

Multiple Zone Stimulation of EGS Wells Ì Key to Reservoir Optimization

Geothermal Energy Utilization Associated with Oil and Gas Development

SMU

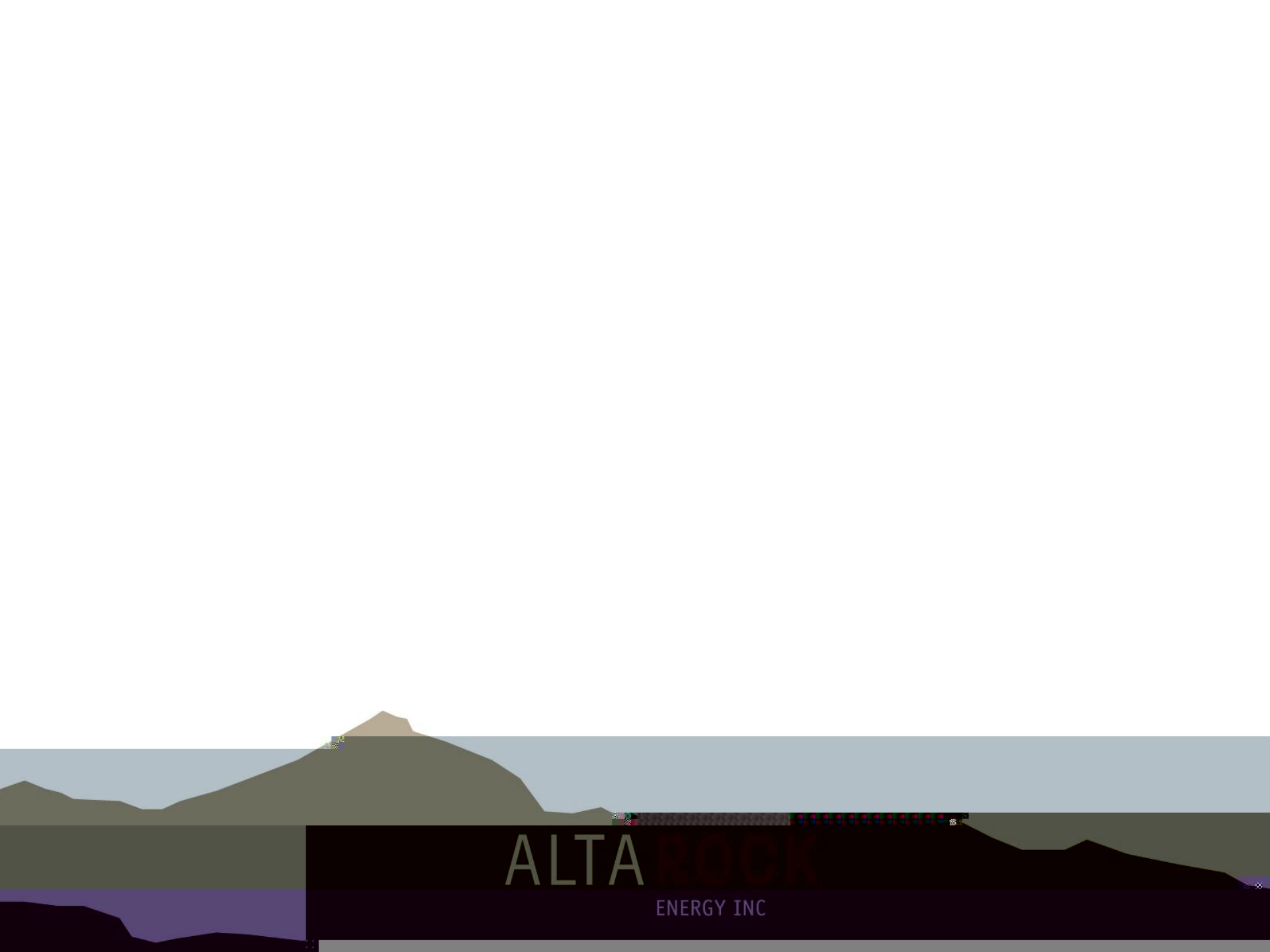
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*Susan Petty, Daniel Bour, Yini Nordin,
Laura Nofziger Ì AltaRock Energy Inc.*

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Operations
- | Outcome & Conclusions





