Increasing Electrical Power Capacity for Military Applications

Jason R. McKenna
U.S. Army Corps Engineer Research & Development Center
Vicksburg, Mississippi
Jason.R.McKenna@erdc.usace.army.mil

OUTLINE

- Army Corps Interest in Energy/Transportation
- Restore Iraqi Electricity (RIE)
- US Thermal/Produced Water conditions
- Potential for “Green” Hydrocarbon Fields
- Short Term Solution
- Observations
- Path Forward

Engineering Research Development Center

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Cold Regions Research and Engineering Laboratory

Champaign, IL
Construction Engineering Research Laboratory

Alexandria, VA
Topographic Engineering Center

Vicksburg, MS
Coastal and Hydraulics Laboratory
Environmental Laboratory
Geotechnical and Structures Laboratory
Information Technology Laboratory

Army Corps Interest in Energy

- USACE has a growing mission to develop energy resources for military facilities worldwide and energy/transportation infrastructure

- OCONUS:
  - Consistent electrical power to the country of Iraq
  - Maneuver Support: transportation/mobility
  - Force Protection: secure energy supply at forward operating bases
  - Consistent, Reliable, and Secure Energy

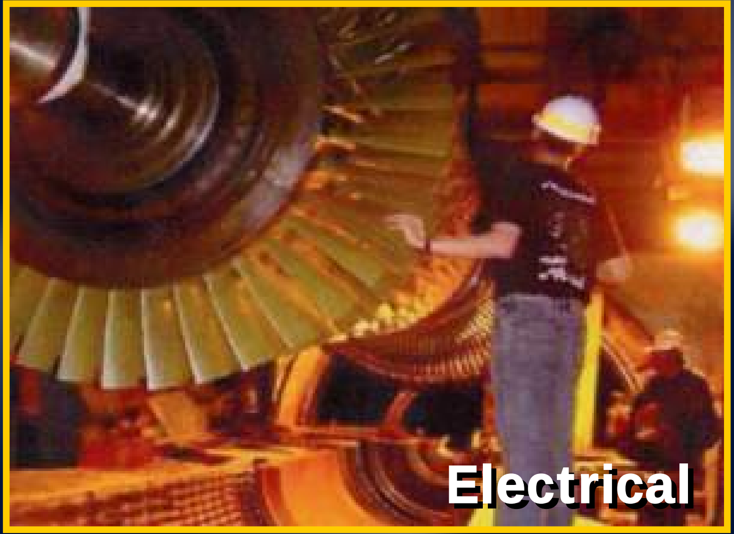
- CONUS:
  - US Gulf Coast energy needs post-Katrina
  - Consistent, Reliable, and Secure Energy

Increasing Iraqi Electrical Power Capacity

The primary task of the Army Corps Gulf Region Division (GRD), Restore Iraqi Electricity (RIE) Directorate, is to

- Support the Iraqi Ministry of Electricity, Project Construction Office (PCO), and Multi-National Force-Iraq (MNF-I).

- GRD's commitment is "putting megawatts on the grid" by
  - upgrading and adding power generation, transmission, and management/control systems
  - contributing to the delivery of reliable and consistent electrical power to the country of Iraq



US Army Corps Mission

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Restore Iraqi Electricity (RIE)

- Iraq
  - Possessed an electrical system capable of producing 9,000 MW in 1990
  - Only producing 3,200 MW in April 2003, well below the demand of 6,500 MW resulting in blackouts across Iraq.
- *Electricity bought from neighboring countries does not reach Baghdad due to frequency differential (49 Hz vs 50 Hz)*
  - *Creates an "island effect"*
- Individual Components of the power system (Generation, Transmission, and Distribution) had either been destroyed or were functioning at reduced capacity due to disrepair.
- Electricity is "the engine that drives the industry" and is essential for restarting Iraq's economy and helping establish peace and stability.
- Currently, electricity is free, so demand is essentially infinite
  - The increasing quality of life for the average Iraqi is increasing the demand for power as fast as MW can be added to the grid

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RIE Projects

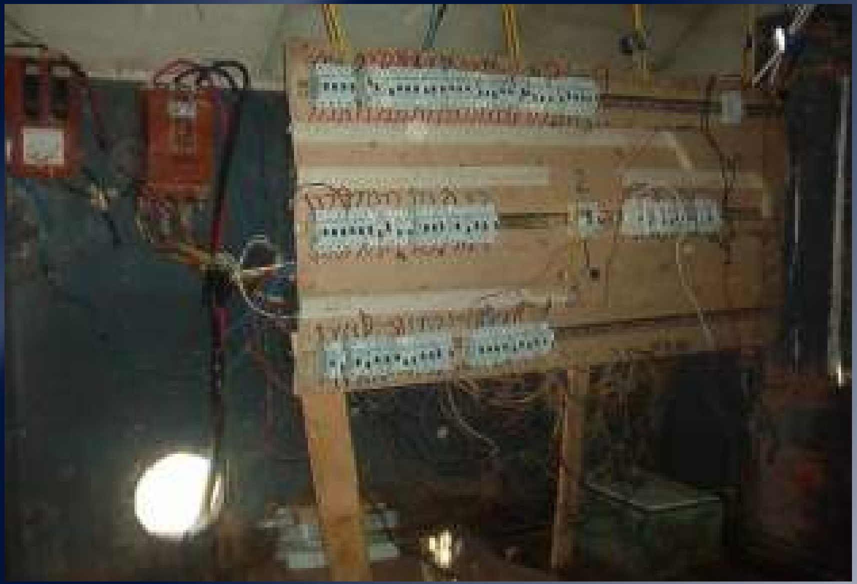
- Generation - Rehabilitation of existing facilities and new generation
- Transmission - Repairs and or expansion of 400KV and 132KV lines
- Substations - Rehabilitate existing or construct new substations
- Communications and Control - Replacement of existing control systems at 400 kV substations and power stations
- Command and Control - Development of a logistics management system

RIE Timeline

- 15 Sep 2003 - Task Force RIE established. Deployed 90 person team
  - Boots on the ground in 14 days (RIE-1)
- 19 Sep 2003 - Signed 3 Contract Task Orders with Perini and Flour to begin work on generation and transmission repairs throughout Iraq
- 25 Jan 2004 - Transitioned from Task Force to Gulf Region Division- RIE established
- 31 Jan 2004 - RIE Generation Achieved a total of 407 MW
- 07 Feb 2004 - Awarded 8 projects (RIE-II)
- 30 Jun 2004 - RIE Generation Achieved a total of 1,348 MW
- 11 Sep 2004 - RIE Generation Achieved a total of 1,621 MW
- 19 Oct 2004 - RIE Generation Achieved a total of 1,813 MW
- 20 Nov 2004 - Transition 15 of 16 power plant sites to the Ministry of Electricity.

Iraqi Distribution Situation

- 30% increase in demand in the last several years
- Distribution networks are overloaded
  - Blackouts range from 6 hours to 10 days
  - Power cannot be delivered to residents or businesses



- 33kV Substations are unsafe and overloaded
  - 150+ Substations are needed
- 4M+ homes are not connected
- Repair crews are overwhelmed

