Advances in Physics Research, volume 5
Soedirman International Conference on Mathematics and Applied Sciences (SICOMAS 2021)

Power Spectrum Analysis of the Satellite Gravity Anomalies Data to Estimate the Thickness of Sediment Deposits in the Purwokerto-Purbalingga Groundwater Basin

Sehah[1,*] Urip Nurwijayanto Prabowo[1], Sukmaji Anom Raharjo[1], Laila Ariska[1]

[1] *Physics Department, Faculty of Mathematics and Natural Sciences, Jenderal Soedirman University*
[*] *Email: sehah@unsoed.ac.id*

ABSTRACT
Analysis of power spectrum of the satellite gravity anomalies data has been carried out to estimate the thickness of sediment deposits in the Purwokerto-Purbalingga Groundwater Basin. Power spectrum analysis uses the Fourier transform principle by converting data from the space domain to the frequency domain. Spectrum analysis has been done on all trajectories placed on the gravity anomaly map which has been corrected and transformed on the horizontal surface. The gradient of the gravity anomalies data spectrum graph is proportional to the depth of the anomaly source boundary plane. The calculation results show that the average depth of the boundary plane of the local anomaly source for each trajectory is 470.89 m. This depth is calculated from the topographic surface, so that this value indicates the thickness of sediment deposits in the Purwokerto-Purbalingga Groundwater Basin.

Keywords: *power spectrum, satellite gravity anomalies data, sediment deposits, Purwokerto-Purbalingga Groundwater Basin.*

1. INTRODUCTION

Gravity survey is one of the geophysical exploration methods. This method can be categorized as a passive method, because to measure physical quantities on the Earth's surface, it does not inject electromagnetic fields or currents into the Earth. The principle of this method is to measure the difference in the gravitational field value on the Earth's surface, which is then mapped its distribution in the form of a gravity anomaly contour map. Earth's gravitational field on the surface is not homogeneous, but its value changes due to differences in rock density, especially the rocks which make up the Earth's crust [1]. In addition, variations in the gravity field are also influenced by geological structures in the subsurface, including topographic conditions or uneven Earth surface relief. All geological conditions in the subsurface affect the measured gravitational field value. Hence, the gravity method can be used to detect rocks or geological structures in the subsurface based on the variations in gravitational field. Generally, the final results of gravity surveys are presented in the form of two-dimensional (2D) or three-dimensional (3D) models of subsurface anomalous sources. In the exploration field, this method has been widely used to identify the accumulation of certain minerals or mining materials. While for disaster mitigation, the gravity method can be applied to detect geological structures such as faults or folds [2], basement rock [3], igneous rock intrusion [4], magma chamber [5], and groundwater basin [6].

Gravity method which is based on the gravimetric satellites have long been developed. The data obtained are free-air gravity anomalies data which is equipped with the geographical position data of location points on the Earth's surface. The satellite gravity anomalies data are not only accessed by countries that own the satellites but can also be accessed by countries that do not have them, such as Indonesia and other countries. Therefore the anomalies data obtained can be used as supporting data for various researches in Geophysics field, which include research for disaster mitigation. The anomalies data obtained can be mapped, so that a global gravity anomaly contour map on the Earth's surface can be obtained [7]. Various natural mineral deposits such as coal, bauxite, zinc, and several other metals which are difficult to detect using other geophysical methods due to extraordinary natural constraints, can be detected globally using the satellite gravity methods. Another consideration of using satellite gravity anomaly data as supporting data for research is the lower cost. Data acquisition directly in the field can cost tens to hundreds of millions of rupiah. Satellite gravity anomalies data are also relatively well used for modeling geological structures and subsurface rocks in the research area [8].

There have been many uses of satellite gravity anomalies data. Satellite gravity anomalies data have been utilized to model hydrocarbon basins in the Timor Island and its surroundings [9]. The gravity anomalies data have also been used to model the geothermal reservoir in the Slamet Volcano area of Central Java [10] and the Bur Ni Geureudong, Aceh [11]. Gravity anomalies data obtained from the satellites are gravity anomalies data which have been corrected up to free-air correction, so that generally all researchers only make bougeur and terrain corrections to obtain the Complete Bougeur Anomaly (CBA) data [12]. The CBA data are the total gravity anomalies data which represents the complete subsurface geological structure, both local and regional. In this study, the CBA data will be applied to estimate the depth boundaries of the local and regional anomalies sources below the Purwokerto-Purbalingga Groundwater Basin. This groundwater basin is the largest groundwater basin in western Central Java and almost no geophysical research has been conducted. The local structure of this basin is estimated to be in the form of alluvial deposits composed of gravel, sand, silt, and clay which fill the basin [13]. While, the regional structure is estimated to be composed of tertiary rocks which are the basement rocks of the groundwater basin [13]. The depth boundaries between the local and the regional sources can be identified using the spectrum analysis [14].

Power spectrum analysis is a technique commonly utilized to estimate the depth boundary of subsurface anomalous sources. Power spectrum analysis uses the Fourier transform principle by converting data from the space domain to the frequency domain. The gradient of the gravity anomaly data spectrum graph is proportional to the depth of the anomaly source plane; where the gradient which has a large value represents a regional anomaly, whereas a gradient which has a small value represents a local or residual anomaly [15]. In order to obtain the thickness of the sediment deposits in the Purwokerto-Purbalingga Groundwater Basin which is assumed to be the local anomalies sources, so power spectrum analysis can be applied to gravity anomalies data. Information about the depth of the sediment deposit obtained from spectrum analysis will show the thickness value. This thickness of the sediment deposits can be used to estimate the groundwater potential in the Purwokerto-Purbalingga Groundwater Basin, because generally the aquifer layers are contained in sedimentary deposits, so the thickness of the sediment deposits can indicate the potential for groundwater contained in it. Hence this information can be used as supporting data for drought disaster mitigation which sometimes occur in Banyumas and Purbalingga Regencies.

