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# Elliðaárdalur low temperature field, Reykjavík, Iceland – 3D modelling and well siting in an urban environment

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## INTRODUCTION

Since the 1930s the utilisation of low temperature geothermal fields in Iceland has greatly improved the inhabitants' quality of life. There is a long history of research, utilisation, and monitoring of low temperature fields within the capital, leaving vast information which could benefit other countries in their management of such fields. This was recognized within the RESULT project (Enhancing REServoirs in Urban deveLopmenT: smart wells and reservoir development) subsidized through the ERANET Cofund GEOTHERMICA.

The Elliðaárdalur geothermal field, located in Reykjavík, Iceland, is one of three low temperature geothermal systems (<120°C) within the capital area, that have supplied district heating for Reykjavík Energy, and has been utilised since 1968. The field lies adjacent to the Elliðaár river, a salmon river situated within a shallow valley that cuts through the city. The area is widely used by locals for hiking and outdoor activities. Geothermal production wells are primarily in the southwestern corner of the field. Elliðaárdalur field is situated only a few kilometres west of the NNE-SSW trending Krýsuvík fissure swarm, part of one of the active volcanic systems of the Reykjanes peninsula, all of which exhibit a similar structural trend. The surface geology is dominated by Quaternary basaltic lava flows, while at depth are alternating basalt lava flows and hyaloclastite formations. More evolved rocks are encountered deeper in the system. The production area is around 1 $km^2$ but the whole geothermal area is between 8 and 10 $km^2$ (Tómasson, 1988). As part of the RESULT project, the vast data available from wells drilled in the late 1960s through the 1980s have been compiled and partly digitised, and a three-dimensional temperature model and a geological model were developed using the Leapfrog Energy software. In addition, a temporal comparison of temperature was made using all available well temperature logs (Helgadóttir et al., 2021). Together these models provide a qualitative assessment of reservoir cooling from 1968 to 2020.

## 1 BACKGROUND

Shortly after production from the Elliðaárdalur geothermal field commenced in 1968, a progressive decline in reservoir temperature was observed in most production wells. According to Tómasson (1988) the aquifers in the area are divided into three different layers, shown in Figure 1, along with a cross-section from the geological model of the area. Aquifer zone A extends to approximately 500 m within the upper basaltic lava series; aquifer zone B is at ~500-1000 m within hyaloclastite formations; and aquifer zone C is below 1000 m in the lower basaltic lava series. The main production is from aquifer B, which hosts the highest reservoir temperatures, reaching up to 110°C. The cooling was attributed to downward flow of colder water from Aquifer zone A due to pressure decline in the hottest part of the system. Initially, wells were cased only to approximately 100 m depth. To mitigate the temperature decline some of the wells were re-cased to greater depths and two of the westernmost wells were sealed. This proved effective in certain parts of the system, however cooling persisted in other areas, especially in the south.