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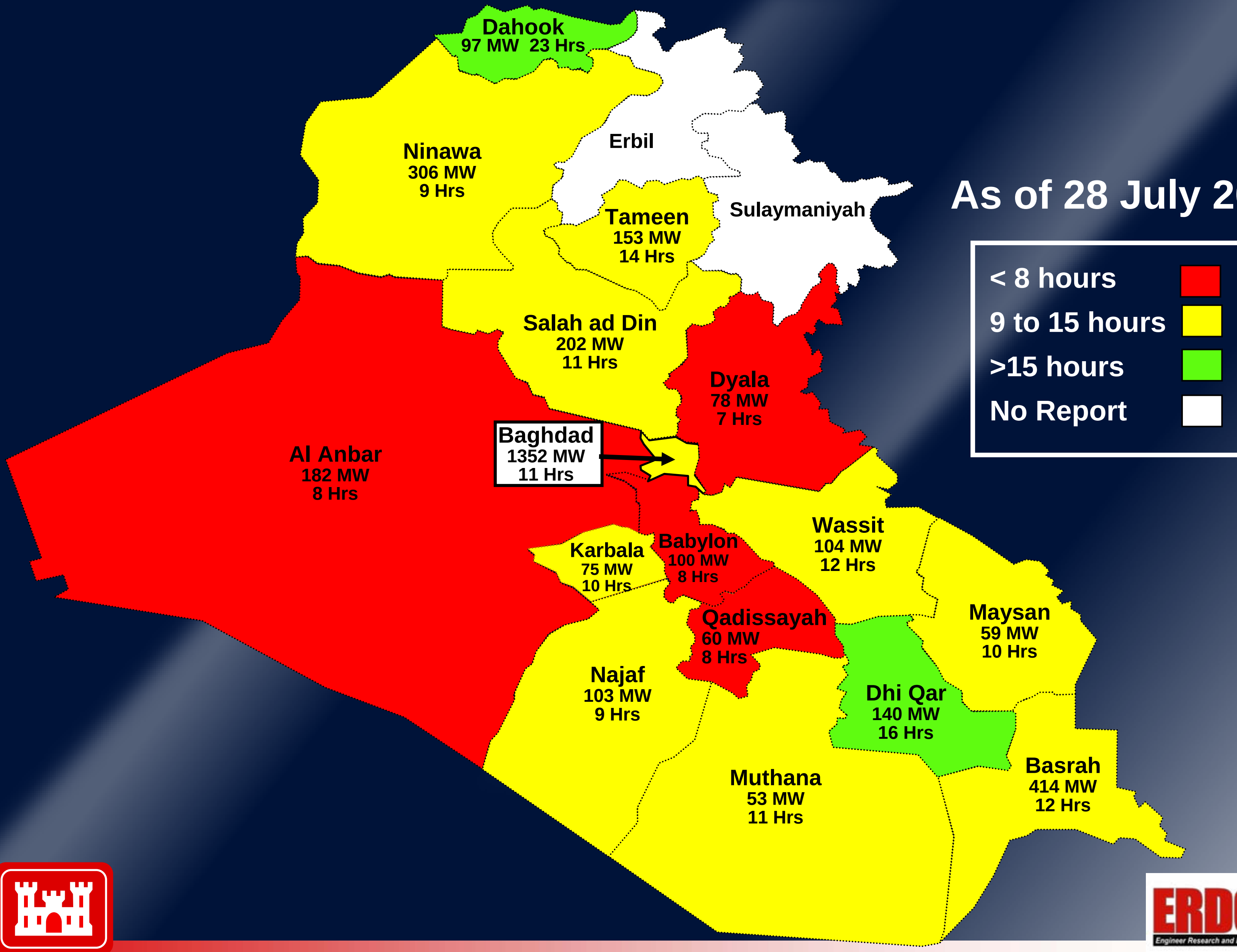
Average Hours of Electrical Service Provided Over a 7 Day Period



As of 28 July 2004

Increasing U.S. Electrical Power Capacity

- US Army Corps has begun to ramp-down activity OCONUS, (particularly post-Katrina)
- Still actively researching energy security for OCONUS activities
- Examining methods to help energy situation in *US* Gulf area
- Factor in:
  - Rising price of electrical power
  - Rising price of hydrocarbons
  - Increased demands for hydrocarbons/electrical power generation
- Leverage existing hydrocarbon fields to…(keep drill costs down)
- Gulf Coast states such as Texas, Louisiana, Mississippi, Alabama, and even Arkansas possess thousands of hydrocarbon wells that reach depths where temperatures are 250 – 400+ °F.
- Yet the Gulf Coast and mid-continent states possess few developed conventional electrical-grade geothermal hydrothermal resources.

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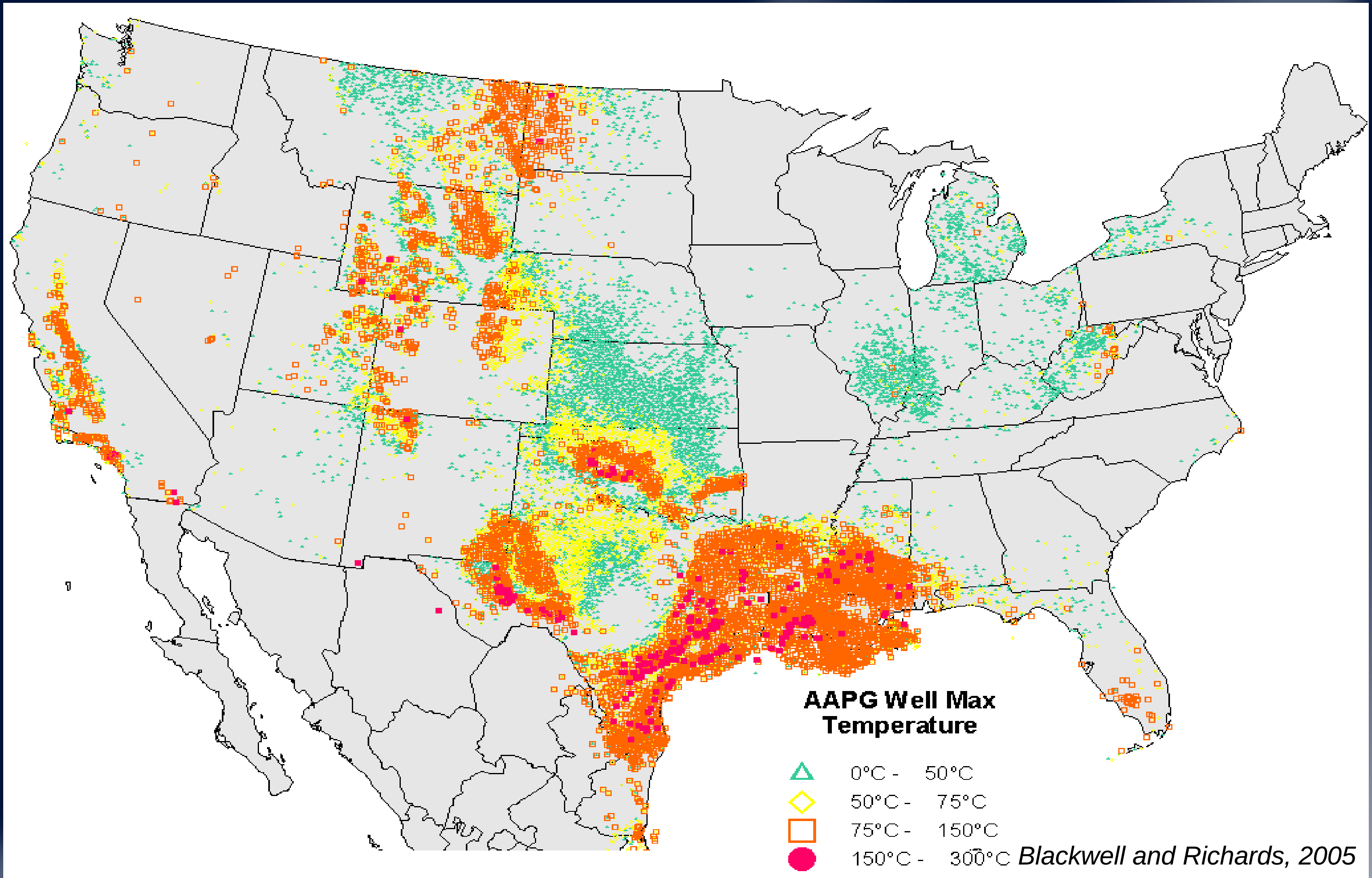
“Green” Hydrocarbon Fields