ALTA

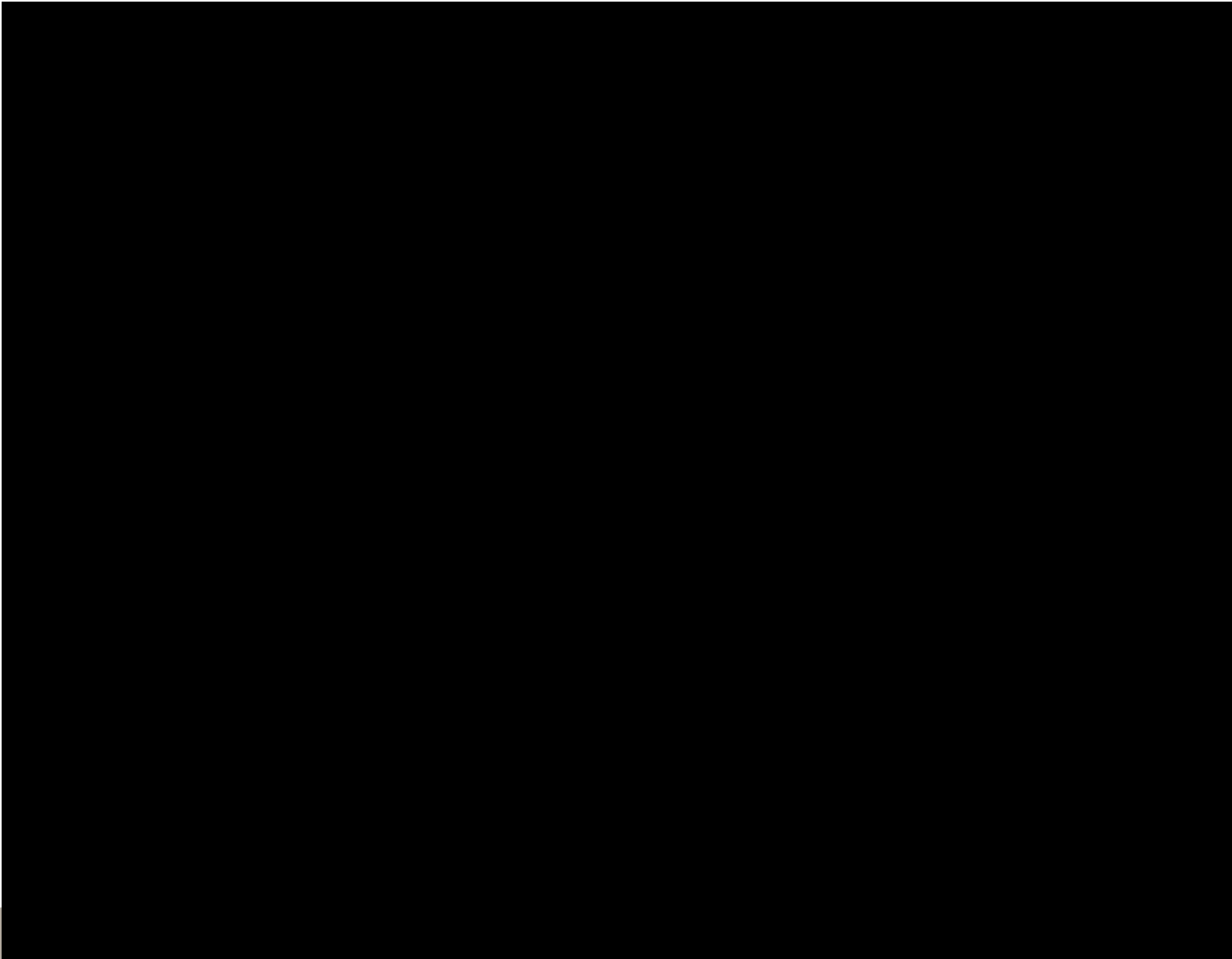
ENERGY INC

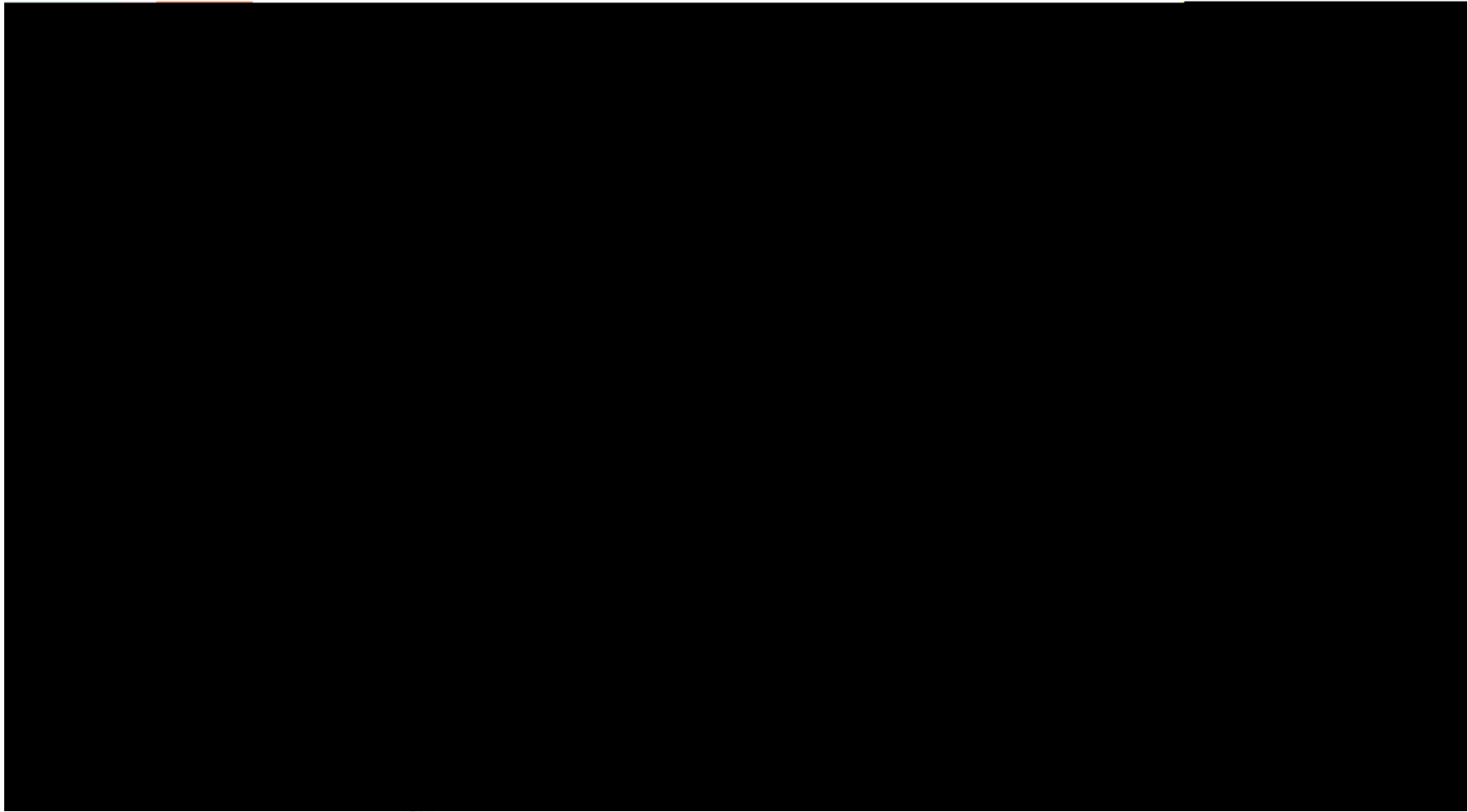
Heat Stored in Rock



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Worldwide EGS Lessons Learned

