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# Case Study of the 3S Kale Incirliova Geothermal Project, Aydın Province, Turkey

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**Keywords**

*Field-development strategy, production-injection configuration, well spacing, acid stimulation, nitrogen lifting, coiled-tubing unit (CTU), electric submersible pump (ESP), scale inhibition, fractured-marble formation*

## ABSTRACT

The Incirliova geothermal project is being developed by 3S Kale Enerji Üretim A.Ş. (3S Kale) in Aydın Province, Turkey. The field is located in the Menderes graben, with a power plant (JES-1) approximately 5 kilometers (km) southwest of the city of Aydın. The plant has a design capacity of 25 MW gross (20 MW net), and it began operation on 15 January 2019. As of mid-March 2019, seven production wells and seven injection wells have been tied into the plant. The geothermal reservoir is hosted in fractured Paleozoic marbles at depths generally in the range of 2,400 to 3,400 meters (m). Maximum bottom-hole temperatures in the field range as high as 259°C, but production temperatures from the primary permeable interval are generally in the range of 150°C to 170°C. Seismic surveys indicate that faults in the northern part of the concession dip to the south, while faults in the southern part of the concession dip to the north. The initial development strategy contemplated production in the north and injection in the south, in the expectation that injected water would move downward on north-dipping structures and U-tube back up along south-dipping structures, extracting heat from deep in the system. This remains part of the field-management strategy, but relatively low permeability encountered in southern wells has led to the dedication of an additional eastern pad to injection. In addition, step-out drilling to the west has identified a productive area for potential make-up drilling in the future. 3S Kale is using electric submersible pump (ESP) technology in some of its production wells, while other production wells are self-flowing. Over time, it is expected that additional production wells will be converted to ESP use.

## 1. Introduction

The Incirliova geothermal project in the Menderes graben of Turkey illustrates implementation of a consistent field-development strategy involving dedicated production and injection areas and reliance on a combination of self-flowing and pumped production wells. 3S Kale Enerji Üretim A.Ş. (3S Kale) is developing the project, which has a binary geothermal plant (JES-1) with a design capacity of 25 MW gross (20 MW net). Plant commissioning began in January 2019 and was still underway as of the date of preparation of this paper. This paper provides a description of the project and the field-development strategy.

## 2. Project Description

The Incirliova project is located in the southern part of the Menderes graben. The JES-1 plant site is about 5 km southwest of the city of Aydın (Figure 1). 3S Kale acquired the Incirliova concession in 2015 and conducted seismic and magneto-telluric (MT) surveys to assess the geologic structure and choose drilling targets. The first well (Incirliova-1) was completed in October 2015 and proved successful, with a measured bottom-hole temperature of 206°C and an initial flow capacity of 360 tons per hour (TPH) at a wellhead pressure (WHP) of 8 bars gauge (barg). The second well (Efeler-1) was completed in December 2015 at a location 5 km east of Incirliova-1. Efeler-1 encountered higher temperatures (259°C), but lower permeability. Although the well would sustain self-flow, its stabilized wellhead pressure after acidizing was about 7 barg, below the target of 8 barg for plant design. 3S Kale decided to focus its production-drilling efforts in the vicinity of Incirliova-1, on the Incirliova pad.

