Technology in a Teapot

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Oilfield Testing Center

Overview of New Methods for Finding and Extracting Oil in an Old Stripper Field at Teapot Dome, Wyoming

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How Can New Technology Help Old Fields?

- Reduce Operating Costs
  - Electrical power consumption
  - Reliability and Maintenance (less down-time)
- Increase Reserves
  - Missed reservoirs – behind pipe; deeper zones
  - Untapped fault blocks
  - Better reservoir characterization
- Increase Daily Production Rate
  - Overcome formation damage
  - Improved pump efficiency

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Outline

- How Can New Technology Help Old Fields?
- What is RMOTC?
- New Technologies for Old Fields Tested at RMOTC:
  - Drilling:
    - rotary steerable systems
    - continuous sidewall coring
    - logging while tripping
    - bit vibration reduction
    - abrasive jet drilling
  - Production:
    - gas injection
    - surfactant soak/ flood
    - hydraulic pumps
    - Stirling generator
    - flow assurance
    - downhole separators
    - leak detection
  - Exploration:
    - electro-magnetic
    - resistivity surveys
    - aeromagnetic
    - 4D seismic
    - high-res. 2D shallow seismic
    - fracture studies
    - geomechanics studies
    - petrographics
    - seismic curvature analysis
  - Renewable energy:
    - geothermal
    - wind
    - solar

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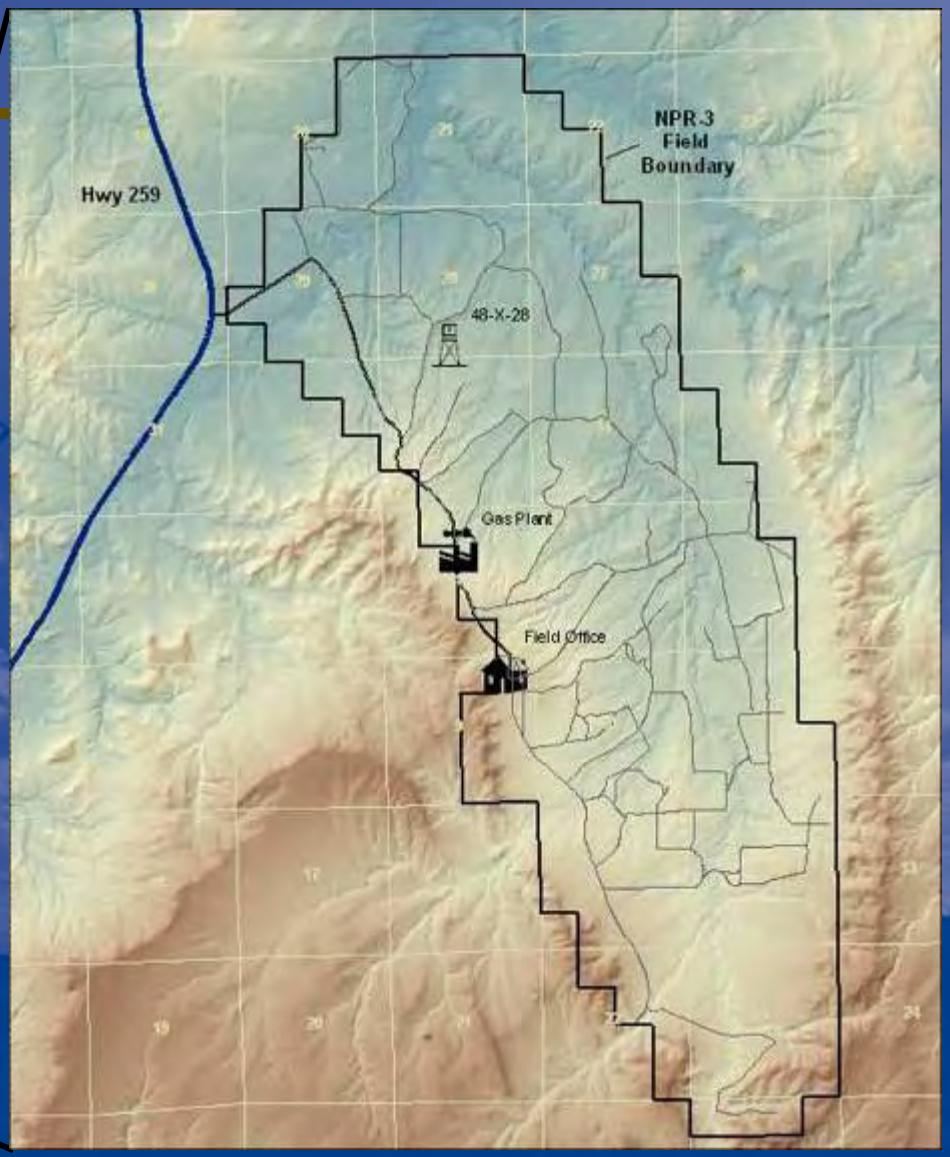
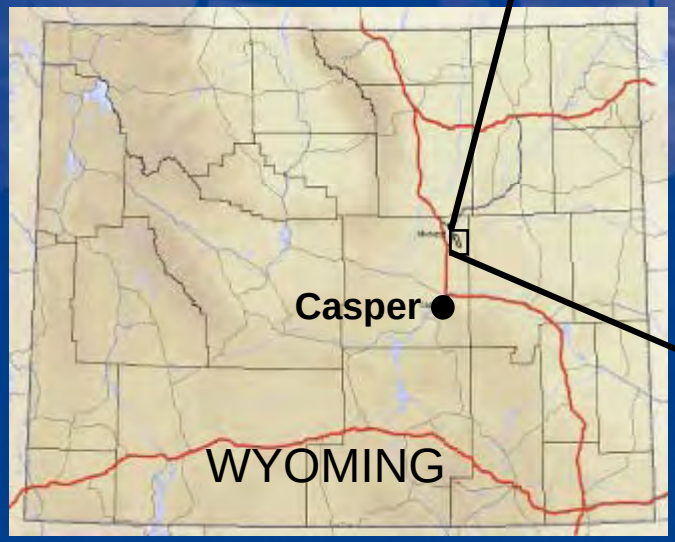
Field Location

- RMOTC is located at Teapot Dome Oilfield within the Naval Petroleum Reserve No. 3 (NPR-3)
- Town offices are located in Casper, WY





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Unique Location for Testing

- Remote, federally-owned and secure site
- 10,000-acre operating oil field
- Full complement of onsite facilities and equipment
- Approximately 1350 well bores; 600+ active wells
- Nine producing reservoirs
- Depths from 250-7000 ft.
- Real world field testing
- Producing, non-producing, and new well drilling opportunities
- Industry experienced specialists
- Varied terrain & weather conditions