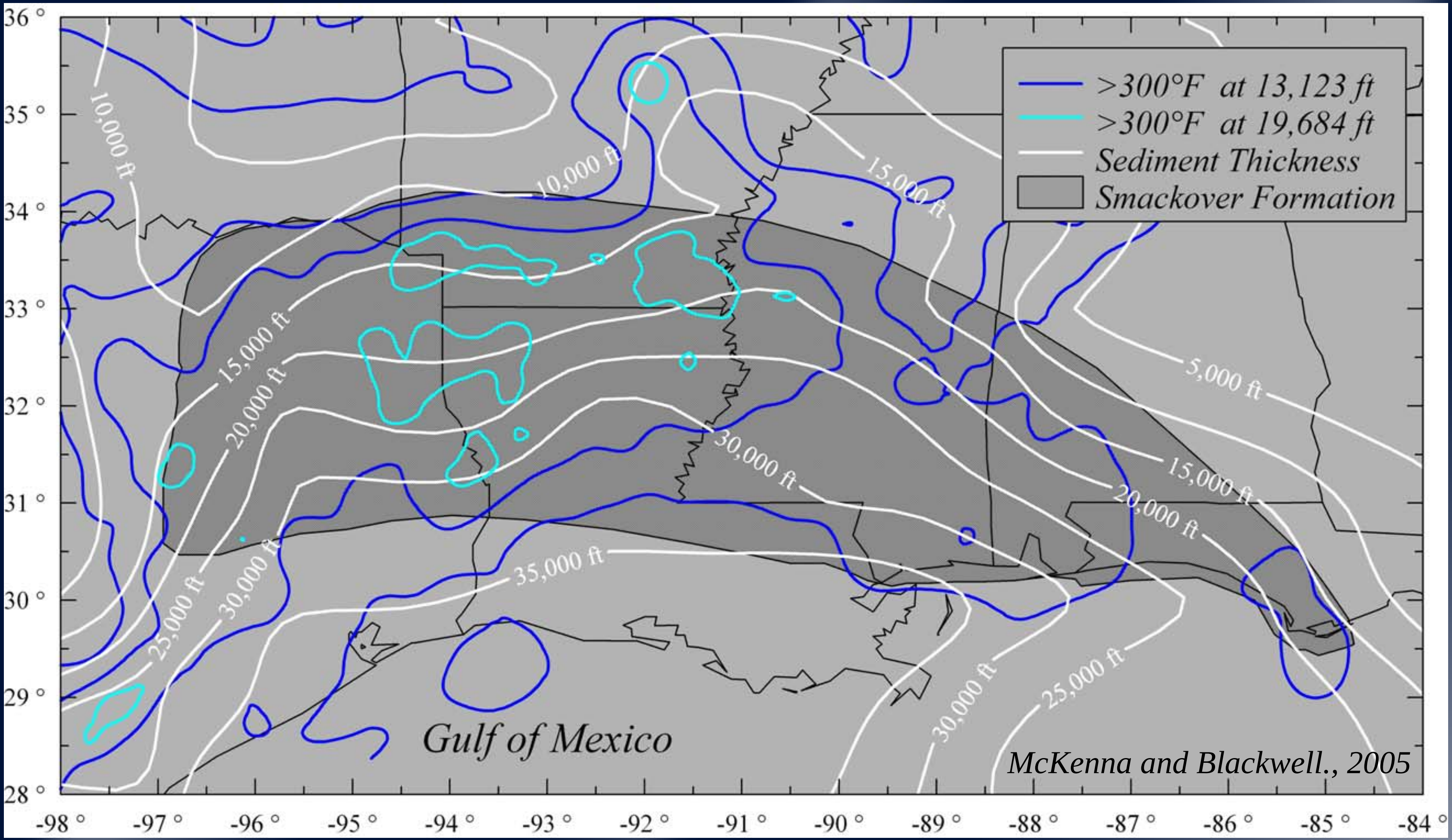
- Electrical power from geothermal energy is a mature concept with over 8,000 MW of installed capacity throughout the world
- Temperatures of over 300 °F are considered economic with binary energy conversion systems.
- Future geothermal development needs to address
  - Occurrence of high temperatures
  - Potential field development costs
- One way to increase the share of geothermal-derived electrical power is to take advantage of conditions that eliminate, or at least, partially mitigate limitations to development encountered in more conventional hard rock sites geothermal sites (Engineered Geothermal Systems or EGS).
- Develop geothermal reservoirs in existing hydrocarbon fields (particularly in the mid-continent and the Atlantic/Gulf coastal plains) to take advantage of the confluence of
  - Existing infrastructure
  - High temperatures
  - High *in situ* fluid flow (engineered or otherwise)

Hydrocarbon Drilling in the US

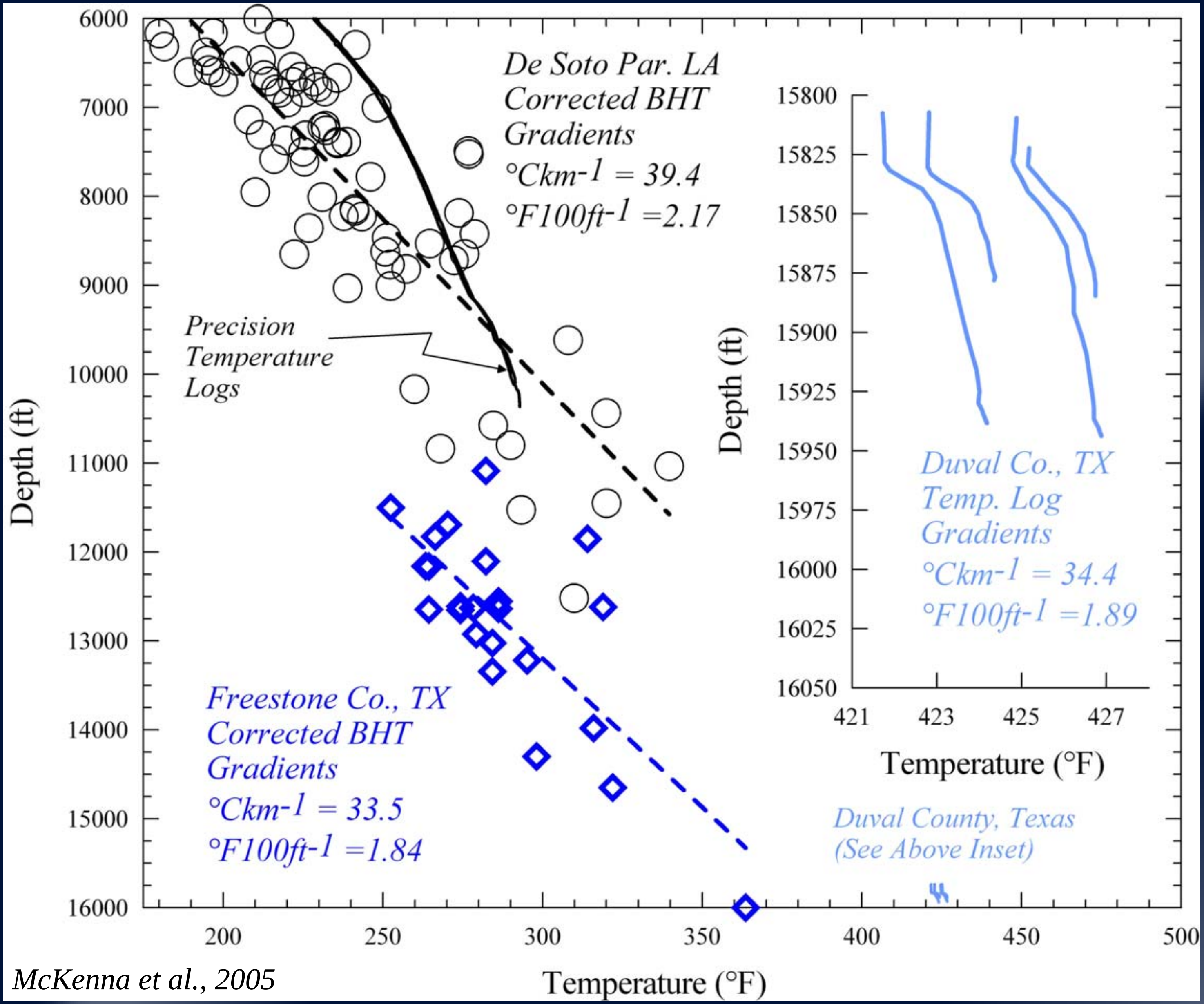


Most attractive aspect is existing infrastructure

High Subsurface Temperatures in the US Gulf Coast



- High thermal gradients paralleling the Jurassic Smackover Trend
- Result of lower thermal conductivity rocks in a moderate heat flow setting, and the presence of sub-surface salt