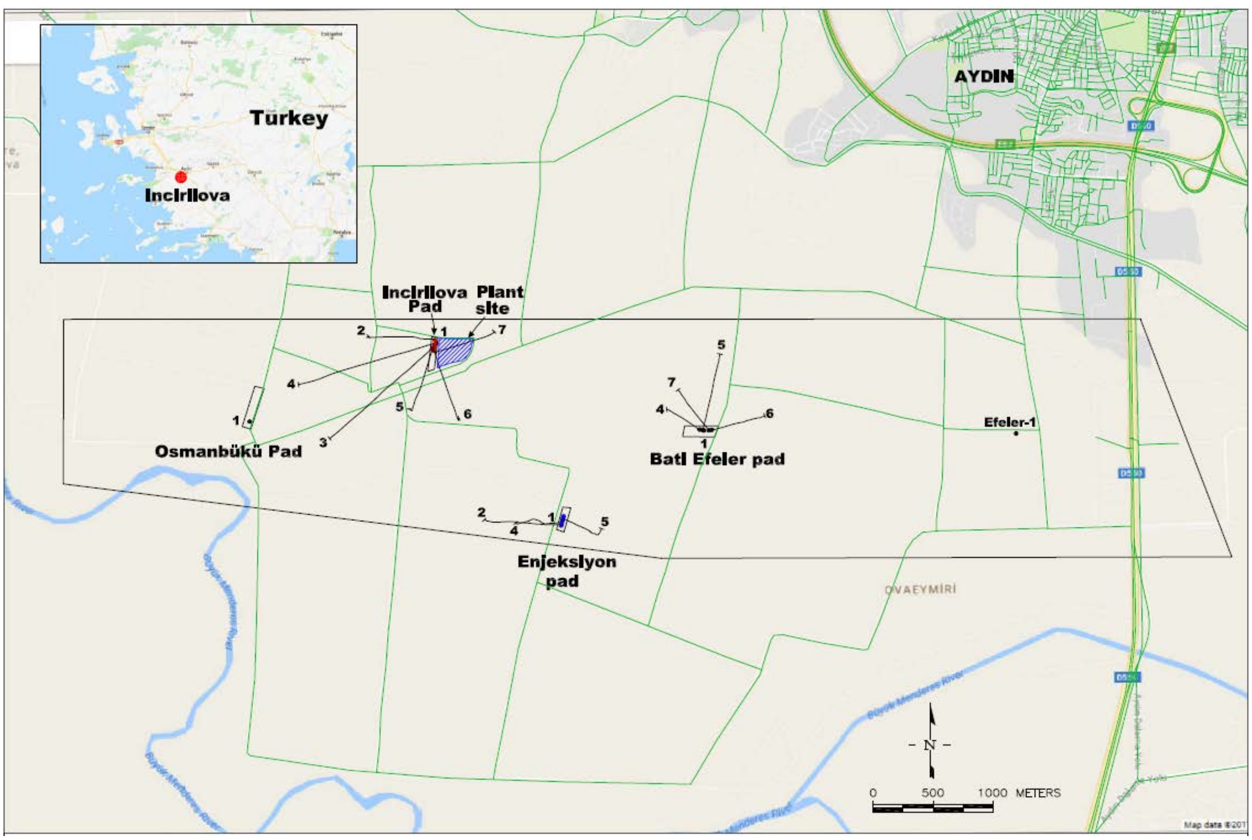


**Figure 1: Incirliova concession boundary and well locations, Aydın Province, Turkey.**

Figure 1 shows the distribution of production and injection wells as of March 2019. The project has eight production wells and nine injection wells. Seven production wells on the Incirliova pad are in active service, and one production well on the Osmanbükü pad further west is awaiting tie-in. Seven injection wells are in active service (four on the Enjeksiyon pad to the south, and three on the Bati Efeler pad to the east), and two more injection wells on the Bati Efeler pad are awaiting tie-in. The JES-1 plant (Figure 2) is located immediately east of the Incirliova pad.

**Figure 2: JES-1 power plant, Incirliova geothermal project, February 2019.**

## 3. Field-Development Strategy

The geothermal reservoir is hosted in fractured Paleozoic marbles at depths generally in the range of 2,400 to 3,400 m. Seismic surveys revealed that faults in the northern part of the concession dip predominantly to the south, while faults in the southern part of the concession dip predominantly to the north (Figure 3). This was the genesis of the basic field-development strategy, which involved production from south-dipping structures in the vicinity of the Incirliova pad, and injection into north-dipping structures from the Enjeksiyon pad near the southern boundary. The hope has been (and remains) that cooler injection water in the south would move downward on north-dipping structures and U-tube back up along south-dipping structures to support northern production, extracting heat from deep in the system. This strategy is similar to the approach that has been successfully applied at the McGinness Hills project in Nevada (Lovekin et al., 2016). Initial testing of wells on the Enjeksiyon pad has demonstrated a pressure connection to wells in the production area, though the pressure response was sufficiently attenuated that thermal breakthrough is not expected to be a concern.

