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ANALYSIS OF GEOTHERMAL WELL PRODUCTION CAPABILITY BASED ON OUTPUT CURVE AND WELLBORE SIMULATION IN AAP FIELD

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Abstract

The assessment of geothermal well production capability plays a crucial role in optimizing geothermal energy generation systems. This study focuses on evaluating the performance of two geothermal wells, ZM-42 and ZM-31, located in the AAP Field, by developing output curves through wellbore simulation techniques. The analysis utilizes field production test results, well casing configuration data, and PTS (Pressure, Temperature, and Spinner) survey data to generate key parameters such as wellhead pressure, fluid flow rate, fluid temperature, enthalpy, and vapor fraction (dryness). These parameters are essential for understanding the thermal and flow characteristics of each well. Wellbore simulations were conducted using specialized software to replicate the flow behaviour of geothermal fluids within the well system. The output curves produced provide a graphical representation of the relationship between wellhead pressure and mass flow rate under various operating conditions. Validation of the simulation was done by comparing the generated curves with actual field measurements. The results show that well ZM-31 demonstrates a higher production capability compared to ZM-42. ZM-31 recorded a flow rate of 96.61 kg/s and an enthalpy of 1134.5 kJ/kg, with a vapor

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ANALYSIS OF GEOTHERMAL WELL PRODUCTION CAPABILITY BASED ON OUTPUT CURVE AND WELLBORE SIMULATION IN AAP FIELD

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Abstract

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I. INTRODUCTION

Geothermal energy is one of the renewable energy sources that has great potential to be developed as a sustainable power plant (Aloysius Afriandi, 2017). Compared to conventional energy sources such as coal and petroleum, geothermal has the advantage of being continuously available, environmentally friendly, and independent of weather conditions (Saptadji & Ashat, 2012). In the midst of increasing energy demand and global climate change issues, the utilization of geothermal energy is one of the strategic solutions in supporting the energy transition towards a greener and more sustainable system (Alhamri & Suryani, 2016).

In the process of geothermal exploration and development, evaluation of well production capability is a fundamental aspect that must be done carefully. The ability of a well to supply geothermal fluid in a stable and efficient manner determines the success of the plant operation (Wall & Dobson, 2016). This evaluation includes not only the characteristics of the reservoir below the surface, but also how the fluid moves through the well to the surface facilities. Therefore, a thorough understanding of fluid behavior and well systems is critical to ensure the technical and economic viability of a geothermal field (Malcolm A. Grant dan Paul F. Bixley, 2011).

One method used to assess the production performance of geothermal wells is through the creation of an output curve. The output curve is a graph that illustrates the relationship between wellhead pressure (WHP) and mass flow rate (Saptadji, 2001). This graph provides an overview of the well's ability to flow fluid at various pressure conditions, thus providing an important basis for designing the optimal operating pressure. By understanding this relationship, operators can maximize fluid production without exceeding the well's capability (Welldon, 2015).

Output curve generation is based on production test data as well as the results of wellbore simulation, which utilizes well casing configuration information, and PTS (pressure, temperature, and spinner) surveys. These simulations yield important parameters such as wellhead pressure, temperature, and vapor fraction (dryness), all of which are needed to accurately construct the output curve graph (Malcolm A. Grant dan Paul F. Bixley, 2011). This method not only provides a technical overview of well conditions, but also helps in making operational decisions in the field (Fachrizal, 2024).

By analyzing the output curve, the performance and efficiency of geothermal fluid production from a well can be measured more precisely and quantifiably (Lempesis et al., 2023). This is important in order to improve the reliability of fluid supply to power plants and optimize the utilization of available geothermal resources. Therefore, the study of the output curve is an important part of geothermal field development studies and needs to be carried out systematically in every stage of exploration and exploitation (Water & Republic, 2008).

II. METHODOLOGY

In this final study, the research process begins with a literature review as a theoretical basis that supports the analysis. This review includes books, technical reports, and scientific journals relevant to geothermal reservoir systems, fluid production mechanisms, and well performance evaluation methods. The purpose of this literature review is to obtain a comprehensive understanding of the basic concepts

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and technical approaches commonly used in geothermal well analysis, especially in the production of output curve as an evaluation tool.

The data used in this study are sourced from the results of field production tests and PTS (pressure, temperature, and spinner) surveys conducted on geothermal wells. The data are then processed through wellbore simulation using specialized software to produce an output curve. This curve presents the relationship between wellhead pressure and fluid mass flow rate, and allows the identification of other well characteristic parameters such as vapor fraction (dryness), fluid temperature, flow rate, and enthalpy. The results of these simulations form the basis for assessing well performance and help determine the most optimal operating strategy.