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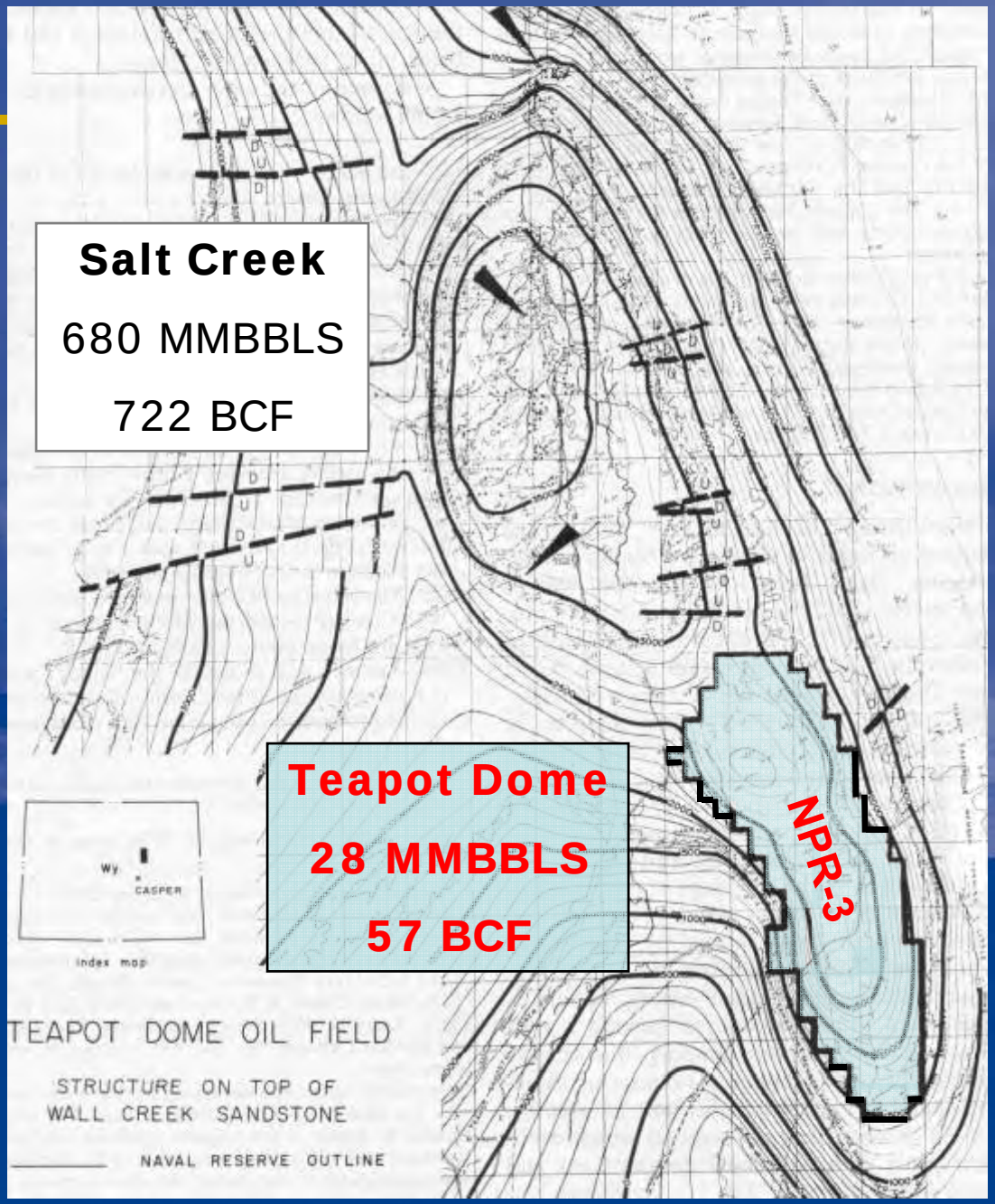
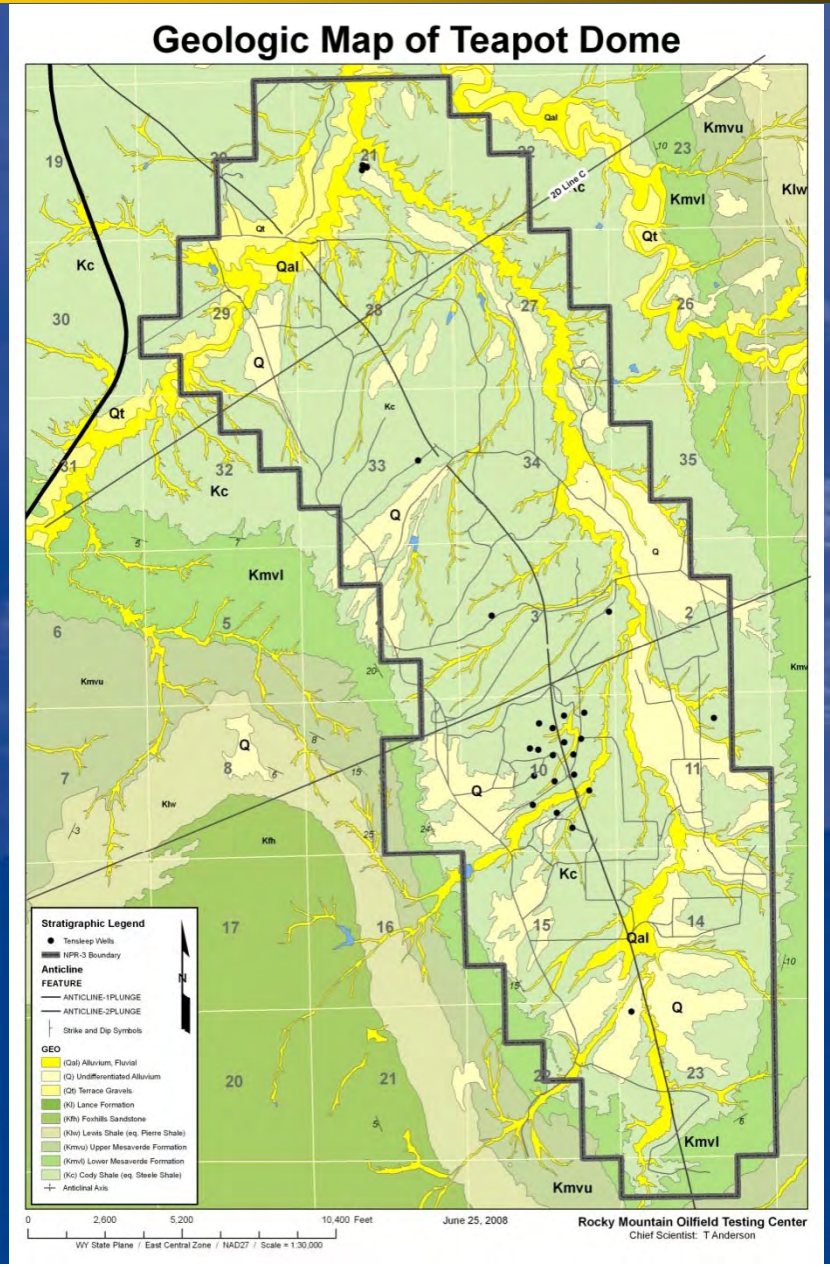
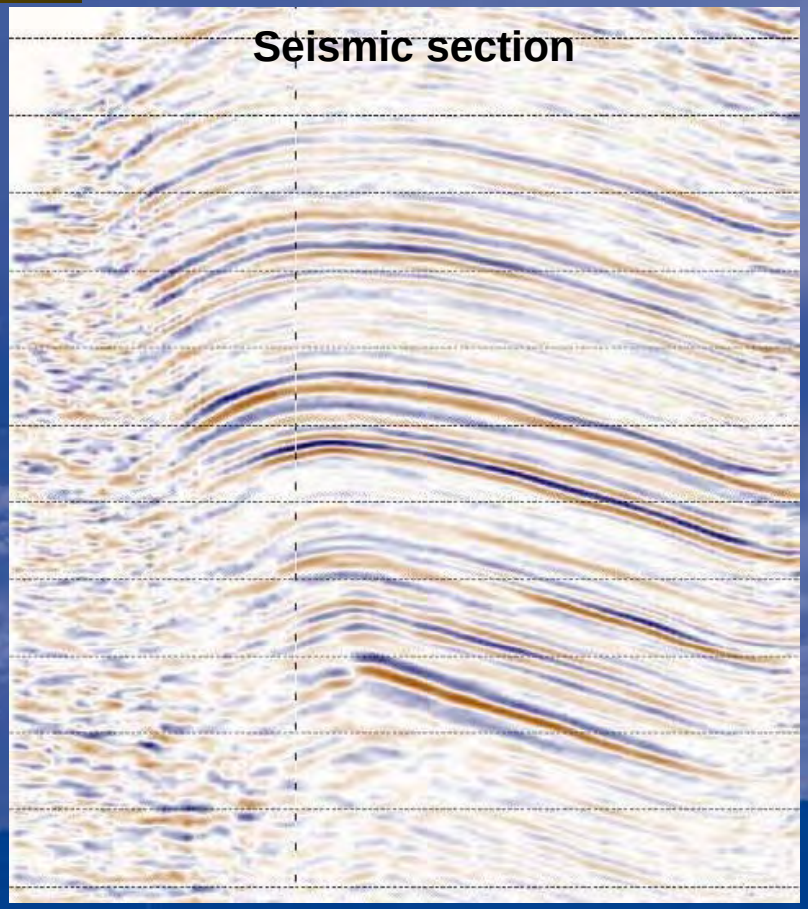
Cumulative Production



Surface Geology and 3D Seismic





Alcova Anticline -- analog

NPR-3 Reservoir Summary

Period	Formation		Lithology	Thickness	Depth (feet)	Productive
Quaternary	Kaycee			0-50		
Upper Cretaceous	Steele			195		
		Sussex		30		□
				290	225	
		Shannon		120	515	■
				1355	635	◙
	Niobrara Shale			450	1990	◙
	Carlisle Shale			240	2440	□
	Frontier	1st Wall Creek		160	2680	□
				245	2840	
		2nd Wall Creek		65	3085	■
				175	3150	
		3rd Wall Creek		5	3325	◙
				265	3330	
Lower Cretaceous	Mowry Shale			230	3595	
	Muddy Sandstone			15	3825	◙
	Thermopolis Shale			135	3840	
	Dakota			85	3975	◙
	Lakota			10	4060	◙
Jurassic	Morrison			270	4070	□
	Sundance	Upper		95	4340	
		Lower		150	4435	□
Triassic	Chugwater Group	Crow Mtn		80	4585	
		Alcova LS		20	4665	
		Red Peak		520	4685	□
Permian	Goose Egg			320	5205	□
Pennsylvanian	Tensleep			320	5525	■
	Amsden			160	5845	
Mississippian	Madison			300	6005	
Cambrian through Devonian	Undifferentiated			780	6305	
Pre-Cambrian	Granite				7085	

- Nine oil-bearing intervals
- Four currently producing
  - *Shannon - depth 500'*
  - *Niobrara Shale 2000'*
  - *2nd Wall Creek 3000'*
  - *Tensleep 5500'*
- Granite Basement 7000'
- Range of rock composition & petrophysics
- Clastics and Carbonates

Reservoir Data

Formation	Shannon	Shales	2nd Wall Ck	Tensleep
OOIP MMBO	144	25	57	4
OGIP BCF	1.4	2.2	45.1	.01
Area, acres	3800	8640	3590	320
Ave Poro.	18 %	n/a	15 %	8 %
Ave Perm.	63 md	n/a	100 md	80 md
Thickness ft.	65	35	30	50
Pressure PSI	25-70	25-250	25-250	2350
Cum. Oil	11.5	4.1	10.3	1.8
Recovery %	8	16	18	45
Cum. Gas	.7	.9	45.1* (inj.)	0
Temp. °F	65	100	125	190
Oil Gravity	29-35	38-42	38	32

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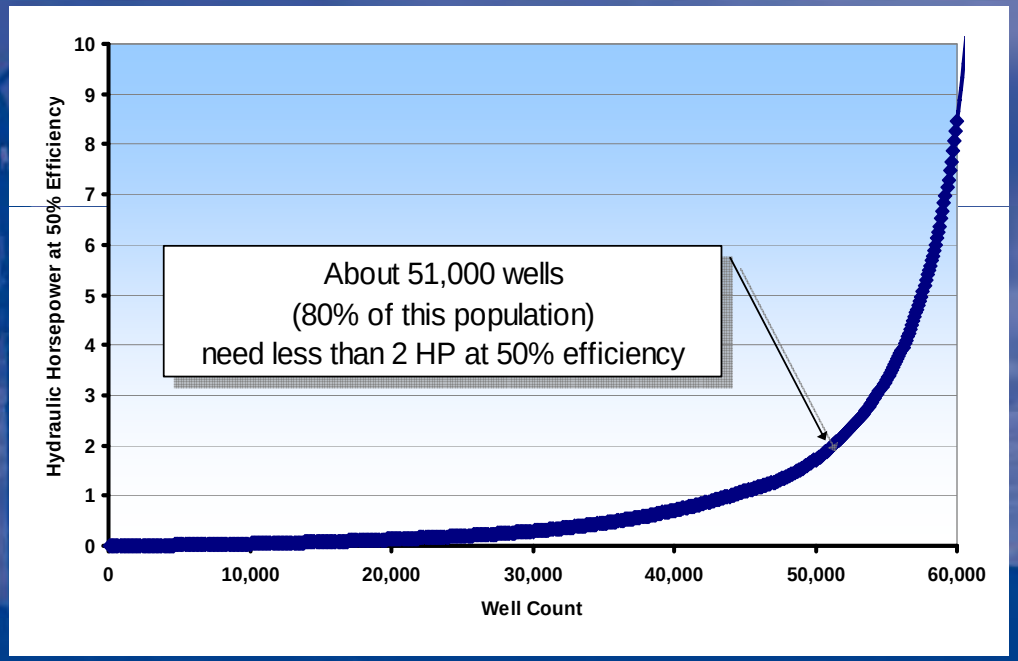
Application of Stirling Cycle Generators in Production Ops

Test partners: BP, Houston; WhisperGen, Adelaide, Australia

Issue: Future Gas Well Deliquification:

- Gas wells can be made more productive lifting very low liquid rates.. generally less than 20 BPD.
- There are a lot (~50,000) of deep gas wells that could benefit from less than 2 HP of lift .. but they are remote and it has to be low cost.



