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Article

Integrated Geoelectric and Hydrogeochemical Survey to Analyze the Potential of Underground Water in Solok, West Sumatra, Indonesia

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Abstract: The purpose of this study was to recommend to the government about the appropriate land use based on geoelectric and hydrochemical works. The results were supposed to be used as models for effective land use. During the study, a groundwater survey using a geoelectrical method was conducted and was used to map an aquifer flow. In general, Solok groundwater mapping was meant to provide information necessary to optimize follow-up activities for the use of clean water. It was also intended to minimize the negative impacts of exploitation and utilization of groundwater. This research aimed to provide information on groundwater conditions in Solok. It focused on the survey of groundwater sources, the inversion of measurement data on Sclumberger electrode configuration geoelectric in thirteen districts, and chemical analysis of pH, Fe, Nitrite, and DHL. The results show there was a great potential for groundwater-unconfined aquifers.

Keywords: potential; groundwater; geoelectrical; chemical parameter; physical parameter

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1. Introduction

Underground water is a natural resource widely used for consumption, activities, agriculture, and industrial use [1,2]. The management of the resource includes inventory, regulation of utilization, permit, guidance, control, and supervision of the recharge areas. This is achieved by relying on the principle of social function and economic value, public benefit, integration, harmony, balance and sustainability [3]. Inadequate information reduces the level of success in planning and managing groundwater sources. This is attributed to the complexities and feedbacks in human-environmental interactions, which necessitates accurate data to improve efficiency and success in planning and managing groundwater sources [4].

Management of groundwater should focus on overcoming the problem of drought. This need to involve a long-term analysis and assessment of groundwater systems and routine monitoring by the government [5]. The management should also aim at filling groundwater regularly. For the ongoing management to be maintained, there is a need to avoid damage or degradation of land resources [6,7]. The study of groundwater management planning furthermore needs to be supported by modeling the flow of aquifers for risk assessment to be carried out by the government in planning and decision making [8].

Groundwater management relates to hydrological data for calculations and modeling, which includes technical and organizational aspects of sustainability [9]. However, a more efficient study on water management involves its sustainable use, and therefore it is necessary to regulate water usage in urban areas, including in the private sector [10]. The use of freshwater aquifers for irrigation purposes indicates a long-term threat, and therefore a legal entity is needed to help overcome the difficulties related to integrated water management. Groundwater is the primary source of freshwater [11, 12].

Proper underground water management need to consider water chemistry, including the presence of heavy metals Fe and Nitrite. Evaluation of Fe needs to be conducted since it affects human health [13]. Generally, Fe concentrations in several locations are always different, and the amount of Nitrite in groundwater affect the resistivity values measured [14].

The study of groundwater involved geophysical methods which analyzed the distribution of leachate in two dimensions [15, 16]. Also, geoelectric applications to determine brine boundaries in alluvial aquifers have been reviewed [17].

Previous studies show that geoelectric applications only provide an overview of subsurface resistivity values associated with rock types and socio-economic aspects for sustainable groundwater management. In this study, a novelty obtained connects the characteristics of aquifer with concentrations of Fe and Nitrite using geoelectric imaging and hydrogeochemical analysis. This research furthermore provides a sustainable groundwater management model for industrial and residential aspects to prevent environmental damage.

2. Materials and Methods

2.1. The Study area

In this research, the study area is about 57.64 km^2 with reference interpretation of the geological formation being the Alluvium of the River (Qal). It consists of igneous rock, quartzite, gravel, sand and clay located in the Members of the Kuantan Formation (Solok Geological Map). This research combined the geoelectric method with hydrogeochemical analysis to determine contamination by Fe and Nitrite in groundwater.

2.2. Analyze water samples

The data involved 13 groundwater samples, with 12 taken from existing wells, and 1 from the drill point at site 4 in Village IX Korong. The chemical characteristics of groundwater were analyzed using the hydrogeochemical method. In-situ parameters of the samples include well depth, well location, water depth, pH, and conductivity measured directly during groundwater sample collection. Figure 1 shows the research area, geoelectric measurement location and groundwater survey. The groundwater samples furthermore were analyzed for anion content using ion chromatography (IC). The water samples are filtered in acid and adjusted to a pH between 2 and 4 to analyse the presence of heavy metals. Also, inductively coupled plasma (ICP) is used to analyze water samples to obtain content cations.

2.2. Geoelectric Survey

A total of 13 sites were investigated with the Resistivitymeter McOHM Mark-2 Model-2115A for 1D geoelectric resistivity imaging. Geodetic data was obtained through a topographic survey producing information on coordinates and altitude. Afterward, these coordinate points are used as measurement parts in geophysical surveys. The geophysical data collection is carried out by the geoelectric method using Schlumberger arrays. This configuration requires 4 electrodes, 2 current and 2 potential. The measurements are made by determining the potential in the middle electrode when the current in the outer rod is injected into the earth. Additionally, the measurement is taken from the smallest to the largest electrode space, while the resistivity values are obtained automatically for each pair of current and voltage electrodes. To obtain true resistivity profiles, the apparent data obtained from the field is processed using IP2Win software. In data processing IP2Win software was used (Loke And Barker, 1996; Loke 2007 software). Based on the map pattern of potential lines formed, it is possible to determine the direction of distribution of aquifers below the surface of the surveyed area.

3. Results

The results and discussion begin with the analysis of physical and chemical parameters of groundwater. Resistivity analysis includes the aquifer system and its anomaly resistivity value. Discussion of physical and chemical parameters of groundwater include Nitrite, conductivity, iron and pH and need to be complemented by search and mapping. The survey location and topography of the study area are shown in Figure 1.

