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The Geoelectric Resistivity Methods to Determine the Presence or Position of Layers and the Aquifer Type in Transition and Inland Tropical Peatlands of Central Kalimantan, Indonesia

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***Abstract*— The decreasing groundwater level (GWL) in degraded tropical peatland areas during the dry season has been one source of annual peat fire disasters in Central Kalimantan. After the severe peatland fire in 2015, Peatland Restoration Agency's strategies' peatland restoration efforts enhance peat moisture and increase the groundwater level of the hundreds of deep wells and canal blocking in the burned area of 2015. This study examines the use of geoelectric resistivity methods in determining the attachment or position of layers and types of aquifers in transition and inland tropical peatland. The research was conducted on transitional peatlands in Sidodadi Village with 19 estimate points of resistivity geoelectric, nine estimate points in the inland swamp in Taruna Jaya Village, and 18 estimate points Kalampangan Village. This research used the quantitative approach is a one-dimensional (1 D) resistivity geoelectric, which using the Schlumberger array. While the qualitative process verified the result of sequences observation with two drill wells in Sidodadi, two drill wells in Taruna Jaya, 18 hand drill wells in Kalampangan, and geological stratigraphy. The research results obtained 4 (four) layers of composition with resistivities ranging from 1.224 - 661.1 Ωm in Sidodadi, ranging from 3.37 – 7,950 Ωm in Taruna Jaya Kalampangan ranging from 5.36 - 16719 Ωm. The geoelectric data and field verification interpretation show that the soil/lithology layer consists of 4 (four) layers: peat, sand, sandy clay, and clay. The type of aquifer is an unconfined aquifer. The type of aquifer is an unconfined aquifer.**

***Keywords*— Geoelectric resistivity; determine position; aquifer; tropical peatland.**

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I. INTRODUCTION

Peatland is one of the natural resources that have an ecohydrological function for human life and livelihoods. Peatland is also functioning as an agricultural object in a broad sense done by individuals or corporations. This function occurs because peatlands are land where the thickness of organic soil is more than 0.40 meters [1]. Peatland near the ground is aerobic, while the transition between peat and mineral soil is anaerobic [2]. In Indonesia, classification of peatland based on hydrological and geological features three are coastal peat (in areas affected by seawater), transitional peat (in areas affected by brackish water), and inland peat (in freshwater areas) [3].

The problem arises on cultivated peatland when entering the dry season because the community and corporations set on fire to make a land clearing. Indonesia's peatlands have been converting to agricultural land and plantations in a large area [4]. The condition of peat or peatland substances is low and dry, so the potential for fire is too high. Land clearing is done by combustion because it requires a cheap cost and speed in clearing the land.

Most researchers and government officials agreed that the cause of peatland fires was the opening of land for smallholders and plantation agribusiness companies [5]. The most considerable disruption affecting peatland ecosystems at a spatial level is wildfires lasting long periods [6]. Peatland fires are caused by deforestation and drainage of peatland, resulting in the degradation of tropical Southeast Asian peatlands [7]. During the dry season, it reduces the supply of surface water and groundwater, so to mitigate peatland fires could be disturbed.

To extinguish a fire requires quite a lot of water. One water source that can still be obtained in the area, especially far away from the river flows during the dry season, is groundwater. Groundwater supplies only 0.61% of total world water distribution, and around 50 to 70 times more is from surface water. The surface water condition is easily known because it can be seen on the ground surface, but it is difficult for groundwater availability. Groundwater is a water resource whose existence is not seen. Geophysical techniques are a sensitive method for knowing geological, hydrological, and biogeochemical parameters [8]. Ground water is water that fills the saturated zone of water, including springs that appear on Earth's surface [9].

The soil/rock layer containing groundwater is called an aquifer to get groundwater to find and know the type and depth. The role of the geophysical method of getting groundwater is to understand the condition of underground hydrogeology adequately and accurately [10]. Vertical Electrical Sounding (VES) is one of the geoelectric methods used in geoelectric resistivity survey techniques. It has been successfully using in determining different lithological positions [11]. The Vertical Electrical Sounding (VES) technique is widely used in electrical resistivity surveys on the horizontal or almost horizontal earth layers [12]. Similarly, the method of Geoelectric resistivity is the most promising and most appropriate in groundwater prospecting; [9]. VES data analysis conducted by the qualitative approach is compared with a soil layer [13]. This research aims to determine the position and type of aquifers in transitional peat areas and inland peat.