B. Dotson, BP America Production Co.
J. Rochelle, U.S. DOE, RMOTC
L. Madden, WhisperGen Ltd.

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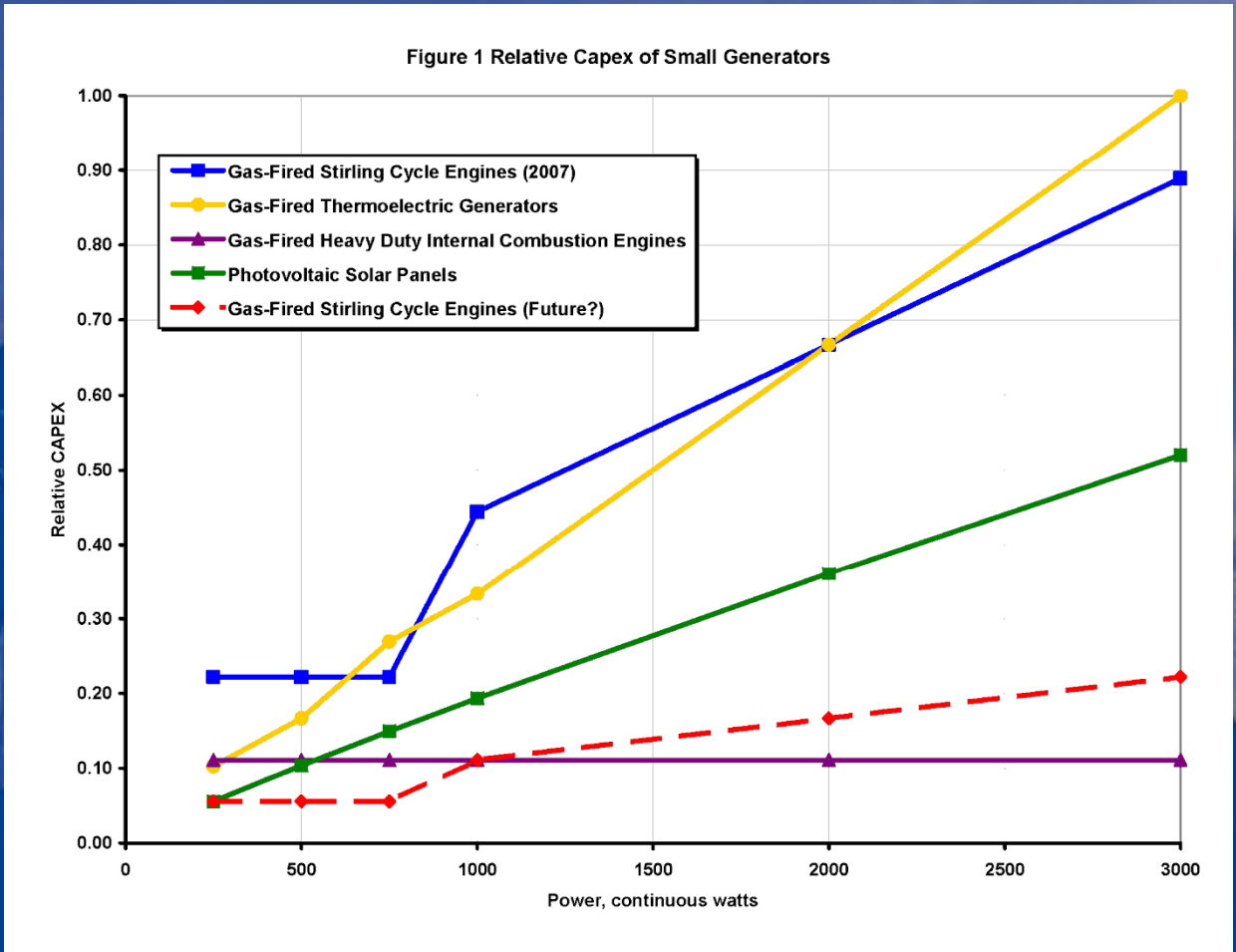
Alternatives & Selection Criteria

- Reliability
- Capital Expenditure
- Operations & Maintenance Cost
- Fuel Cost

For gas wells, gas fuel is almost always available without transport.

Stirling Cycle has maintenance advantages



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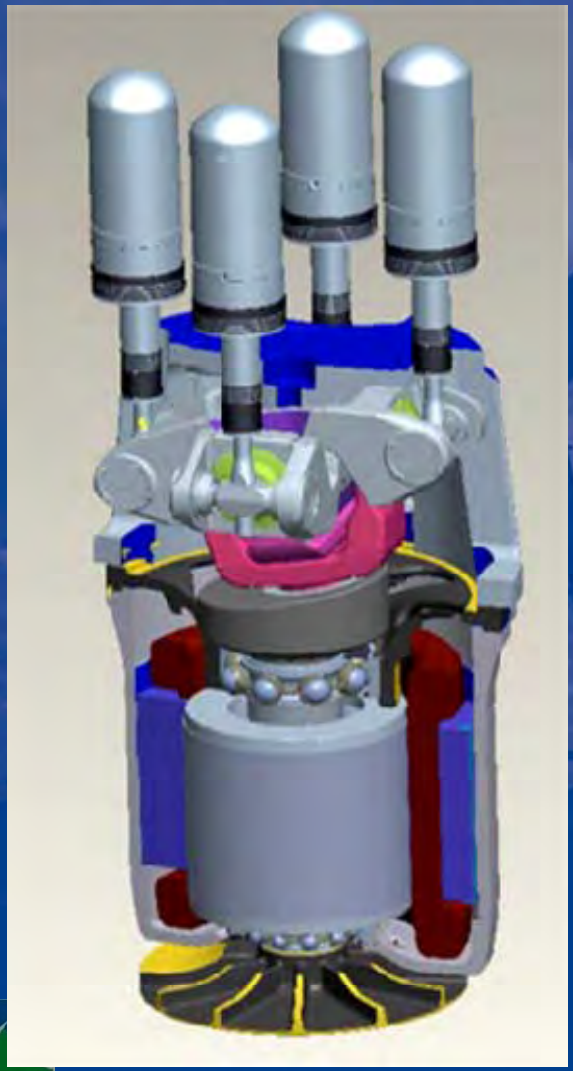
Stirling Cycle Engine



Stirling external combustion engine

- Simple concept with 200 years of history
- Pistons are powered by nitrogen gas inside a sealed chamber
- The gas expands and contracts as it is heated and cooled
- A wobble yoke transfers the pistons linear motion into rotational motion to generate electricity
- Cooling water is heated during this process and this is available for other uses (similar to a cogen)

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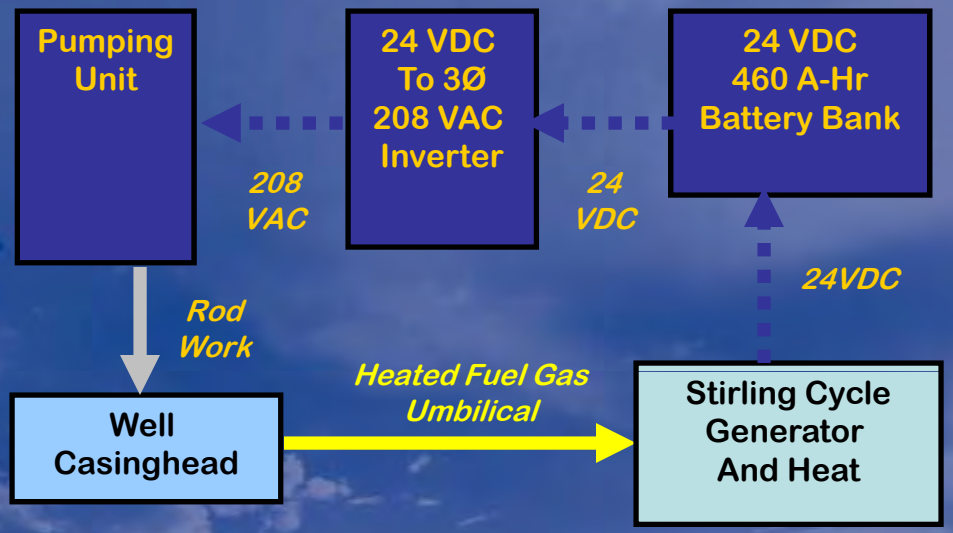
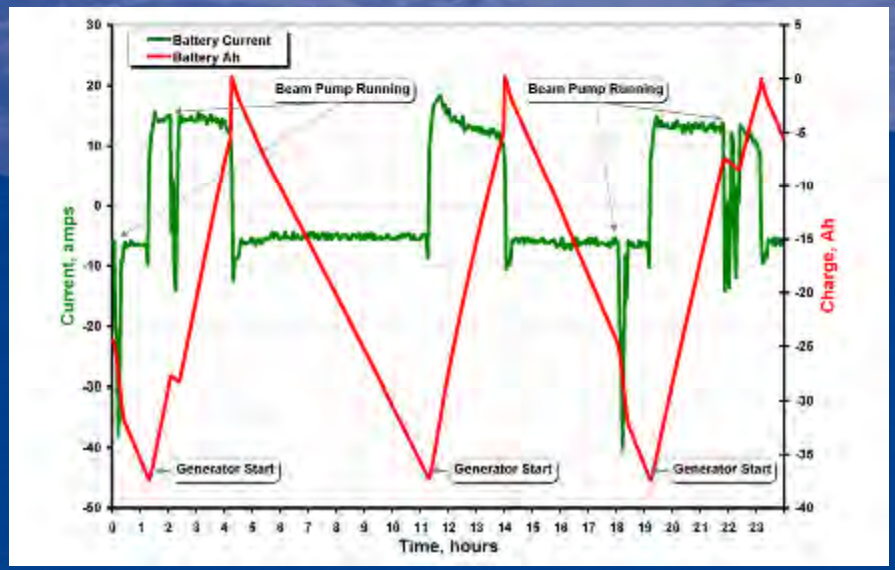
DC Buffer Concept

- DC Generator automatically charges the battery bank at 800W (19kWh / day).
- Battery bank is sized to supply additional power when demand exceeds generation.
- The peak load is supplied by the batteries.
- Depending on electrical loads, battery bank of 400 -1200 Ah battery bank (24V) is normal.
- AC power is available (via an inverter) whenever needed.





