IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 11, Issue 4 Ser. I (July. – Aug. 2023), 40-51
www.iosrjournals.org

Revealing Aquifer Potential With Audio Magnetotelluric (ADMT)Method:Case Study At Bangli Bali Narcotics Correctional Centre

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Abstract:
Research has been conducted at Bangli Bali Narcotics Correction Centre. This research is expected to reveal the state of the borehole aquifer and the potential of the aquifer with the Audio Magnetotelluric (ADMT) method. The research was conducted on six measurement trajectories. The result obtained is that in all six trajectories there is a layer of rocks. These rocks are thought to come from the eruption of Mount Batur Purba. At the research site, the distribution of water is more in the western area, while in the eastern area there is less, although there is but deeper, namely on trajectory 2 220 m depth. On trajectory 6 (northernmost trajectory) the aquifer is found at a depth of 50 m, while on trajectory 4 (southernmost trajectory) the aquifer is found at a depth of 65 m. The direction of water flow is from north to south (from trajectory 6 to trajectory 4). The condition of the borehole at Bangli Narcotics Prison in well 1 is that the aquifer lacks potential, so only a little water can be taken. In well 2 the water potential is there, presumably the pump or well drilling did not reach the position of the aquifer, so it needs to be rechecked. The aquifer potential around Bangli Bali Narcotics Correction Centre is very large, the potential discharge is estimated to be 166.9925 litres/second. The best position for drilling to obtain groundwater is on trajectory 3, 4, 5 and 6.

Keywords: *aquifer, audio magnetotelluric, discharge, potential*

Date of Submission: 09-07-2023 Date of Acceptance: 19-07-2023

I. Introduction

Bangli Bali Narcotics Correction Centre is one of the Class II A Narcotics Correctional Institution. Meanwhile, Bangli Bali Narcotics Correction Centre uses borehole water for its water needs. In the prison there are three boreholes, but until now two have not functioned and only one is left and even this water cannot be maximum so that there is still a shortage of water. For this reason, a solution needs to be found. The solution that will be done is to make a new borehole well and analyse the jamming of existing wells so that it is deemed necessary to map the potential of aquifers in the Bangli Bali Narcotics Correction Centre environment.

Mapping aquifer potential can be done using geological, hydrogeological and geophysical approaches. Geophysical approaches using Remote Sensing (RS) and Geographical Information System (GIS) have often been done[1]–[5].Likewise, the mapping of groundwater potential using geoelectric methods has also often been carried out[6]–[10]. In addition, mapping aquifer potential can also be done using the Audio Magnetotelluric Method (ADMT)[11]–[15].

The research of aquifer potential using the ADMT method is expected to reveal the potential and position of aquifers in the research area. This research is also expected to be an example of revealing aquifer potential in other places. The ADMT method is a geophysical method that utilises natural electromagnetic (EM) fields as a source of waves or energy to determine the resistance-type structure of the subsurface. The method is a passive measurement method by measuring the electric field (E) and magnetic field (H) in the frequency domain on the earth's surface. The ADMT method is able to investigate the subsurface from a depth of a few tens of metres to thousands of metres below the earth's surface. The natural source of EM fields generally comes from three frequency-dependent sources, where the frequency range reaches 0.0001 Hz to 10000 Hz, namely[16].

a. High-frequency signals (>1 Hz) originating from lightning activity,
b. Medium-frequency signals (<1 Hz) come from the resonance of the earth's ionospheric layer,
c. Low-frequency signals (<<1 Hz) come from the sun's black spots (sun-spots)

The ADMT method has a working principle based on the electromagnetic induction process that occurs in subsurface anomalies. The electromagnetic field that penetrates the subsurface will induce subsurface conductive anomalies to produce secondary currents (eddy current). The secondary current (eddy current) produced is then recorded by ADMT equipment[16]. An illustration of this situation can be seen in the following figure.

