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Estimating Well Cost for Enhanced Geo System Applications

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Estimating Well Costs for Enhanced Geothermal System Applications

1. INTRODUCTION

Enhanced geothermal system (EGS) reservoir performance is controlled by the interplay of a complex set of parameters: reservoir, geologic, drilling, well completion, plant design, and operation. In order to identify, analyze, and mitigate the economic risks of any EGS prospect, one must first understand the relative importance of each of these parameters, how its relative importance changes under different constraints, and how they interactively affect EGS production. To date, no comprehensive parametric study on EGS is known to have been conducted within the industry. U.S. industry has not conducted a comprehensive study because it considers EGS an emerging technology. The parametric studies reported in the literature have only considered a limited set and range of parameters, thus potentially skewing their results.

The amount of work that can be extracted from a geothermal fluid and the rate at which this work is converted to power increase as the fluid's temperature increases. The relationships between temperature and work (ideal or actual) illustrate the preference for higher fluid temperatures. Since drilling costs per foot generally increase with depth, and temperature gradients are at best linear with depth (if not slightly decreasing), it is apparent that at some depth the increase in temperature does not warrant increased drilling costs. Drilling cost results published to date are based on assumed relationships between drilling costs and depth that have no statistical basis and only illustrate the impact that drilling costs will have on the ability to access higher-temperature EGS resources. This indicates the need to know the precise relationship between drilling costs and depth. Once that relationship is established, a more realistic evaluation can be made one that incorporates these costs. Because pumping costs from increased lift and greater frictional loss with length of wellbore increase with depth, and parasitic load impacts power generation potential as well, all must be included in a study of comprehensive cost of EGS power versus depth.

The first goal is to assemble reasonable drilling-costs-with-depth formulae for various regions of the United States and couple them with energy-recovery-with-depth as they relate to regional temperature gradients. Additional controls on the economic depth relationship will be the selling price of energy produced and the flow rate of each well. Obviously, higher gradient areas and areas with relatively low drilling costs have greater interest.

1.1 Regional Drilling Costs

To determine the areas from which to collect historical drilling costs, the nation-wide 4- and 6-km temperature gradient data developed by the Southern Methodist University Geothermal Laboratory and maps prepared by Idaho National Laboratory (Figures 1 and 2) was used.