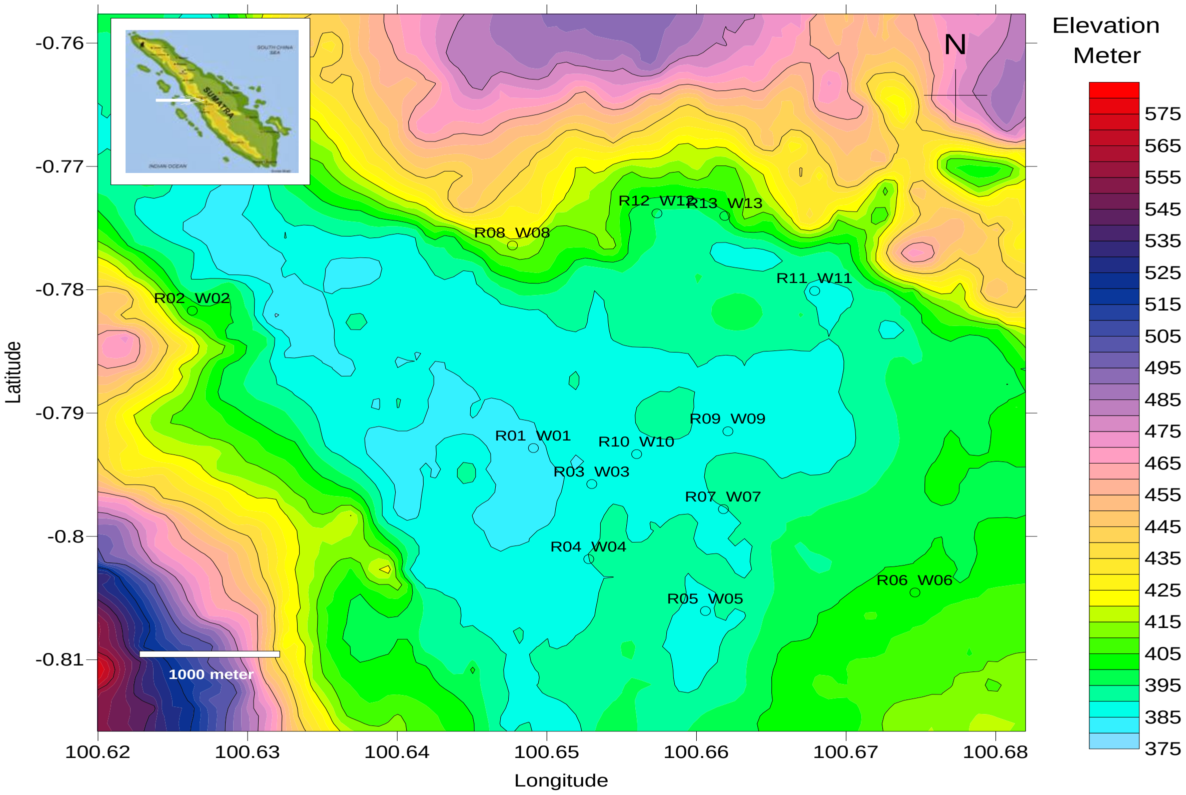

Figure 1. Survey location and research area topography

3.1. Hydrogeochemical Groundwater

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The results of the analysis of physical and chemical parameters are shown in Table 1. The elevation values of sampling locations are at intervals of 395 to 415 meters above sea level, as shown in Figure 2.

Based on data obtained from existing wells, the lowest depth is in the Village VI Suku from 5.52 m to 77.9 meters, while the maximum is at the Village Tanah Garam, which is 15.53 m to 68.93 meters. The allocation of groundwater is shown in Table 1. In general, the pH in the area of the study was appropriate. It was in accordance with the clean water quality standards based on the Minister of Health Regulation No. 416/Per/IX/1990, i.e. pH = 7.

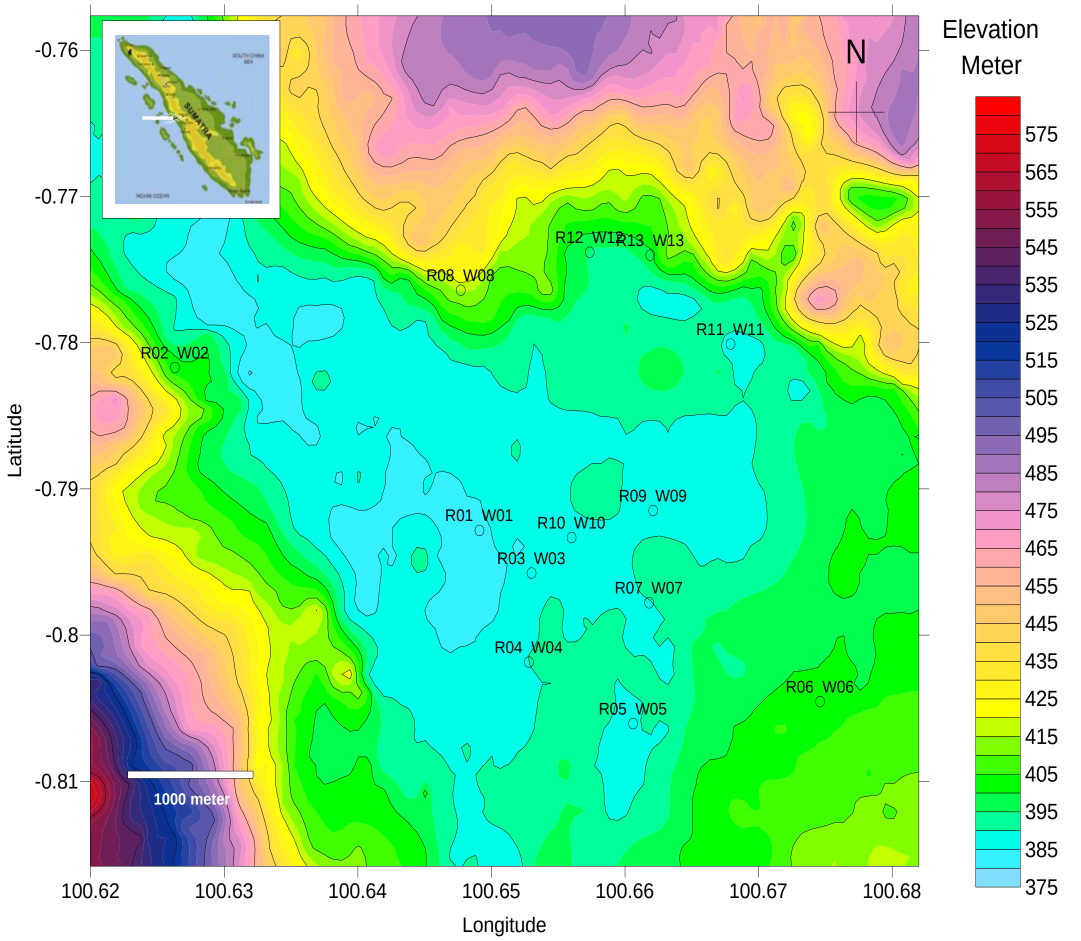

Figure 2. Elevation of the study sampling location

Table 1. Data from groundwater Hydrogeochemical measurements.