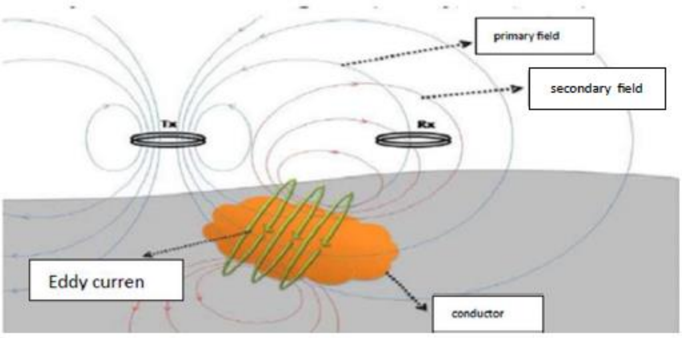

Figure 1.ADMT Method works

One of the assumptions used in the ADMT method is that the electromagnetic field is a plane wave, where the magnetic field is perpendicular to the electric field[17].

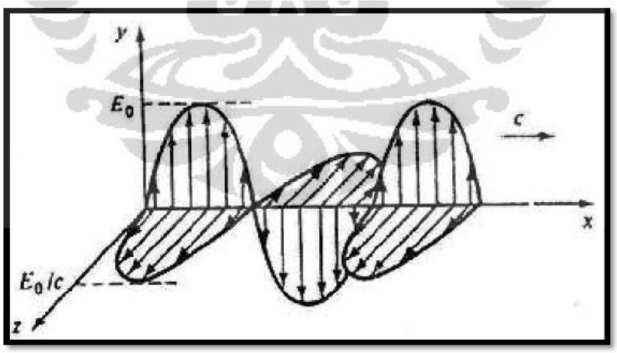

Figure 2. Illustration of electromagnetic waves

The ADMT method largely utilises the electromagnetic field which has a correlation with Maxwell's law. This electromagnetic wave phenomenon can be derived from Maxwell's equations[17].

$$\vec{\nabla}.\vec{E} = -\frac{\rho}{\varepsilon_0} \quad (1)$$

$$\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \quad (2)$$

$$\vec{\nabla}.\vec{B} = 0 \quad (3)$$

$$\vec{\nabla} \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t} \quad (4)$$

Description:
E: electric field intensity (Volt/metre)
B: magnetic field induction (Tesla or Weber / metre2)
H: magnetic field intensity (Ampere / metre)
J: electric current density (Ampere / m3)
D: dielectric displacement (Coulomb/metre2)
ρ: electric charge density (Coulomb / m3)
where ε is electrical permittivity (F/m); μ is magnetic permeability (S/m) and σ is electrical conductivity (Ωm), J is the total electric current density (A/m2).
By performing several operations and variations on Maxwell's equations, the resistance-type and phase equations are obtained as follows [16]

$$\rho_a = \frac{\mu}{\omega}|Z|^2 \qquad (5)$$

Description:
ρ: apparent resistivity (Ωm)
ω: frequency (Hz)
μ: magnetic permeability (S/m) ar
Z : Impedance (Ω)

Based on the nature of electromagnetic field propagation in conductive anomalies, the penetration depth depends on the frequency used and the resistivity of the subsurface material. It can be said that the smaller the frequency used, the penetration power of electromagnetic waves will be deeper. The range of electromagnetic waves through the material so that it has an intensity of 1/e of the original intensity can be written[16]:

$$\delta = \sqrt{\frac{2\rho}{\mu\omega}} \approx 500.\sqrt{\frac{\rho}{f}} \qquad (6)$$

δ: skin depth
ρ: apparent resistivity (Ωm)
ω: frequency (Hz)
μ: magnetic permeability (S/m) ar

It can be seen that the effect of lower resistivity leads to lower penetration power. These field quantities are measured in the ADMT method to obtain the resistivity of the material (ρ).

As explained above, the result of ADMT measurement is rock resistivity (ρ), if the rock contains water, the resistivity value will decrease[18] . Rock resistivity is also influenced by its environment[19].

Based on the explanation above, the research background can be formulated as follows:
a.How is the state of the borehole aquifer in Bangli Bali Narcotics Correction Centre?
b. How is the mapping of aquifer potential around Bangli Bali Narcotics Correction Centre?
So that the purpose of this research are:
a.To determine the state of borehole aquifers inBangli Bali Narcotics Correction Centre
b.To map the potential of aquifers aroundBangli Bali Narcotics Correction Centre.