Project				



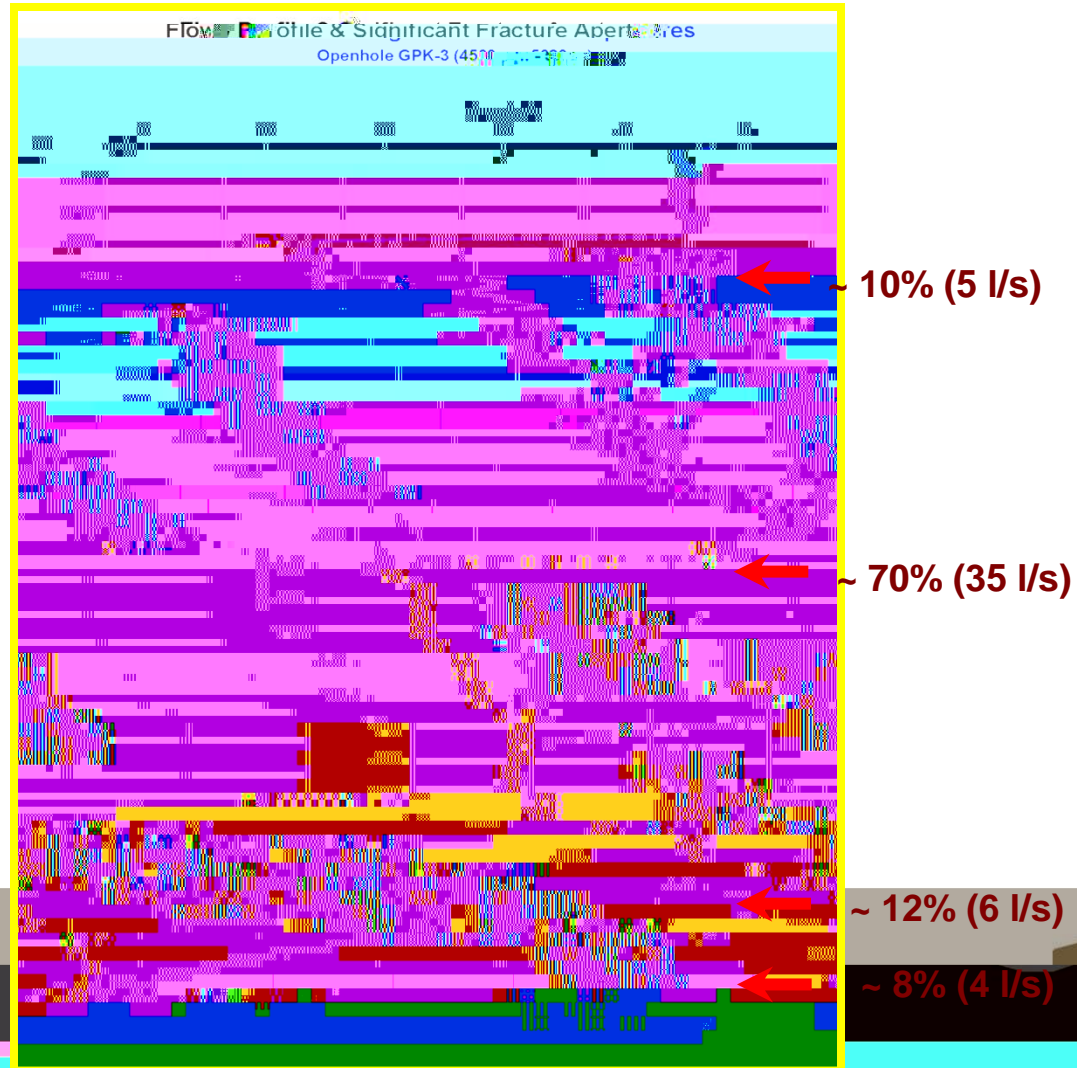
Worldwide EGS Lessons Learned

- i First well needs to be drilled and stimulated in order to design the entire system
- i Stimulation is through shearing of pre-existing fractures instead of creating new tensile fractures
- i High flow rates with long path length are needed
- i Need technology for multiple zone stimulation
 - We currently do not have reliable open-hole packer for zonal isolation**



Current Stimulation Technology

- i Inject fluid from the surface
- i Most permeable zone in well takes fluid and is stimulated
- i Remaining zones only take limited amounts of fluid.
- i Increasing flow by increasing injection pressure risks induced seismicity



Reservoir Optimization

Single Fracture Network

Limitations of Single Fracture

- i Flow through a single stimulated fracture network provides minimal heat exchange area
- i Flow rates are then limited by the maximum injection pressure which will extend fractures

Increase the rate of cooling at the production well

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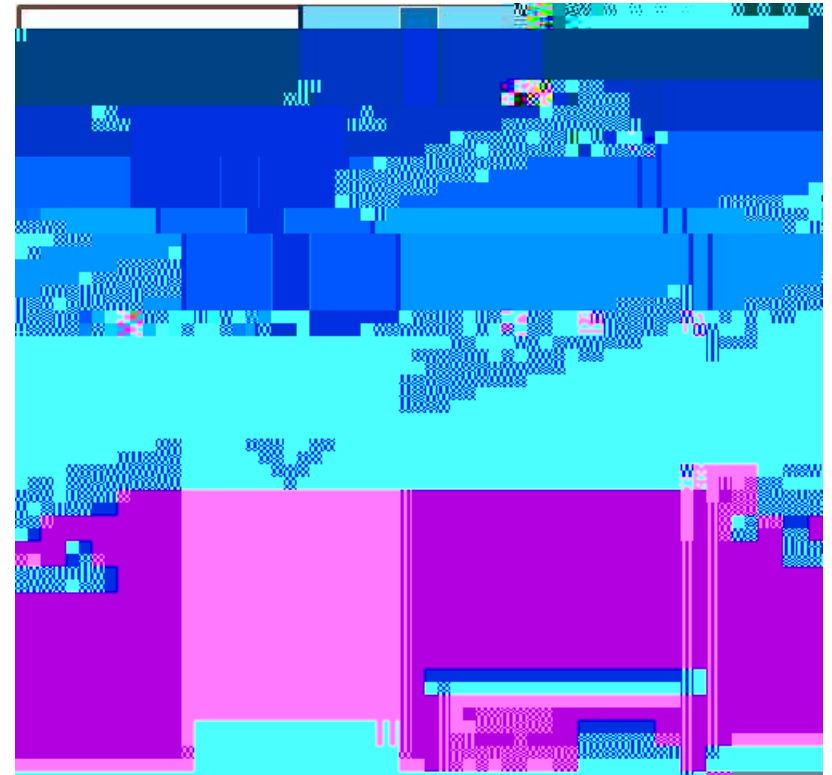


Reservoir Optimization

Benefits of Multiple Fractures

- i Multiple fractures allow for flow through two or more fracture networks
- i More rock heat exchange area is contacted
- i Pressure drop through system is reduced allowing higher flow rates
- i Additional flow will allow for greater production on a per well basis

