Successful Installation of Indonesia's First Dual Electric Submersible Pump System for Dewatering Applications

Albert Ryanta[1], Muhammad Nur Wangsa Saputra[1], Marco Senduk[2], Dhoni Anggoro[2], Ibnu Husodo[1]

[1]*PT Schlumberger Geophysics Nusantara, Wisma Mulia (Suite 4301), South Jakarta 12710, Indonesia*

[2]*PT. Archi Indonesia, Menara Rajawali, 19th Floor, South Jakarta 12950, Indonesia*

Abstract

Araren open-pit mine is the primary pit that produces gold in Toka Tindung, North Sulawesi, Indonesia. The mine produces hot water, with the water discharge in the pit of up to 0.42 m3/s. Wells were drilled and equipped with electric submersible pumps (ESPs) to discharge the hot groundwater before it reaches the pit. The use of a dual ESP system was recommended to increase the dewatering system's discharge capacity without drilling any new wells. The dual ESP system uses a Y-tool connected to the production tubing which enabled two ESP strings to be installed in one well and run simultaneously.

Introduction

Water Properties

The mature hot groundwater in Araren pit comes from a geothermal reservoir in which the fluid is mostly in the water phase, not the gas phase. Lateral groundwater flow is more dominant than the upward flow of deep geothermal gas. Gas and high-pressure water do not flow to the pit, but hot water continues flowing to this zone from the lateral groundwater flow.

A simplified schematic model of the hot groundwater discharge in Araren pit is shown in Figure 1. The geothermal fluids may contain a small quantity of gas, such as hydrogen sulfide (H2S). Maximum temperature of the hot water can reach 373 K at certain depths and zones.

High Dewatering Rate

A pumping test and a physical-chemical groundwater properties assessment were conducted. A drawdown test was performed to determine the value of well/aquifer loss. The constant drawdown test was conducted in 24 hours using a 0.058 m3/s discharge rate and resulted in a groundwater level decrease of 12 m (117 kPa drawdown) from the initial groundwater level. These data were used to generate inflow from the water reservoir (Figure2) using the Darcy method (Schweizer 2015).

Groundwater flow modeling was built using geological and hydrological data, and some assumptions were made as a result of limitations in the hydrogeological data. The model was constructed using Araren