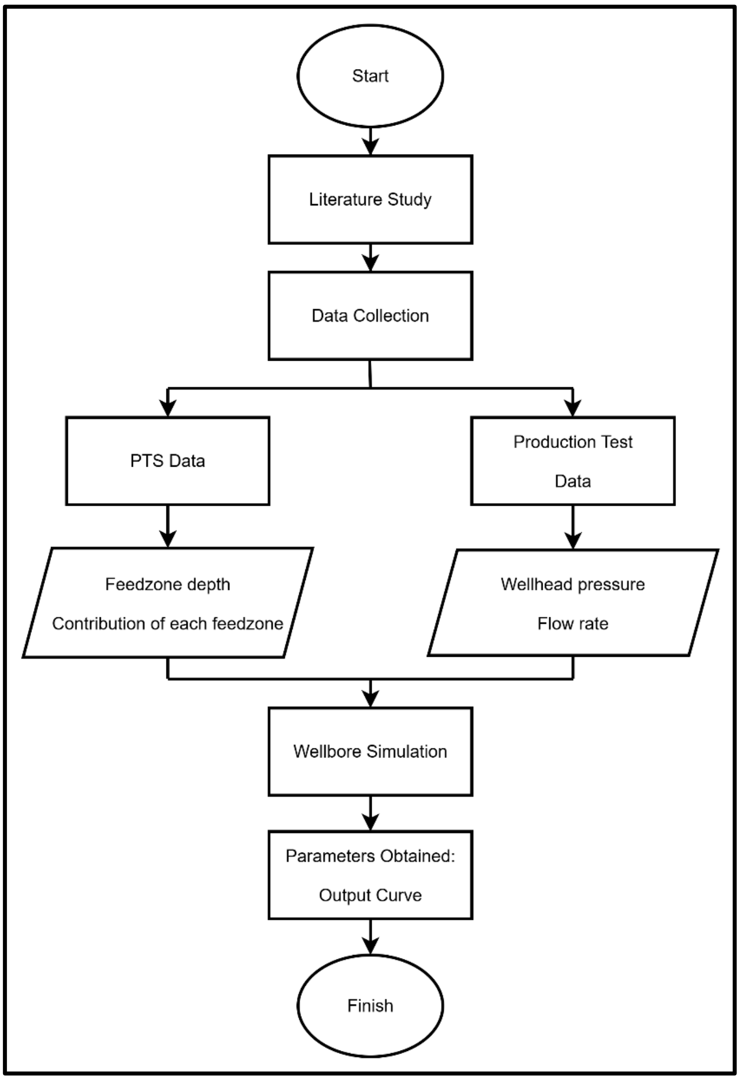

Figure 2. 1 Flow Chart

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III. RESULTS AND DISCUSSION

The initial stage in the simulation process involves collecting data from three main sources, namely production test data, casing configuration data, and PTS (pressure, temperature, spinner) survey data. Data taken from the production test results include pressure and fluid flow rate. Meanwhile, in the casing configuration, the parameters used include section length (mMD), vertical extent (mTVD), and casing identifier. The data obtained from the PTS survey consists of depth, flow rate, reservoir pressure, and reservoir temperature.

The three types of data are then entered into the wellbore simulation software. Production test data is input into the Wellhead Conditions table, casing data is entered in the Casing Geometry table, while the PTS survey data is input into the Feedpoints table. An illustration of data entry in each table can be seen in Figure 3. as follows.