Thermal data for several areas in the Texas and Louisiana areas

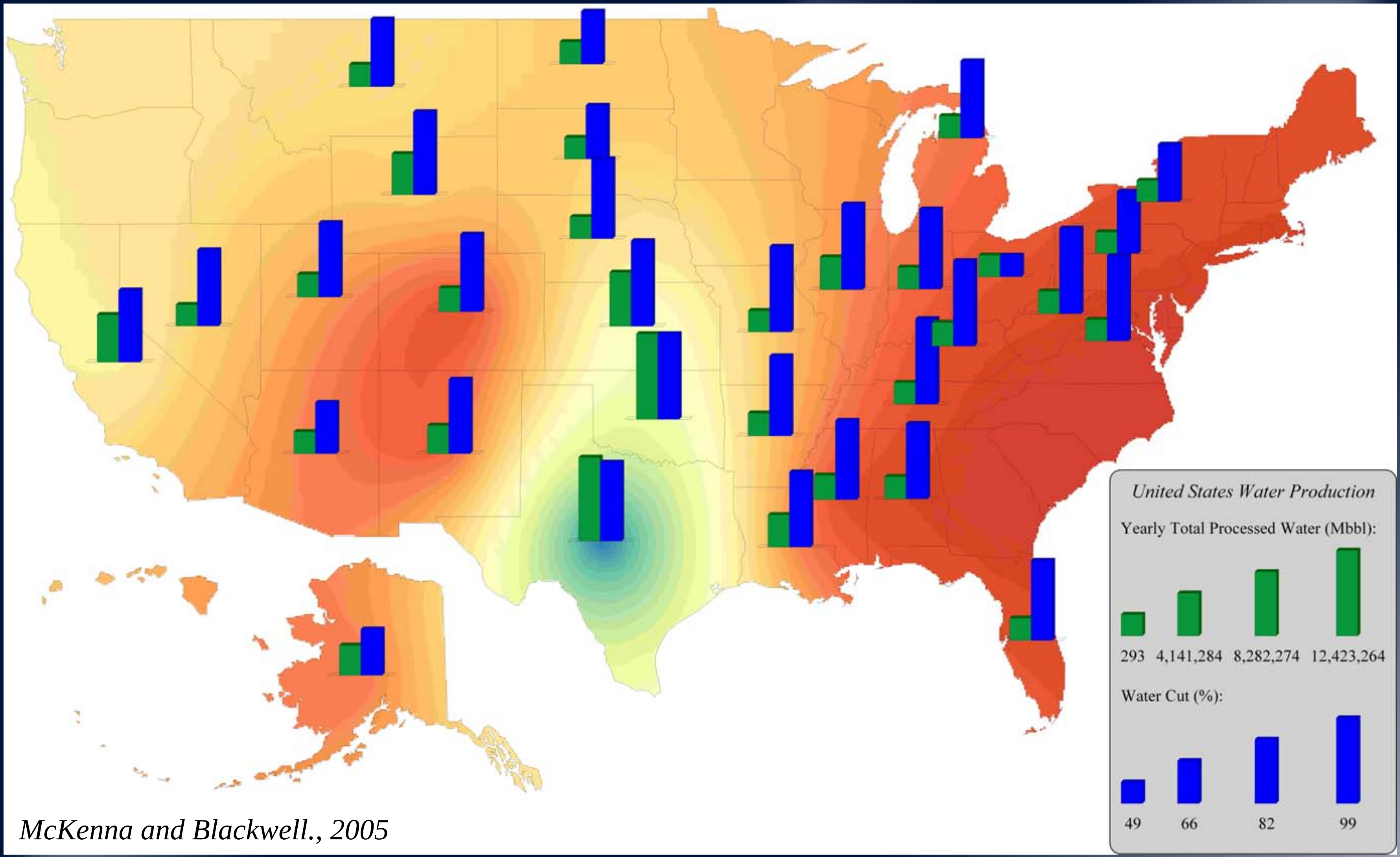
All three areas are situated in the high gradients areas paralleling the Gulf Coast.

The existence of temperatures in excess of 250 °F by 9,000 -12,000 ft suggest favorable conditions for future development.

What is the Producibility of Large Amounts of (hot) Water in the US?

- The critical factor required for successful geothermal electrical power generation is sufficiently high *in situ* permeability to provide fluid flow rates equal to or greater than 1,000 gpm (kgpm).
- In certain water-flood fields in the Gulf Coast region of the United States, the produced water/oil cut is 95%.
  - Some of these fields produce 50,000 barrels/day of fluid (20-40 wells)
  - Paid for (in terms of pumping costs), by existing operations.
- Collecting and passing this fluid through a binary electrical plant is readily performed
  - Most produced fluid is already passed to a central collection facility for hydrocarbon separation and water disposal
- Piggy-backing on existing infrastructure eliminates the need for expensive drilling and hydrofracturing operations that plague EGS
  - Reducing the majority of the upfront cost of geothermal electrical power production is critical to its widespread use
- The primary unknown and hence limiting factor for domestic use is the magnitude of the combined flow rates in existing hydrocarbon fields.

Processed Water from Hydrocarbon Production

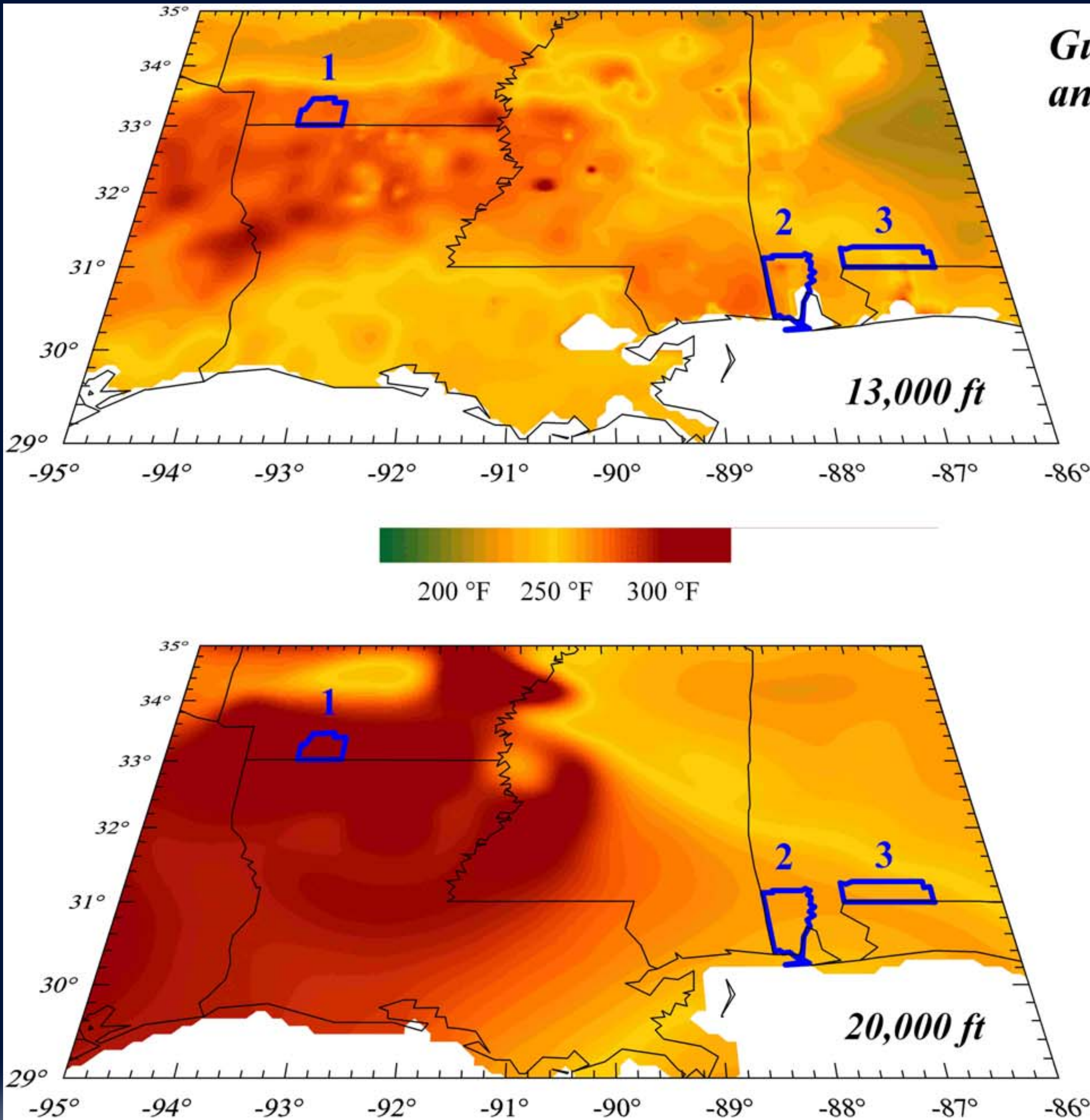


Water produced is on the order of 5 x 10^{10} bbl/year (data taken from Curtice and Dalrymple, 2004).

Produced Water in Existing Hydrocarbon Fields

- Production data from the hydrocarbon industry indicate that most of the hydrocarbon bearing basins and Gulf Coast Plain in Texas, Louisiana, Mississippi, and Alabama host
  – Elevated temperatures
  – High potential for significant water flow (unfortunately from the point of view of the industry).
- In mature hydrocarbon fields, the disposal of produced water is a problem (i.e., expense)
  – Economic exploitation can be found in most of the basins in the continental United States.