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Generator Package

Enclosure contains the Stirling generator, the battery bank, the inverters, and the heat trace tank and pump.

Sucker Rod Application

- Installed in Feb. 2007 at RMOTC north of Casper, WY.
- Well produces about ½ barrel/day of oil. The 3 HP (2.25 kW) motor runs about 15 minutes 4 times per day.
- As of May 2008 total operating hours are 3200.

Conclusions:

- *Stirling Cycle can be used in the oilfield.*
- *Viable option for combined power and heat where low maintenance is important.*

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Tensleep Formation Produced Water

190° - 200° F

Low TDS and chlorides

Surface cooling and discharge

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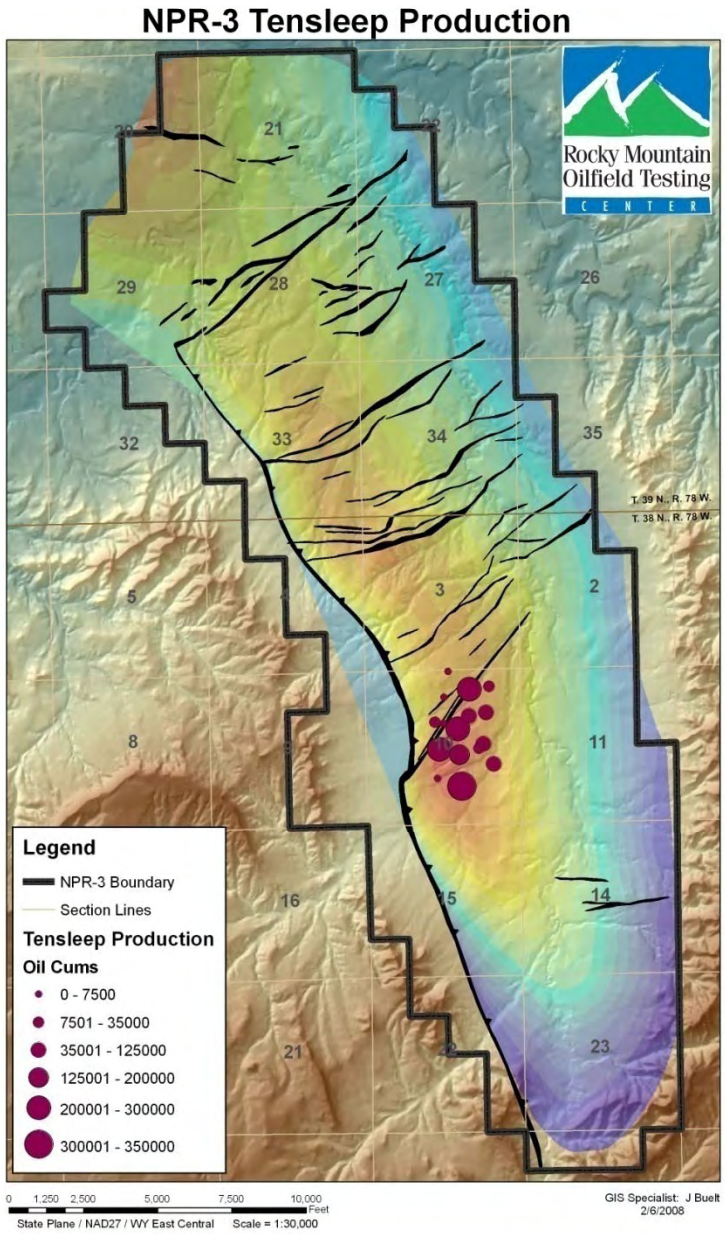
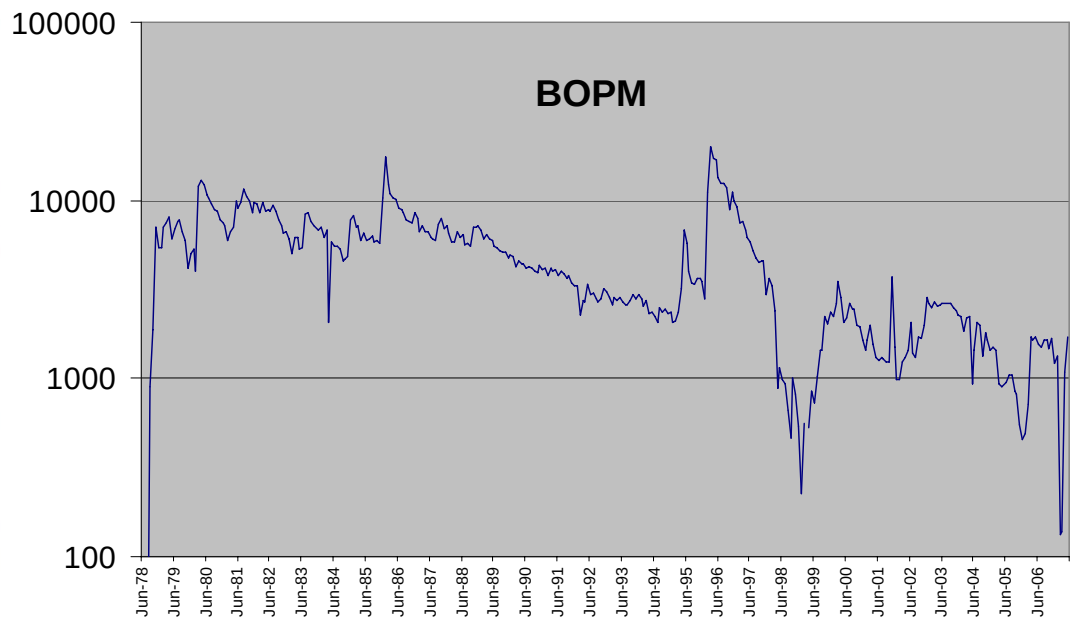
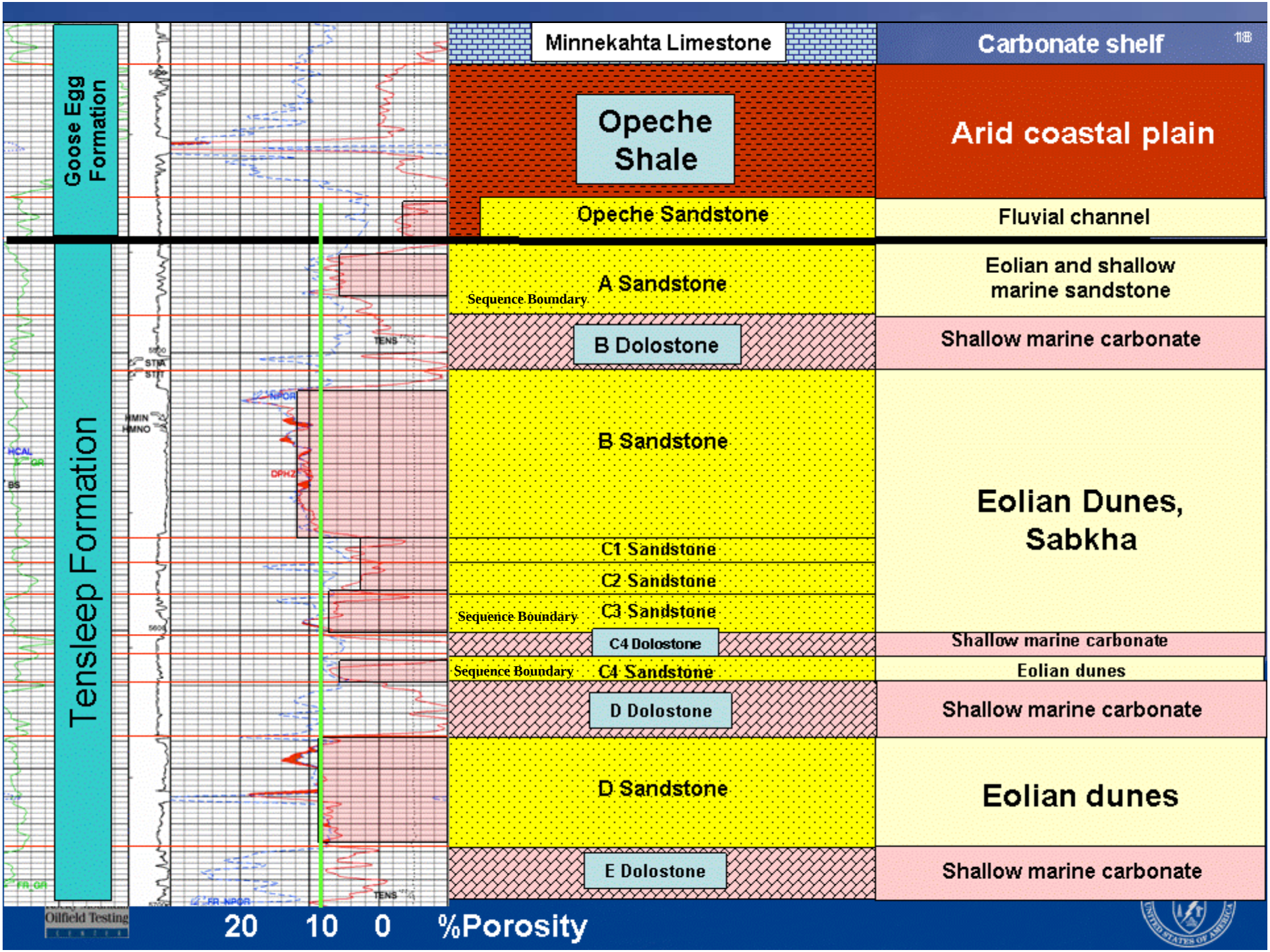
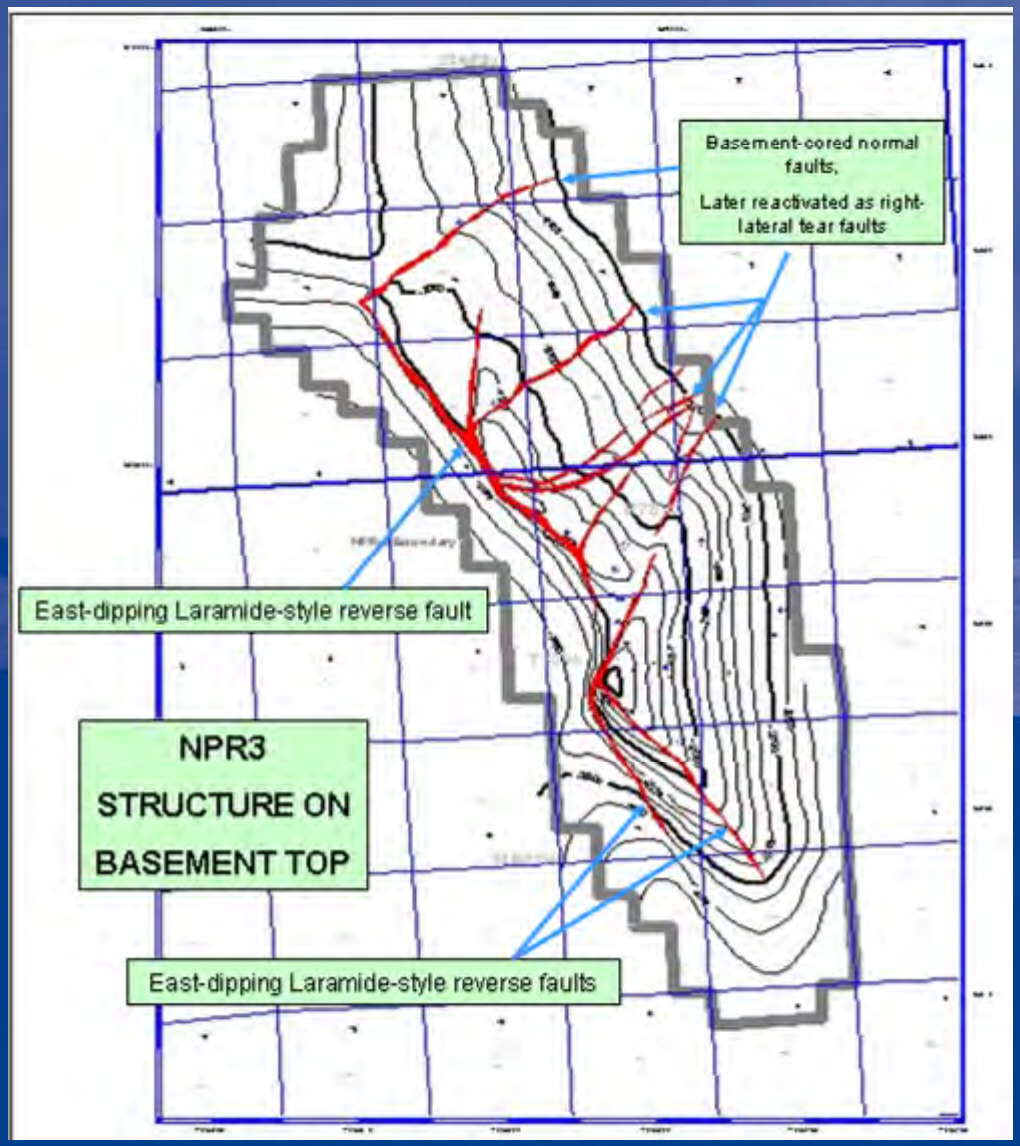
Tensleep Production History






