Study of Increase Geothermal Well Production Rate by Downhole Pump Installation for Utilization in Power Plant

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Abstract. A geothermal well is one of the main components in the geothermal field. The well is essential for geothermal utilization and connecting between reservoir and surface. Based on the condition to discharge fluid toward the surface, wells are categorized as self-discharge wells (able to discharge naturally to surface) and non-self-discharge wells (not able to discharge naturally to surface). For wells categorized as non-self-discharge with low pressure and low-medium temperature, an artificial method needs to be implemented, which is the use of downhole pump technology, namely electrical submersible pump (ESP) or line shaft pump (LSP). This condition occurs in well in Tulehu geothermal field (X-1). Downhole pump technology has been developed in several geothermal fields in other countries and has been proven to increase geothermal well production. The purpose of this research is to determine the appropriate engineering design for the implementation of a downhole pump in X-1 well and the net power output that can be produced. The research method was carried out analytically from evaluating and analyzing well-testing results, including completion test and production test to determine the condition and characteristics of the well, performing technical design calculation for downhole pump implementation, and calculating the binary cycle analysis of power plant obtain net power generated. Optimum pump setting depth in 600 meters depth that can produce mass flow rate 48.28 kg/s, and optimum model is ORC power plant with Butane working fluid that can produce Net Power Output 1.382 MW for ORC power plant model combined with ESP-2.

1. Introduction
A geothermal well is one of the main components in a geothermal energy utilisation that can flow geothermal fluid from a reservoir to the surface. Based on the capability of flow fluid to the surface, a geothermal well can be categorized as a self-discharge well and a non-self-discharge well [1]. Self-discharge is a well that can flow naturally to the surface, while a non-self-discharge well is a well that cannot flow naturally to the surface. Several problems and conditions can cause a well that cannot flow naturally to the surface: low permeability of reservoir, wellbore formation damage, low pressure, and low temperature. The solution that can be implemented to this well is based on the problem and condition of this well [2, 3]. It needs artificial lift technology such as a downhole pump for a well that has low pressure and low-medium temperature [4]. Well, that has a condition with a low production rate occur
in Tulehu geothermal field. Based on well testing, low production is caused by low pressure and low temperature. A method that can be implemented to this well is an artificial lift with downhole pump technology.

The downhole pump has been implemented in many low-medium enthalpy geothermal fields to increase energy and prevent boiling at the wellbore [5]. Advantages of downhole pump implementation in geothermal wells [6] are increased well production rate, better energy recovery, and decreased calcite scaling potential. There are two types of downhole pump commonly used in geothermal well, Line Shaft Pump (LSP) and Electrical Submersible Pump (ESP). The two types have characteristics, lack, and advantages that described in Table 1 [6]:

|                         | Line Shaft Pump                          | Electrical Submersible Pump              |
|-------------------------|------------------------------------------|------------------------------------------|
| Higher motor efficiency, motor operates in air, little losses in power cable | Relatively lower motor efficiency, motor operates in oil at elevated temperatures, higher losses in power cable | |
| Usually lower speed (1750 rpm or less) | Usually higher speed (3600 rpm) | |
| Higher temperature capability, up to 250°C | Lower temperature capability but sufficient for most direct heat and some binary power applications | |
| Shallower setting, 600 m maximum | Deeper settings. Up to 3,650 m | |
| Longer installation and pump pull time | Less installation and pump pull time | |
| Generally lower purchase price than ESP | Generally higher purchase price than LSP | |

Selection of downhole pump type based on several considerations such as well schematic and well characteristics [6]. The fluid temperature produced from Tulehu well categorized as medium temperature so that it is suitable to be utilized in a binary cycle power plant. In a binary cycle power plant, geothermal fluid is utilized in the heat exchanger with secondary fluid. Therefore, it is necessary to make a preliminary study about the feasibility of downhole pump implementation in Indonesia’s geothermal wells at the Tulehu geothermal field.

