Newberry EGS Demonstration

Project Officer: Lauren Boyd

Total Project Funding: $46.8 m

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EGS Demonstrations, Recovery Act

Relevance/Impact of Research

Primary Goals

- Demonstrate the development and operation of an **Engineered Geothermal System**
- **Create EGS reservoir** around existing well NWG 55-29.
- Stimulate **multiple fracture zones** using diverter technology.
- Drill **production well** into mapped fracture network.
- Complete **Circulation Test** of producer and injector**.**

EGS development problem addressed

- Traditional open-hole stimulation can only enhance permeability of one zone
- Multiple zone stimulation can provide >3x flow per well & improve economics

Technical barriers and challenges to overcome

- High reservoir temperature (400º to 600ºF) precludes use of conventional logging and zone isolation tools
- Lack of rock mechanics and seismic models in greenfield development due to lack of deep core, and no natural or induced seismicity, prevent site-specific seismicity modeling in advance of permitting and stimulation.
- Ultra-low permeability rock requiring robust stimulation equipment to perform high pressure stimulation over a longer period of time.

Non Technical barriers and challenges

- Fear of unknown and low risk tolerance of public and regulatory agencies

Relevance/Impact of Research

Project Scope Meets or Exceeds DOE EGS Demonstration Objectives

1. Determine pre-stimulation flow rate for at least one EGS field site by 2010
   - In summer 2010, AltaRock measured a baseline injection rate of **1.3 kg/s** (22 gpm at 1153 psig) in existing injection well NWG 55-29.
2. Demonstrate reservoir creation that achieves a flow rate of 20 kg/s by 2015
   - Two wells with target production rates of **20 kg/s** plan to be completed into the newly created EGS reservoir by 2015.
3. Achieve a 10% increase in flow rate for EGS field site demonstration by 2011
   - 2014 stimulation results for NWG 55-29 increased flow rates by 500% over native state, baseline injectivity.
   - 2015 drilling and stimulation plan will include dual well stimulation in order to increase the EGS reservoir size further.
4. Model the reservoir conductivity at an EGS system demonstration by 2011
   - 2012 and 2014 stimulation has been successfully modeled in a numerical model. Results of EGS reservoir creation and conductivity testing will be modeled as part of full-field conceptual model.

Scientific/Technical Approach

Innovation 1: Multiple zone stimulation through thermally-degradable zonal isolation materials (TZIM) in order to increase overall well permeability.

- Non-mechanical zonal isolation material - No rig required during treatment
- Breakdown products are non-hazardous
- Suite of materials developed that degrade with time at various temperatures

Innovation 2: EGS characterization tools developed to predict induced seismicity, mitigate seismic risks, and characterize EGS reservoir.

- Stress and fracture analysis from BHTV used with AltaStim stimulation design software
- Induced Seismicity Mitigation Plan to meet 2012 DOE Protocol
- Distributed Temperature Sensing (DTS) system to track zone isolation
- Conservative and non-conservative tracers injected to assess surface area and temperature of stimulated zones.

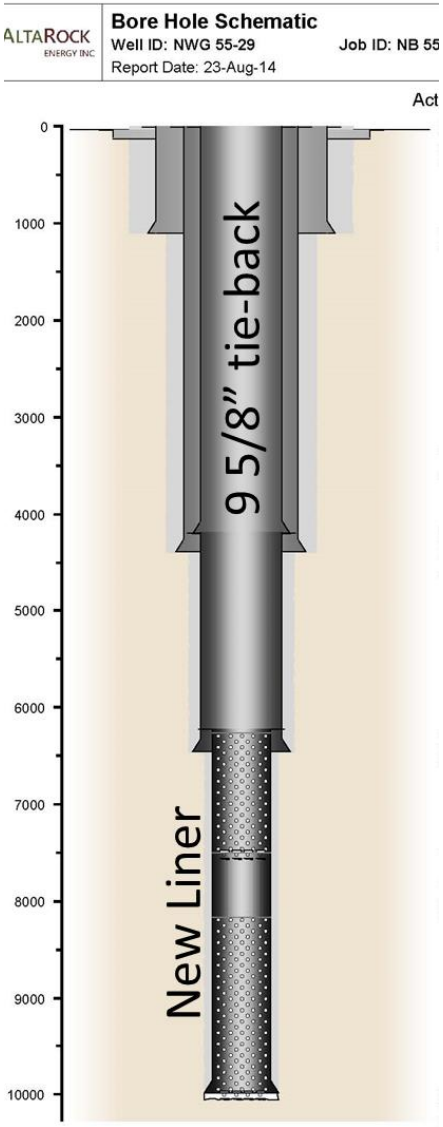
Innovation 3: Use multi-stage centrifugal pumps in order to reduce high pumping costs and reliably conduct 24/7 stimulations for weeks.

