Drilling Program Well 16B(78)-32

Drilling Well on Paper

March 2, 2023

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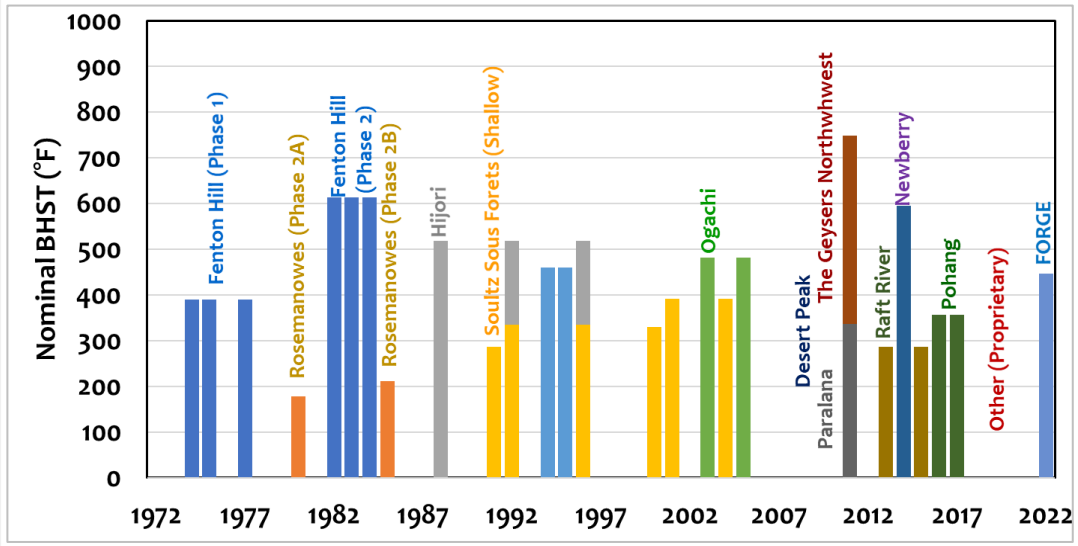
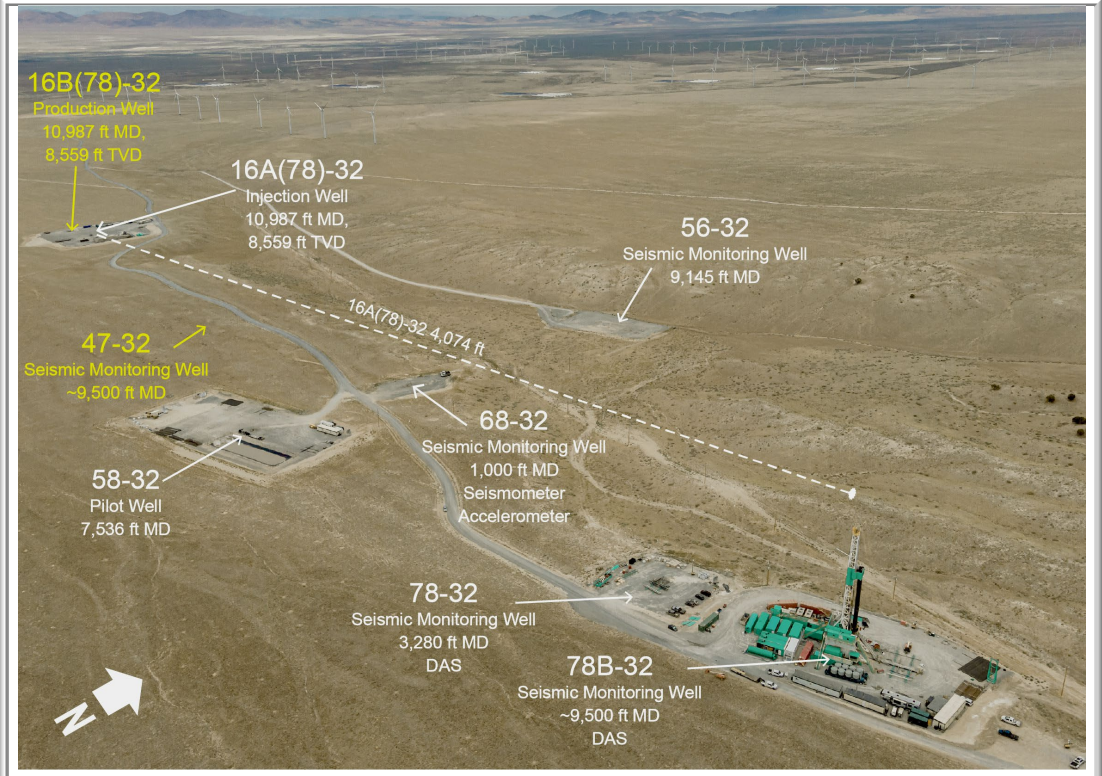
FORGE U.S. Department of Energy

From Fenton Hill – to – FORGE (Frontier Observatory for Research in Geothermal Energy)





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U.S. Department of Energy

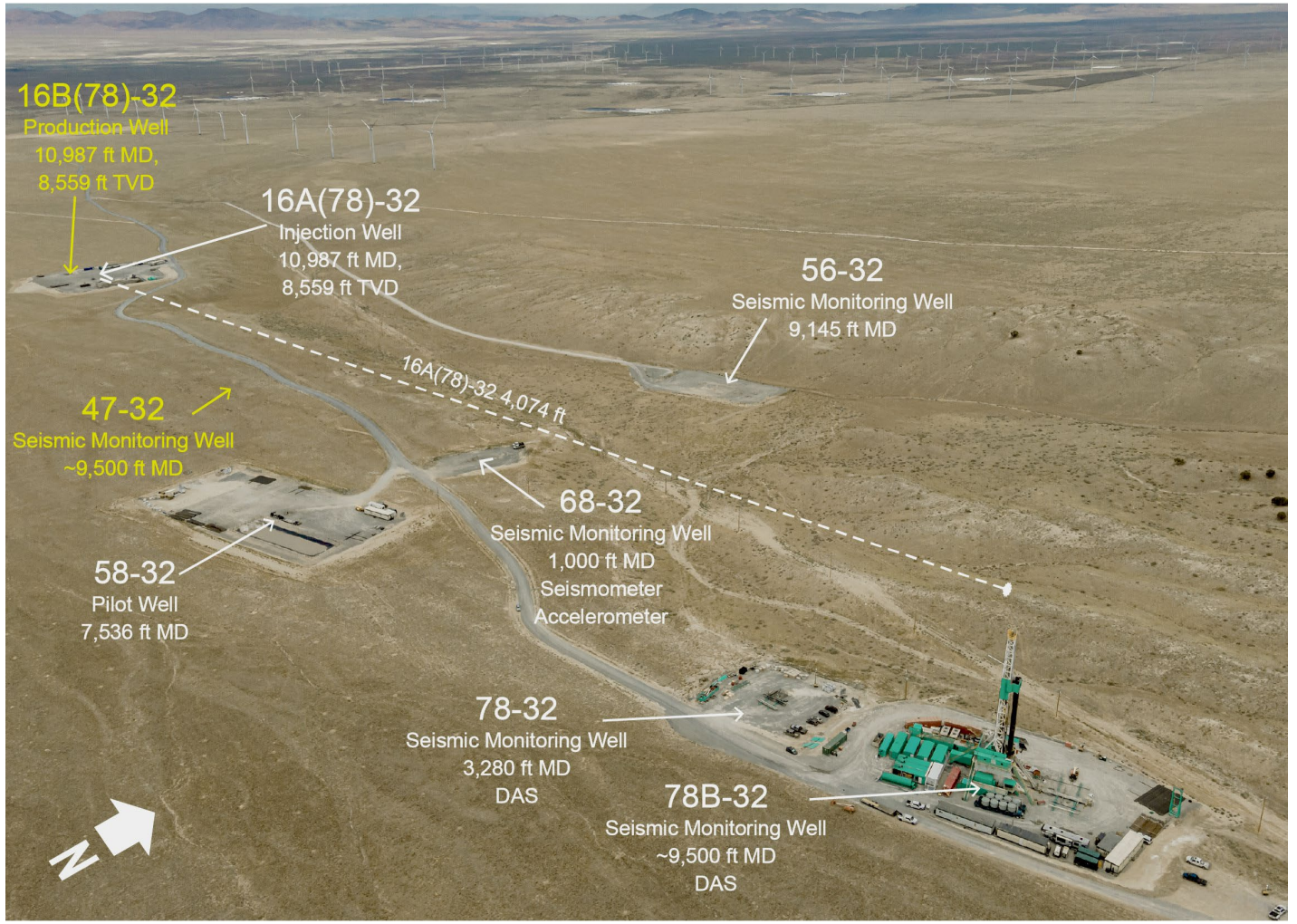
Funding for this work was provided by the U.S. DOE under grant DE-EE0007080 "Enhanced Geothermal System Concept Testing and Development at the Milford City, Utah FORGE Site"

We thank the many stakeholders who are supporting this project, including Smithfield, Utah School and Institutional Trust Lands Administration, and Beaver County as well as the Utah Governor's Office of Energy Development and Utah's Congressional Delegation.

Operational and Scientific Objectives

Operational and Scientific Objectives

1. Provide a doublet pair to Well 16A(78)-32
- Establishing a connection(s) with well 16A(78)-32 (through hydraulic fractures created in April 2022) is a primary objective



Operational and Scientific Objectives

1. **Provide a doublet pair to Well 16A(78)-32**
- **Safe Operations**
- **Traffic Light System in Place for Operations**
- **Site Manager: Garth Larsen**
- **Check-In Station**
- **Coordinate Visitors**

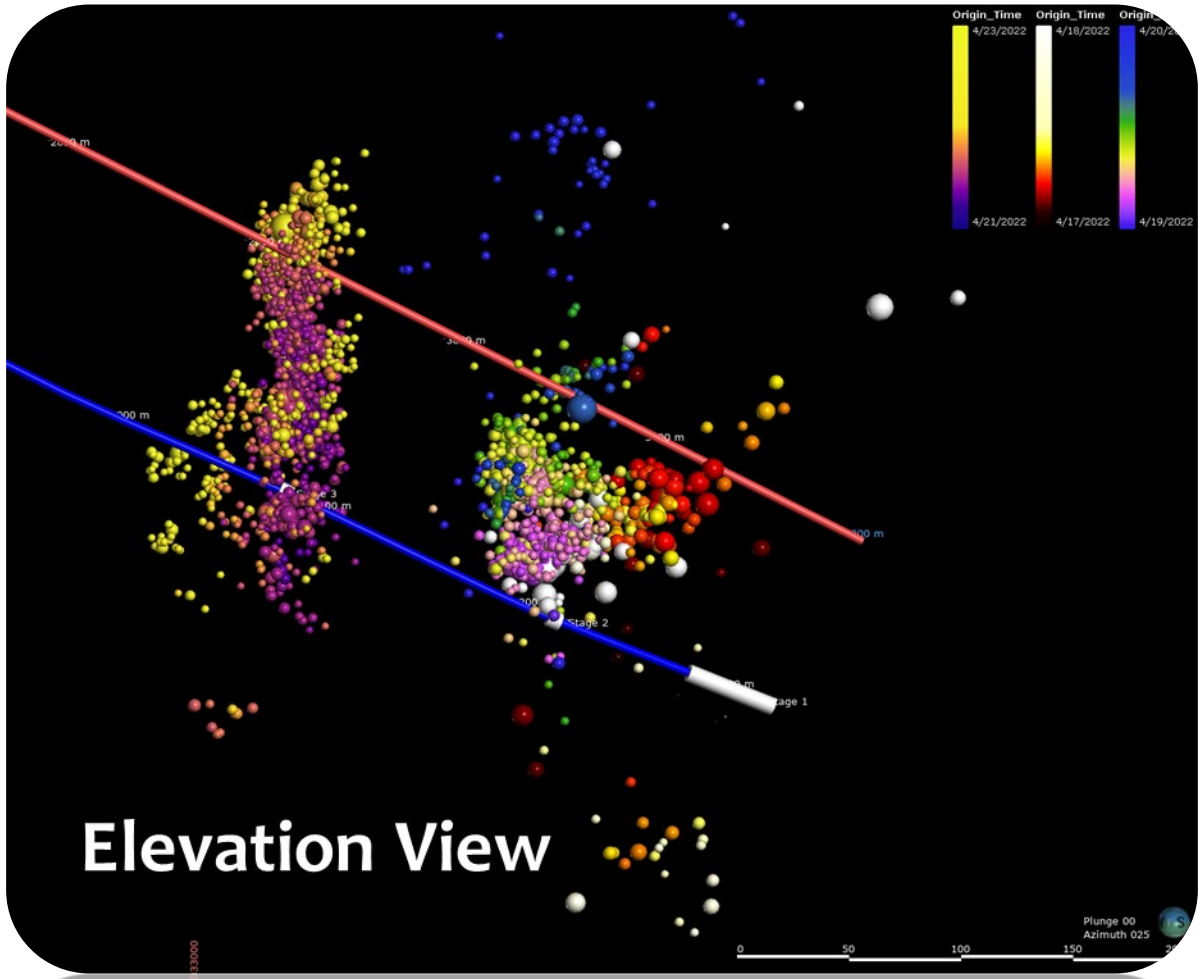
Seismic Mitigation

A seismic mitigation plan is in place based on a traffic light concept. All drilling activities could be amended or suspended in accordance with this mitigation plan, at any time.

- The occurrence of an event with a magnitude greater than or equal to 2 within 3 km of the rig will trigger notification of Orange; M≥3 will trigger Red. Orange is stop operations and assess. Red is terminating operations.
- If there are ten or more events with magnitudes greater than or equal to 1, within 3 km, in 24 hours, Orange is triggered.
- Confirmation or suspicion of events propagating along a fault plane.
- If there are excessive mud losses that cannot be cured, Orange will be triggered.

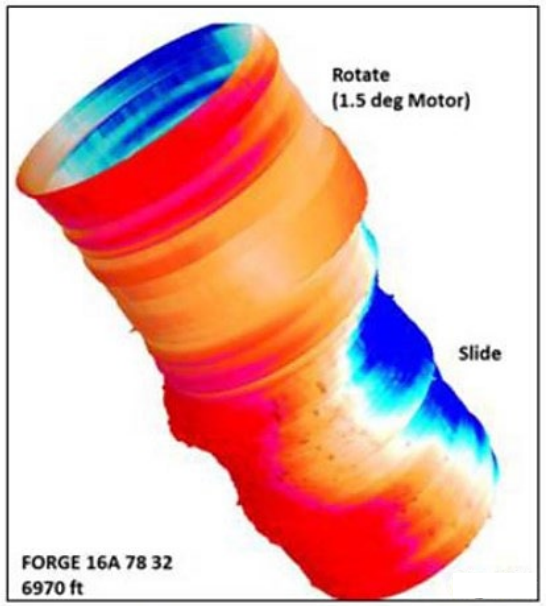
Operational and Scientific Objectives

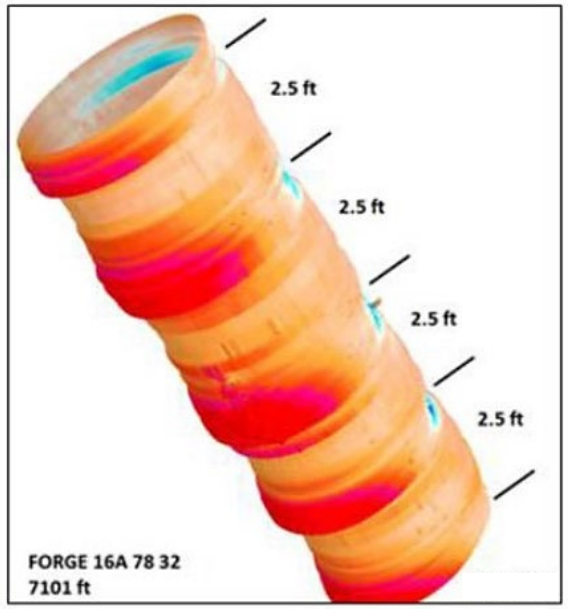
1. Provide a doublet pair to Well 16A(78)-32
- Build angle at ~5.5°/100 ft MD to 65° tangent so that Well 16B(78)-32 is vertically offset from Well 16A(78)-32 by 300 ft TVD

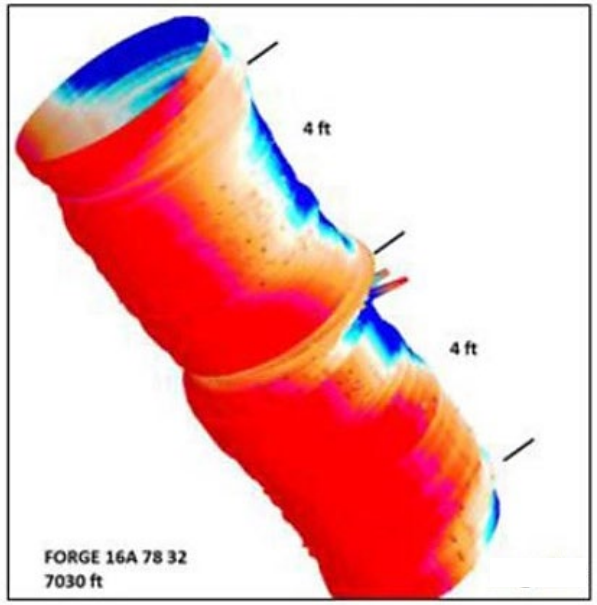


Operational and Scientific Objectives

2. Attempt to reduce rugosity by bit redesign, BHA modifications, RSS, …





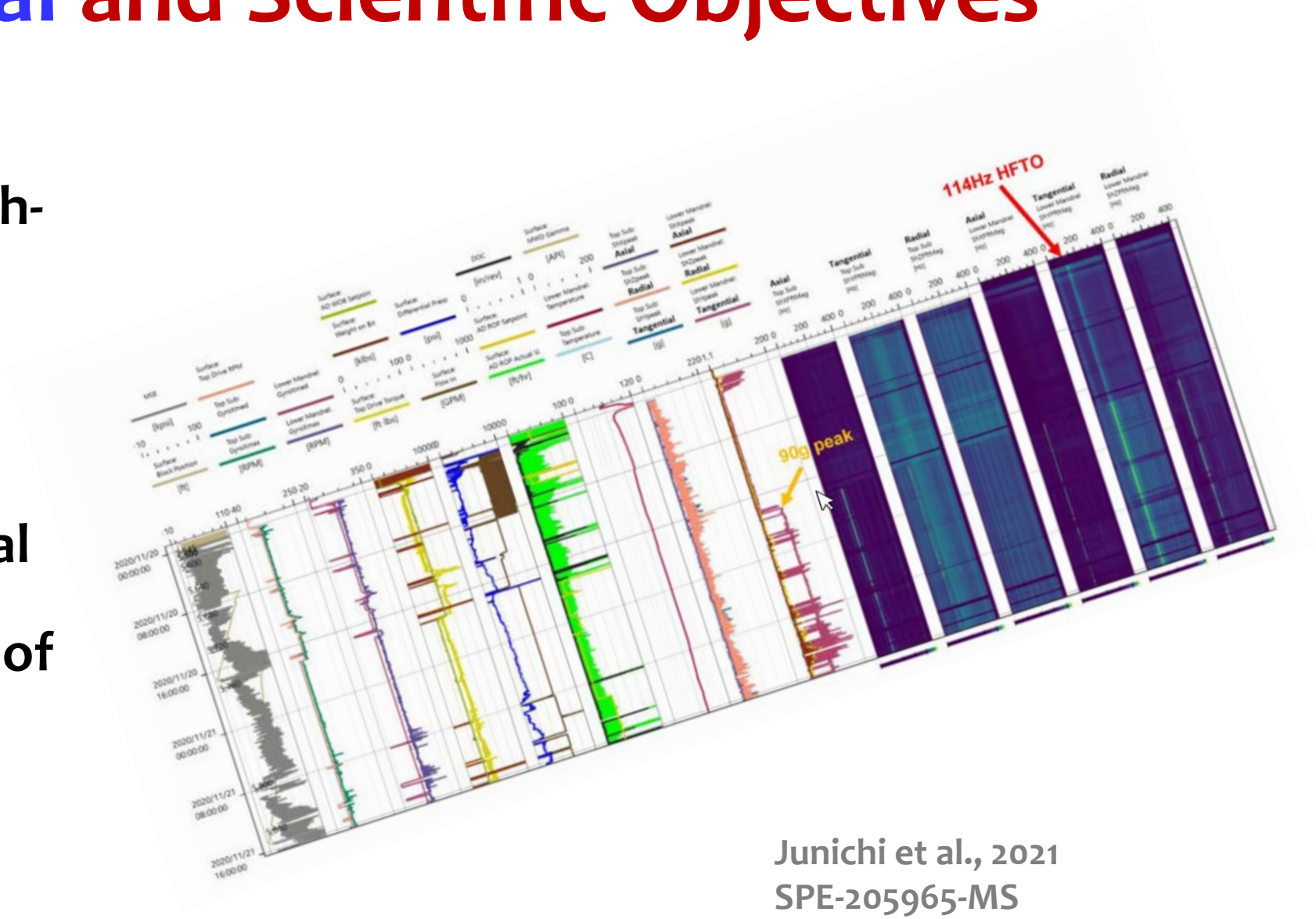


Images Courtesy of Dupriest and Noynaert
IADC/SPE-208798-MS, 2022

Operational and Scientific Objectives

3. Near-bit vibrations measured

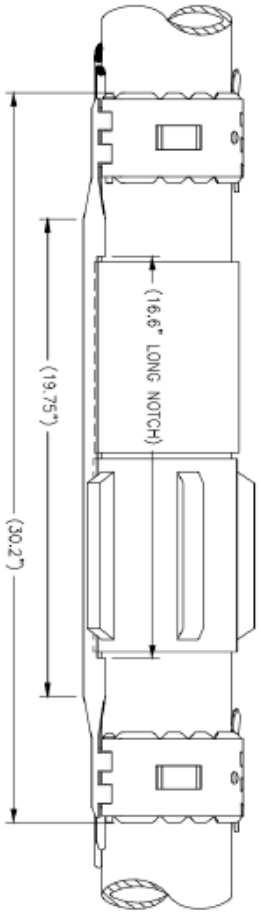
- Providing low and high-frequency data from near-bit pucks
- Primary goals are evaluating drilling dysfunction and assessing if mechanical properties can be inferred independent of logging
- Crosshole logging in future.

