International Journal of Recent Trends in Engineering & Research
ISSN (ONLINE) : 2455 – 1457
IMPACT FACTOR : 4.101

MODEL OF TEMPERATURE DISTRIBUTION GEOTHERMAL PESANGGRAHAN GEOTHERMAL SYSTEM, CENTRAL JAVA, INDONESIA

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Abstract— The Pesanggrahan geothermal field is located at Central Java, Indonesia. A numerical model proposes to understand the temperature distribution since the steady state condition up to transient model. The first step of research method was running the temperature simulation to determine the temperature background from the surface to the bottom of volcanic body on the steady state model. We assumed that there is no magma in the steady state model. Background temperature distribution and pattern of mass fluxes calculate for 100,000 years to get the steady-state condition. The next step is modelling temperature and pressure distribution caused by the magma intrusion. The final result shows that high-temperature reservoir has a good correlation to the geothermal manifestations of Sileri that has been research by Layman et.al. (2002), we interpret that the reservoir is located at a depth between 2000 - 2300 m with a temperature range from 300-350 °C. The intrusion model also contributed the mass flux flow pattern of water from the reservoir to the surface as the upflow zone (that is Sileri hot water manifestation and the outflow zone was discharged to the south and the north directions.

Keywords—Pesanggrahan, Hydrothermal, simulations, temperature, pressure

I. INTRODUCTION

Geothermal systems in Indonesia generally originate from volcanic affiliate systems. This system is characterized by the appearance of surface manifestations around the area. According to the direct surface manifestations will be found in many geothermal systems that have high reservoir temperatures (> 220 ^{o}C)[1]. The emergence of geothermal manifestations in the form of warm springs certainly attracts attention for research on subsurface interpretation using geophysical methods.

Geothermal manifestation area Dieng is located on the volcanic plateau of Dieng, Central Java, Indonesia at an altitude of about 2000 meters above sea level. Geothermal manifestations of Sileri hot water have high temperature production with reservoir temperatures at a depth of 2000-2300 ranging from 300-335 ^{o}C [2].

Surface manifestations also appear in the north east of the area of Dieng Geothermal manifestations in the form of hot springs located in the Sangubanyu area. The manifestation of the Sangubanyu hot spring is located in the village of Pesanggrahan, Bawang Subdistrict, Batang Regency and located in the northern part of the Dieng geothermal area. Sangubanyu is topographically located at an altitude of 775 m above sea level and is geographically located in the southeast of the capital city of Batang Regency. At present there is no research that explains the geothermal system from the manifestations of Sangubanyu hot water.

Research to find out the relationship between the manifestations of Sangubanyu and Dieng hot water can be done by describing the subsurface temperature distribution using numerical analysis. It can be indicated that Sangubanyu is an outflow zone of the Dieng geothermal system. Modeling the subsurface temperature distribution is done by forward modeling which can show the temperature distribution in the next few years and see steady state responses from the hydrothermal system of the research area to the heat source. In this modeling using physical parameters in the form of temperature and surface pressure.

In this study modeling the subsurface temperature distribution of the geothermal manifestation area of Dieng to Sangubanyu was done numerically using the help of HYDROTHERM 2.2 software introduced by Hayba and Ingebritsen in 1994 [3]. 2D modeling can predict the subsurface temperature distribution values of existing geothermal systems. By combining the results of modeling and supporting information, namely geological data, appearance in the field, and the results of research that has been conducted around the research area, it is expected to produce a model of subsurface temperature distribution and subsurface fluid flow that can explain the formation of geothermal systems in the research. It is expected that the results of this modeling will be able to provide information on the distribution of the subsurface temperature of Dieng to Sangubanyu as a tool for developing the exploration phase of existing geothermal resources.

II. CONCEPTUAL MODEL

Geothermal system is the process of convection of water in the upper crust in a limited space and flowing heat from the heat source to heat absorption on the surface. Surface water (meteoric water) originating from the sea, lakes, rivers, rain and others seeps beneath the surface into ground water, flows and comes into contact with the body of the magma in the form of hot igneous rocks in the reservoir which will warm up to moisture and hot water (hydrothermal) which is one of the natural energy resources. Conduction heat transfer occurs through direct contact between heat sources and rocks, while convection heat transfer occurs due to contact between water and heat sources (Saptadji, 2012).

