

Interpreting the aquifer in the Limbungan Village, Rumbai Pesisir District, Pekanbaru City using the Schlumberger geoelectric method

Yunita Megawati Batubara¹, Erman Taer¹, Juandi Muhammad^{1,2,*}, Rahmi Dewi¹, Zulfa¹

¹Department of Physics, Universitas Riau, Pekanbaru 28293, Indonesia

²Master of Disaster Management Study Program, Universitas Riau, Pekanbaru 28131, Indonesia

*Corresponding author: juandi@lecturer.unri.ac.id

ABSTRACT

The availability of groundwater in Limbungan Village, Rumbai Pesisir District, Pekanbaru City is crucial for ensuring clean water for local communities. Because subsurface geological conditions vary, aquifer characteristics also differ, making it necessary to identify the aquifer's presence and properties using an effective method. This study applies the Schlumberger configuration geoelectrical method to characterize the aquifer based on the distribution of subsurface resistivity values. Measurements were conducted along two profiles of 100 m each using a resistivity meter. The collected field data (current and potential difference) were processed with IPI2WIN software to generate a resistivity-depth model using one-dimensional (1D) inversion. The results indicate that subsurface resistivity values range from 6.94 Ω m to 259 Ω m, with a low inversion error of 3.66%, demonstrating good agreement between field measurements and the model. The subsurface materials consist of fine- to coarse-grained lithologies, including clay, silt, fine sand, coarse sand, and gravel. Aquifer zones were identified in the 5th and 6th layers, showing resistivity values of 186 Ω m and 259 Ω m, with thicknesses greater than 60 m. These resistivity characteristics suggest coarse-grained formations with high porosity and permeability, implying strong potential for groundwater storage and flow. Vertically, the aquifer occurs at depths of approximately ± 6 m to more than 70 m and is interpreted as a relatively stable confined aquifer. Overall, the Schlumberger geoelectric method proves effective for non-destructive aquifer identification and can serve as a reference for groundwater resource exploration.

Keywords: Aquifer; geoelectrical; groundwater; resistivity; Schlumberger

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INTRODUCTION

Groundwater is a vital and irreplaceable natural resource for the sustainability of human life, ecosystems, and the economic development of a region. Globally, groundwater supplies approximately 50% of all drinking water needs, 40% of agricultural irrigation needs, and 30% of industrial water needs [1]. In Indonesia, dependence on groundwater is even greater, reaching 60% – 70% of total household and industrial clean water needs, with national consumption exceeding 20 billion m^3 per year [2]. This situation makes groundwater management and exploration a strategic agenda for meeting the community's basic needs.

Pekanbaru City, the capital of Riau Province and the center of economic growth in Sumatra, is facing serious challenges in clean water

management. With a population that has surpassed 1 million and an average population growth rate of 3.5% per year, Pekanbaru's clean water needs continue to increase dramatically year after year. Ironically, the production capacity of the Tirta Siak Pekanbaru Regional Drinking Water Company (PDAM) is only able to serve around 60% of the community's total needs, forcing the remainder to be met independently from groundwater sources through dug wells and drilled wells [3]. This uncontrolled groundwater exploitation has resulted in a consistent decline in groundwater levels of 0.5 – 1 meter per year in suburban areas, including the Rumbai Pesisir District.

Limbungan Village, located in the Rumbai Pesisir District, is an area with unique geomorphological characteristics: hilly terrain with elevations between 50 – 150 meters above

sea level. This hilly topography creates complexities in the hydrogeological system, where aquifer distribution tends to be uneven and fragmented in rock crevices or certain alluvial layers. Based on regional geological data from the Pekanbaru Sheet, the geological formations comprising this area are dominated by the Petani Formation, which consists of alternating mudstone, sandstone, and siltstone of Late Miocene–Pliocene age, with relatively low to moderate permeability. This condition limits the aquifer potential in the Limbungan hills and makes it difficult to predict without adequate geophysical investigation.

The clean water problem in Limbungan Village is not merely a technical issue but has become a significant socio-economic problem. Field surveys indicate that approximately 40% of Limbungan Village residents rely on privately drilled wells as their primary source of household drinking water. However, most of these wells often dry up during the dry season due to lack of knowledge about the exact location and depth of the aquifer [4]. Drilling wells without accurate scientific data not only wastes significant investment costs but also has the potential to damage the soil structure due to drilling at inappropriate locations and depths. Without a comprehensive aquifer distribution map, local governments' clean water infrastructure development plans are difficult to implement effectively and efficiently.