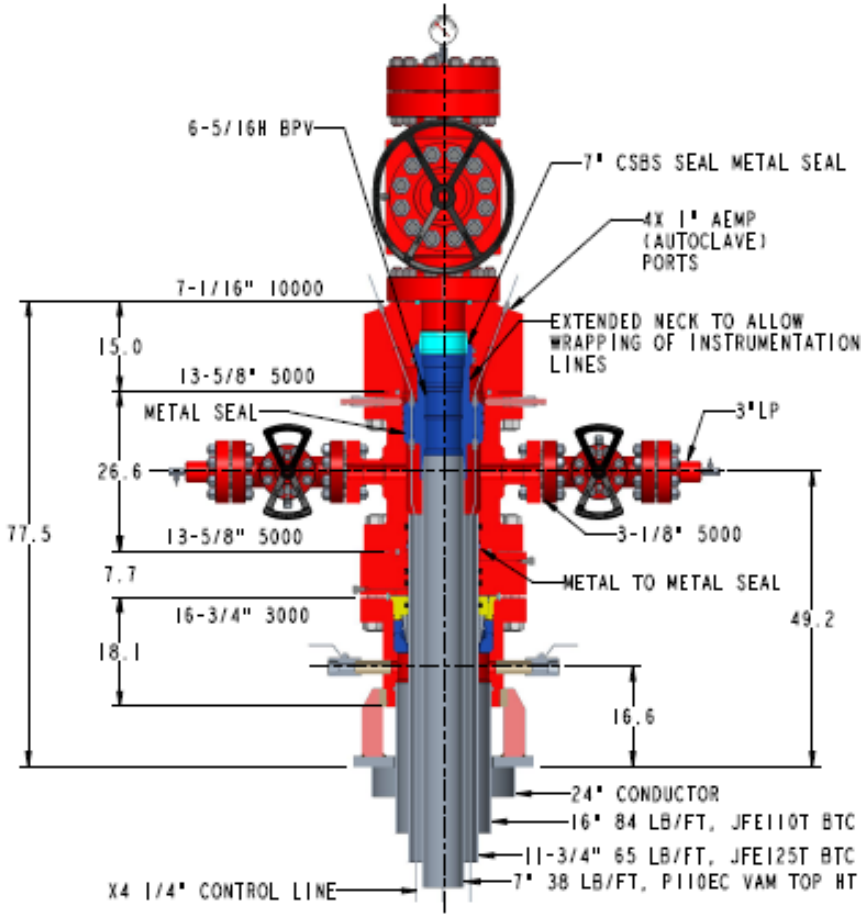


Junichi et al., 2021
SPE-205965-MS

Operational and Scientific Objectives

4. Run three fiber optic strings for the University of Texas and Rice University research programs
- Installation protocols are being developed with Shell and Silixa
- Wellhead by Stream-Flo
- Design Guidance by Mark Woitt (Fervo)





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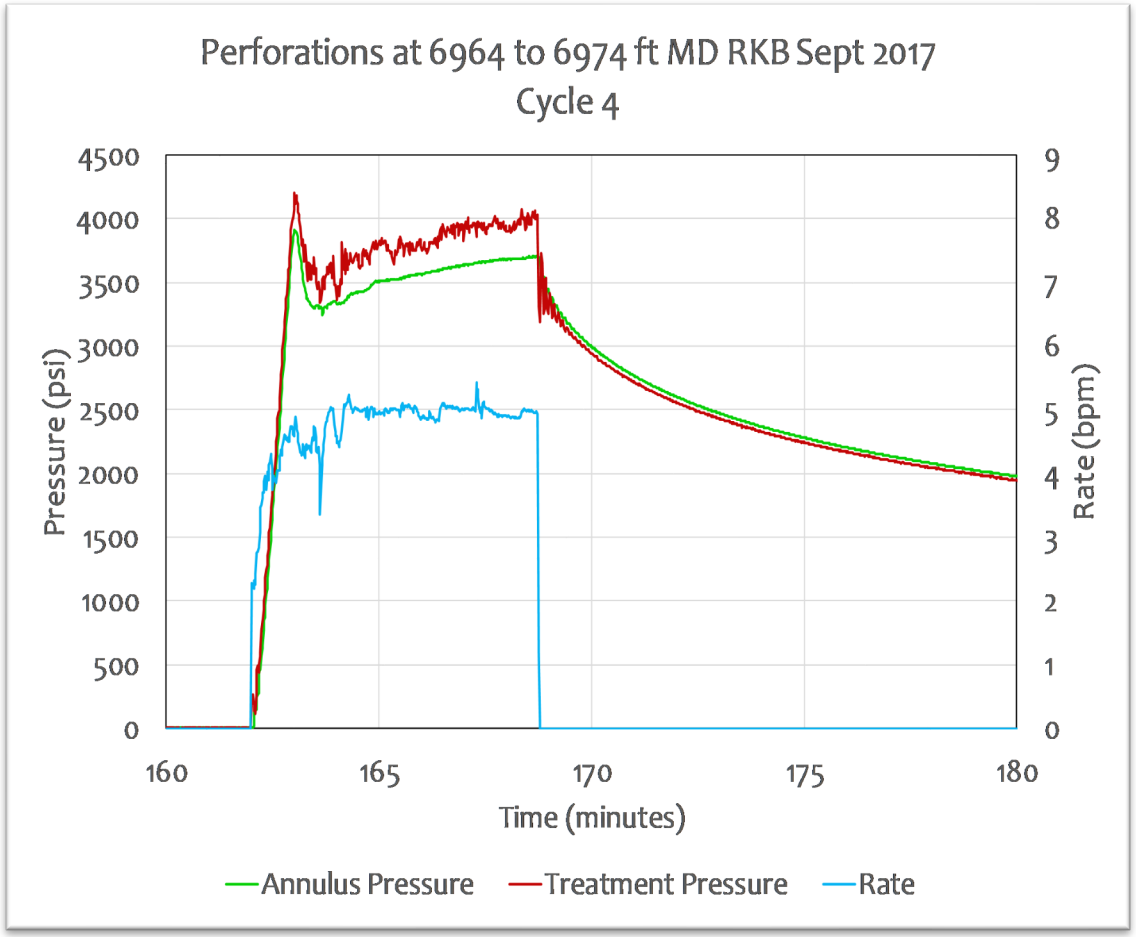
Operational and Scientific Objectives

5. Stress measurements as part of Battelle's research program

- From shoe at 4,960 feet to TD at 10,497 ft MD
- Not to exceed ten days
- Openhole before running production casing
- Also SNL's ASR (Anelastic Strain Recovery)



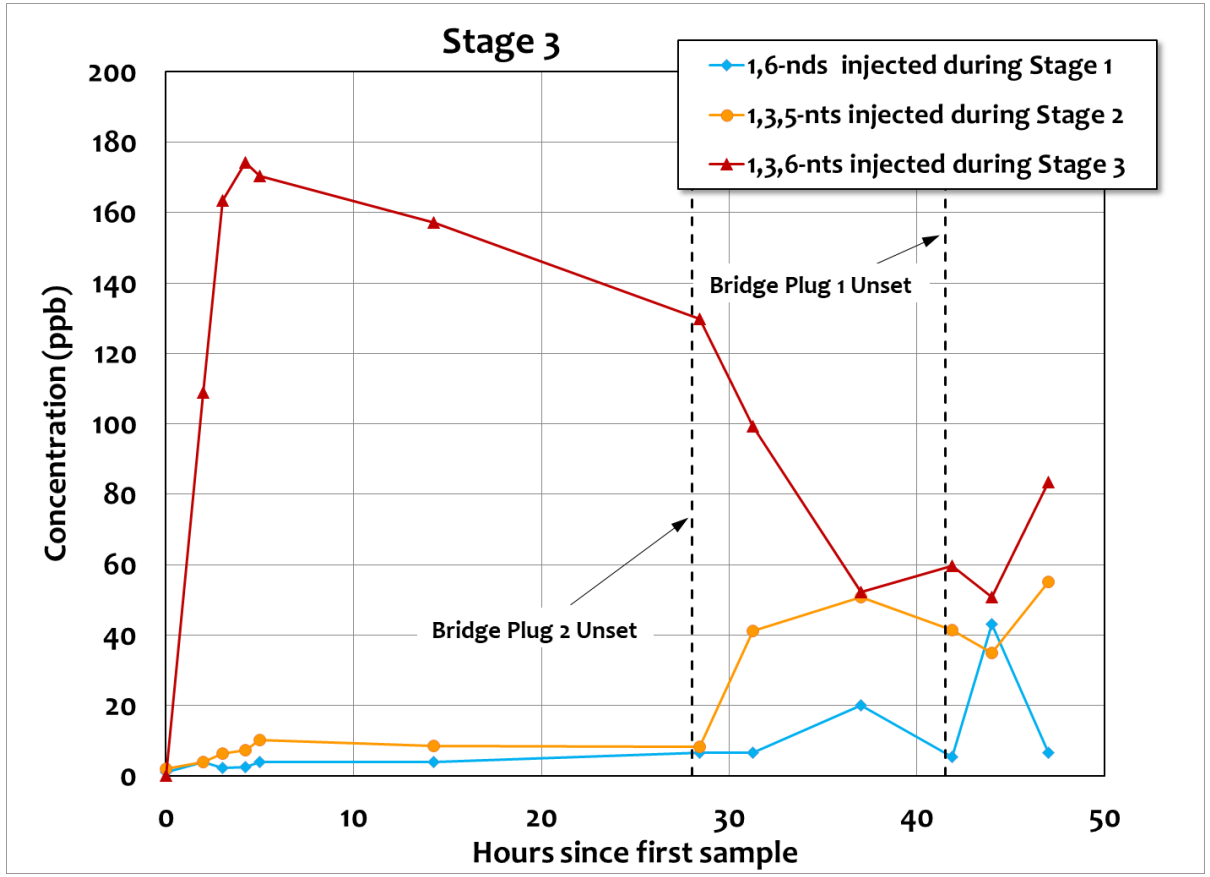
Operational and Scientific Objectives

6. Strategically Core toe of well (final 500 ft before TD) either continuously or in strategic sections to search for fractures, tracers, and other fracture diagnostics (e.g., microproppant)

- Core vertical section (5,200-69 ft)
- Core allocated for geologic characterization, mechanical properties, and R&D activities

Operational and Scientific Objectives

7. Acquire openhole and cased hole logs – multiple ultrasonic and resistivity imaging runs, quad combo at TD, and cement evaluation
- Monitoring for tracers and microproppant
- Plan on PLT/PTS suites or at least high-resolution temperature to look for fractures in communication with well 16A(78)-32



Operational and Scientific Objectives

8. Carry out strategic injection/circulation testing to do preliminary evaluations of connectivity between the two wells
- Monitor wellhead pressures in all offsets when possible
- Potential remedial activity ….

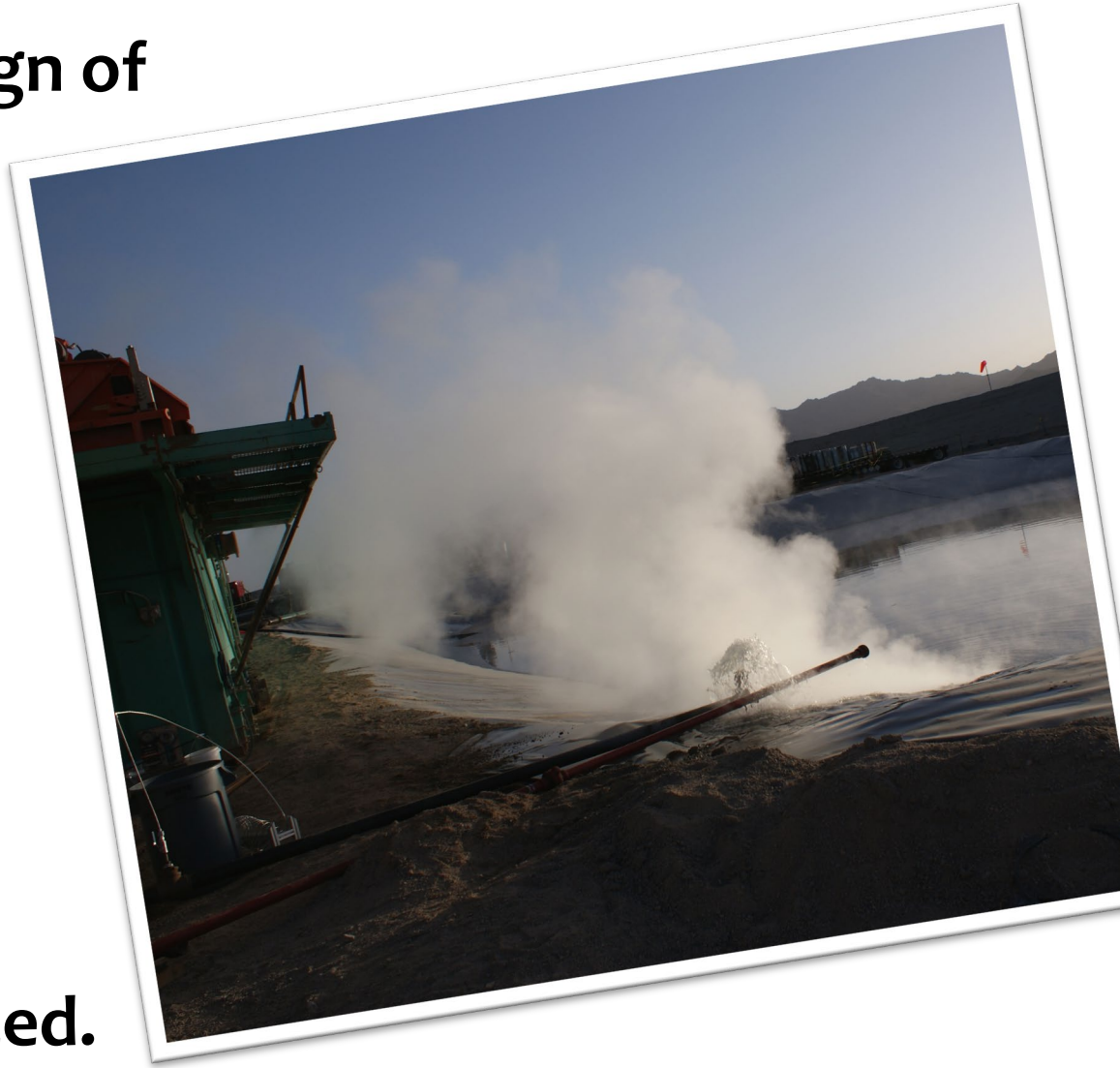
Operational and Scientific Objectives - Recap

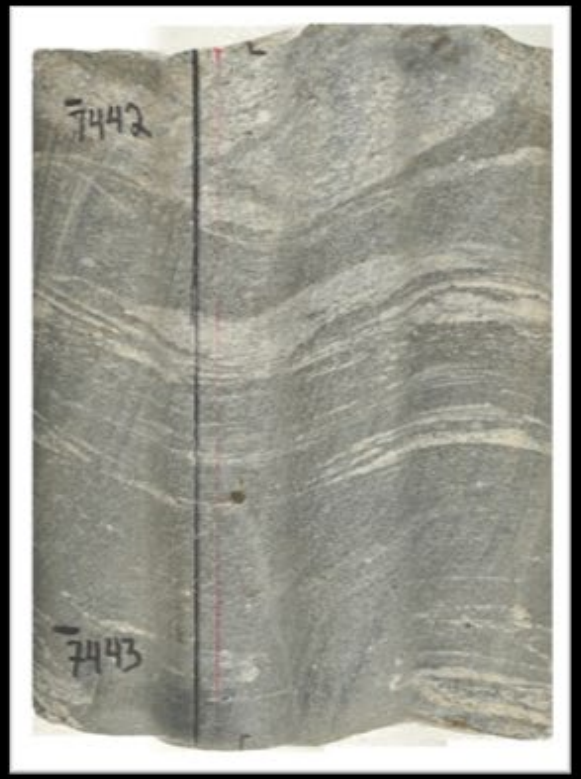
- Short section of particle drilling
- More extensive at-bit monitoring – particularly HFTOs
- Slightly modified PDC bit designs
- Coring to capture legacy hydraulic fractures
- Trying RSS (conventional steering available) – hole quality rather than ROP
- Running three fiber optics cables

Continued ….