1.1. Basic Theory

The gravity method in geophysical surveys is based on Newton's law of attraction between two masses where the magnitude of the force between two masses m_1 and m_2 separated by *a* distance *r* can be writen [16]:

$$\vec{F}(\vec{r}) = -G\frac{m_1 m_2}{r^2}\hat{r} \tag{1}$$

where F is the force (newton), r is the distance between two masses of objects (meters), m_1 and m_2 are the masses of each object (kg), and *G* is the universal gravitational constant (6.67×10^{-11} Nm^2/kg^2). The force per unit mass of a particle m_1 at a distance *r* from m_2 is called the gravitational field of the particle m_1, which can be expressed as [16]:

$$\vec{E}(\vec{r}) = \frac{\vec{F}(\vec{r})}{m_2} - G\frac{m_1}{r^2}\hat{r} \tag{2}$$

Since the gravity field is conservative, it can be written as the gradient of a scalar potential function $U(\vec{r})$, so that the above equation can be written as [16]:

$$\vec{E}(\vec{r}) = -\nabla U(\vec{r}) \tag{3}$$

where $U(\vec{r}) = -G\frac{m_1}{r}$ is the gravitational potential of mass m_1.

The gravitational potential at a point in space is a summation, so that the gravitational potential of a continuous mass distribution at a point outside the mass distribution can be solved using integrals. If the continuous mass has a density ρ inside the volume *V*, then the potential at a point *P* outside the volume *V* as shown in Figure 1, can be expressed as [16]:

$$U_P(\vec{r}) = -\int_V \frac{G}{\left|\vec{r}^2 - \vec{r}_0^{\,2}\right|}dm = -G\int_V \frac{\rho(\vec{r}_0)}{\left|\vec{r}^2 - \vec{r}_0^{\,2}\right|}d^3\vec{r}_0 \tag{4}$$

where $\left|\vec{r}^2 - \vec{r}_0^{\,2}\right| = \sqrt{r^2 + r_0^2 - 2r\,r_0\cos\gamma}$

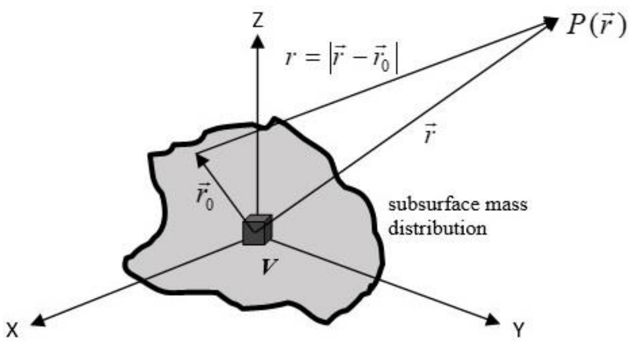

Figure 1 The gravitational potential at point P on the earth's surface due to the continuous distribution of mass in the subsurface [16].

If the volume integral is taken for the entire volume of the earth, then the gravitational potential at the earth's surface can be obtained. While the gravitational field can be obtained by differentiating the gravitational potential so that the equation [16]:

$$\vec{E}(\vec{r}) = \left|-\nabla U_P(\vec{r})\right| \tag{5}$$

The value of the Earth's gravitational field is often referred to as the gravitational acceleration and is given the symbol g. Based on equation (5), the value of the earth's gravitational field can be expressed by the equation [16]:

$$g(\vec{r}) = \left|-\vec{E}(\vec{r})\right| = \left|\nabla U_P(\vec{r})\right| \tag{6}$$

Equation (6) can be described more completely into equation (7):

$$g(\vec{r}) = -G\int_V \frac{\rho(\vec{r}_0)\, z\, d^3\vec{r}_0}{(x^2+y^2+z^2)^{3/2}} \tag{7}$$

$$g(\vec{r}) = -G\int_V \frac{\rho(\vec{r}_0)(z_0-z)\, d^3\vec{r}_0}{\left[(x-x_0)^2+(y-y_0)^2+(z-z_0)^2)\right]^{3/2}} \tag{8}$$

Based on this equation (8), the value of the gravitational field on the earth's surface varies. The value of the earth's gravitational field is influenced by the position of latitude, longitude, altitude, and the distribution of mass in the subsurface, that is a function of the density of the subsurface body mass and the shape of the earth as shown by integral boundaries. The rocks with various densities will affect the earth's gravitational field on the surface. Variations in the gravitational field on the earth's surface can also be affected by subsurface geological structures, including topographic or uneven relief of the earth's surface. In a gravity survey, the value of the gravitational field or gravitational acceleration as a result of the measurement is given in gal units, where 1 gal = 10^{-5} m/s^2. However, the gravity field anomalies data measured in the field are generally very small, in the milligal range.