The geoelectric resistivity method has been scientifically proven to be one of the most effective, economical, and non-invasive geophysical methods for groundwater exploration. The basic principle of this method is to inject an electric current into the earth through a current electrode, then measure the resulting potential difference through the potential electrode to obtain the resistivity value of the subsurface rock [5]. Each type of rock and fluid has a different resistivity value, so aquifer zones containing freshwater can be identified based on characteristic resistivity values. Freshwater groundwater in sedimentary rocks generally has a resistivity value between 10 – 150 Ωm , while hard, impermeable rocks

have much higher resistivity values, above 1000 Ωm [6].

Among the various electrode configurations available, the Schlumberger configuration was chosen in this study because it has several specific and relevant advantages. First, the Schlumberger configuration is very sensitive to vertical resistivity variations, thus providing detailed information on the stratification of subsurface rock layers to significant depths. Second, the Vertical Electrical Sounding (VES) method with the Schlumberger configuration is very suitable for hilly topography because it can identify fragmented aquifer layers. Third, the resulting data can be processed using IPI2WIN software to produce a 1D model of the vertical resistivity cross-section that describes the lithology and depth of each layer. Third, the resulting data can be processed using IPI2WIN software to produce a 1D vertical resistivity cross-section model depicting the lithology and depth of each subsurface rock layer [7].

Based on the problems and urgency outlined above, this study, entitled "Interpretation of Aquifers in the Limbungan Village Area, Rumbai Pesisir District, Pekanbaru City Using the Schlumberger Geoelectric Method," is necessary. This research is expected to produce an accurate aquifer distribution model in the hilly area of Limbungan Village as a scientific basis for decision-making related to the management and development of sustainable groundwater resources in Rumbai Pesisir District, Pekanbaru City.

LITERATURE REVIEW

Geology and Geomorphology of the Research Area

Regionally, the Rumbai Pesisir District is part of the Central Sumatra Basin, a Tertiary sedimentary basin dominated by clastic sedimentary rocks. Based on the Pekanbaru Geological Map (1:250,000 scale), the dominant rock formation in the research area is the Petani Formation, dating from the Late Miocene to Pliocene (N15–N21), composed of

gray mudstone, brownish-yellow fine-to-medium sandstone, and siltstone with a cross-bedded sedimentary structure. These lithological characteristics have direct implications for the potential and distribution of groundwater in the region, as the sandstone and siltstone layers act as potential aquifers, while the thick mudstone layer functions as an impermeable layer (aquitard) [8].

Geomorphologically, the research area is classified as an undulating hilly area with varying slope gradients. These conditions affect infiltration, surface flow, and groundwater distribution. In areas with steep slopes, surface flow is more dominant than infiltration, so the potential for groundwater recharge is relatively small. Conversely, in areas with gentle slopes, such as valleys and slope foothills, infiltration

is greater, potentially creating groundwater accumulation zones [9].

Aquifers

Aquifers are layers of rock or sediment capable of storing and transmitting sufficient water to be used as a groundwater source. The ability of a layer to function as an aquifer is largely determined by the rock's physical properties, particularly its porosity and permeability. Porosity indicates the rock's capacity to store water, while permeability indicates the rock's ability to transmit water through its interconnected pores [10]. Thus, a layer can have high porosity but not function as an aquifer if its permeability is low, as is the case with mudstone.