In addition, this research is also expected to provide important information to the public, government agencies, and the commercial sector to promote sustainable groundwater management. The results of this study are essential for the proper administration, management, and long-term use of groundwater resources specifically in Bangli Bali Narcotics Correction Centre and in Bangli Regency in general.

II. Research Methods

Place of research.
The research was conducted at the Bangli Bali Narcotics Correction Centre located in Banjar Buungan Jl. Purasti Tiga, Susut District, Bangli Regency, Bali Province.

Data source

There are two types of research data, namely primary data and secondary data. Primary data was taken directly in the field by taking measurements using Audio Magnetotellurik (ADMT) equipment to obtain an overview of the distribution of aquifers in Bangli Bali Narcotics Correction Centre located in Banjar Buungan Jl. Purasti Tiga Susut Subdistrict, Bangli Regency, Bali Province. Secondary data were obtained from literature and data/information from Bangli Bali Narcotics Correction Centre.

Equipment used in research
The equipment used for primary data collection are:
a.Set of Audio Magnetotelluric tools consisting of ADMT type ADMT 300 HT2, to take measurements.
b.Laptop / android phone, for recording and analysing data.
c.HT, for communication when taking data
d.GPS, to determine the coordinate point of measurement
e.50 m long meter, to determine the measurement position
f.AIDU programme, for data processing
Primary data is data taken directly in the field. The steps to collect primary data using the ADMT 300 HT2 tool set can be explained as follows:

a. Determine the target to be measured, in this case the aquifer.
b. Estimate the flow direction.

c. Make a measurement trajectory in the transverse direction of the target flow direction (aquifer), also determine the length of the trajectory, for example 50 m, adjust to the conditions in the field.
d. Determine the measurement points, the distance between points, for example 5 m, adjust to the conditions in the field. In order to be able to make contours, measurement of at least 6 measurement points

e.Preparation for taking measurements at predetermined points.
- Turn on the ADMT tool and laptop (Android phone)
- Turn on each Bluetooth (ADMT tool and Android phone)
- Open the AIUDU programme to start the measurement.
- Pair the ADMT tool with the Android phone via Bluetooth
- Android phone settings which include: data storage file name, distance of each measurement point, measurement depth range (100 m, 200 m, 300 m).

f.Start taking measurements.
- Place the ADMT tool at the measurement point
- On the Android phone select the "New Measurement" menu
-Click the "Measure" menu and wait until it finishes taking data
- Click "confirm", then continue by moving the ADMT tool to the next measurement point.
-And so on until the last point of measurement.

Data analysis

The measured data was analysed with the AIDU program so that the resistivity contour data came out. The steps of data analysis on Android phones are as follows:

a. After completing the data collection process, the next step is to analyse the data with the AIDU program. Select the "Draw" menu.
b. Select the "Isoline graph" menu
c. Wait for a while so that the resistivity contour of the measurement results appears. This resistivity contour is analysed to obtain groundwater potential in Catur Village.
d. Interpretation of measurement data is also based on geological data and hydrological data of the data collection area.

III. Research Results

Research area

Data collection was carried out atBangli Bali Narcotics Correction Centre. The location can be seen in the following figure.

Figure 3. Research area

Geological conditions of the research area

Geologically, the rocks of the study area are volcanic rock formations of the Ancient Buyan Beratan group consisting of volcanic breccia and lava, locally tuff (Qvbb)[20]. Examples of these rocks can be seen in the riverbed. To obtain data on the position of the aquifer, research needs to be conducted.

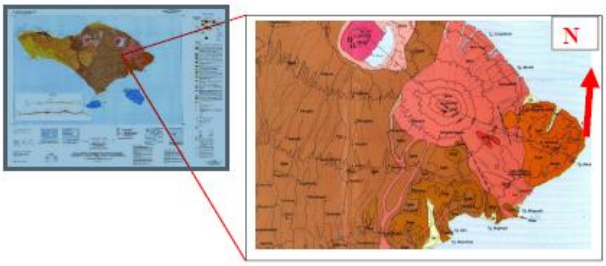

Figure 4. Geological map of the research area

Hydrogeological conditions of the data collection area

Hydrogeologically, the research area is the Denpasar Tabanan groundwater basin with a discharge of 5-10 l/s [21] as shown below.