No	Location	**X.m**	**Y,m**	W.Depth, m	DHL (mikromhos/cm)	pH	Nitrit Mg/l	Fe Mg/l	Utilization
1	Village VI Suku	0.792836	100.6491	5.52	100.7	7.025	0.040	1.085	Settlements, Agriculture
2	Village Tanah Garam	0.7817	100.6263	15.53	87.72	7.157	0.068	0.956	Recharge, conservation, settlement
3	Village Sinapa Piliang	0.795756	100.653	6.02	89.29	7.5	0.075	0.53	Settlements, Agriculture

4	Village IX Korong	0.801842	100.6528	13.8	86.21	6.975	0.058	0.425	Settlements, Agriculture
5	Village KTK	0.806047	100.6606	11.2	93.46	7.3	0.032	0.53	Settlements, Agriculture
6	Village Simpang Rumbio	0.804547	100.6746	12.1	95.24	7.3	0.06	0.453	Industrial area
7	Village Aro IV Korong	0.797786	100.6618	9.13	106.27	6.6	0.076	0.28	Settlements, Agriculture
8	Village Kampung Jawa	0.776408	100.6477	12.8	92.59	6.7	0.03	1.34	Industrial area
9	Village Pandan Air Mati	0.791475	100.6621	12.1	105.6	7.1	0.03	0.05	Settlements, Agriculture,
10	Village Koto Panjang	0.793328	100.656	7.94	101.32	7.075	0.048	0.328	Settlements, Agriculture
11	Village Tanjung Paku	0.780094	100.6679	7.76	86.21	7.1	0.063	0.307	Settlements, Offices
12	Village Laing	0.767475	100.6558	15.3	94.34	6.9	0.095	0.59	Recharge (Imbuhan), conservation, settlement
13	Village Nan Balimo	0.767475	100.6558	9.1	102.77	6.933	0.049	0.967	Settlements, Offices

The pH is relatively lower on the north, specifically in the location of W08 in the east and west. A low pH value is also found towards the south at the sample W07, as shown in Figure 3 (a). The small value in the south is due to the relatively lower area, which increases the potential for flooding. This condition leads to a lot of deposited organic matter in the region, making the water acidic. Furthermore, Nitrite concentration in the north is relatively higher than in the east or west, specifically at the W12 sample location. It is relatively lower than to the west and east at the sample location W05. Additionally, Nitrite concentrations in the central part of the city of Solok is relatively small, including the samples W01, W10, and W09, as shown in Figure 3 (b). Nevertheless, its

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concentration in the north is due to the relatively higher than in the northern area containing mineral rocks with a lot of Nitrite compounds. The low concentration in the south is due to the reduction of rocks or minerals which contribute to nitrite compounds, as shown in Figure 3 (b). In general, the quality of underground water in Solok City based on Nitrite content has always been below the quality standard (3 mg/L), (Permenkes No. 416 of 1990 and drinking water quality standards according to the Decree of the Minister of Health Number 492/MENKES/PER/IV/2010).

The concentration of iron from east to west is relatively higher in samples W02, W08 and W01, but small in W09, W07, W04, W05, and W06, as shown in Figure 3 (c). Its low concentration to the south is evidenced by the high pH (Figure 3 (a)). Conductivity values from east to west are relatively small at sample locations W02 and W04, each with high pH values (Figure 3 (a)). However, conductivity is relatively moderate in the middle part of the city of Solok compared to the surroundings, such as at locations W01, W10 and W13. This is due to the high elevation with many rocks or metal mineral compounds which increase and dissolve in water, resulting in high conductivity values, as shown in Figure 3 (d) Figure 3. Hydrogeochemical Survey

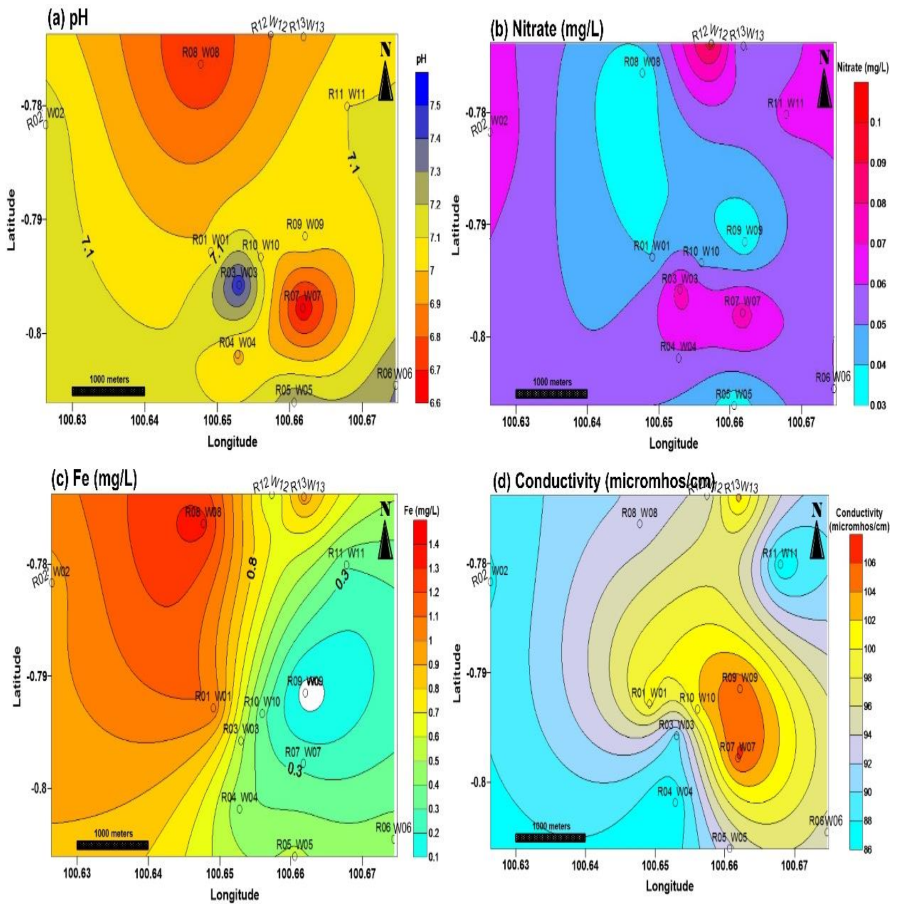

Figure 3. Hydrogeochemical Survey

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3.2. Geoelectrical resistivity