2. Well Condition and Characteristic

2.1. Well Trajectory and Well Schematic
Drilling activity of X-1 well at Tulehu geothermal field was carried out in 35 days from June 27th, 2017 to August 17th, 2017, at rig floor elevation 65.14 meters. Drilling activity carried out with directional drilling to predicted permeable zones in the Banda Fault and Banda Hatuasa Fault, as shown in (Figure 1). From the drilling results, the depth of the well reached 1712 meters from the target of 1800 meters, and there was a total loss of circulation.

Based on the casing diameter used, X-1 well is included in the standard hole category using production casing with a diameter of 9-5 / 8” to depth of 775 meters and slotted liner of 7” from a depth of 716 meters as shown in (Figure 1). Drilling activities are operated with directional drilling, and Kick off Point (KOP) is at a depth of 350 meters.
2.2. Feed Zone Depth Location
The approximate depth of the feed zone in the well can be identified from well testing. One of the testings is from the water loss test, which has also been carried out on X-1 well. Based on the analysis of the water loss test on X-1 well, it indicates that there are possible three feed zones as follows:

1. Feed zone at depth 950 – 985 m
2. Feed zone at depth 1050 – 1080 m
3. Feed zone at depth 1200 – 1230 m

2.3. Static Pressure and Temperature
Well pressure and temperature profiles can be obtained from the heat-up test. Heat-up tests have been carried out on X-1 well. The heat-up test was carried out at intervals of 1 day, 11 days, and 36 days. When the well was shut-in for 36 days, the temperature profile showed that the maximum temperature in the well was 138°C (Figure 2). Based on the heat-up test, there is an indication of an identified feed zone at 750 m depth, and since the temperature profile at the left side of BPD indicates a compressed liquid reservoir.

Figure 1. Well Schematic X-1 Well [7].
2.4. Well Permeability

The well permeability value describes the ability of reservoir rocks in the well to drain fluid. Permeability value shows the ability of the reservoir to drain fluid. Well permeability can be shown by permeability thickness obtained from the pressure fall-off test. Pressure fall-off test on X-1 well has been done after gross permeability test is completed at the injection rate of 880 GPM, injection rate hold for that rate and stopped, making pressure decline. Injection rate and pressure profile during the gross permeability test and pressure fall-off test conducted at X-1 is shown in (Figure 3).

![Figure 2. Static Pressure and Temperature Profile based on Heat-up Test [7].](image)

![Figure 3. Injection Rate and Pressure Profile X-1 Well.](image)

Calculation to obtain permeability thickness value (kh) and skin factor done by using equations below [8]

\[
k_h = \frac{2.303 \mu q}{4\pi m}
\]  

(1)
\[ S = 1.151 \left[ \frac{P_{th} - P_i}{m} - \log \left( \frac{4kh}{\mu} \left( \frac{1}{Gth} \frac{t}{r_w^2} \right) \right) + 0.251 \right] \] (2)

The calculation results are shown in Table 2.

### Table 2. The calculation for Permeability Thickness X-1 Well.

| Parameter                  | Value | Units          |
|----------------------------|-------|----------------|
| \( m \)                   | 0.147 | bar/cycle      |
| \( h \)                   | 1370.08 | kJ/kg        |
| Dynamic Viscosity          | 8.42E-05 | Pa.s        |
| Specific Volume            | 1.04E-03 | m³/kg       |
| Kinematic Viscosity        | 8.79E-08 | m²/s        |
| \( Q_m \)                 | 55.4 | kg/s          |
| Transmissivity (kh)        | 6.0E-11 |                |
|                           | 60.5 | darcy meter   |

2.5 Production Capacity Estimation

Production tests on X-1 well had been conducted from February 5\(^{th}\), 2018 to February 24\(^{th}\), 2018. Production tests used a lip pressure horizontal discharge method. The discharge pipes used are 5 inches, 6 inches, and 8 inches depending on the changes of wellhead pressure, lip pressure, and valve openings during the test. Output curve from production test shows total mass flow rate around 11.78 kg/s – 38.8 kg/s at wellhead pressure 2.6 bara – 3.17 bara.

3. Pressure Drop Calculation and IPR

3.1 Pressure Drop Calculation

Data from the production test on X-1 well are wellhead pressure, brine flow rate, vapour flow rate, and total mass flow rate. A well-flow simulation or pressure drop calculation is performed on production test data to determine the estimated flowing bottom hole pressure (\( P_{wf} \)) when geothermal fluid is produced. Other parameters used as additional data from the production test are the well geometry and estimated depth of feed-zone.