- Centrifugal pumps can quickly adjust to the well behavior and maintain steady injecting pressure. More stimulation control than positive displacement pumps.
- HP (Newberry) Mode: in series with bypass line to allow sufficient flow to keep pumps cool when injecting to very low permeability wells

Accomplishments, Results and Progress

Phase 2.2 was successful in its goal to repair and re-stimulate NWG 55-29. Phase 2.2 accomplishments include:

- Casing was repaired by running $9^{5}/_{8}$in casing tie-back inside to the $13^{3}/_{8}$in casing and cementing up the PAS line to block off the hole and .
- Set perforated liner to the bottom of the hole to prevent possibility of hole collapse.
- Successfully stimulated well, including conducting two perforation shots to notch formation.
- Proved viability of new diverter material – blocked off an existing zone so that a new zone became stimulated.
- Implemented lessons-learned from the 2012 stimulation to streamline stimulation operations. Phase 2.2 stimulation effort had far less down-time than the 2012 stimulation;



Accomplishments, Results and Progress

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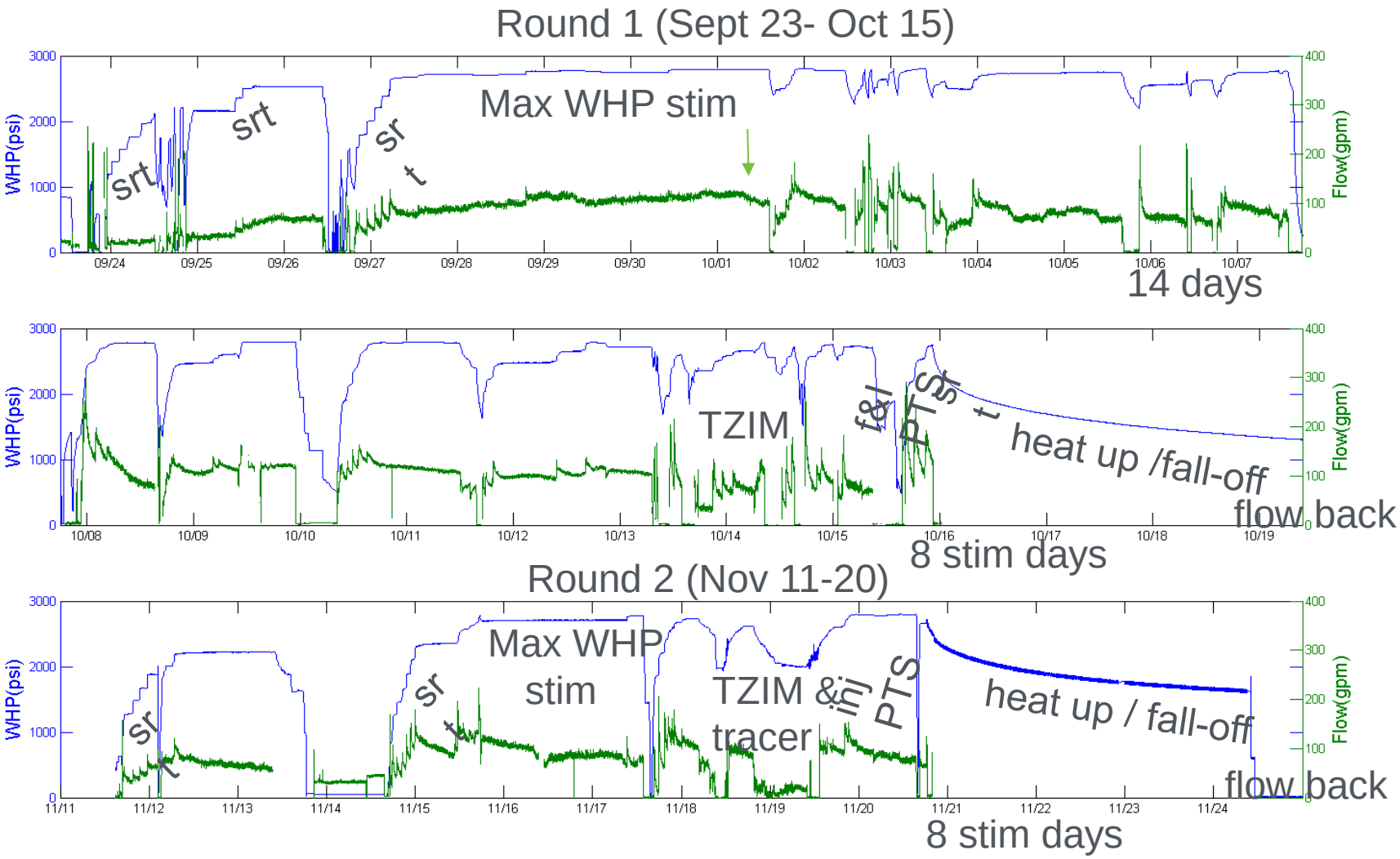
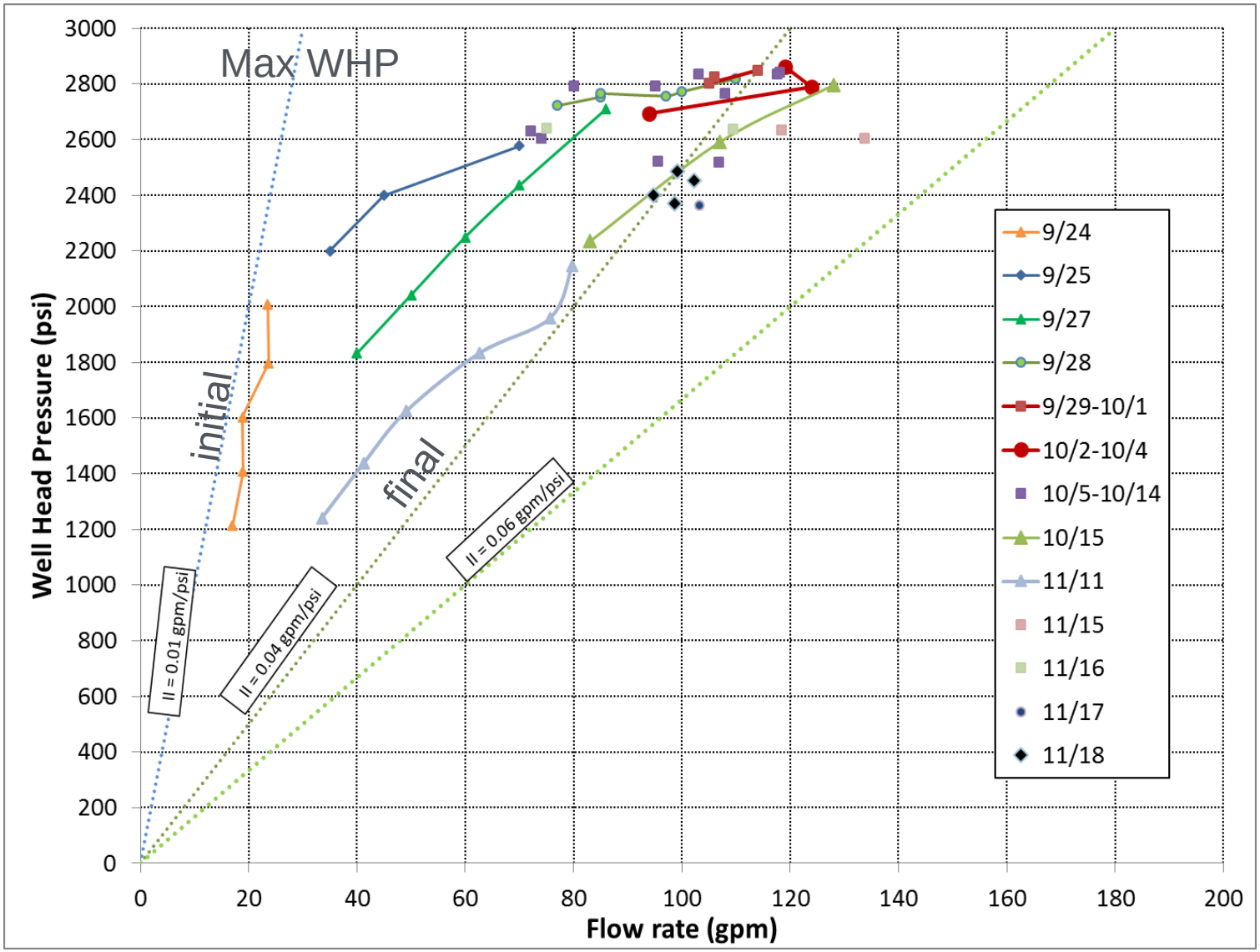
Original Planned Milestone/ Technical Accomplishment	Actual Milestone/Technical Accomplishment	Date Completed
Phase 1 Planning Report Submitted		August 26, 2011
Environmental Assessment Submitted		December 20, 2011
BLM and DOE Issue Finding of No Significant Impact		April 5, 2012
Phase 2.1 Stimulation Begins		Oct. 16 – Dec 11, 2012
Phase 2.2 Drill 1st producer into EGS reservoir and stimulate	Phase 2.2 Well repair & stimulation	Aug-Nov 2014
Phase 2.2 Report and Stage Gate		April-May 2015 (Planned)
Phase 2.3 Drill 2nd producer into EGS reservoir and stimulate.	Phase 2.3 Drill and stimulate one production well. Test connectivity	June-October 2015 (Planned)
Phase 2.4-3 Circulation Test		October 2015 (Planned)