Operational and Scientific Objectives - Recap

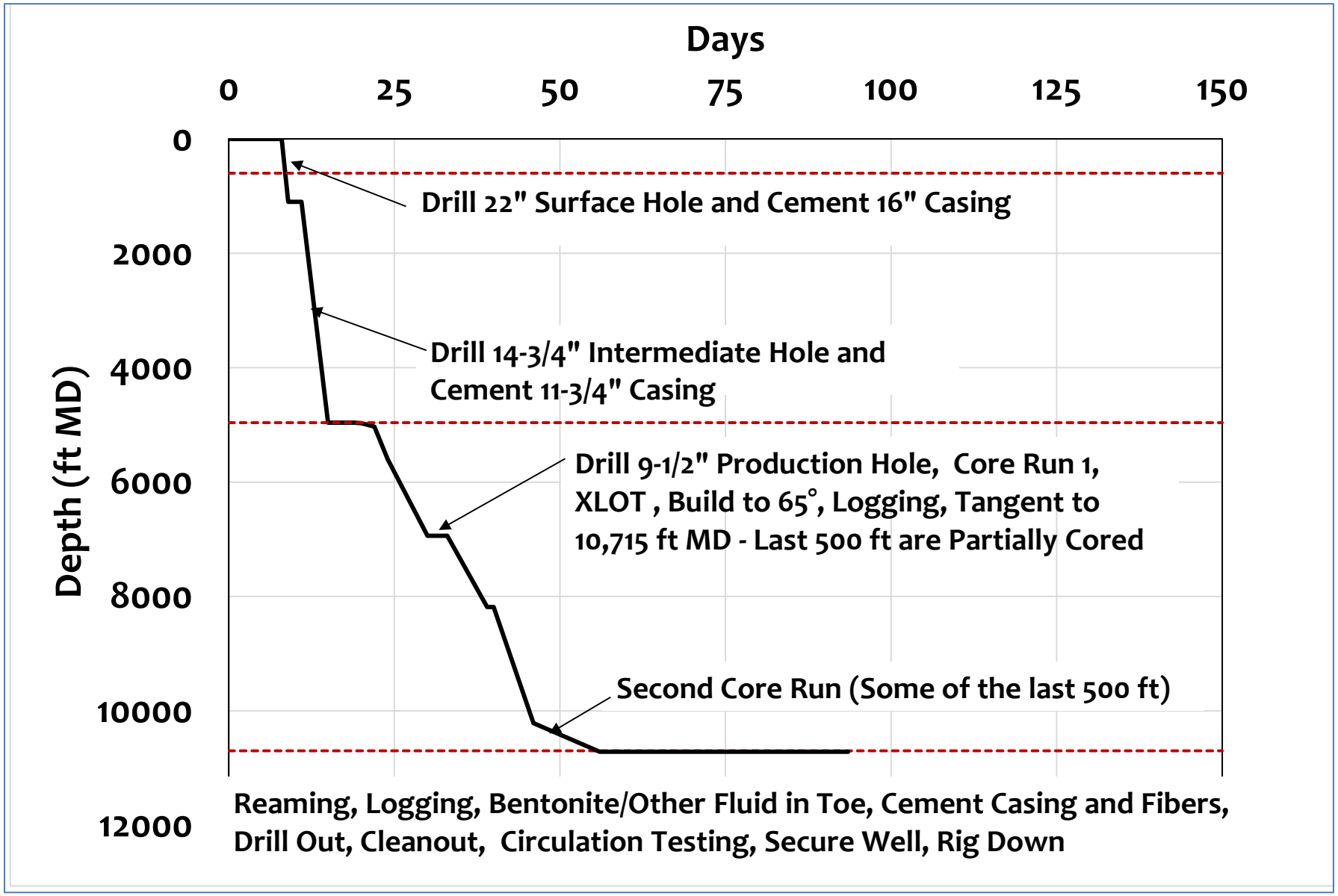
- Significantly more attention and design of cementing
- Battelle and Baker - openhole stress measurements
- Extensive logging to map previously created fractures
- Three rounds of circulation testing – before casing, after casing (500 ft of openhole), multi-day circulation campaign.
- Other potential tool testing, drilling fluids, BHA modifications – not finalized.





Anticipated Schedule and Days vs. Depth

Anticipated Schedule

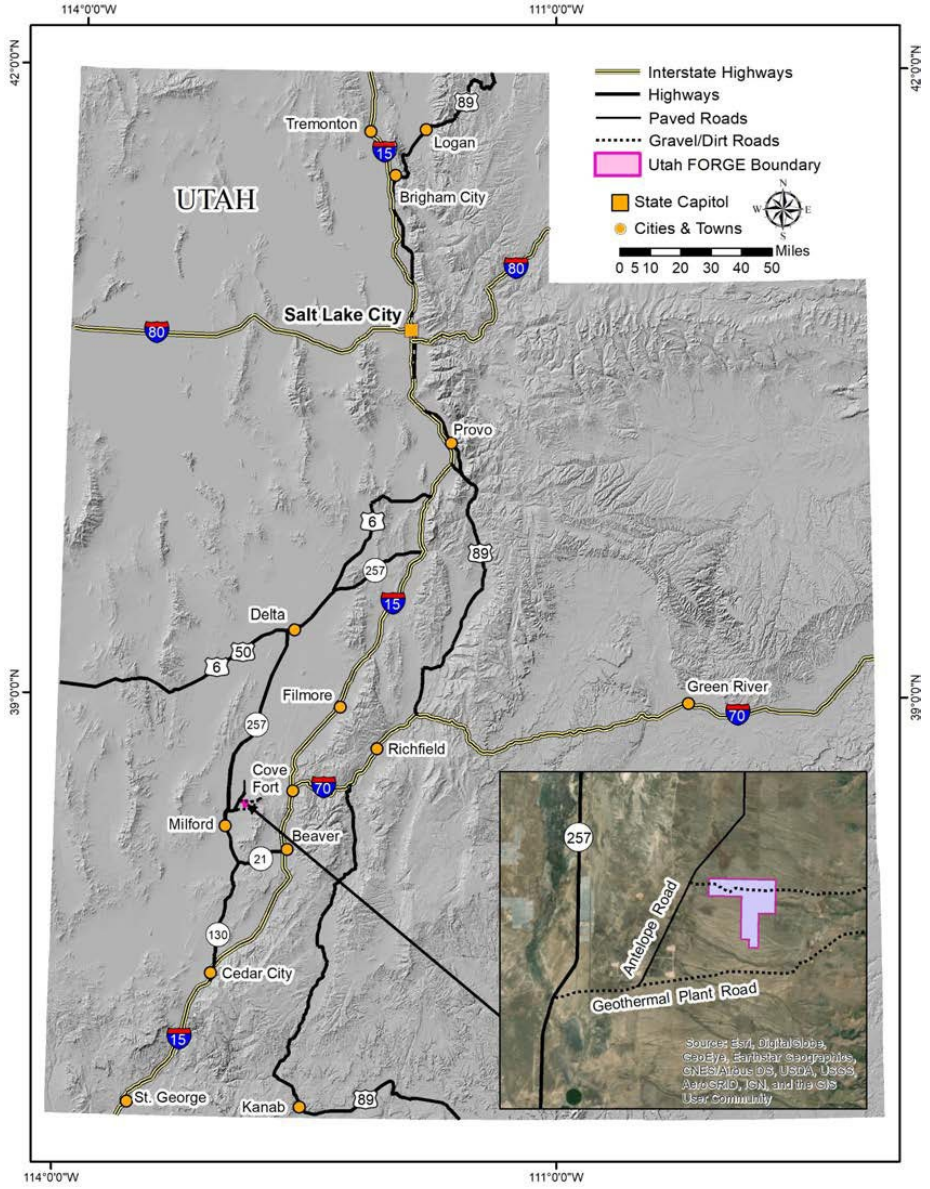


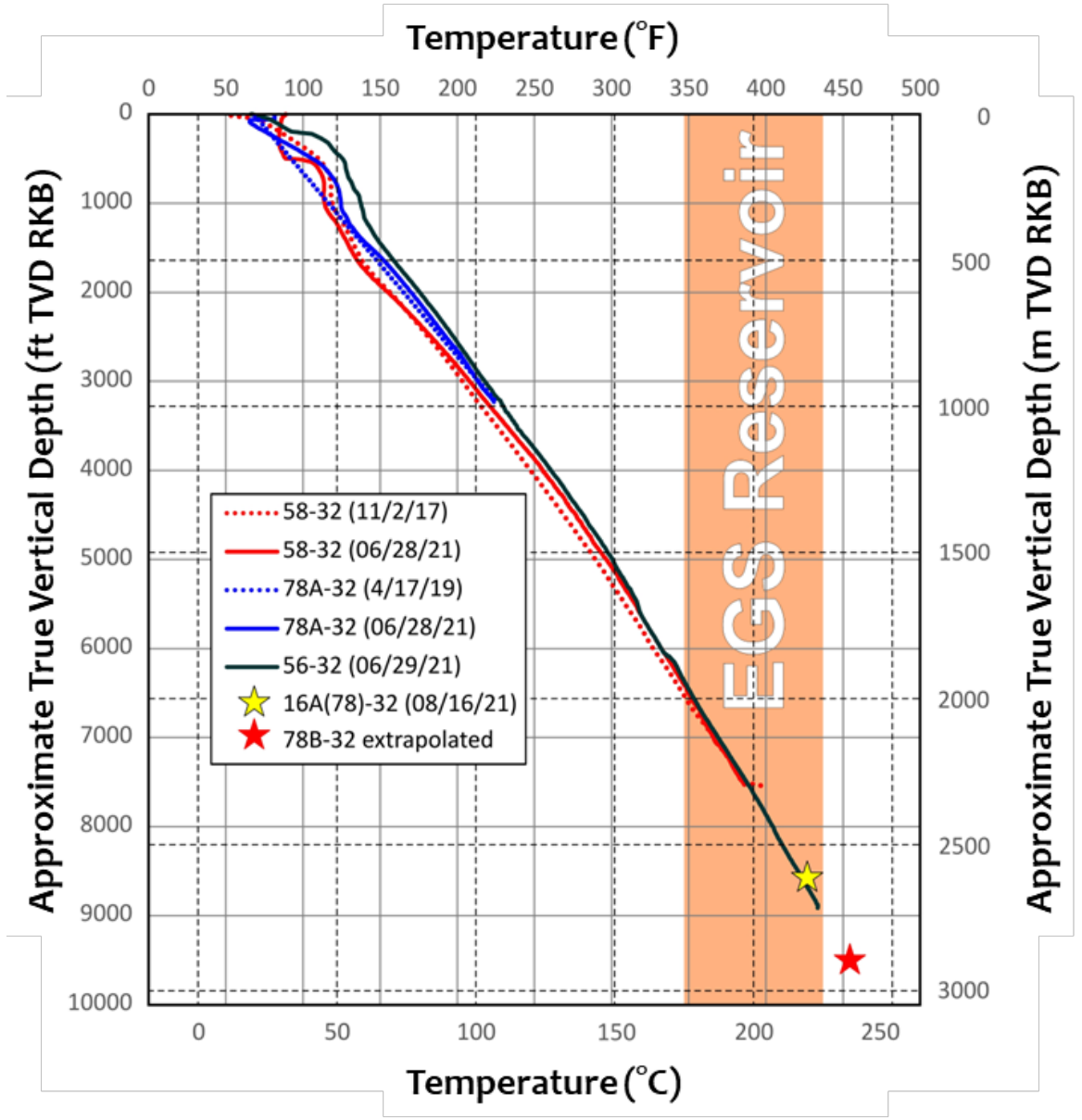
Anticipated Schedule

Depth	Days	Cumulative	Date	Activity	
0	0	0	15-Apr	MI Start	
0	6	6	21-Apr	Move In and Rig Up	
0	2	8	23-Apr	On Location, All Hands Training	
1100	1	9	24-Apr	Drill Surface	Complete drilling Surface hole 22"
1100	2	11	26-Apr	Surface Run csg, cmt, NU BOPE, WOC	Complete Surface hole Phase
4960	4	15	30-Apr	Drill Intermediate	Complete drilling Intermediate hole 14 3/4"
4960	3	18	3-May	Run Csg, Cement, NU BOPE	
4960	1	19	4-May	WOC	Complete Intermediate hole Phase
4970	1	20	5-May	Drill Out Shoe and XLOT	Start Production Hole 9-1/2"
5030	2	22	7-May	Cut cores 4970 to 5030	Core #1
5600	2	24	9-May	Drill to just above KOP with Particle Drilling	
6938	6	30	15-May	Drill 5.5° / 100' curve	EOC 6938
6938	3	33	18-May	Triping and Circulate condition hole, logging for Isolation scanner	
8184	6	39	24-May	Drilling 65° tangent	
8184	1	40	25-May	Logging	
10215	6	46	31-May	Drill 9-1/2" hole to core point	
10715	10	56	10-Jun	Cut cores and drill from 10215 to 10715 includes ream out core	Core #2 and drilling
10715	4	60	14-Jun	Run Logs	
10715	1	61	15-Jun	Gyro	
10715	4	65	19-Jun	Ghost Runs and Reaming	
10715	10	75	29-Jun	Battelle Stress Measurements (if tests do not work could be less)	
10715	1	76	30-Jun	Spot viscosified fluid and bentonite	
10715	5	81	5-Jul	Run casing with fiber and cement, WOC	
10715	3	84	8-Jul	ND production Head, Run CET, CCL	
10715	5.5	89.5	13-Jul	Circulation Testing	
10715	4	93.5	17-Jul	Rig down and Released	
TD	**93.5**	**93.5**	**17-Jul**	**Total Days**	

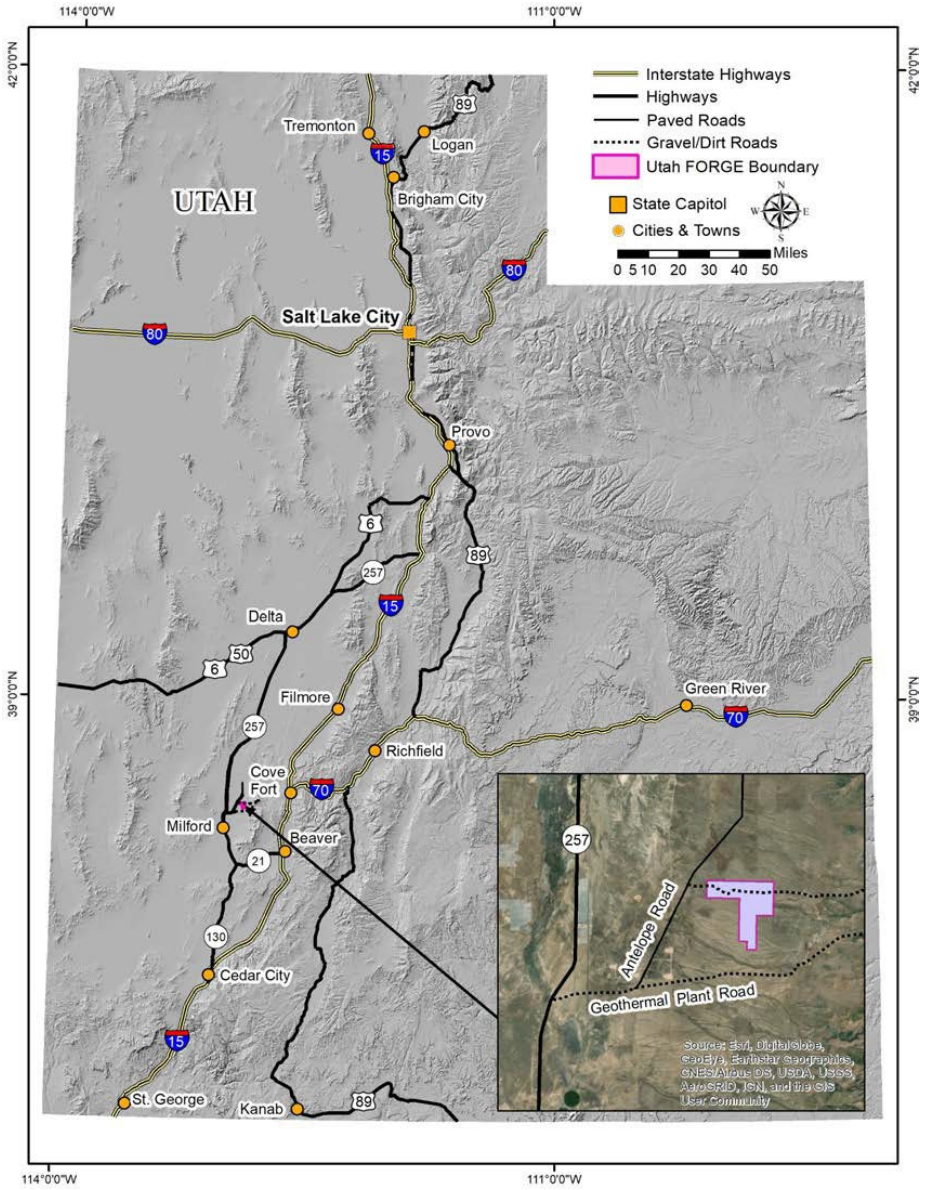
Location and Context

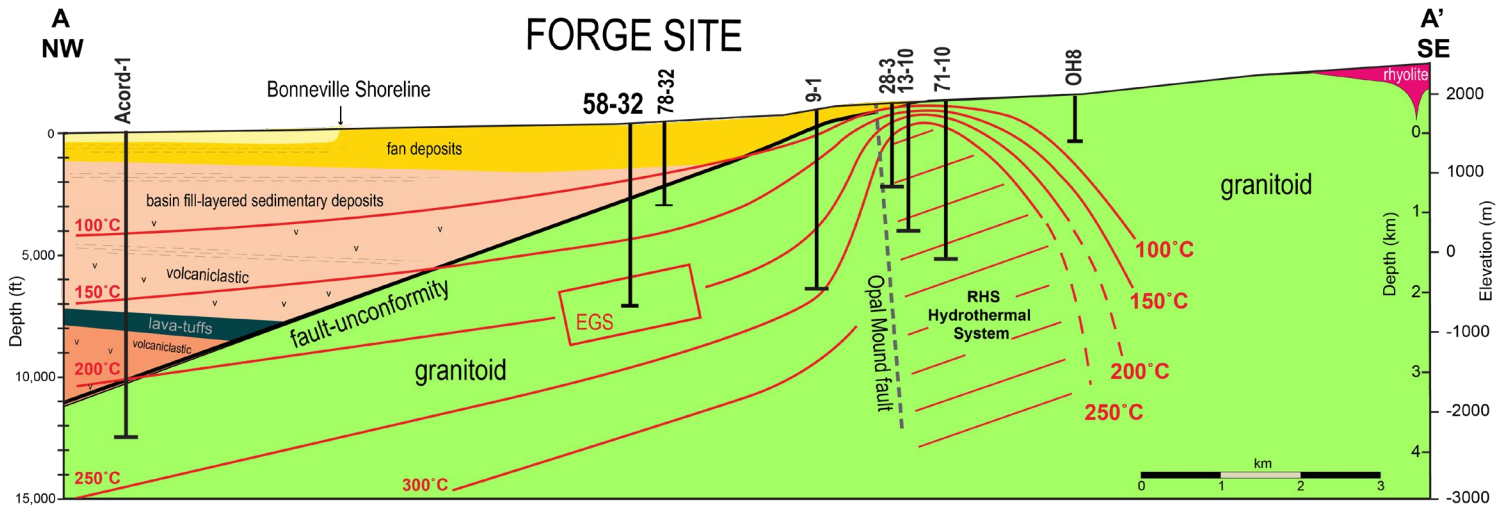
Operational and Scientific Objectives - Recap





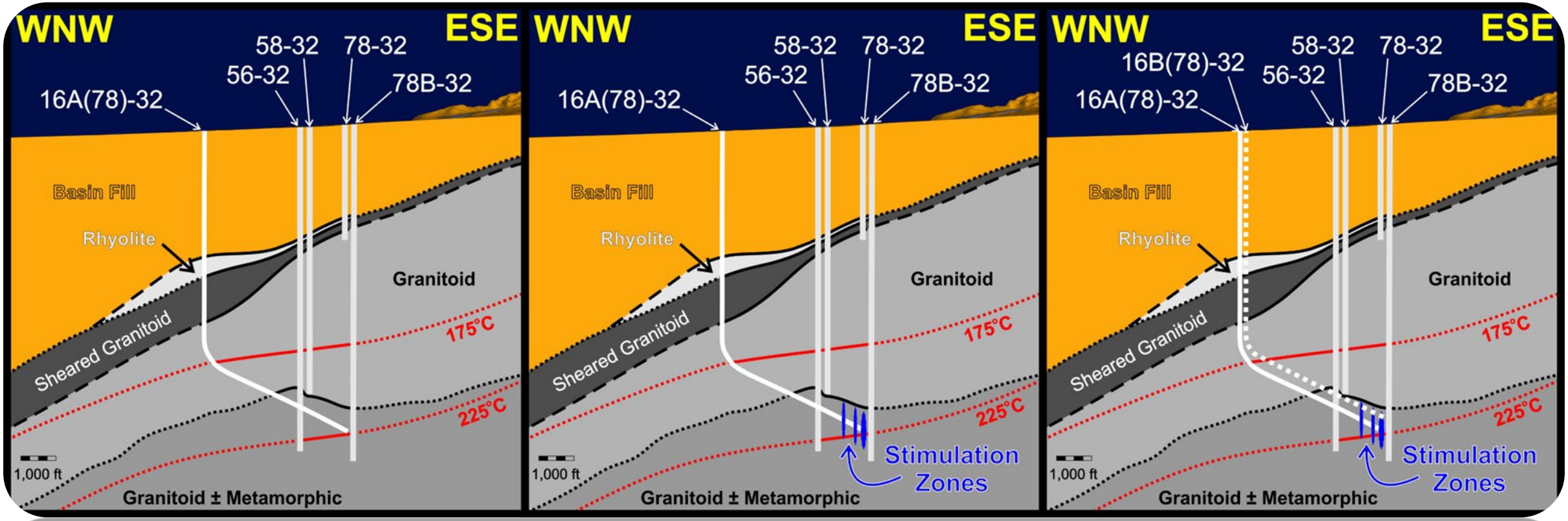
Operational and Scientific Objectives - Recap