Bottom-hole temperatures in the Enjeksiyon-pad wells have been generally higher than in the Incirliova-pad wells (as high as 221°C). However, the Enjeksiyon-pad wells have had generally lower permeability than the Incirliova-pad wells. In response to this result, 3S Kale decided to dedicate the Bati Efeler pad (2 km east of JES-1) to injection as well. The Osmanbükü -1 was drilled as a step-out to the west, and it has proved to be productive. 3S Kale plans use the Osmanbükü pad for make-up production drilling as needed in the future. Thus, the current production-injection strategy has evolved into an arrangement with production in the western area of the concession (Incirliova and Osmanbükü pads) and injection in the central area of the concession (Enjeksiyon and Bati Efeler pads). The eastern area of the concession remains as a possible area for future expansion if sufficient permeability in this area can be found or engineered. In the near term, 3S Kale is considering injection into Efeler-1 at low pressure through a temporary line, in hopes of inducing thermal fracturing that may improve permeability in the area. This approach (if implemented) would be similar to the stimulation of a hot, low-permeability well at Soda Lake, Nevada by two years of temporary injection (Lovekin et al., 2017).

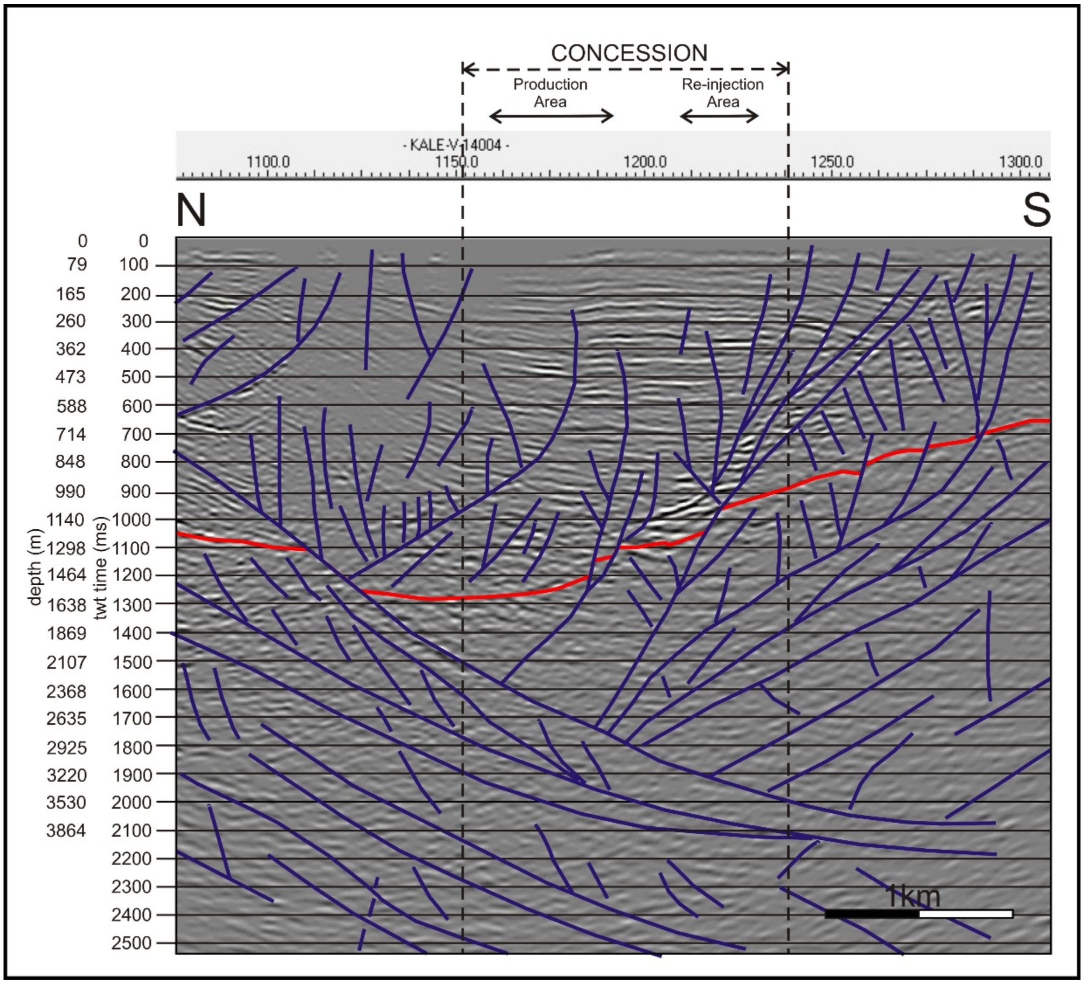


**Figure 3: Seismic cross-section of Incirliova geothermal project**

3S Kale has conducted its drilling campaign in a manner that minimizes surface disturbance and maximizes sharing of common wellhead facilities and pipelines. Because the reservoir target (a fractured-marble formation) has good lateral continuity, the drilling success rate has been very high: every well has been capable of self-flow at potentially commercial temperatures. The Incirliova pad adjacent to the JES-1 plant has seven production wells radiating like spokes on a wheel, with the discovery well (Incirliova-1) drilled vertically at the center. Downhole spacings between production locations have been maintained at a minimum of about 500 m. Drilling on the Bati Efeler pad has used a similar configuration: an initial vertical well, with successive wells radiating out from it. (Note that wells on a given pad – after the first well - are not necessarily drilled in numerical order; for instance, wells numbered 2 and 3 have yet to be drilled from the Bati Efeler pad.) Spacing between downhole locations of adjacent injection wells has been allowed to be closer, because pressure interference between injection wells has been expected to be of less consequence than pressure interference between production wells. At the Enjeksiyon pad, wells after the initial vertical well have been positioned in a line along the southern border, with a downhole separation of at least 800 from the nearest production well (greater than 1,000 m for most producer-injector pairs).