Gulf Coast Temperature and Water Production



1

1,077,487 bbl water/month
~7,600 ft @ ~ 210 °F
(Magnolia Smackover Unit 1)

2

272,836 bbl water/month
21,596-655; 21,762-784 @ ~ 325 °F
(individual gas well)

3

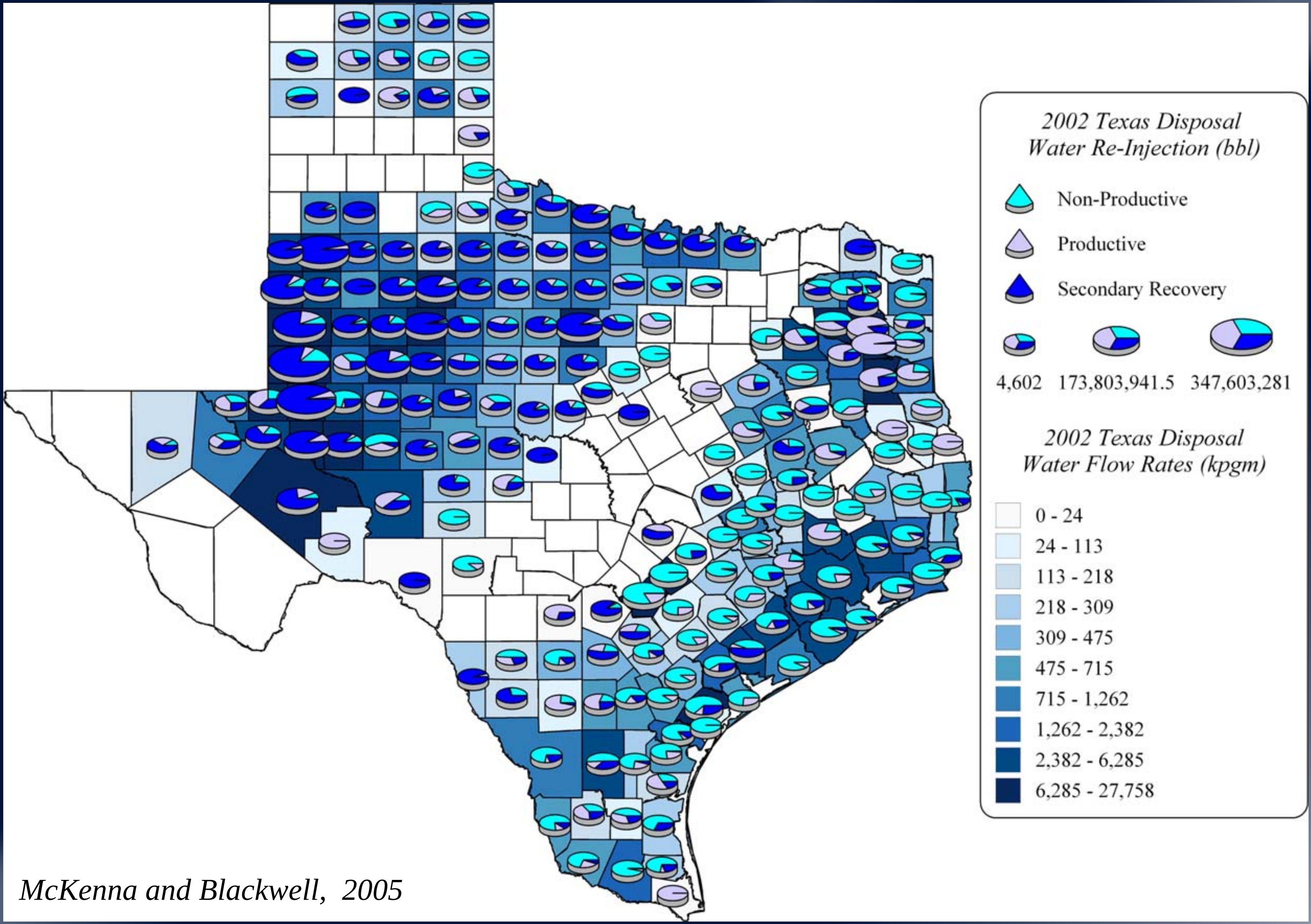
660,479 bbl water/month
15,380-15,470 ft @ ~ 270 °F
(individual oil well)

Data taken from:
Arkansas Oil and Gas Commission
http://www.aogc.state.ar.us/index.htm
Alabma State Oil and Gas Board
http://www.ogb.state.al.us/

McKenna and Blackwell., 2005

Coastal MS/AL are ideal candidates for geothermal electrical power generation

Texas Water Production



McKenna and Blackwell, 2005

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Required Flow Rates For Electrical Power Generation

- The inlet temperature necessary to obtain electrical power in binary plants is a function of wellbore flow rate and binary generator heat exchanger fluid type (e.g., Mines, 1997; Pritchett, 2000; Goranson, 2004; McKenna and Blackwell, 2005; McKenna et al., 2005).

- In order to generate 1.5 MW of electricity at a reservoir temperature of 300 °F requires a flow rate of about 1,000 gpm, or about 1,029,000 bbs/month.

- State production records in both Arkansas, Alabama and Texas suggest that the combined flow rates for production wells in existing hydrocarbon fields in these areas is sufficient to meet the 1,000 gpm flow rate requirement.

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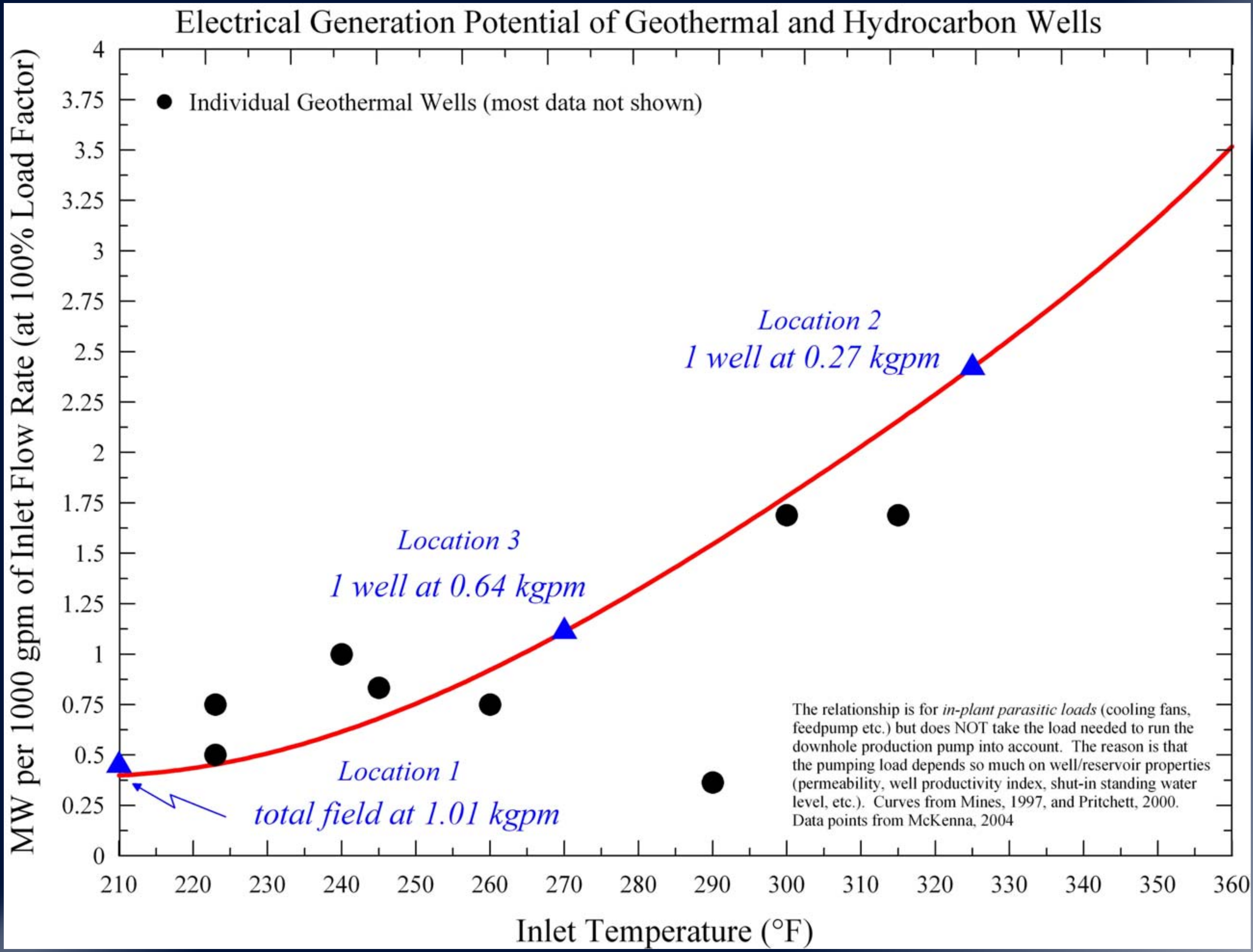