- Production casing diameter : 9 5/8 inches
- Production casing depth : 700 meters
- Production liner diameter : 8½ inches
- Casing roughness : 0.0000457
- Inclination : 32°
- Feed zone depth : 750 meters

Since the temperature profile based on the heat-up test at the left side of BPD indicates a compressed liquid reservoir (single-phase liquid), pressure drop calculations use homogenous correlation types. After calculating the pressure drop with a homogenous correlation type, the estimated flowing bottom hole pressure (\( P_{wf} \)) is shown in Table 3 as follows:
Table 3. Estimated Pwf based on Pressure Drop Calculation.

| WHP (bar) | Qliquid (kg/s) | QVapor (kg/s) | QTotal (kg/s) | Fraction | PReservoir (bar) | Pwf (bar) |
|-----------|----------------|---------------|---------------|----------|------------------|-----------|
| 2.82      | 33.26          | 1.64          | 34.90         | 0.05     | 67               | 29.65     |
| 2.81      | 35.85          | 2.03          | 37.88         | 0.05     | 67               | 29.34     |
| 2.79      | 36.23          | 2.14          | 38.37         | 0.06     | 67               | 28.79     |

3.2. IPR (Inflow Performance Relationship) Curve
Based on production test data, estimated well flowing pressure from pressure drop calculation and estimated reservoir pressure from the heat-up test can be used as the basis for constructing IPR (inflow performance relationship) curve. The curve describes the correlation between the well flowing pressure (Pwf) and mass flow rate that can be produced [9]. The initial data used in constructing the IPR curve are shown in Table 4.

Table 4. Initial Data to construct the IPR Curve.

| WHP (bara) | Pwf (bara) | PRes (bara) | Q (kg/s) |
|------------|------------|-------------|----------|
| 2.82       | 29.65      | 67          | 34.90    |
| 2.81       | 29.34      | 37.88       |          |
| 2.79       | 28.79      | 38.37       |          |

Based on the static temperature profile and BPD, it indicates a compressed liquid reservoir. Therefore, IPR curve was carried out by using a linear regression correlation for a single phase. IPR curves that show the correlation between Q generated against Pwf will be used as a reference in determining the optimal Q that can be generated by wells after a downhole pump installation. Regarding the IPR curve, the optimal Q is obtained based on the depth of the well’s production zone and the setting of the downhole pump depth. The IPR curve obtained from a linear regression correlation see (Figure 4).

![Figure 4. IPR Curve using Linear Regression Method.](image-url)
4. Downhole Pump

Condition and characteristics of the well can be obtained based on well testing, well flow simulation, and IPR curves. It can be used as a basis data to carry out technical calculations of downhole pumps to find out the most optimal technical parameters in the installation of downhole pumps, including pump setting depth, optimum mass flow rate, total dynamic head, and brake horsepower to drive the pump motor [10, 11, 12, 13].

4.1. Pump Setting Depth

The optimal estimated pump setting depth is around 200 – 300 meters above the estimated production zone (feed zone). In specific pump setting depth values, it will give different optimal mass flow rate based on IPR curve that describes the correlation between flowing bottom hole pressure ($P_{wf}$) and mass flow rate that limited by pump suction pressure value must be higher than boiling pressure so that geothermal fluid remains maintained water saturation. Therefore, calculation experiment can be performed using several pump setting depth values to obtain the most optimal pump setting depth values.