1.2. Spectrum Analysis

Spectrum analysis is a method used to estimate the depth of regional and residual anomalous sources based on the CBA anomalies data that has been distributed on a horizontal surface. In order to estimate the depth of the anomalous source, the Fourier transform process can be carried out. Spectrum analysis utilizes the Fourier transformation to convert the anomaly amplitude from the spatial domain into the wavenumber or frequency domain. The purpose of the conversion is to obtain continuous data. The form of the Fourier transform can be expressed by the equation [17]:

$$F(k) = \int_{-\infty}^{\infty} f(x) e^{-ikx} dx \tag{9}$$

$F(k)$ is frequency domain signal, $f(x)$ is time domain signal, while k is a wave number whose value can be determined by using the equation [17]:

$$k = \frac{2\pi}{\lambda} = 2\pi f \tag{10}$$

Equation (9) is a Fourier transformation on a complex function, which consists of real and imaginary numbers, such as Equation (7) [17]:

$$\left|F(k)\right| = \operatorname{Re}F(k) + \operatorname{Im}F(k) = \left[\left\{\operatorname{Re}F(k)\right\}^2 + \left\{\operatorname{Im}F(k)\right\}^2\right]^{1/2} = A \tag{11}$$

where A is the amplitude value.

If the anomaly data is random and has no relationship, then the result of the Fourier transform of the anomalies data becomes [17]:

$$A = Ce^{|k|(z_0 - z')} \tag{12}$$

where A is the amplitude and C is a constant. If Equation (7) is logarithmized, it will get a relationship between the amplitude (A) and wave number (k) and depth ($z_0 - z'$), so that it will give the result of a straight line equation as shown in Equation (13). Estimated depth for each type of anomalies data can be done by performing linear regression in each zone [17] as shown in Figure 2. Based on Equation (13), we can make a comparison pattern of the results of the Fourier transform between ln A and k to classify the depth boundaries of regional and residual anomalies.

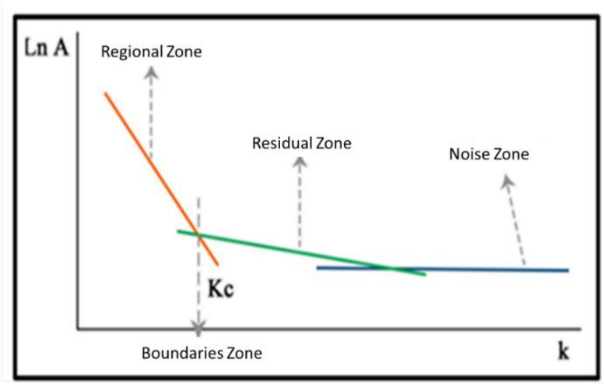

Figure 2 Linear regression procedure for spectrum analysis to estimate the maximum depth of regional and residual anomalous sources.

The depth limit of the anomalous sources can be estimated through the gradient value of the linear equation for each zone. The depth limit of the residual zone marked with the green line in Figure 1 is assumed to be the depth of sediment (alluvial deposit) in the groundwater basin that is the target of this research. The depth and thickness of alluvial deposits in the basin indicate the potential for freshwater contained in it.

2. EXPERIMENTAL METHODS

This research has been done in April – July 2021 at Geophysics Laboratory, Jenderal Soedirman University Purwokerto, Indonesia. The gravity anomalies data and the geographic positions data have been accessed from website: http://topex.ucsd.edu/cgi-bin/get_data.cgi, that is provided by the Scripps Institution of Oceanography University of California San Diego, USA [18]. Gravity anomalies data and geographical position data acquired have been gridded regularly in the ASCII – XYZ format according to the geographic position boundaries entered. The spatial resolution for latitude and longitude is 1.0 minute per grid, meanwhile the accuracy of the gravity anomalies data is 0.1 mGal and the elevation data is 1 m [19]. The distribution of data points in the field is shown in Figure 3.

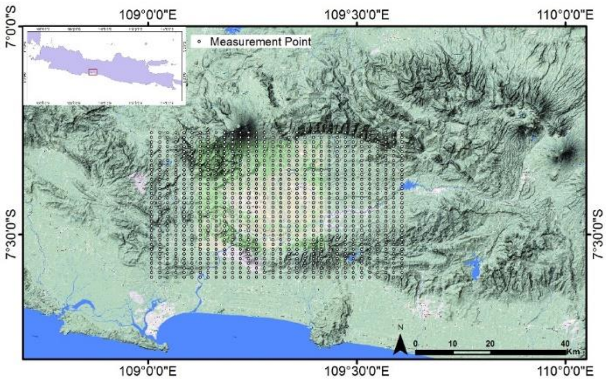

Figure 3 Research location; Purwokerto-Purbalingga Groundwater Basin, and distribution of data points in the field.

2.1. Equipment and Material

Several equipment used in this research consists of a laptop connected to the internet to access satellite gravity anomalies data equipped with the geographic position data, the Google Earth to obtain the boundaries of the research area, and the geological map as a guide for modeling and lithological interpretation. Meanwhile several of the software used consists of Microsoft Excel for Bouguer correction and power spectrum analysis of anomalies data, Gravity 900 for topographic correction, Fortran 77 for processing gravity anomalies data such as reduction to horizontal surface and upward continuation, and Surfer for depicting gravity anomaly contour map.

2.2. Procedure of Research

Satellite gravity anomalies data obtained are free-air gravity anomalies data. These data do not require free-air correction because the data acquisition is carried out at the same elevation datum. The latitude correction is also not needed, because the satellites have calculated the gravity values effect on differences in latitude positions. In addition, with the distance from the mass center of the earth to the orbital trajectory of the satellite, the difference in the acceleration value due to gravity caused by the difference in latitude does not have much effect. Several convensional corrections commonly applied for measurements of ground gravity such as equipment height correction and drift correction are also not required [12]. Hence, the data corrections made to the free-air satellite gravity anomalies data (Δg_{FA}) to get the Complete Bouguer Anomaly (*CBA*) data are only bougeur correction (*BC*) and topographic correction (*TC*), as shown in Equation (13) [12]:

$$CBA = \Delta g_{FA} - BC - TC \tag{13}$$

The CBA data are still spread on the topographic that are a function of geographical position of longitude, latitude, and altitude, so that it can be expressed as $\Delta g(\lambda,\vartheta,h)$. Reduction of anomalies data to a horizontal surface must be conducted, because in the next data processing, the data must be distributed at a horizontal surface [17]. One method that can be applied to reduce anomalies data to a horizontal surface is the Taylor series approximation which can be stated as Equation (15). The basic principle of the Taylor series is to use a derivative function at a point to extrapolate the function around that point. Therefore, this method can be utilized to estimate the potential field value (i.e. gravity and magnetic fields) at points outside the observation field. Equation (15) is stated in the form of iteration; where $\Delta g(\lambda,\vartheta,h_0)$ are *CBA* data that are spread on a horizontal surface. The data can be estimated through an approach; i.e. $\Delta g(\lambda,\vartheta,h_0)$ data obtained from *i*-th iteration are used to obtaine $\Delta g(\lambda,\vartheta,h_0)$ values in the $(i+1)$-th iteration. The iteration is carried out sufficiently to reach a convergent value. For the initial guess values before iteration, so that $\Delta g(\lambda,\vartheta,h_0)$ values on the right of Equation (15) can be filled by $\Delta g(\lambda,\vartheta,h)$ which are the CBA data that are distributed on the topographic [17].

$$\Delta g(\lambda,\vartheta,h_0)^{[i+1]} = \Delta g(\lambda,\vartheta,h) - \sum_{n=0}^{\infty} \frac{(h-h_0)^n}{n!} \frac{\partial^n}{\partial h^n} \Delta g(\lambda,\vartheta,h_0)^{[i]} \tag{13}$$

Gravity anomalies data obtained from Equation (13) is *CBA* data originating from the local and regional anomalous sources in the subsurface of the research area. In order to estimate the depth of the regional and residual anomalous sources, power spectrum analysis can be applied using Equation (13) [15]. Technically, spectrum analysis of gravity anomalies data can be done along all trajectories placed on the *CBA* contour map which has been distributed on the horizontal surface. Based on the results of spectrum analysis, the sediment thickness can be predicted. The sediment thickness can be assumed to be the thickness of alluvial deposits which fill the groundwater basin. All hydrological processes such as recharge, drainage, and discharge of groundwater occur in the alluvial deposits. Hence the sediment thickness value can indicate the groundwater potential in the basin.

3. RESULTS AND DISCUSSION

Free-air corrected satellite gravity anomalies data have been successfully accessed and extracted from: http://topex.ucsd.edu/cgi-bin/get_data.cgi provided by the Scripps Institution of Oceanography, University of California San Diego USA [18]. The data have been equipped by longitude, latitude, and altitude data. The number of data which has been successfully accessed is 814 data distributed over the position of 109.0083° – 109.6083° E and 7.2554° – 7.6026° S, with anomalies values ranging of 53.40 – 300.40 mGal. Meanwhile the topographical elevation of the research area has a value ranging of 7 – 2495 m. The topographic contour of the research area can be seen in Figure 4, while the free-air satellite gravity anomaly contour is shown in Figure 5. Geologically, the Purwokerto-Purbalingga Groundwater Basin is occupied a depression zone between the North Serayu and South Serayu Mountains [13]. This basin also stretches from Banyumas Regency in the western to Banjarnegara Regency in the east. The lowest elevation of the groundwater basin area is 27.22 m at the position of 109.34163° E and 7.45635° S. Meanwhile the lowest free-air gravity anomaly value is 53.20 mGal at the position of 109.41436° E and 7.34674° S. Both of the contour maps indicate a slightly different center location of the Purwokerto-Purbalingga Groundwater Basin. The topographic map and the free-air gravity anomaly map have similar patterns, due to the very large influence of topographic mass on free-air gravity anomalies data.

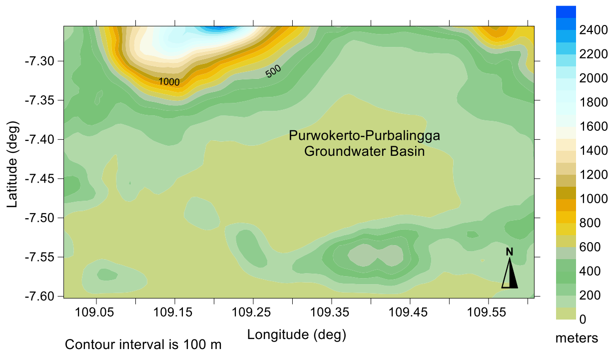

Figure 4 The topographic contour map of the research area; Purwokerto-Purbalingga Groundwater Basin area.

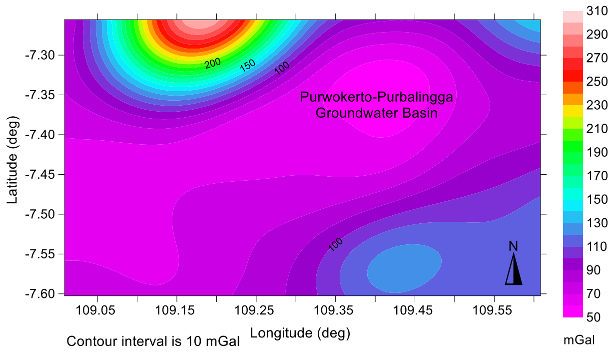

Figure 5 The free-air satellite gravity anomaly contour map of the research area.