Geoelectric surveys and measurements were carried out at 13 locations. The results are shown in Figure 4 (a) to (m). Figure 4a through to 4m shows the result of inverse modeling, which requires field observation to match the model data. Table 2 shows the rock types and layers in the study area.

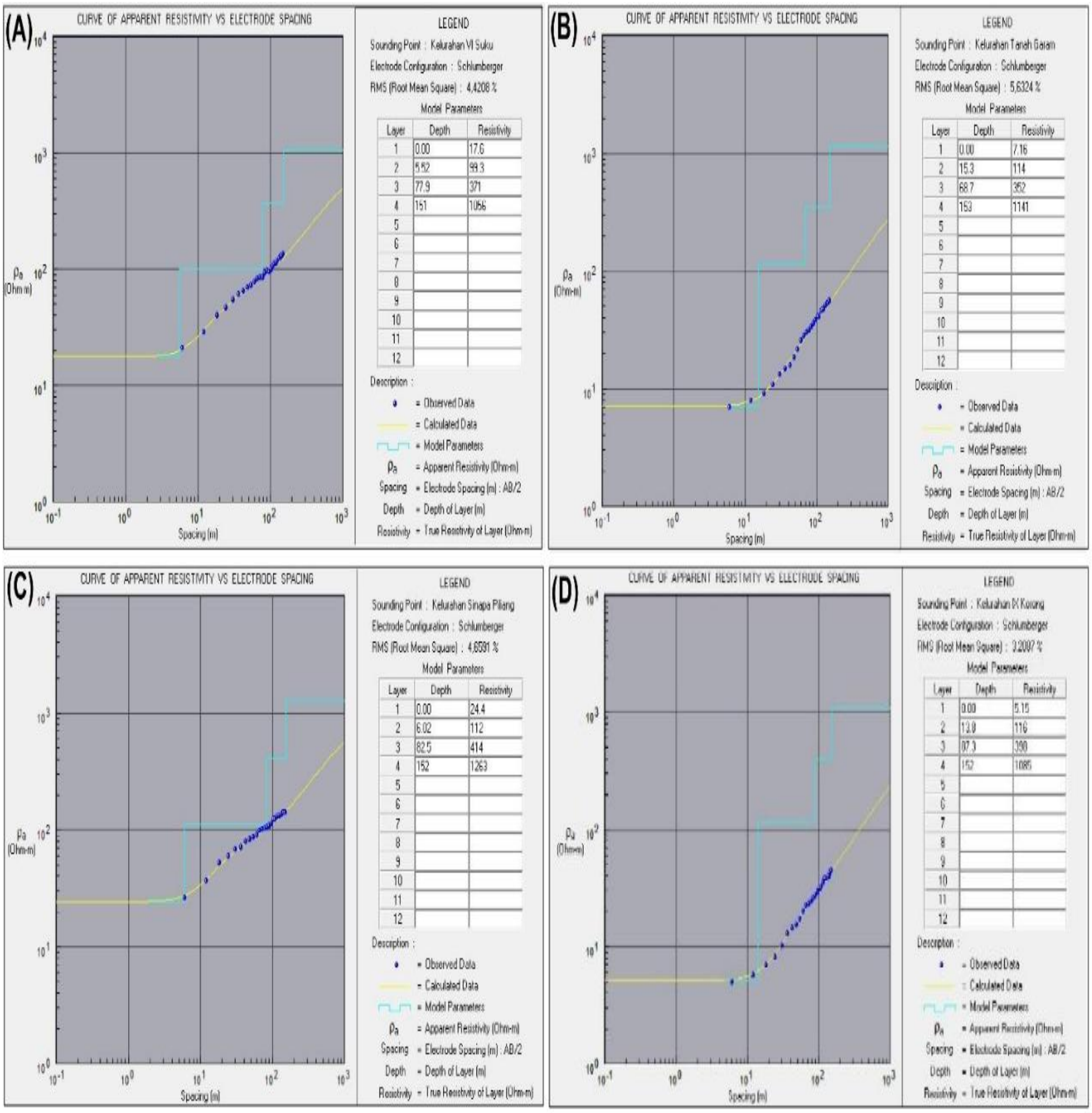

Figure 4. Geoelectric profile of the 13 villages. (a) VI Suku, (b) Tanah Garam, (c) Sinapa Piliang, (d) XI Korong, (e – m) in appendix.

Table 2. Interpretation of Geoelectric Survey Results

Location	Coordinate		Inteterpratation Results
	N	E	
Village VI Suku	0° 47' 34.21"	100° 38' 56.7"	4 rock layers. The first layer resistivity value is 17.6 Ωm with a thickness of this layer is 5.52 m, this layer is interpreted as a clay layer. The second layer, the resistivity value of 99.3 Ωm with a thickness of this layer 72.38 m, is interpreted as a layer of sandy loam containing surface water. The third layer with a resistivity of 371 Ωm with a thickness of this layer 73.1 m this layer is

