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COLLAB
A PATH TO FORGE
U.S. DEPARTMENT OF ENERGY

Analysis of pressure/flow response data from the EGS Collab Project

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The EGS Collab project is a multi-institution DOE EREEE project where R&D in an underground facility (SURF) is being used to increase our understanding of intermediate scale rock mass response to hydraulic stimulation and flow, thus increasing our understanding of the thermal-hydrological-mechanical-chemical response of the rock to engineered activities.

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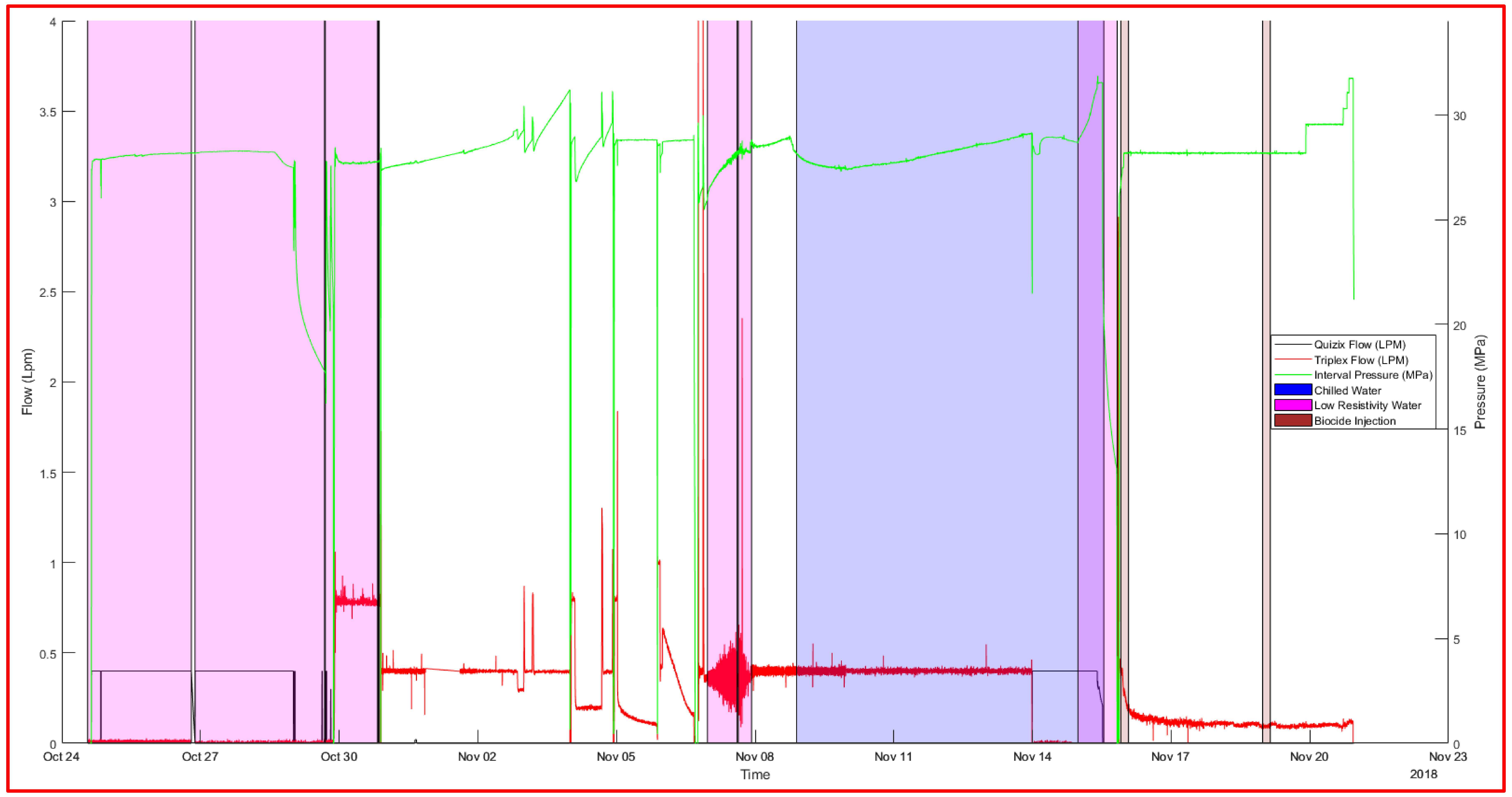
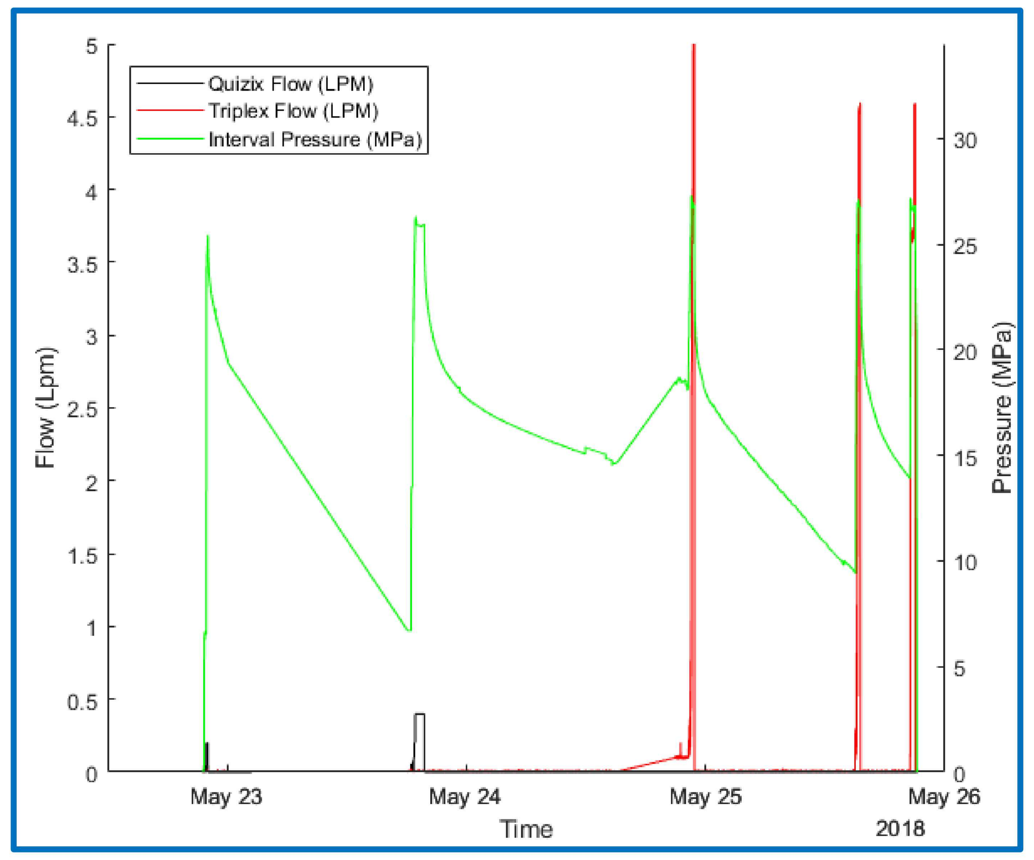
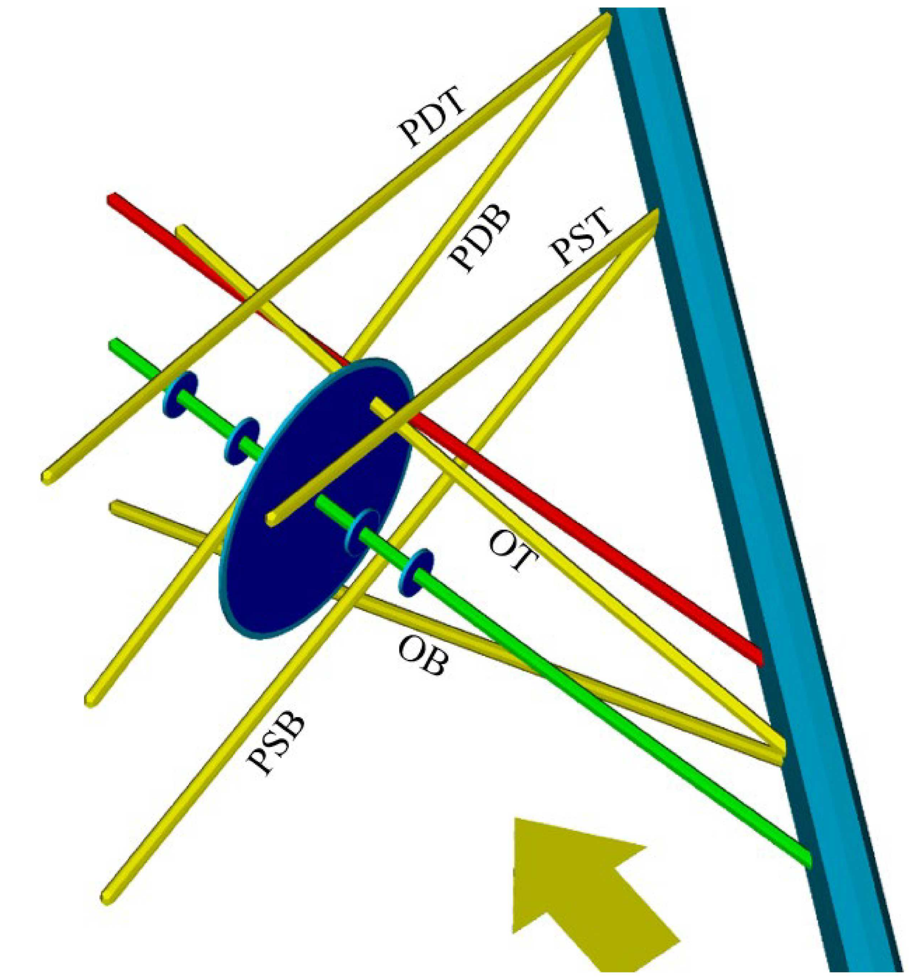
Introduction