Indications of the existence of a geothermal system in an area can be seen based on the presence or absence of geothermal manifestations that appear on the surface due to certain physical and geological conditions that cause hot water to rise to the surface due to hot fluids flowing and interacting with geological structures either through fracture zones and cesarean [4]. Symptoms of geothermal appearance on the surface in the form of hot springs, hot soil, geysers, fumarole, solfatara [5].

Geothermal energy sources come from magma which is inside the earth. Magma acts as a hot rock that conducts conductively heat to the surrounding rock [6]. Convection heat transfer occurs in hydrothermal fluid inside the pores of the rock, then this hydrothermal fluid will move upward through rocks that have large permeability and will be retained by impermeable (clay cap) rock layers so that it is not easily penetrated or passed both by fluid and steam [7]. Productive geothermal reservoirs must have high porosity and permeability, large size, high temperature, and sufficient fluid content. Permeability is produced by stratigraphic characteristics and structural elements. The skirt cap which has low permeability is very necessary to cover the reservoir is very necessary to prevent the escape of hot fluid accumulation in the reservoir

Generally the classification of geothermal systems is based on several aspects such as fluid origin, fluid temperature in the reservoir, and type of heat source. Geothermal systems based on fluid origin are divided into two, namely cyclic system and storage system. Cyclic system that is when a fluid from a geothermal system originates from meteoric water which experiences infiltration and enters deep beneath the surface, then heats up, and moves up to the surface as a hot fluid. Storage systems are formed when water is stored in rocks in a geological time scale that is long enough and insituely heated, both as a fluid in formation and as water from the hydration process in minerals [8].

There are several different standards in determining the classification based on the temperature of this reservoir. Classify the reservoir temperature <150^{o}C as a low temperature system, and a reservoir with a temperature of ≥ 150 ^{o}C is classified as a high temperature system. geothermal systems into three, namely low temperature, medium temperature (intermediate) and high temperature. Low temperature systems have reservoir temperatures <125^{o}C, medium temperature systems have reservoir temperature ranges between 125^{o}C - 225^{o}C, while high temperature systems have reservoir temperatures > 225^{o}C [1].

There are two types of geothermal systems based on their heat sources, namely volcanogenic and non-volcanogenic. Volcanogenic system is a geothermal system whose source of heat comes from magma activity. Non-volcanogenic system is a geothermal system whose source of heat is not related to volcanic activity [9].

III. NUMERICAL MODEL

In solving a problem, it can be solved numerically with the help of computers using numerical methods, nowadays computing is done in real-time with processes that can be controlled simultaneously and quickly. Some basic numerical methods can be learned to solve practical problems such as iteration, interpolation, integration, and differentiation solutions. The computational process with numerical methods is done through the stages of modeling, selection of mathematical methods, programming, computational execution, and interpretation of results [10].

Numerical construction of the hydrothermal system can be modeled numerically using the Hydrotherm2.2 program [3]. This program can calculate multi-phase flow of muni and steam in the temperature range 0 ^oC to 1200 ^oC and pressure in the range of 0.5 to 10,000 bar. Surface temperature can be obtained by an empirical formula formulated by Minakami.

$$T = T_0 - 0{,}0061\left(\frac{^oC}{m}\right) \times H \qquad (1)$$

where T_0 is the reference starting temperature (^oC) and H is the surface height (m). The subsurface temperature will increase with increasing depth of 0.046 ^oC / m. The vertical pressure distribution is expressed as hydrostatic and the surface boundary pressure value is 1,013 bar, this indicates that the hydrological boundary conditions on the surface are permeable. In areas that do not yet have geological information such as well data, all physical parameters are assumed to be homogeneous, including the nature of rocks [11]

The variables used in this study were input data on topography, pressure, and surface temperature of the study area. The main instrument used in modeling this hydrothermal system is a computer device, the Asus A4551 laptop, with interCore specifications 16-4210U up to 2.7 GHz, 4GB Ram, Nvidia Geforce 820M, which is used to process numerical data and 2D modeling.

Supporting instruments used in this study are: Software Hydrotherm2.2, used to process the calculation of temperature distribution, pressure, flow of water mass flux and flow of water vapor from the input of notepad ++ software program listing in .in format, Notepad ++ software, used to create program listings from the initial model, initial pressure and initial temperature and become the editor of the output of the Hydrotherm2.2 software. Global Mapper 18 software, used to create a topographic map of the boundary of the research area by dividing it into a grid of blocks to determine the topographic value point. Microsoft Exel software, used to process topographic data until the initial model is formed, initial pressure distribution, and initial temperature distribution as input to be used as program listing Software Origin 2017, used to make an overview of 2D modeling of hydrothermal systems.