- Pseudo-consolidated alluvium overlies granitic thermal reservoir
- Contact at Well 16B(78)-32 location expected to be at 4550 ft MD/TVD
- Potential non-potable water at ~700 ft GL

Geologic Conceptualization



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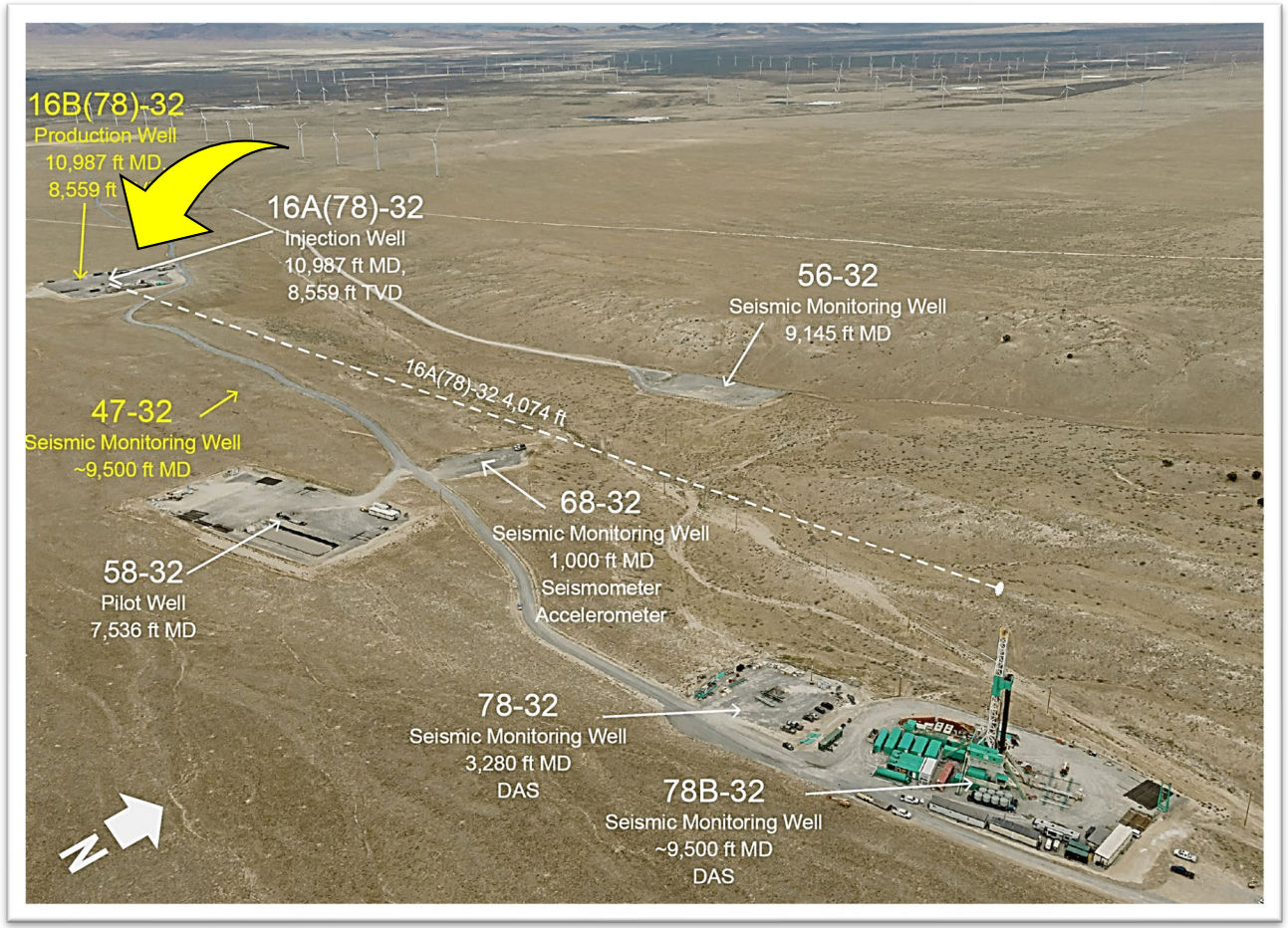
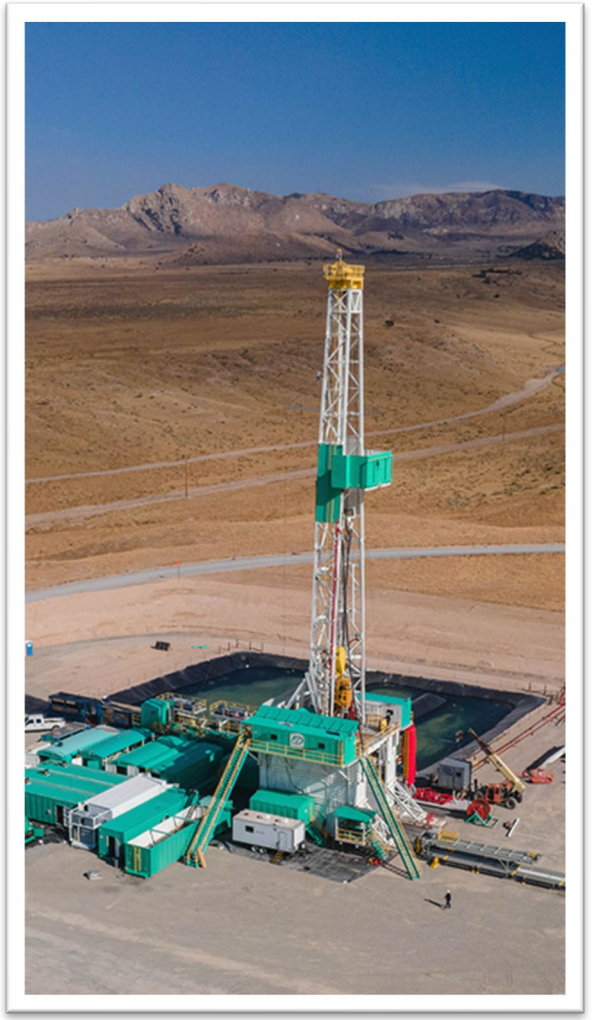
The FORGE Site

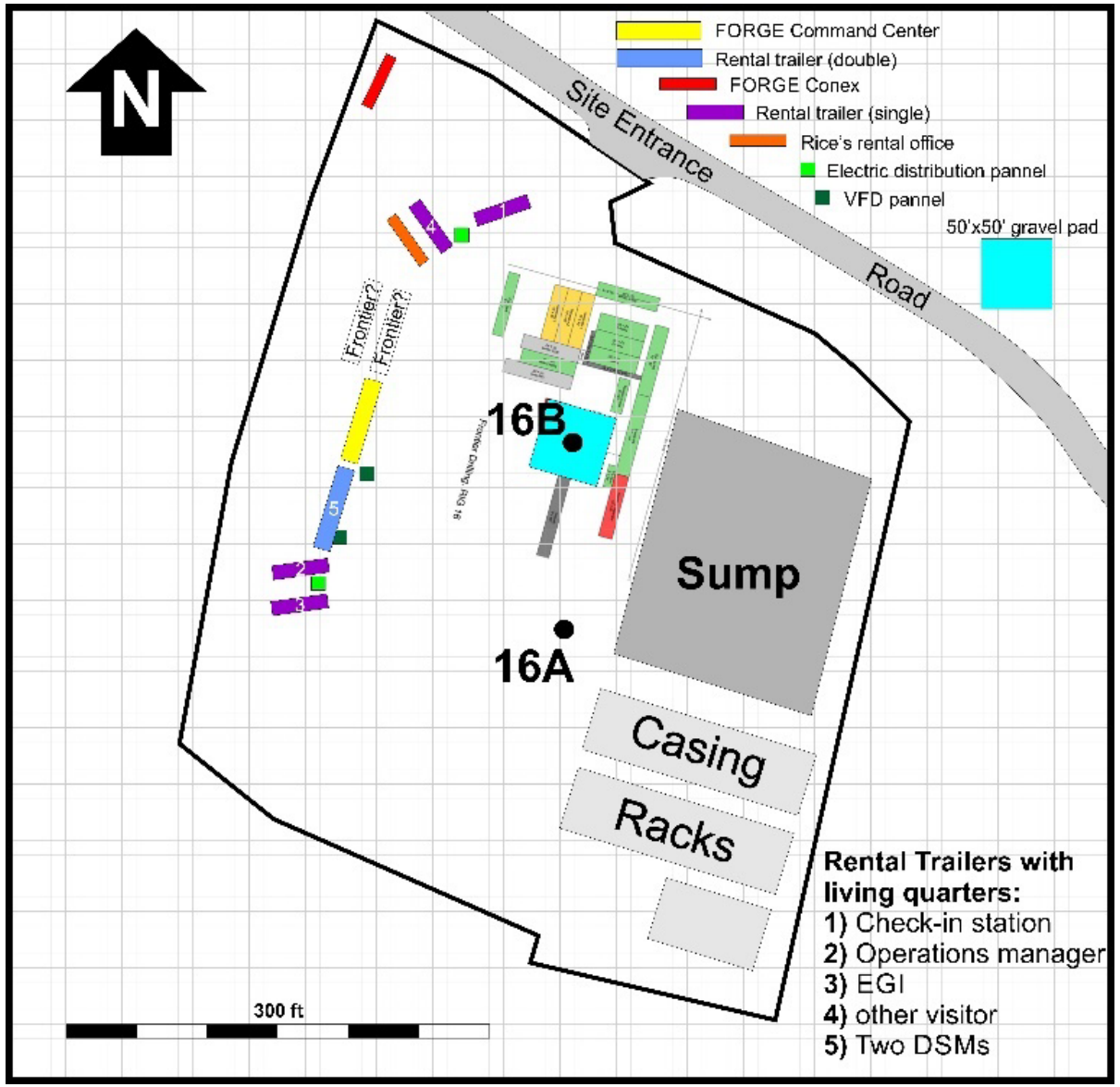


- Seventh well drilled
- Sister well to 16A(78)-32

Rig will be Frontier Rig 16

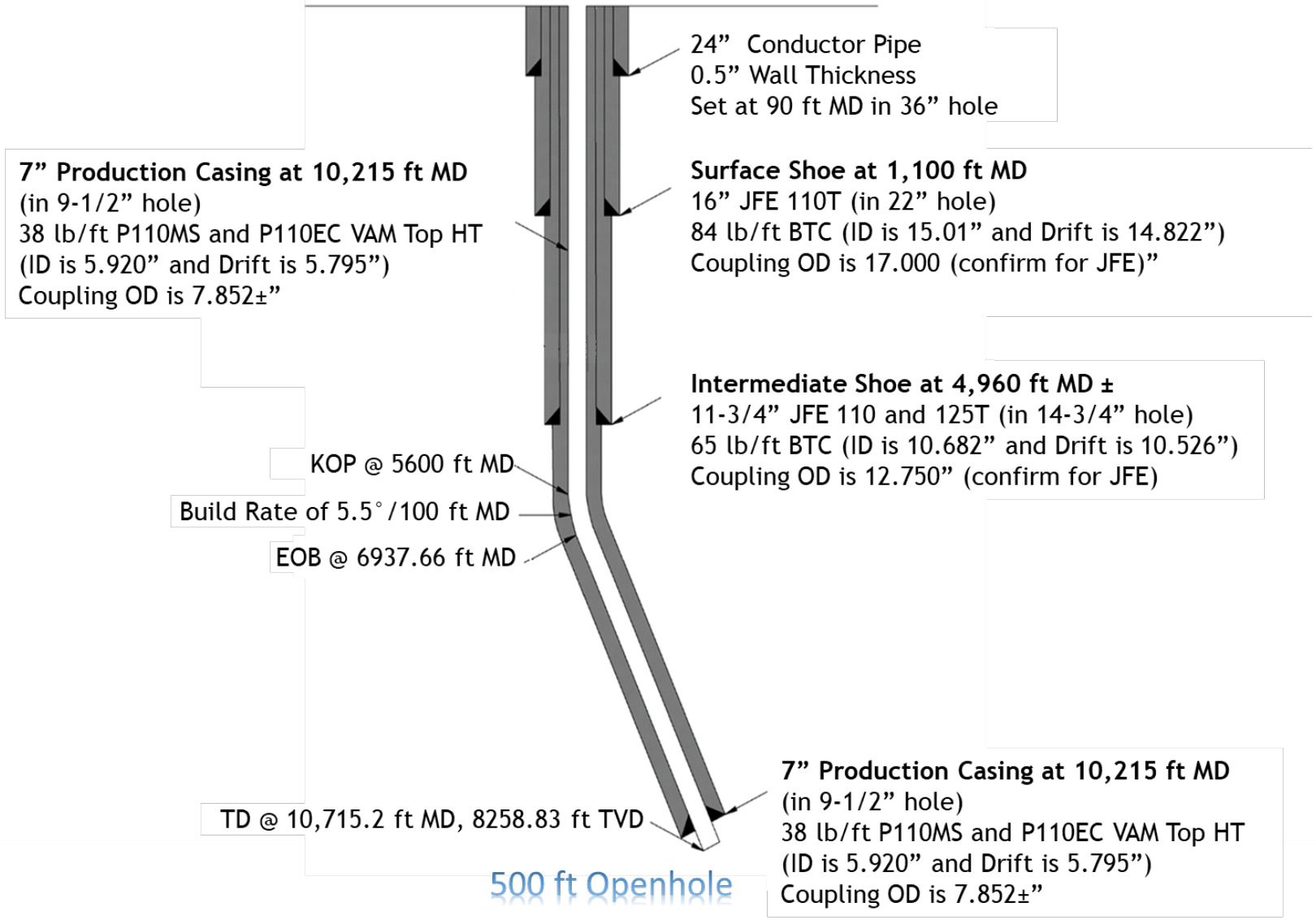


16-32 Pad


N
Site Entrance
Road
FORGE Command Center
Rental trailer (double)
FORGE Conex
Rental trailer (single)
Rice's rental office
Electric distribution pannel
VFD pannel
50'x50' gravel pad
Frontier?
Frontier?
16B
16A
Sump
Casing
Racks
300 ft
Rental Trailers with living quarters:
1) Check-in station
2) Operations manager
3) EGI
4) other visitor
5) Two DSMs

Planned Program

Synopsis of Planned Activities



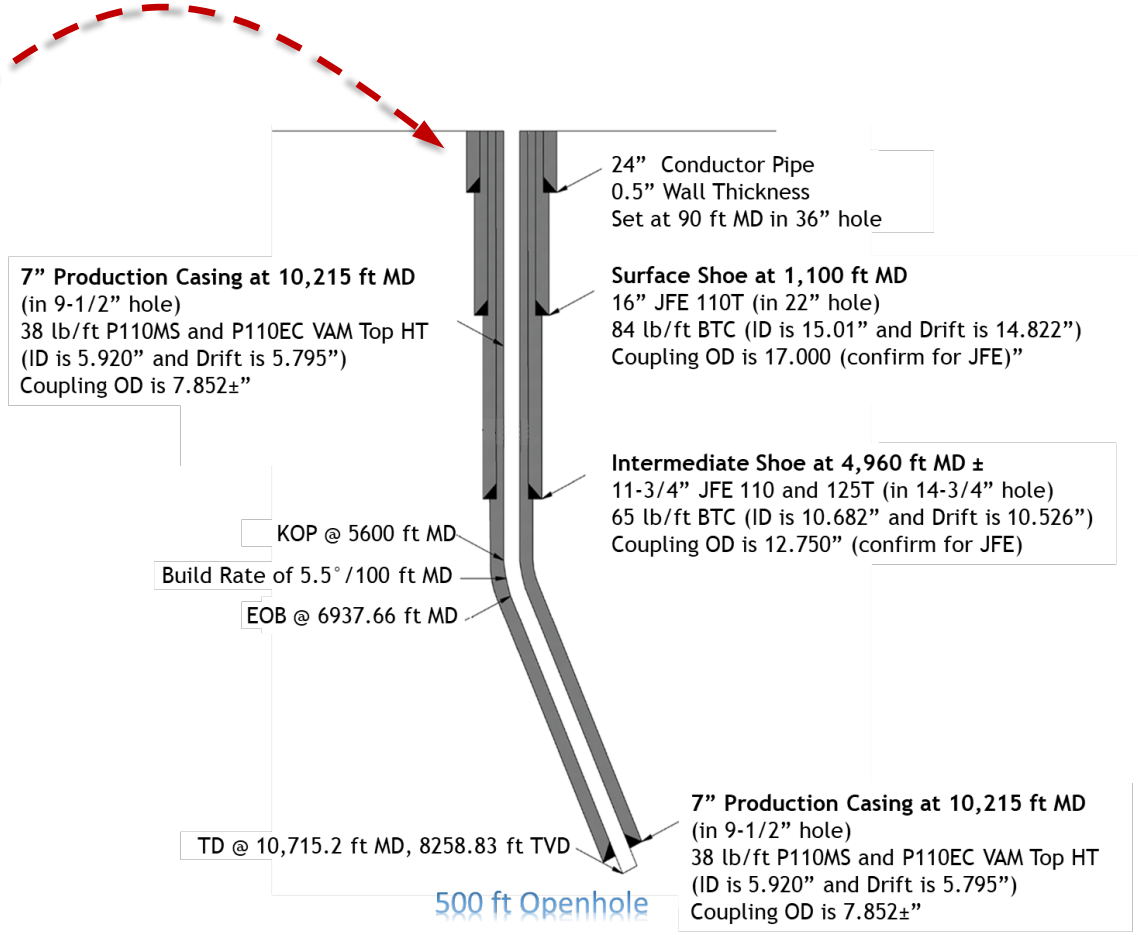
Conductor, Mousehole and Surface Hole

Conductor and Mousehole

- Wyoming Casing will install
- Scientific Drilling has completed trajectory and collision analysis

22” Surface Hole to 1,100 ft MD

- Rig will be Frontier 16
- Drill 22” hole to 1,100 feet (casing on location)
- Set 16” casing (84 ppf, L-80, BTC)
- SLB will cement
- Install the casing head [Stream-Flo]
- Install and pressure test BOPE [21-1/4-inch bid is out]



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Scientific Drilling

BHA Data Sheet

Job #				BHA #:	1	Hole Size :	22"	Motor # :	
Customer:	Utah Forge			Date In:		Date Out:		Motor OD:	9.15"
Well:	16B (78)-32			Depth In:	90	Depth Out:	1100	Tot.Ftge.:	1010
Well Loc.:	Milford Utah			Slide.Hrs.:		Slide Ft.:		Slide.ROP:	
County/St.:				Rot.Hrs.:		Rot.Ft.:		Rot.ROP:	
Rig :	Frontier Drilling			Drlg Hrs.:		Slide WOB:		Avg.ROP:	
DD:				Circ.Hrs.:		Rot. WOB:		Steering%:	
DD:				Tot D&C Hrs:		Avg. Tq.:		Rotate % :	
MWD:				R/S Config.:	7:8,5.7	Avg RPM :		GPM:	1200
MWD:				ABH Set:	0°	Incl. In:		SPP On:	
Mud Type:		Mud PV:		Mud YP:		Incl.Out:		SPP Off:	
Mud Wt.:		Chloride:		BHT F		Azimuth In :		Delta P:	
Mud Vis.:		Sand % :		Solid %:		Azimuth Out :		Avg.DLS:	

