Challenges in Deep Exploration and Brackish Groundwater Development

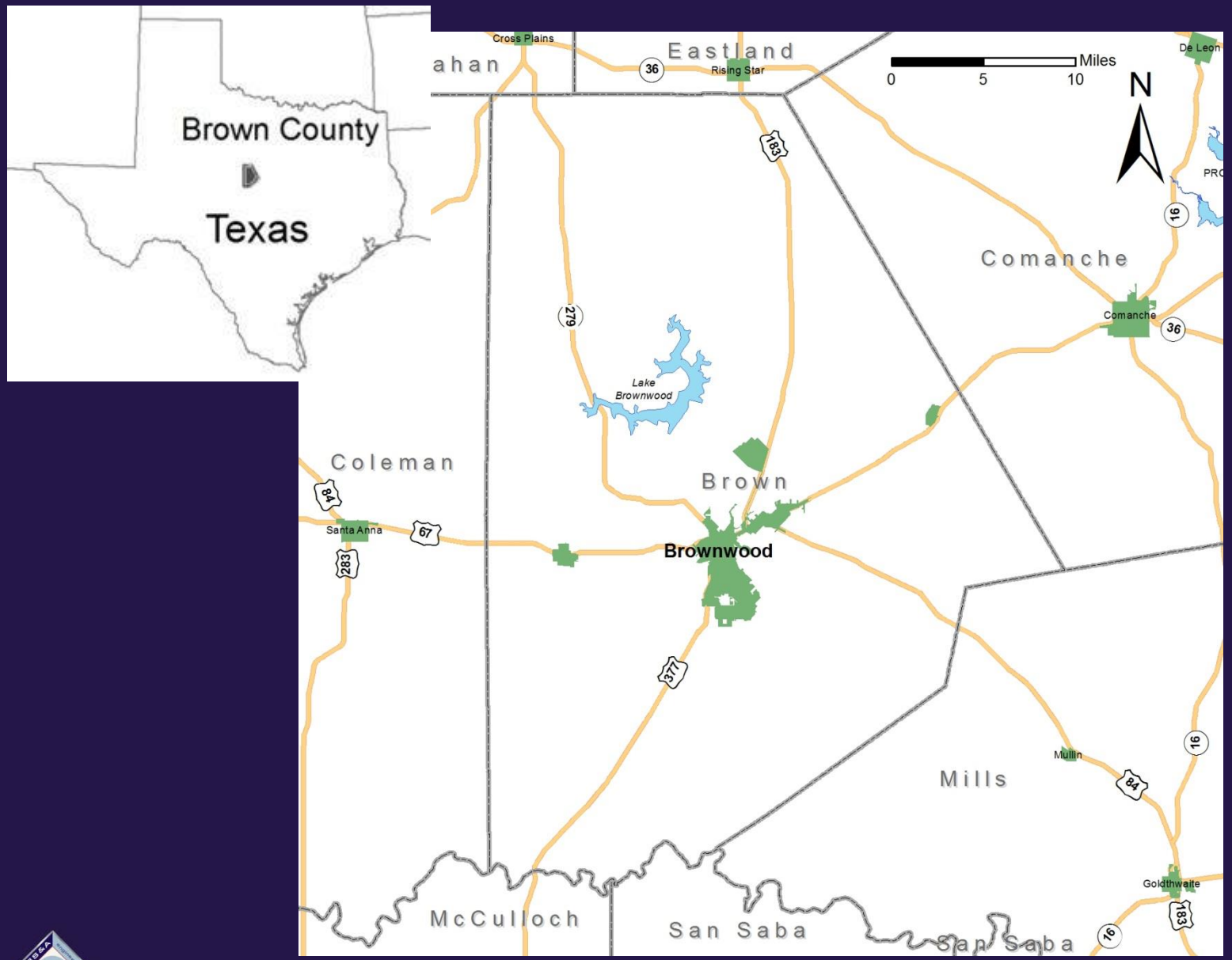
Brown County Water Improvement District No. 1 – Exploration Well

Andrew Donnelly, P.G.
Daniel B. Stephens & Associates, Inc.