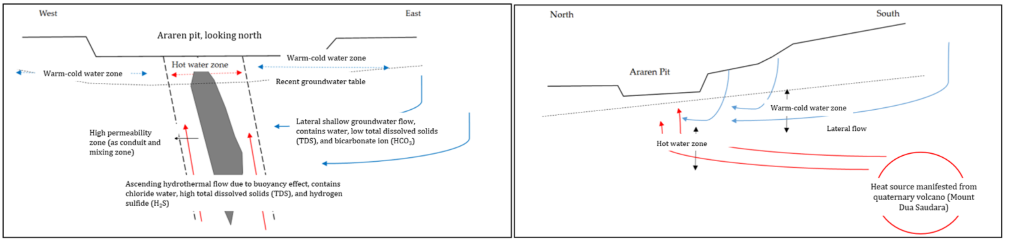

Figure 1 *Araren Pit Hot Groundwater Discharge Schematic Model.*

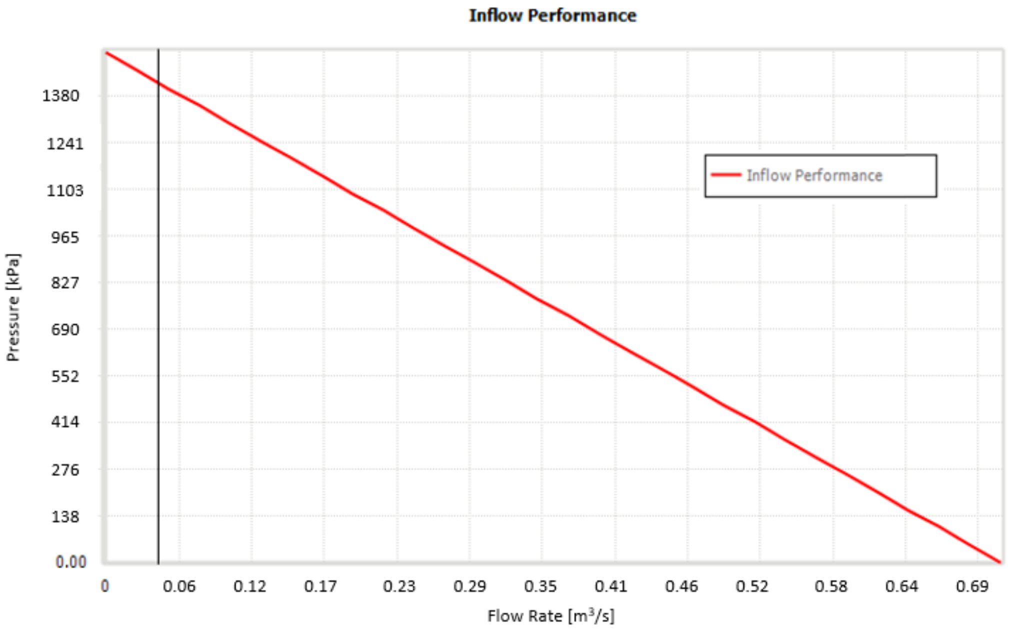

Figure 2 *Araren Pit Well Aquifer Inflow Performance.*

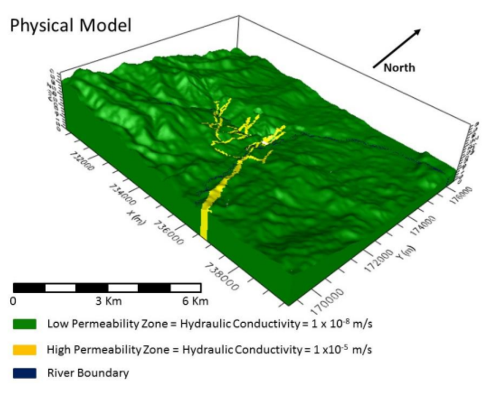

Figure 3 *Araren Pit Permeability Model.*

pit as the model boundary (Fajana 2020). A detailed conceptual model of this study is shown in Figure 3.

Water-Well Drilling Following Groundwater Path

Outside-pit dewatering is intended to prevent an influx of shallow groundwater into the pit. A vertical borehole is drilled to pump the groundwater before it reaches Araren pit, to decrease the quantity of groundwater in the pit. On the basis of groundwater modeling to predict the hot groundwater pumping required in Araren pit (Figure 4), the total discharge required to decrease the groundwater table is 0.42 m3/s. The discharge is handled by seven pump units, with a discharge rate of approximately 0.06 m3/s per pump. Pump unit should be installed at a depth of 200 m, with a minimum well diameter of 356 mm (14 in).

Project Solution

Artificial Lift: ESPs for Highly Efficient, High-Rate Production

Because of the required discharge rate of approximately 0.06 m^3/s per well and because the available power source is electrical power, ESPs were the most suitable artificial lift option (Clegg *et al.* 1993). ESPs were also selected because they meet the operational temperature requirements; temperatures of as much as 373 K were expected (Schlumberger 2011). Table 1 shows the ESP general specifications (Schlumberger 2017).

Typical ESP strings comprise the following equipment: from top to bottom, a centrifugal pump, intake, protector section, and electric induction motor (Figure 5).