Item	Description	Vendor	S/N	F/N	Stab. OD	OD	ID	Connection	Length	Cum. Length
1	PDC Bit	NOV				22	3 1/2	7 5/8 Reg Pin	1.80	1.80
2	Mud Motor	SDI		W/Stab	9 1/2	21 7/8	3 1/2	7 5/8 Reg Box 7 5/8 Reg Box	38.00	39.80
3	Stabilizer			2.4	9 1/2	21 7/8	3 3/4	7 5/8 Reg Pin 7 5/8 Reg Box	6.00	45.80
4	Non Mag Drill Collar	SDI				9 1/2	4 1/4	7 5/8 Reg Pin 7 5/8 Reg Box	30.00	75.80
5	Non Mag Pony Collar	SDI				9 1/2	4 1/4	7 5/8 Reg Pin 7 5/8 Reg Box	10.00	85.80
6	Non Mag Support Sub	SDI				9 1/2	4 1/4	7 5/8 Reg Pin 7 5/8 Reg Box	2.90	88.70
7	Non Mag Gap Sub	SDI				9 1/2	4 1/4	7 5/8 Reg Pin 7 5/8 Reg Box	6.00	94.70
8	Non Mag Pony Collar	SDI				9 1/2	4 1/4	7 5/8 Reg Pin 7 5/8 Reg Box	11.00	105.70
9	6 Drill Collars	Rig				9 1/2	3 3/4	7 5/8 Reg Pin 7 5/8 Reg Box	186.00	291.70
10										
11										
12										
13										
14										
15									Total BHA Length =	291.70

BHA Weights :	Wt in Air = 75 lb	Wt in Mud = 75 lb	
BHA Expected Behavior	Maintain Strait Hole		7 5/8 Reg M/U = 60,200 #
			6 5/8 Reg M/U = 38,500 #
			4 1/2 IF M/U = 28,000 #

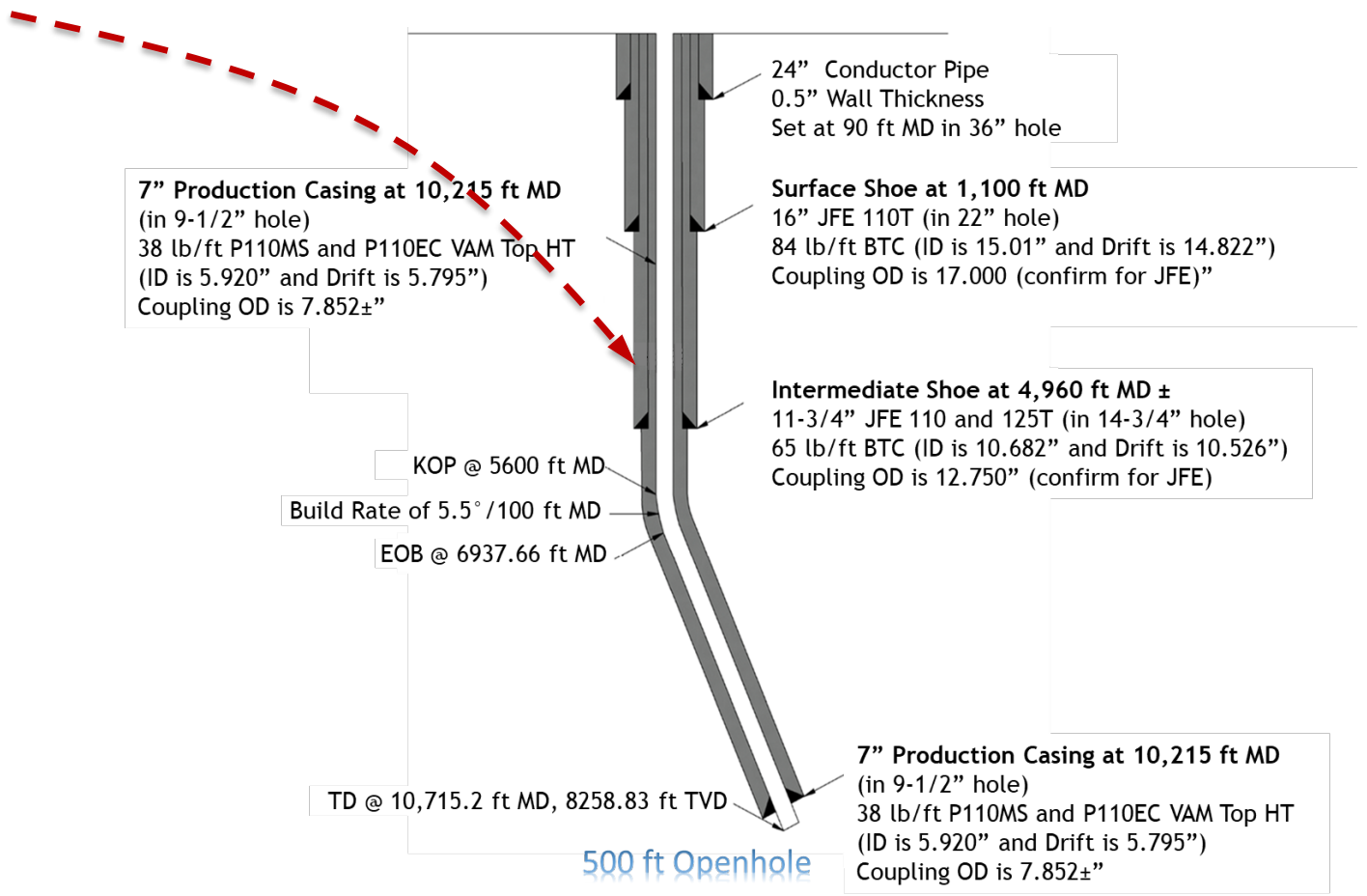
Conductor, Mousehole and Surface Hole

Item	Description		
Bit	PDC 22" Surface hole		
Mud	Weight (ppg)	Viscosity (seconds)	Filtrate (mL)
	8.6-9.2	50-60+	8-12 (<20)
	Lime/Gel/Water System: Drill 22-inch hole with flocculated Clay-based mud system; add Gel and Soda Ash/Lime as needed to maintain adequate viscosity/rheology for good hole cleaning (PV alap, YP 20-25+, gel strengths >8/>12). Use Gel, Sawdust, Polyvis (PHPA) to sweep and stabilize hole as needed; thin mud with Desco CF/water. Maintain pH of 9.0-10.0 with Lime/Soda Ash. Start DMA/PAC polymer additions @ 500 ft. If encountered, control lost circulation with conventional LCM pills - refer to LCM. Decision Tree for lost circulation considerations is in Appendix D. Total Mud Volume: TBD bbl is ~800 bbl (250 bbl surface volume) Temperature: BHST from 70°F to 120°F		

11-3/4” Intermediate Casing in 14-3/4” Hole

Intermediate Hole to 4,960 ft MD/TVD

- Drill out 16” casing shoe and perform an FIT (formation integrity test)
- Drill 14-3/4” vertical hole to 4,960± ft



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Well Loc.:	Milford Utah			Slide.Hrs.:		Slide Ft.:		Slide.ROP:	
County/St.:				Rot.Hrs.:		Rot.Ft.:		Rot.ROP:	
Rig :	Frontier Drilling			Drlg Hrs.:		Slide WOB:		Avg.ROP:	
DD:				Circ.Hrs.:		Rot. WOB:		Steering%:	
DD:				Tot D&C Hrs:		Avg. Tq.:		Rotate % :	
MWD:				R/S Config.:	7:8,5.7	Avg RPM :		GPM:	1200
MWD:				ABH Set:	0°	Incl. In:		SPP On:	
Mud Type:		Mud PV:		Mud YP:		Incl.Out:		SPP Off:	
Mud Wt.:		Chloride:		BHT F		Azimuth In :		Delta P:	
Mud Vis.:		Sand % :		Solid %:		Azimuth Out :		Avg.DLS:	

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	4 1/2 IF M/U = 28,000 #

Item	Description
Bit	TCI 14-3/4-inch to drill out the shoe - San Joaquin PDC 14-3/4-inch Intermediate hole (above granite) - NOV TKC66-A4 PDC 14-3/4-inch Intermediate hole (granodiorite) - NOV TKC83
BHA #2	Drill out the shoe with TCI
BHA #3	PDC bit, mud motor, stabilizer, NMDC, NM pony collar, NM support sub, NM gap sub, NM pony collar, six drill collars (see Figure 15)

Mud	Weight (ppg)	Viscosity (seconds)	Filtrate (mL)
	8.6-9.5	45-60	6-8

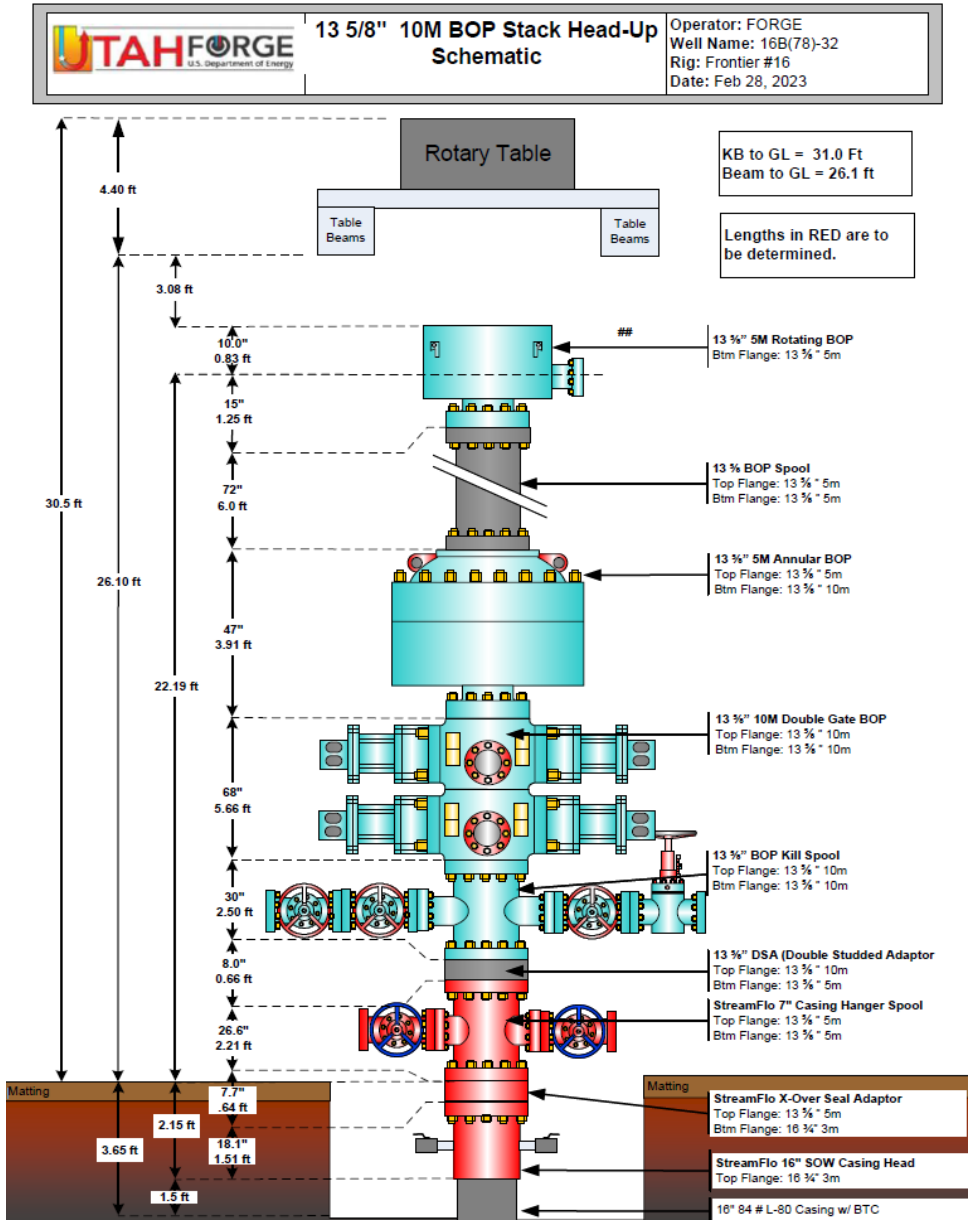
TBD: Freshwater HT LSND System, adding Gel/Polyvis/Xanthan Gum as needed to maintain adequate viscosity/rheology for good hole cleaning (PV alap, YP 15-25, gel strengths >8/>12). Use Gel, Polyvis, Sawdust, Altavert pills to sweep hole on a regular basis; thin mud with Desco CF if/as needed. Maintain mud weight with Barite if/as needed) to control any artesian influx. Use DMA/PAC Polymers for desired fluid loss control and to enhance wellbore stability, TORKease/Walnut to reduce torque and drag, and 2-4 ppb Micro C for Wellbore Strengthening sweeps. Discontinue Micro C additions once into 100% granite. Maintain pH of 10.5-11.0 with Lime/Caustic Soda. If encountered, control lost circulation with conventional MicroC/LCM pills and drill cuttings. Once in 100% granite switch hole to fresh water, start monitoring MSE and Spurt loss for enhanced ROP.

Mud Volume: 1,550 bbl (surface volume of 500 bbl)
Temperature Range: 125°F to 300°F BHST

Synopsis of Planned Activities

11-3/4” Intermediate Casing in 14-3/4” Hole

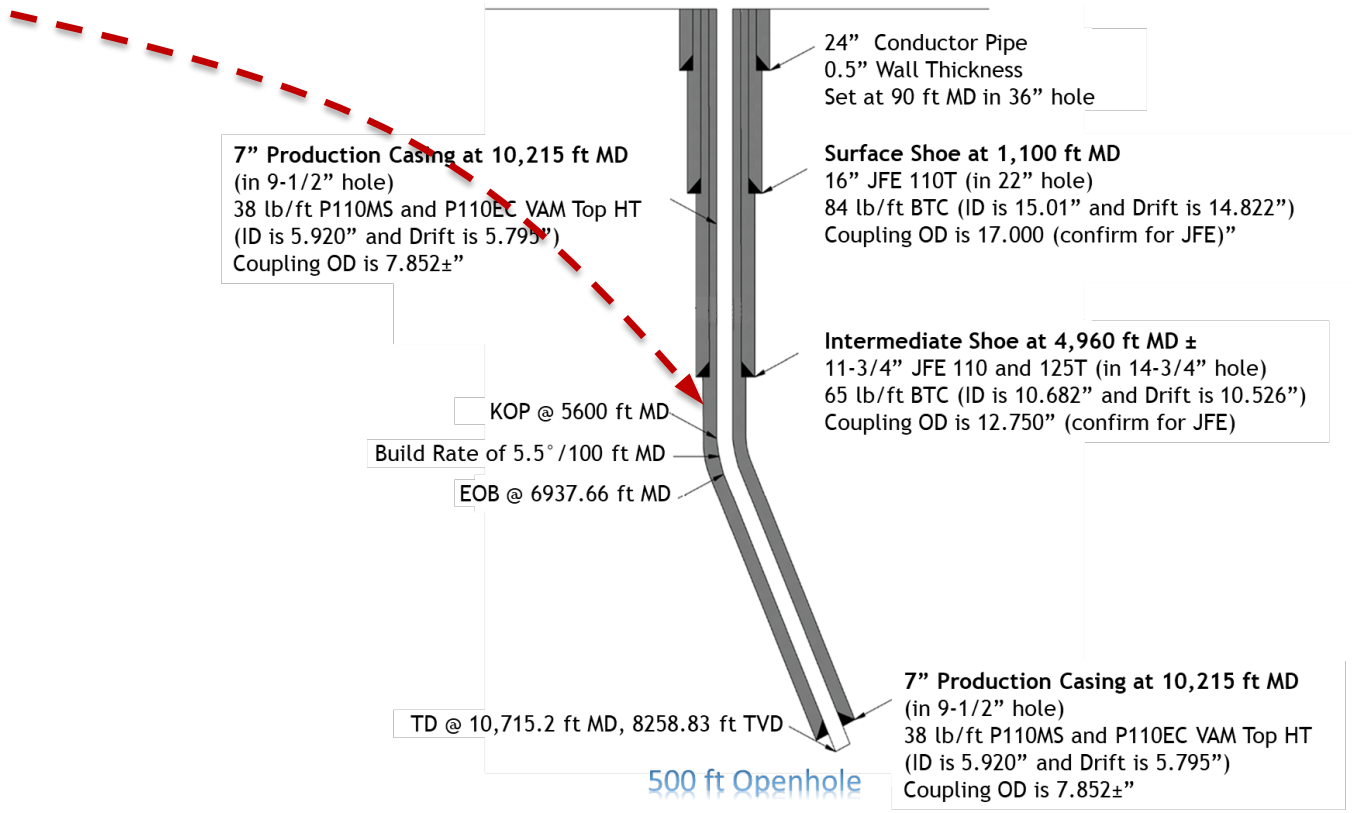
- Shoe depth about 400 ft below anticipated alluvium-granite contact
- Well 16A(78)-32 drilled alluvium to “official” granite contact at 4520-50± ft MD/~TVD
- Openhole logging will not be done
- Run and cement 11-3/4" casing
- Install wellhead and ancillary equipment and NU and pressure test BOPE



9-1/2” Production Hole

9-1/2” Production Hole from 4,960 ft to 4,970 ft± MD/TVD

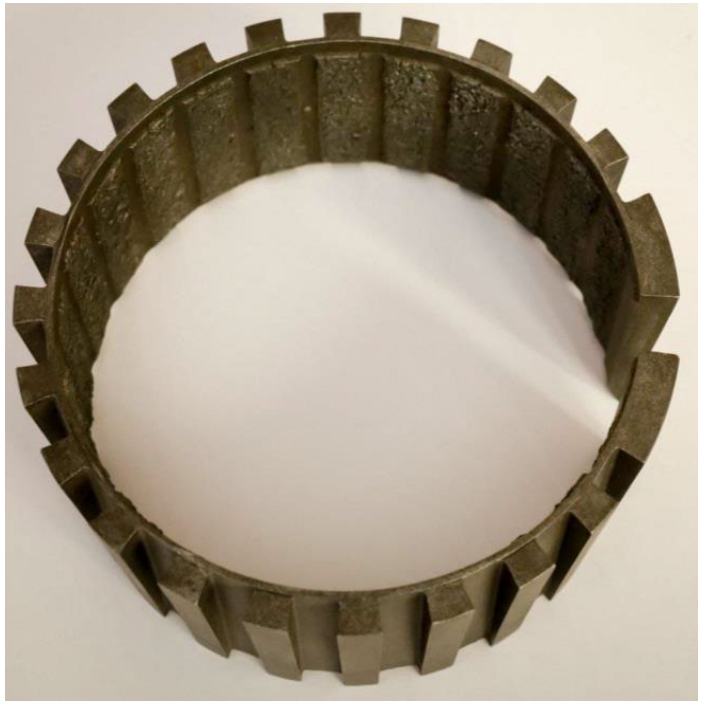
- Pressure test casing and BOPE
- Drill out shoe (PDC)
- Run an XLOT (Extended Leakoff Testing)



Coring in Vertical Section

9-1/2” Production Hole from 4,970 ft to 5,030 ft± MD/TVD

- Canamera will core
- Core from 4,970 to 5,030 ft
- Cut two 30 feet runs of 4-inch core.
- Bit will be 8-3/4”
- Some of the core will be allocated for ASR (Anelastic Strain Recovery by SNL)



Synopsis of Planned Activities

9-1/2” Production Hole from 5030 ft to 5,550 ft± MD/TVD

- MI RU NOV for Particle Drilling
- Circulate 16 YP fluid
- Trip in the hole with a 9-1/2” Particle Bit
- Ream Cored Hole and Drill Ahead