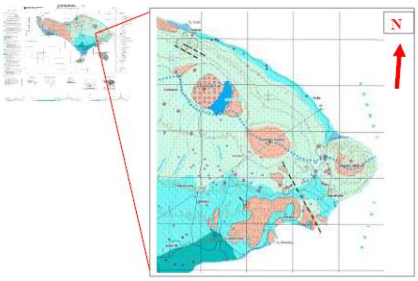

Figure 5. Hydrogeological map of the research area

Measurement trajectory in the research area

The topography is relatively flat To get more accurate results, six measurement trajectories were made, Trajectory 1 (A-A'); Trajectory 2 (B-B'); Trajectory 3 (C-C'); Trajectory 4 (D-D'); Trajectory 5 (E-E'); Trajectory 6 (F-F'); The length of each trajectory adjusts to the conditions in the field such as the presence of fences or walls, buildings and others that do not allow for data collection at that point. The length of the track and the distance between points can be seen in the following table.

Table 1. Length and distance between measurement points on each track

No.	Track Name Track	Length (m)	Distance between measurement points (m)
1	Trajectory 1	40	4
2	Trajectory 2	20	2
3	Trajectory 3	20	2
4	Trajectory 4	50	5
5	Trajectory 5	50	5
6	Trajectory 6	35	3.5

The measurement trajectory can be seen in the following figure.

Figure 6. Measurement trajectory

Contours of relative resistivity data

The research results in the form of relative resistivity data. This data is analysed with AIDU 2D software to obtain the amount of resistivity to depth in the form of contours, then based on this relative resistivity contour can be interpreted aquifer position. The relative resistivity contour and aquifer position of each track can be seen in the following figure.