Goose Egg Formation
Tensleep Formation
Minnekahta Limestone
Carbonate shelf
Opeche Shale
Arid coastal plain
Opeche Sandstone
Fluvial channel
A Sandstone
Sequence Boundary
Eolian and shallow marine sandstone
B Dolostone
Shallow marine carbonate
B Sandstone
Eolian Dunes, Sabkha
C1 Sandstone
C2 Sandstone
Sequence Boundary
C3 Sandstone
C4 Dolostone
Shallow marine carbonate
Sequence Boundary
C4 Sandstone
Eolian dunes
D Dolostone
Shallow marine carbonate
D Sandstone
Eolian dunes
E Dolostone
Shallow marine carbonate
Oilfield Testing
20
10
0
%Porosity

Basement Structure



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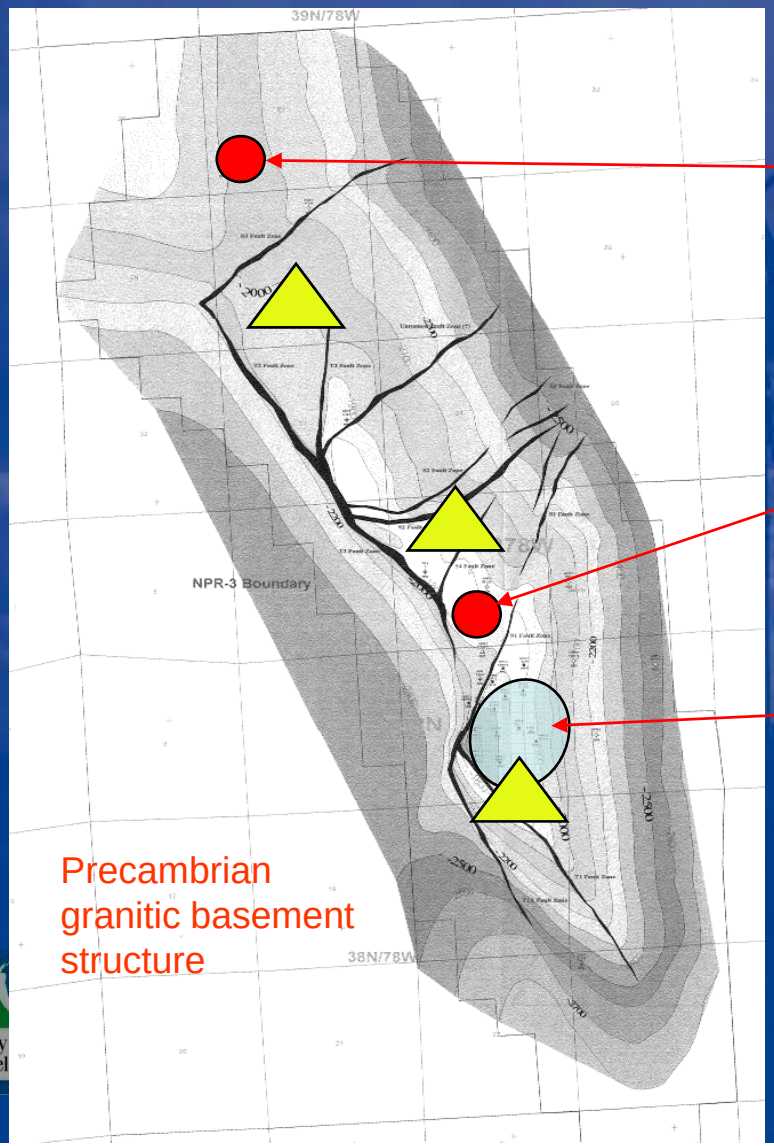
Possible Geothermal Supply Well Locations

