FORMATION THERMAL CONDUCTIVITY TESTING OF THE LEDGER FORMATION IN LANCASTER COUNTY, PENNSYLVANIA

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Introduction

- Geothermal Basics…no not Old Faithful
- Study Area
- Methods
- Results
- Conclusion

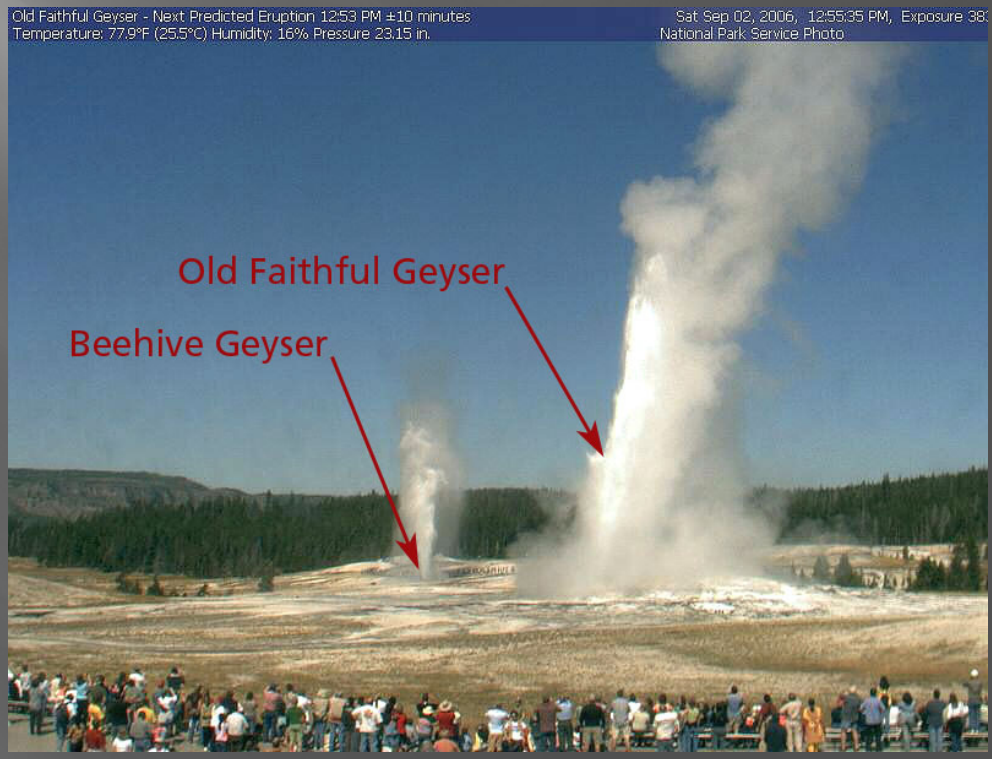


Image Source:
http://www.nps.gov/archive/yell/tours/livecams/oldfaithful/images/oldfaithful-beehivelabeled.jpg

Geothermal Basics

- Heat Pumps
- Building Loads
- Thermal Properties
- Drilling Conditions
- Ground Temperature
- System Design

Image Source: www.braxisenergy.com

Geothermal Basics

- The earth is a massive sink for solar energy
- Earth energy is available on any site
- The earth maintains a very consistent temperature