IV. RESULT AND DISCUSSION

The map boundary of the research area is from the area of Dieng geothermal manifestation which has numerical research previously up to Sangubanyu as a research object with an area of 17867 × 21366 m (as shown on figure 1) to be 21 × 21 blocks with a thickness of block area between 100 to 2366 m (figure 2). Topographic modeling of the research area is intended to facilitate the insertion of physical parameters on the grid, blocks, and slices. Grid distribution in the research area is based on research objects, namely the manifestations of Dieng and Sangubanyu Geothermal Heat. So that in the area the distance between grids is smaller and tight.

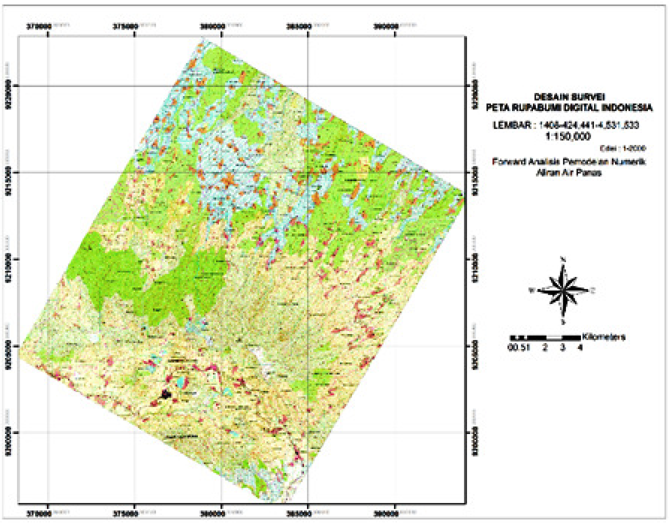

Figure 1. The coverage area of the research

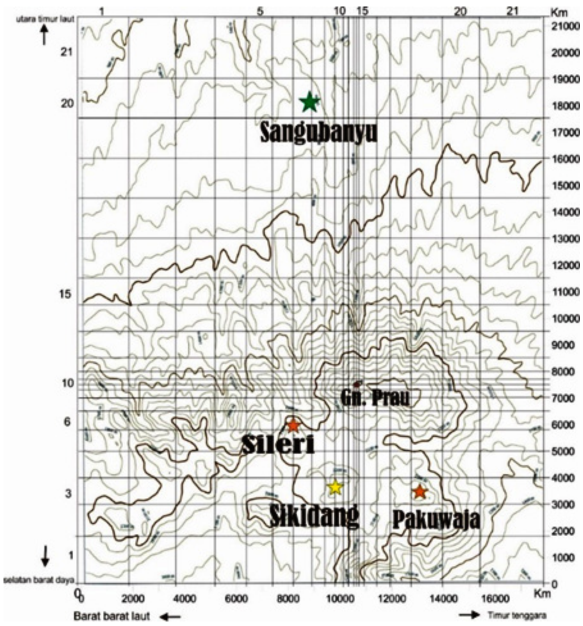

Figure 2. Grid division blocks of the research area

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The next model is to divide into 20 layers in a vertical direction with different thicknesses from 100 m to 2000 m. Vertical topographic initial modeling is taken from the slice which has the highest elevation point, which is at slice 10, directed east southeast - west northwest as shown in Figure 3.

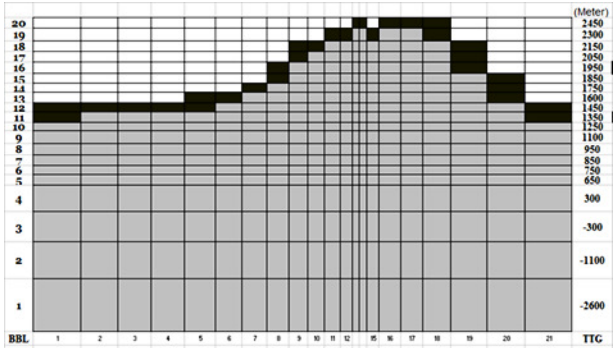

Figure 3. The initial 2D model of the topography is vertically trending east-west-northwest