3.1. Gravity Anomaly Data Processing

The free-air gravity anomalies data were corrected by bouguer and topographic corrections to get complete bouguer anomaly (CBA) data. Bouguer correction is done to reduce the rock masses effect in the earth's crust between the spheroid surface and the data point at the topographic surface [20]. Meanwhile terrain correction is done to reduce the topographic masses effects on the earth's surface which are relatively rough with large differences in elevation, such as mountains, ravines, hills, and valleys around the measurement point [20]. After both corrections were applied, then the Complete Bouguer Anomalies data (CBA) was obtained with values of 49.66 – 152.65 mGal. The CBA contour map of the research area is shown in Figure 6. Based on the contour map, the groundwater basin is interpreted to be located in the low anomaly zone (closure in purple). It is because in general alluvial deposits that fill the basin have low gravity anomaly values [21].

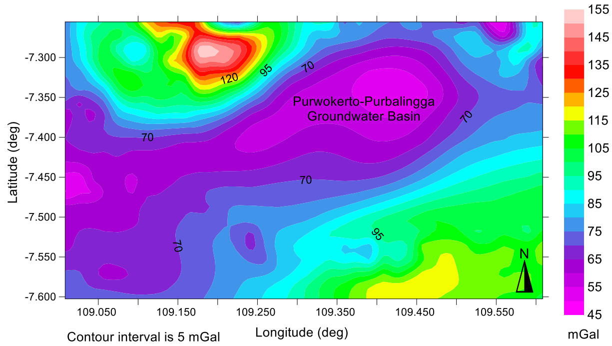

Figure 6 The CBA contour map of the research area which are distributed on the topographic surface.

The CBA data are still spread over the topographic that are a function of geographical position (longitude, latitude, altitude), so that the anomalies data must be reduced to a horizontal surface according to Equation (13) [17]. It is because the anomalies data can not be processed at the next stage if the data are not spread on a horizontal surface. According to Cordell and Grauch's suggestion [17], the horizontal surface was chosen at an average height of the topographic, i.e. 269.00 m above the reference spheroid surface, so that the convergence of Equation (13) can take place quickly. The CBA map which has been spread on a horizontal surface is shown in Figure 7. Based on the anomaly data range, The CBA data which have been spread on the horizontal surface show more convergent than the data which are still distributed on the topographic, with values ranging of 49.78 – 152.50 mGal.

3.2. Power Spectrum Analysis

Spectrum analysis is applied to CBA data that have been spread on a horizontal surface, because the CBA data are combination of anomalies data originating from regional and local sources. The gravity anomalies data to be spectrum analyzed, extracted from the CBA map along the trajectories placed above it. The placement of the trajectories is adjusted to the Geological Map of the research area, especially the Purwokerto-Purbalingga Groundwater Basin area, as can be seen in Figure 7. The calculation of the spectrum analysis have been done based on Equation (15) using the Microsoft Excel. The analysis results are in the form of a graph to obtain the information on the maximum depth of the residual and regional anomalies sources based on some graphs slopes values. The calculation results of the spectrum analysis of anomalies data are shown in Figures 8 to Figure 13. The linear gradient taken at the residual zone points shows the maximum depth for the local anomaly sources, with the results are shown in Table 1. As it is known that the CBA contour map is distributed at an average topographic height (269.00 m), then the depth obtained from the spectrum analysis for each trajectory must be corrected by that value. The thickness of the sediment deposits is obtained by adding the corrected depth to the topographic height of each trajectory.

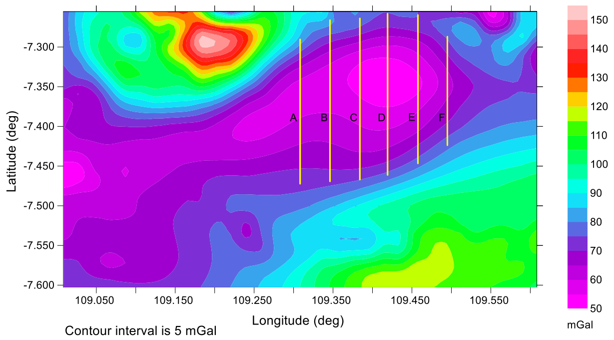

Figure 7 The CBA contour map of the research area that are distributed on the horizontal surface i.e. average topographic height of the research area, and the position of the data trajectories for power spectrum analysis.

Power spectrum analysis has been carried out using the Fourier transform on anomalies data along a predetermined tajectories. A low wavenumber (*K*) value shows that the frequency (*f*) value is also low. The low frequency signal indicates that the subsurface rock type is relatively homogeneous, which is a characteristic of regional gravity anomaly sources [22]. Otherwise a high wavenumber value (*K*) indicates a high frequency value (*f*). Generally, high frequency signals come from the shallow and local anomalous sources. The shallow and local structures are generally not homogeneous, but have relatively varied densities [22]. Hence, the graph between wavenumber (*K*) and *Ln A* that produces these two gradients can be interpreted as the maximum depth of the regional anomaly sources for the larger gradient, and the maximum depth of the local anomalous sources for the smaller gradient, as described in Equation (12) [17]. Qualitatively, the local anomaly sources can be interpreted as sedimentary deposits trapped in the basin. In Figure 7, the sedimentary deposits are characterized by low anomalies values (closure in purple). Based on the Geological Map for Purwokerto-Tegal Sheet, these sedimentary deposits are estimated to originate from the alluvium formation; that is the material for groundwater aquifers [13].