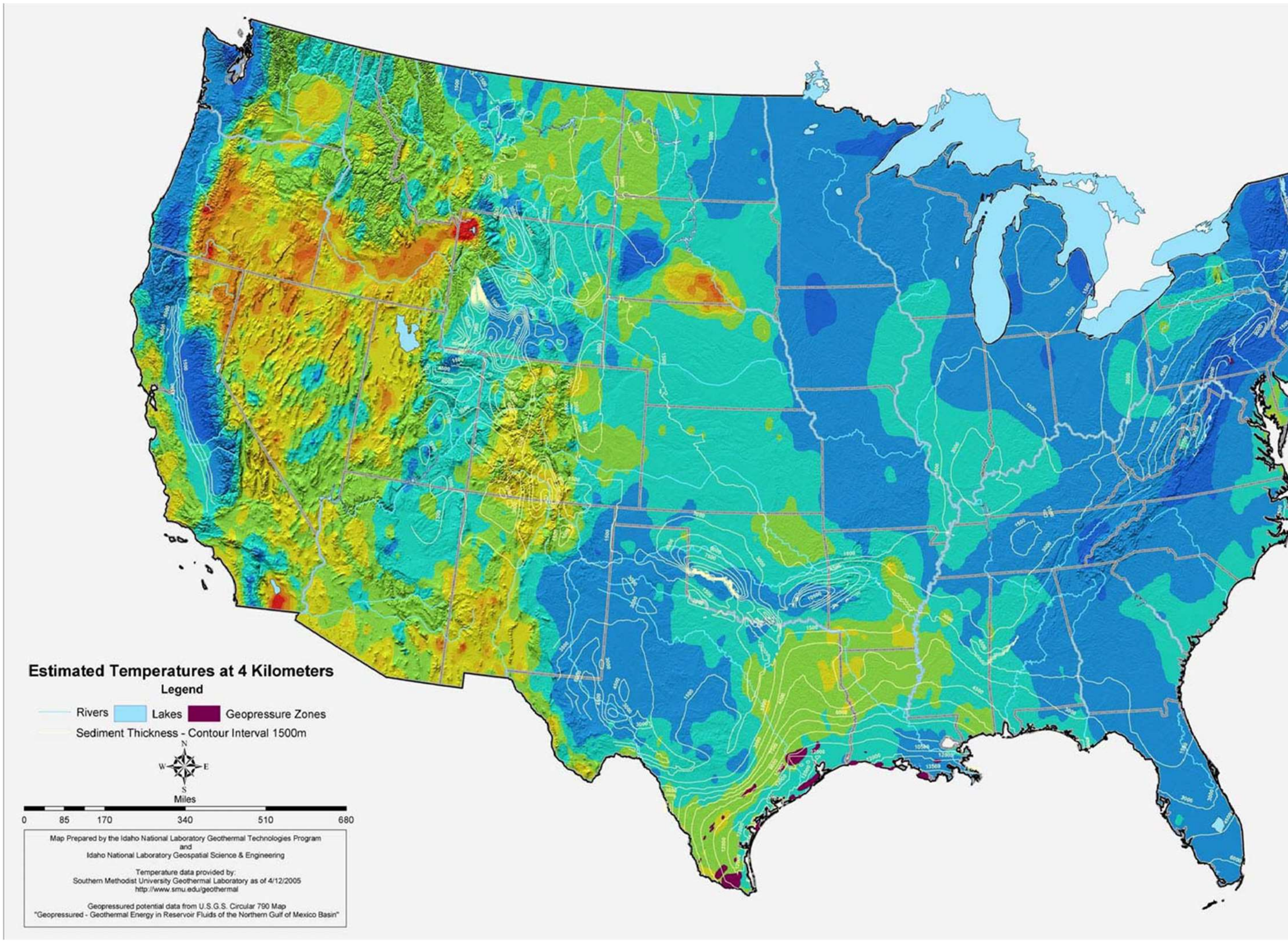

Figure 1. Estimated temperatures at 4 km [based on data from Blackwell and Richards (2004), Southern Methoc

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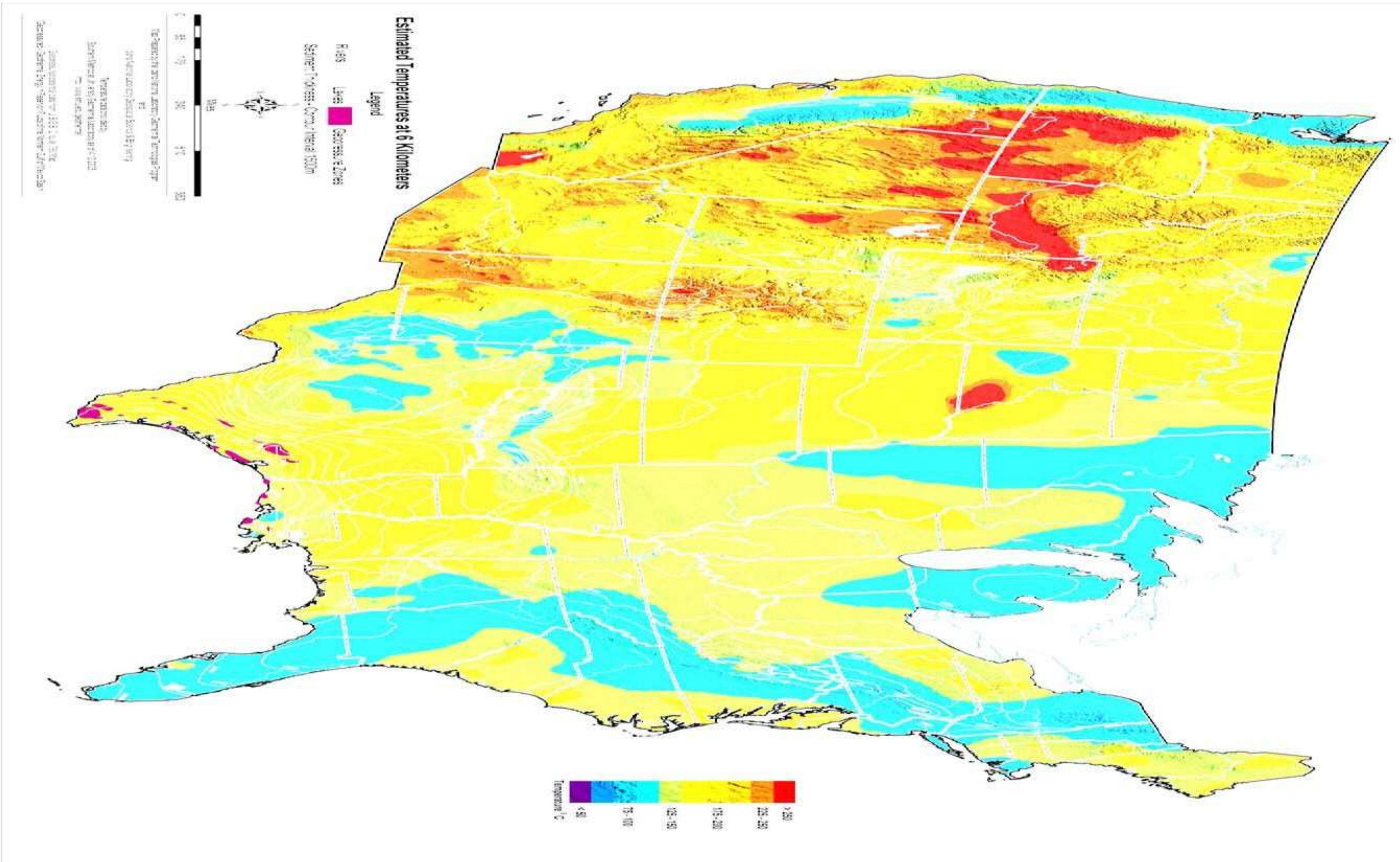

