Descriptions of reservoir basin subsurface structure in UNNES based on microgravity data

S Supriyadi*, K Khumaedi, F Setiawan, M Yani, and T M Mukromin

Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Indonesia

*Corresponding author: supriyadi@mail.unnes.ac.id

Abstract. UNNES reservoir basin as a characteristic of the Conservation University is around 12 years old. This relatively long span of time has never been carried out a physical study of a subsurface structure. This study aims to describe the subsurface layer based on gravity data. The method used is to use gravity by calculating the elevation of each measuring point and by tidal correction and drift correction. Both of these corrections are to reduce the tidal and fatigue effects of the gravimeter. Measurements were done in July 2019 (dry season). The results of the study based on observational gravity data indicate that the value of a large gravity is in the north-south part and the smallest value is in the west part of the reservoir basin. The structure of the first layer which has an average density of 2.7 g/cm$^3$ thick 75 m below the surface. The second layer is dominated by andesite rock with an average rock density of 2.8 g/cm$^3$ thick 50 m below the first layer. While the lowest layer is a layer dominated by basalt rock with an average rock density of 3.1 g/cm$^3$ thick more than 40 m below second layer.

1. Introduction

Universitas Negeri Semarang (UNNES) is located in Sekaran Sub-District, Gunungpati District, which is a center of education and a science house with heterogeneous communities. In Universitas Negeri Semarang campus there is reservoir which is an area that is used to absorb and to hold water. Reservoir basin as a characteristic of UNNES has been around 12 years old. In this relatively long span of time no physical study has ever been carried out on the subsurface structure. This study aims to describe the subsurface layer based on gravity data. Descriptions of the subsurface structure can provide information about the structure of the subsurface layer in the components of rocks that are different from one another.

Geophysical methods that can be used to estimate the condition of the subsurface structure of the reservoir are various. Among the geophysical methods, the gravity method is a suitable method to describe the condition of the Reservoir basin subsurface. The gravity method was chosen because it has a high sensitive response, inexpensive, and only requires a relatively short time. In the gravity method, the basis and purpose of being able to interpreted the gravity anomaly data is the difference in density values for each layer of rock below the surface. The gravity method is one of the methods in geophysical science that is passive or indirect, meaning that in taking gravity data there is no need to respond to the surface of the earth. To determine and predict the subsurface conditions of the survey area can be done by the gravity method by observing variations from rock density in subsurface. Gravity measurements can utilize variations in the gravitational field where density contrast are present, particularly lateral variations associated with geology or structure of subsurface [1-3]. Thus
the use of the gravity method in this study is expected to give information or provide an overview of the structure of subsurface layers in the UNNES Reservoir basin.

The basic concept of the gravity method is Newton's law of gravity \[ 4-5 \]. The gravity on the surface of the earth shows the magnitude of the attraction of anomalous objects beneath the surface in the direction to the center of the earth and is a derivative of the force generated through Newton's law \[ 6-7 \]. The theory of gravity is based on Newton's law of attraction between two particles or mass of objects which is shown in equation 1.

\[
F(\vec{r}) = -G \frac{m_1m_2}{r^2} \hat{r} \tag{1}
\]

Equation (1) states the attractional force experienced by objects \( m_2 \) due to object \( m_1 \) and vice versa. The negative sign in the equation above shows that the force acts in the opposite direction to the pull of the two masses. The schematic attractional force of two objects with mass \( m \) with distance \( r \) is shown in Figure 1 below:

![Figure 1. The attractional force scheme of two objects distance r](image)

In the application of geophysical science the preferred component is a field rather than a force by reducing equation 1 to equation 3 as in the following equation:

\[
F = gm_2 \tag{2}
\]

If

\[
\bar{E}(\vec{r}) = g = G \frac{m_1}{r^2} \hat{r} \tag{3}
\]

so that the magnitude of a field is obtained in this case the gravitational field. Gravity values obtained need to be done some data correction before interpreting geological. This is because in the gravity method research shown differences in the value of gravity from one place to another. The difference in reading the value of gravity in a point on the surface of the earth is influenced by several factors including variations in topography, variations in height, tides, shocks on tool springs, latitude, and variations in subsurface density. In the gravity method, there are several corrections including tide, drift, latitude, free air correction, bouguer correction, and terrain correction.

The UNNES Reservoir basin area has a subsurface structure containing volcanic breccia units of the Kaligetas Formation. The rock consists of breccia and lava with inserts of lava and fine tuff to coarse, locally at the bottom found claystone containing mollusk and tuff sandstone, breccias, with components in the form of andesite, basalt, pumice, with a tuff base. The results of gravity measurements interpreted by geological maps can be used to determine subsurface structures.

2. Methods

Geophysical methods commonly used for groundwater exploration and subsurface structure \[ 8-10 \]. This effectiveness can reduce cost for exploration. There are various methods for interpreting gravity data for different geological and structural analysis \[ 11 \]. The distribution of gravity measurement points forms a grid with a specified interval spacing point distance \[ 12 \]. This study to analyse the structure of the subsurface layer of UNNES Reservoir basin, measurements were made on 15 points scattered around UNNES Reservoir basin. The distance between points is 10 meters because of the
small area of Reservoir basin and to get the density data so that the results are accurate. The study uses a Scintrex CG-5 Gravimeter tool that has accuracy to the order of microGal and GPS shown in Figure 2.