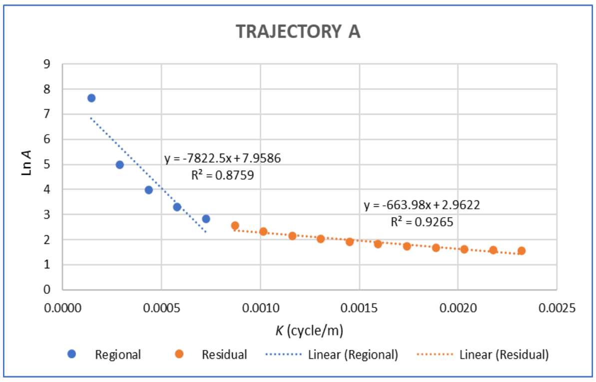

Figure 8. The result of power spectrum analysis of the CBA data on trajectory A which have been spread on a horizontal surface.

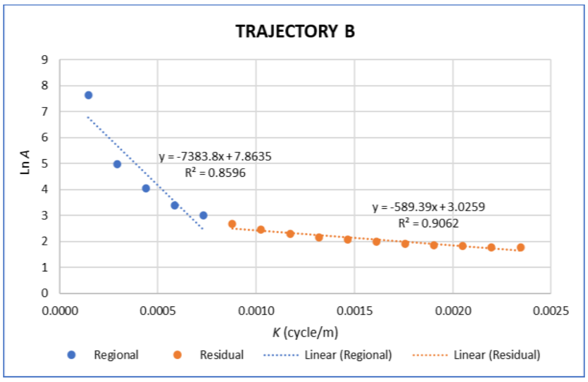

Figure 9. The result of power spectrum analysis of the CBA data on trajectory B which have been spread on a horizontal surface.

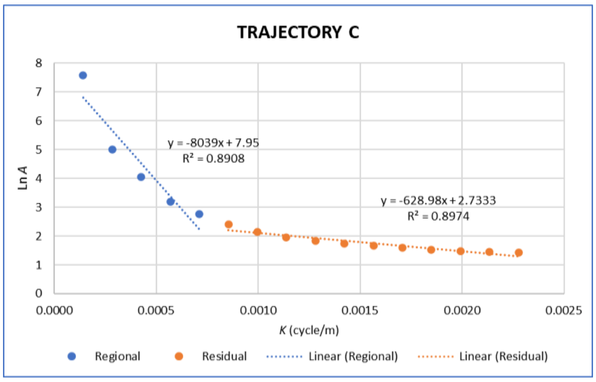

Figure 10. The result of power spectrum analysis of the CBA data on trajectory C which have been spread on a horizontal surface.

The calculation results as seen in Table 1 show that the average thickness of sedimentary deposits in the Purwokerto-Purbalingga Groundwater Basin is about 470.89 m. According to the geological information the deposits are estimated to be composed of sand, silt, clay, and gravel [13] with a high groundwater content. This basin occupies the central of Central Java and is known as the Serayu Valley. This valley separates the North Serayu Mountains and South Serayu Mountains. The

Serayu Valley extends from west to east through several regions, such as Majenang, Ajibarang, Purwokerto, Banjarnegara, and Wonosobo [23]. The rock formations under the Alluvium formation are thought to be igneous rocks, which can act as an aquifuge (impermeable layer) for groundwater aquifers in the Purwokerto-Purbalingga Groundwater Basin [13]. These formations are thought to be andesitic lava rocks of Slamet Volcano and tertiary intrusive rocks. Stratigraphically, these rock formations are under the Alluvium formation [13]. In an effort to prove and support the results of this study, a geoelectric survey with vertical sounding method can be applied in the Purwokerto-Purbalingga Groundwater Basin area.

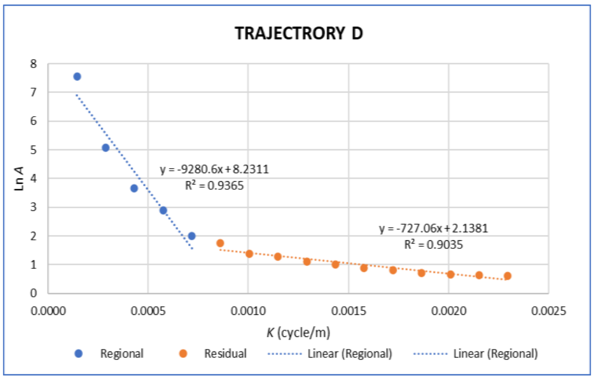

Figure 11. The result of power spectrum analysis of the CBA data on trajectory D which have been spread on a horizontal surface.

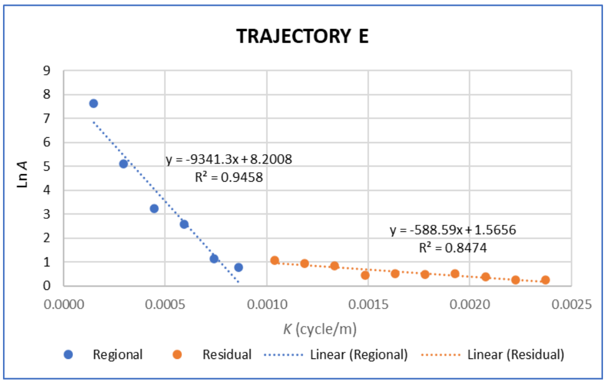

Figure 12. The result of power spectrum analysis of the CBA data on trajectory E which have been spread on a horizontal surface

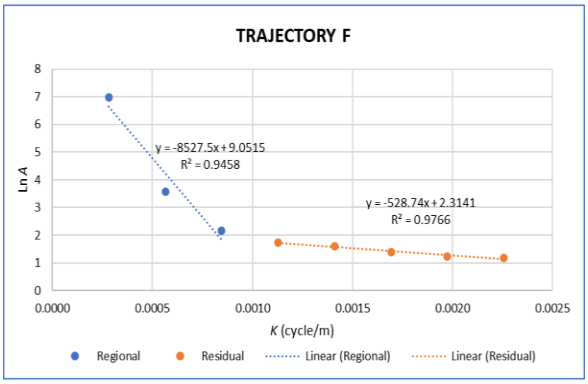

Figure 13. The result of power spectrum analysis of the CBA data on trajectory F which have been spread on a horizontal surface.