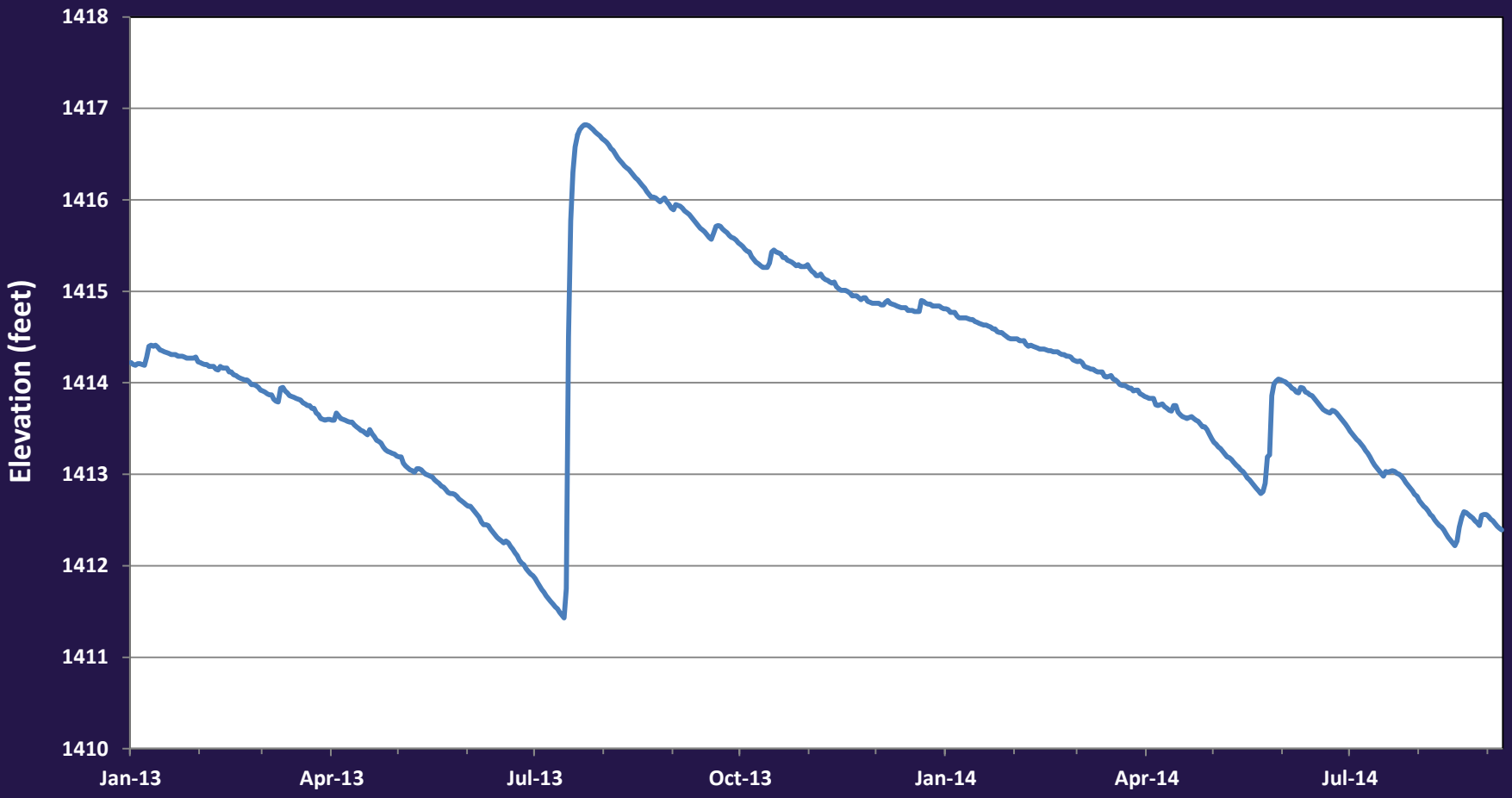
William Gamblin, P.E.
Apex Geoscience, Inc.