II. Materials and Methods

The methods used in this research were quantitative and qualitative descriptive. This research was conducted in 3 (three) locations, namely, 1 (one) place representing transitional peat in Sidodadi Village, Pulang Pisau Regency, and 2 (two) sites serving in the inland peat area in the Taruna Jaya Village, Pulang Pisau Regency, and Kalampangan Village, Palangka Raya City, Central Kalimantan Province.

The types of equipment used in field observations are geoelectric resistivity equipment, shallow drilling equipment, GPS, storage batteries, handy talkies, geological compasses, measuring instruments, hand drills, and a set of shallow water drills. Materials used in the form of the research location map (Fig. 1), regional geological map (Fig. 2), Central Kalimantan groundwater basin map (Fig. 3).

This research was initiated from the primary data retrieval in Sidodadi Village, Taruna Jaya Village, and Kalampangan Village. This study also uses several potential electrode configurations in the resistivity method, such as the Schlumberger, Wenner, and Dipole Sound configurations [9]. The geophysical method used was geoelectric resistivity, horizontal geoelectric mapping, usually using the Schlumberger electrode configuration [10]. The initial stage determines the location of the measurement point and reads its coordinates using GPS equipment. A portable GPS is used to know the geographical area and elevation of a site [14]. Next, at each point was carried out resistivity measurement using resistivity geoelectric equipment.

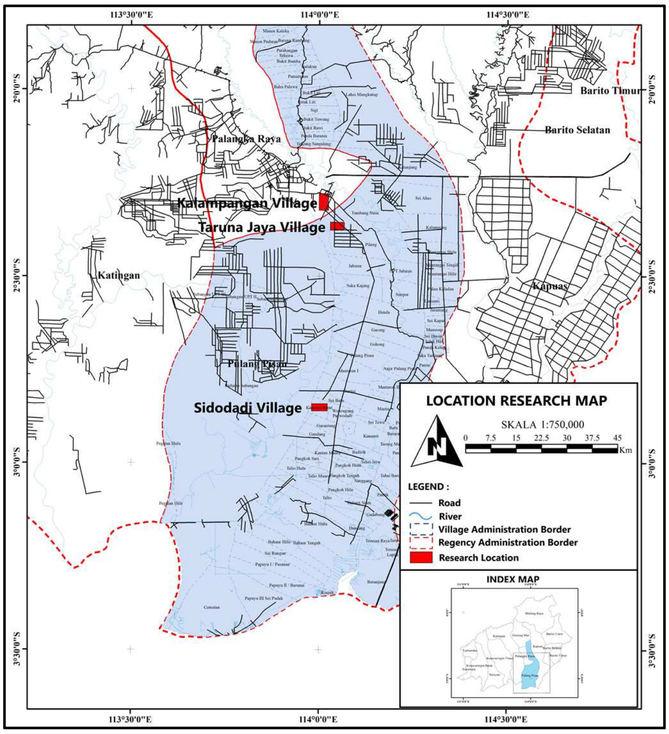

Fig. 1 Research location

The measurement model was 1 D (one dimensional) with a Schlumberger configuration. The current expanse of electrodes starts from 1.5 meters to the farthest 300 meters, while the potential electrode expanses from 0.5 meters to 50 meters. Data that was read when measuring is the magnitude of the current given and the potential measurable difference. The next activity was to drill a shallow well with a depth of 30 meters, Sidodadi and Taruna Jaya's village, each of the two wells. The data was obtained in the form of lithology and the layout of depth. In Kalampangan Village, drilling using hand drills up to a depth of 2.5 meters as much as 18 holes.