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			interpreted as gravel. The fourth layer with a large resistivity of 1056 Ωm, this layer is the innermost layer that can be known from the measurements made.
Village Tanah Garam	0° 46' 54.12",	100° 37' 34.52	4 rock layers. The first layer resistivity value is 7.16 Ωm with a thickness of this layer is 15.53 m, this layer is interpreted as a clay layer. The second layer, the resistivity value of 114 Ωm with a thickness of 53.4m, is interpreted as a layer of sandy loam containing surface water. The third layer with a resistivity of 352 Ωm with a thickness of this layer 84.3m this layer is interpreted as gravel. The fourth layer with a large resistivity of 1141 Ωm, this layer is the innermost layer that can be known from the measurements made.
Village Sinapa Piliang*	0^0 47′ 44,72″	103^0 39′ 10,65″.	there are 4 layers of rock. The first layer resistivity value is 24.4 Ωm with a thickness of this layer is 6.02m, this layer is interpreted as a clay layer. The second layer, the resistivity value of 112 Ωm with a thickness of 76.3m, is interpreted as a layer of sandy loam containing surface water. The third layer with a resistivity of 414 Ωm with a thickness of this layer 69.5m this layer is interpreted as gravel. The fourth layer with a large resistivity of 1263 Ωm, this layer is the innermost layer that can be known from the measurements made.
Village IX Korong	0^0 48′ 6.63″:	103^0 39′ 10.09″.	shows there are 4 layers of rock. The first layer resistivity value of 5.15 Ωm with a thickness of this layer is 13.8m this layer is interpreted as a clay layer. The second layer has a resistivity value of 116 Ωm with a thickness of this layer 73.5m which is interpreted as a layer of sandy loam containing surface water. The third layer with a resistivity of 398 Ωm with a thickness of this layer 64.7 m this layer is interpreted as gravel. The fourth layer with a large resistivity of 1263 Ωm, this layer is the innermost layer that can be known from the measurements made.
Village KTK	0^0 48′ 21.77″	100^0 39′ 38.27″.	there are 4 layers of rock. The first layer resistivity value of 23 Ωm with a thickness of this layer is 11.2 m, this layer is interpreted as a clay layer. The second layer, the resistivity value of 107 Ωm with a thickness of 74.7 m, is interpreted as a layer of sandy loam containing surface water. The third layer with a resistivity of 397 Ωm with the thickness of this layer 67.1m this layer is interpreted as gravel. The fourth layer with a large resistivity of 1263 Ωm, this layer is the innermost layer

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			that can be known from the measurements made.
Village Simpang Rumbio	0° 48' 16.37"	: 100° 40' 28.44"	there are 4 layers of rock. The first layer resistivity value of 18.6 Ωm with a thickness of this layer is 12.1 m this layer is interpreted as a clay layer. The second layer has a resistivity value of 105 Ωm with a thickness of this layer of 70.4m is interpreted as a layer of sandy loam containing water surface. The third layer with a resistivity of 401 Ωm with a thickness of this layer 69.5m this layer is interpreted as gravel. The fourth layer with a large resistivity of 1129 Ωm, this layer is the innermost layer that can be known from the measurements made.
Village Aro IV Korong	: 0° 47' 52.03":	100° 39' 42.64".	there are 4 layers of rock. The first layer resistivity value is 11.8 Ωm with a thickness of this layer is 9.13m this layer is interpreted as a clay layer. The second layer has a resistivity value of 94.1 Ωm with a thickness of this layer of 75.07 m which is interpreted as a layer of sandy loam containing surface water. The third layer with a resistivity of 338 Ωm with a thickness of this layer 68.8m is interpreted as gravel. The fourth layer with a large resistivity of 1164 Ωm, this layer is the innermost layer that can be known from the measurements made.
Village Kampung Jawa	0° 46' 35.07" :	100° 38' 51.82".	there are 4 layers of rock. The first layer resistivity value is 29.6 Ωm with a thickness of this layer is 12.8 m this layer is interpreted as a clay layer. The second layer has a resistivity value of 108 Ωm with a thickness of this layer of 73.4 m which is interpreted as a layer of sandy loam containing surface water. The third layer with a resistivity of 404 Ωm with the thickness of this layer 67.8m is interpreted as gravel. The fourth layer with a large resistivity of 1164 Ωm, this layer is the innermost layer that can be known from the measurements made
Village Pasar Pandan Air Mati	0° 47' 29.31":	100° 39' 43.53".	there are 4 layers of rock. The first layer resistivity value of 14 Ωm with a thickness of this layer is 12.1 m this layer is interpreted as a clay layer. The second layer has a resistivity value of 94.7 Ωm with a thickness of this layer of 71.8m which is interpreted as a layer of sandy loam containing surface water. The third layer with a resistivity of 377 Ωm with a thickness of this layer 68.1m this layer is interpreted as gravel. The fourth layer with a large resistivity of 1276 Ωm, this layer is the innermost layer that can be known from the measurements made.

Village Koto Panjang	0° 47' 35.98":	100° 39' 21.73"	there are 4 layers of rock. The first layer resistivity value of 19.7 Ωm with a thickness of this layer is 7.94m this layer is interpreted as a clay layer. The second layer has a resistivity value of 98.7 Ωm with a thickness of this layer of 73.66 m which is interpreted as a layer of sandy loam containing surface water. The third layer with a resistivity of 393 Ωm with a thickness of this layer 72.4m this layer is interpreted as gravel. The fourth layer with a large resistivity of 1130 Ωm, this layer is the innermost layer that can be known from the measurements made.
Village Tanjung Paku	0° 46' 48.34"	: 100° 40' 4.34".	there are 4 layers of rock. The first layer of resistivity value of 25.2 Ωm with a thickness of this layer is 7.76m this layer is interpreted as a clay layer. The second layer has a resistivity value of 116 Ωm with a thickness of this layer of 75.54m which is interpreted as a layer of sandy loam containing surface water. The third layer with a resistivity of 397 Ωm with a thickness of this layer 69.7m this layer is interpreted as gravel. The fourth layer with a large resistivity of 1063 Ωm, this layer is the innermost layer that can be known from the measurements made.
Village Laing	0° 46' 2.91"	100° 39' 20.72".	there are 4 layers of rock. The first layer of resistivity value is 33 Ωm with a thickness of this layer is 15.3m this layer is interpreted as a clay layer. The second layer has a resistivity value of 106 Ωm with a thickness of 70.3m which is interpreted as a layer of sandy loam containing surface water. The third layer with a resistivity of 391 Ωm with a thickness of this layer 68.4m this layer is interpreted as gravel. The fourth layer with a large resistivity of 1129 Ωm, this layer is the innermost layer that can be known from the measurements made.
Village Nan Balimo	0° 46' 48.68"	100° 39' 8.77".	there are 4 layers of rock. The first layer resistivity value of 8.8 Ωm with a thickness of this layer is 9.1 m this layer is interpreted as a clay layer. The second layer has a resistivity value of 97.3 Ωm with a thickness of 73.6m which is interpreted as a layer of sandy loam containing surface water. The third layer with a resistivity of 393 Ωm with a thickness of this layer 69.3m this layer is interpreted as gravel. The fourth layer with a large resistivity of 1114 Ωm, this layer is the innermost layer that can be known from the measurements made.