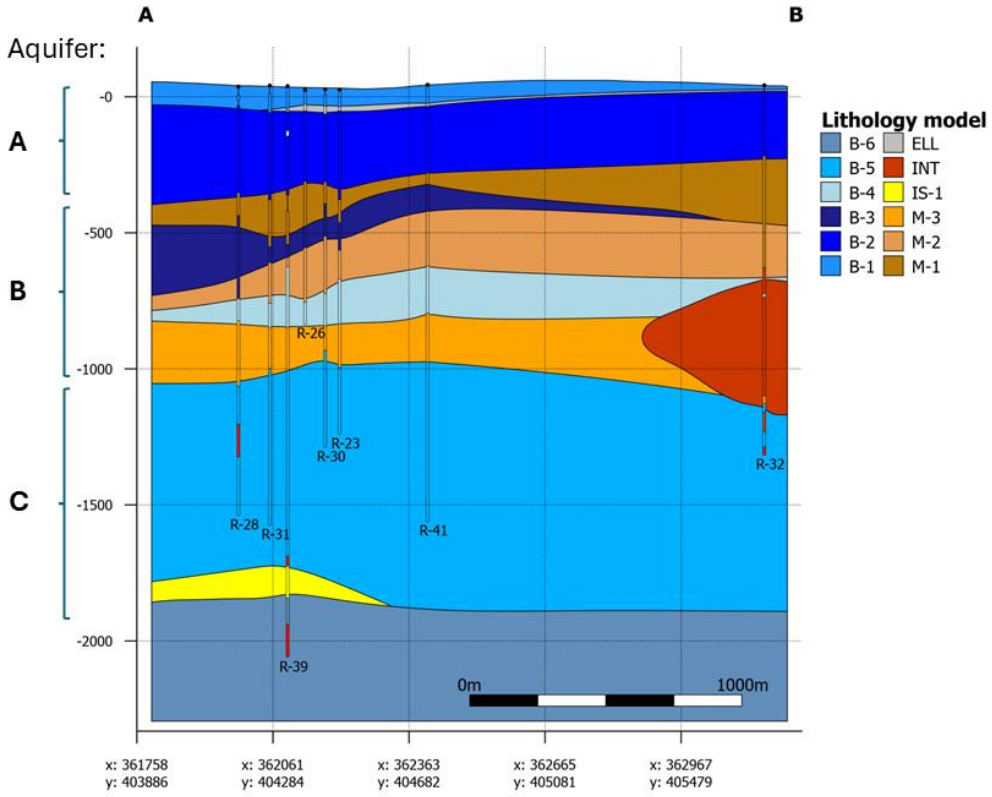



**Figure 1. Geological model of the Elliðaárdalur field from SSW, where most of the production wells are located, to NNE towards Grafarvogur area. Division of aquifers comes from Tómasson (1988).**

In addition to the observed temperature decline, geochemical changes have also occurred within the system, some of which have affected production. Most notably, the increase in $O_2$ has led to the corrosion of downhole pumps, pipelines and surface infrastructure. To reduce pressure drawdown in the low temperature geothermal fields of Reykjavík, heated groundwater from power plants in the Hengill area was added to the district heating system in 1990 (from the Nesjavellir power plant) and again in 2010 (from the Hellisheiði power plant). In recent years, the operation strategy has shifted toward improving the utilisation efficiency of the low temperature fields, including the Elliðaárdalur area (Tómasdóttir et al., 2023). The work done within the RESULT project has increased the understanding of the system. It has become clear that the intrusion of colder fluids does not only happen through fractures and fissures, but also from idle production wells that may function as flow paths from cooler zones to the hotter parts of the system. According to Tómasdóttir et al. (2023) historical production data indicate, for example, that rather than allowing wells to idle for a prolonged time a more stable production scheme across all wells should be adopted. Among other proposed actions for the field is the drilling of new wells.

## 2 DISCUSSION

Several factors must be considered when siting new geothermal wells, the most critical being the identification of sufficiently high temperatures and adequate permeability. In the case of the Elliðaárdalur field, the three-dimensional temperature and geological models (among other datasets) facilitate visualisation of the subsurface and are valuable tools for identifying favourable drilling dargets.

A temperature gradient map of the capital area (Figure 2) suggests that the geothermal system follows a NNE direction. However, other temperature anomalies are also evident, particularly within the main production area where a distinct N-S oriented trend is observed. Another anomaly extends northwestward toward the Laugarnes geothermal field, aligning with mapped northwest striking fractures southeast of Elliðaárdalur. This suggests that there may be underlying northerly and northwesterly trending fractures intersecting a NNE-SSW oriented fracture, thereby enhancing permeability, promoting the upflow of hotter water. Accoustic televiewer data from two wells within the field suggest that the fracture system at depth may be complex, with the most common fracture trends being N-S to NE-SW as well as NNW-SSE (Helgadóttir, 2021). The formation temperature model (Figure 3) shows that the hottest flow appears to originate from the NNE while a cooler zone is to the south or SSW, likely resulting from the structural influence of the Krýsuvík fissure swarm, allowing colder fluids to

circulate to greater depths. The highest temperatures occur at depth in the NNE near well R-32 and rise toward shallower levels closer to R-41 and the main production area.