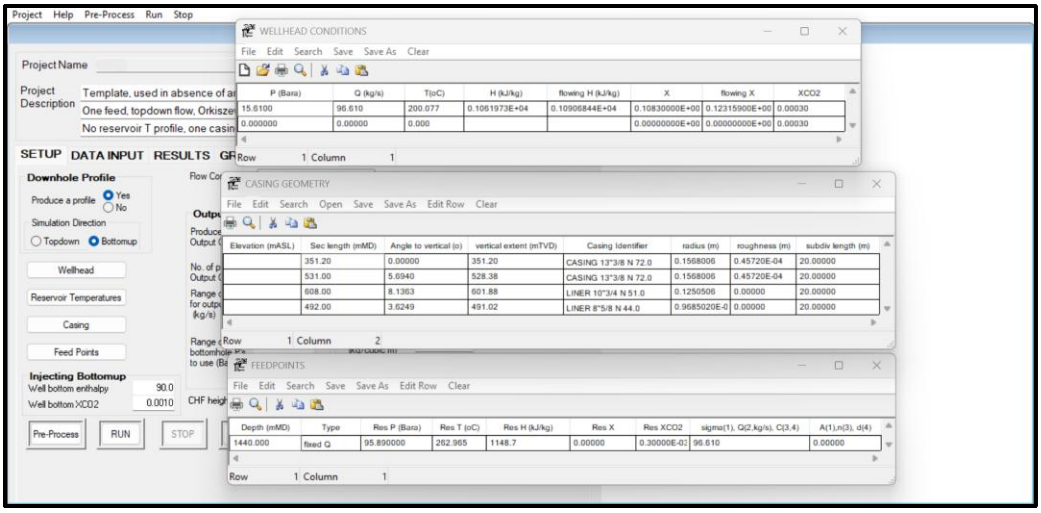

Figure 3. 1 Wellbore Simulation

After all the data is entered into the software, the simulation process continues by running the pre-process and run functions. This step will produce output curves and results that show the characteristics of the well performed by the wellbore simulation. These results provide a visualization of well performance based on the parameters that have been inputted previously. The output curve and result of the wellbore simulation can be seen in detail in Figure 3.2 and Figure 3.3 as follows.

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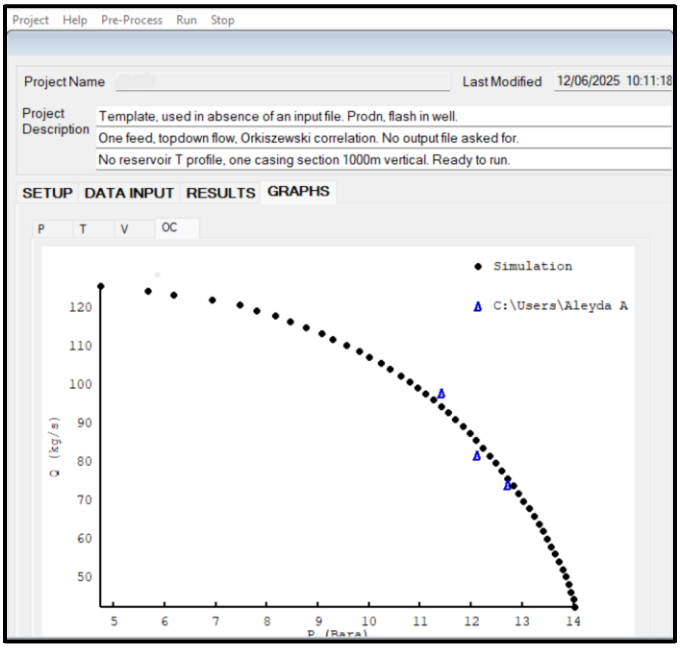

Figure 3. 2 Output Curve ZM-42

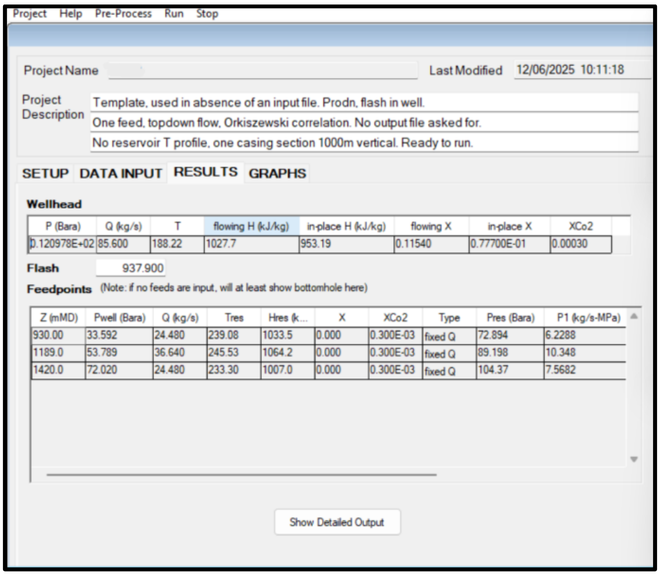

Figure 3. 3 Result ZM-31

The following is the output curve and result of wellbore simulation at well ZM-31 which can be seen in Figure 3.4 and Figure 3.5.