4.2. Pump Suction Pressure

By using parameter values of $P_{wf}$ (bottom hole well flowing pressure in bars), FZ (estimated depth of feed zone in meters), and PSD (pump setting depth in meters), then pump suction pressure in bars can be calculated by Equation (3).

\[
P_{\text{Suction Pressure}} = P_{wf} - ((FZ - PSD) \times 0.0981)
\]

4.3. Total Dynamic Head

Total Dynamic Head consists of three components: Net Water Lift, Friction Loss, and Wellhead Discharge Pressure. Using parameter values of Net Water Lift, Friction Loss, and Wellhead Discharge Pressure in bars, Total Dynamic Head (bars) can be calculated by Equation (4).

\[
\text{Total Dynamic Head} = \text{Net Water Lift} + \text{Friction Loss} + \text{Wellhead Discharge Pressure}
\]

Net Water Lift (bar) can be calculated using Equation (5).

\[
\text{Net Water Lift} = (PSD \times 0.0981) - PSP
\]

By using parameter PSD, which is Pump Setting Depth (meters), and PSP, which is Pump Suction Pressure (bar), Friction loss ($P_f$) in bars can be calculated using Equation (6).

\[
P_f = \frac{124.8 \times F_f \times v^2 \times PSD}{386.04 \times d_i}
\]

Using parameter $F_f$ is friction factor fanning, $v$ is the fluid velocity in m/s, and $d_i$ is inner tubing diameter in meters. Friction factor fanning can be calculated by Equation (7).

\[
F_f = \frac{1.74 - 2 \log(2\epsilon)}{4}
\]

With $\epsilon$ is roughness.

Fluid velocity ($v$) in m/s can be calculated using Equation (8).

\[
v = \frac{q_{wf}}{(\pi/4) \times (d_i^2)}
\]
With \( q_{\text{wf}} \) is the volumetric flow rate in \( \text{m}^3/\text{s} \), and \( d_i \) is inner tubing or casing diameter in meters. Wellhead Discharge Pressure is the desired discharge pressure at the wellhead.

### 4.4. Downhole Pump Type Selection
Selection of pump type based on the pump requirement of minimum well casing and optimum range has to meet the estimated mass flow rate and production casing of X-1 well. Head and brake horsepower per stage can be obtained by plotting mass flow rate on the pump performance curve. Those parameters will be used to calculate the total stages required and total brake horsepower.

### 4.5. Total Stages Required dan Brake Horsepower
Total Stages Required can be calculated by Equation (9).

\[
\text{Total Stages Required} = \frac{\text{TDH}}{\text{Head per stage}} \tag{9}
\]

By using TDH is Total Dynamic Head and Head per Stage is a single-stage head obtained from the pump performance curve.

Break Horsepower required by the pump can be calculated by Equation (10).

\[
\text{BHP} = \text{Total Stages Required} \times \text{(BHP stage)} \tag{10}
\]

Using Total Stages Required is the number of stages, and the BHP stage is Brake Horsepower per stage from the pump performance curve.

### 5. Organic Rankine Cycle (ORC) Power Plant
When the produced geothermal fluid is classified as low-medium temperature, the ideal conversion technology is binary conversion technology. In ORC binary power generation systems, the turbine is not driven directly by vapour from geothermal fluid but by vapour from working fluid with a lower boiling point. The thermodynamic cycle in the binary power plant is a closed cycle \([14]\). The schematic diagram in Figure 5 shows the main components of the binary cycle.

#### 5.1. Turbine Expansion Process
Thermodynamic analysis in the turbine expansion process is like a steam turbine, assuming it neglects potential and kinetic energy, and the process is in adiabatic and steady condition. The Equation of process in a turbine can be expressed as follows:

![Figure 5. ORC Power Plant Schematic.](image)
\[ W_t = m_{wf} \times (h_1 - h_2) = m_{wf} \times \eta_t \times (h_1 - h_{2s}) \]  
(11)

\[ h_2 = h_1 - (\eta_t \times (h_1 - h_{2s})) \]  
(12)

By using \( m_{wf} \) is mass flow rate of working fluid (kg/s), \( h_1 \) is working fluid enthalpy through the turbine (kJ/kg), \( h_2 \) is the enthalpy of working fluid in Condition 2 (kJ/kg), \( h_{2s} \) is working fluid enthalpy in Condition 2s (kJ/kg) and \( \eta_t \) is turbine efficiency.

