DE-RISKING GEOTHERMAL PROJECTS BY RE-THINKING WELL DESIGN AND THE WELL CONSTRUCTION MINDSET

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ABSTRACT

To optimize well output, prevent premature failures, and extend the lifespan of geothermal wells, a new and holistic interdisciplinary approach is required in project management to ensure enhanced recovery and efficient performance become the new status quo.

This paper proposes solutions that in the past could have been perceived as not economically viable; the aim is to foment discussion around the standard approach to well design and challenge ourselves to adopt a more holistic, strategic, and innovative way of planning well construction.

This can be achieved by integrating data acquisition not only during appraisal stages but also within well construction and production/injection phases with permanent monitoring systems, proper material selection to mitigate structural and flow-assurance issues, and use of well engineering technological solutions rather than compartmentalizing disciplines and reducing them to so-called drilling challenges.

Based on experience, but starting with *zero-scope*, we can begin to establish minimum requirements and identify appropriate solutions that could increase success rates with the lowest budget increment, consequently reducing overall project risk.

Good practice would be to increase the involvement of geoscientists to optimize the positioning, trajectory, and quantity of wells, and this can lead to better, smarter, and more efficient decision-making to extricate some of the most challenging geothermal projects. To do this, it is crucial to ensure continuous proactive communication over the different sub-surface development stages, and not reduce any aspect to a trivial afterthought.

1. INTRODUCTION

A hallmark of geothermal development has long been the drawn-out development phases due to the justifiable geological due diligence that is required before drilling can commence. This process consists of a multidisciplinary combination of geochemical, geostructural, geophysical and rock mechanic disciplines, which are all required to determine and estimate the required volumes and depths to get to the target, usually to be confirmed by an exploration well. However, somewhere in the project management phases, when transitioning to drilling and completion, this cautious approach is abandoned by what an outsider might mistake for a one-size-fits-all solution.

With roughly 40-50 per cent of development cost going into the subsurface, much focus has been on keeping drilling and completions costs to a minimum. As a result, there exists a very simple template design in geothermal well construction, which seems to be the preconceived default solution for most applications, regardless of conditions. These wells are designed to manage high thermal cycling, but it is also designed based on a low-cost mindset, which often results in a poorly performing well. For example, the International Finance Corporation 2013 report on drilling success, which was based on a sample of over 2,600 wells, found that the first wells in a new field have an average success rate of only 59 per cent. Once more is known about the field, this number rises to 78 per cent, but over time additional injection and makeup wells are added to the field to recover losses stemming from changes in flow or pressure, and even shifts in geology, resulting in additional expenses.

By building on experience and maintaining the utmost respect for the thermal challenges and fragile sedimentary nature of hydrothermal systems, drilling and completion considerations should be further implemented into the mindset of any given geothermal development, without reducing it to standardized practice that happens towards the end of the process. Instead, this paper argues for a shift away from a reactive drilling and completions approach, towards a proactive strategy which will reduce the number of wells required, prolong lifespan, and ultimately help reduce the Levelized Cost of Energy (LCOE) for geothermal projects.

2. CONTEXT

Geothermal well engineers across the globe adhere to standards like New Zealand's Code of Practice for Deep Geothermal Wells (NZS 2403:2015), or the Handbook of Best Practice for Geothermal Drilling (Finger & Blankenship 2010). Conforming to practice in this way has helped design and develop solutions for managing the combination of thermal challenges and upper well losses occurring due to high-fracture formations. At the same time, this has created replicable methods with a proven track record of success, easing the minds of investors. This approach takes confidence in a basic well design and enlisting relevant recommended practices when it comes to selecting size, defining, or estimating flow rates, well geometry instructions, material selection guidelines, cement program key points, etc. But more importantly, they mention the importance of following instructions and the attention to special requirements.

Although this approach accounts for serious challenges such as preventing the casing from rising into the wellhead due to thermal stress, more elaborate and problem-specific solutions could be implemented without totally disregarding the financial restraints in the overall project. The default conventional geothermal well design relies on the use of a single perforated liner (see Figure 1), which can run for hundreds if not thousands of meters. This design is likely to intercept loss or cooler zones, as well as feed zones along the way, thereby compromising one or a few good feed zones, all in an effort to improve the overall flow rate. As such, the approach assumes that all potential thief zones will be managed by the surface system, reducing the lower completion solely to a structural role as something preventing the borehole from collapsing, rather than being concerned with efficiency.

Furthermore, over their lifespan, wells will likely have to deal with everything from pressure loss and corrosion, to sediments (e.g. silica) building up in the liner and slowly reducing output. It is therefore important to design and plan a well that is capable of adapting.