Brown County Water Improvement District #1

- Water supplier for most of Brown County and some of Coleman County
  - City of Brownwood, City of Bangs, Brookesmith Special Utility District, soon to add City of Early and Zephyr
- Lake Brownwood is sole source
- Water supply issues due to drought
- Diversification

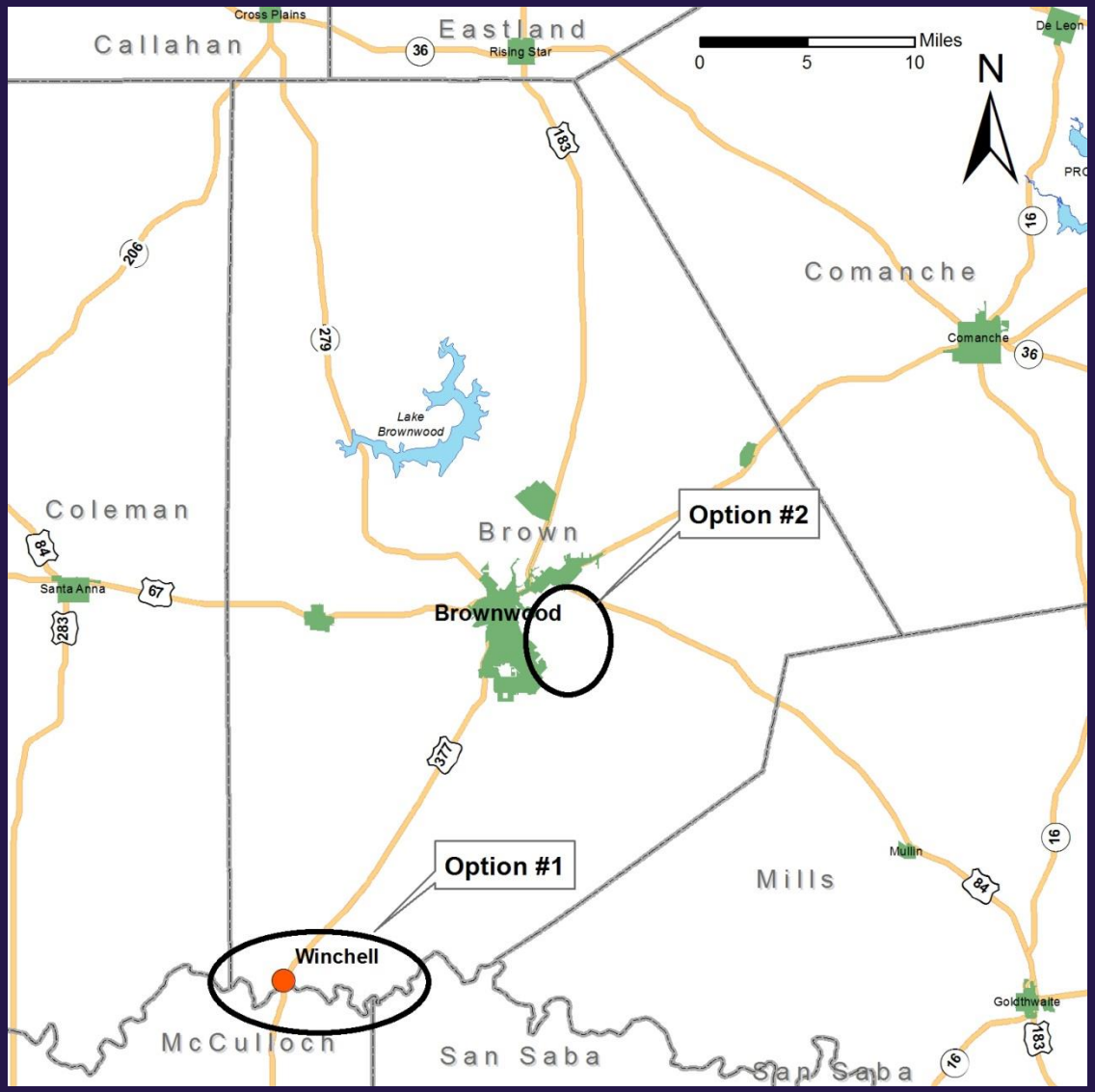

Brown County
Texas
Cross Plains
Eastland
Rising Star
De Leon
Miles
0
5
10
N
Comanche
Comanche
Lake
Brownwood
Coleman
Brown
Brownwood
Santa Anna
Mullin
Mills
Goldthwaite
McCulloch
San Saba
San Saba