3.3. Distribution of Geoelectric Resistivity

Figure 5 shows the resistivity contours at various depths. In this study, its resentation was carried out for the surface (Figure 5a), depth of 260m (Figure 5b), 300m (Figure 5c), 340m (Figure 5d) and 380m (Figure 5e). The surface is at intervals of 10 to 50 ohms while the lithological interpretation is likely to be Clay. The resistivity contour at a depth of 260 meters with an interval of resistivity values is 1100 to 1300 Ohm which contain Sandstone lithology. The contour at a depth of 300 meters has resistivity at intervals of 300 to 400 ohms and therefore has Gravel lithology. Still, the contour at a depth of 340 meters has a resistivity value of 50 to 150 Ωm which means it contains groundwater lithology. Resistivity contour at a depth of 380 meters with resistivity values at 10 to 150 Ωm, which is interpreted to contain ground water lithology.

Based on the Geoelectric survey, the Laing and Tanah Garam Villages serves as a Recharge area. The Solok City government should make efforts to maintain the catchment area by planting trees and avoid underground water pollution. The area is efficient for underground water conservation as well as for residential purposes, but not suitable for industrial estate.

Kampung Jawa Village is has the potential to be industrial regions, while Nan Balimo Village and Tanjung Paku Village are appropriate residential or office areas.

Simpang Rumbio Village is appropriate for an industrial area, especially for processing firms, as well as for underground water utilization.

Pasar Pandan Air Mati Village, Aro IV Korong, KTK, Koto Panjang, Sinapa Piling, IX Korong, and VI Suku are fit for residential or agricultural areas. The government also needs to create a catchment area for the sustainability of underground water.

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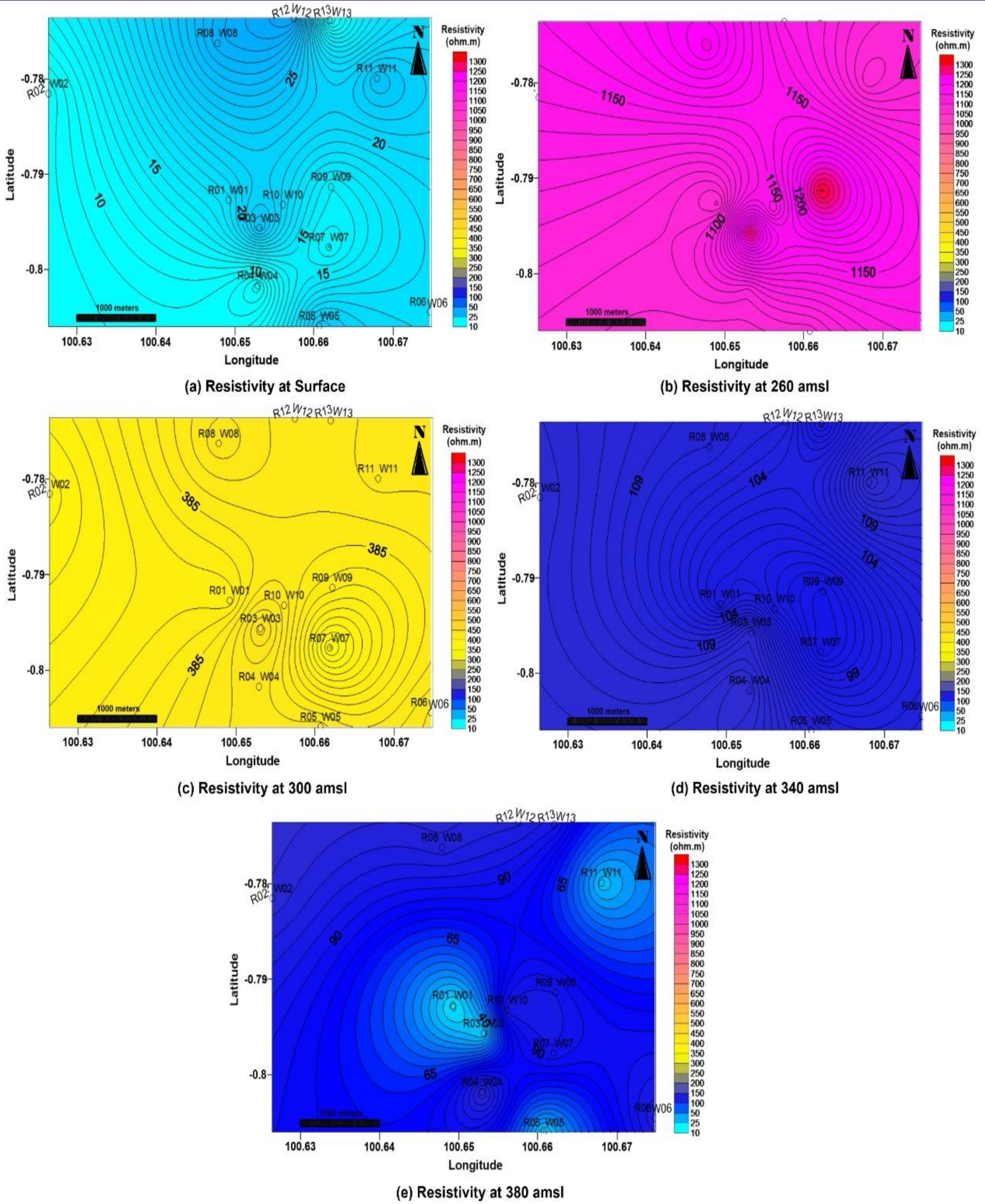

Figure 5. Resistivity Mapping at various depths

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3.4. Subsurface Geological Modeling

Based on the results of the Solok City geoelectric study, subsurface geology is modelled as shown in figure 6. The first layer on the surface is composed of clay lithology, the second is clay sand, and the third is the gravel and the Bedrock Layer. The flow pattern model is indicated by the direction of the arrows in red.