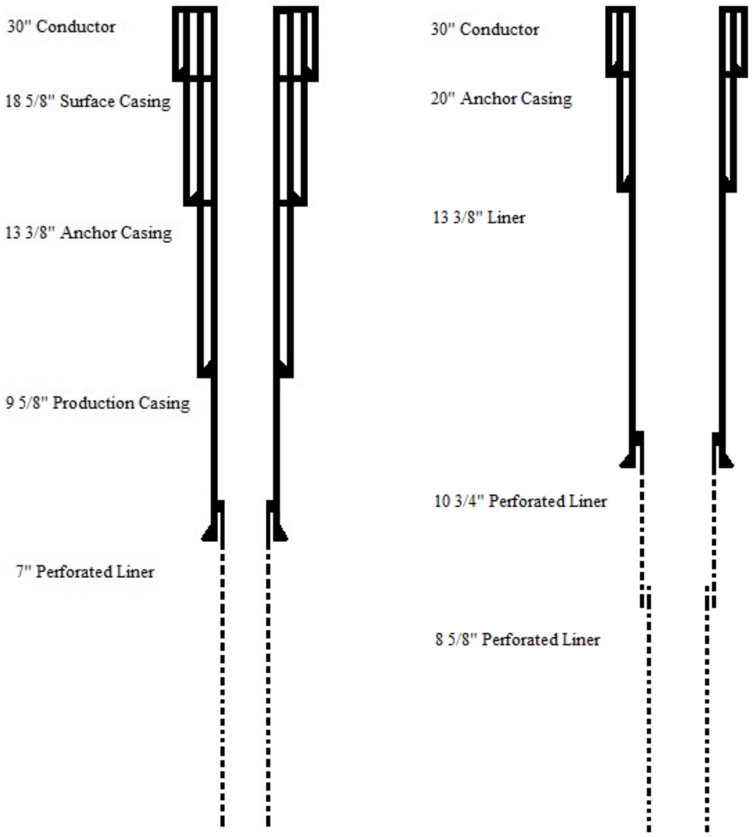

Figure 1: A standard geothermal well design (left) example, typically with tieback in the 9 5/8". Right, is a large well design with no surface casing, allowing for a greater mass flow.

3. DISCUSSION & METHOD

To promote an open-minded discussion and foster a well design concept selection culture as part of a geothermal project risk assessment, we might need to defy our instincts and habits and avoid following previous schematics from similar jobs, resist temptation to optimize scope by down-grading specs or eliminating a phase or a barrier, and simply update calculations to verify integrity. These familiar strategies often hide mid and long-term impacts by omitting increased and unplanned operational costs related to challenges such as severe scale milling, remedial relining, squeezing, new perforations, sidetracking, new drilling, and seemingly endless other possibilities.

The idea of a holistic approach that considers drilling and completion as part of the overall project planning phase, could present the way forward to help untap the full potential of the geothermal industry, where depending on the case, well construction and operational costs can represent upwards of 60 per cent of a project's capital expenditures (CAPEX). By encouraging the integration of the appraisal stages all the way through production/injection phases, well lifecycle and operational aspects can be brought into the well construction and conceptual design debate.

With a pre-defined method that takes into consideration past experience as a database rather than a mould or obligatory reference, projects could design concepts starting from *zero-scope* from the inside out. By starting with a single borehole, and from that point on, incorporating considerations into production requirements, presence of contaminants, fluid/steam conditions and properties, thief zone history, flow assurance and pumping issues etc, a more robust and reliable well design can be planned and prepared ahead of time, so that CAPEX savings do not come at the expense of the long-term OPEX. Now extrapolate this to a project or a group of projects, and we have an immediate CAPEX reduction associated with the increase in scale and a more predictable finance planning now that events and onsite adjustments can be anticipated.

4. RESULTS

This new approach could boost the use of innovative solutions, such as passive monitoring systems, to enhance production management by implementing open hole isolation packers to provide immediate and reliable zonal isolation, thus reducing dependence on the cement curing optimally and carrying less risk of contamination and trapping of fluids that could lead to casing failure.

By implementing autonomous flow controls devices, the wells will benefit both in the stimulation stage and later in production management, as the flow controls – which will naturally account in size for the required flow capacity to support the mass flow requirements – will make the well manageable over its lifespan. Furthermore, selecting the right smart materials to assist in reducing unplanned interventions, combined with prognostic health management, can also be applied especially for the subsurface pumping systems. Still, more investments and incentives in research and development should also be expected.

With each well delivering a higher efficiency output, and the number of duds having been reduced if not entirely eliminated, the need for makeup wells to be drilled will also be removed, and costs can be reduced significantly over the system's lifespan while allowing for a greater degree of control across the different zones. This previously unprecedented degree of control over the well will grant the operator the ability to close one or more zones that might, over time, come to compromise the overall efficiency of the well or entire system. With a monitoring system in place, greater levels of predictability are possible, allowing for planned intervention and for injection wells to return fluids to an especially desired layer of the formation.

As a positive side effect of reducing the number of wells required, the number of well-pads and surface piping will also be reduced, resulting in a smaller surface footprint. This will help preserve the often highly biodiverse and unique nature that rests on top of the hydrothermal systems, many of which are located in national parks.

From a workover and intervention perspective, it's well known that cost of planned maintenance is significantly less than urgent and unexpected operations. By considering a proactive maintenance program based on the field's unique properties, with planned intervention to reduce or prevent scaling from reaching unmanageable levels, it should be possible to ultimately assist in prolonging the well's lifespan and improve the Levelized Cost of Energy (LCOE) for geothermal. The same approach can also be implemented when relining, rejuvenating, and repurposing existing wells, as re-completing them is cheaper than drilling entirely new ones. By proactively factoring as many project phases as possible into the well design, the entire project ultimately stands to benefit.

5. CONCLUSION

A holistic, interdisciplinary, innovative, and open-minded approach would potentially reduce initial expenditures and drastically reduce operational cost. With the use of well engineering technological solutions, the output of every well can be optimized from day one, extending its lifespan and providing the operator with more flexibility to manage efficiency. Shifting from a reactive to proactive approach sounds even more natural. Such a plan requires time, but in the long run, it will save time, reduce cost and risk, resulting in better renewable investment and more efficient wells.

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