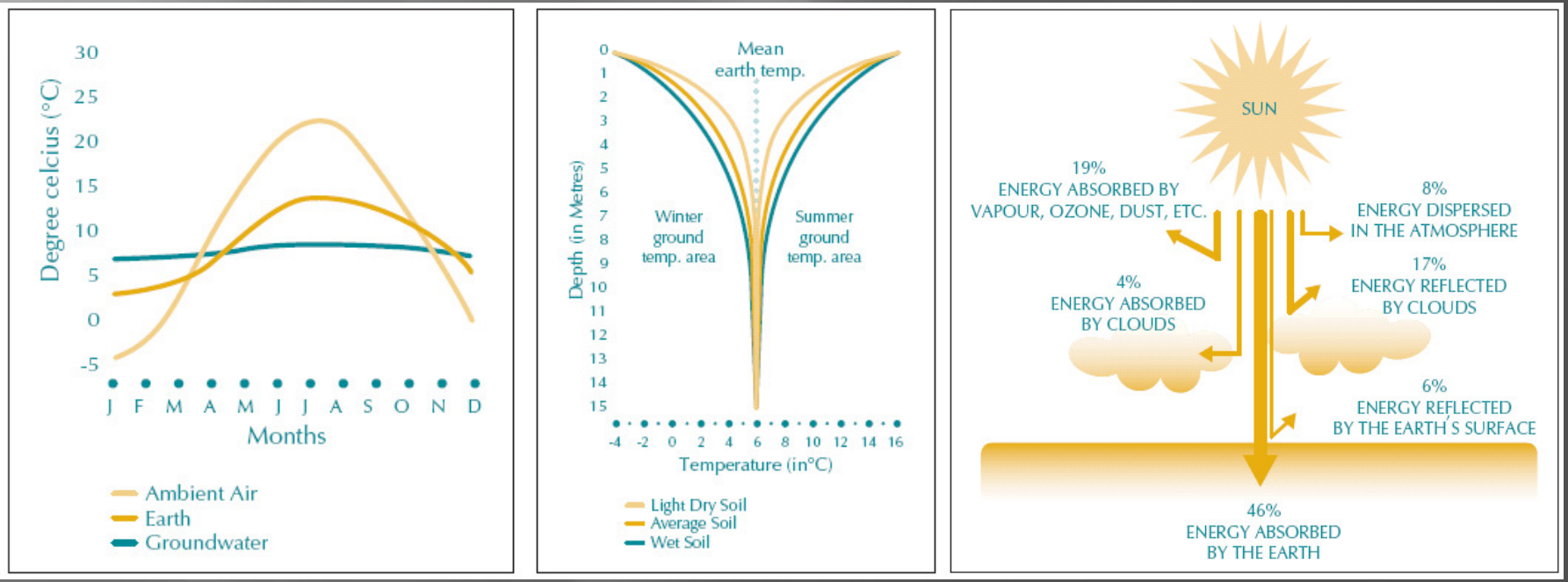
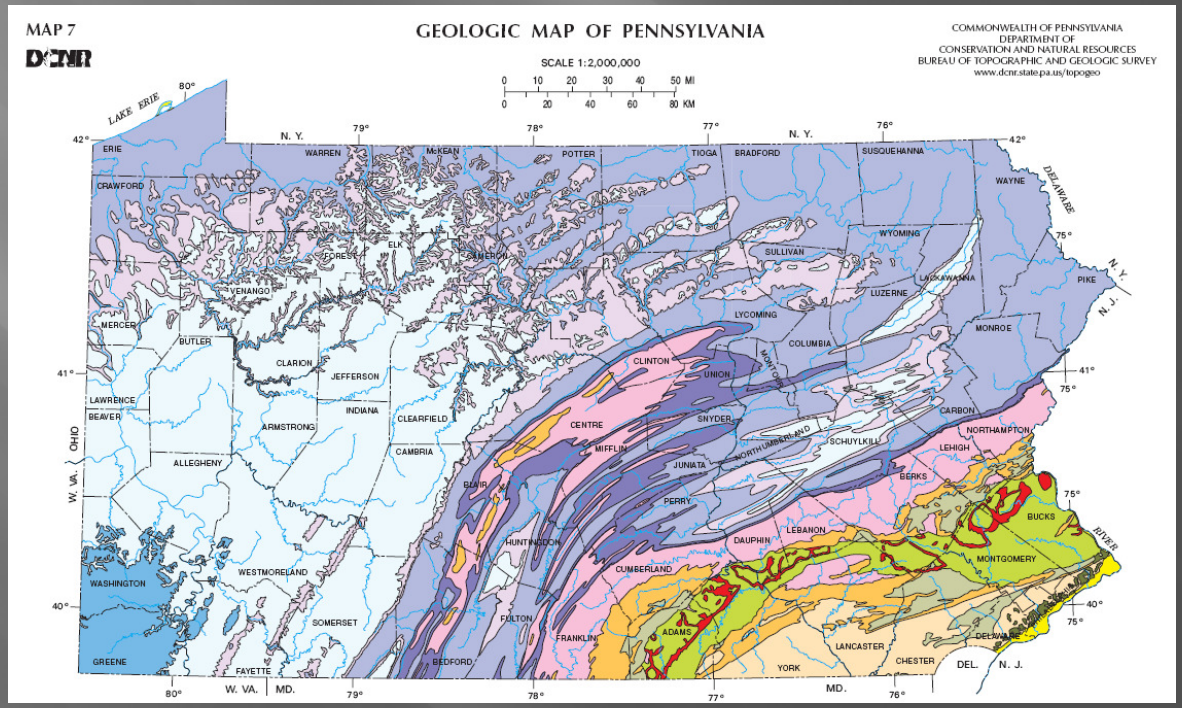


Image Source: www.retscreen.net

Geothermal Basics

- Geology of the site is very important
- Soil, bedrock and groundwater flow influence the systems ability to transfer heat.
- Pennsylvania has very diverse geology.



