200-1350 mg/l
As	11 ug/l	11 ug/l
U	0.028 mg/l	0.022 mg/l



Lessons Learned from Rio Rancho Cased Hole Straddle Packer and Dynamic Sampling

- In deep wells where artesian flow may be encountered, run a spinner log to rule out (or quantify) upward flow
- Do not allow any delay between development and testing!
- Results need to be interpreted in the context of regional geology/hydrology
- Dynamic sampling provides excellent predictive results – often too late, and at significant cost



Summary and Conclusions

- Each method has pros and cons in terms of cost, data quality, and applicability to particular hydrogeologic settings
- Limitations (and benefits) of each need to be recognized and made clear to the client prior to onset of a project
- In all cases, despite problems/unforeseen conditions, water quality was improved by conducting a testing program prior to production well construction



Questions?

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