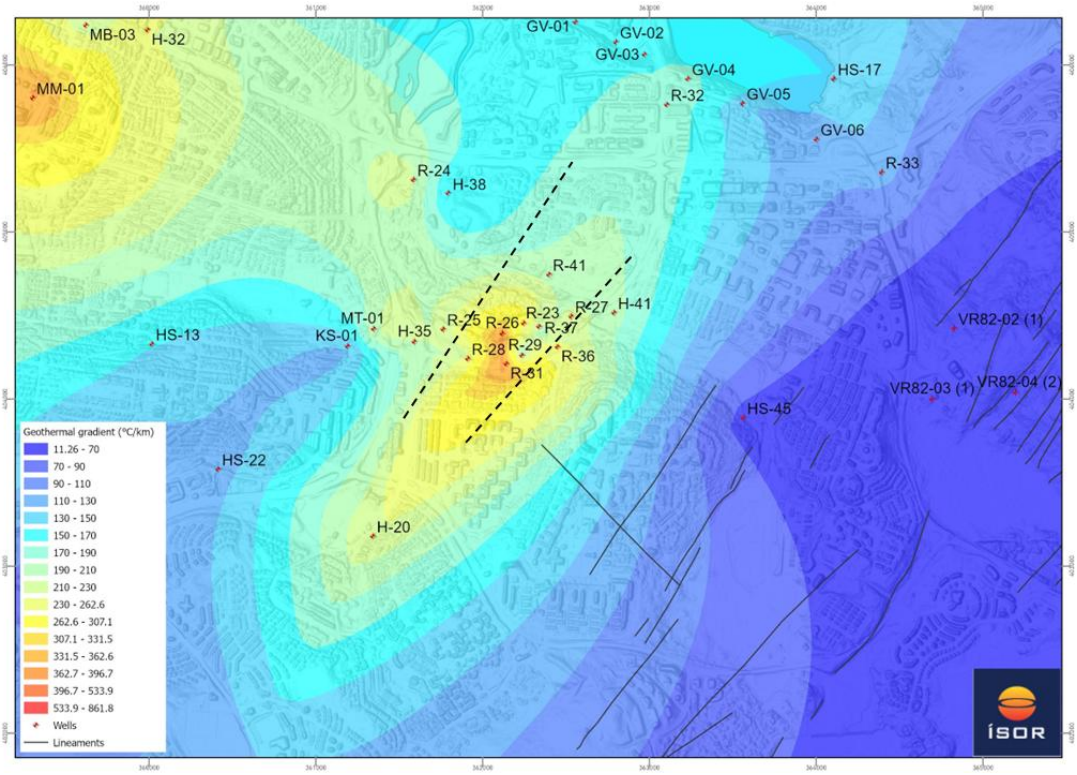



**Figure 2. Temperature gradient map of the Elliðaárdalur field and surroundings (Kristinsson and Óladóttir, 2025). Hydrological barriers suggested by Tómasson (1988) are shown as black dashed lines.**