Synopsis of Planned Activities

Surface Set up With Fully Automated Control System

Control and Monitoring Cabin

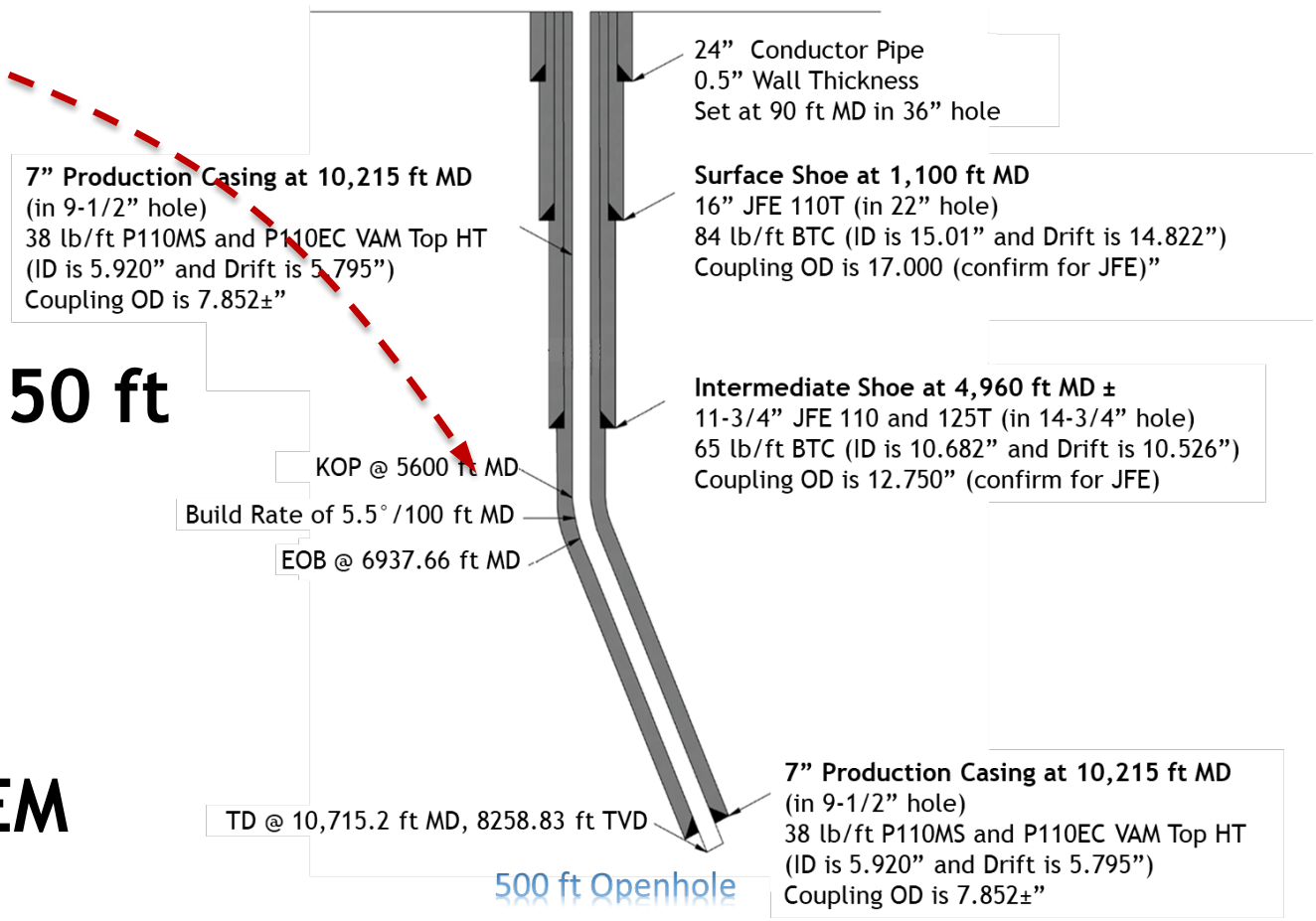
Particle Injection Unit

Particle Processing, Recovery and Storage Unit

Synopsis of Planned Activities

9-1/2” Production Hole from 4,970 ft to KOP at 5,600 ft± MD/TVD

- Circulate hole
- Drill ahead to KOP from 5,550 ft
- Run high-end cement evaluation tool, SLB Isolation Scanner
- Run gyro survey (have SDI EM in 14-3/4” hole)
- Looking for hole quality and deviation



Synopsis of Planned Activities

9-1/2" Production Hole Section 5,550 to 5,608' MD/TVD

- RIH with PDC bit and RSS and drill to KOP at 5,638 ft MD/TVD

9-1/2" Production Curve - 5,600' to Landing at 6,938' MD

- Drill curve at ~5.5°/100' with KOP @ 5,600' and projected curve landing (EOB) is at 65° and 6,938' MD. Hold azimuth at 105°
- Run UBI or equivalent to look for wear of the 11-3/4" casing
- Will be repeated after drilling some of tangent, to monitor casing wear (at about 8,184 ft MD) and hole quality
- Also, openhole run will allow assessment of rugosity.

Synopsis

9-1/2" Production Hole Section 5,550 to 5,608' MD/TVD

- RIH with PDC bit and RSS and drill to KOP at 5,638 ft MD/TVD

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- Run UBI or equivalent to look for wear of the 11-3/4" casing
- Will be repeated after drilling some of tangent, to monitor casing wear (at about 8,184 ft MD) and hole quality
- Also, openhole run will allow assessment of rugosity.

Scientific Drilling

BHA Data Sheet

Job #				BHA #:	3	Hole Size :	9 1/2	Motor # :	
Customer:	Utah Forge			Date In:		Date Out:		Motor OD:	7"
Well:	16B (78)-32			Depth In:		Depth Out:		Tot.Ftge.:	
Well Loc.:	Milford Utah			Slide.Hrs.:		Slide Ft.:		Slide.ROP:	
County/St.:				Rot.Hrs.:		Rot.Ft.:		Rot.ROP:	
Rig :	Frontier Drilling			Drlg Hrs.:		Slide WOB:		Avg.ROP:	
DD:				Circ.Hrs.:		Rot. WOB:		Steering%:	
DD:				Tot D&C Hrs:		Avg. Tq.:		Rotate % :	
MWD:				R/S Config.:	Halo	Avg RPM :		GPM:	650
MWD:				ABH Set:	RSS	Incl. In:		SPP On:	
Mud Type:		Mud PV:		Mud YP:		Incl.Out:		SPP Off:	
Mud Wt.:		Chloride:		BHT F		Azimuth In :		Delta P:	
Mud Vis.:		Sand % :		Solid %:		Azimuth Out :		Avg.DLS:	

Item	Description	Vendor	S/N	F/N	Stab. OD	OD	ID	Connection	Length	Cum. Length
1	9 1/2 Bit					9 1/2	2	4 1/2 Reg P	0.85	0.85
2	Halo RSS	SDI			9 3/8	7		4 1/2 Reg Box / 4 1/2 IF Box	35.00	35.85
3	Non Mag IB Stabilizer	SDI			9 1/4	6 3/4	3 1/4	4 1/2 IF Pin / 4 1/2 IF Box	6.00	41.85
4	Non-Mag Pony Collar	SDI				6 3/4	3 3/4	4 1/2 IF Pin / 4 1/2 IF Box	15.00	56.85
5	Non Mag Drill Collar	SDI				6 3/4	3 3/4	4 1/2 IF Pin / 4 1/2 IF Box	30.00	86.85
6	FG Roller Reamer					6 3/4	3 1/4	4 1/2 IF Pin / 4 1/2 IF Box	6.00	92.85
7	Titan 22 6/7 7.1 7.15 Mud Motor	SDI		Rev/Gal 0.23		7.15.		4 1/2 IF Pin / 4 1/2 IF Box	38.00	130.85
8	Filter Sub	SDI				6 3/4	3 1/4	4 1/2 IF Pin / 4 1/2 IF Box	4.00	134.85
9										
10										
11										
12										
13										
14										
15										

Total BHA Length = 134.85

BHA Weights : Wt in Air = Wt in Mud =

BHA Expected Behavior	

UTAH FORGE U.S. Department of Energy

www.

Item	Description
Bits	Drill out the shoe - tricone 9-1/2" hole - Baker Hughes or San Joaquin PDC 9-1/2" Production hole (Vertical & Tangent) - NOV TKC83 PDC 9-1/2" Production hole (Curve) - NOV TKC73 PDC - Baker Hughes 9.5" D406VX
BHA	TBD - vendor and consultants to advise
Motor	TBD - vendor and consultants to advise

Mud	Weight (ppg)	Viscosity (seconds)	Filtrate (mL)
	8.4-9.2[1]	27+/Sweeps	NC

Freshwater/Xanthan/Mechanical Sweeps. Continue drilling 9-1/2-inch hole with water and sweeps. If fill is found on connections, sweep the hole with small amounts of xanthan gum as needed for hole cleaning. Circulate before connections longer if fill is observed, and if a problem pump xanthan gum sweeps before trips. If circulation is not sufficient initiate mechanical sweeps of Altavert (temperature degradable HPA[2]), sawdust, or cotton seed hulls to clean the well bore. Maintain pH of 10-11 with lime/caustic soda. Use barite as needed to dry pipe while staging in and out of hole - safety issue addressed on past wells. Monitor spurt loss and SCE to enhance drilling efficiencies and MSE.

Monitor corrosion rates onsite and treat any unacceptable rates with corrosion additives. If severe lost circulation is encountered, consider drilling blind and/or using temperature degradable LCMs - refer to LCM Decision Tree for lost circulation considerations. Filtrate control should not be needed through this (granite) interval...if desired, DMA or other appropriate HTHP

Mud Volume: 1,550 bbl (600 bbl surface volume)
Temperature Range: 300°F to 425°F BHST

Scientific Drilling

BHA Data Sheet

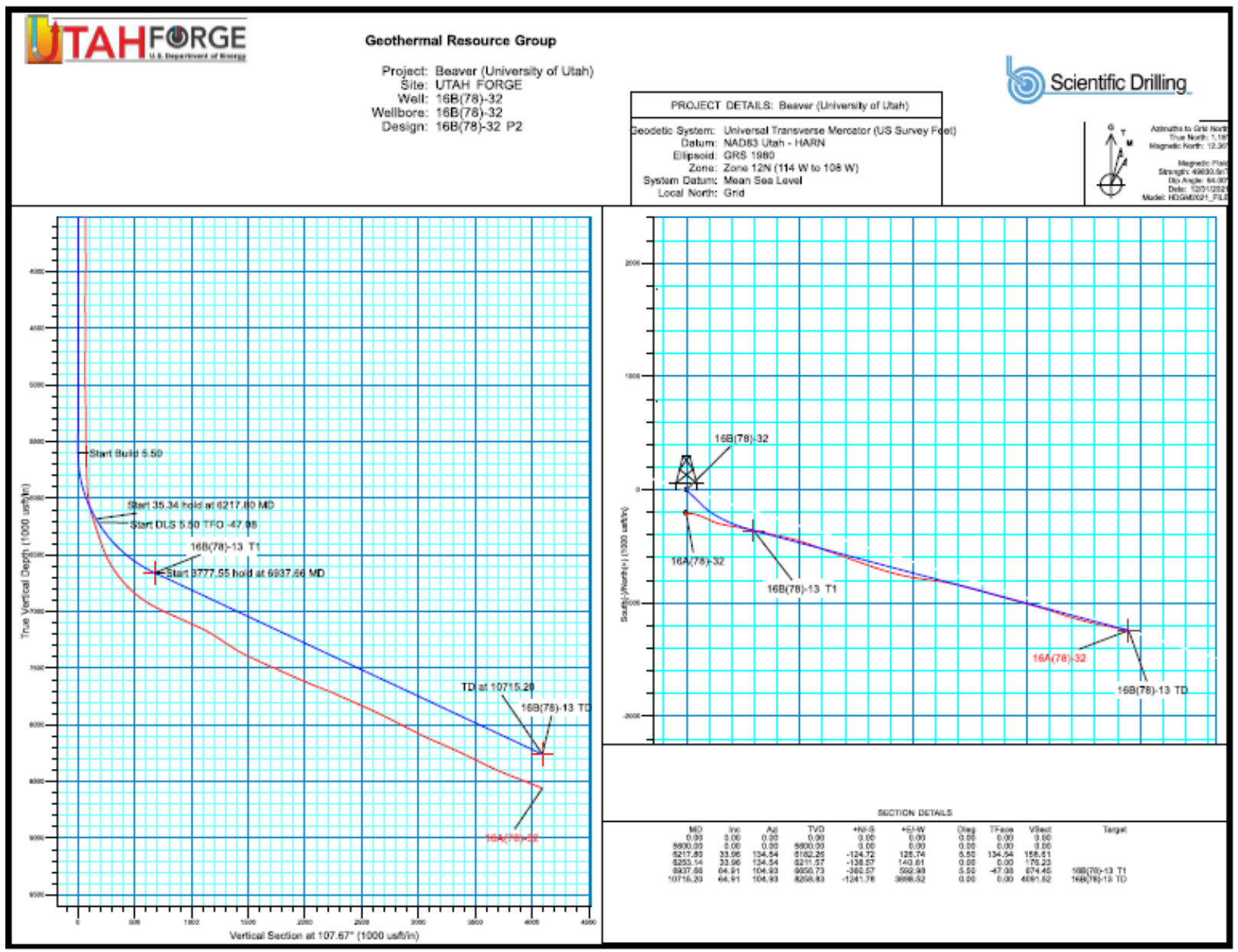
Job #		BHA #:	3	Hole Size :	9 1/2	Motor # :	
Customer:	Utah Forge	Date In:		Date Out:		Motor OD:	7"
Well:	16B (78)-32	Depth In:		Depth Out:		Tot.Ftge.:	
Well Loc.:	Milford Utah	Slide.Hrs.:		Slide Ft.:		Slide.ROP:	
County/St.:		Rot.Hrs.:		Rot.Ft.:		Rot.ROP:	
Rig :	Frontier Drilling	Drlg Hrs.:		Slide WOB:		Avg.ROP:	
DD:		Circ.Hrs.:		Rot. WOB:		Steering%:	
DD:		Tot D&C Hrs:		Avg. Tq.:		Rotate % :	
MWD:		R/S Config.:	Halo	Avg RPM :		GPM:	650
MWD:		ABH Set:	RSS	Incl. In:		SPP On:	
Mud Type:	Mud PV:	Mud YP:		Incl.Out:		SPP Off:	
Mud Wt.:	Chloride:	BHT F		Azimuth In :		Delta P:	
Mud Vis.:	Sand % :	Solid %:		Azimuth Out :		Avg.DLS:	

Item	Description	Vendor	S/N	F/N	Stab. OD	OD	ID	Connection	Length	Cum. Length
1	9 1/2 Bit					9 1/2	2	4 1/2 Reg P	0.85	0.85
2	Halo RSS	SDI			9 3/8	7		4 1/2 Reg Box 4 1/2 IF Box	35.00	35.85
3	Non Mag IB Stabilizer	SDI			9 1/4	6 3/4	3 1/4	4 1/2 IF Pin 4 1/2 IF Box	6.00	41.85
4	Non-Mag Pony Collar	SDI				6 3/4	3 3/4	4 1/2 IF Pin 4 1/2 IF Box	15.00	56.85
5	Non Mag Drill Collar	SDI				6 3/4	3 3/4	4 1/2 IF Pin 4 1/2 IF Box	30.00	86.85
6	FG Roller Reamer					6 3/4	3 1/4	4 1/2 IF Pin 4 1/2 IF Box	6.00	92.85
7	Titan 22 6/7 7.1 7.15 Mud Motor	SDI		Rev/Gal 0.23		7.15.		4 1/2 IF Pin 4 1/2 IF Box	38.00	130.85
8	Filter Sub	SDI				6 3/4	3 1/4	4 1/2 IF Pin 4 1/2 IF Box	4.00	134.85
9										
10										
11										
12										
13										
14										
15										

Total BHA Length = 134.85

BHA Weights : Wt in Air = Wt in Mud =

BHA Expected Behavior	


Geothermal Resource Group
Project: Beaver (University of Utah)
Site: UTAH FORGE
Well: 16B(78)-32
Wellbore: 16B(78)-32
Design: 16B(78)-32 P2
Scientific Drilling
PROJECT DETAILS: Beaver (University of Utah)
Geodetic System: Universal Transverse Mercator (US Survey Feet)
Datum: NAD83 Utah - HARN
Ellipsoid: GRS 1980
Zone: Zone 12N (114 W to 108 W)
System Datum: Mean Sea Level
Local North: Grid
Start Build 5.50
Start 35.34 hold at 6217.80 MD
Start DLS 5.50 TFO -47.98
16B(78)-13 T1
Start 3777.55 hold at 6937.66 MD
TD at 10715.29
16B(78)-13 TD
16A(78)-32
True Vertical Depth (1000 usft/in)
Vertical Section at 107.67° (1000 usft/in)
16B(78)-32
16A(78)-32
16B(78)-13 T1
16A(78)-32
16B(78)-13 TD
SECTION DETAILS
MD Inc Azi TVD +N/-S +E/-W DLeg TFace VSect Target
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
5600.00 0.00 0.00 5600.00 0.00 0.00 0.00 0.00 0.00
6217.80 33.96 134.54 6182.26 -124.72 125.74 5.50 134.54 156.51
6253.14 33.96 134.54 6211.57 -138.57 140.61 0.00 0.00 176.23 16B(78)-13 T1
6937.66 64.91 104.93 6650.73 -360.57 592.99 5.50 -47.98 674.45 16B(78)-13 TD
10715.29 64.91 104.93 8256.83 -1241.78 3696.52 0.00 0.00 4091.52

Synopsis of Planned Activities

Drill 9-1/2” 65˚Tangent Hole from 6938 ft MD to 8,184 ft MD

- Drill and then run another UBI casing survey to look for wear
- Drill ahead with a 65° tangent. Hold azimuth at 105˚ to true north
- Keep 300 ft between this well and well 16A(78)-32
- Run UBI to in evaluate fractures, rugosity and casing wear
- Confirm and be aware of temperature limitations

Drill 9-1/2" 65˚ Tangent Hole from 8,184 ft to 10,215 ft MD

- This is for drilling to near TD, pending a subsequent stage for coring
- Drill 9-1/2” hole at 65˚ angle at N105˚E from 8,184’ to 10,215’ MD

Synopsis of Planned Activities

Drill 9-1/2” 65˚Tangent Hole from 6938 ft MD to 8,184 ft MD

- Drill and then run another UBI casing survey to look for wear

Item	Description
Bit	PDC 9-1/2" Production hole (Vertical & Tangent) - NOV TKC83 PDC - Baker Hughes 9.5" D406VX
BHA	Bit, Halo RSS, NM IB stabilizer, NM pony collar, NM drill collar, full gauge roller reamer, Titan 22 6/7 7.1 7.15 mud motor, filter sub - see Figure 20

- This is for drilling to near TD, pending a subsequent stage for coring
- Drill 9-1/2” hole at 65˚ angle at N105˚E from 8,184’ to 10,215’ MD

Synopsis of Planned Activities

Core from 10,215 ft to 10,715 ft MD

- Call out tracer team to be sampling returns
- Coring strategic sections (Canamera)
- The basis for coring strategic sections over the 500 ft openhole section in well 16A(78)-32 where the Stage 1 frac was pumped and an additional 300 ft where the Stage 2 frac was pumped.
- Cuttings need to be caught much more frequently and returned fluids sampled almost continuously
- After each coring run, TIH hole and ream and drill ahead with 9-1/2" bit to 10,715'MD
- ALLOCATE ONE SECTION OF THIS CORE TO THE UNIVERSITY OF OKLAHOMA FOR ASR TESTING

Synopsis of Planned Activities

Core from 10,215 ft to 10,715 ft MD

- Call out tracer team to be sampling ret
- Coring strategic sections (Ca
- The basis for cor
  section i

- 9,880-9,920 (core from 9,870 ft MD to 9,930 ft MD - for Stage 3) - NOTE THIS MEANS CORING BEFORE REACHING THE ZONE THAT WILL REMAIN OPENHOLE (BEFORE 19,215 FT MD)
- 10,320-10,360 (core from 10,310 to 10,370 ft MD)
- 10,520-10,560 (core from 10,510 to 10,570 ft MD)

ity and returned

hole and ream and drill ahead with 9-
MD

E ONE SECTION OF THIS CORE TO THE UNIVERSITY OF OKLAHOMA FOR ASR TESTING

Synopsis of Planned Activities

Logging (SLB)