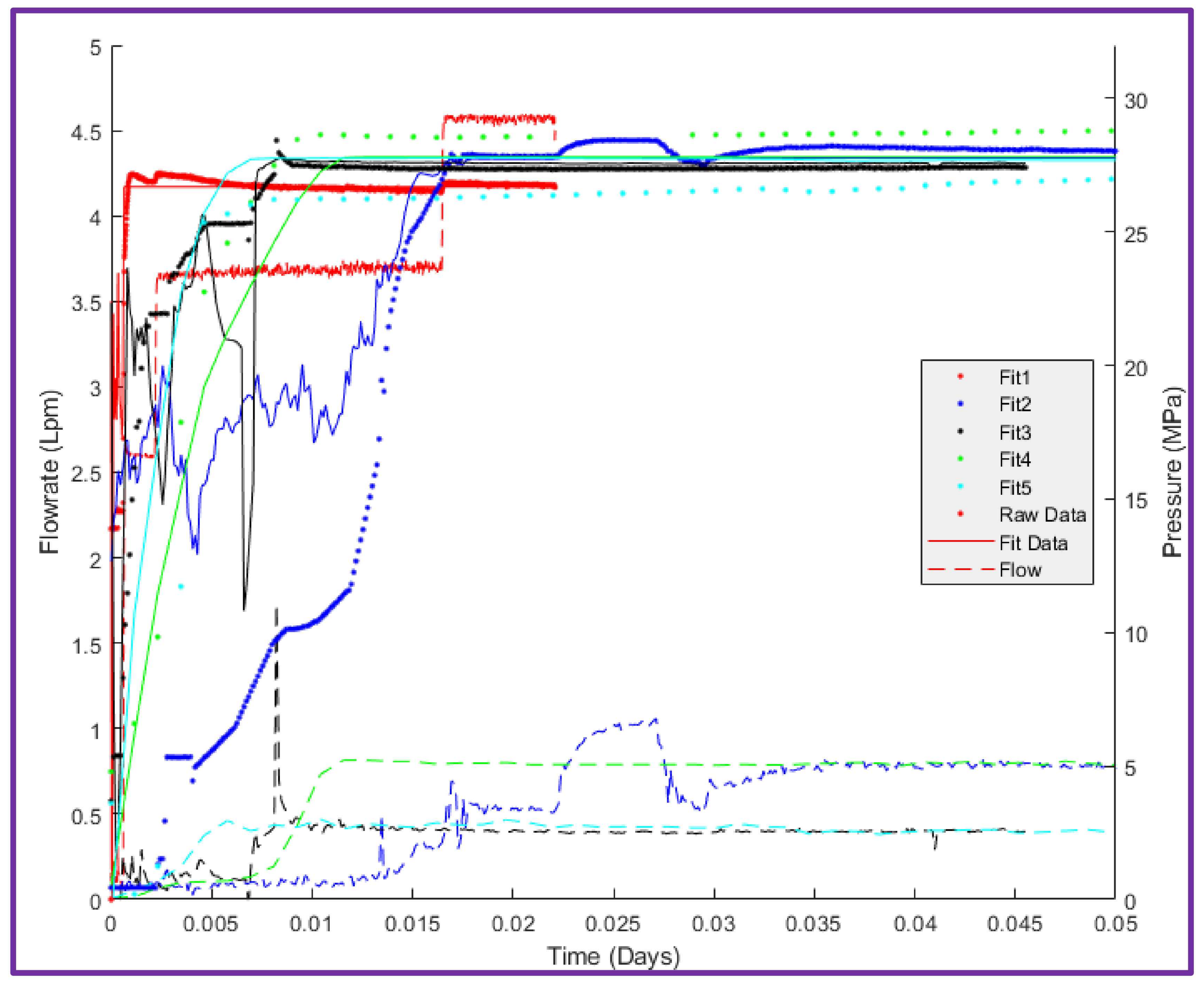
A series of fracture and flow tests are being performed at the Sanford Underground Research Facility (SURF) as part of the EGS Collab project. The tests involve generating a communicating fracture(s) between two boreholes, and monitoring flow through the generated fracture(s). A long-term flow test was performed at the end of October 2018 through early November of 2018 between the injection and production wells at the EGS Collab site on the 4850 Level of SURF. This paper will present an analysis of the pressure, and flow during this test as compared with the initial fractures. Analysis and interpretation of the variation in the efficiency of the connection as the injection conditions changed is presented. Recovery of injected fluid is between 70 and 85%. Injection conditions varied from constant pressure, to constant rate, with formation induced pressure rise at constant flow rate, and multiple flush cycles to induce pressure decrease from apparent fracture plugging.