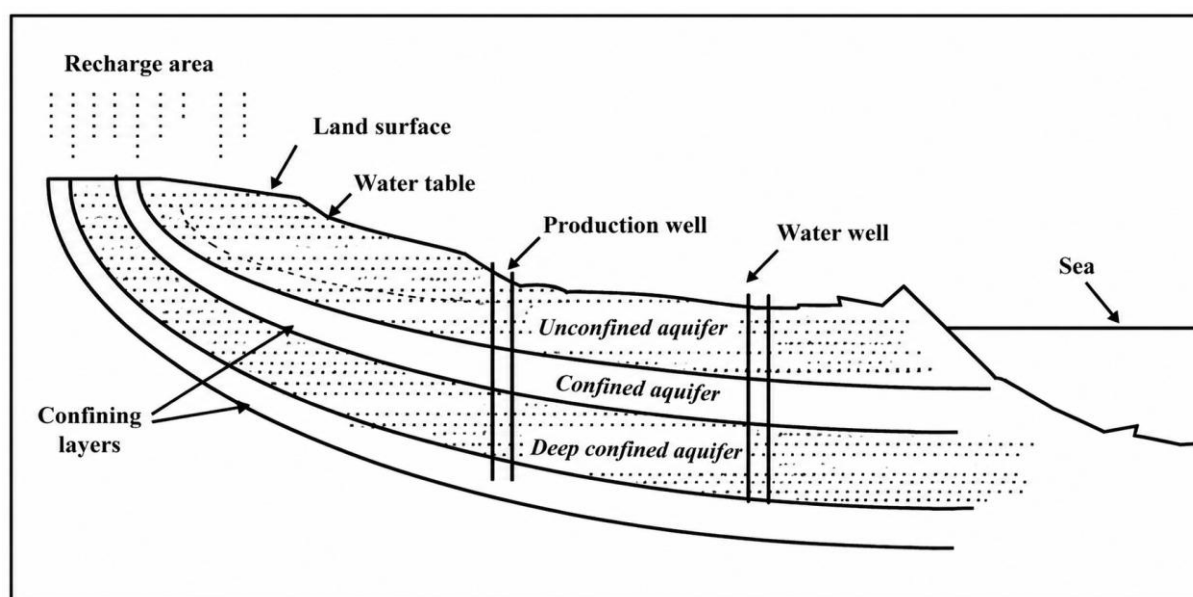


Figure 1. Aquifer classification [11].

Hydrogeologically, aquifers serve not only as a storage medium but also as a pathway for groundwater flow controlled by hydraulic gradients. Groundwater will flow from areas with high potential energy to areas with lower potential energy. Under these conditions, rock layers such as sandstone and gravel generally act as good aquifers because they have relatively large grain sizes and good pore connectivity, allowing water to flow more easily [12]. Conversely, clay layers tend to

function as impermeable layers (aquicludes) because they have very low permeability.

RESEARCH METHODS

This research was conducted in Limbungan Village, Rumbai Pesisir District, Pekanbaru City, using the Schlumberger configuration geoelectric method. Geoelectric data collection was carried out using a resistivity meter, with field measurements along a 100-meter path,

where electrodes were inserted into the ground surface at specific distances according to the configuration requirements. This method was used to obtain subsurface resistivity information related to soil and rock layer conditions. The

measurement data was then processed using IP2WIN software, which generated resistivity cross sections and subsurface layer mapping, thus more clearly representing the geological conditions in the study area.