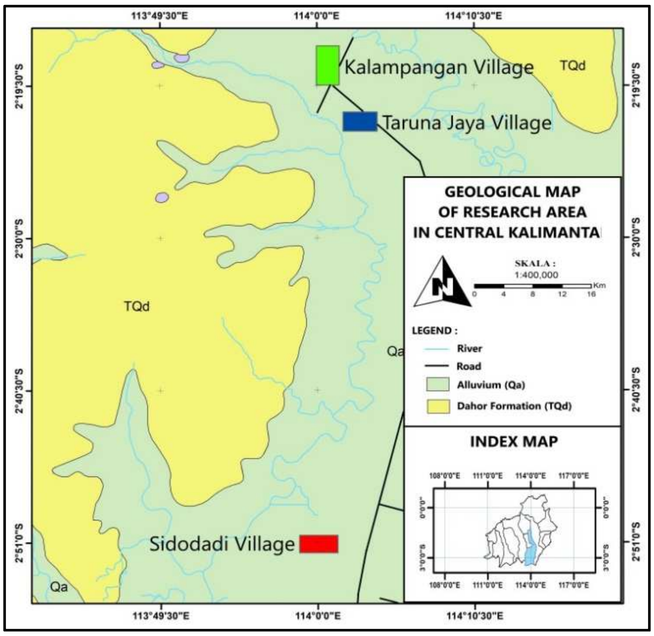

Fig. 2 Regional Geology map of research

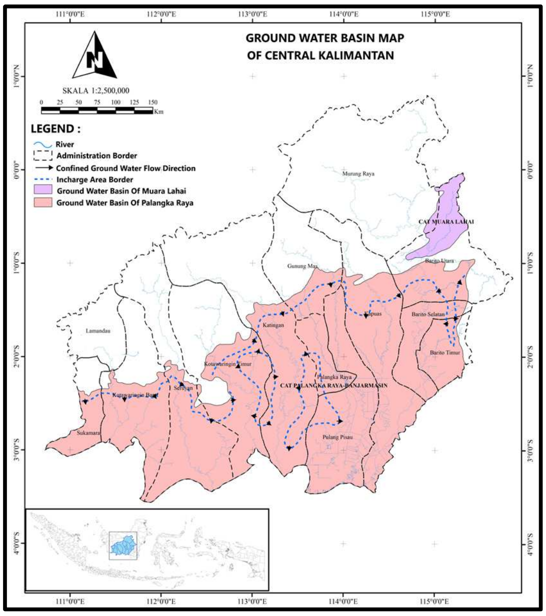

Fig. 3 Central Kalimantan Groundwater Basin Map

The secondary data is the lithology layer of the regional geological map published in 2007. Information on groundwater basin conditions is taken from the groundwater basin map of Central Kalimantan. Geoelectric data processing using IPI2WIN software. The IPI2WIN software generates the lithological resistivity value below the surface of each measurement point. Apparent resistivity should be the same as layer resistivity at high and low-frequency limits [15]. It was an apparent resistivity.

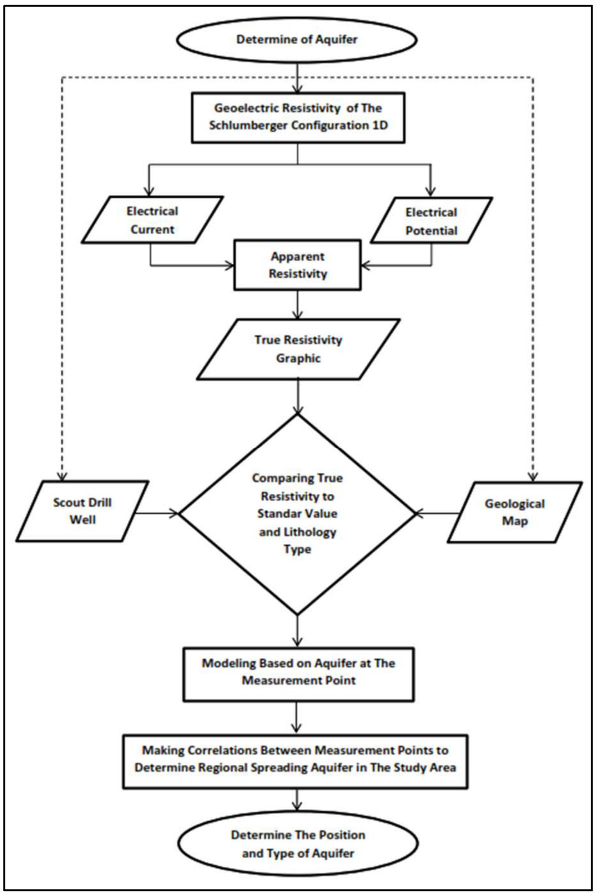

Fig. 4 Research flowchart

The IPI2WIN software is using to convert the apparent resistivity value to the actual resistivity value. The software used an iterative way that minimizes the difference between prediction and measurement. It results in a sub-surface structure [16]. This resistivity value was then interpreted by comparing it with the standard's values [17], [18]. Also, it considers the number of layers, the sequence of well-bore lithology, and the geological map in interpreting.