5.2. Condenser Process

By using \( h_3 \) is working fluid enthalpy (kJ/kg) in Condition 3, heat transfer between working fluid and cooling fluid in the condenser can be expressed as follow:

\[ Q_c = m_{wf} \times (h_2 - h_3) = m_{cf} \times C_{cf} \times (T_x - T_y) \]  
(13)

5.3. Feed Pump Process

Working fluid pressure drops in the turbine because of the expanding effect. The pressure of the working fluid is returned to evaporation pressure at the pump. By using \( h_4 \) is working fluid enthalpy in Condition 4 (kJ/kg) and \( \eta_{pump} \) is pump efficiency, the power to be transferred to working fluid from the pump can be expressed as follow;

\[ W_{pump} = m_{wf} \times (h_4 - h_3) \]  
(14)

\[ h_4 = h_3 + \frac{(h_{4s} - h_3)}{\eta_{pump}} \]  
(15)

5.4. Heat Exchanger Process

There is a process of geothermal fluid transferring its heat to binary cycle working fluid in the heat exchanger. Pre-heater gives heat to increase working fluid to boiling point in Condition 5. Evaporation happens from Conditions 5-1 to working fluid. The minimum difference in temperature between entering geothermal fluid and the leaving geothermal fluid is known as “pinch point. Thus, the two-heat exchanger can be analyzed separately as follows

Pre-heater:

\[ Q_{ph} = m_b \times C_b \times (T_b - T_c) = m_{wf} \times (h_5 - h_4) \]  
(16)

Evaporator:

\[ Q_E = m_b \times C_b \times (T_a - T_b) = m_{wf} \times (h_1 - h_3) \]  
(17)

6. Result and Discussion

6.1. Downhole Pump Calculation

One parameter that can be considered to choose a suitable downhole pump type is the production casing diameter. Production casing diameter of X-1 well is 9 5/8 inches. The line shaft pump (LSP) and electrical submersible pump (ESP) have the minimum casing diameter requirement. The minimum well casing diameter for LSP is 13 3/8 inches and minimum well casing diameter for ESP is 4 1/2 inches. Since the production casing diameter of X-1 well is 9 5/8 inches, the suitable downhole pump type for X-1 well is an electrical submersible pump (ESP).

Downhole pump calculation can be carried out based on well condition and characteristics obtained from well testing and well flow simulation. The purpose of downhole pump calculation is to find out the most optimal technical parameters in installing the downhole pump, such as pump setting depth, optimal mass flow rate, total dynamic head, and brake horsepower.

Estimated depth setting of the pump around 200 meters above the well production zone (feed zone). Determination of the pump depth setting will impact the electrical power needed to drive the pump.
motor. With the production zone at a depth of 750 meters, the trial estimate of pump depth is set at several depth values of 500 - 600 meters.

The estimated pump setting depth is 150 - 300 meters above the production zone’s depth (feed zone). Determination of pump setting depth will impact brake horsepower and the mass flow rate of geothermal fluid. Optimal mass flow rate for each pump setting depth obtained from IPR curve with limitation pump suction pressure must be higher than boiling pressure and NPSH required. Table 5 shows the optimal mass flow rate, \( P_{wf} \), and total dynamic head for each pump setting depth.

**Table 5. Optimal Mass Flow Rate and Total Dynamic Head for Each Pump Setting Depth.**

| Pump Setting Depth (meter) | Feed Zone (meter) | \( P_{wf} \) (bar) | Mass Flow Rate (kg/s) | Pump Suction Pressure (bar) | Total Dynamic Head (meter) |
|---------------------------|------------------|-------------------|----------------------|-----------------------------|---------------------------|
| 500                       | 750              | 29                | 38.22                | 4.475                       | 518.16                    |
| 530                       | 750              | 26                | 41.24                | 4.418                       | 554.09                    |
| 550                       | 750              | 24                | 43.25                | 4.38                        | 578.47                    |
| 580                       | 750              | 21                | 46.27                | 4.323                       | 615.71                    |
| 600                       | 750              | 19                | 48.28                | 4.285                       | 641.02                    |

Based on optimal mass flow rate 38.22 kg/s – 48.28 kg/s or 20000 bbl/day – 26236 bbl/day and production casing size 9 5/8 inches, therefore two types of ESP selected based on those parameters (based on ESP manufacturer catalogue) shown in Table 6.[10] [15]