The typical program for evaluating new wells at the Incirliova project has entailed an initial flow period of less than a day to clean up the well after drilling, followed by a heat-up period of at least several weeks and a flow test of several days. Most wells have been stimulated with acid injected through a coiled-tubing unit (CTU), as well as a CTU nitrogen lift to help recover spent acid and dissolution products. The acid stimulations have yielded significant improvements in permeability, with post-acid Productivity Index (PI) values typically in the range of 10 to 45 TPH/bar for production wells.

3S Kale conducted a multi-well test in late 2016 using the first three wells on the Incirliova pad. This test included two 2-day periods of flow by individual wells with no injection, followed by 18 days of flow from one well (Incirliova-1) with injection into another well (Incirliova-2) and pressure monitoring in the third well (Incirliova-5). The results of the test supported a conclusion that the field could support a plant size of 25 MW gross, as documented in a feasibility study prepared in the spring of 2017. At the same time, pressure responses measured during the test indicated that the project would eventually need to transition from self-flowing production to pumped production. The timing of this transition was uncertain, but it was expected to occur within a few years after plant start-up.

In the fall of 2018, 3S Kale tested the Osmanbükü -1 well with an electric submersible pump (ESP), to verify that the option of using ESPs for the project would be viable. The ESP installation included the use of a capillary tube extending below the pump to allow injection of an inhibitor to prevent calcium carbonate scaling. This test lasted approximately one week, and the ESP functioned well throughout the test. Downhole temperatures at the pump intake rose to 142°C and were projected to reach about 150°C. Flowing surveys from the production wells on the Incirliova pad have indicated downhole flowing temperatures generally in the range of 150°C to 170°C, which is within the range of application for current ESP technology. Thus, the project should be in a position to transition to a greater use of ESPs in production wells when the time comes. At present, the project is relying on a combination of self-flowing production wells and production wells equipped with ESPs.

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