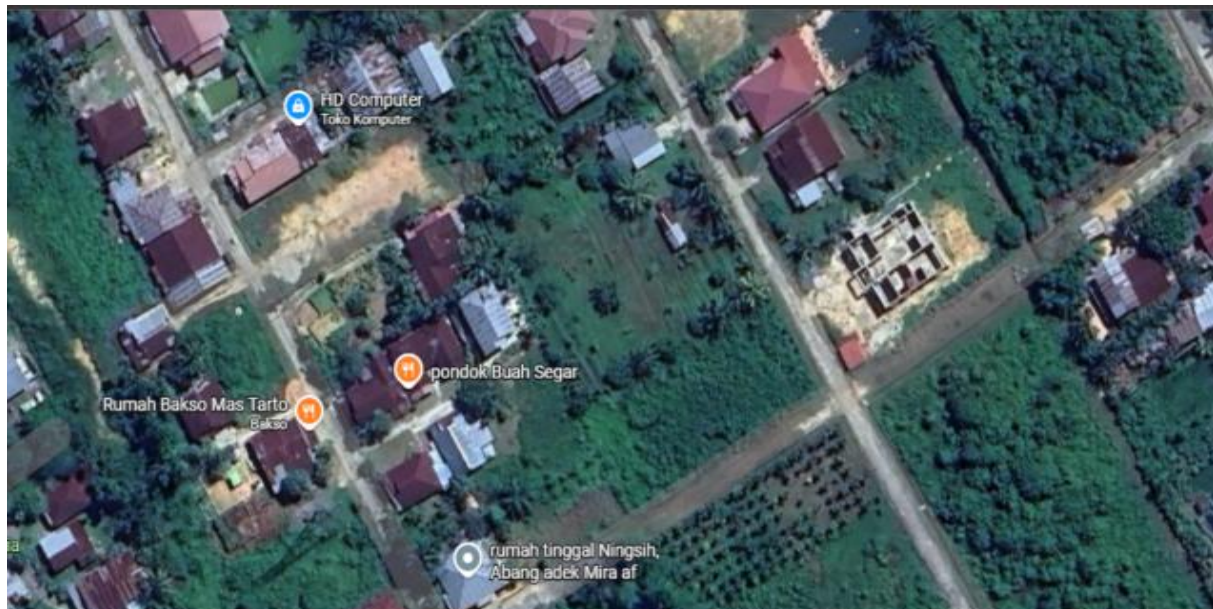


Figure 2. Research track map.

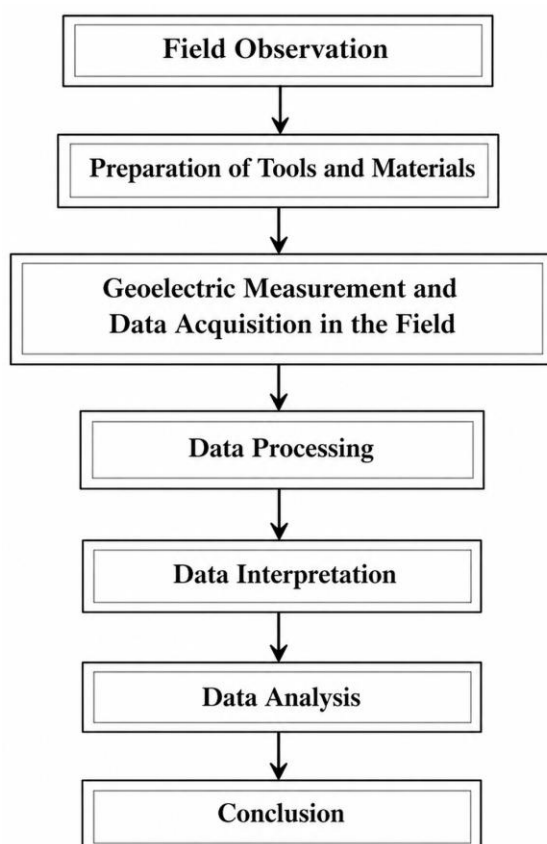


Figure 3. Research flowchart.

Research Location and Time

This research was conducted on Selais Street, Limbungan Village, Rumbai Pesisir District, Pekanbaru City. The Schlumberger configuration geoelectric method was used to obtain subsurface resistivity values to identify the potential presence of groundwater in the study area. Measurements were conducted on a single 100-meter track, located at coordinates 0°33'46.2" North Latitude and 101°27'46.7" East Longitude.

RESULTS AND DISCUSSION

Geoelectric Data Processing and Interpretation Results

Geoelectric measurements in this study were conducted on Jl. Selais, Limbungan Village, Rumbai Pesisir District, Pekanbaru City, using a Schlumberger configuration. The measurement data, in the form of apparent resistivity, was then processed through a one-

dimensional (1D) inversion process using IPI2WIN software to obtain the actual resistivity values with depth.

The inversion results are displayed in the form of a sounding curve, showing the

relationship between the measured apparent resistivity values and the subsurface resistivity model, as shown in Figure 4.