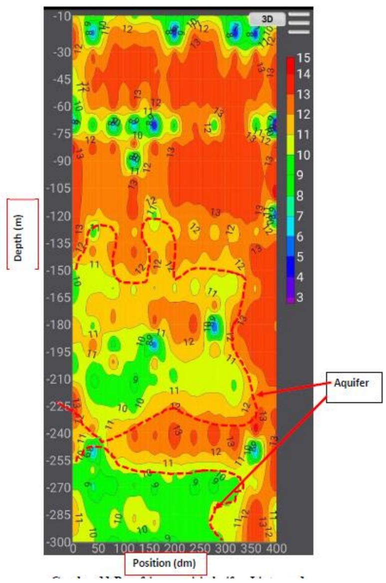

Figure 7. Interpretation of aquifer position trajectory 1

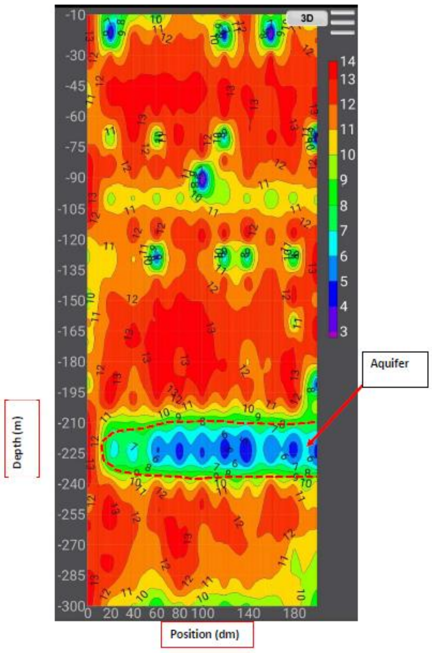

Figure 8. Interpretation of aquifer position trajectory2

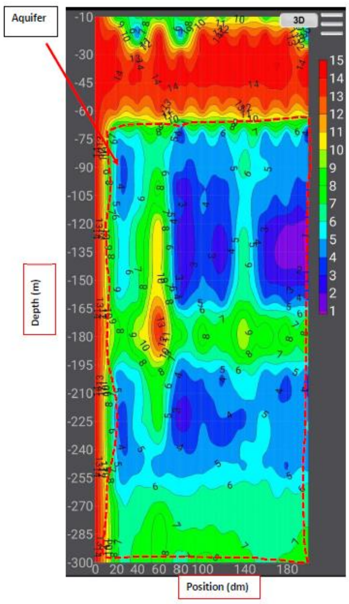

Figure 9. Interpretation of aquifer position trajectory3

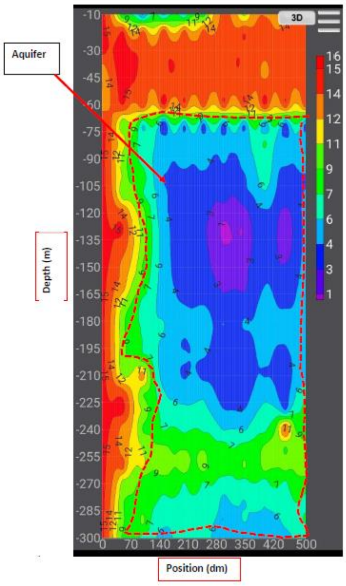

Figure 10. Interpretation of aquifer position trajectory4

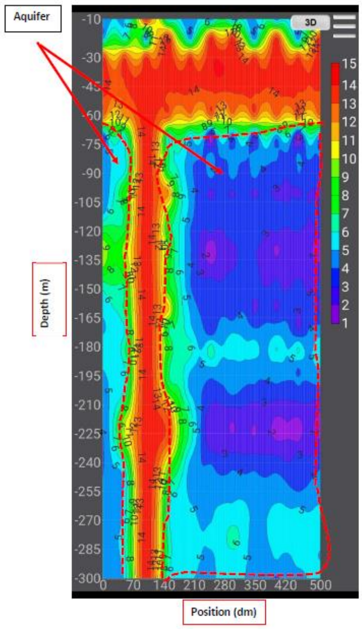

Figure 11. Interpretation of aquifer position trajectory5

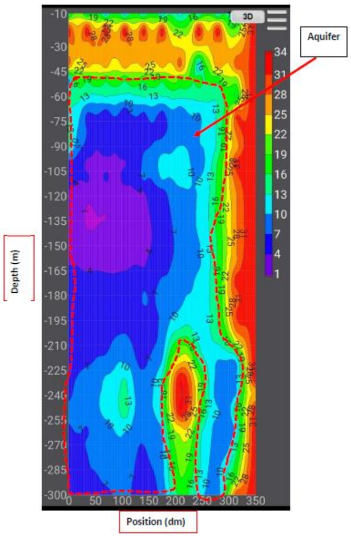

Figure 12. Interpretation of aquifer position trajectory6

In summary, the resistivity contours and interpretation of each aquifer in all measurement passes can be described as follows:

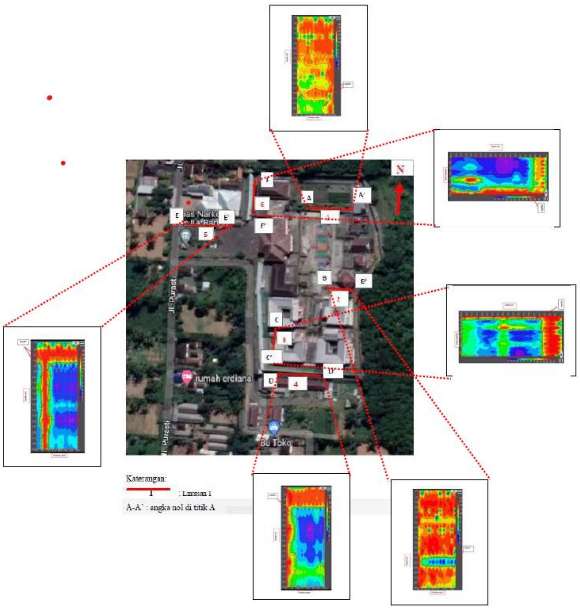

Figure 13. Estimation of aquifer position in each traverse

IV. Discussion

Hydrogeological conditions of the research area

Of the six trajectories obtained, there are visible layers of existing rocks. These rocks are thought to have originated from the eruption of Mount Batur Purba as listed in the Geological Map of Bali (Hadiwidjojo. M.M.P, 1971). In the research location, the distribution of water is more in the western area, while in the eastern area there is less, although there is but deeper, namely ontrajectory 2 is 220 m depth. In traverse 6 (northernmost traverse) the aquifer was found at a depth of 50 m, while in traverse 4 (southernmost traverse) the aquifer was found at a depth of 65m. The difference in ground surface height between traverse 6 and traverse 4 is 10 m. The distance between traverse 6 and traverse 4 is 156 m, so the hydrostatic gradient becomes ($\delta h/ \delta l$) = 25/156 = 0.1603. The direction of water flow is from north to south (from traverse 6 to traverse 4). A sketch of the hydrostatic gradient of the study area can be drawn as follows:

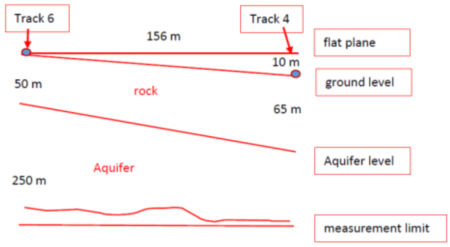

Figure 14. Sketch of the hydrostatic gradient of the study area (not to scale)

Estimation of existing water discharge can be done with Dercy's Law as follows (Kodoatie, 1996):

$Q = A\,k\,(\delta h/\,\delta l)$ (7)

Where Q is the water discharge that can be taken, A is the aquifer cross-sectional area, k is the aquifer conductivity and (δh/ δl) is the aquifer hydraulic gradient. Assuming the thickness of the aquifer is 250 m (according to the observation boundary), the length of the aquifer is 30 m (according to the observation), the cross-sectional area of the aquifer (A) becomes 250 m x 30 = 7500 m2. The conductivity of the sandy aquifer (assumed) is 12 m/day. Then the existing water discharge is:

$Q = A\,k\,(\delta h/\,\delta l)$ (8)

= 7500 x 0,0001389 x 0,1603

= 0,166992525 m^3/second

= 166,9925 liter/secon

Well evaluation

The well position is located at point 24 of traverse 1 as shown below:

Figure 15. Position of point 24 in data collection

The depth of the well is 75m while the pump position is 70m. The complaint that occurs is that the water can come out only briefly, then the water does not come out again until waiting for some time to be turned on again. This condition can be explained as follows:

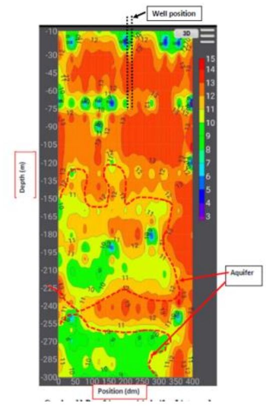

Figure 16. Position of the well with respect to trajectory 1

A sketch of the well position and pump depth can be seen in Figure 17. It appears that the well was only drilled and the pump installed by drawing water from the aquifer with a small discharge. This condition of the well or pump cannot be sustained because the area has a small aquifer.

Trajectory 6 of the well is in position 15, well depth data and pump position data are not available. Based on the ADMT measurement results, it can be interpreted that this well still has an aquifer with a depth of 50 m to the bottom (300 m) at position 15 m. The lack of water coming out of the pump is due to the absence of a pump. The absence of water coming out of the pump is possible that the pump did not get the position of the aquifer. The solution is to re-lift the pump, then ascertain the depth of the existing well, reinstall the pump in the existing aquifer position.

Well construction plan

The best positions for making wells are on trajectory 3, 4, 5 and 6 with each position and depth as follows:

Table 2. Well construction position

No.	Trajectory	Position (m)	Well depth (m)
1	Trajectory 3	15-20	65-300
2	Trajectory 4	10-50	65-300
3	Trajectory 5	14-50	65-300
4	Trajectory 6	0-30	50-300

The existing reserve water debit is 166.9925 litres/second as discussed above.

V. Conclusions

Based on this research it can be concluded that:

a. The state of the borehole inBangli Bali Narcotics Correction Centre in well 1 is indeed less potential aquifer, so that only a little water can be taken. In well 2, there is water potential, allegedly the pump or well drilling is not reaching the position of the aquifer, so it needs to be re-examined.
b. The aquifer potential around Bangli Bali Narcotics Correction Centre is very large, the potential discharge is estimated to be 166.9925 litres/second. The best position for drilling to get groundwater is on trajectory 3, 4, 5 and 6.

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