Wellhead pressure and flow rate during stimulation



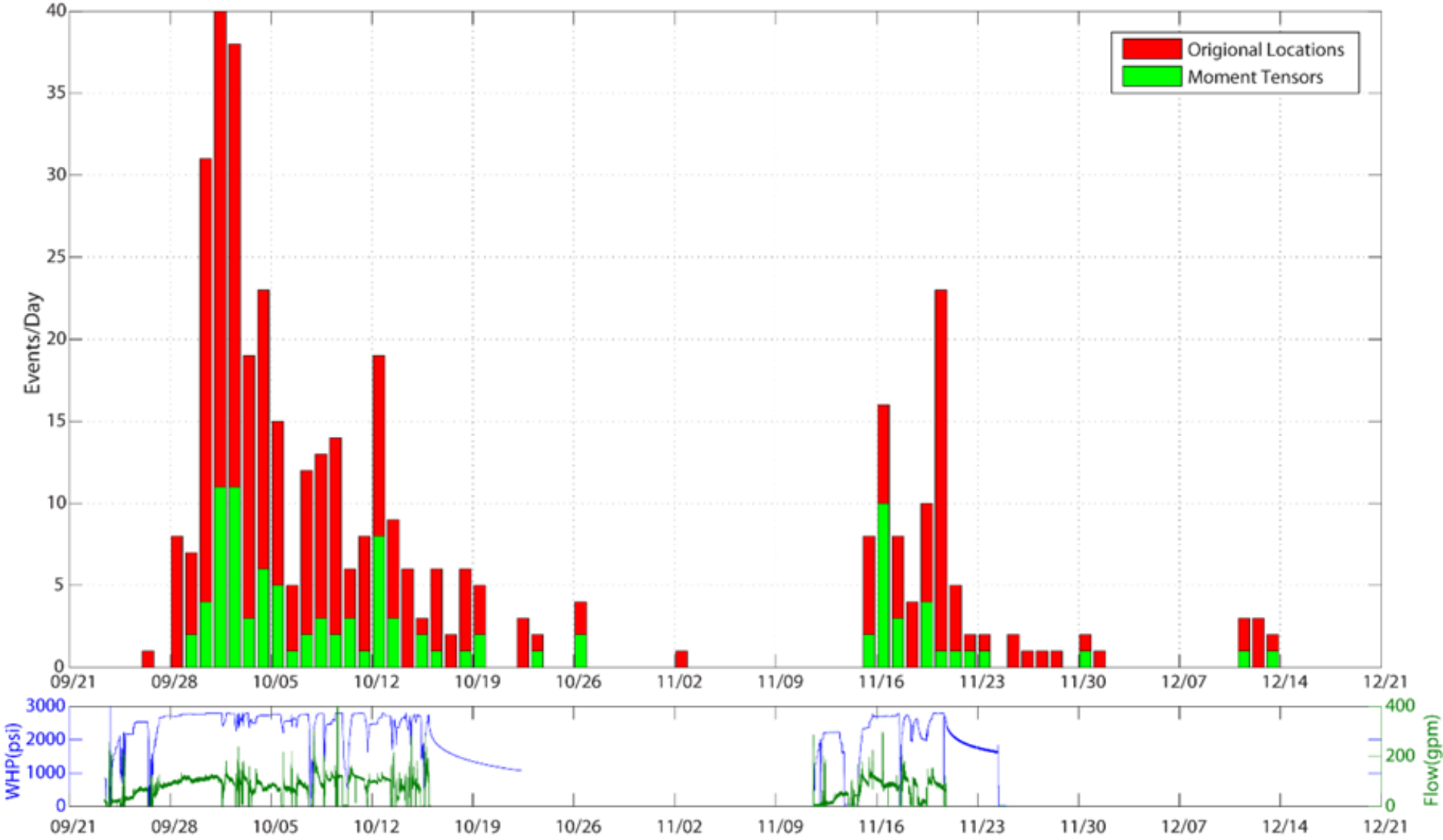
Accomplishments, Results and Progress



Summary of permeability measures

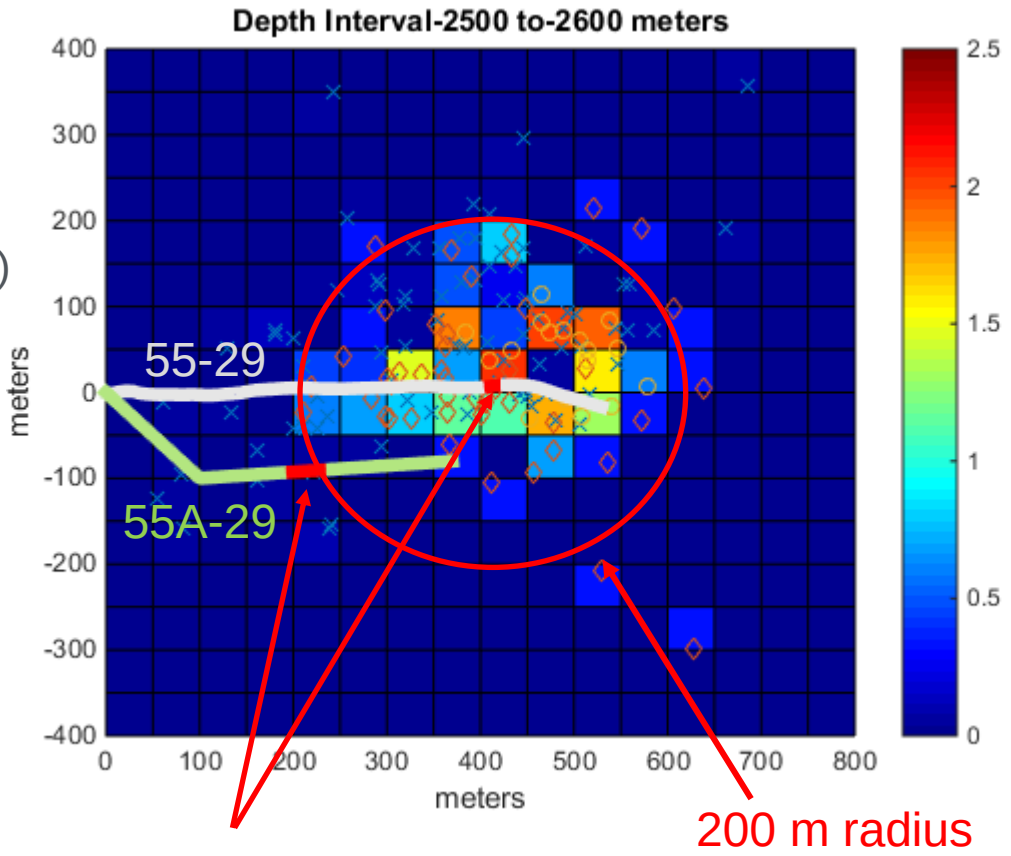
Method	Measure	Initial Value	Final Value	Units	Final/ Initial
Pressure vs Flow	Injectivity	0.01	0.05	psi/gpm	5
Horner Analysis	Transmissivity Permeability	$2x10^{-15}$ $1x10^{-17}$	$2.9x10^{-13}$ $1.46x10^{-13}$	m^3 m^2	145
Horner Analysis	Fracture size		25,500	m^2	
Hall Plot	Permeability	$1x10^{-17}$	$1.34x10^{-15}$	m^2	134
THM Model	Permeability (elements <50 m from well)	$1x10^{-17}$	10^{-13} to 10^{-16}	m^2	10-10,000
THM Model (apriori)	Bulk Permeability	$1x10^{-17}$	$7x10^{-17}$	m^2	7