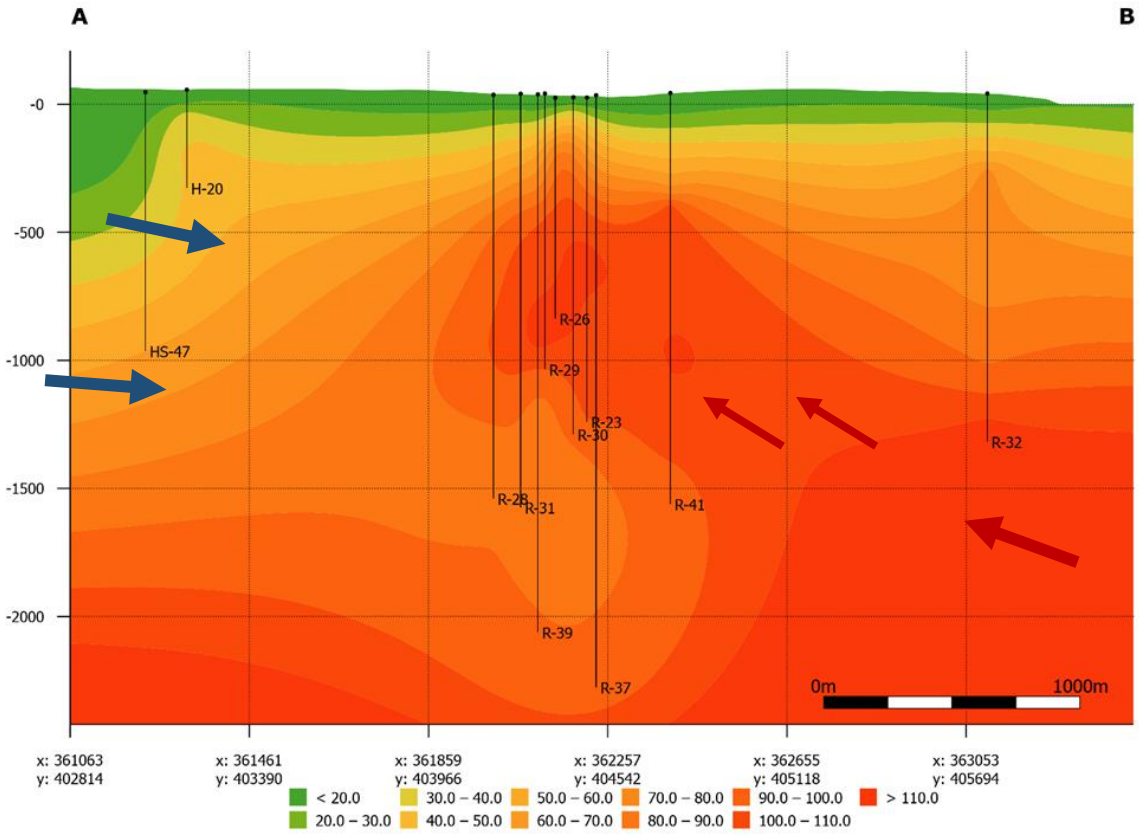



**Figure 3. Cross section through the formation temperature model of the Elliðaárdalur geothermal field from SSW to NNE. Red arrows indicate the flow of hot water and blue arrows the flow of colder water.**

Hydrological barriers appear to be present within the main geothermal area (Tómasson, 1988). These barriers are thought to trend NNE, similar to the dominant fissure and fracture orientation just east of the field (Figure 2). They may have persisted over a long time as suggested by an apparent variation in the depth at which epidote first appears in the well cuttings. Wells located within the inferred barriers encounter epidote at significantly shallower depths compared to wells located outside them. Epidote, in this case, represents the former thermal and pressure condition of the system, potentially prior to erosion of the original volcanic pile.

The area north of the river contains a single production well, R-41, which was previously not in use due to its distance from the main production area. Since 2020, R-41 has been utilised as a production well. Although it has experienced slight cooling since the onset of production, hardly any $O_2$ has been detected. The well currently produces water at approximately 92°C and has an average discharge compared to other wells in the field. However, it remains uncertain whether oxygen levels or cooling will change over time, as production of the well only began in 2020.

## 3 CONCLUSIONS

Given that historical cooling has predominantly affected the southern part of the field, in addition to downward flow from aquifer A, it is recommended that new wells be sited north of the Elliðaár river, in a location close to R-41, to optimize thermal output and minimise the risk of oxygen introduction. At least one well is recommended to be deviated toward a northerly direction at an angle such that it intersects the inferred underlying NNE structure, also exploring the area even further north.

Current studies indicate that the area surrounding well R-41 is promising for new geothermal well development, based on temperature measurements and well discharge data. Nevertheless, several uncertainties remain, including the precise distribution and connectivity of subsurface fractures and the potential impact of oxygen influx on production. Additional challenges arise from the urban setting and limited space available for well drilling and surface infrastructure. The siting of new wells has taken this into account and a few locations in an area north of the river have been suggested.

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