Geothermal Basics

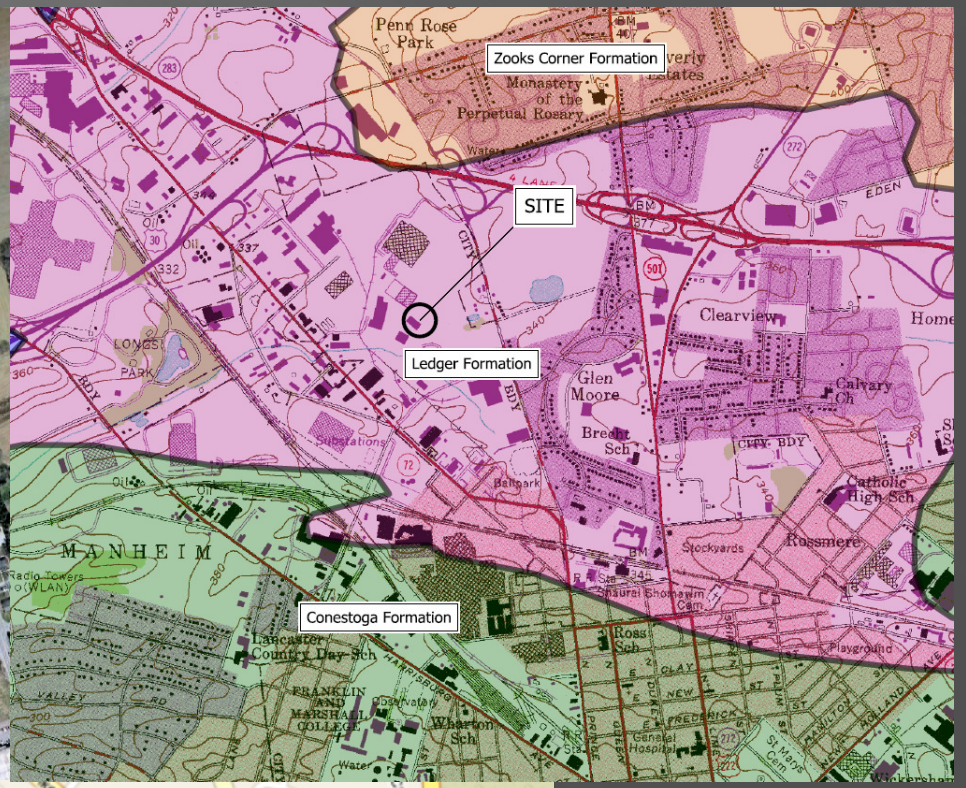
- Rock Thermal Conductivity Properties

Rock Type	Thermal Conductivity* Btu/h·ft·°F (W/m·°C)	Density lb/ft^3 (g/cm^3)
Granite (25% quartz)	1.5 - 2.1 (2.60 - 3.63)	165 (2.64)
Andesite	0.9 - 1.4 (1.56 - 2.42)	160 (2.56)
Basalt	1.2 - 1.4 (2.08 - 2.42)	180 (2.88)
Limestone	1.4 - 2.2 (2.42 - 3.81)	150 - 175 (2.40 - 2.80)
Sandstone	1.2 - 2.0 (2.08 - 3.46)	160 - 170 (2.56 - 2.72)
Wet Shale (no quartz)	0.6 - 0.9 (1.04 - 1.56)	130 - 165 (2.08 - 2.64)
Dry Shale (no quartz)	0.5 - 0.8 (0.86 - 1.38)	130 - 165 (2.08 - 2.64)
Gneiss	1.3 - 2.0 (2.25 - 3.46)	160 - 175 (2.56 - 2.80)
Schist	1.4 - 2.2 (2.42 - 3.81)	170 - 200 (2.72 - 3.20)