Lake Brownwood Water Levels



Brown County Brackish-Water Project Study

- Prepared by Bureau of Economic Geology—
  J.P. Nicot, Allan Standen, et al.
  - Broad study of available groundwater in Brown County
  - Focused on the Hickory Formation and the Ellenburger Formation as the most promising sources for groundwater in Brown County
  - Two recommended options for exploration wells


Callahan
Cross Plains
Eastland
Rising Star
36
183
206
279
Lake Brownwood
Coleman
Santa Anna
84
67
283
Brown
Brownwood
Option #2
377
Option #1
Winchell
McCulloch
San Saba
Comanche
Comanche
36
De Leon
16
Miles
0
5
10
N
Mills
Mullin
84
16
Goldthwaite
183
San Saba
16

Ellenburger Exploratory Well

- BCWID#1 chose to go with suggested Option #2
- Land available close to existing treatment plant
- Information on a nearby well
- Designated as Ellenburger/Hickory Exploration Well Ell-1

Ellenburger Exploratory Well

- Total depth expected to be around 3,600 feet to the bottom of the Hickory Formation
- Upper aquifers and potential oil and gas-bearing formations to be cased off
- Open hole in Ellenburger (and temporarily down to bottom of Hickory)

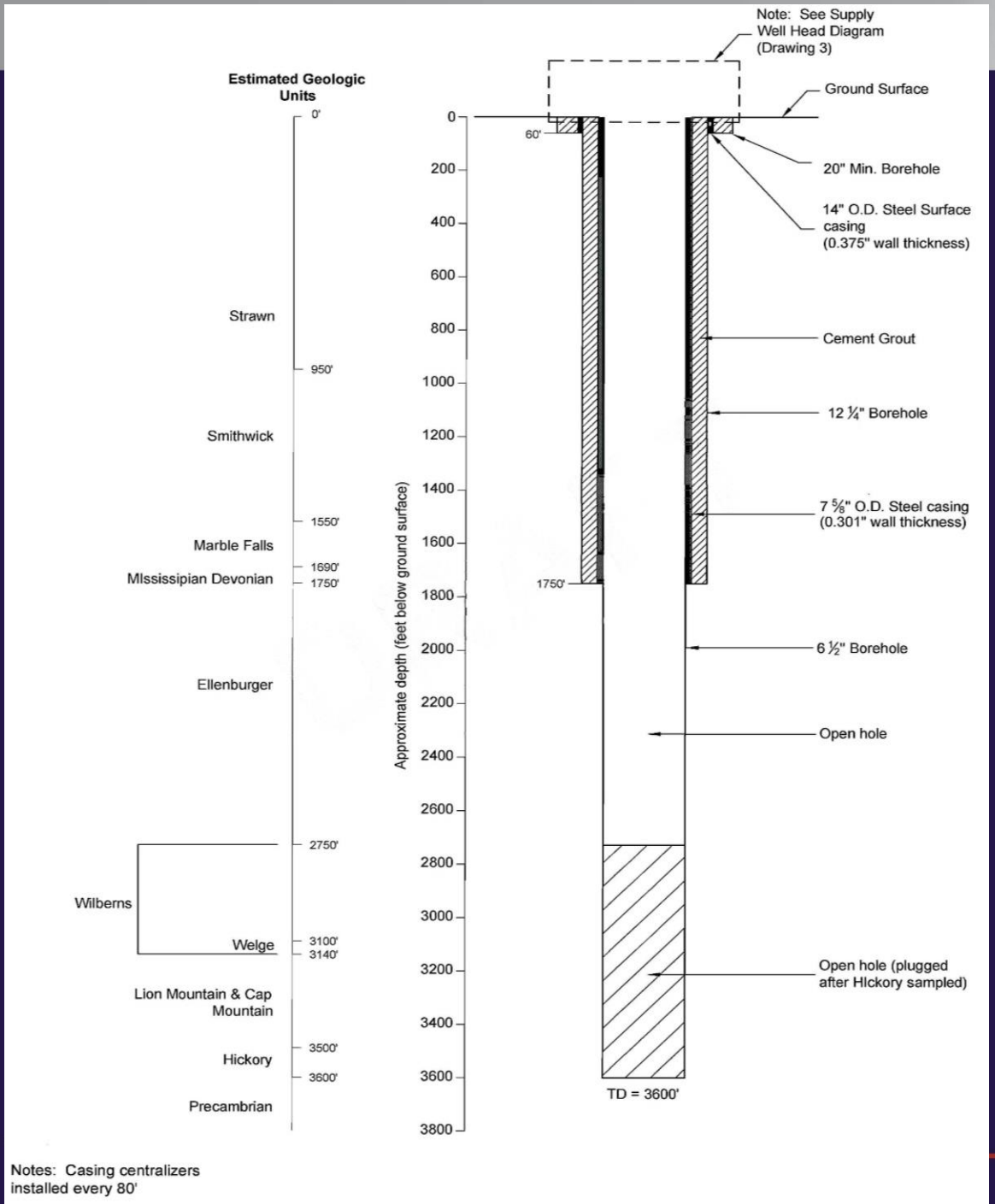
Ellenburger Exploratory Well

- Potential flow rate of up to 500 gpm
- Hot Wells well reportedly flowed at around 730 gpm in the 1920s
- Artesian conditions expected
- Local oil and gas drillers warned of potential high pressures in targeted formations

Brown County Water Improvement District No. 1

Exploration Well Ell-1 Design and Installation

Well Design



Notes: Casing centralizers installed every 80'

Exploratory Well Design

- Bids were solicited and received in May 2013