Test partner: Ormat Technologies, Reno, Nevada



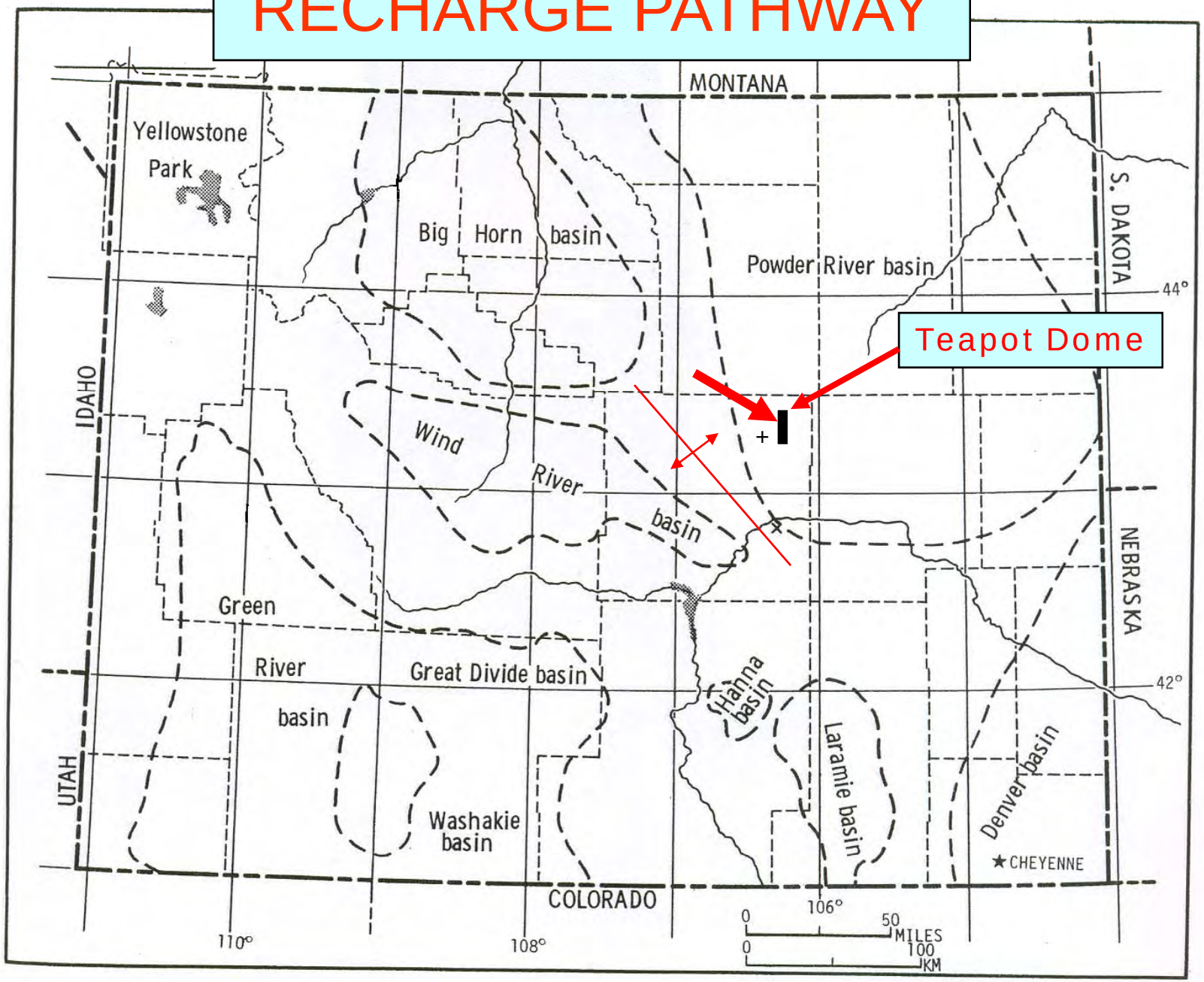
17-WX-21
Madison and Tensleep
Possibly 35 MBWPD flowing