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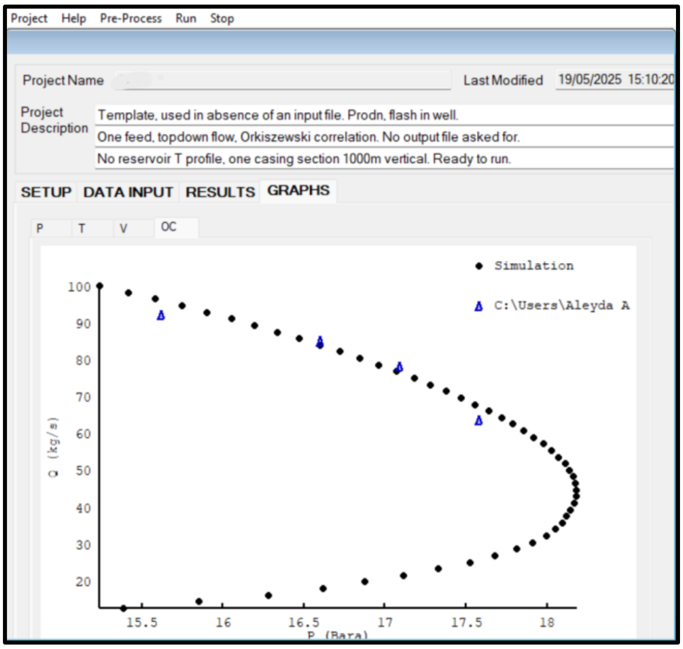

Figure 3. 4 Output Curve ZM-31

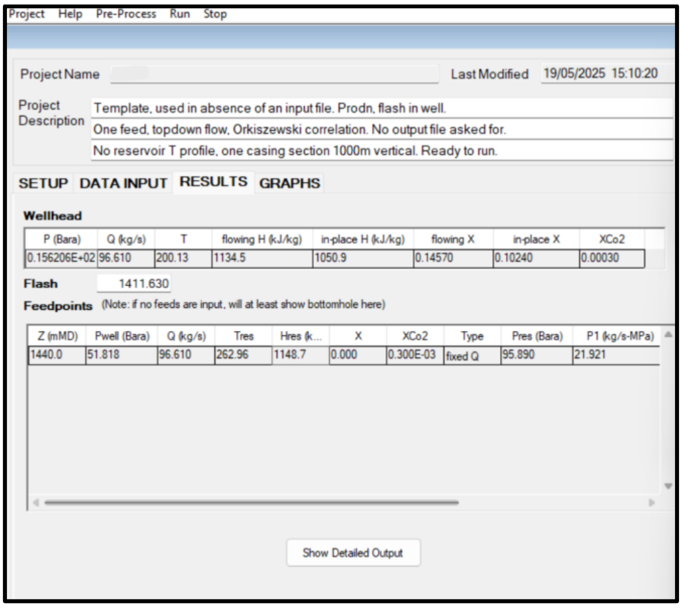

Figure 3. 5 Result ZM-31

Figure 3.2 and Figure 3.4 show the output curve that illustrates the relationship between wellhead pressure (WHP) and fluid mass flow rate (Q). These graphs are obtained through wellbore simulation and are used to evaluate the production capability of geothermal wells under various pressure conditions.

The output curve can be said to be valid when it is matched with the measured data (production test), which is shown in the form of a blue dot on the output curve. If the simulation curve shows

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matching with the data and reaches Maximum Discharge Pressure (MDP), which is the maximum pressure limit at which the well can still flow fluid to the surface, then the graph is considered accurate and can be used as a basis for analyzing the performance and production potential of the well.

Meanwhile, Figure 3.3 and Figure 3.5 show the results of wellbore simulations that describe the characteristics of geothermal fluids in the wellhead and reservoir zones. Parameters at the wellhead include wellhead pressure (WHP), wellhead temperature (WHT), total flow rate (potential flow), enthalpy, vapor fraction (dryness). The dryness value is used to separate the flow rate of steam and water (brine) based on each phase.

Meanwhile, in the reservoir zone (Feedpoints), the simulation shows data on the fracture zone depth (feedzone), reservoir pressure and temperature, fluid enthalpy, and flow rate of each feedzone. This data is important to assess the contribution of each feedzone to the total well production. Overall, the simulation results provide a comprehensive picture that supports the design of geothermal production systems efficiently and in accordance with well characteristics.

The wellbore simulation results for well ZM-42 located in Field X can be seen in Table 3.1 as follows.