  - Stewart Brothers Drilling, Boart Longyear, and Layne Christensen Company
- Bids ranged in price from $700K to over $1.8 Million
- Stewart Brothers was awarded contract in June 2013 and mobilized to the site in late June and early July
- Drilling operations began the first week of July 2013

Drilling and Well Construction

- Surface casing installation
  - 13⅜” steel
  - Installed to 185’ below ground surface (bgs)
  - BOPD installed on surface casing

Drilling and Well Construction

- Main casing installation
  - 12¼” borehole
  - 7⅝” steel
  - Installed into the top of the Ellenburger Formation at 1,735’ bgs
  - BOPD Installed on main casing

Drilling and Well Construction

- During borehole drilling
  - Cuttings samples were collected every 10 feet
  - Plumbness and alignment
  - Geophysical logging
    - Gamma, normal resistivity, fluid resisitivity, spontaneous potential, temperature, neutron, sonic, caliper, and deviation logs


CREST

Drilling and Well Construction

- Open borehole geology
  - Ellenburger LS and Dolomite, 1,706’-2,936’ bgs (1,230 ft thick)
  - San Saba LS (interbedded LS and shale), 2,936’-3,134’ bgs
  - Welge Sandstone, 3,134’-3,206’ bgs
  - Hickory Sandstone, 3,206’-3,556’ bgs (350 ft thick)
    - Five major units identified

Development and Water Sampling

- Packer testing in Hickory Formation
  - Set inflatable packer at top of Hickory Formation
  - Isolated Hickory Formation was developed (air lifting) and a representative sample collected
  - Total dissolved solids (TDS) of Hickory = 78,200 ppm (seawater is ~35,000 ppm)
  - Radium 226 = 2,000+ pCi/L (EPA MCL = 5)