Multiple Fracture Network



GETEM Modeling Results

i Inputs

30 kg/sec base flow

4 km depth well

i Results

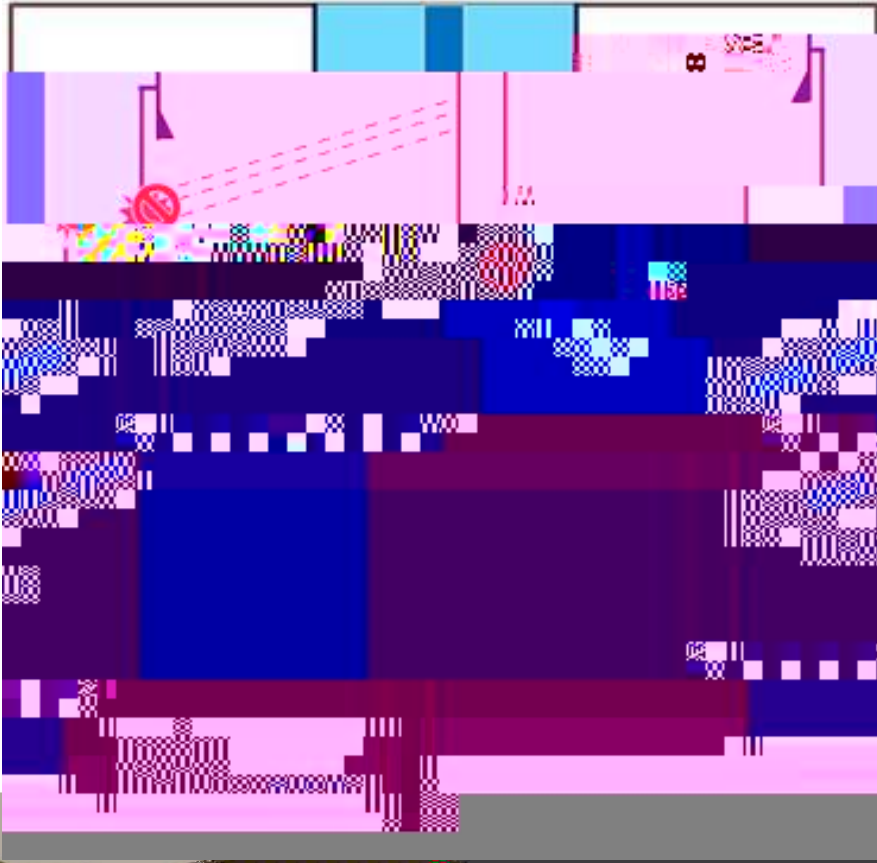
Flash system had 40% reduction in power cost

Binary system had 50% reduction in power cost

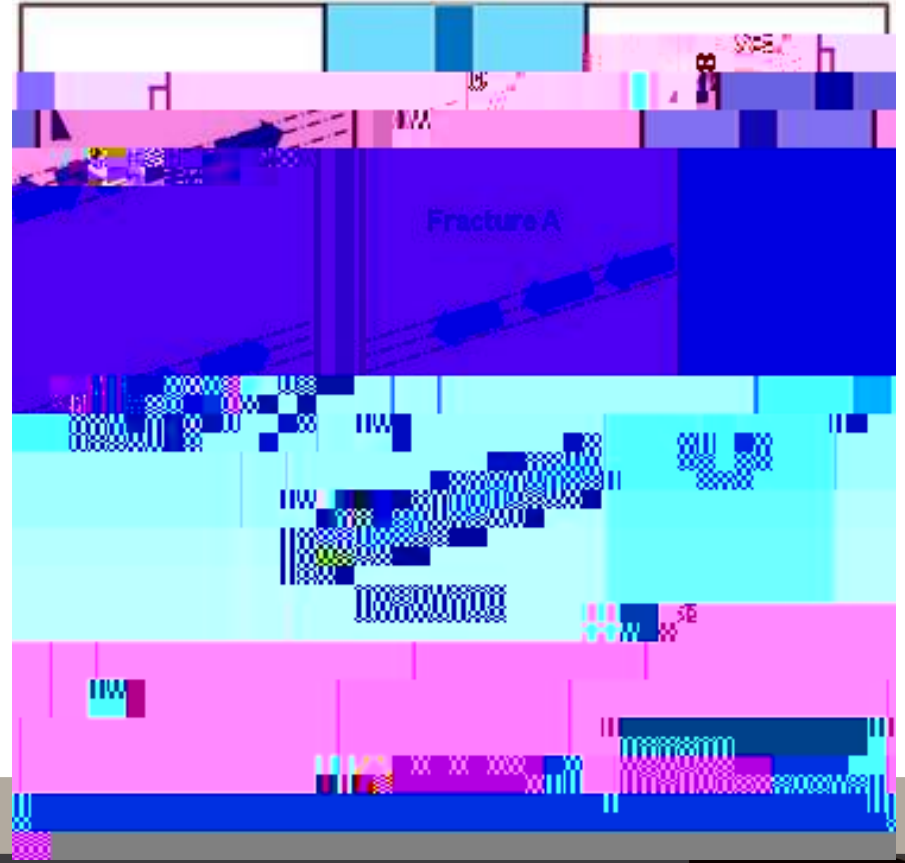
Flash/Binary	Temperature (° C)	Improvement	Cost of Power 2010 (cent/kw)