Electrical Generation Potential of Geothermal and Hydrocarbon Wells
Individual Geothermal Wells (most data not shown)
Location 2
1 well at 0.27 kgpm
Location 3
1 well at 0.64 kgpm
Location 1
total field at 1.01 kgpm
The relationship is for in-plant parasitic loads (cooling fans, feedpump etc.) but does NOT take the load needed to run the downhole production pump into account. The reason is that the pumping load depends so much on well/reservoir properties (permeability, well productivity index, shut-in standing water level, etc.). Curves from Mines, 1997, and Pritchett, 2000. Data points from McKenna, 2004
MW per 1000 gpm of Inlet Flow Rate (at 100% Load Factor)
Inlet Temperature (°F)
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
2.75
3
3.25
3.5
3.75
4
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350
360

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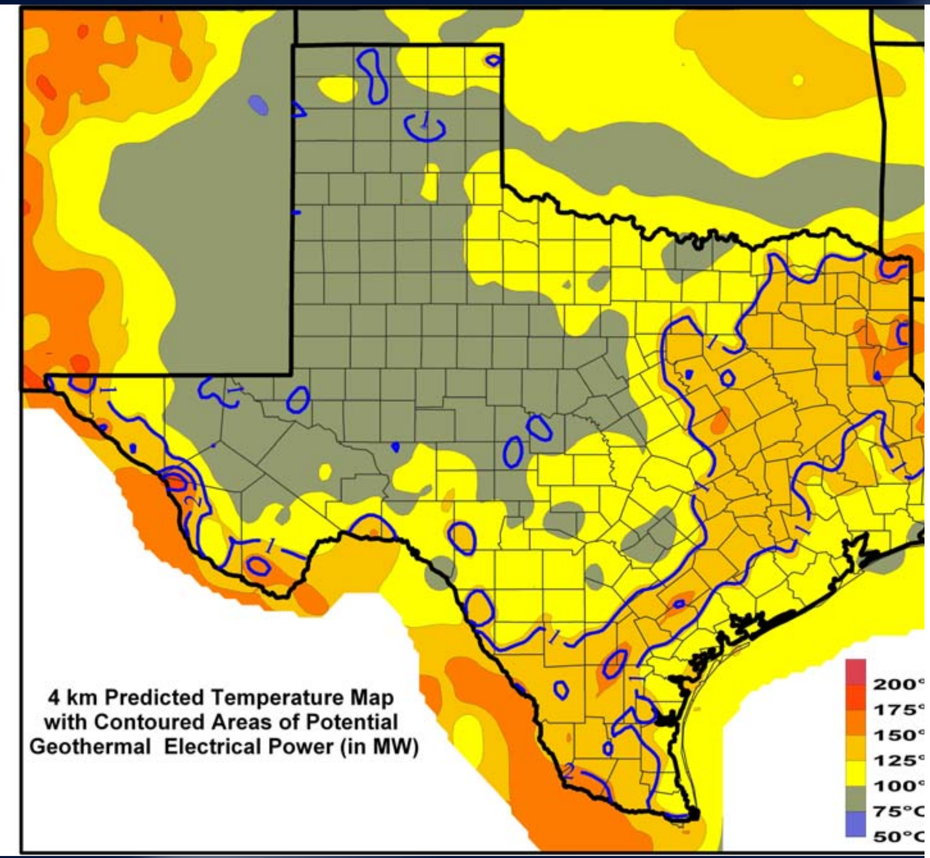
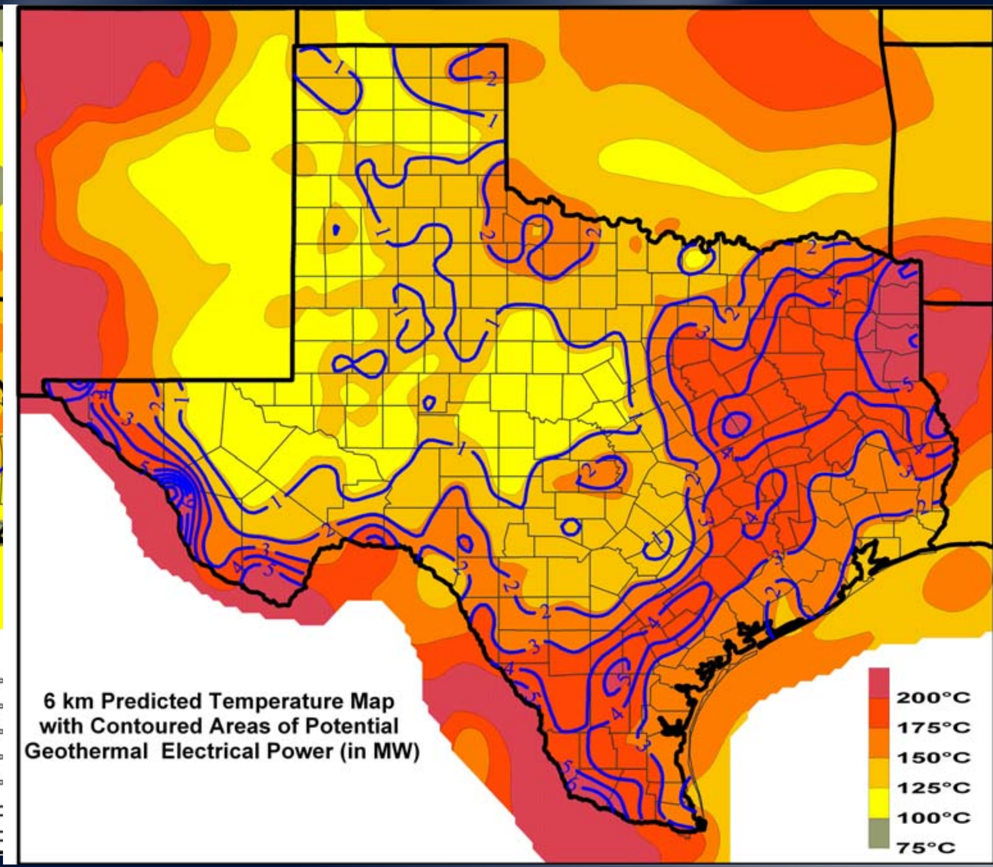
Texas Electrical Power Potential





Statewide Geothermal Power From Existing Gulf Coast Hydrocarbon Production

State	Yearly Total Processed Water (bbl)	Processed Water Cut (%)	Water Production Rate (kgpm)	Statewide Power at 210 °F (MW)	Statewide Power at 400 °F (MW)
Alabama	203,223,404	95.1	15.4	7.0	37.8
Arkansas	258,095,372	97.2	20.0	9.1	49.1
Florida	160,412,148	97.2	12.5	5.6	30.5
Louisiana	2,136,572,640	95.2	162.5	73.6	398.0
Mississippi	592,517,602	96.7	45.8	20.7	112.1
Oklahoma	12,423,264,300	99.5	986.6	446.7	2416.4
Texas	12,097,990,120	96.8	935.1	423.3	2290.2

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Short-Term Solution: Portable Binary Generators

Portable skid-mounted well head binary power plants (~250 kW each) can be attached to existing collection/ separaion tanks

Immediate increase in installed capacity

Necessary DoD R&D

- Defining a protocol for determining if geothermal energy is appropriate for a forward operating base or permanent military installation
- Optimizing the use/number of small binaary generators to meet specific operational needs
- Tying portable binary systems into the electrical grid at select forward operating bases
- Defining a protocol for the use/scalability of existing hydrocarbon infrastructure for direct use
- Investigate working fluids for use in portable binary generators.
- Investigate cooling mechanisms (other than air) for these systems, particular in hot arid climates
- Rapid reservoir simulations and heat extraction simulations for sustainability
- Mapping potential temperature/fluid reservoirs
- Evaluate the best methods for stimulating/completing wells to enhance the production rates of hot fluids.
- Determine new pumping techniques to reduce power consumption