Accomplishments, Results and Progress

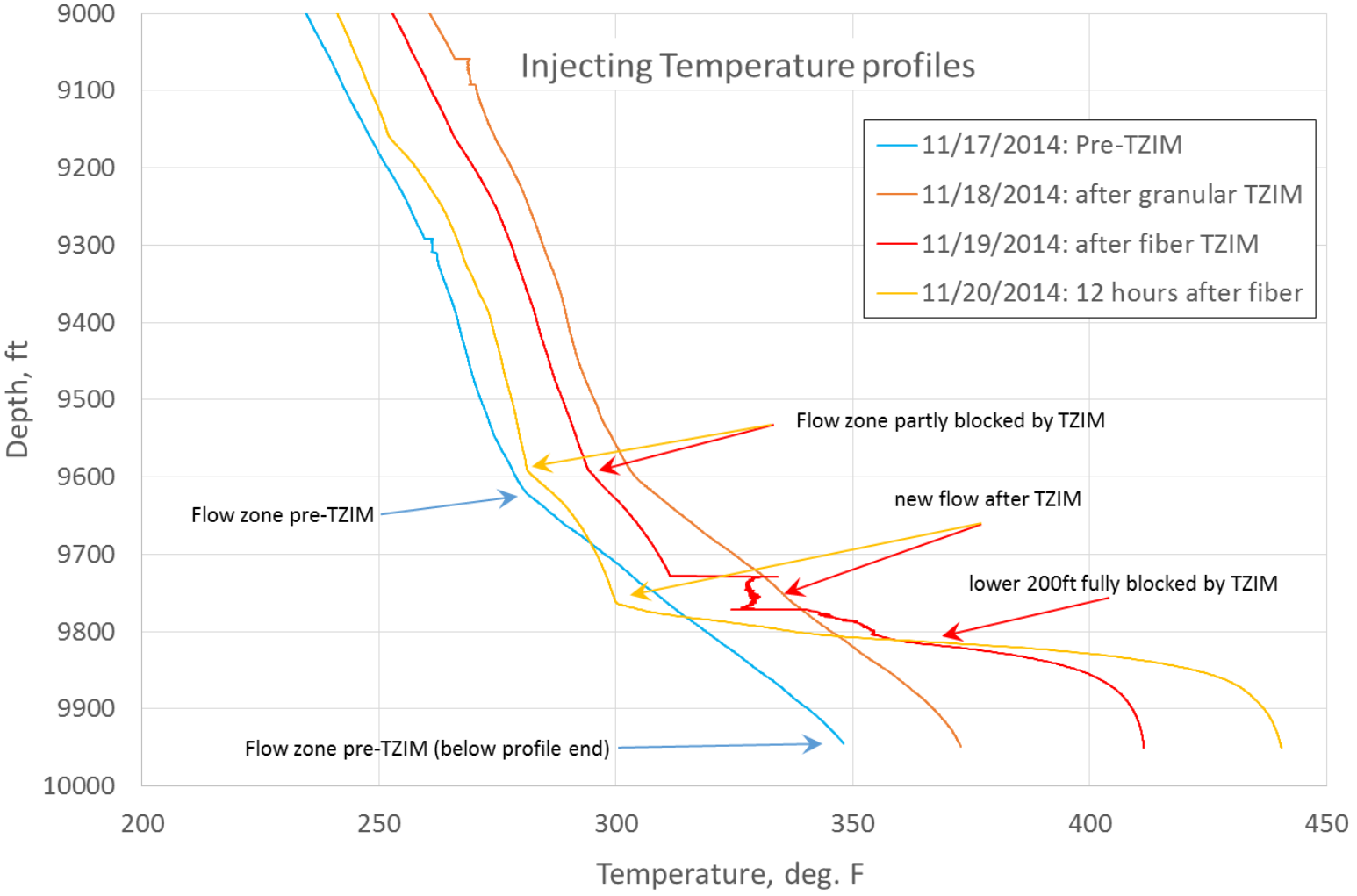


Weighted Seismic Density (confidence) maps

- Combine 4 data sets, with weighting:
  - 40% MT locs (circles, N=100)
  - 45% LBNL relative relocs - 16 phase picks (triangles, N=58)
  - 10% LBNL relative relocs - 10 phase picks (diamonds, N=250)
  - 5% Original locations (crosses, N=400)
- 50x50x100 m grid, 11 depth slices
- What is liklihood that MEQ's are within a given grid block?
- Weighted toward better located and bigger events
  - biggest 58 events are counted 4 times
  - an undercount compared to seismic moment weighting



Evidence for TZIM Blocking



Future Directions

- Finish Phase 2.2 report and pass DOE Go/No-Go
- Drill production well: June 1-August 15
- Stimulate production well and dual-stimulation Sept. 1-30
- Conduct 30-day two-well connectivity test with tracers to refine characterization of the developed EGS reservoir.

Milestone or Go/No-Go	Status & Expected Completion Date
Post-stimulation Stage Gate	Report review in progress: Completed April 2015
Drill production well into created EGS reservoir	Planning: Complete August 2015
Stimulate production well and NWG 55-29	Planning: Complete September 2015
Conduct dual well connectivity test	Planning: Complete October 2015

Summary

- Phase 2.2 began with repairing the casing leak detected in 2013 logging results. A $9^{5}/_{8}$in tie-back liner was successfully installed and cemented.
- Five week stimulation in two rounds were conducted: September 24-October 15, and November 11-20.
- Stimulation improved injectivity by 5X and permeability by 100X.
- Geochemistry of produced fluids suggests average reservoir temperature of 250ºC.
- TZIM allowed stimulation of multiple zones.
- Microseismic array continued to performed well.
- Advanced seismic analysis critical for design of producer target.
- Challenges overcome
  - Improved stimulation/operating efficiency after implementing 2012 lessons learned.
  - Various interpretations of seismicity used to create weighed seismic density maps.

Additional Information

- The very high temperature of the Newberry Volcano EGS reservoir is a blessing and a curse:
  - Instrumentation is challenged in these high temperatures
  - High temperature fluids mean we need less flow to get the same energy to the surface.
- Where do we go from here?
  - Improve reliability of seismic locations by developing high temperature calibration methods for better velocity models.
  - Continuous temperature data is important to stimulation monitoring and control but DTS cables are not robust. We need to work on more robust cable.
  - Additional data from fiber optics could be helpful to monitoring EGS stimulations:
    - Fiber optic seismometers
    - Distributed acoustic sensing
    - Downhole pressure