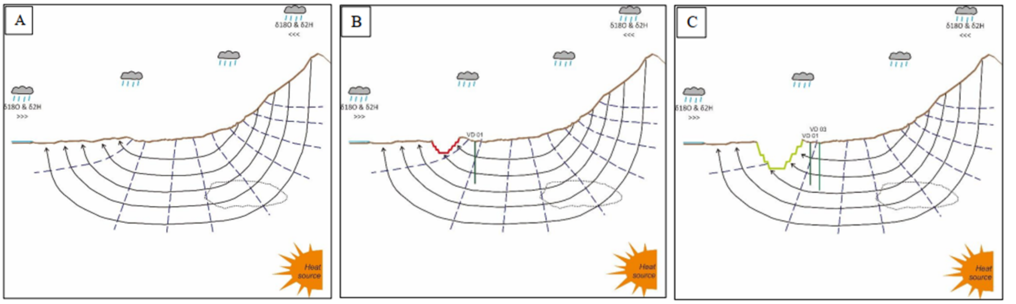

Figure 4 *Araren Pit Groundwater Flow Modeling.*

Table 1 *ESP general specifications.*

Parameter	Value
Discharge rate	200–96,000 BLPD (0.00036–0.177 m^3/s)
Operational temperature	Up to 477 K for standard applications and up to 573 K for high-temperature applications
Corrosion resistance	Available for H2S and CO_2 environments
Well casing size	114 mm to 346 mm (4.5" to 13.625 ")

Table 2 *Araren pit well and fluid reference data for ESP design.*

Parameter	Value
Target discharge rate	0.042 m^3/s
Fluid gravity	1000 kg/m^3
Inflow performance	Static reservoir pressure of 1469 kPa, well flowing pressure of 1379 kPa, discharge rate at well flowing pressure of 0.043 m^3/s
Reservoir/production zone depth	280 m
Reservoir temperature	373 K
Tubing type and size	114 mm (4.5 in)
Casing size	273 mm (10.75 in)
Power source	360 V, 50 Hz

Initial ESP Design for Araren Pit Wells

The well and fluid reference data used to design the ESP are summarized in Table 2.

Pump setting depth was set at 260 m to maintain the fluid level above the pump during production at approximately 123 m and provide sufficient liquid pressure at the ESP intake. This application required high-rate ESPs and was completed with variable speed drive and a downhole sensor for optimization (Giden *et al.* 2017).

A 171.5-mm centrifugal pump was selected on the basis of the target rate (up to 0.048 m^3/s) and well casing size (273 mm). After the pump type was selected and the number of stages was calculated, 20 pump stages were selected to accommodate the pump depth and the required rate. After calculating ESP sizing, ESP material

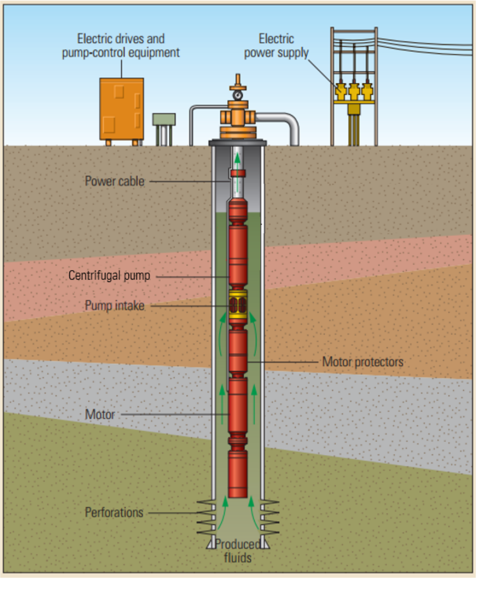

Figure 5 *Typical ESP Equipment.*

Table 3 Specifications for the dual ESP installed in the well.

Selection Parameters	Bottom ESP	Top ESP	Remarks
Pump type	20-stage centrifugal pump	27-stage centrifugal pump	Operating range from 0.03 to 0.048 m^3/s
Available pumphead	250–370 m	209–385 m	Pumphead should be greater than required head
Pump outside diameter	171.5 mm (6.75")	143 mm (5.62")	Should be smaller than well casing diameter
Stages material	Ni-resist cast iron	Ni-resist cast iron	Suitable for mildly abrasive environment
Pump bearing	Abrasive-resistant zirconia	Abrasive-resistant zirconia	Suitable for mildly abrasive environment
Required power	156–164 kW	160–168 kW	Motor sizing must be greater than required power
Elastomer	Highly saturated nitrile	Fluoroelastomer	Suitable for fluid temperatures up to 450 K
Pump shaft material	30 mm (1.18 in)	30 mm (1.18 in)	High-strength shaft rated for 587–919 kW
Housing material	Carbon steel	Carbon steel	Suitable for mildly corrosive environment

Table 4 Summary of ESP strings installed in the well.