Above is shown a pressure and flow time history for the fracture at the 50m notch in the testbed. Note that shaded sections of the plot indicate periods of injection of cold water, DI water, and biocide depending on color. Results from sections of this curve were compared with the pressure and flow response from the initial fracturing of the system (shown in the upper right in the blue box). It was noticed during testing that each subsequent reopening of the fracture required ever increasing pressures (albeit with a slow climb). Also noted was that when flowing at a constant rate a trend of increasing pressure would develop, whereas when injecting at constant pressure the flow would decrease to a relatively low level. Changing the conditions of the injected fluid was tried to see if it was possible to eliminate this effect, however during the time period studied herein, there was little more than temporary success, most noteably through "flushing" the interval by briefly increasing flow rates in an attempt to flush debris from the near borehole region.



The pressure increase behavior at fracture opening was modeled empirically resulting in the equation below to describe the changes in conditions. The table below shows the flowrates, propagation pressures and Initial Shut in Pressure for the five peaks shown in the figure to the upper right.

Currently there is another flow test underway at this location with chilled water to investigate the heat transfer into and out of the rock. The results in this presentation appear to be a transient as the current test appears to be at steady state conditions.

Test	Flow Rate (L/min)	Propagation Pressure (MPa)	ISIP (MPa)
Frac 1 (~1.5 m)	0.2	25.43	25.37
Frac 2 (~5 m)	0.4	25.95	25.82
Frac 3 (Drive to Production)	5.0	26.88	25.31
Flow 1	4.5	26.71	25.36
Flow 2	4.5	26.74	25.14

$$\boldsymbol{p = a - e^{\frac{-(Q-b)}{c}}}$$

$$a = 0.997(T) - 731344$$

This image depicts the relative orientation of the wells with regards to the drift and the expected hydraulic fracture. The thick teal cylinder is the west drift of the 4850 level at SURF, with the bottom of the image pointing towards "Governors Corner". The yellow cylinders are the monitoring boreholes which have geophysics monitoring equipment grouted into place. The green cylinder is the injection borehole with the notched locations indicated, and the red cylinder is the production borehole. Note that the blue disks indicate the notch locations and that the third location is shown with the penny shaped hydraulic fracture. While a stimulation was perfomed at the third notch, the fourth notch was the location used to connect the injection and production boreholes for this study.

The equation for the pressure increase takes the form shown in above. Where p is the interval pressure in psi, Q is the flowrate in Lpm, and a,b, and c are fitting parameters. The values of b and c are 0.667 and 0.0795 respectively. The value of a varies with time as shown in Eq. 2. Note that in Eq. 2, a is the value which is fed into Eq. 1 and T is measured in days using the proleptic ISO calendar.

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