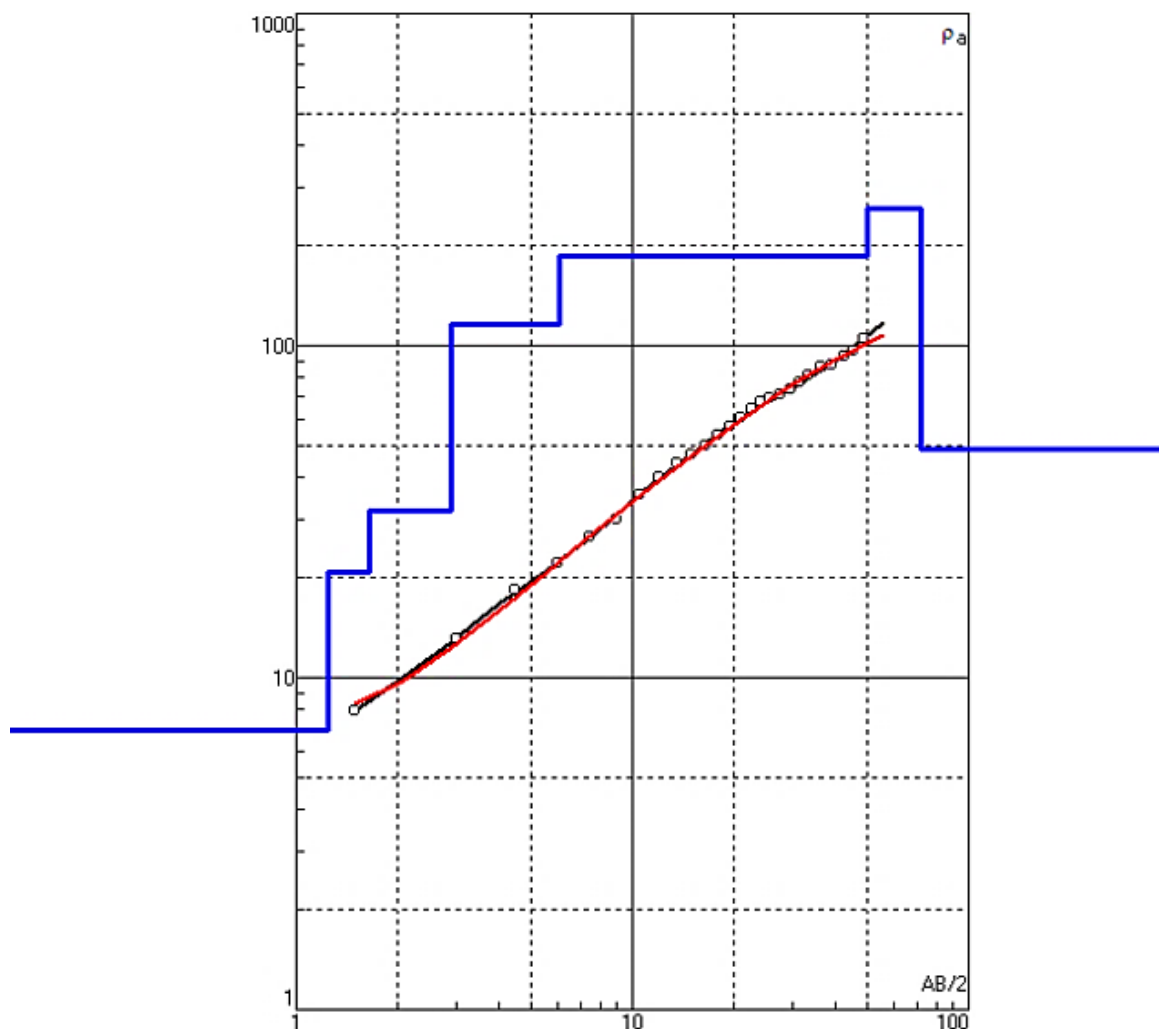


Figure 4. Geoelectric data inversion results curve (IPI2WIN).

The inversion results show an error of 3.66%, indicating a good agreement between the measured curve and the model curve. This relatively small error indicates that the obtained subsurface model is sufficiently representative

for use in interpreting the geological and hydrogeological conditions of the study area.

The inversion parameters, including resistivity, thickness, and layer depth, are shown in Table 1.

Table 1. First-traverse processing results.

Resistivity value (ρ)	Soil layer thickness (h)	Soil layer depth (d)
6.94	1.25	1.26
20.8	0.395	1.64
31.8	1.25	2.89
116	3.18	6.07
186	43.9	50
259	22	72
48.7	-	-

Based on the data processing results, a subsurface model was obtained consisting of seven layers with resistivity values ranging from 6.94 Ωm to 259 Ωm . This variation in resistivity reflects differences in lithology and the physical conditions of the rocks, particularly in terms of water content and grain size.

The first to fourth layers have resistivity values ranging from 6.94 Ωm to 116 Ωm , interpreted as representing fine- to medium-grained materials, such as clay, silt, and fine sand. These materials generally have low permeability, making them less effective in storing and draining groundwater and tend to act as a cover layer.