Table 3. 1 Wellbore Simulation Results ZM-42

		WELLHEAD		
P (bara)	**Q (kg/s)**	**T (°C)**	**H (kJ/kg)**	**Flowing X**
0.12	85.60	188.22	1027.7	0.11
		FEEDPOINTS		
Ked. (mMD)	**Pres (bara)**	**Q (kg/s)**	**Tres (°C)**	**Hres (kJ/kg)**
930	72.89	24.48	239.08	1033.5
1189	89.19	36.64	245.53	1064.2
1420	104.37	24.48	233.30	1007.0

The wellbore simulation results for well ZM-31 located in Field X can be seen in Table 3.2 as follows.

Table 3. 2 Wellbore Simulation Results ZM-31

		WELLHEAD		
P (bara)	**Q (kg/s)**	**T (°C)**	**H (kJ/kg)**	**Flowing X**
0.15	96.61	200.13	1134.5	0.14
		FEEDPOINTS		
Ked. (mMD)	**Pres (bara)**	**Q (kg/s)**	**Tres (°C)**	**Hres (kJ/kg)**
1440	51.81	96.61	262.96	1148.7

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IV. CONCLUSION

Based on the results of wellbore simulations conducted on wells ZM-42 and ZM-31 in Field X, it can be concluded that the two wells have different production characteristics, both in terms of their flow potential and fluid thermal parameters. The ZM-31 well shows higher production performance than ZM-42, with a fluid flow rate of 96.61 kg/s and a wellhead temperature of 200.13°C, and fluid enthalpy of 1134.5 kJ/kg. Meanwhile, well ZM-42 has a flow rate of 85.60 kg/s with a lower temperature and enthalpy of 188.22°C and 1027.7 kJ/kg, respectively.

In addition, the vapor fraction (dryness) in well ZM-31 is also higher (0.14) than ZM-42 (0.11), indicating the potential for more optimal separation of vapor and brine. In terms of feedzones, ZM-31 has one dominant zone at 1440 mMD that accounts for the overall flow rate, while ZM-42 has flow distribution from three different feedzones. Overall, the output curve results and simulation visualization indicate that ZM-31 is superior in production capacity, thus more to be optimized as the main production well in the geothermal energy generation system at AAP Field.

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VI. LITERATURE

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ANALYSIS OF GEOTHERMAL WELL PRODUCTION CAPABILITY BASED ON OUTPUT CURVE AND WELLBORE SIMULATION IN AAP FIELD

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Abstract

The assessment of geothermal well production capability plays a crucial role in optimizing geothermal energy generation systems. This study focuses on evaluating the performance of two geothermal wells, ZM-42 and ZM-31, located in the AAP Field, by developing output curves through wellbore simulation techniques. The analysis utilizes field production test results, well casing configuration data, and PTS (Pressure, Temperature, and Spinner) survey data to generate key parameters such as wellhead pressure, fluid flow rate, fluid temperature, enthalpy, and vapor fraction (dryness). These parameters are essential for understanding the thermal and flow characteristics of each well. Wellbore simulations were conducted using specialized software to replicate the flow behaviour of geothermal fluids within the well system. The output curves produced provide a graphical representation of the relationship between wellhead pressure and mass flow rate under various operating conditions. Validation of the simulation was done by comparing the generated curves with actual field measurements. The results show that well ZM-31 demonstrates a higher production capability compared to ZM-42. ZM-31 recorded a flow rate of 96.61 kg/s and an enthalpy of 1134.5 kJ/kg, with a vapor fraction of 0.14. In contrast, ZM-42 exhibited a lower flow rate of 85.60 kg/s, enthalpy of 1027.7 kJ/kg, and a vapor fraction of 0.11. These differences indicate superior separation efficiency and thermal performance in ZM-31. Furthermore, ZM-31's production is dominated by a single feed zone, while ZM-42 relies on multiple contributing zones. In conclusion, based on output curve analysis and well simulation results, ZM-31 is recommended as the primary production well for further optimization in the AAP geothermal field, contributing to more efficient and reliable energy output.

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I. INTRODUCTION

Geothermal energy is one of the renewable energy sources that has great potential to be developed as a sustainable power plant (Aloysius Afriandi, 2017). Compared to conventional energy sources such as coal and petroleum, geothermal has the advantage of being continuously available, environmentally friendly, and independent of weather conditions (Saptadji & Ashat, 2012). In the midst of increasing energy demand and global climate change issues, the utilization of geothermal energy is one of the strategic solutions in supporting the energy transition towards a greener and more sustainable system (Alhamri & Suryani, 2016).