- RIH with a high-resolution temperature survey to look for zones where either preferential cooldown or preferential warmback are occurring which may indicate fractures
- Rig up and log production hole section
  - Run a quad-combo (resistivity, sonic, density, neutron)
  - Run UBI (ultrasonic borehole imager or equivalent)
  - Run FMI (formation microimaging or equivalent)
  - Convey by ThruBit

Synopsis of Planned Activities

Gauge Runs from 4960± ft to 10,715 ft MD

- After logging, gauge runs will be carried out

Battelle Stress Measurements

- With the hole open, Battelle will implement their stress measurement program

Project Title: A Multi-Component Approach to Characterizing In-Situ Stress at the U.S. DOE FORGE EGS Site: Laboratory, Modeling and Field Measurement

UNIVERSITY OF UTAH SUBAWARD AGREEMENT NO. 10039612-Battelle-2-2439-AF1

Task 3
In-Situ Measurement of Stress

Presented at 16B(78)-32 Drill Well on Paper (DWOP) Meeting

by

Mark Kelley (Battelle)
Philip Davis, Steve Smith, Masroor Alam (Baker Hughes)

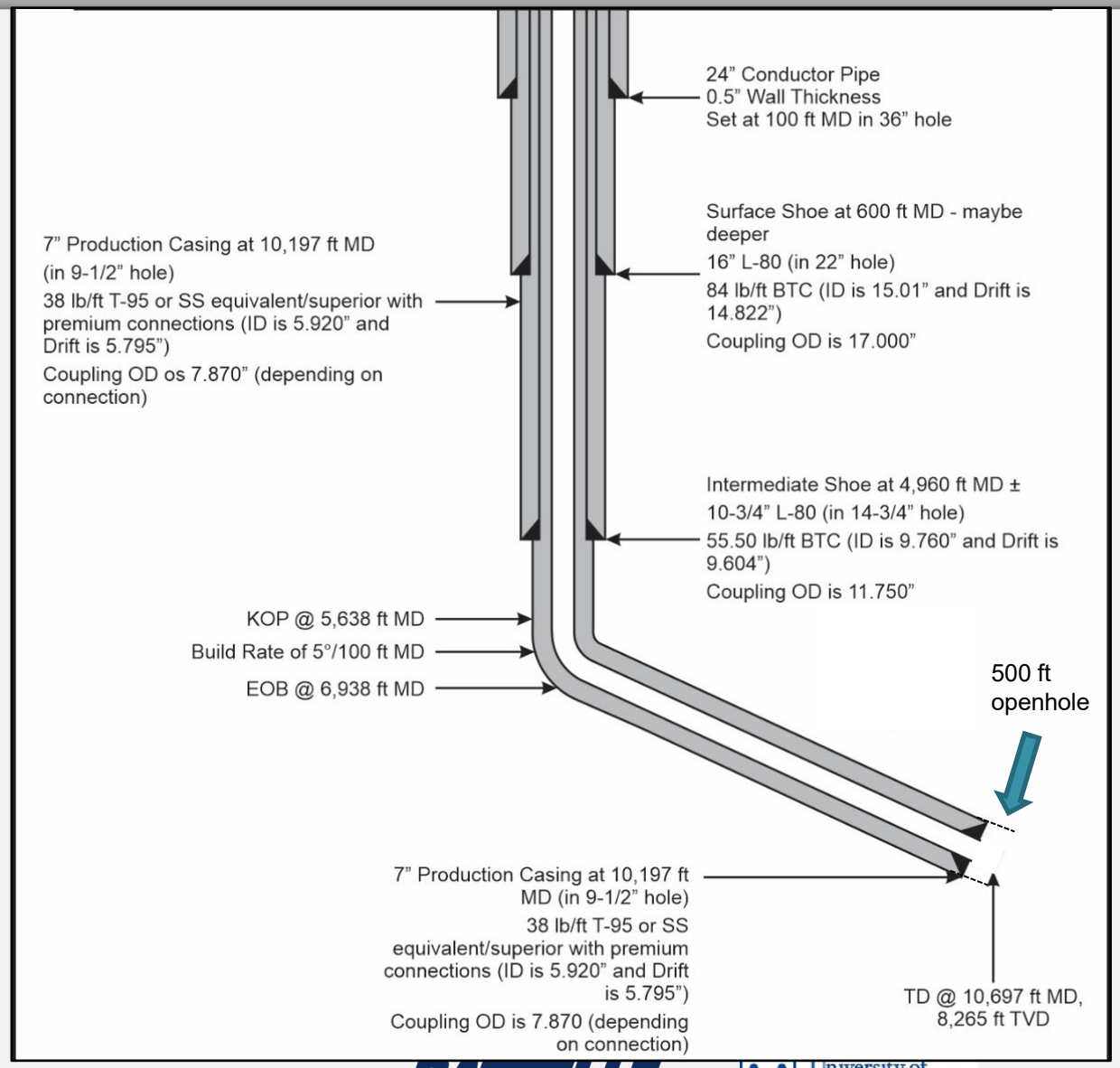
March 2, 2023

Objective of Task 3 (in-Situ Measurement of Stress)

- This project will attempt to characterize stress distribution as a function of depth through the geothermal reservoir by conducting minifrac tests at multiple depths in the 16(B)78-32 borehole.

Well 16B(78)-32 Plan

- The minifrac testing will be conducted in the 9.5-inch diameter borehole after it is drilled to total depth but before the final deep casing string is installed.



Max testing depth will be ~9,000 ft

Minifrac Test

- A typical minifrac test is a brief low volume\high pressure injection of water into a short (~1 m) interval of rock isolated with a straddle packer
- Injection continues until break down is observed followed by a monitoring period to record pressure decline until the fracture closes; parameters that can be observed from the pressure behavior include:
  - FBP (Fracture breakdown) is observed in the initial cycle
  - FPP (Fracture propagation pressure)
  - ISIP (Initial shut-in pressure)
  - FCP (Fracture closure pressure) – minimum in situ stress magnitude.
- Usually, the injection test is repeated 2 to 3 times after the initial cycle
- Azimuth of the maximum horizontal stress can be determined from image and sonic logs obtained after fracturing

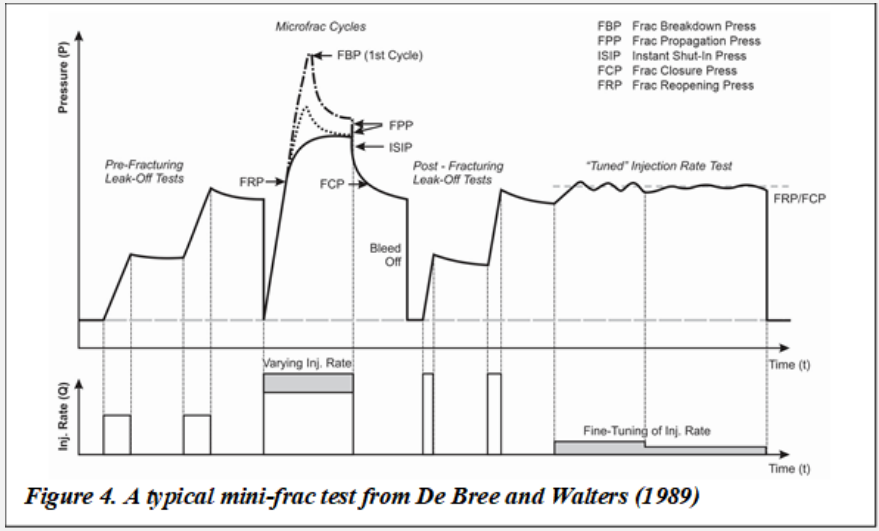


Figure 4. A typical mini-frac test from De Bree and Walters (1989)

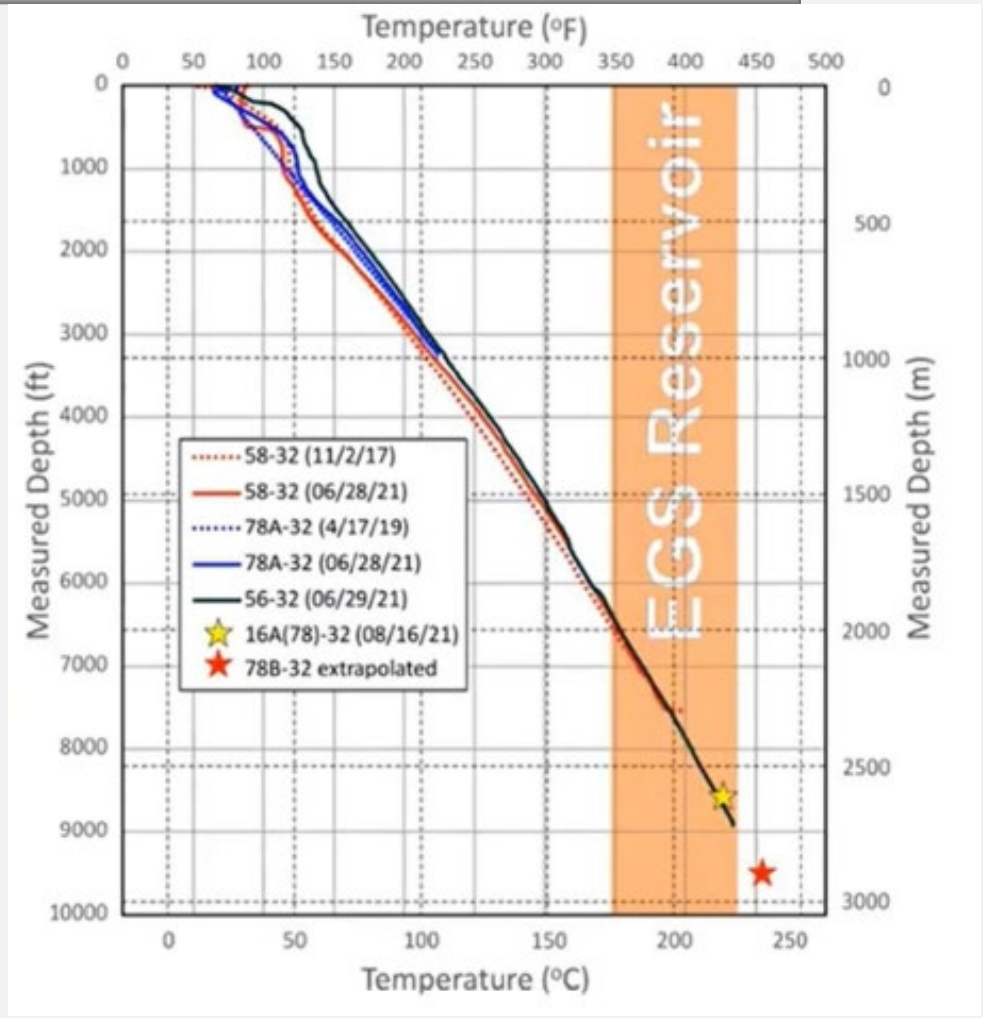
De Bree, P. and J.V. Walters (1989). Micro/minifrac test procedures and interpretation for *in situ* stress determination; International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts; Volume 26, Issue 6, December 1989, Pages 515-521.v

Approach for Conducting Minifrac Tests

- Minifrac tests will be conducted using Baker Hughes Reservoir Characterization Explorer (RCX) logging tool
- The testing tool is equipped with a straddle packer with vertical spacing of 1 meter; a pump for injecting fluid into the test interval; sensors for pumping rate, pressure and temperature in test interval, packer pressure, and diagnostics; and, and real-time readout (display) and data-logging/recording capabilities.
- The testing tool will be deployed on drill pipe to minimize risk of stuck tool.
- The high bottomhole temperature (approx. 430 °F ambient) will necessitate intermittent circulation with drill-mud coolers to maintain the temperature below the upper temperature rating of the test equipment (350 °F).
- Potential high breakdown pressures require backup approach for creating fractures if limit of straddle packer tool is exceeded (sleeve packer frac method).
  - Straddle packer 4,090 psi
  - Sleeve packer 7,470 psi
- Image logs and sonic log will be acquired before and after the minifrac tests to image the newly created fractures

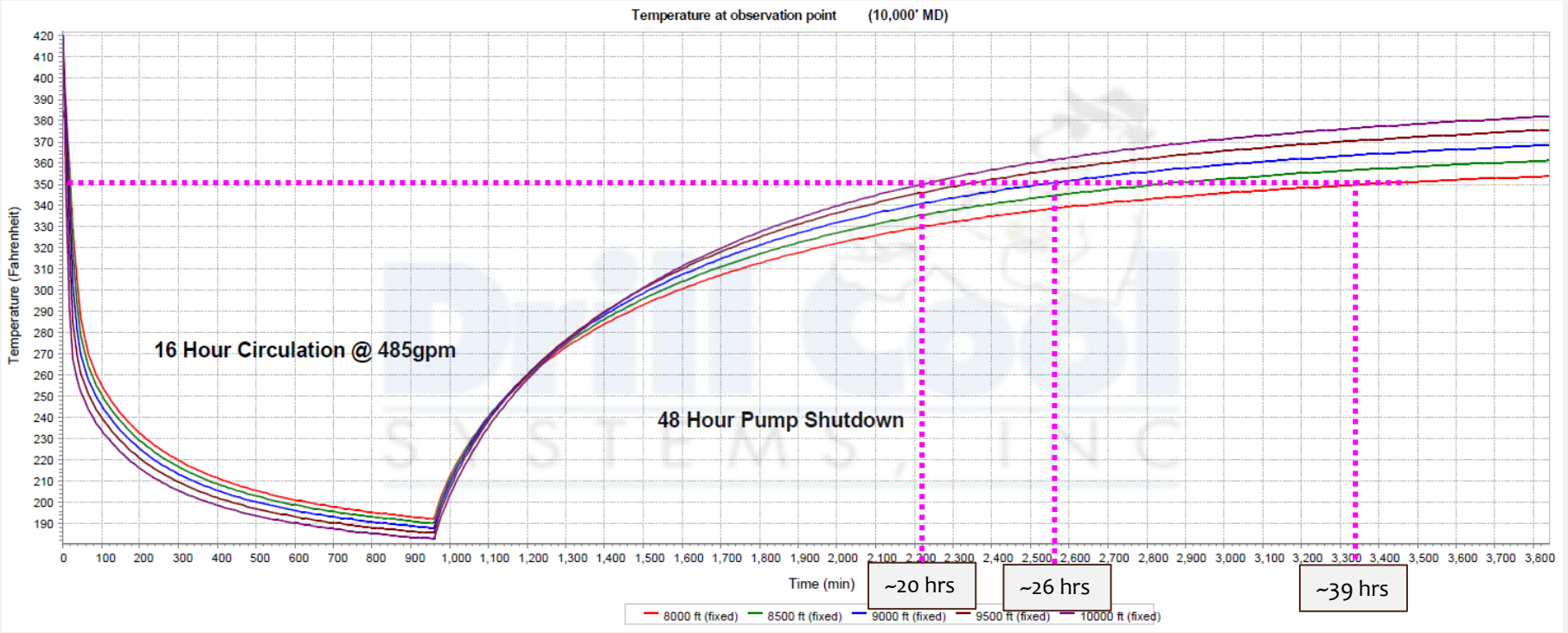
Overcoming High Temperature

- At the TVD of the 16B(78)-32 well (approximately 8,500 ft), maximum expected temperature is approximately 430°F.
- Temperature exceeds temperature limit of Baker's tools (350°F); therefore, it will be necessary to actively cool the borehole by circulating fluid for a period of time before lowering tools into the borehole.



Temperature Modeling

- Effectiveness of circulation cooling was modeled by Drill Cool Inc. to simulate cooling in the 16B(78)-32 well
- Max testing depth will be 9,000 ft MD due to time required to deploy with PCL



This plot shows that a 16-hour circulation event will reduce temp to ~180 °F to 195 °F between 8,000 to 10,000 ft MD and that temperatures will rebound to 350 °F after ~20 hours at 10,000 ft, ~26 hours at 9,000 ft, and ~39 hours at 8,000 ft after circulation stops.

Logging/Testing/Cooling Sequence

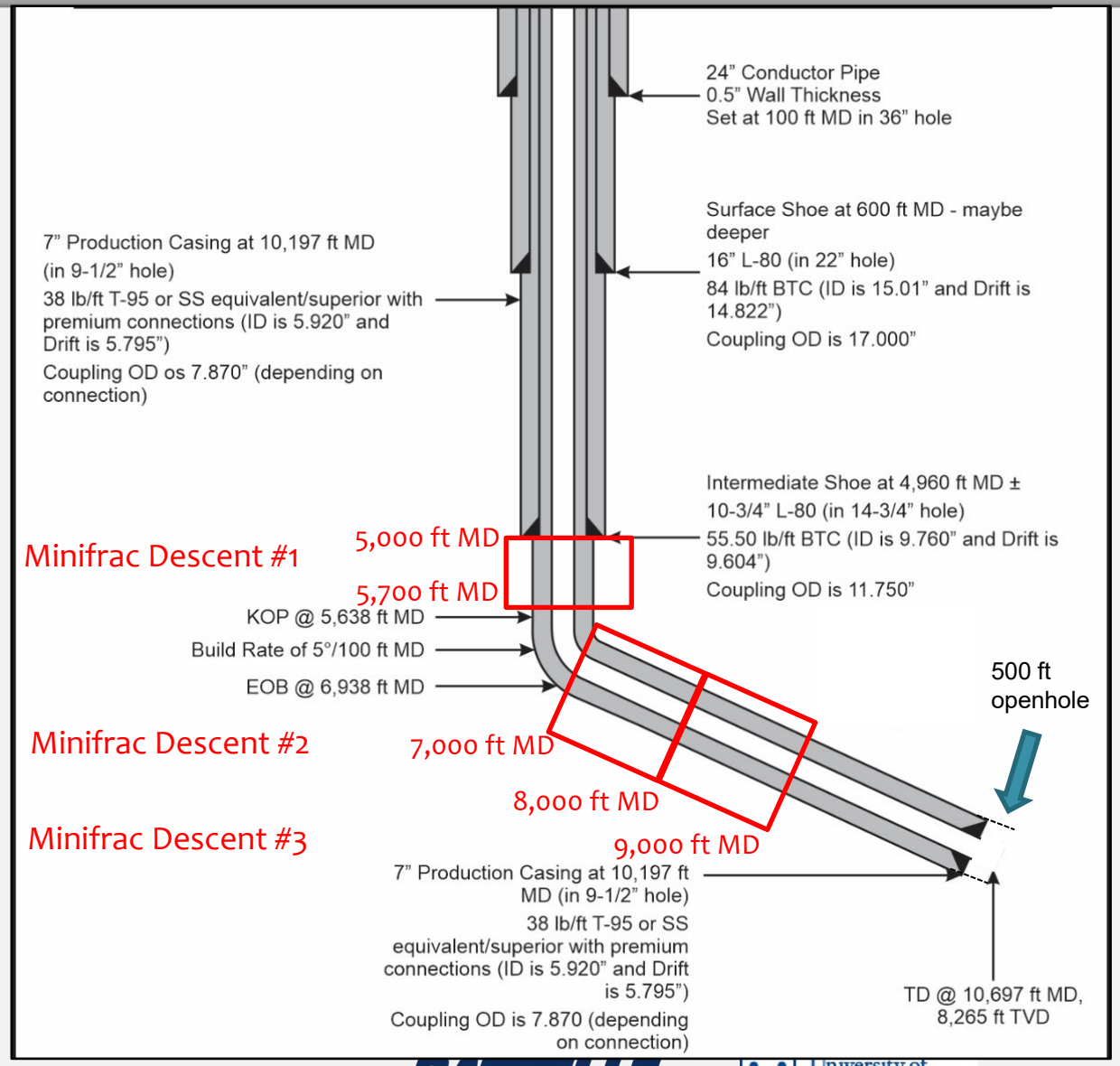
- Five (5) pipe conveyed descents, including
  - one descent to acquire the baseline logs before mini-frac testing,
  - three descents to conduct minifrac testing, and
  - one descent to acquire repeat logs after minifrac testing.
- Five (5) cooling events – one immediately before each of the five logging/testing runs.
  - 26 hours in duration – includes 5 hrs to TIH, 16 hrs circulation, and 5 hrs to TOH