* this represents the mid-range for samples of rock

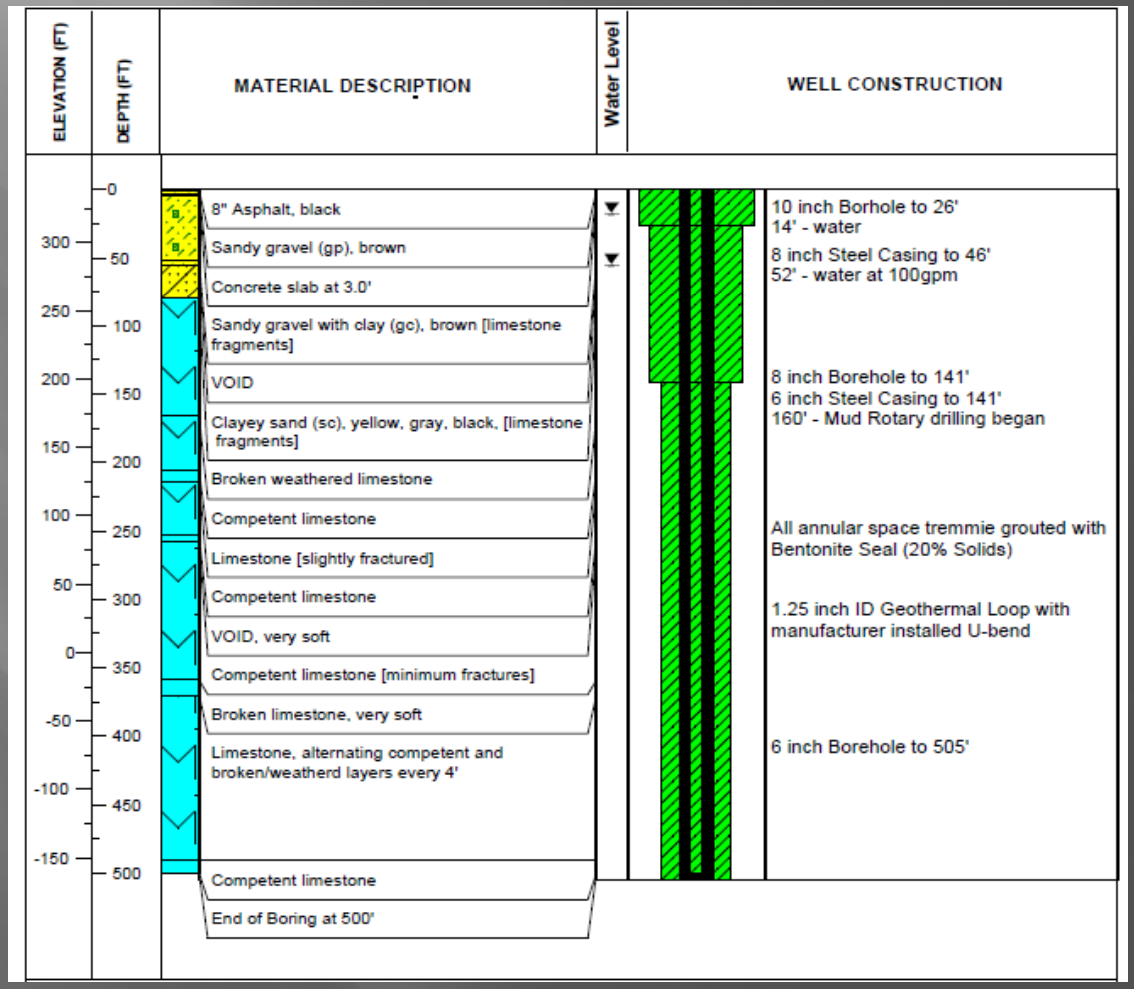
Study Area

- Red Rose Transit Authority in Lancaster, Pennsylvania



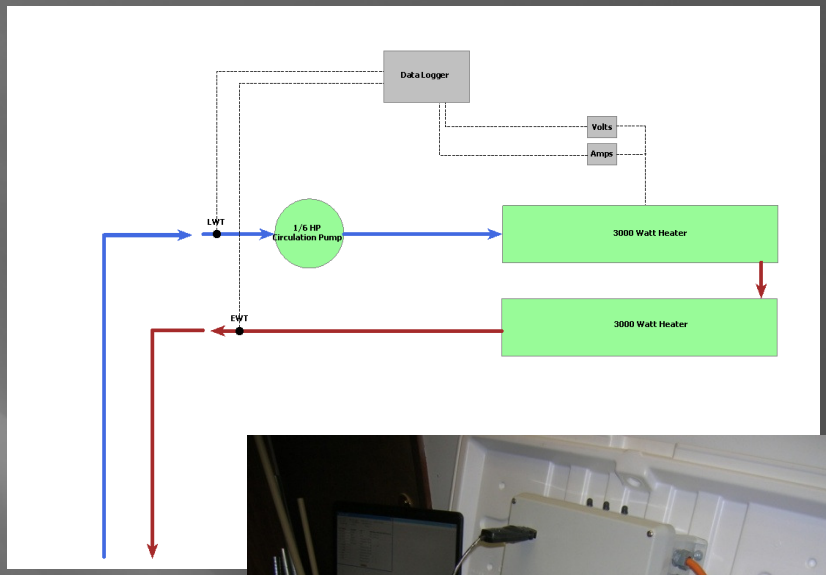
Study Area

Driller's Log



Methods

- In-Situ Testing



Methods

LINES SOURCE MODEL

$$T = \frac{q}{4\pi\alpha}\int_{r^2/4\alpha t}^{\infty}\frac{e^{-u}}{u}du\cdots$$

$$W(u) = -\gamma - \ln u + u - \frac{u^2}{2\times 2!} + \frac{u^3}{3\times 3!} - \frac{u^4}{4\times 4!} + \cdots$$