Figure 6 shows the condition of underground water flow in Laing and Tanah Garam villages, interpreted as a Recharge area. The Solok City government needs appropriate handling measures for the sustainability of underground water. This involves maintaining the catchment area by planting trees and avoiding underground water pollution. The area is well used for underground water conservation, though it is not suitable for industrial estate designation. It is fit for residential designation since the conservation of underground water sources remains secure. Additionally, the government needs to make efforts to enforce environmental laws relating to the private sector as developers or development of space must continue to preserve the environment through legal products such as the need to make biopori wells to maintain the sustainability of underground water. The direction of underground water flow from Laing to Sinapa Piliang, and from Tanah Garam to Sinapa Piliang, as can be seen in Figure 6. Information on thickness and type of lithology in the study area can be seen in Table 2.

Table 2. Information on lithology thickness in the study area

Location	Thickness (m)		
	Clay	**Clay Sand**	**Gravel**
Tanah Garam	15,3	53,4	84,3
VI Suku	5,52	72,38	73,1
IX Korong	13,8	73,5	64,7
Sinapa Piliang	6,02	76,3	69,5
Koto Panjang	7,94	73,66	72,44
KTK	11,2	74,7	67,1
Aro IV Korong	9,13	75,07	68,8
Pasar Pandan Air Mati	12,1	71,8	68,1
Simpang Rumbio	12,1	70,4	69,5
Tanjung Paku	7,76	75,54	69,7
Nan Balimo	9,1	73,6	69,3
Kampung Jawa	12,8	73,4	67,8
Laing	15,53	70,3	68,4

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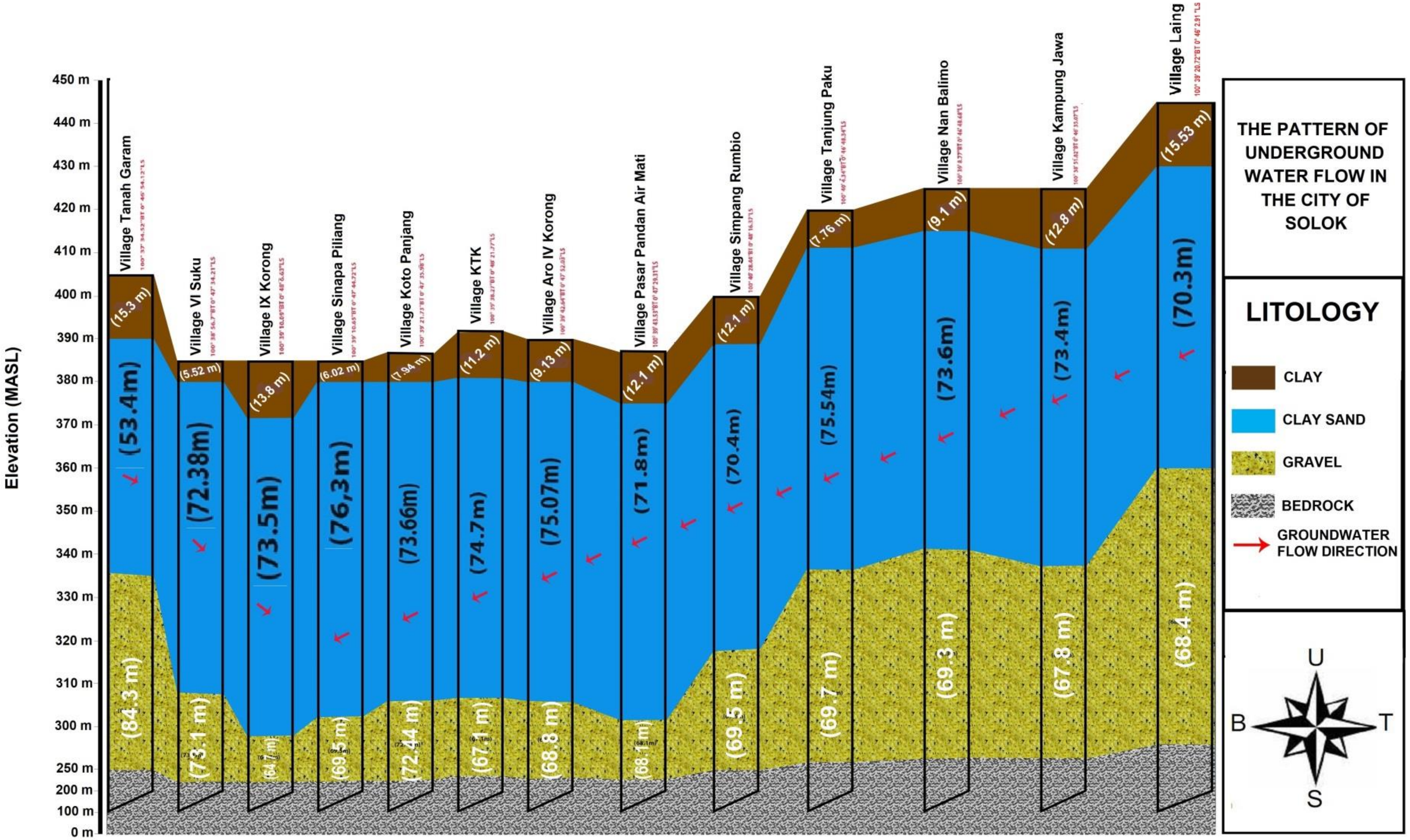

Figure 6. Geological Modeling of the Surface of the City of Solok, West Sumatra, Indonesia Based on Geoelectric studies

3.5. Regional Development Recommendations Based on Groundwater Potential and Conservation and Utilization of Groundwater in the Villages of Kampung Jawa, Nan Balimo and Tanjung Paku.