Inflatable Packer

Grout Plugging Lower Borehole

- Well design called for bottom of borehole to be sealed off to complete well in Ellenburger Formation
  - First Grout Plug up to 3,385’ bgs (Target was 2,900)
  - Second Grout Plug up to 2,995’ bgs
  - Third Grout Plug up to 2,865’ bgs (Isolated Ellenburger)
    - Pump test and analytical collected
  - Fourth Grout Plug up to 2,648’ bgs
    - Pump test and analytical collected

Development and Water Sampling

- Ellenburger Formation
  - Airlifting and pumping development
  - Bottom Seal at 2,865’ bgs
    - TDS = 22,200 mg/L
    - Gross Alpha ~200 pCi/L
  - Bottom Seal at 2,648’ bgs
    - TDS = 14,200 mg/L
    - Gross Alpha ~2 pCi/L

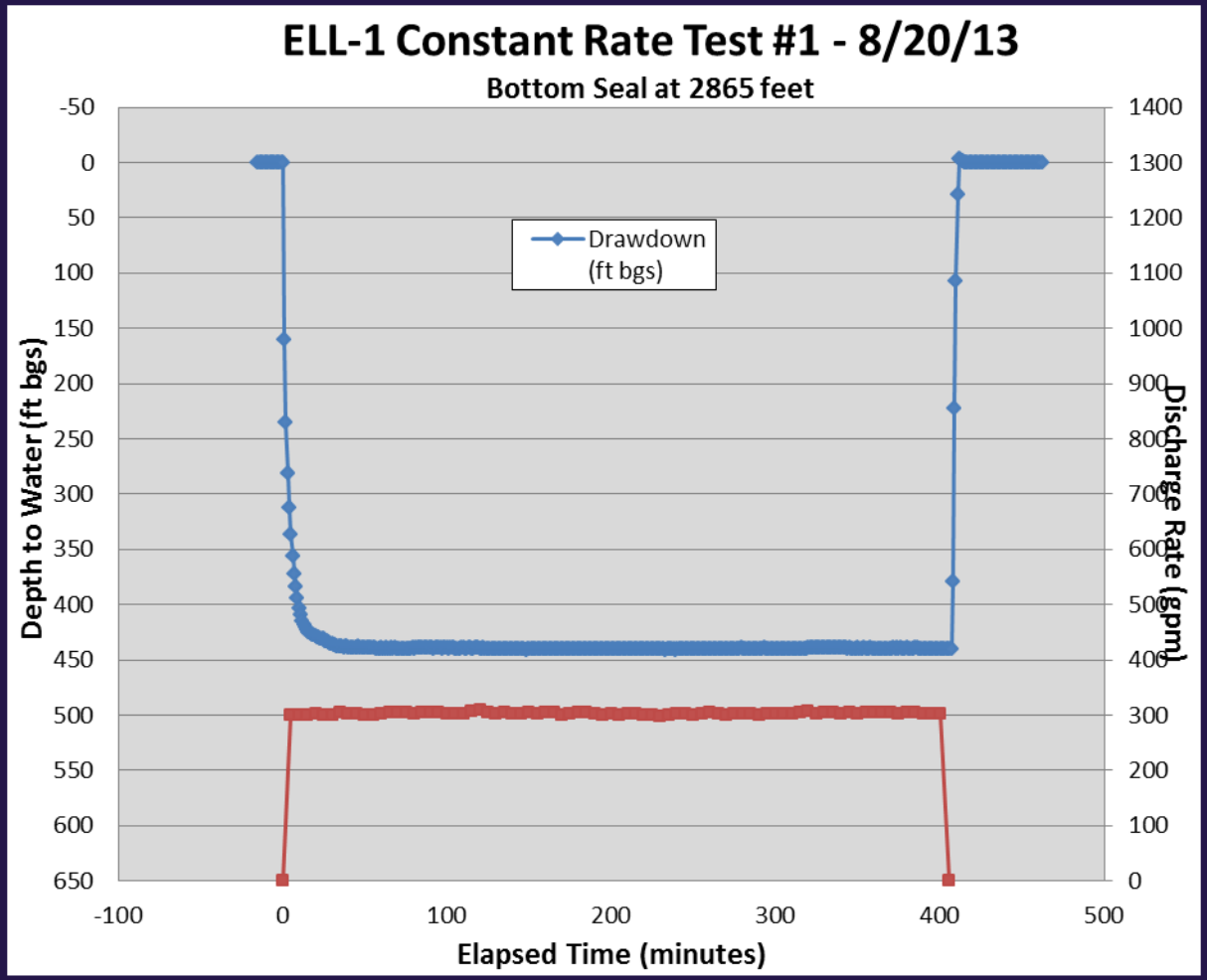
Aquifer Pumping Tests

- Ellenburger Formation
  - Step and constant rate
  - Bottom seal at 2,865’ bgs
    - Flow rate = 300 gpm with 440 feet of drawdown
    - Flow rate could be over 500 gpm if pump was set lower
  - Bottom seal at 2,648’ bgs
    - Flow rate = 150 gpm with 565 feet of drawdown
    - Flow rate could be over 300 gpm if pump was set lower

Ell-1 Constant Rate Test 1

Total Ellenburger: Bottom Seal at 2,865 ft

- First constant rate test run at 300 gpm for 400 minutes
- Drawdown stable at 440 ft



Video Logging


2241. 1'

Wellhead Completion

Projected Cost Range for Build-Out

- Carollo Engineers
  - Flow Rate: 5 MGD
  - Supply Wells: 500 gpm
  - RO: 2-Stage
  - Pipeline: Southern Route
  - Disposal Deep Well Injection
- Estimated Project Cost = $70 Million
  - Low projection = $45 M; high projection = $95 M)
- $14 M per MGD BCWID, $13 M per MGD San Angelo