Interpretation of geological data was necessary for translating quantitative value into an available and realistic picture of the Geological sense [19]. After knowing the well-borehole rock lithology, the next step is to connect between measurement points to produce a vertical cross-section along the cross-sectional direction. The Cross-section correlation used Corel Draw software. Flowchart research is shown in Fig. 4.

III. Result and Discussion

A. *Resistivity Values in the Research Area*

1) Resistivity values in Sidodadi village: Measurement of resistivity in Sidodadi Village is to measure 19 (nineteen) points spread in research. Measurement stretches using a Schlumberger configuration with a stretch of 150-300 meters. From the measurement and processing of data using IPI2WIN software, there are 4 (four) layers with a resistivity ranging from 1.224 – 661.1 Ωm. In complete could be seen in Table I below:

TABLE I
INTERPRETATION RESULT OF GEOELECTRIC DATA PROCESSING IN SIDODADI VILLAGE

Postcode	Depth (meters)	Resistivity (Ωm)	Lithology/soil
Sd1	0 – 0.951	75.1	Peat
	0.951 – 1.637	15.7	Sandy-clay
	1.637 – 14.14	39.7	Sand
	14.14 – 34.94	298	Sand
	34.94 – 99.44	2.73	Clay
	99.44 - ~	219	Sand
Sd2	0 – 0.558	22.3	Peat
	0.558 – 0.994	141	Sand
	0.994 – 7.33	27.3	Sand
	7.33 – 56.23	124	Sand
	56.23 - ~	124	Sand
Sd3	0 – 0.9	35.37	Peat
	0.9 – 1.973	182.1	Sand
	1.973 – 43.26	11.16	Sandy-clay
	43.26 – 101.8	90.58	Sand
	101.8 - ~	49.66	Sand
Sd4	0 – 0.9	50.4	Peat
	0.9 – 1.97	250	Peat
	1.97 – 4.32	6.44	Clay
	4.32 – 103.4	119	Sand
	103.4.8 - ~	4.79	Clay
Sd5	0 – 0.9	55.7	Peat
	0.9 – 1.97	207	Sand
	1.97 – 9.52	22.1	Sandy-clay
	9.52 – 45.62	184	Sand
	45.62 - ~	42.5	Sand
Sd6	0 – 0.9	76.4	Peat
	0.9 – 4.01	104	Sand
	4.01 – 8.29	12.4	Sandy-clay
	8.29 – 46.99	195	Sand
	46.99 - ~	40.2	Sand
Sd7	0 – 0.235	682.5	Peat
	0.235 – 4.177	166.2	Peat