Time Assumptions

Event/Descent	Depth (ft MD)	Activity and duration	Total Duration (hrs)
Cooling events	9,000	TIH (5 hrs) Circulate (16 hrs) TOH (5 hrs)	26
Descents #1 and #5	9,000	R/up (3 hrs) RIH/latch (4.4 hrs) log down XMAC/log up STAR-UXPL (10.4 hrs) unlatch/POOH (4 hrs) R/down (2 hrs)	23.8
Descent #2	5,000 to 6,200	R/up (3 hrs) RIH/latch (5.1 hrs) Minifrac Testing (12.3 hrs) unlatch/POOH (4.2 hrs) R/down (2 hrs)	26.6
Descent #3	8,000 to 9,000	R/up (3 hrs) RIH/latch (6.4 hrs) Miniftrac Testing (12.5 hrs) unlatch/POOH (5.4 hrs) R/down (2 hrs)	29.3
Descent #4	7,000 to 8,000	R/up (3 hrs) RIH/latch (5.6 hrs) Minifrac Testing (12.8 hrs) unlatch/POOH (4.7 hrs) R/down (2 hrs)	27.8
		Total	261.3

Well 16B(78)-32 Plan

- Three minifrac descents will be attempted
- Descent #1 will be conducted in the vertical section of the borehole above a depth corresponding to 350 F



Max testing depth will be ~9,000 ft

Tool Configuration

- 2 tool string configurations will be used for the 5 descents.
- Configuration #1: baseline and post mini-frac logging descents.
  - DSL, STAR, ORIT, XMAC, UXPL, ZDL, ORIT, GR
- Configuration #2: mini-frac descents.
  - DSL, RCX (SP-SLVP), WGI(3CAL), HFIND
- Tool conveyance will be via PCL

Acronym	Service Type
PCL	Pipe Conveyed Logging
DSL	Digital Spectralog
STAR	Borehole Resistivity Imager
ORIT	Orientation Tool
XMAC	Acoustic
UXPL	Acoustic Imager
RCX	Microfrac Tool
SP	Straddle Packer
SLVP	SleeveFrac Packer
3CAL	3-arm caliper
HFIND	Hole Finder

See detailed tool drawings in Field Test Plan

Synopsis of Planned Activities

Openhole Circulation Evaluation

Connection Evaluation from 16A(78)-32

- Establish connectivity but do not to create additional connections.
- Before casing, only inject from 16A(78)-32 to establish where the hydraulic fractures have grown.
- Install instrumentation and recording equipment (EDR or otherwise).
  - measurement at 16B(78)-32 and 16A(78)-32 wellheads (or in-well if possible) of temperature and pressure.
  - Monitor pressure in offsets and temperature
  - Measure barometric pressure

Synopsis of Planned Activities

Openhole Circulation Evaluation

Connection Evaluation from 16A(78)-32

- Rig up flow system at 16B(78)-32 flow lines
- Run iron to one or more frac tanks (i.e., have enough tanks and plumbing for flowback)
- In line between wellhead and frac tank have a flow meter, throttle valves, pressure measurement, temperature measurement, valved line for fluid sampling
- Rig iron to 16A wellhead. Be prepared to pump at up to 5,000 psi
- Flow partitioning in Well 16A(78)-32 will need to wait until fall stimulation campaign

Synopsis of Planned Activities

Openhole Circulation Evaluation

Connection Evaluation from 16A(78)-32

- Rig up low-rate pumping equipment (could include low-rate triplex, cementers, modified rig pump with bypass and upgraded instrumentation and recording)
- Rate and pressure measurements required (temperature and pressure measured at wellhead as well)
- Bullhead friction reduced water down casing in well 16A(78)-32
- Monitoring on Well 16B(78)-32 could include intervention cable, 3-1/2” tubing to get dead string, spinner survey while injecting

Synopsis of Planned Activities

Openhole Circulation Evaluation

Connection Evaluation from 16A(78)-32

Stage	Rate (bpm)	Volume (bbl)	Incremental Time (minutes)	Cumulative Volume (bbl)	Cumulative Time (minutes)	Cumulative Time (hr)
	0	0	0	0	0	0
1	1	120	120	120	120	2
2	2.5	300	120	420	240	4
3	5	600	120	1,020	360	6
4	2.5	50	20	1,070	380	6.33

Synopsis of Planned Activities

Place Weighted Brine Below Location of Casing Shoe

- Place weighted or viscosified brine below where shoe for the 7-inch casing would be set. Top with bentonite or sepiolite
- Prevent cement from entering uncased hole

Run Casing and Cement

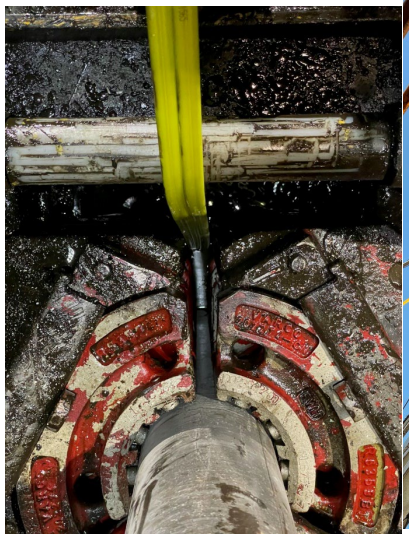
- Dummy Run: Mock up shoe equipment, certain number of casing joints, casing coupling protectors, dummy fiber termination devices and RIH looking for locations where hang-ups could occur. If they are located, go back to remedial operations to eliminate rugosity, ledges, tight hole, etc.
- Run Casing and FO Separate iWOP:
- Run and cement 7-inch casing with fiber optics
- Run fiber optics with casing as called out in the prognosis

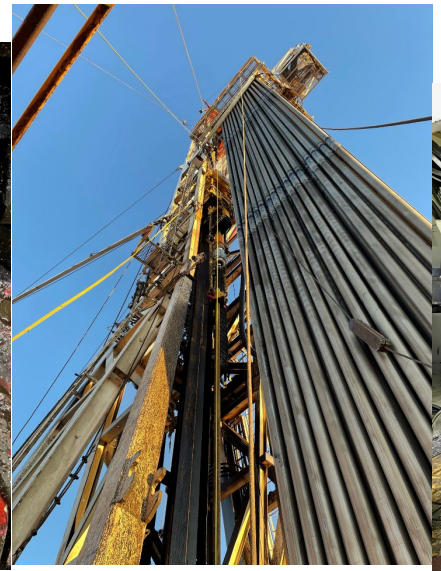
Instrumentation Installation – A Helicopter View

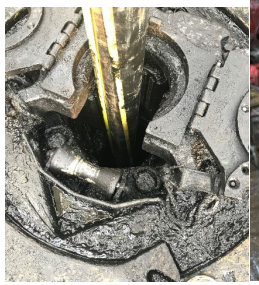
This is a brief overview. A lot more detail will be covered in a subsequent iWOP

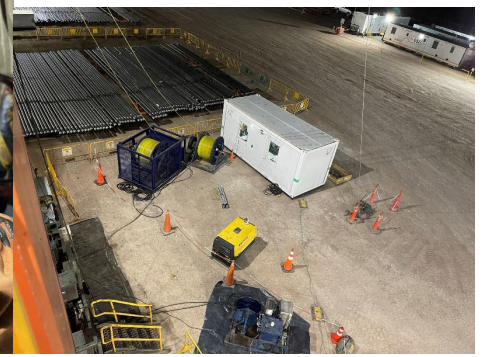
Primary Take-aways

- Three easily damaged lines will be run from three spooling units located at ground level.
- Lines will be launched downhole from a sheave cluster mounted at a height close to the monkey board.
- Running speed will be in the order of 5 joints/hour in the deviated section to 10 joints/hour in the vertical.
- Special protectors will use specialized tooling, provided by Baker but all hands can help.
- Drill floor population will be higher than normal.
- Drill string will be laid down before RIH with casing.
- Teamwork and communication is key to a successful installation
- This is not our first rodeo, but we also learn every time. This will not be an exception.









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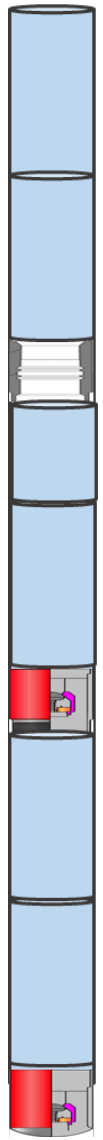
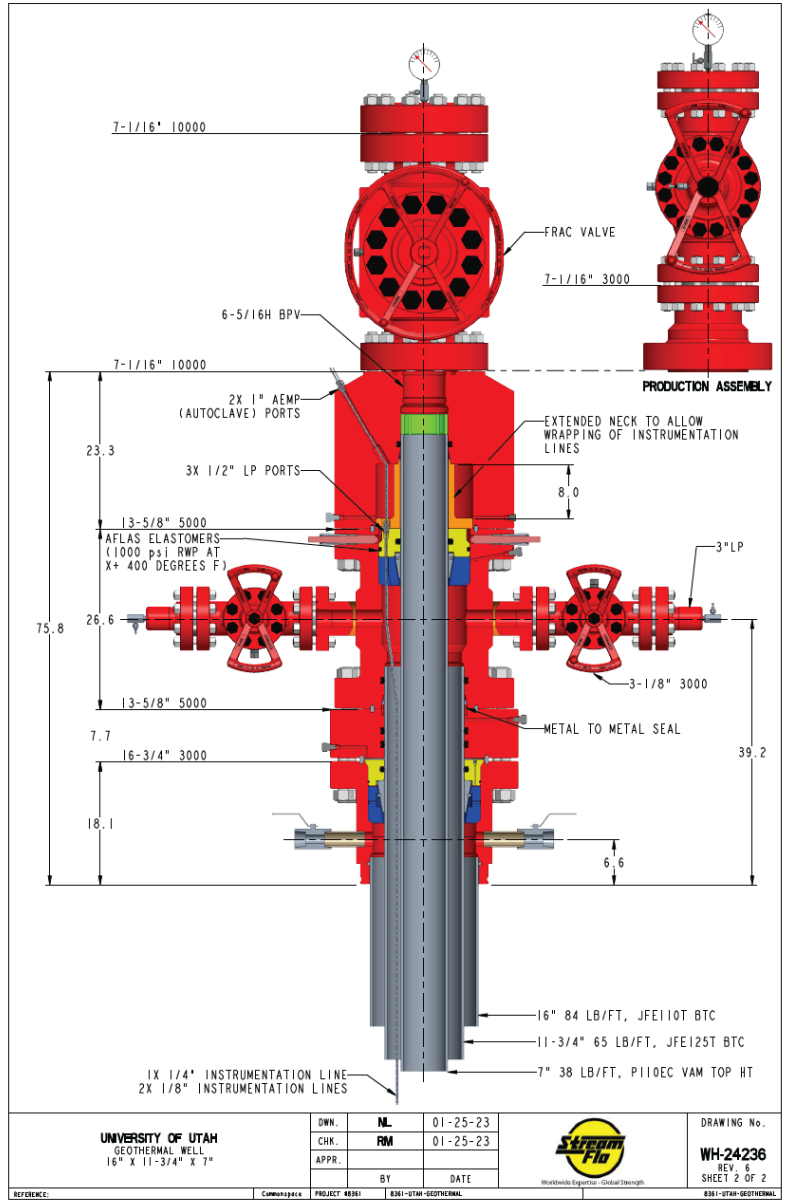

7-inch casing joint
7-inch casing joint
PetroQuip locating nipple
7-inch marker joint
7-inch casing joint
7-inch float collar
7-inch casing joint
7-inch casing joint
7-inch float shoe


7-1/16' 10000
FRAC VALVE
7-1/16" 3000
6-5/16H BPV
7-1/16" 10000
PRODUCTION ASSEMBLY
2X 1" AEMP (AUTOCLAVE) PORTS
EXTENDED NECK TO ALLOW WRAPPING OF INSTRUMENTATION LINES
23.3
3X 1/2" LP PORTS
8.0
13-5/8" 5000
AFLAS ELASTOMERS (1000 psi RWP AT X+ 400 DEGREES F)
3"LP
75.8
26.6
3-1/8" 3000
13-5/8" 5000
METAL TO METAL SEAL
7.7
16-3/4" 3000
39.2
18.1
6.6
16" 84 LB/FT, JFE110T BTC
11-3/4" 65 LB/FT, JFE125T BTC
7" 38 LB/FT, P110EC VAM TOP HT
1X 1/4' INSTRUMENTATION LINE
2X 1/8" INSTRUMENTATION LINES
UNIVERSITY OF UTAH
GEOTHERMAL WELL
16" X 11-3/4" X 7"
DWN. NL 01-25-23
CHK. RM 01-25-23
APPR.
BY DATE
DRAWING No.
WH-24236
REV. 6
SHEET 2 OF 2
REFERENCE:
PROJECT 48361
8361-UTAH-GEOTHERMAL

Synopsis of Planned Activities

Change BOPE and Pressure Test

- Nipple down 13 5/8” BOPE. Nipple up wellhead - 10,000 psi with 7-inch casing. Nipple up BOPE.

Drill Out Shoe and Circulate Out Weighted Fluid to 10,715 ft MD

- LD 5-1/2” Drillpipe. PU 3-1/2” and drill out shoe
- Circulate out weighted brine (etc.) from open hole section so further circulation testing can be carried out.
- RU wireline and run bond log.
- Run gyro survey.
- Logging to determine location of fiber optics is deferred

Synopsis of Planned Activities

Repeated Connection Evaluation from 16A(78)-32

Post-Cementing

- Repeat connectivity evaluations, assess cementing damage and FO signature
- Only inject from 16A(78)-32 to establish where hydraulic fractures have grown

Stage	Rate (bpm)	Volume (bbl)	Incremental Time (minutes)	Cumulative Volume (bbl)	Cumulative Time (minutes)	Cumulative Time (hr)
	0	0	0	0	0	0
1	1	120	120	120	120	2
2	2.5	300	120	420	240	4
3	5	600	120	1,020	360	6
4	2.5	50	20	1,070	380	6.33

Synopsis of Planned Activities

Remedial Work if No Connectivity

- Small rate injection in Well 16B(78)-32 if no connection or indication of cementing damage to fracture systems in openhole
- Mitigation prognosis would be refined on the fly
- Would entail pumping down newly installed casing at low rates
- Injection and flowback
- Keep the low-rate pumping equipment on location
- TIH and circulate well 16B(78)-32 to clean out the well

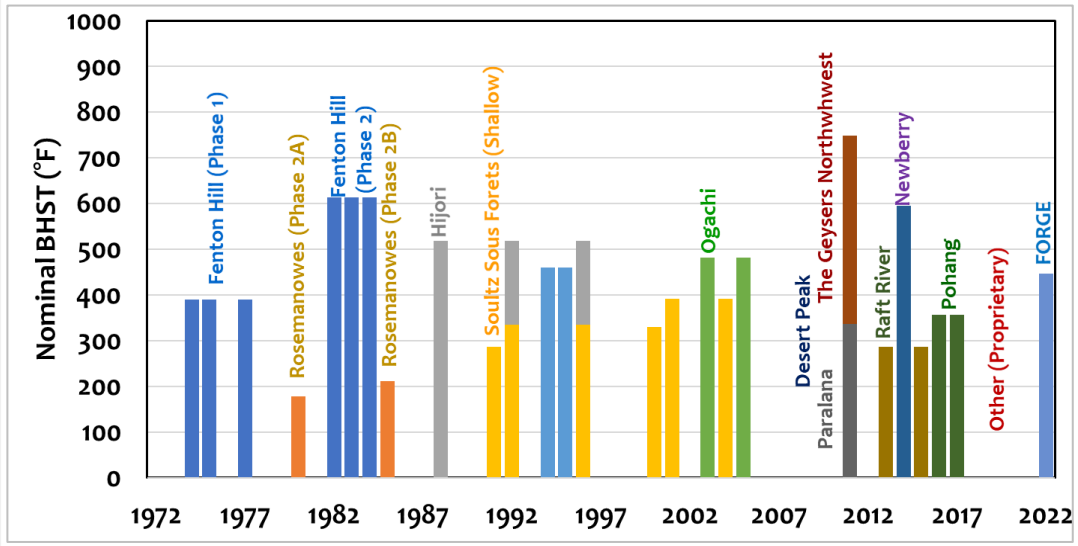
Synopsis of Planned Activities

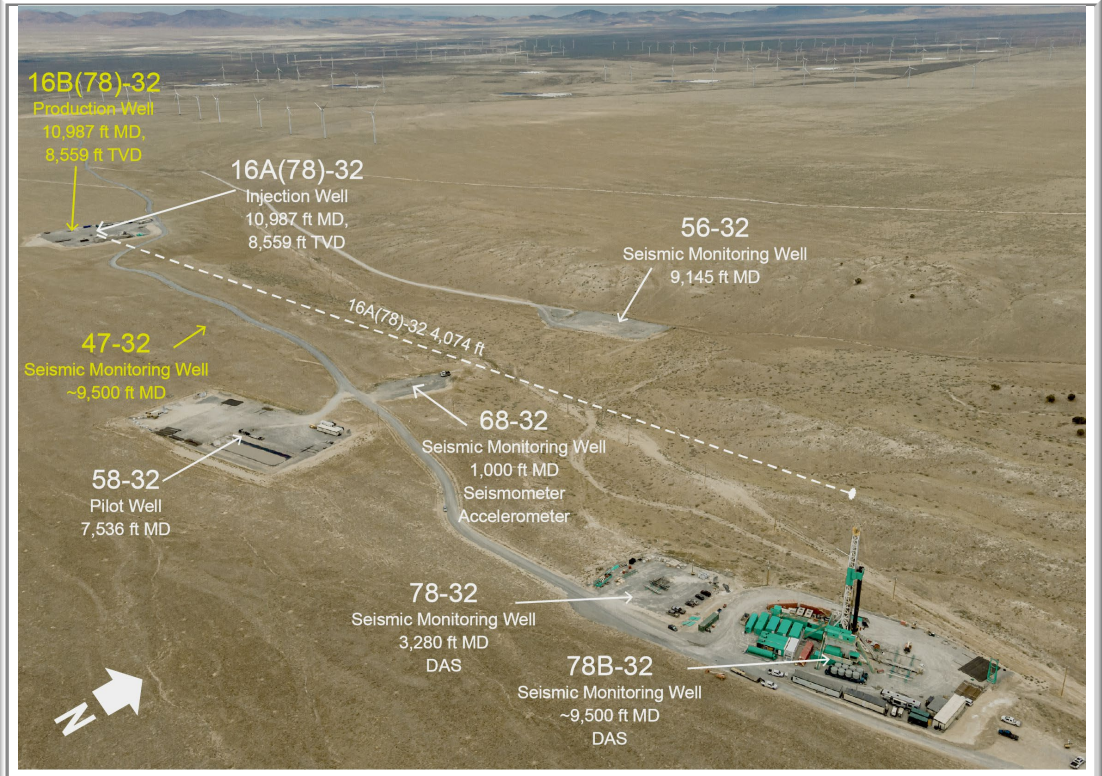
Additional Circulation Testing

- Carried out after rig released
- Prefaced on assumption that conductivity of fractures higher with injection rather than production (aperture variation along fractures) and that it will be an essentially closed system
- Consider going to 20 bpm per Karen Olsen

State	Rate (bpm)	Volume (bbl)	Incremental Time (minutes)	Cumulative Volume (bbl)	Cumulative Time (minutes)	Cumulative Time (hr)
	0	0	0	0	0	0
1	0.25	25	100	25	100	1.7
2	1	185	185	210	285	4.8
3	2	185	92.5	395	377.5	6.3
4	5	370	74	765	451.5	7.5
5	10	1850	185	2615	636.5	10.6
6	0	0	1440	2615	2076.5	34.6
7	0.25	25	100	2640	2176.5	36.3
8	1	185	185	2825	2361.5	39.4
9	2	185	92.5	3010	2454	40.9
10	5	370	74	3380	2528	42.1
11	10	1850	185	5230	2713	45.2
12	0	0	2880	5230	5593	93.2

From Fenton Hill – to – FORGE (Frontier Observatory for Research in Geothermal Energy)





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