57-WX-3
Madison and Tensleep
Possibly 10 MBWPD flowing

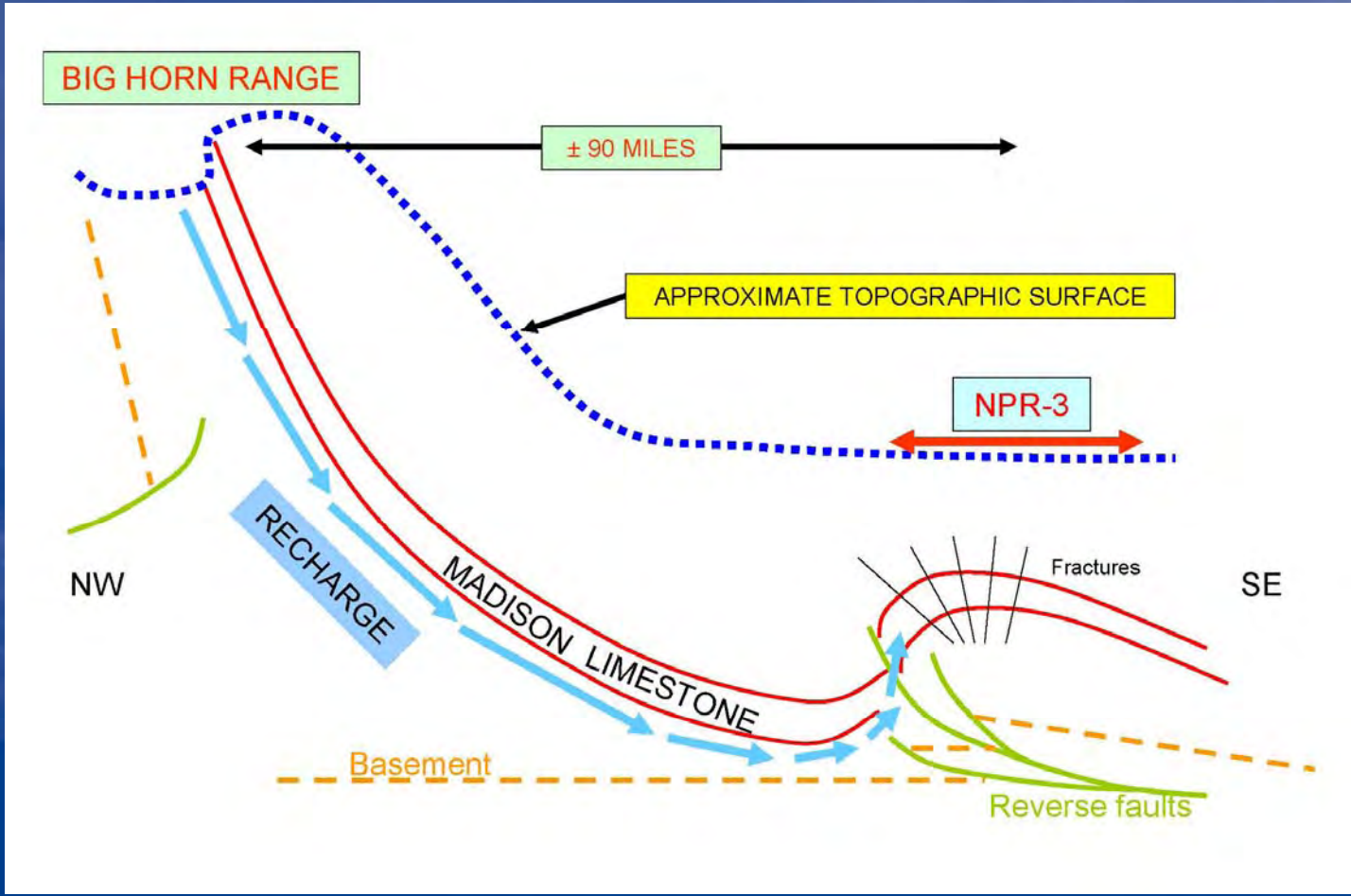
TENSLEEP PRODUCING AREA

OTHER POSSIBLE TENSLEEP SOURCE WELLS AND DEEPENING CANDIDATES

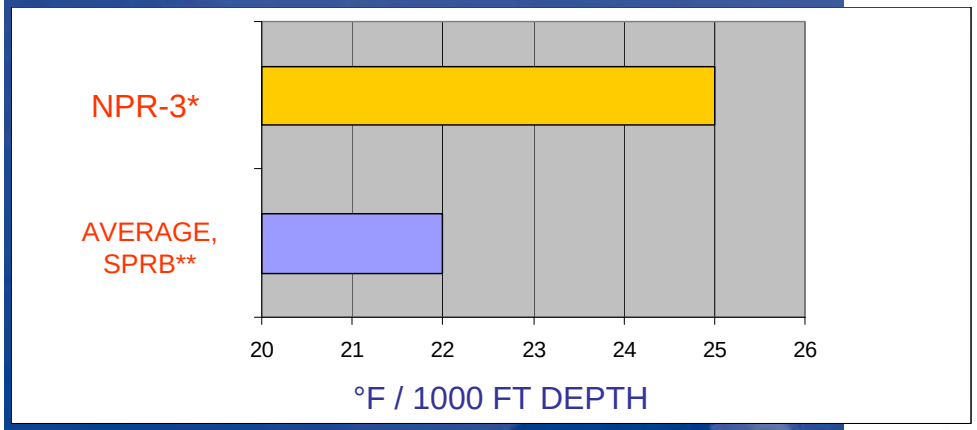
RECHARGE PATHWAY



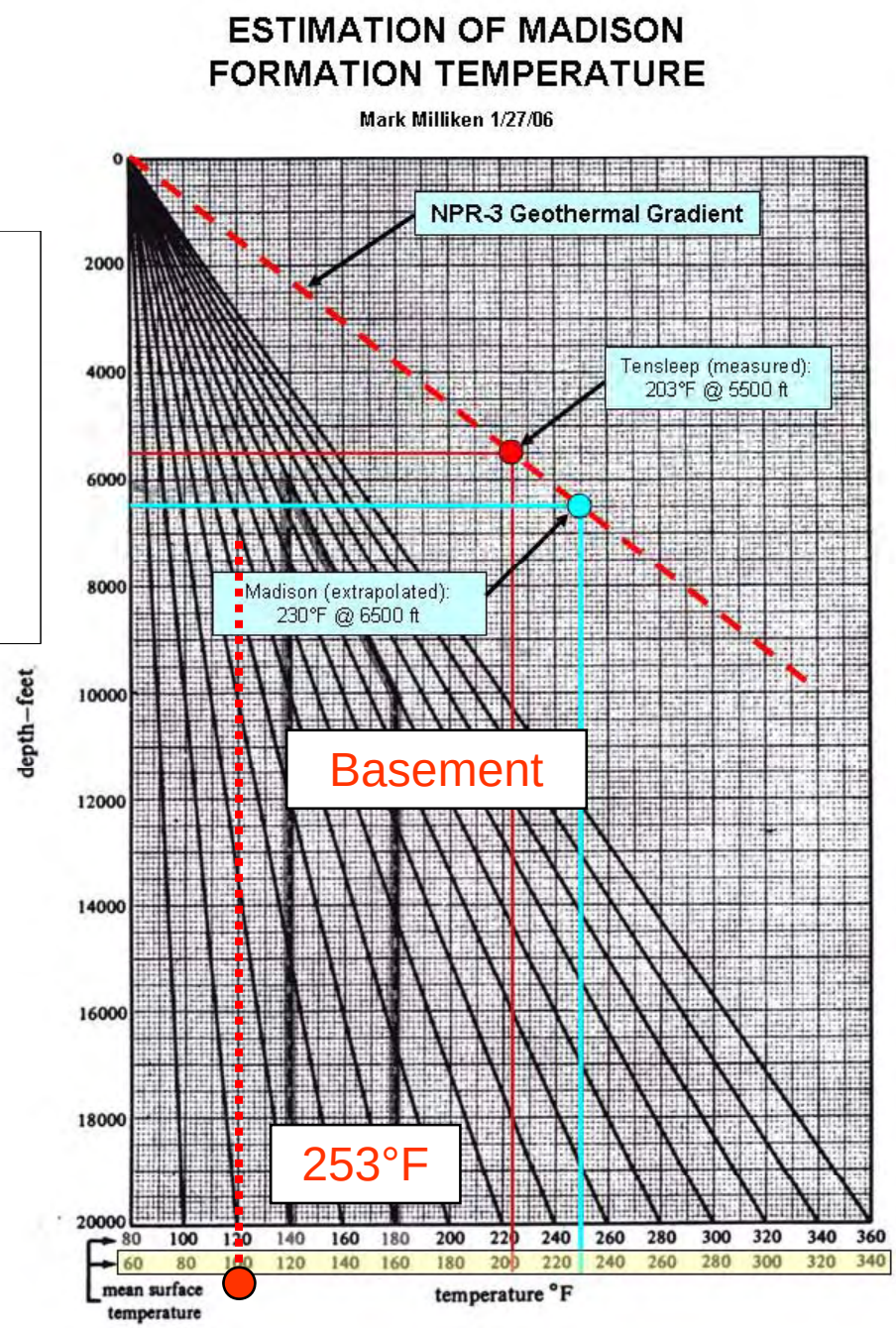
NPR-3 Recharge System



Geothermal Gradient



*Projected from Tensleep data
**Southern Powder River Basin; WSGS data, 1986



Projected Geothermal Potential

Well	Zone	Rate, MBWPD		Comments
		Low	High	
17-WX-21	Madison	20	25	Flowing
17-WX-21	Tensleep	4	10	Needs perforating
41-2-X-3	Tensleep	1	3	Flowing
41-2-X-3	Madison	6	12	Needs deepening
48-X-28	Tensleep	2	6	Flowing
61-2-X-15	Tensleep	2	6	Flowing
61-2-X-15	Madison	6	12	Needs deepening
57-WX-3	Madison	2	6	Flowing
Total all other Tensleep Production		40	60	Pumping
Total Flowing Production		43	80	Projected
Total Pumping & Production		86	160	Projected
All Potential Production		126	210	All on pump

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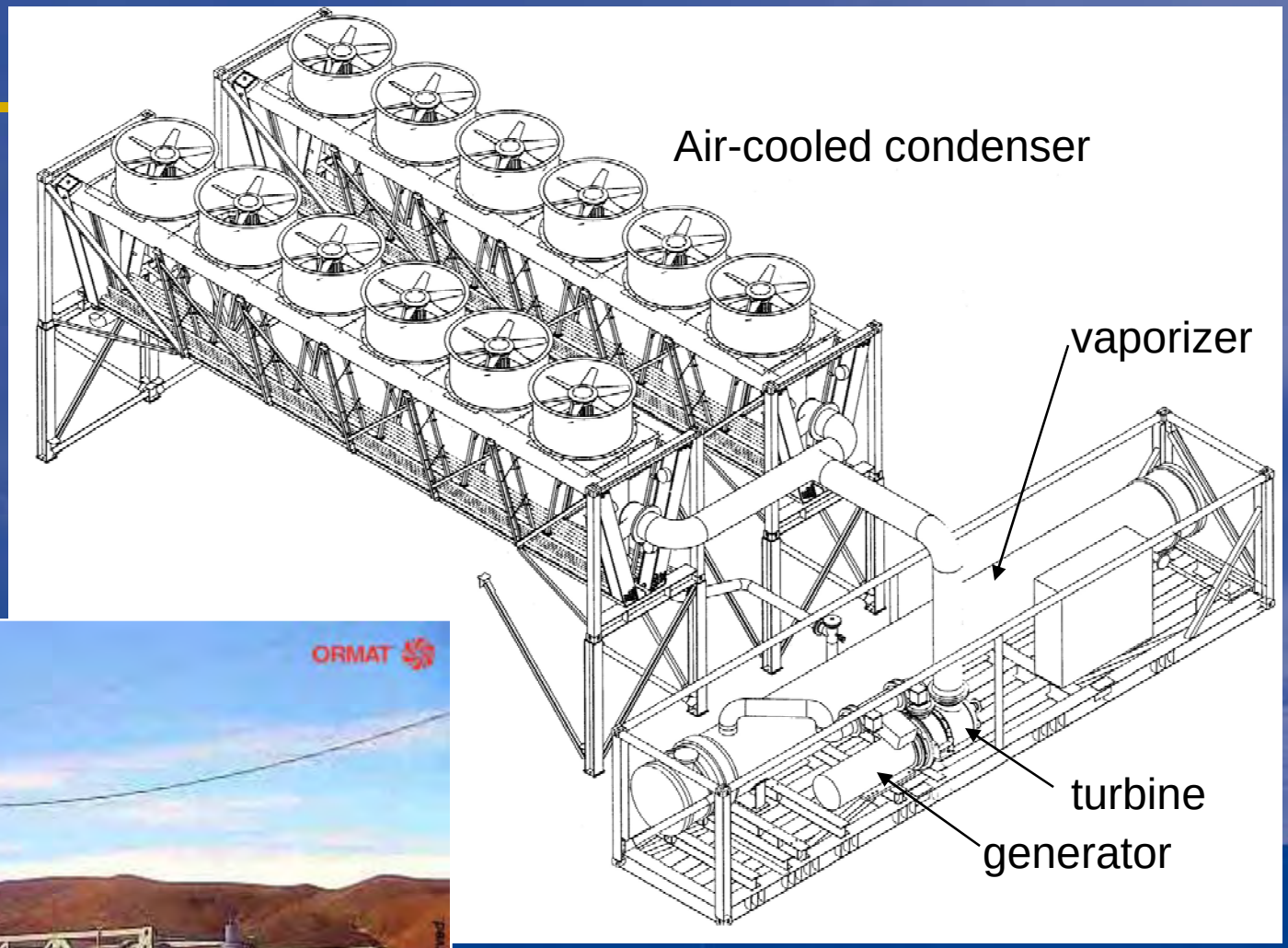
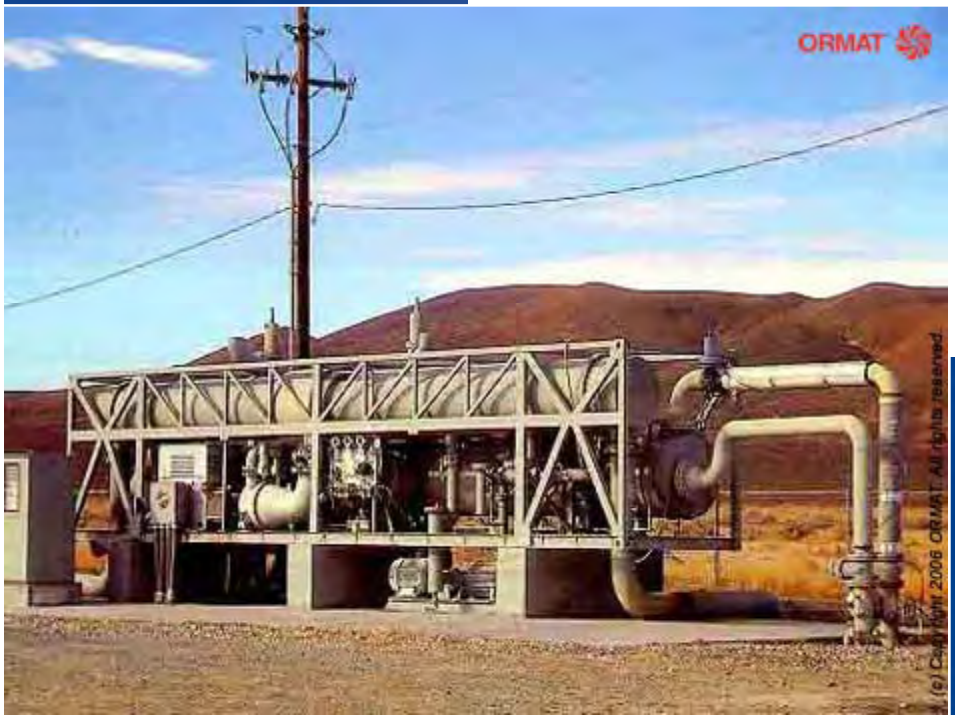
Proposed OEC Unit

(Ormat Energy Converter)





Wabuska, NV – 700 kW, 219°F

Projected Performance – Demonstration Project

Flow Rate:	584,000 pounds per hour
Inlet Temperature:	170°F
Outlet Temperature:	152°F
Ambient Temperature:	50°F
Generator Gross Power:	180 kW
Net Power Output:	132 kW