![Gravimeter and GPS](image)

**Figure 2.** (a) Gravimeter Scintrex CG-5 (b) GPS

To know the location of the points to be measured, research survey design is needed. The survey design of Reservoir basin is shown in Figure 3.

![Survey design](image)

**Figure 3.** Survey design research method of the gravity of UNNES reservoir basin

Based on Figure 3 we can see the measurement points surrounding the Reservoir basin. After measuring then the data is processed using Microsoft Excel and Oasis Montaj software. The data obtained is performed initial and further corrections using Microsoft Excel until a complete bouguer anomaly is obtained. From the bouguer anomaly then made 2 tracks transversely to determine the structure layer below the surface of the reservoir basin which can be modeled using the Oasis Montaj software.

### 3. Results and Discussion

Observation gravity values at each measuring point are different. Observation gravity is inversely proportional to topography if $g_{obs}$ has a high value, it shows a low topography, whereas if $g_{obs}$ has a low value, it shows a high topography. This is in accordance with Newton's law of gravity which states that the force is inversely proportional to the square of the distance from the earth's core (the
radius of the earth). The higher the measurement point (high topography), the farther the distance from the earth's core or in other words, the radius of the earth is longer. The measurement results of the observed gravity in the Reservoir basin area can be seen in the following Figure 4:

![Figure 4](image)

**Figure 4.** Map of distribution of observation gravity anomaly in UNNES reservoir basin area

After obtaining map of observation gravity anomaly from the initial processing, the next step is to make a bouguer anomaly map to be able to make incisions or trajectories that aim to interpret and model the structure of the subsurface layer of the reservoir basin surface in 2 dimensions. Bouguer anomaly value is the total value of anomaly caused by the influence of rock mass density from the center of the earth's core to the surface of the earth which can then be separated into regional anomalies and residual anomalies [13-16]. To get bouguer anomaly, further correction is needed in the form of latitude correction, free air correction, terrain correction, and bouguer correction. The anomaly value obtained is the target in the research survey [17-18]. Results of the bouguer anomaly this area can be seen in Figure 5.

![Figure 5](image)

**Figure 5.** The UNNES reservoir basin bouguer anomaly

Based on the UNNES Reservoir basin bouguer anomaly shown in Figure 5, it can be seen that the range of anomaly values is between 1.7 to 2.6 mGal. Low anomaly are in the north and east of the area indicated by gradations of blue with a range of 1.7 to 1.8 mGal. The high anomaly is in the southeast, which is indicated by gradations of red to pink that have values ranging from 2.2 to 2.6 mGal. After
get Bouguer anomaly next step is filtering using moving average filter. The main aim of the filtering techniques is to separate the anomalies of different wavelengths from each other. The local anomalies of shallow sources are corresponding to the anomalies of short wavelengths or high frequencies while the regional anomalies of deep sources are corresponding to long wavelengths or low frequencies [19]. To model the structure of the subsurface layer, the incision is made as 2 tracks as shown in Figure 6.

Figure 6. Tracks of 2 dimensional modeling of the subsurface structure of reservoir basin

From Figure 6 there are 2 tracks, A-A’ which have a southeast-northeast direction and a B-B’ path with a west to east direction. 2D Modeling Results of A-A’ path UNNES Reservoir basin layer can be seen in Figure 7.

Figure 7. 2D Modeling results on A-A’ track

From the results of 2-dimensional modelling on the track A-A’ can be seen that there are 3 layers of component rocks namely the soil layer composed of a mixture of sand, sandstone and andesite rocks which have an average rock density of 2.7 g/cm$^3$. Soil layer is on the surface to a depth of 75 m below the surface (thick 75m). Then the second layer is dominated by andesite rock which has an average rock density of 2.8 g/cm$^3$ at a depth of 75 m to 125 m below the surface (thick 50 m). While the lowest layer is a layer dominated by basalt rock with an average density of 3.1 g/cm$^3$ at a depth of more than 125 m below the surface (thick more than 50 m). The top layer is a topographic effect that does not take into account its density or its density can be ignored. For the results of modelling the subsurface layer B-B’ track can be seen in Figure 8.
Based on Figure 8 can be seen that the subsurface layer of the reservoir basin is composed of 3 layers, the same as the A-A’ track 2-dimensional modeling for both trajectories has an error of 0.017. Small error value due to dense measurement points in narrower areas.

4. Conclusion

Based on the results of research that has been done to describe the structure of the subsurface layer on UNNES Reservoir basin, it can be concluded that there are 3 layers below the surface of the reservoir, namely the soil layer which has an average density of 2.7 g/cm³ of rock on the surface to a depth of 75 m below the surface. The second layer is dominated by andesite rock with an average rock density of g/cm³ at a depth of 75 m to 120 m below the surface. While the lowest layer is a layer dominated by basalt rock with an average rock density of 3.1 g/cm³ at a depth of more than 120 m below the surface.

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