**Table 6. Minimum Requirement for LSP and ESP.**

| Pump Type | Minimum Well Casing (inches) | Optimum Range (bbl/day) |
|-----------|-----------------------------|-------------------------|
| ESP-1     | 8.625                       | 16000 – 25000           |
| ESP-2     | 7                           | 20000 – 30000           |

Optimal mass flow rate for each pump setting depth plotted on pump performance curve to find pump efficiency, brake horsepower per stage, and head per stage for two types ESP. Total stages required and total brake horsepower can be calculated based on those parameters. Brake horsepower for each pump setting depth and those two types ESP is shown in Table 7 and Table 8.

**Table 7. Brake Horsepower for Each Pump Setting Depth ESP-1.**

| Pump Setting Depth (meter) | Feed Zone (meter) | \( P_{wf} \) (bar) | Mass Flow Rate (kg/s) | Pump Suction Pressure (bar) | Total Dynamic Head (meter) | Brake Horsepower (kW) |
|----------------------------|------------------|-------------------|----------------------|-----------------------------|---------------------------|-----------------------|
| 500                        | 750              | 29                | 38.22                | 4.475                       | 518.16                    | 279.12                |
| 530                        | 750              | 26                | 41.24                | 4.418                       | 554.09                    | 332.45                |
| 550                        | 750              | 24                | 43.25                | 4.38                        | 578.47                    | 370.69                |
| 580                        | 750              | 21                | 46.27                | 4.323                       | 615.71                    | 436.89                |
| 600                        | 750              | 19                | 48.28                | 4.285                       | 641.02                    | 516.32                |
Table 8. Brake Horsepower for Each Pump Setting Depth ESP-2.

| Pump Setting Depth (meter) | Feed Zone (meter) | P_{wf} (bar) | Mass Flow Rate (kg/s) | Pump Suction Pressure (bar) | Total Dynamic Head (meter) | Brake Horsepower (kW) |
|----------------------------|-------------------|--------------|-----------------------|---------------------------|--------------------------|-----------------------|
| 500                        | 750               | 29           | 38.22                 | 4.475                     | 518.16                   | 48.54                 |
| 530                        | 750               | 26           | 41.24                 | 4.418                     | 554.09                   | 56.27                 |
| 550                        | 750               | 24           | 43.25                 | 4.38                      | 578.47                   | 60.90                 |
| 580                        | 750               | 21           | 46.27                 | 4.323                     | 615.71                   | 72.59                 |
| 600                        | 750               | 19           | 48.28                 | 4.285                     | 641.02                   | 79.51                 |

The comparison of each pump setting depth with mass flow rate and brake horsepower is shown in (Figure 6 and 7). A correlation of deeper pump setting depth will give a higher mass flow rate and high brake horsepower based on those graphs. Determining the most suitable pump setting depth will be done by comparing the net power output produced after the ORC power plant calculation.

Figure 6. Correlation of Pump Setting Depth with Mass Flow Rate and BHP ESP-1.
6.2. Organic Rankine Cycle (ORC) Power Plant Model Calculation

Organic Rankine Cycle (ORC) condition

The Organic Rankine Cycle (ORC) parameter and specifications for the model are set as follows:

- **Brine temperature**: 138°C
- **Wellhead Pressure**: 4 bara
- **Mass flow rate**: 48.28 kg/s (pump setting depth 600 m)
- **Pinch point**: 5°C
- **Turbine efficiency**: 90%
- **Feed pump efficiency**: 75%
- **Pre-Heater efficiency**: 90%
- **Evaporator efficiency**: 90%