	Discharge Rate Design (m^3/s)	Pump	Protector	Motor	Cable
Bottom ESP	0.042	171.5-mm pump, 20 stages	Modular bag and labyrinth	223 kW, 477 K rated	42-mm^2 conductor size, lead barrier, and stainless steel armor
Top ESP	0.046	143-mm pump, 27 stages	Modular bag and labyrinth	223 kW, 477 K rated	42-mm^2 conductor size, lead barrier and stainless steel armor

was selected on the basis of well-fluid properties and temperature. Optimal pump specifications (Table 3) were selected after reviewing a successful ESP application in India that provided a 0.1 m^3/s discharge rate with dissolved carbon dioxide, oxygen, chlorides, and sulfate-reducing bacteria in the water (Jha *et al*. 2012).

Dual ESP for High-Rate Production

As mining activity increased, a greater discharge rate than the initial rate was required. Because an ESP had been previously installed in the well, an approach using an additional ESP in the well was studied. Because the use of a dual ESP results in a greater total pump diameter, a smaller pump was studied for installation with the initial ESP. Using a Y-tool and a smaller pump would be required to install a dual ESP, which would provide a greater discharge rate than that of a single pump (Rizza *et al*. 2017). The Y-tool acts as a branch to connect the two pumps. Because installing two pumps side by side would create a larger cumulative outside diameter than the well casing size, an approach stacking two sets of ESPs was studied. An 89-mm bypass tubing was installed in parallel with the top pump and acts as an extended connection for the bottom pump. Pump specifications for the top and bottom ESPs are provided in Table 3. A summary of the installed ESPs is provided in Table 4. Details regarding the dual ESP design are shown inFigure 6.

Results

To determine the performance of the dual ESP, the discharge rate, power use, and well flowing pressure were measured and compared to the initial targets (Table 5). Data gathered in September 2021 showed that the dual ESP's working as per design. The intake-pressure data shows that the actual intake pressure was greater than the simulated intake-pressure data, demonstrating that the actual inflow was greater than the surveyed inflow.

However, it was measured that the cumulative discharge rate was 6.82% less than the