	4.177 – 32.11	87.92	Sand
	32.11 – 66.46	336.2	Sand
	66.46 - ~	3.091	Clay
Sd8	0 – 0.272	1115	Peat
	0.272 – 3.982	72	Peat
	3.982 – 19.58	32.8	Sand
	19.58 – 42.68	603	Sand
	42.68 - ~	1.61	Clay
Sd9	0 – 0.9	162.5	Peat
	0.9 – 1.881	86.66	Peat
	1.881 – 17.26	136.6	Sand
	17.26 – 35.98	265.4	Sand
	35.98 - ~	44.25	Sand
Sd10	0 – 0.655	228.4	Peat
	0.655 – 6.732	112.9	Peat
	6.732 – 15.64	36.91	Sand
	15.64 – 36.86	427.4	Sand
	36.86 - ~	1.224	Clay
Sd11	0 – 0.9	70.8	Peat
	0.9 – 4	95.2	Peat
	4 – 8.28	229	Peat
	8.28 – 17.2	58.4	Sand
	17.2 – 35.93	285	Sand
	35.93 - ~	44.6	Sand
Sd12	0 – 2.08	58.9	Peat
	2.08 – 4.8	333	Peat
	4.8 – 14.75	33.2	Sand
	14.75 – 24.95	1194	Sand
	24.95 - ~	11.2	Clay
Sd13	0 – 3.53	59	Peat
	3.53 – 7.38	186	Peat
	7.38 – 14.53	33.9	Sand
	14.53 – 33.93	624	Sand
	33.93 - ~	8.83	Clay
Sd14	0 – 3.46	89.8	Peat
	3.46 – 6.73	275	Peat
	6.73 – 11.55	51.1	Sand
	11.55 – 71.85	263	Sand
	71.85 - ~	5.98	Clay
Sd15	0 – 1.4	102	Peat
	1.4 – 2.6	53.5	Peat
	2.6 – 6.52	282	Peat
	6.52 – 11.23	25.2	Sand
	11.23 – 82.83	140	Sand
	82.83 - ~	6.8	Clay
Sd16	0 – 2.49	71.9	Peat
	2.49 – 8.12	212	Peat
	8.12 – 15.48	32.3	Sand
	15.48 – 34.58	508	Sand
	34.58 - ~	14.2	Sandy-clay
Sd17	0 – 1.453	340.9	Peat
	1.453 – 2.279	116.1	Peat
	2.279 – 21.60	324.5	Sand
	21.60 – 68.63	661.1	Sand
	68.63 - ~	6.058	Clay
Sd18	0 – 1.869	340.2	Peat
	1.869 – 3.882	217.6	Peat
	3.882 – 8.062	633.4	Peat
	8.062 – 16.74	101.8	Sand
	16.74 – 72.25	402.4	Sand
	72.25 - ~	70.54	Sand
Sd19	0 – 1.838	231	Peat
	1.838 – 7.478	189	Peat
	7.478 – 15.11	490	Sand
	15.11 – 30.55	174	Sand
	30.55 – 61.8	424	Sand
	61.8 - ~	50.6	Sand

Further, an overview of the surface is made cross-section through Sd1, Sd3, Sd5, Sd6, Sd7, Sd9, Sd11, Sd13, Sd14, Sd19, Sd18, Sd17 (Fig. 5).

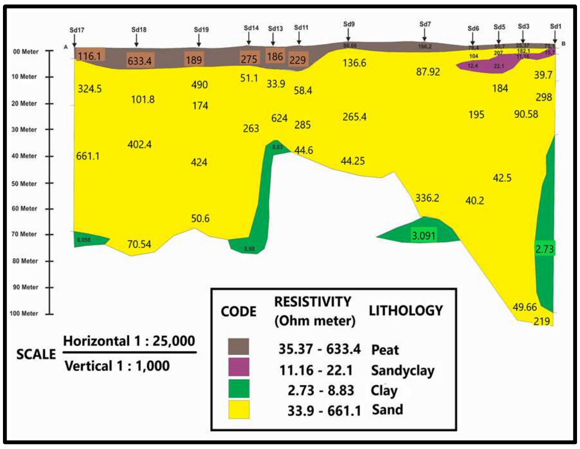

Fig. 5 Lithology Profile in Sd1-Sd17 directions

2) Resistivity value in Taruna Jaya village: Measurement of resistivity in Taruna Jaya Village measures 9 (nine) points spread in research. Measurement stretch using a Schlumberger configuration with a distance between 100 - 300 meters. The measurement and processing of data using Software IPI2WIN obtained 4 (four) composition layers with a resistivity ranging from 3,37 - 7950 Ωm. In complete could be seen in Table II below:

TABLE II
INTERPRETATION RESULT OF GEOELECTRIC DATA PROCESSING IN TARUNA JAYAVILLAGE

Point code	Depth (meters)	Resistivity (Ωm)	Lithology/soil
TR 1	0 – 0.596	486	Peat
	0.596 – 5.342	175	Peat
	5.342 – 39.66	4614	Sand
	>39.66	14.9	Sandy-clay
TR 2	0 – 1.58	306	Peat
	1.58 – 2.74	70.1	Peat
	2.74 – 14.64	305	Sand
	14.64 – 61.34	1885	Sand
	>61.34	61.1	Sand
TR 3	0 – 0.29	2728	Peat
	0.29 – 10.69	171	Peat
	10.69 – 33.09	3798	Sand
	>33.09	3.52	Clay
TR 4	0 – 0.438	1171	Peat
	0.438 – 4.818	89.79	Peat
	4.818 – 69.89	563.5	Sand
	>69.89	12156	Sand
TR 5	0 – 0.395	1171	Peat
	0.395 – 3.995	37.8	Peat
	3.995 –11.82	2697	Sand
	>11.82	29	Sand
TR 6	0 – 0.521	1281	Peat
	0.521 – 1.009	60.51	Peat
	1.009 – 8.631	179.4	Peat
	8.631 – 34.43	1423	Sand
	>34.43	4.292	Clay
TR 7	0 – 0.9	408.8	Peat
	0.9 – 3.703	143.2	Peat
	3.703 – 15.11	425.8	Sand
	15.11 – 30.55	7950	Sand
	>30.55	5.688	Clay
TR 8	0 – 0.952	367	Peat
	0.952 – 1.919	132	Peat
	1.919 – 4.542	537	Sand
	4.542 – 12.11	190	Sand
	12.11 – 27.97	5443	Clay
	>27.97	3.37	
TR 9	0 – 1.789	224	Peat
	1.789 – 4.35	120	Peat
	4.35 – 22.44	4667	Sand
	>22.44	23.6	Sandy-clay

Further, as an overview of the surface is made cross-section through Tr9, Tr1, Tr2, Tr3, and Tr4 (Fig. 6).

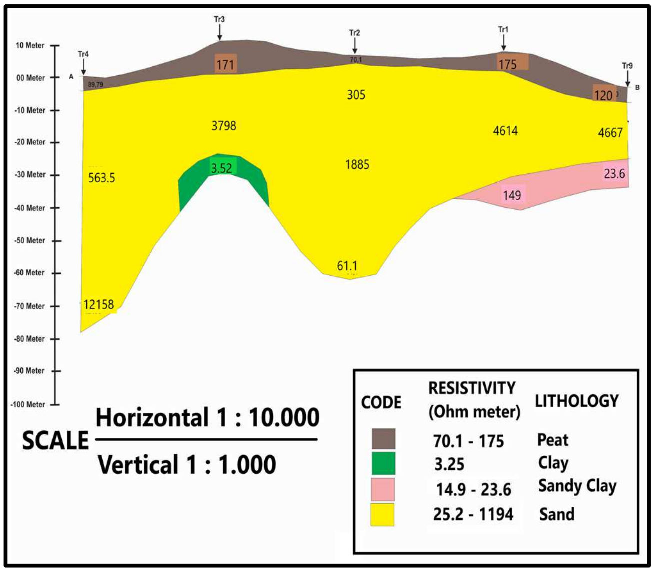

Fig. 6 Lithology Profile in TR9 – TR4 directions

3) *Resistivity in Kalampangan Village:* Measurement of resistivity in Kalampangan Village is to measure 18 (eighteen) points spread in research. Measurement stretches using a Schlumberger configuration with a stretch of between 75 - 250 meters. The measurement and processing of data using Software IPI2WIN obtained 4 (four) composition layers with a type of resistivity ranging from 5.36 - 16719 Ωm. In complete could be seen in Table III below:

TABEL III
INTERPRETATION RESULT OF GEOELECTRIC DATA PROCESSING IN KALAMPANGAN VILLAGE

Point code	Depth (meters)	Resistivity (Ωm)	Lithology/soil
KL 1	0 – 2.93	41.1	Peat
	2.93 – 22.30	4770	Sand
	>22.30	7.51	Clay
KL 2	0 – 1.09	91.47	Peat
	1.09 –2.15	38.72	Peat
	2.15 – 9.39	423.90	Sandy-clay
	9.39 – 20.76	6728	Sand
	>20.76	7.15	Clay
KL 3	0 – 2.31	50.20	Peat
	2.31 – 7.01	139	Sandy-clay
	7.01 – 17.80	61.72	Sand
	>17.80	5.51	Clay
KL 4	0 – 0.9	94.60	Peat
	0.9 – 1.88	35	Peat
	1.88 – 9.43	442	Sandy-clay
	9.43 – 37.30	2200	Sand
	>37.30	12.70	Clay
KL 5	0 – 2.57	48.15	Peat
	2.57 – 75.19	1143	Sand
	>75.19	10.53	Clay
KL 6	0 – 2.01	46.60	Peat
	2.01 – 22.20	385	Sandy-clay
	22.20 – 40.10	1858	Sand
	>40.10	5.36	Clay
KL 7	0 – 0.97	124.10	Peat
	0.97 – 1.99	26.84	Peat
	1.99 – 75.27	1023	Sand
	>75.27	15.05	Clay
KL 8	0 – 1.99	48.30	Peat
	1.99 – 4.34	145	Sandy-clay
	4.34 – 20.80	3533	Sand
	>20.80	3.26	Clay
KL 9	0 – 0.9	87.10	Peat
	0.9 – 1.97	31.70	Peat
	1.97 – 9.58	173	Sandy-clay
	9.58 – 20.90	9477	Sand
	>20.90	6.12	Clay
KL 10	0 – 0.90	212	Peat
	0.90– 1.97	43.60	Peat
	1.97 – 9.49	231	Sandy-clay
	9.49 – 56.60	2052	Sand
	>56.60	231	Sandy-clay
KL 11	0 – 0.9	130	Peat
	0.9 –1.97	25.70	Peat
	1.97 – 9.55	245	Sandy-clay
	9.55 – 20.90	9124	Sand
	>20.90	12.10	Clay
KL 12	0 – 1.02	118	Peat
	1.02 – 2.23	19.40	Peat
	2.23 – 14.80	6759	Sand
	>14.80	7.46	Clay
KL 13	0 – 0.99	99.3	Peat
	0.99 – 2.09	20.80	Peat
	2.09 – 9.61	8721	Sand
	>9.61	24.80	Sandy-clay
KL 14	0 – 0.93	60.42	Peat
	0.93 – 2.24	417.20	Sandy-clay
	2.24 – 33.54	1673	Sand
	>33.54	442.40	Sandy-clay
KL 15	0 – 0.72	158	Peat
	0.72 – 1.51	21.9	Peat
	1.51 – 6.06	12941	Sand
	>6.06	272	Sandy-clay
KL 16	0 – 0.60	150	Peat
	0.60 – 1.58	15.30	Peat
	1.58 – 26	2820	Sand
	>26	98.20	Sandy-clay
KL 17	0 – 0.87	101	Peat
	0.87 – 1.73	15	Peat
	1.73 – 6.37	16719	Sand
	>6.37	224	Sandy-clay
KL 18	0 – 2.44	68.49	Peat
	2.44 – 6.92	239.4	Sandy-clay
	6.92 – 65.96	1579	Sand
	>65.96	20.41	Sandy-clay

Further, as an overview of the surface is made cross-section through Kl15, Kl16, Kl17, Kl18 (Fig. 7).

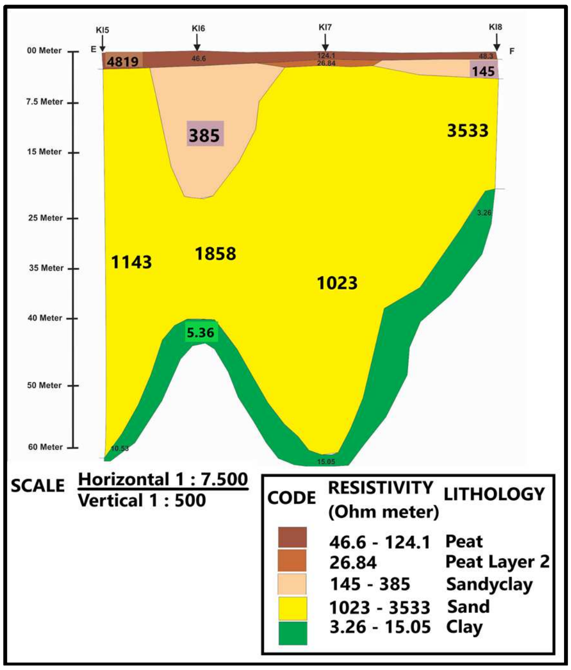

Fig. 7 Lithology Profile in Kl5 – Kl8 directions

B. Lithology Interpretation in Research Areas.

Lithological interpretation based on resistivity data supports by geological conditions and soil stratification. The data come from resistivity measurement, geological map, boreholes, and hand drills. The resistivity value obtained in the field is converted into soil/lithology. Geoelectrical resistivity is associated with sub-surface geological structures, porosity, and water saturation in rocks [12]. Based on the 2007 Amuntai Geological Map, the study area's lithology consists of peat, kaolin clay, grains and gravel, and sand interspersed with silt. The lithology is a sediment/alluvium deposit.