Making numerical models of subsurface temperature distribution begins with making numerical block construction containing physical rock parameters in the study area. These parameters are in the form of permeability, porosity, specific heat and heat conductivity [3]. Permeability is considered to be the most important parameter in controlling fluid flow in a geothermal system. In this study rock types are made in heterogeneous and isotropic characters. From previous studies the value of permeability was determined from well testing and obtained values from 1.3 to 6.5 darcy-m. Other rock physical parameters have the same values for all rocks, namely the density type 2500 Kg / m3, porosity 0.1, thermal conductivity 2.5 W / m K, and specific heat 1000 J / Kg K [12].

The surface of each block has a constant value and there is no fluid flow in the block boundaries. In HYDROTHERM2.2 [3] to index blocks that can flow between blocks of user input the active block input label includes positive integer values, constant blocks with -1, and inactive blocks with values of 0. Vertical pressure distribution using the concept of hydrostatic pressure with the pressure at the ground level is set at the value of 1,013 bar. Vertical temperature distribution follows the empirical formula of temperature gradient according to the height point with temperature at ground level according to [12] at an altitude of 2000 masl, the manifestation area of dieng has a constant temperature of 15^{o}C.

Steady state models are made with the aim of obtaining a state of natural temperature distribution beneath the surface of the manifestation without any heat source disturbance in it to obtain steady state of the subsurface temperature distribution calculated up to 100,000 years with the reason that the calculation time is so long which affects the circulation of meteoric water which takes a very long time to get deeper into the surface. Calculation of 80,000 years is needed to get steady state which in the following years there has been no change in temperature distribution This steady state modeling uses slice 8 south-west - north east with 500 m block thickness, this slice cuts the Sikidang manifestation area, Sileri, and Sangubanyu.

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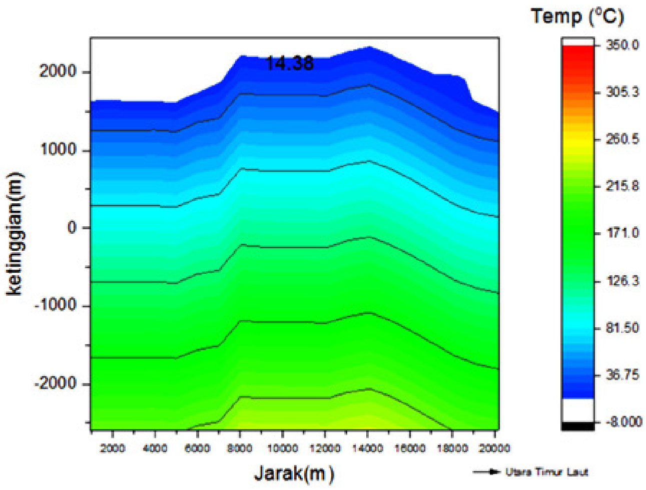

Figure 4. Modeling steady state distribution of subsurface temperature slice 8 in year 0

The results of steady state modeling of subsurface temperature distribution of slice 8 north-northeast in the 0 year range will be presented in Figure 6 with an altitude range from 2600 m below the surface to 2500 m above the surface. Based on previous research information, namely at an altitude of 2000, the Dieng area has a constant temperature of 15 oC. By assuming a sub-homogeneous, isotropic rock layer and calculation of the vertical distribution of hydrostatic pressure and temperature.

Temperatures at a height of 2000 m ranged from 14-15 ^{o}C and this is in accordance with previous studies in the study area. then proceed with modeling steady state subsurface temperature distribution for 100,000 years coming in with a range of 20,000 years which will be presented in Figure 5 shows the temperature of the the simulation 100,000th year.