**ORC Model Calculation Result**

A thermodynamic cycle model of ORC power plant schematic set up to enable detailed calculation. Optimal condition obtained by trying some values for turbine inlet pressure and condenser pressure. Based on the calculation, the correlation of change in turbine inlet pressure and condenser pressure is when the turbine inlet pressure and condenser pressure increase, ORC power output will decrease. It is shown in Figure 8 and Figure 9. The ORC model’s optimal condition with working fluid butane is at condition turbine inlet pressure 15.26 bara and condenser pressure 2.7 bara for mass flow rate 44.86 kg/s (pump setting depth 600 m).
There are four working fluids used in this research. Working fluids are selected based on technical and environmental aspects. Working fluids used at the ORC model are isopentane, isobutane, pentane, and butane. ORC model calculation has been carried out with each working fluid and optimal condition based on a variation on turbine inlet pressure and condenser pressure. Comparison of ORC power output and thermal efficiency produced by each working fluid is shown in Table 9. The most suitable working fluid is butane that produces the highest ORC power output and thermal efficiency. ORC power output produced by model calculation using butane working fluid is 1358.08 kW with a thermal efficiency of 12.52%.
**Table 9.** Comparison of ORC Power Output and Thermal Efficiency for Each Pump Setting Depth.

| Working Fluid | Turbine Inlet Pressure (bar) | Condenser Pressure (bar) | Q Turbine (kW) | ORC Power Output (kW) | Thermal Efficiency |
|---------------|------------------------------|--------------------------|----------------|-----------------------|-------------------|
| Isopentane    | 6.33                         | 1.50                     | 1325.28        | 1184.49               | 10.11%            |
| Isobutane     | 21.78                        | 4.00                     | 1705.11        | 1438.53               | 12.38%            |
| Pentane       | 4.70                         | 1.50                     | 1072.86        | 963.01                | 8.21%             |
| Butane        | 15.26                        | 2.70                     | 1677.80        | 1461.55               | 12.52%            |

Determination of optimal pump setting depth is based on Net Power Output that can be produced. Brake Horsepower can be obtained based on pump calculation and ORC model calculation produced ORC power output. Compiling results from pump calculation and ORC model calculation can produce Net Power Output for each pump setting depth (500 m – 600 m). Correlation of change in pump setting depth and Net Power Output is shown in Table 10 and Figure 10 for ESP-1, Table 11 and Figure 11 for ESP-2. The most optimal net power output is at 600 m pump setting depth that produces a Net Power output of 1,382 kW for the ORC model with butane working fluid combined with ESP-2.

**Table 10.** Net Power Output for Each Pump Setting Depth ESP-1.

| Pump Setting Depth (meter) | ORC Power Output (kW) | Brake Horsepower (kW) | Net Power Output (kW) |
|----------------------------|-----------------------|-----------------------|-----------------------|
| 500                        | 1157.06               | 279.12                | 877.94                |
| 530                        | 1248.43               | 332.45                | 915.98                |
| 550                        | 1309.3                | 370.69                | 938.61                |
| 580                        | 1400.67               | 436.89                | 963.78                |
| 600                        | 1461.55               | 516.32                | 945.23                |

**Figure 10.** Correlation between Pump Setting Depth and Net Power Output ESP-1.
Table 11. Net Power Output for Each Pump Setting Depth ESP-2

| Pump Setting Depth (meters) | ORC Power Output (kW) | Brake Horsepower (kW) | Net Power Output (kW) |
|-----------------------------|-----------------------|-----------------------|-----------------------|
| 500                         | 1157.06               | 48.54                 | 1108.52               |
| 530                         | 1248.43               | 56.27                 | 1192.16               |
| 550                         | 1309.3                | 60.90                 | 1248.40               |
| 580                         | 1400.67               | 72.59                 | 1328.08               |
| 600                         | 1461.55               | 79.51                 | 1382.04               |

Figure 11. Correlation between Pump Setting Depth and Net Power Output ESP-2.

7. Conclusion
Based on the well testing, X-1 well has the condition and characteristic with high permeability (transmissivity 60.5 darcy meter), low pressure, and low-medium temperature (139°C). So it is suitable to implement an artificial lift method such as a downhole pump on this well. Type of downhole pump that suitable for X-1 well is electrical submersible pump, and there are two types of ESP (ESP-1 and ESP-2) meet requirement condition (minimum well casing and optimum range) based on optimum range mass flow rate and production casing diameter of X-1 well. Optimum pump setting depth in 600 meters can produce a mass flow rate of 48.28 kg/s. The optimum model is an ORC power plant with Butane working fluid that can produce a net power output of 1.382 MW for the ORC power plant model combine with ESP-2.

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