In the fifth layer, the resistivity value increases to 186 Ωm with a thickness of approximately 43.9 meters, indicating a change in lithology to coarse-grained materials such as coarse sand or gravel. This increase in resistivity indicates a reduction in the dominance of clay materials and an increase in the grain size and porosity of the rock.

Layer 6 exhibits the highest resistivity value, at 259 Ωm , with a thickness of approximately 22 meters. This high resistivity value can be interpreted as very coarse-grained material with possibly varying levels of water saturation. In general, these conditions still support the presence of porous zones that have the potential to store groundwater.

Meanwhile, in layer 7, the resistivity value decreases again to 48.7 Ωm , indicating a change in lithology to more conductive material, such as clay or water-saturated rock. This layer is interpreted as a confining layer (aquitard) that controls the groundwater flow system above it.

Overall, the resistivity distribution pattern shows a vertical change from finer material at the top, to coarser material in the middle, and back to more conductive material at the bottom. This pattern is an important indicator in identifying the presence and location of aquifers in the study area.

Table 2. Resistivity classification of aquifer characteristics [13].

Resistivity (Ωm)	Aquifer characteristics	Hydrogeological interpretation
< 20	Highly conductive	Clay, no potential as an aquifer
20 – 50	Conductive	Low permeability, weak aquifer
50 – 150	Moderate	Confined aquifer
150 – 300	High	Good aquifer (coarse sand)
300 – 1000	Very high	Very good aquifer (gravel)
> 1000	Highly resistive	Hard rock, non-aquifer

Analysis and Interpretation of Aquifer Characteristics Based on Geoelectric Data

Based on the results of geoelectric data processing and interpretation, the aquifer zone in the Limbungan Village area was clearly identified in layers 5 and 6. This interpretation is based on a combination of resistivity values, layer thickness, and stratigraphic relationships between layers.

Layer 5, with a resistivity of 186 Ωm and a depth of 50 meters, is interpreted as the main part of the aquifer. This resistivity value indicates a dominance of coarse-grained material such as coarse sand, which hydrogeologically has good water storage

(porosity) and permeability. The large layer thickness indicates that this zone has significant groundwater storage capacity. Layer 6, with a resistivity of 259 Ωm and a thickness of approximately 22 meters, is a continuation of the same aquifer system. Although its resistivity value is higher, this condition does not necessarily indicate the absence of water; rather, it can be influenced by variations in grain size, saturation level, and material compaction. Thus, layer 6 remains interpreted as part of the aquifer that plays a role in the groundwater storage and flow system. To clarify this interpretation, the distribution of subsurface layers and the location of the aquifer are presented in Table 2.

Based on the results of the interpretation of geoelectric data using the Schlumberger method, the main aquifer in the Limbungan Village area, Rumbai Pesisir District, Pekanbaru City is located in the 5th and 6th layers, characterized by large thickness, medium to deep depth, and composed of coarse-grained material that has good potential for storing and transmitting groundwater.

CONCLUSION

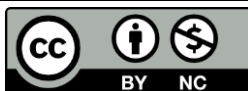
Based on the results of research and interpretation of geoelectric data conducted in Limbungan Village, Rumbai Pesisir District, Pekanbaru City, the following conclusions can be drawn:

1. The quality of the Schlumberger geoelectric data inversion on the Selais Street in Limbungan Village shows a good level of agreement, as indicated by an error value of 3.66%. This indicates that the obtained subsurface resistivity model is sufficiently representative for interpreting geological and hydrogeological conditions.
2. The subsurface structure consists of seven layers with resistivity values ranging from 6.94 Ωm to 259 Ωm . The resistivity variation indicates vertical changes in lithology: the upper layer is dominated by fine-grained material (less effective as an aquifer), the middle layer exhibits coarser material (more potential as an aquifer), and then the lower layer becomes more conductive, serving as a flow barrier.
3. The main aquifer zone is found in the 5th and 6th layers, with characteristics of high resistivity (around 186 Ωm and 259 Ωm), large thickness, and medium to deep depth. This layer is interpreted to be composed of coarse-grained material (e.g. coarse sand/gravel) which has good potential as a groundwater storage and flow, while the layer below it acts as a limiting layer (aquitard) that controls the flow system.

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