Table 1. The maximum depth limit for local and regional anomaly sources based on the results of spectrum analysis for each trajectory

Data Trajectories	Topographic Height (m)	Maximum Depth Limit (m)		Sediment Thickness (m)
		Residual (Local)	Regional	
Trajectory A	109.42	663.98	7822.50	504.40
Trajectory B	90.18	589.39	7383.80	410.57
Trajectory C	62.63	628.98	8039.00	422.61
Trajectory D	118.41	727.06	9280.60	576.47
Trajectory E	155.23	588.59	9341.30	474.82
Trajectory F	176.76	528.74	8527.50	436.50

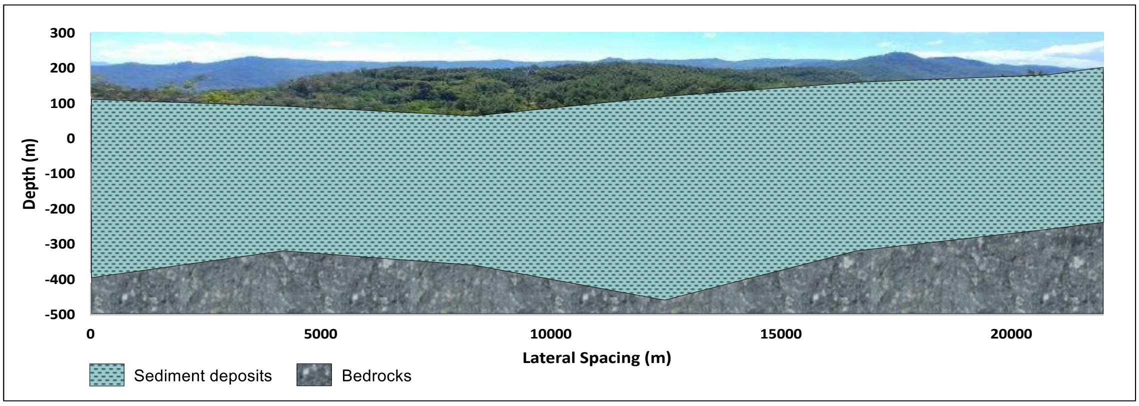

Figure 14. The position of the data trajectories for power spectrum analysis on a CBA contour map which has been spread on the horizontal surface.

4. CONCLUSION

Analysis of power spectrum of the satellite gravity anomalies data has been carried out to estimate the thickness of sediment deposits in the Purwokerto-Purbalingga Groundwater Basin. This basin occupies the Serayu Valley which separates the North Serayu Mountains and South Serayu Mountains. Analysis of power spectrum uses the Fourier transform principle by converting data from the space domain to the frequency domain. Analysis of power spectrum has been carried out along all trajectories placed on the Complete Bouguer Anomaly (CBA) map. The CBA data are free air satellite gravity anomaly data which have been corrected by bouguer and topographic corrections and have been transformed to a horizontal surface. The gradient of the gravity anomalies data spectrum graph is proportional to the depth of the anomaly source plane; where the larger gradient represents a regional anomaly sources, meanwhile the smaller gradient represents a local anomaly sources. The calculation results show that the average depth of the boundary plane of the local anomaly sources for each trajectory is 470.89 m. This depth is calculated from the topographic surface, so this value indicates the thickness of sediment deposits in the Purwokerto-Purbalingga Groundwater Basin.

AUTHORS' CONTRIBUTIONS

All authors (S, UNP, SAR, LA) contributed to the PREPARATION of the manuscript, DATA PROCESSING and DATA INTERPRETATION. The second author (UNP) contributed to the CREATION of the map. The third author (SAR) contributed to the preparation of SOFTWARE and TOOLS. While the fourth author (LA) contributed in data ACQUISITION and DATA MODELING.

ACKNOWLEDGMENTS

All authors would like to thank the Rector and the Chairman of the Research and Community Service Institute (LPPM) of Jenderal Soedirman University for the research funding provided. The authors also would like to thank the Dean of the Faculty of Mathematics and Natural Sciences of Jenderal Soedirman University for the internet network and other facility that have been provided. The authors would like to express gratitude to the research teams of the Physics Department of Jenderal Soedirman University, for the collaboration in data acquisition and data processing.

REFERENCES

[1] M. Dumberry, J. Bloxham, Variations in the Earth's Gravity Feld Caused by Torsional Oscillations in the Core, Geophysical Journal International, vol. 159, no. 2, 2004, pp. 417 – 434. DOI: doi.org/10.1111/j.1365-246X.2004.02402.x

[2] D. Darisma, Marwan, N. Ismail, Geological Structure Analysis of Satellit Gravity Data in Oil and Gas Prospect Area of West Aceh-Indonesia, J. Aceh Phys. Soc., vol. 8, no. 1, 2019, pp. 1 – 5. DOI: doi.org/10.24815/jacps.v8i1.12750

[3] V. Chakravarthi, K. Mallesh, B. Ramamma, Basement Depth Estimation from Gravity Anomalies: 2.5D Approaches Coupled with the Exponential Density Contrast Model, Journal of Geophysics and Engineering, vol. 14, 2017, pp. 303 – 315. DOI: doi.org/10.1088/1742-2140/aa5832.

[4] A.M. Al-Rahim, W.A. Lima, Basin or Intrusion, a New Method to Resolve Non-Uniqueness in Gravity Interpretation, Iraqi Journal of Science, vol. 57, no. 1B, 2016, pp. 408 – 491.