Figure 2. Estimated temperatures at 6 km [based on data from Blackwell and Richards (2004), Southern Methodist

Based on the information from these maps and temperature data, this course is limited to areas in the Western, Mid-continent, and Southern United States. These areas have the greatest potential for early success with EGS technology. Alaska and Hawaii were not included in this drilling analysis. And because several geothermal operators with proprietary concerns limited the availability of geothermal drilling data in many of these areas, this course concentrates on the vast drilling dataset from the oil and gas industry.

However, some specific geothermal drilling data from studies by Lovekin and Mansure are included. Table 1 summarizes depth and cost data representative of geothermal wells completed between 1997 and 2000 in Central America and the Azores (Lovekin et al. 2004). To escalate these prices to account for inflation, the costs of all wells have been escalated to equivalent U.S. dollars as of 1 July 2021, using the Producer Price Index. Figure 3 is a curve fit to the data in Table 1.

Table 1. Drilling costs from 1997 to 2021 for Central America and the Azores.

Depth Interval (ft)	Number of Wells	Total Footage	Total Cost ($K)	Average Depth (ft)	Average Cost/Well ($K)	Median Cost/Well ($K)
0–1,249	1	679	280	679	280	280
1,250–2,499	8	15,692	10,415	1,961	1,302	1,258
2,500–3,749	0	0	0	0	0	0
3,750–4,999	5	21,535	10,857	4,307	2,171	2,148
5,000–7,499	24	139,757	65,081	5,823	2,712	2,482
7,500–9,999	20	167,065	68,834	8,353	3,442	3,453
10,000–12,499	3	32,968	11,495	10,989	3,832	3,913
12,500–14,999	0	0	0	0	0	0
15,000–17,499	0	0	0	0	0	0
17,500–19,999	0	0	0	0	0	0
20,000+	0	0	0	0	0	0
Total	61	377,696	166,962	6,192	2,737	2,577

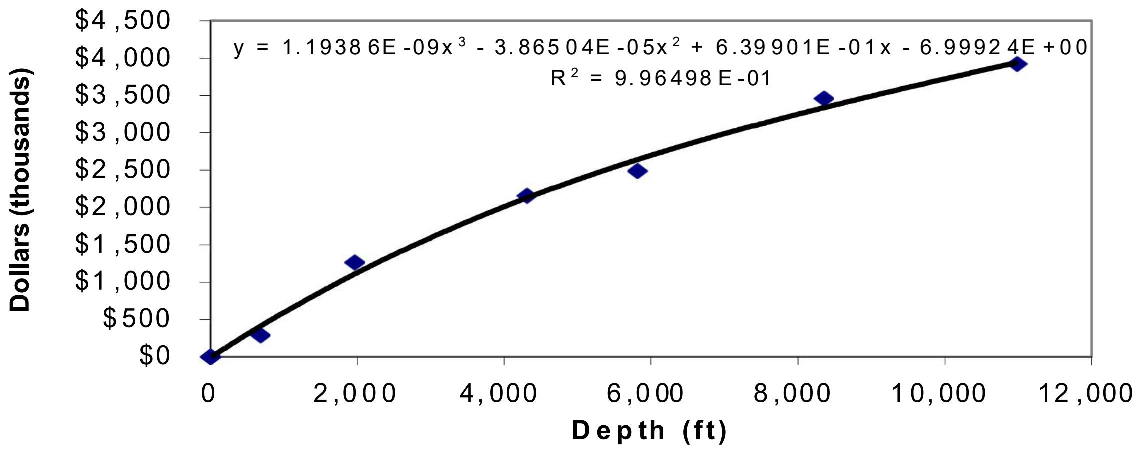

Figure 3. Average depth versus median cost from Table 1 for geothermal wells in Central America and the Azores from 1997-2021 (from Table 1 data).