The lithological conditions in these three villages have a small difference on infiltration of surface water into the underground system based on the thickness of the upper clay layer. For this reason, Kampung Jawa is an environmental-friendly industrial area while Nan Balimo and Tanjung Paku are appropriate either for residence or office areas. The moderate infiltration rates in these two areas make it safe for office and domestic waste to penetrate underground. Environmental legislation to protect underground water resources from industrial and domestic pollution are supposed to be maintained.

3.6. Regional Development Recommendations Based on Groundwater Potential and Conservation and Utilization of Groundwater in the Simpang Rumbio Village.

The environmental conditions makes Simpang Rumbio a suitable for processing and underground water utilization industries. This is because the first layer is a clay with a very small permeability level. According to environmental legislation, it should be used as an industrial processing area. Since the area has a good aquifer thickness, it is appropriate or industrial underground water use. However, efforts to conserve natural resources through environmental laws need to be monitored in the implementation.

3.7. Regional Development Recommendations Based on Groundwater Potential and Conservation and Utilization of Groundwater in Pasar Pandan Air Mati Village, Aro IV Korong Village, KTK Village, Koto Panjang Village, Sinapa Piliang Village, IX Korong Village, and VI Suku Village

Based on geological lithology conditions, aquifer thickness, flow and topography patterns, Pasar Pandan Air Mati Village, Aro IV Korong, KTK, Koto Panjang, Sinapa Piling, IX Korong, and VI Suku are appropriate areas for residential or agricultural use. This is because the area has a basin where underground water accumulates from Recharge. The government must ensure the area is not used as an industrial site but reserved as a conservation area. The government also needs to create a catchment area to reserve plants for underground water to be maintained.

3.8. Potential and Quality of Underground Water in Solok City based on Hydrogeochemical survey

The sampling are then compared to clean water quality standards with 416 of 1990 according to the Decree of the Minister of Health No. 492/MENKES/PER/IV/2010. The quality of underground water in Solok either equals the the lower limit of clean water quality standards or exceeds this threshold. However, it is below the upper limit standards, except at the Gawan. Based on the pH indicator, the underground water in the City of Solok is quality and should be used for clean water needs, except at the Gawan. In general, the pH from the field measurement is either equal to the lower limit of drinking water quality standard or exceeds this threshold. It is, however, smaller than the upper limit of quality standards, except for Gawan.

The underground water in the City of Solok produces clean water since the Fe value falls below quality standard, except in some regions. Areas with Fe content above the threshold include Nan Balimo (Nushalla Darul Jadid), Galanggang Betung (Baitil Amanah Mosque), VI Suku (Mushalla Nurul Ilmi), Tanah Garam (Mushalla Al Muttaqin), Kampung Jawa (Ainul Yakin Mosque), and Jawa Village (Nurul Yaqin Mosque).

The iron content in the underground water exceeds the standard of drinking water quality(0.3 mg/L), except in locations such as Sianik Rice Field, VI Suku (Musahlla Baitul Izzah), VI Suku (Musahalla darul Hikmah), Gawan, Tanah Garam, Tanjung Paku (Musahlla Al Iklas), PPA (Mosque of Irsyaddunnas), and Simpang Rumbio Village. Also, the Nitrite content is below the clean water quality standard (1 mg/L).

There are several human activities which lead to underground water pollution, apart from domestic wastes such as rubbish and septic tanks directly disposed of in rock layers. There is also waste from the market and hospitals, as well as from tofu industry which pollute underground water.

Based on the evaluation of groundwater data and the DHL, the Solok City area is divided into two parts. First, potential underground water areas are on the edge of the Kampung Jawa village, VI. Suku. The depth of the groundwater varies from 5.52 m to 12.8 m below, with electrical conductivity (DHL) between 104 to 107 micromhos/cm. Residents usually use underground water from the wells. Second, there is a large underground water potential areas in the Laing village, Nan

Balimo, Tanjung Paku, Sinapa Piling, Pandan Air Mati Market, Tanah Garam, IX. Korong, KTK, Koto Panjang, Aro IV. Korong, and Rumbio Intersection. The depth of the groundwater varies from 6.02 m to 15.3 m. Also, there is electric conductivity (DHL) between 86 - 103 micromhos/ cm, which indicates the quality of underground water. In general, the value of DHL in Solok City shows the groundwater is fresh quality.

4. Conclusions

This study analyzed the potential of underground water using geoelectric surveys and hydrogeochemical analysis in 13 villages in the City of Solok, West Sumatra, Indonesia. It also examined hydrogeochemical groundwater samples from community wells and drilling results on the geoelectric measurement trajectory. From the survey results, several recommendations have been made on the use and development of the region. This include a medium and a large underground water potential area with a wide distribution and the designation of recharge areas, settlements, offices, industrial and agricultural regions.

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APPENDIX

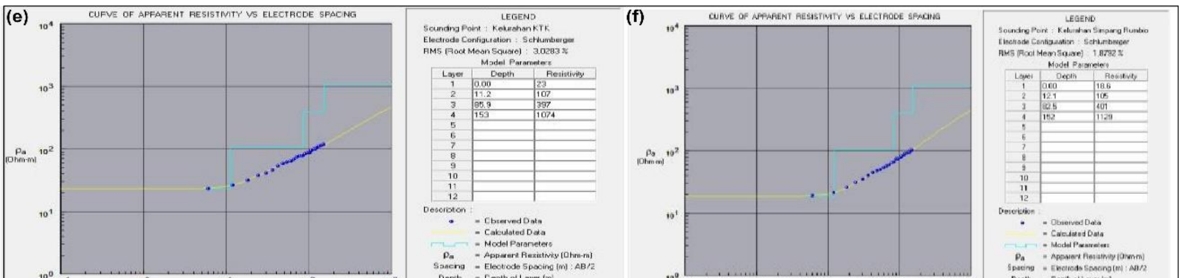

Figure 4. Geoelectric profile of the 13 villages. (e) KTK, (f) Simpang Rumbio, (g) IV Korong, (h) Kampung Jawa, (i) Pasar Pandan Air Mati, (j) Koto Panjang, (k) Tanjung Paku, (l) Laing, and (m) Nan Balimo