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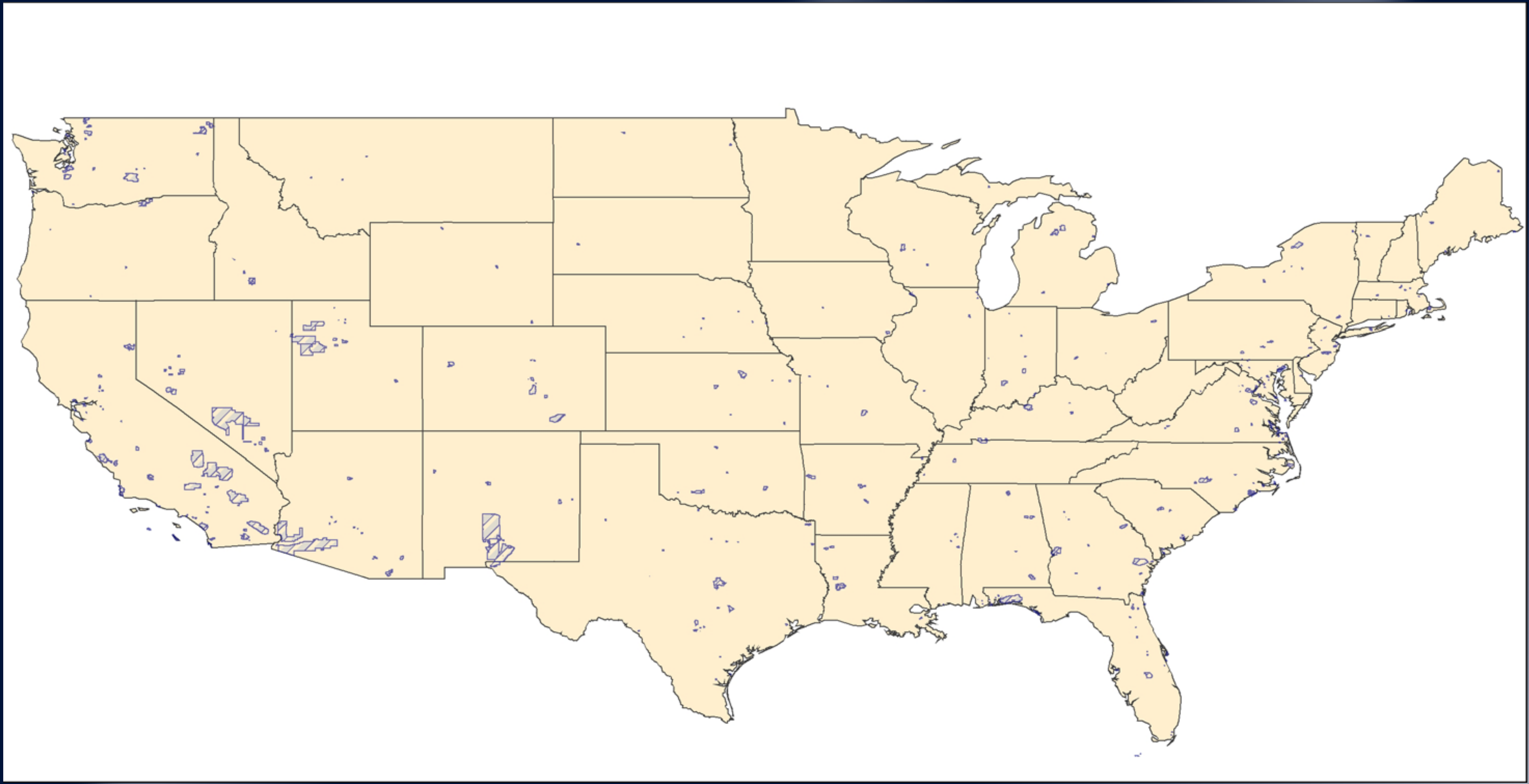
Path Forward: DoD Owned Land



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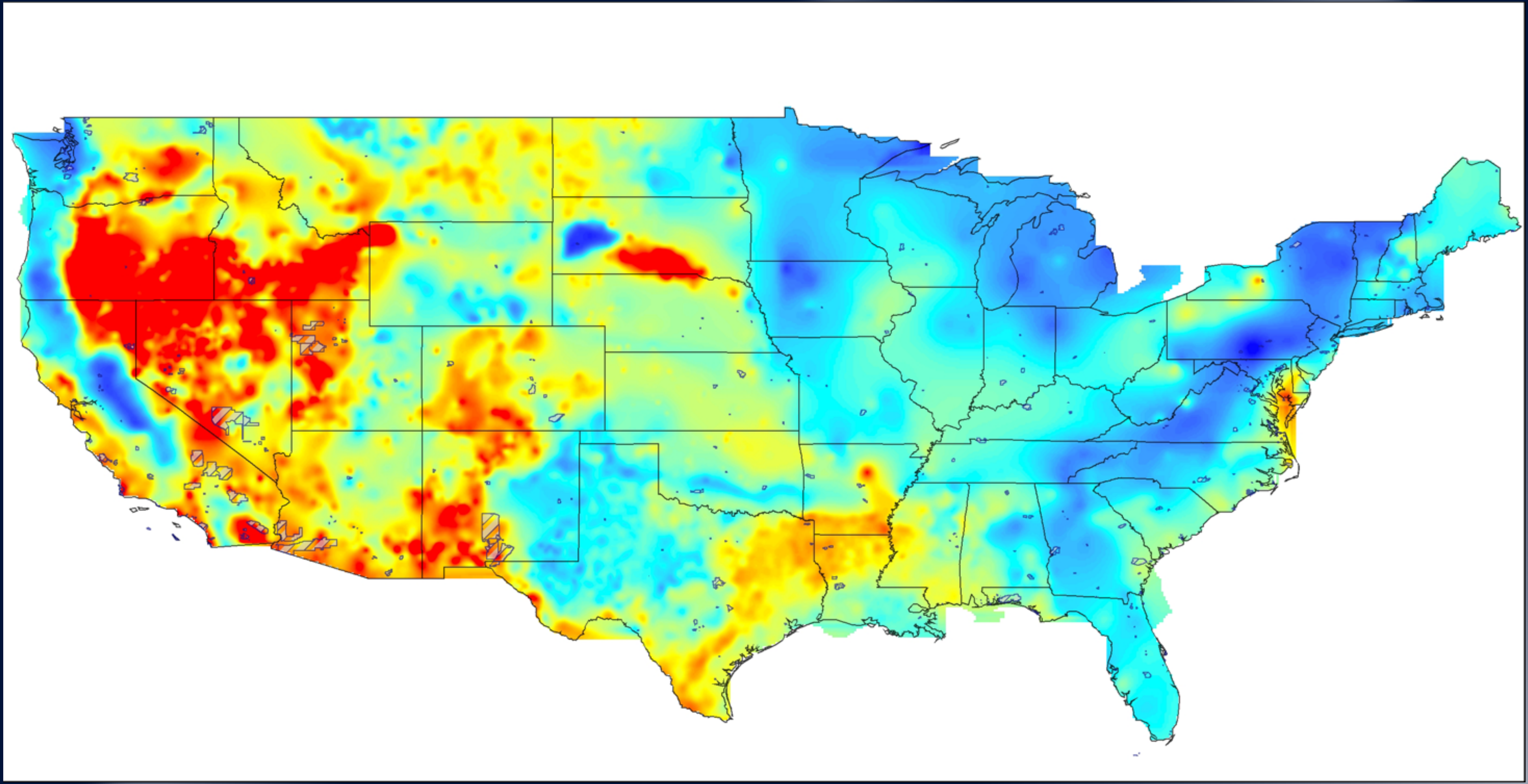
Temperatures at 9,800 ft Depth