[5] W.A. Permadi, A. Setyawan, I. Nurdin, Interpretation of the Subsurface of Merapi Volcano with Gradient Analysis and 2D Modeling of Gravity Data, Youngster Physics Journal, vol. 5, no. 4, 2016, pp. 433 – 440.

[6] A. Zainuddin, R. Risman, I.G.B. Darmawan, I.B.S. Yogi, Analysis of Gravity Anomaly for Groundwater Basin in Bandarlampung City Based on 2D Gravity Modeling. The 9th International Conference on Theoretical and Applied Physics (ICTAP), IOP Conf. Series: Journal of Physics, vol. 1572, no. 012006, 2020. DOI: doi:10.1088/1742-6596/1572/1/ 012006

[7] O.B. Andersen P. Knudsen, Global Gravity Field From The Ers 1 And The Geosat Geodetic Mission Altimetry – The Mediterranean Sea. European Space Agency, Geodetic division, Rentemestervej 8 DK2400 Copenhagen NV, Denmark, 2020.

[8] J.G. Motta, C.R. de Souza Filho, E.J.M. Carranza, C. Braitenberg, Archean Crust and Metallogenic Zones in The Amazonian Craton Sensed by Satellite Gravity Data, Scientific Reports, vol. 9, no. 2565, 2019, pp. 1-10.

[9] M. Yanis, Marwan, N. Kamalia, Application of Sattelite GEOSAT and ERS as an Alternative Method of Measuring Gravity Ground in Hydrocarbon Basin on Timor Island, Majalah Geografi Indonesia, vol. 33, no. 2, 2019, pp. 64 – 68. DOI: doi.org/10.22146/mgi.50782

[10] A.P.A. Reswara, Sehah, Estimation of Geothermal Reservoir Layers in the Slamet Volcano Area by Utilizing Satellite Gravity Anomaly Data, Berkala Fisika, vol. 17, no. 2, 2014, pp. 45 – 54.

[11] D.R. Putri, M. Nanda, S. Rizal, R. Idroes, N. Ismail, Interpretation of Gravity Satellite Data to Delineate Structural Features Connected to

Geothermal Resources at Bur Ni Geureudong Geothermal Field, The 3rd International Conference on Natural and Environmental Sciences (ICONES), IOP Conf. Series: Journal of Physics, vol. 364, no. 012003, 2019. DOI:10.1088/1755-1315/364/1/012003

[12] A.D. Maulana, D.A. Prasetyo, Mathematical Analysis on Bouguer Correction and Topographic Correction of Topex Satellite Gravity Data in Determining Geological Conditions, Case Study of the Palu Koro Fault, Central Sulawesi. Jurnal Geosaintek, vol. 5, no. 3, 2019, pp. 91 – 100. DOI: dx.doi.org/10.12962/j25023659.v5i3. 6100

[13] M. Djuri, H. Samodra, T.C. Amin, S. Gafoer, Geological Map of the Purwokerto and Tegal Sheet, Java. Center for Geological Research and Development, Bandung, 1996.

[14] K.S. Kumar, R. Rajesh, R.K. Tiwari. Regional and Residual Gravity Anomaly Separation Using the Singular Spectrum Analysis-Based Low Pass Filtering: A Case Study From Nagpur, Maharashtra, India. Exploration Geophysics, vol. 49, no. 3, 2018, pp. 398 – 408. DOI: 10.1071/EG16115

[15] M. Apriani, M. Yusuf, A.M. Julius, D.T. Heryanto, A. Marsono, Estimation of Sediment Thickness with Power Spectral Analysis on Gravity Anomaly Data (Case Study in DKI Jakarta). Geomatika. vol. 23, no. 2, 2017, pp. 65 – 74.

[16] W.M. Telford, L.P. Gedaart, R.E. Sheriff, Applied Geophysics, Cambridge, New York, 1990. doi.org/10.1017/CBO9781139167932.

[17] R.J. Blakely R.J., Potential Theory in Gravity and Magnetic Applications, Cambridge University Press, New York, USA, 1995. DOI: doi.org/10.1017/CBO9780511549816

[18] D.T. Sandwell, H.F. Smith, Global Marine Gravity from Retracked GEOSAT and ERS-1 Altimetry: Ridge Segmentation versus Spreading Rate. Journal of Geophysical Research, vol. 114, no. B1, 2019, 1-18. DOI: doi.org/10.1029/2008JB006008

[19] H.F. Smith, D.T. Sandwell, Global Seafloor Topography from Satellite Altimetry And Ship Depth Soundings. Science, vol. 277, 1997, pp. 1957-1962,. DOI: 10.1126/science.277. 5334.1956.

[20] J. Reynolds, M., An Introduction to Applied and Environmental Geophysics. Chichester: John Wiley and Sons Ltd, 1997, 796p.

[21] M.I. Nurwidyanto, I. Novianti, S. Widodo, Estimation of the Relationship of Porosity and Permeability in Sandstone (Case Study of the Kerek Formation, Ledok, Selorejo). Berkala Fisika, vol. 8. No. 3, 2005, pp. 87 – 90.

[22] R.D. Indriana, Estimation of Sediment Thickness and Depth of Mohorovicic Discontinuity in East Java with Power Spectrum Analysis of Gravity Anomaly Data. Berkala Fisika, vol. 11, no. 2, 2008, pp. 67 – 74.

[23] F. Ramadhan, Geology and Modeling of Purwokerto-Purbalingga Groundwater Basin. Thesis S-1. Geological Engineering Study Program. Jenderal Sudirman University. Purwokerto, 2020.