In the process of geothermal exploration and development, evaluation of well production capability is a fundamental aspect that must be done carefully. The ability of a well to supply geothermal fluid in a stable and efficient manner determines the success of the plant operation (Wall & Dobson, 2016). This evaluation includes not only the characteristics of the reservoir below the surface, but also how the fluid moves through the well to the surface facilities. Therefore, a thorough understanding of fluid behavior and well systems is critical to ensure the technical and economic viability of a geothermal field (Malcolm A. Grant dan Paul F. Bixley, 2011).

One method used to assess the production performance of geothermal wells is through the creation of an output curve. The output curve is a graph that illustrates the relationship between wellhead pressure (WHP) and mass flow rate (Saptadji, 2001). This graph provides an overview of the well's ability to flow fluid at various pressure conditions, thus providing an important basis for designing the optimal operating pressure. By understanding this relationship, operators can maximize fluid production without exceeding the well's capability (Welldon, 2015).

Output curve generation is based on production test data as well as the results of wellbore simulation, which utilizes well casing configuration information, and PTS (pressure, temperature, and spinner) surveys. These simulations yield important parameters such as wellhead pressure, temperature, and vapor fraction (dryness), all of which are needed to accurately construct the output curve graph (Malcolm A. Grant dan Paul F. Bixley, 2011). This method not only provides a technical overview of well conditions, but also helps in making operational decisions in the field (Fachrizal, 2024).

By analyzing the output curve, the performance and efficiency of geothermal fluid production from a well can be measured more precisely and quantifiably (Lempesis et al., 2023). This is important in order to improve the reliability of fluid supply to power plants and optimize the utilization of available geothermal resources. Therefore, the study of the output curve is an important part of geothermal field development studies and needs to be carried out systematically in every stage of exploration and exploitation (Water & Republic, 2008).

II. METHODOLOGY

In this final study, the research process begins with a literature review as a theoretical basis that supports the analysis. This review includes books, technical reports, and scientific journals relevant to geothermal reservoir systems, fluid production mechanisms, and well performance evaluation methods. The purpose of this literature review is to obtain a comprehensive understanding of the basic concepts

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and technical approaches commonly used in geothermal well analysis, especially in the production of output curve as an evaluation tool.

The data used in this study are sourced from the results of field production tests and PTS (pressure, temperature, and spinner) surveys conducted on geothermal wells. The data are then processed through wellbore simulation using specialized software to produce an output curve. This curve presents the relationship between wellhead pressure and fluid mass flow rate, and allows the identification of other well characteristic parameters such as vapor fraction (dryness), fluid temperature, flow rate, and enthalpy. The results of these simulations form the basis for assessing well performance and help determine the most optimal operating strategy.

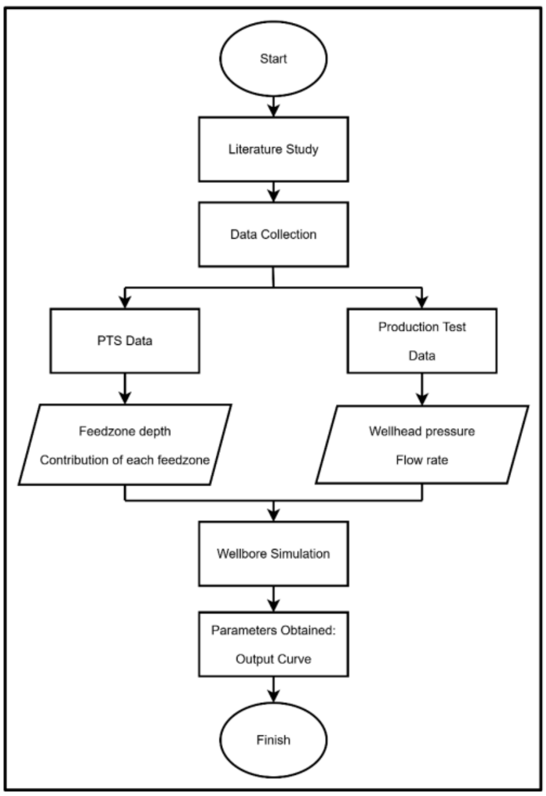

Figure 2. 1 Flow Chart

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III. RESULTS AND DISCUSSION

The initial stage in the simulation process involves collecting data from three main sources, namely production test data, casing configuration data, and PTS (pressure, temperature, spinner) survey data. Data taken from the production test results include pressure and fluid flow rate. Meanwhile, in the casing configuration, the parameters used include section length (mMD), vertical extent (mTVD), and casing identifier. The data obtained from the PTS survey consists of depth, flow rate, reservoir pressure, and reservoir temperature.