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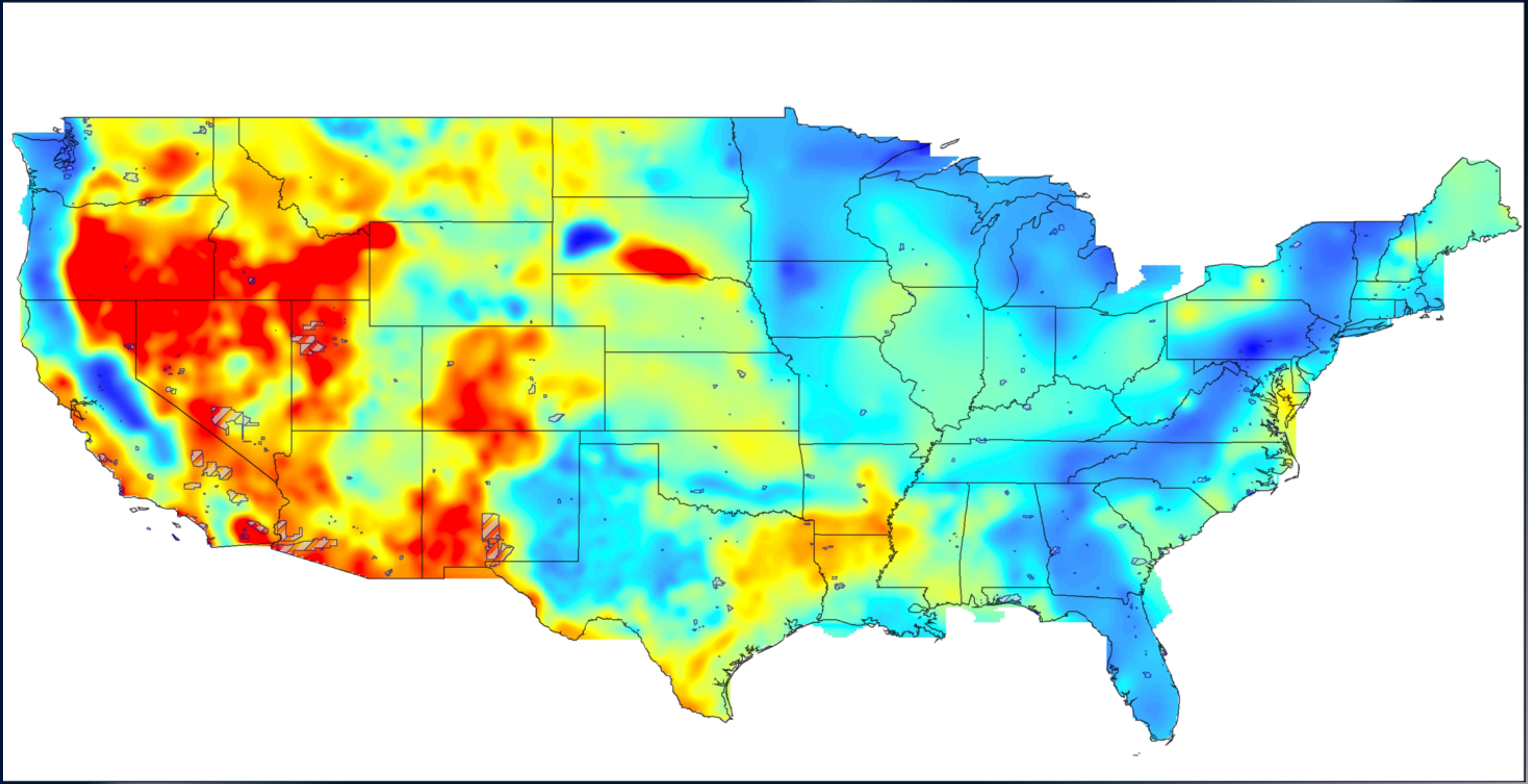
Temperatures at 19,600 ft Depth



DoD Lands Thermally Suitable for Electrical Power

- 1,260,232 acres at 9,800 ft depth above 210 °F (5,100 km^2 at 3 km above 100 °C)

- 1,853,283 acres at 19,600 ft depth above 210 °F (7,500 km^2 at 6 km depth above 100 °C)

- Can potentially generate
  - 630 GW at 9,800 ft
  - 926 GW at 19,600 ft

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Thermally Suitable DoD Land for Geothermal Electrical Power

Aberdeen PG, MD	9,800/19,600 ft	160/265 °F
Camp Lejeune, NC	9,800/19,600 ft	185/433 °F
Camp Pendleton, CA	9,800/19,600 ft	266/275 °F
Elgin AFB, FL	9,800/19,600 ft	185/293 °F
Ft. Bragg, NC	9,800/19,600 ft	161/260 °F
Ft. Bliss, TX	9,800/19,600 ft	250/430 °F
Ft. Polk, LA	9,800/19,600 ft	230/365 °F
Ft. Leonard Wood, MO	9,800/19,600 ft	170/271 °F
Meridian NAS, MS	9,800/19,600 ft	195/300 °F
Pasacougla NAS, MS	9,800/19,600 ft	215/330 °F

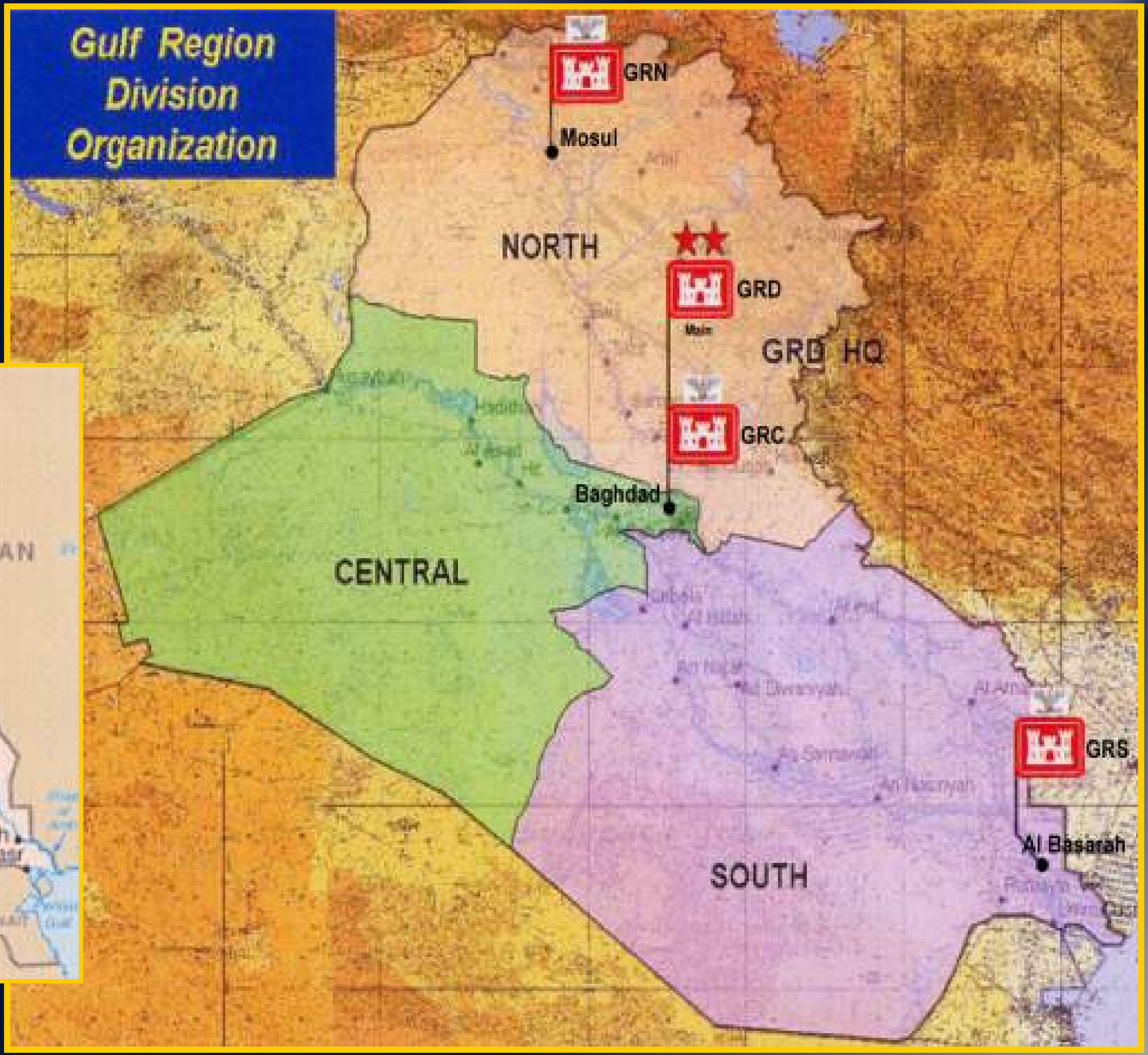
Observations I

- Not a silver bullet for current energy demands, but one of many brass bullets
- Preliminary analysis shows that for this type of "conventional" geothermal development in a hydrocarbon setting
  - may require ~30 wells per field to generate the required flow rate in some of the more marginal temperature fields,
  - estimate of the number of wells could be substantially reduced if deeper/hotter wells are utilized.
- The success of the methodology is not critically dependent on the number of wells required to generate the flow rate
  - most of the produced fluid is centrally collected for separation anyway
- Production occurs at such high rates that cooling prior to heat extraction is not a concern either.
- Given current limitations in heat extraction technology, the success of the approach requires that the hydrocarbon fields utilized for geothermal exploitation are producing
  - pump/disposal costs are met by the production company
- Process can be made more efficient
  - Sell-back excess capacity

Observations II

- Assuming ~$4.0/bbl is used by production companies to meet electrical needs in EOR (i.e., water-flood fields)
  - Approach outlined here has a ROI of ~3 years
- Timeline for development: Now
  - No increase in CO_2 emissions
  - No strain on other resources
  - No transportation costs
  - Relatively cheap: binary generators cost ~1 M for 1 MW
- Geothermal is a sustainable renewable if the reservoir is managed properly
- Consistent with maximizing hydrocarbon recovery through EOR techniques (or not)
- Leverages current need for energy security/independence

The Path Forward...



Questions?