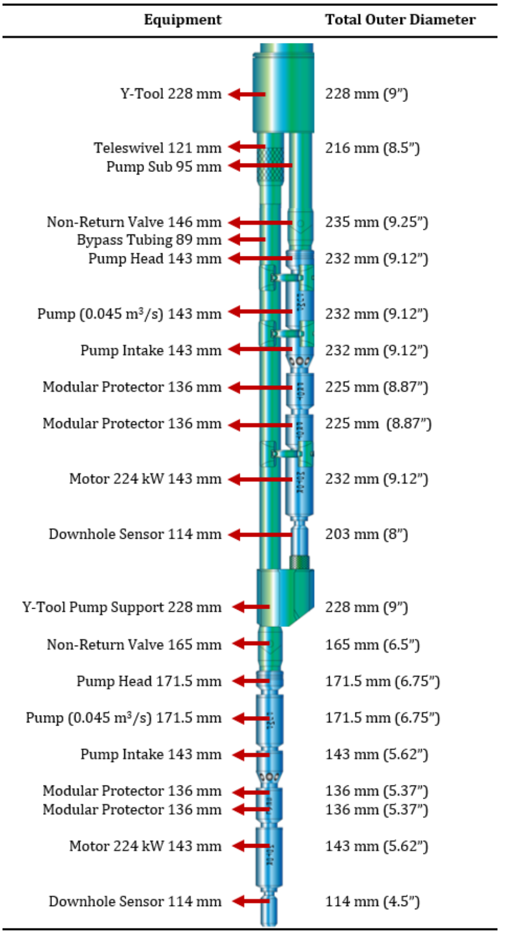

***Figure 6** Dual ESP String Configuration.*

designed rate, with the power usage 4.51% less than the designed use. The difference between the design and the actual result was hypothetically caused by friction loss inside the tubing and the Y-tool. Increased pressure in the surface flowline and tubinghead also occurred, in addition to an increase in the discharge rate. As the discharge rate increases, a larger production tubing size in the well will be required to maximize the potential discharge rate of the ESP per the design. To support deeper mining activity, a greater ESP discharge rate or dual ESP deployment should be considered for future ESP installations in other wells. The plan for well drilling in the area should also be reviewed to support further pit and mining activity development.

Conclusion

The dual ESP successfully generated the designed discharge rate to support the pit dewatering project. Because of the wide selection of ESPs available, a dual ESP design can be used to meet any discharge rate required in limited well casing sizes by using two pumps that run simultaneously and are connected using a Y-tool. Additional ESP accessories installed in downhole and surface equipment can help operators modify available ESP assets to match the ESP application design. In this study, the successful deployment of a dual ESP in a single well demonstrates the maturity of integration between ESP technology, ESP design, and service execution to fulfill required engineering services

References

Clegg JD, Bucaram SM, Hein, Jr NW (1993) Recommendations and comparisons for selecting artificial-lift methods(includes associated papers 28645 and 29092). J Pet Technol 45(12): 1128–1167, doi: 10.2118/24834-PA

Fajana AO (2020) Groundwater aquifer potential using electrical resistivity method and porosity calculation: a case study. NRIAG Journal of Astronomy and Geophysics, 9(1):168–175, doi: 10.1080/20909977.2020.1728955

Giden I, Kometer B, Buerssner P, Lobianco L (2017) Re-development of an onshore mature oil field to double gross production by the use of sensor-equipped electrical submersible pumps. SPE Europec, 79th EAGE Conference and Exhibition, Paris, France, 12–15 June, doi: 10.2118/185870-MS

***Table 5** Comparison of dual ESP design and actual results.*

ESP	Average Discharge Rate (m^3/s)			Average Power Use (kVA)			Intake Pressure (kPa		
	Design	Actual	Deviation	Design	Actual	Deviation	Design	Actual	Deviation
Bottom ESP	0.042	0.039	−7.14%	261	235.95	−9.60%	1055	1151	9.15%
Top ESP	0.046	0.043	−6.52%	259	260.6	0.62%	883	1062	20.31%
Cumulative	0.088	0.082	−6.82%	520	496.55	−4.51%			

Jha M, Singh R, Chavan C, Karthik R, Simpson A, Sudharshana J (2012) High rate ESP application in onshore Rajasthan fields: case study. SPE Artificial Lift Conference and Exhibition, Manama, Bahrain, 27–28 November, doi:doi.org/10.2118/163117-MS

Rizza G, Luppina S, Bucci A, Rinaldi F, Ogidi M, Legname R, Cappuccio P, Sgambati A, Gonzalez Zamora M, Valente A (2017) Successful installation of the first dual ESP completion system in Val D'Agri Field. Offshore Mediterranean Conference and Exhibition, Ravenna, Italy, 29–31 March

Schlumberger (2011). REDA hotline high-temperature ESP systems. Schlumberger. https://www.slb.com/-/media/files/al/brochure/hotline-br.ashx. Accessed 19 August 2022

Schlumberger (2017). REDA High-Efficiency Pumps. Schlumberger. https://www.slb.com/-/media/files/al/product-sheet/high-efficiency-pumps-ps.ashx. Accessed 19 August 2022

Schweizer B (2015) Darcy's law and groundwater flow modelling. Snapshots of modern mathematics from Oberwolfach, Mathematisches Forschungsinstitut Oberwolfach. doi:10.14760/SNAP-2015-007-EN. Accessed 19 August 2022