Temporary Diverters

Diverter Sealing Zone



Degraded Diverter



AltaRock Proprietary Temporary Diverters

Design

- i Particle size distribution of material that will allow for packing and sealing of fracture
- i Remain in place and withstand differential pressure during 2nd stimulation
- i Degrade to non-damaging products after stimulation as well heats back up
- i Require instruments in hole during treatment to monitor and verify that diversion has occurred

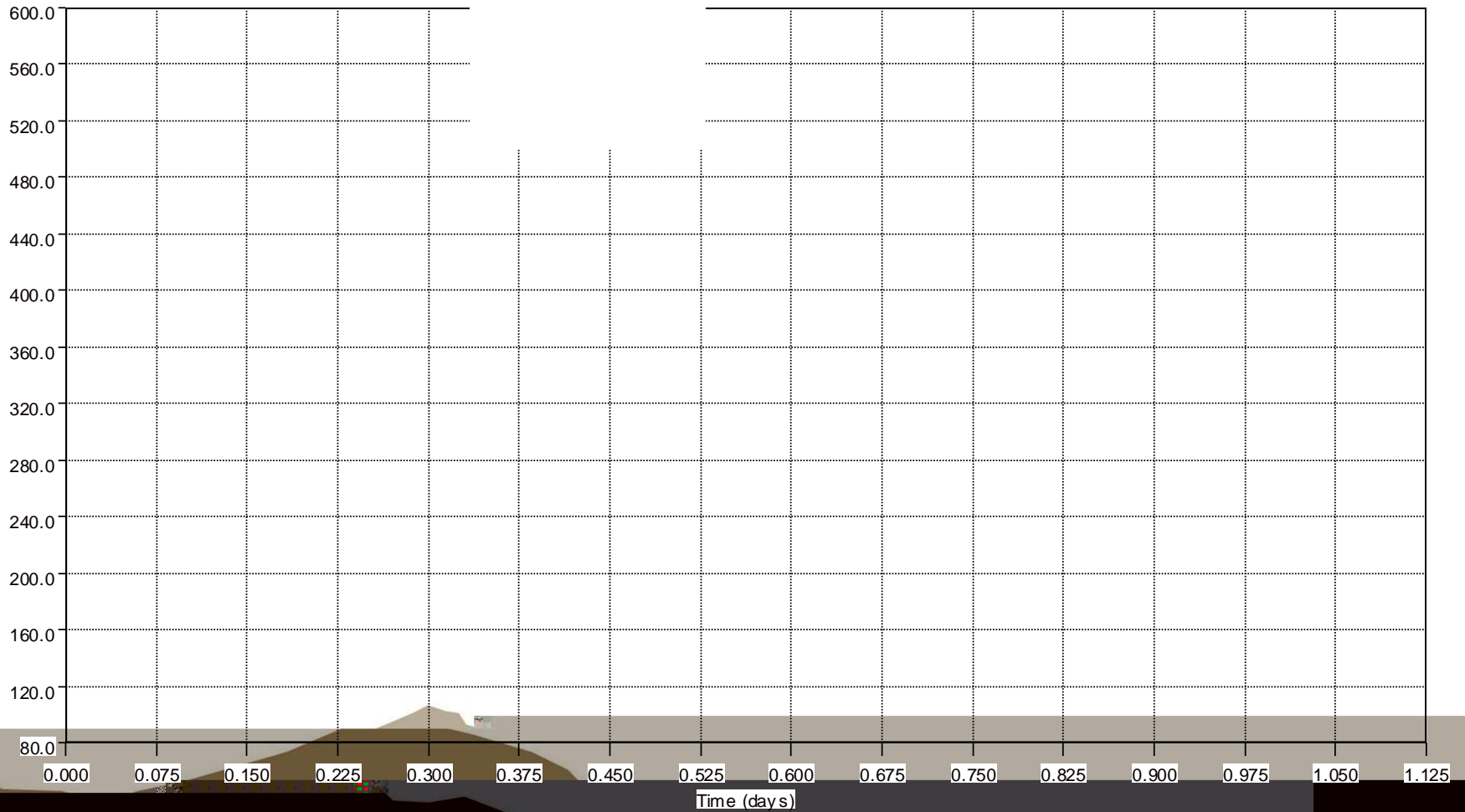
Benefits

- i Increased production reduces cost of power production
- i No Rig required during treatment
 - Major cost Savings**
 - Reduce Operational risk**
 - Create fractures in succession without moving packer and waiting on rig**
- i Can be used even when slotted liner is in place
 - Cannot use mechanical isolation like packers in well with slotted liner**