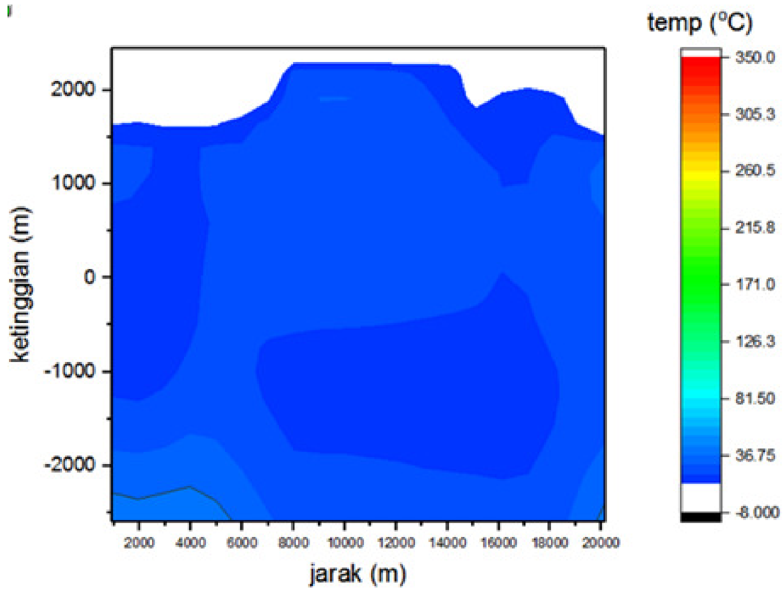

Figure 5. Steady state model shows subsurface temperature distribution slice8 in the 100,000th year

International Journal of Recent Trends in Engineering & Research (IJRTER)
Volume 04, Issue 11; November - 2018 [ISSN: 2455-1457]

Figure 6 shows that in column 8 slice 6 with a depth of 2000-2600 m below the surface it can be considered a reservoir. By entering rock parameters and reservoir temperature of 300oC, we obtained an intrusion model for subsurface temperature in the year 80,000.

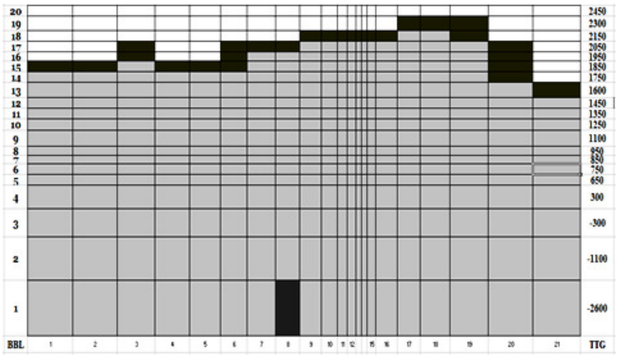

Figure 6. Vertical slice 6 west northwest - east southeast

The temperature distribution and mass flux pattern in transient conditions calculated after 80,000 years or at steady state as shown on figure 7. Heat sources are at a distance of 2000-2300 m which is interpreted as a reservoir of sileri geothermal manifestation, mass flow of hot water from a reservoir directly to the surface is an upflow geothermal manifestation with a mass flux flow velocity of 10-8 (unit g / sec cm2) and Mass flux flow also flows towards the south-west which is towards the Sikidang geothermal manifestation and towards north-east which is indicated to flow to the Sangubanyu geothermal manifestations as the outflow zone of the existing heat source.

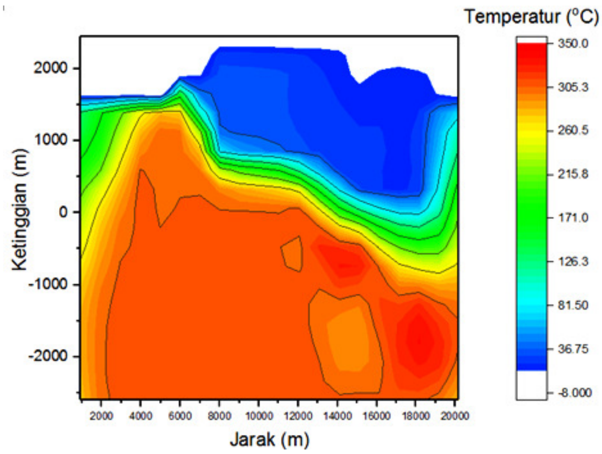

Figure 14. The 80,000th year distribution of intrusion models in slice 8

IV. CONCLUSION

Based on the modeling results of steady conditions the subsurface temperature distribution that has been made is concluded in the 80,000 year steady state has been obtained, this is indicated in the year after the 80,000 year has not shown a change in the pattern of temperature distribution. The results of the intrusion model found that the flow of water mass flux from the Sileri reservoir directed towards the surface formed a sileri upflow zone and directed towards the south towards the Sikidang Geothermal manifestations, Pakuwaja and headed north towards the Sangubanyu Geothermal manifestation.

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