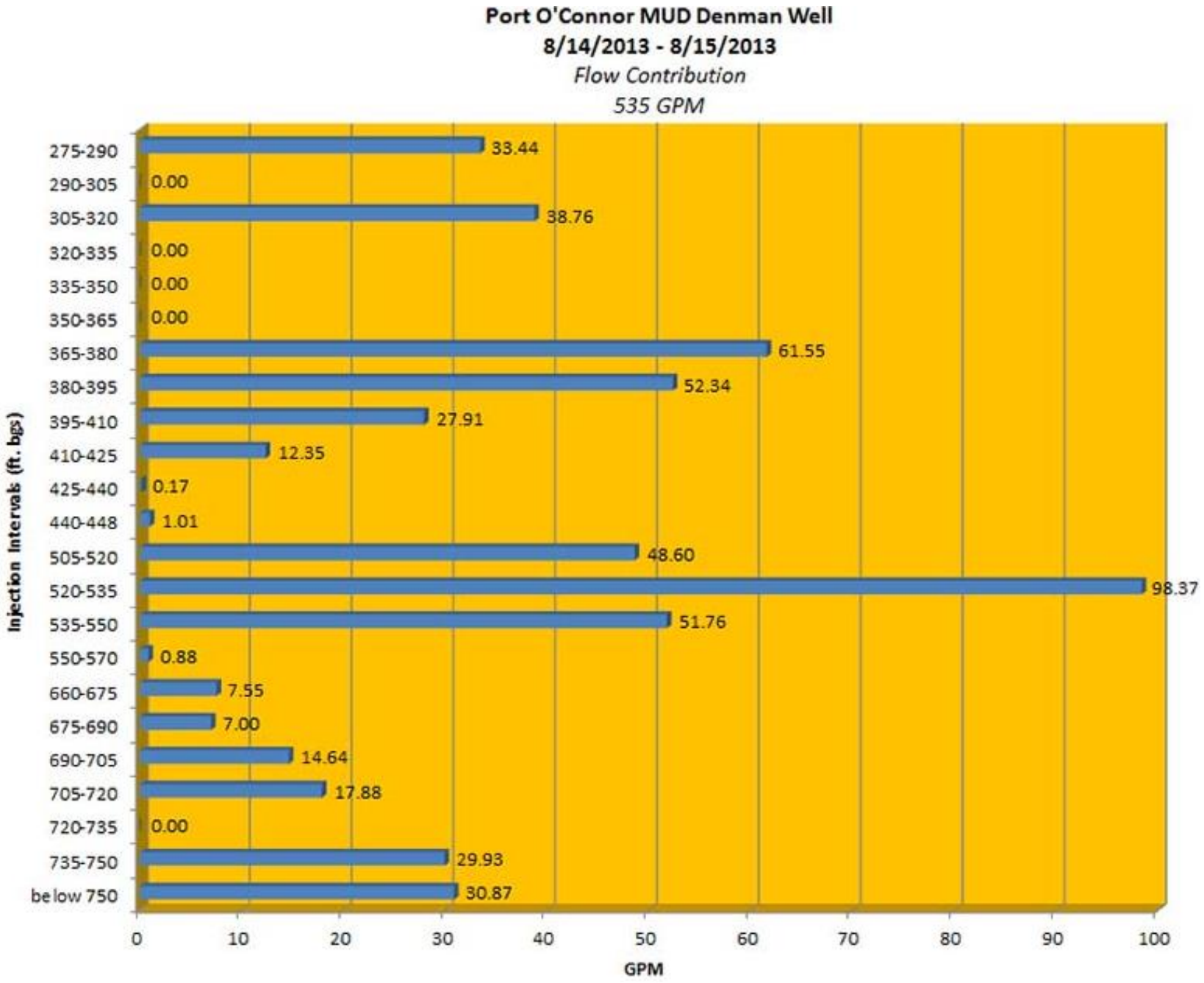
Recommendations for Further Development

- Well Characterization
  - Dynamic Well Flow and Concentration Profiling
- Well Flow Enhancement
  - Lateral Jetting

Miniaturized Down-Hole Diagnostics

- Depth-dependent flow and water quality data collection
- Profile TDS and flow rate in selected zones

BESST INC.
GLOBAL SUBSURFACE TECHNOLOGIES
www.besstinc.com


Port O'Connor MUD Denman Well
8/14/2013 - 8/15/2013
Flow Contribution
535 GPM
Injection Intervals (ft. bgs)
275-290
290-305
305-320
320-335
335-350
350-365
365-380
380-395
395-410
410-425
425-440
440-448
505-520
520-535
535-550
550-570
660-675
675-690
690-705
705-720
720-735
735-750
below 750
33.44
0.00
38.76
0.00
0.00
0.00
61.55
52.34
27.91
12.35
0.17
1.01
48.60
98.37
51.76
0.88
7.55
7.00
14.64
17.88
0.00
29.93
30.87
0
10
20
30
40
50
60
70
80
90
100
GPM

Recommendations for Further Development

- Utilize
  - Well flow and concentration profiling
  - Geophysical logs (porosity, etc.)
  - Lithology log
  - Video log
- Well flow enhancement
  - Lateral Jetting

Lateral Jetting

- Lateral is Advanced via High-Pressure Acidization
  - Used in the oilfield for over 30 years; several companies utilize this technology
  - Great technology for limestone formations
  - Laterals jetted with acid formulation at 5,000 to 15,000 psi
  - Typical lateral is ~300 feet in length
  - Initial jetting outward is relatively quick: 300 feet in a minute or so; pullback is slower (45 minutes) and widens hole to 2 to 3 inches in diameter
  - Has potential to increase flow rate by 100 gpm per lateral

Lateral Jetting

Lateral Jetting

- Options
  - Laterals can be “frac’ed” to connect vertically over a limited formation distance
- Estimated cost
  - ~$6,000 per lateral
  - $15,000 to $20,000 for mobilization depending on if specific downhole tools are available

Lateral Jetting

Conclusions

- Ellenburger Aquifer wellfield is promising but will be a challenge to develop.

- Brown County Water Improvement District No. 1
  - Currently vetting out all options for additional supply
    - City of Brownwood Re-Use
    - Hickory well field in southern Brown County.

Questions?

Ell-1 Ellenburger/Hickory Exploration