Temperature Modeling

Thermal Cooling from Injection \dot{I} 10 bpm

Temperatures vs. Time - Injection - Annulus



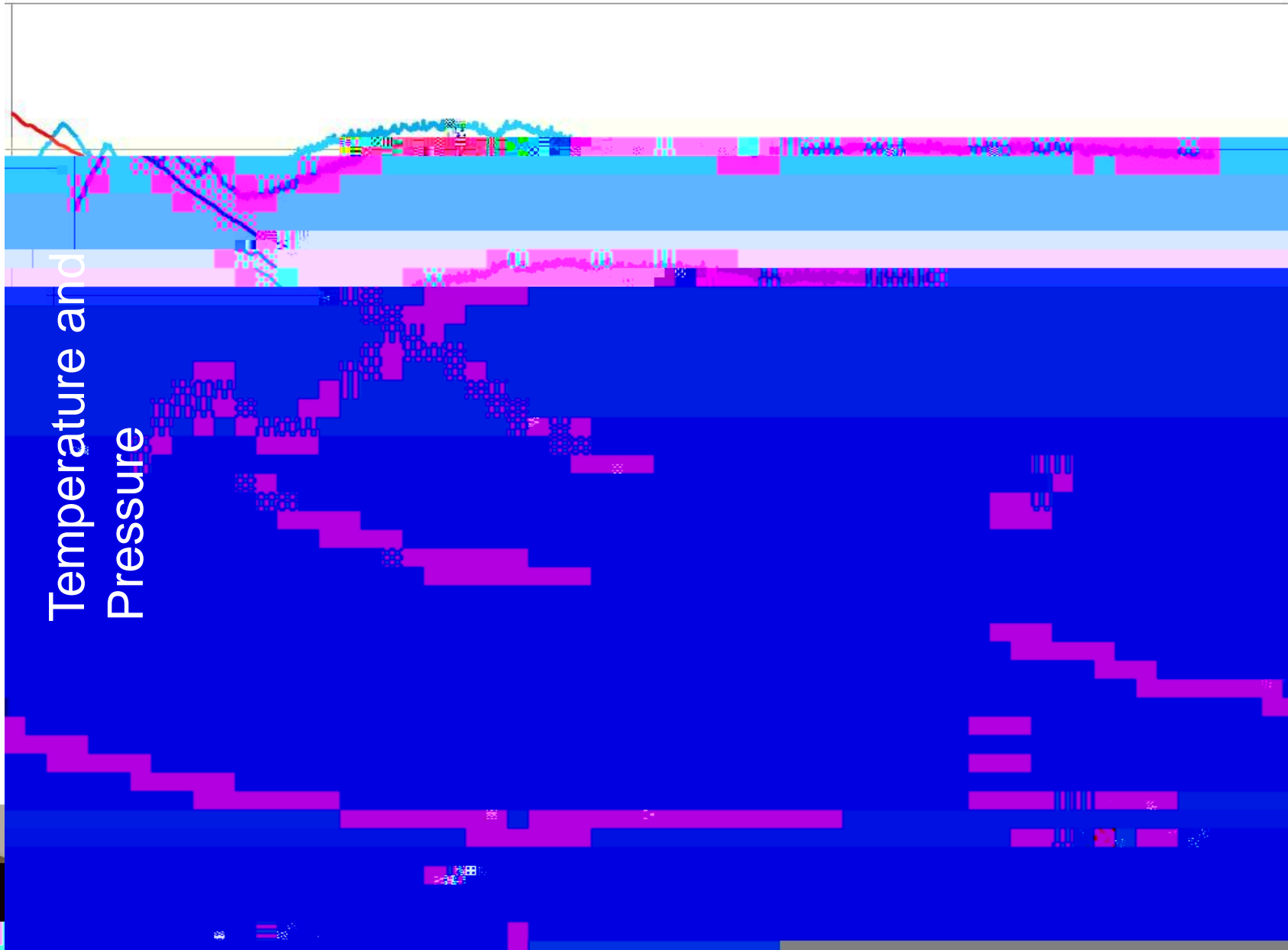


Diverter Test No. 1

- i Injected water into well prior to the diverter test
- i Multiple rates of 150, 300, and 500 gpm
- i Measured temperature at bottom of hole



Diverter Test No.1 T & P vs. Time Monitormtted@500



Diverter Test Temperature vs. Depth Monitoring



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Injection Pressure Comparison



Outcomes & Conclusions – Test No. 1

- The first field trial of AltaRock Proprietary Diverter successful
- Highly permeable fractures temporarily sealed
- The presence of a slotted liner with 1/2" slots did not pose a problem
- Injection profile in well could be modified temporarily
- Fluid could be pushed deeper into the wellbore
- Finally, transmissivity calculations (kh) before and after the test imply full degradation of the diverter material – value held steady at 55,000 md-ft.