The three types of data are then entered into the wellbore simulation software. Production test data is input into the Wellhead Conditions table, casing data is entered in the Casing Geometry table, while the PTS survey data is input into the Feedpoints table. An illustration of data entry in each table can be seen in Figure 3. as follows.

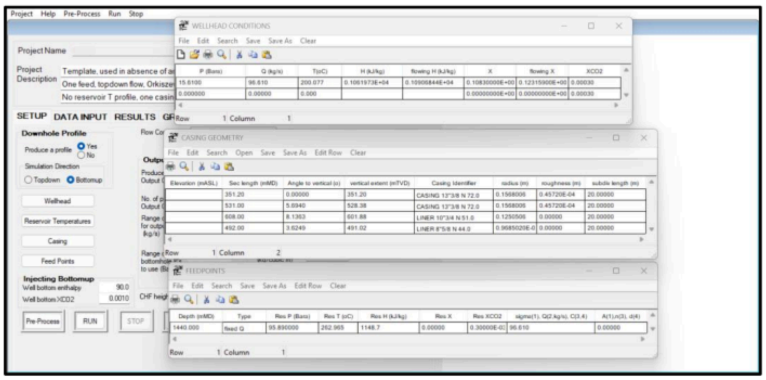

Figure 3. 1 Wellbore Simulation

After all the data is entered into the software, the simulation process continues by running the pre-process and run functions. This step will produce output curves and results that show the characteristics of the well performed by the wellbore simulation. These results provide a visualization of well performance based on the parameters that have been inputted previously. The output curve and result of the wellbore simulation can be seen in detail in Figure 3.2 and Figure 3.3 as follows.

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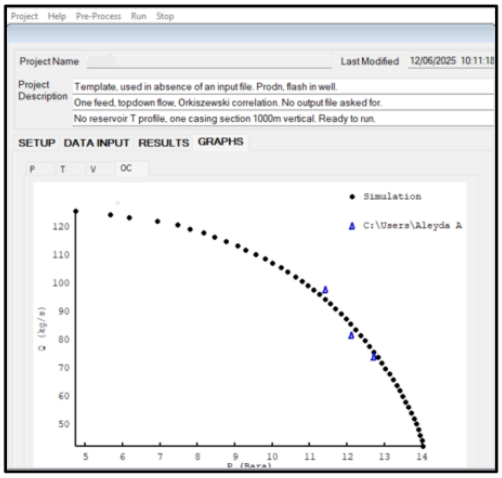

Figure 3. 2 Output Curve ZM-42

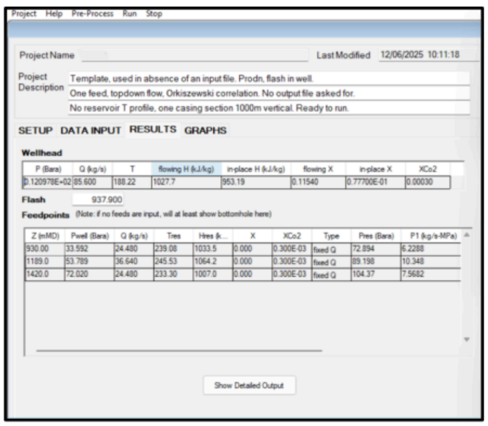

Figure 3. 3 Result ZM-31

The following is the output curve and result of wellbore simulation at well ZM-31 which can be seen in Figure 3.4 and Figure 3.5.

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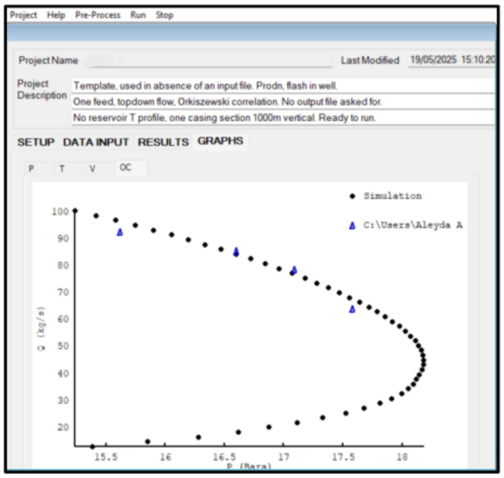