CONVOLUTION OF LINE SOURCE

$$(f * g)(t) = \int_{-\infty}^{\infty} f(t-\tau)g(\tau)d\tau\P$$

$$\Delta T(t) = \frac{Q}{4\pi\lambda}\int_{r^2/4\alpha t}^{\infty}\frac{e^{-u}}{u}du = \frac{Q}{4\pi\lambda}W(u)\P$$

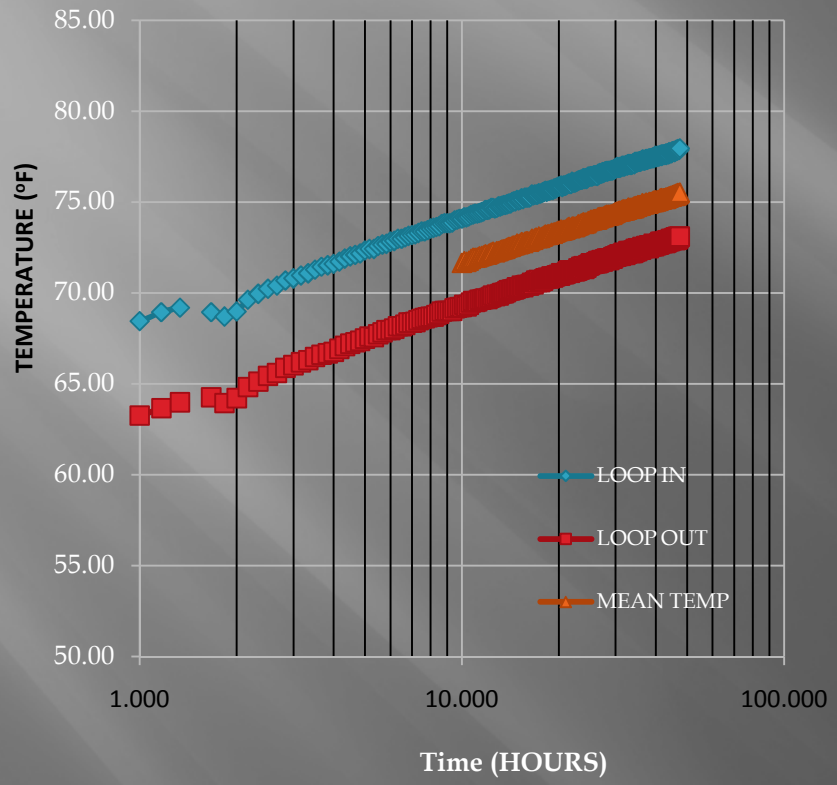
$$R_s(t) = \frac{W(u)}{4\pi\lambda}\P$$

$$\Delta T(t) = QR_s(t)\P$$

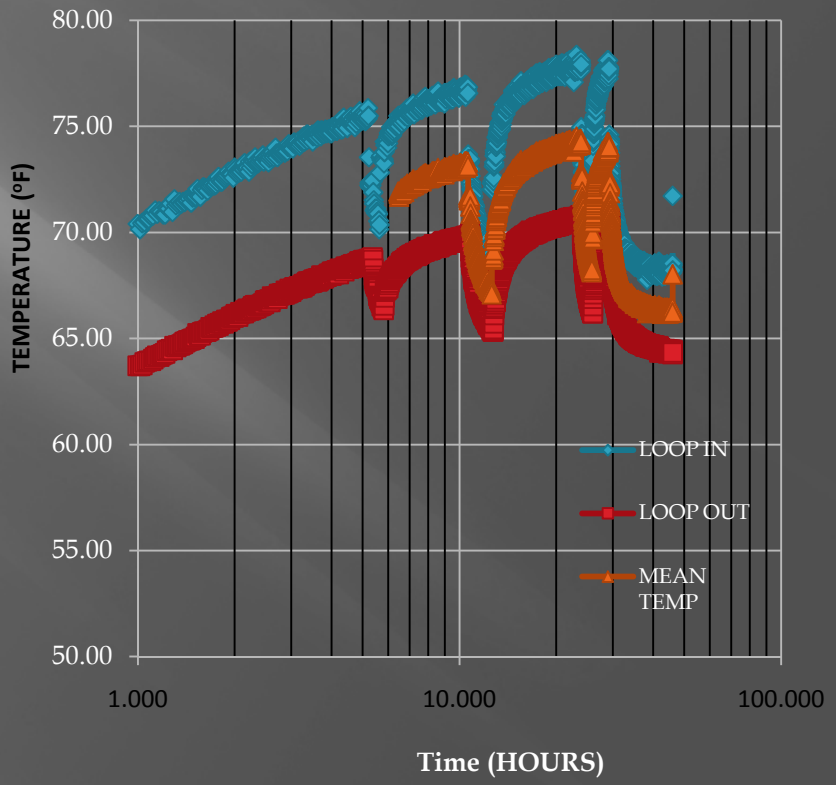
$$\Delta T(t) = \sum_{\tau=1}^{\infty} Q(t-\tau)\{R_{s\tau} - R_{s\tau-1}\}\P$$