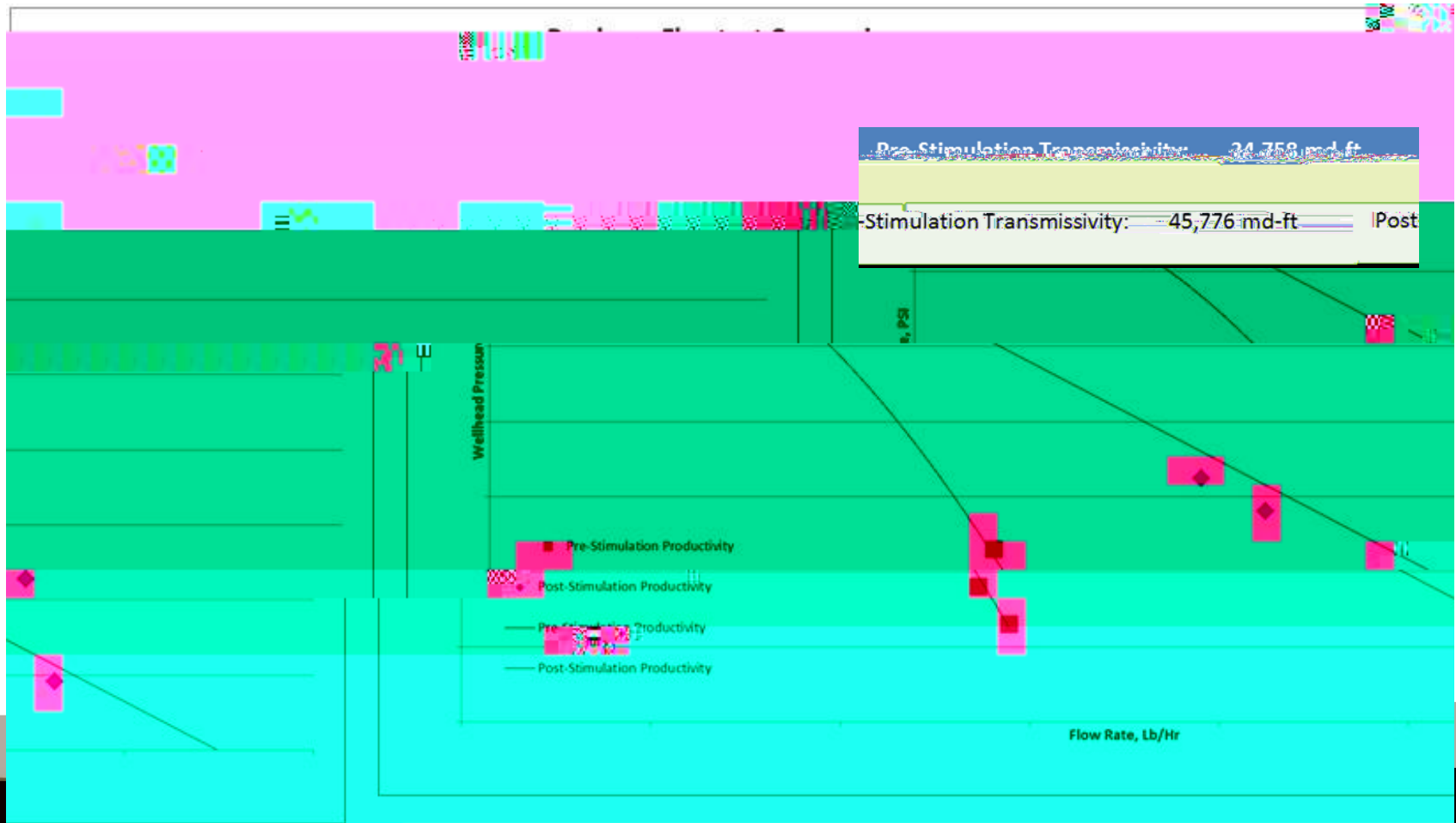


Tracer Test Results - Test No.2

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Flow Test Results - Test No.2



Outcomes & Conclusions | Test No.2

- | Successful diversion and stimulation (tracer tests)
- | Improved long term production
- | Improved permeability due to stimulation (Transmissivity)
- | Enhanced production from deeper interval



Conclusions

- i AltaRock Proprietary Chemical Diverters have potential to greatly reduce the cost of EGS power and to enhance production of hydrothermal production wells

 - Increase power production on a per well basis**

 - GETEM modeling indicates up to 50% or more reduction in power costs**

- i Field tests provide support of concept of using chemical diverters to temporarily divert flow in actual wells

 - Even with slotted liners already in place**

Questions?