Figure 3. 4 Output Curve ZM-31

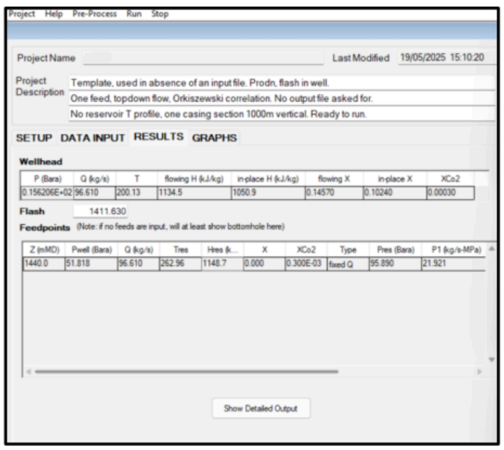

Figure 3. 5 Result ZM-31

Figure 3.2 and Figure 3.4 show the output curve that illustrates the relationship between wellhead pressure (WHP) and fluid mass flow rate (Q). These graphs are obtained through wellbore simulation and are used to evaluate the production capability of geothermal wells under various pressure conditions.

The output curve can be said to be valid when it is matched with the measured data (production test), which is shown in the form of a blue dot on the output curve. If the simulation curve shows

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matching with the data and reaches Maximum Discharge Pressure (MDP), which is the maximum pressure limit at which the well can still flow fluid to the surface, then the graph is considered accurate and can be used as a basis for analyzing the performance and production potential of the well.

Meanwhile, Figure 3.3 and Figure 3.5 show the results of wellbore simulations that describe the characteristics of geothermal fluids in the wellhead and reservoir zones. Parameters at the wellhead include wellhead pressure (WHP), wellhead temperature (WHT), total flow rate (potential flow), enthalpy, vapor fraction (dryness). The dryness value is used to separate the flow rate of steam and water (brine) based on each phase.

Meanwhile, in the reservoir zone (Feedpoints), the simulation shows data on the fracture zone depth (feedzone), reservoir pressure and temperature, fluid enthalpy, and flow rate of each feedzone. This data is important to assess the contribution of each feedzone to the total well production. Overall, the simulation results provide a comprehensive picture that supports the design of geothermal production systems efficiently and in accordance with well characteristics.

The wellbore simulation results for well ZM-42 located in Field X can be seen in Table 3.1 as follows.

Table 3. 1 Wellbore Simulation Results ZM-42

WELLHEAD				
P (bara)	**Q (kg/s)**	**T (°C)**	**H (kJ/kg)**	**Flowing X**
0.12	85.60	188.22	1027.7	0.11
FEEDPOINTS				
Ked. (mMD)	**Pres (bara)**	**Q (kg/s)**	**Tres (°C)**	**Hres (kJ/kg)**
930	72.89	24.48	239.08	1033.5
1189	89.19	36.64	245.53	1064.2
1420	104.37	24.48	233.30	1007.0

The wellbore simulation results for well ZM-31 located in Field X can be seen in Table 3.2 as follows.

Table 3. 2 Wellbore Simulation Results ZM-31

WELLHEAD				
P (bara)	**Q (kg/s)**	**T (°C)**	**H (kJ/kg)**	**Flowing X**
0.15	96.61	200.13	1134.5	0.14
FEEDPOINTS				
Ked. (mMD)	**Pres (bara)**	**Q (kg/s)**	**Tres (°C)**	**Hres (kJ/kg)**
1440	51.81	96.61	262.96	1148.7

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IV. CONCLUSION

Based on the results of wellbore simulations conducted on wells ZM-42 and ZM-31 in Field X, it can be concluded that the two wells have different production characteristics, both in terms of their flow potential and fluid thermal parameters. The ZM-31 well shows higher production performance than ZM-42, with a fluid flow rate of 96.61 kg/s and a wellhead temperature of 200.13°C, and fluid enthalpy of 1134.5 kJ/kg. Meanwhile, well ZM-42 has a flow rate of 85.60 kg/s with a lower temperature and enthalpy of 188.22°C and 1027.7 kJ/kg, respectively.

In addition, the vapor fraction (dryness) in well ZM-31 is also higher (0.14) than ZM-42 (0.11), indicating the potential for more optimal separation of vapor and brine. In terms of feedzones, ZM-31 has one dominant zone at 1440 mMD that accounts for the overall flow rate, while ZM-42 has flow distribution from three different feedzones. Overall, the output curve results and simulation visualization indicate that ZM-31 is superior in production capacity, thus more to be optimized as the main production well in the geothermal energy generation system at AAP Field.

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VI. LITERATURE

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