Furthermore, from the data of two drill wells in Sidodadi Village whose depth is 30 meters each, which is at the estimated point Sd6, the lithological layer consists of the top is peat as thick as 6.0 meters, underneath which is a sandy-clay 3.0 meters thick, and the bottom is a layer of sand. The position of the groundwater level is 0.35 meters. From the well in Sd13, the top layer is peat as thick as 6.0 meters, underneath is sand with a thickness of about 24.0 meters, and the bottom is clay. The position of the groundwater is 0.40 meters.

The two drill wells in Taruna Jaya Village shows that the first well (H5) consisting of the top layer is peat with a thickness of 4.0 meters, underneath is sand with a thickness of 23.0 meters, after which the clay is 6.0 meters thick, and the sand is 7.0 meters thick. The position of the groundwater level is 0.60 meters. The second drill well (H0) composed of the top layer, is peat with a thickness of 6.0 meters, then the bottom layer is sand as thick as 34.0 meters. The position of the groundwater level is 0.55 meters. From 18(eighteen) hand drills in Kalampangan Village, each depth between 1 – 2.5 meters shows that the top layer is peat, underneath which is sand and sandy clay. The position of the groundwater level at an interval between 1.00 - 1.50 meters.

The result of interpretation of each research site is in the Sidodadi Village area; the order of soil/lithology layers, in general, is the top layer of peat underneath the sand, which in some places is interbedded by sandy clay and clay. Layering is a sedimentary material that the same sedimentation process has precipitated. Interbedding of different contrast lithofacies may indicate a depositional environment [20]. The cross-section of sediment is based on thickness measurements in each lithology layer of the drill hole. The deposition environment interprets the lithologies, structures, and fossils in the sediment [21].

C. Aquifer Interpretation in Research Areas.

The groundwater is mainly found in porous and permeable land layer zones [22]. Geological formations that can be aquifers are gravel and sand deposits, granite cracks, and alluvium deposits. The alluvial area aquifers' permeability has implications for sedimentary variation in lateral thickness and area [23]. From the type of lithology in the research area, sand can be an aquifer layer. Furthermore, drill well data was detected that water came from beneath the surface. Following both things, it can conclude that the sand layer in the research area is the layer of aquifers.

The relationship between the sand layer as an aquifer layer and the soil's surface is the permeable layer of peat. The type of aquifer that has a relationship with the ground level is classified as an unconfined aquifer. The aquifer with no impermeable layer is called an unconfined aquifer and has the characteristic that the aquifer's water is related to atmospheric pressure [24].

In The Village of Taruna Jaya, the order of the soil/lithology layer, in general, is the top layer of peat underneath the sand, which in some place's sides by sand-clay and clay that form lenses structures. The sand layer's relationship as an aquifer layer and the ground level is a porous layer, the condition, thus illustrating that the aquifer layer in the research area is classified as an unconfined aquifer).

Similarly, the conditions in a Kalampangan Village area that is the order of the soil/lithology layer are generally the top layer of peat, under which the sand, which in some places is covered by sand-clay and clay which lenses form structure. The relationship between the sand, aquifer, and the ground level is the porous layer, hence the aquifer in the research area, including an unconfined aquifer. Based on the interpretation results in 3 research locations of similar aquifer models, or in other words, the condition of aquifers in inland peat areas and peat transitions is no different.

IV. Conclusion

Based on the study results, it can be concluded that the value of resistivity in Sidodadi Village varies between 1.22 – 661.10 Ωm, in Taruna Jaya Village between 3.37 – 7,950.00 Ωm, and in Kalampangan between 5.36 – 16,719.00 Ωm. Next, the soil/lithology layer in Sidodadi, Taruna Jaya, and Kalampangan are peat, sand, sandy-clay, and clay. The sand layer is an aquifer. This type of aquifer is an unconfined aquifer in depth: in Sidodadi Village - ranges from 0.56 – 103.40 meters; In Taruna Jaya Village ranges from 1.92 – 69.89 meters, and in Kalampangan Village ranges between 1.73 – 65.96 meters. The further research purpose is to know the aquifer's potential through the pumping test method.

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