Results

Typical Conductivity Test

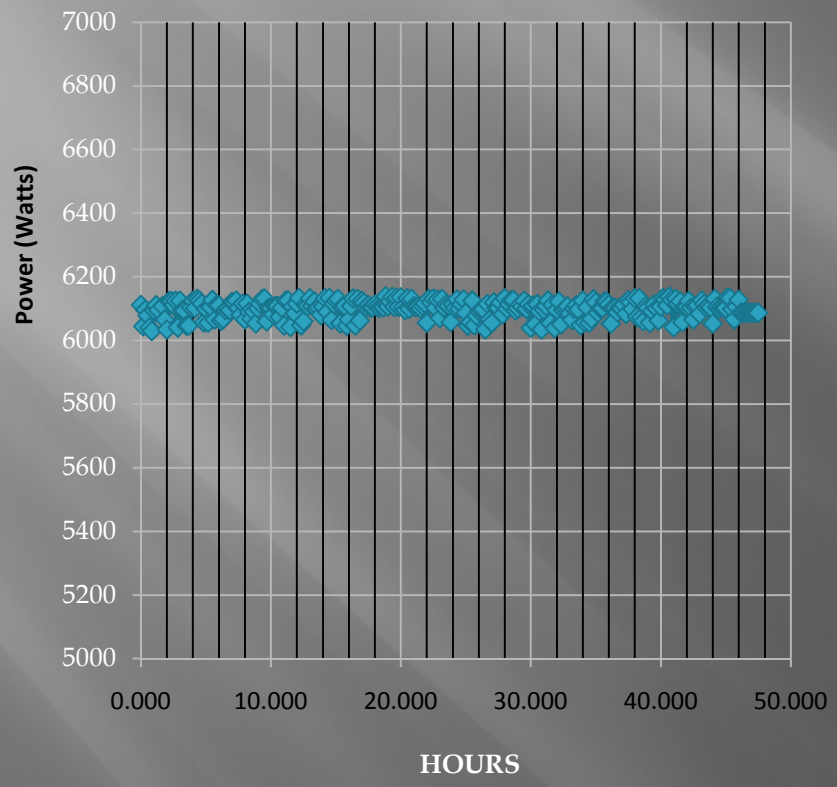


RRT Conductivity Test

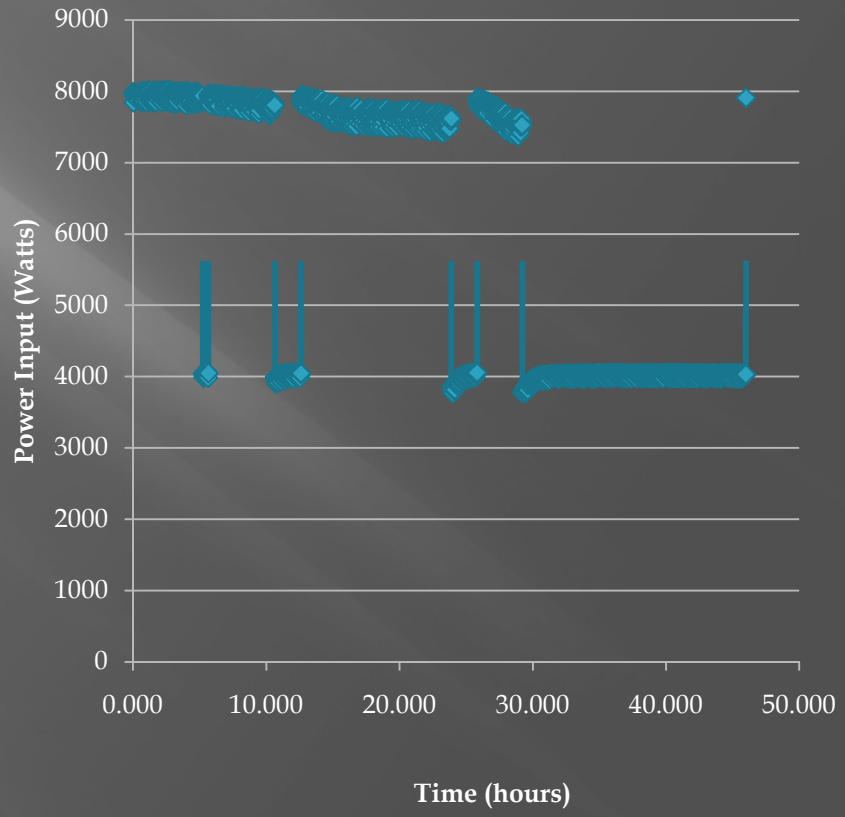


Results

Typical Power Input

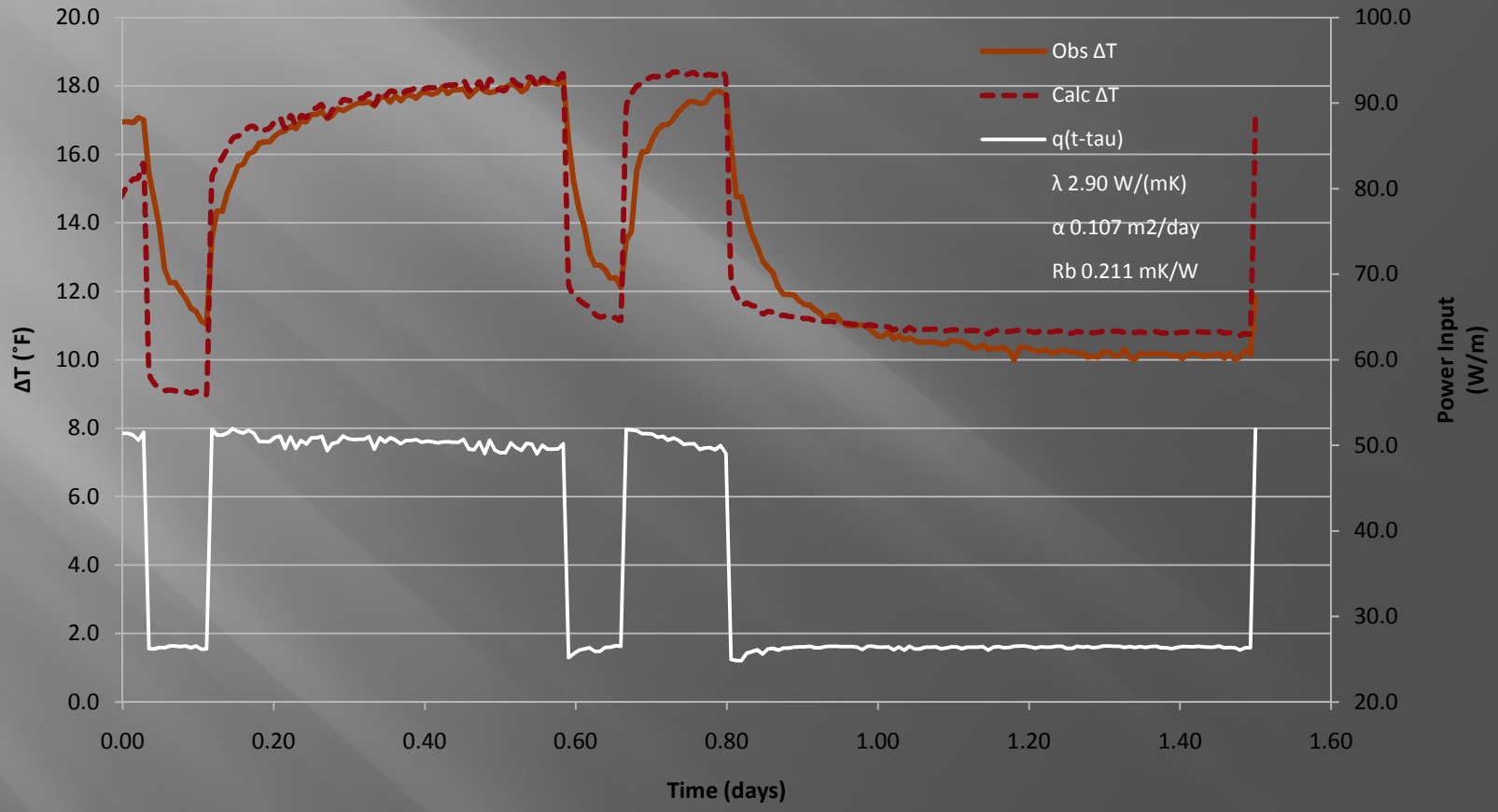


RRT Power Input

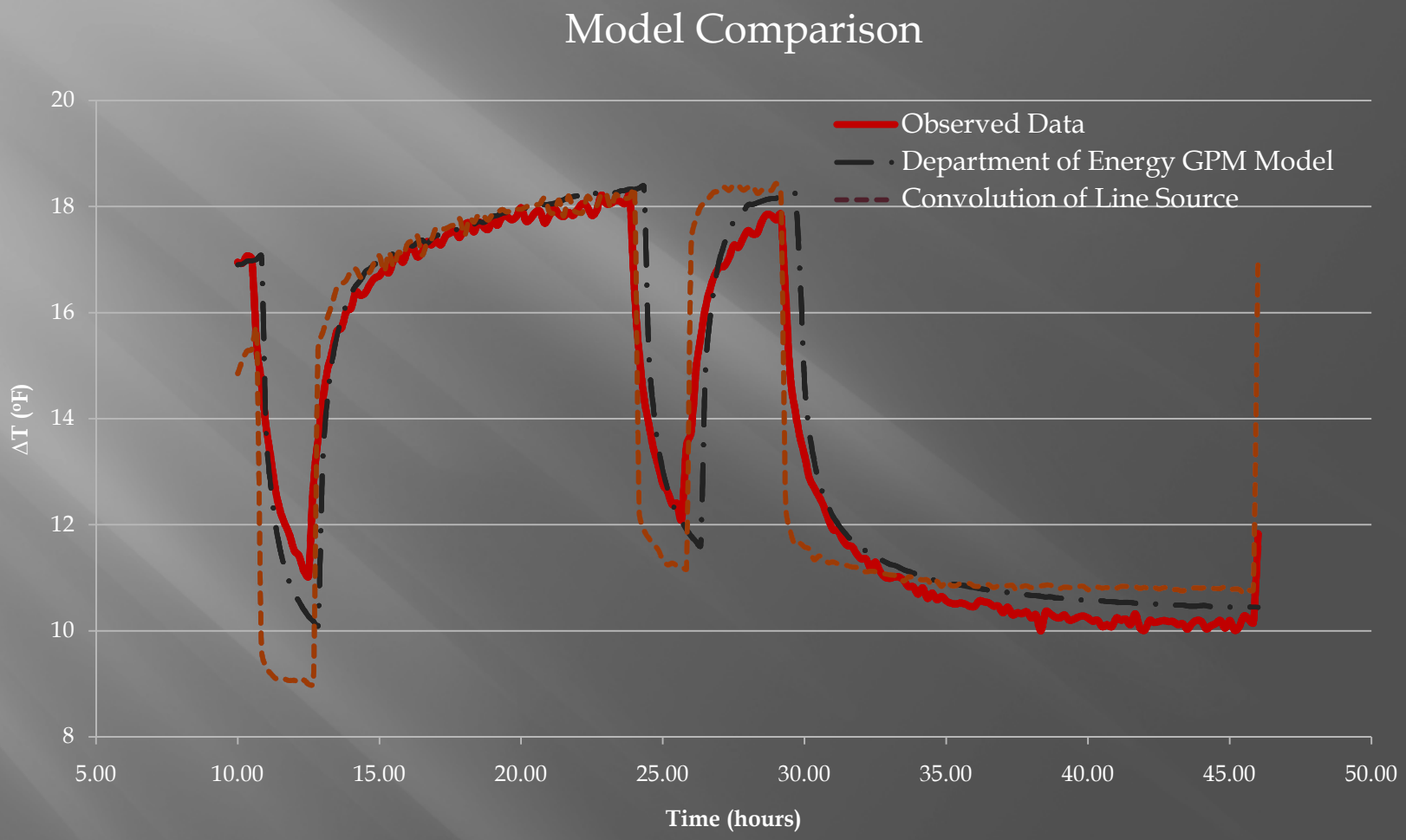


Results

Spreadsheet Model Output



Results


Model Comparison
Observed Data
Department of Energy GPM Model
Convolution of Line Source
ΔT (°F)
20
18
16
14
12
10
8
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
Time (hours)

Conclusion

Thermal Conductivity Testing was successful.

Source	Thermal Conductivity Dolomite (BTU/hr-ft-F°)	Borehole Resistance hr-ft-F°/ BTU
Clauser and Huenges 1995	1.44 to 3.18	N/A
Convolution of Line Source	1.68	0.37
GPM Numerical Model	1.72	0.23

- Well field would be difficult to complete due to drilling conditions.
- Convolution of the Line Source is a viable solution method
- Continued testing of the solution should be performed with field data
- Numerical evaluation of synthetic formations could be used to test

THANK YOU