Total Field-wide Power Potential

1 MW can be extracted from 1.7 MBWPD at 200° F (SMU data)

For 130 MBWPD, power = 130/1.7 = **76 MW**

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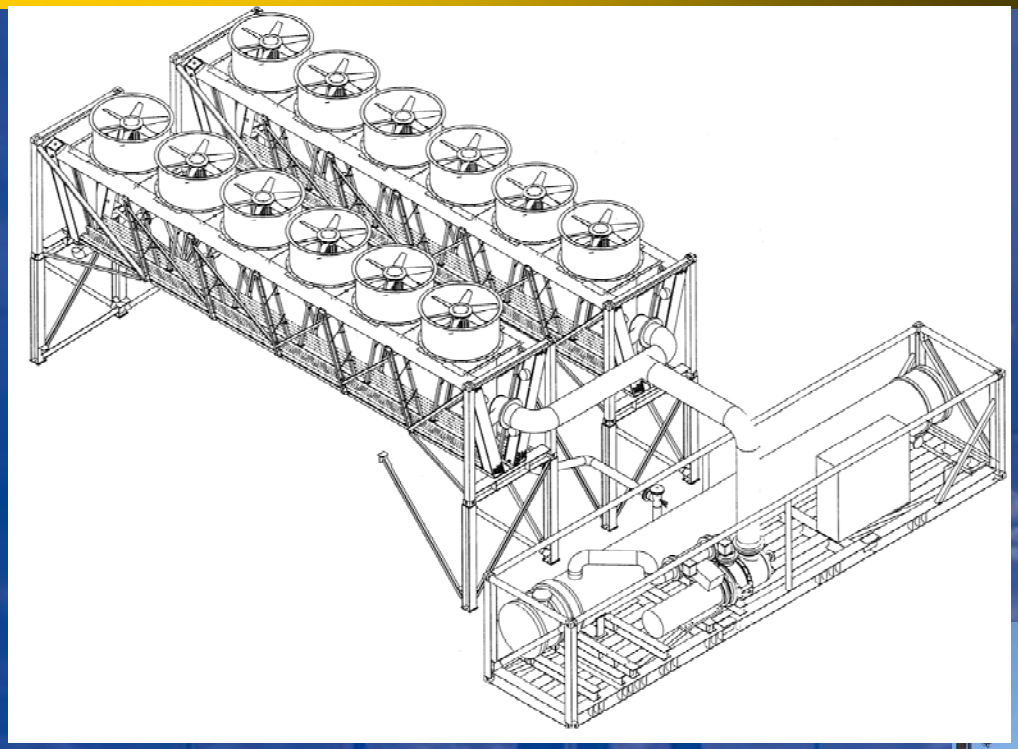
Installation, June, 2008



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Operation, September, 2008

Water throughput:
45,000 BWPD
at 197° F
40-50 kW power output
at initial startup

ORMAT

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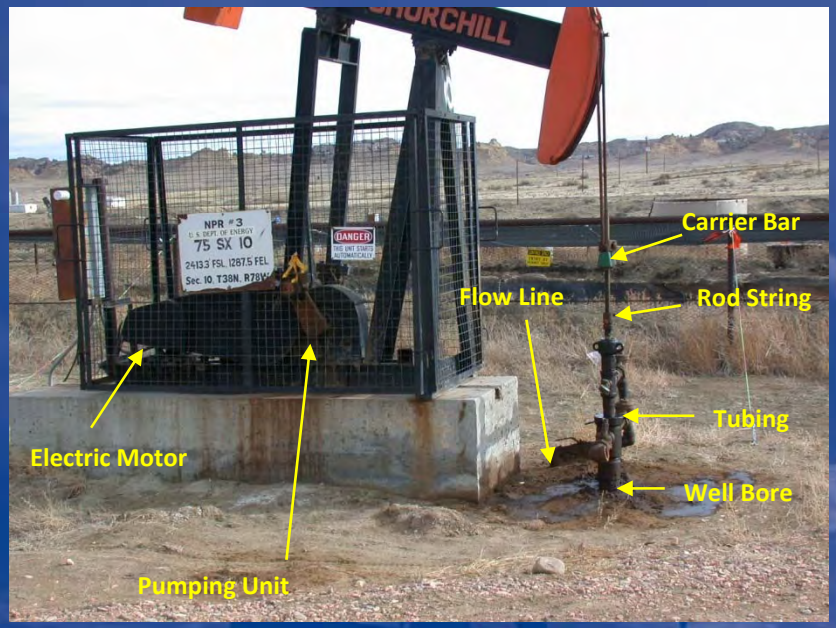
Geothermal – Direct Oil Pump

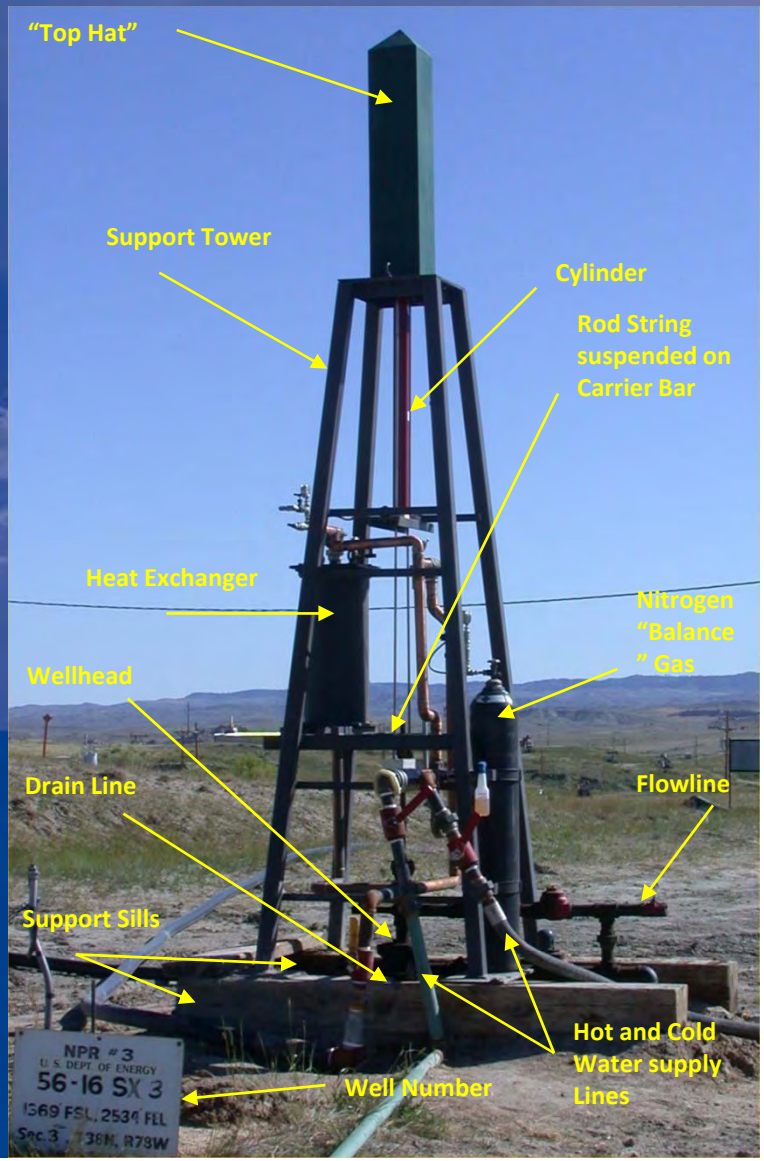


Conclusions

"The THEngine is a dynamic system that could substantially reduce the amount of electricity required to operate an oil well. The field trial did result in proof that the system is capable of lifting produced fluids out of an oil well utilizing energy available from a hot water source. However, the day-to-day operations were problematic when compared to an electrically powered pumping unit. Maintaining consistent and reliable unmanned operation was an issue. Although significant progress was made in the development of the system, additional development and field testing is needed before the THEngine can be considered a reliable means of producing an oil well. "

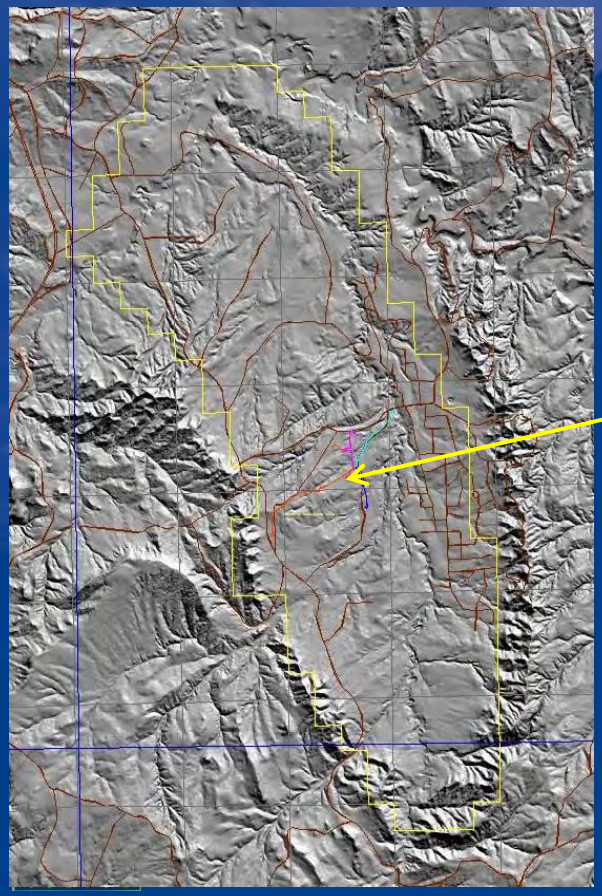
Partner: Deluge, Inc.

"Thermal Hydraulic Engine"



Testing and Application of Wind Energy in an Oilfield

Partners:
Casper College, NREL, and Pacificorp (Rocky Mountain Power)



Wind Energy Program – Phases

The program will be accomplished in four phases:

- First, a small-scale wind turbine (6kW, 18-ft diameter rotor, 50-ft tower/hub height) will be connected to an existing building off-grid at NPR-3.
- Second, a meteorological tower and wind turbine-diesel backup system will be connected off-grid to a small oilfield pumping unit.
- The third phase, which will occur concurrently with phases 1 and 2, will be a coordinated public relations and awareness campaign.
- The final phase will be the development and implementation of a renewable energy technician education and training program. Students will begin their studies at Casper College and through agreements with the University of Wyoming, may complete advanced degrees in renewable resources or mechanical engineering.

Casper College

ROCKY MOUNTAIN POWER

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NREL National Renewable Energy Laboratory

Solar Powered Shipping Pump

- Photovoltaics (PV) have been used for a long time for low-power applications in the oilfield such as SCADA, RTU, and communications.
- This 2-kW PV system provides AC power to a shipping pump, which transfers the produced oil (about 30 BOPD) from an intermediate storage tank to the main shipping tank.
- A future test phase could include powering a 2-hp motor driving a small pumpjack

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Partner: NREL National Renewable Energy Laboratory