Zoning groundwater vulnerability in residential areas around the Terjun landfill using the aplis method

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Abstract. The development of the Medan City area causes an increase in population, increased activity, changes in the use of water catchment land into residential land, one of which is around the Terjun landfill area, Medan Marelan District. This is directly proportional to the increasing need for water. This study aims to determine how much pollution vulnerability in groundwater with the APLIS Method approach (Altitud, Pendiente, Litologia, Infiltration Prefencial, Seule). Zoning of groundwater vulnerability with the APLIS Method results in a low vulnerability class with a classification of >20-40%.

1. Introduction

Groundwater is water found in the pores of rocks below the ground surface in the water-saturated zone. Interaction occurs between groundwater in the subsurface and the soil layer, especially with aquifers consisting of sand or rock that allows groundwater storage [1, 2, 3].

The development of the Medan City area causes an increase in population, increased activity, changes in the use of water catchment land to residential land, one of which is around the Terjun landfill area, Medan Marelan sub-district. This is directly proportional to the increasing need for clean water and the risk of water pollution including groundwater. Utilization and management of groundwater must be based on the concept of balance and sustainability of water resources and the concept of environmentally sound management [4]. A study related to groundwater pollution in Medan City is needed with the study location around the Terjun landfill area, Medan Marelan sub-district.

The APLIS method with the results of groundwater vulnerability zoning research shows that the potential vulnerability of groundwater in the research area is divided into 4 classes, namely very low, low, medium, and high [5, 6, 7]. This method can be considered as a new branch of studies on aquifer calculations using remote sensing and GIS [8, 9].

Espinoza et al. [10] compared the APLIS and modified APLIS methodologies with a study area in La Florida, the eastern slope of the Andes mountains, with an altitude of approximately 2500 m and an annual precipitation of approximately 1500 mm, and came to the conclusion that the former APLIS model estimates the recharge of karst aquifers suitable for the Mediterranean region, while the modified APLIS model is suitable for the study area located in Peru. The APLIS model was used by Martos-Rosillo et al. [11] to investigate carbonate formation recharge. The research takes into account both annual indirect recharge from the aquifer through groundwater resources as well as direct recharge through cracks or even small holes. Aquifer recharging in rainy and dry years in the karst region of Andalusia, Spain, was studied by Lara Kirn et al. [12]. In a study, Andreo et al. [5] estimated surface recharge levels using the APLIS approach and displayed the findings as maps of the regional distribution. The method was successfully applied in calculating the amount of recharge value, namely that the calculation of the APLIS method using intrinsic variables did not exceed 5% difference with other methods.

This study aims to determine the magnitude of groundwater vulnerability with the APLIS Method, around the Terjun Landfill, Medan Marelan District, Medan City.

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2. Materials and Methods

2.1 Research Time and Location

The research was conducted from August to October 2022. This research was conducted in the settlement around Terjun Landfill, Medan Marelan sub-district, Medan City, this location was chosen because this area has settlements whose groundwater is potentially polluted by leachate from the landfill. The general research location can be seen in Figure 1.

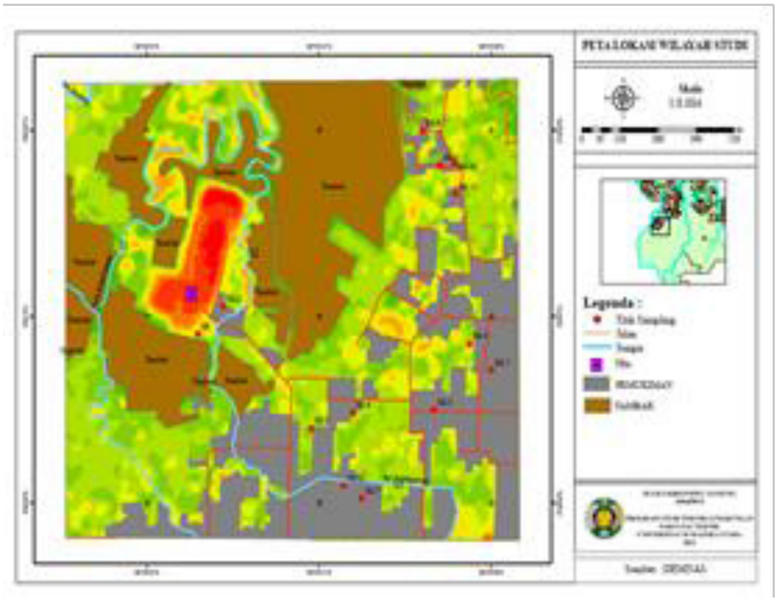

Fig. 1. Location of the study area

2.2 Research Methods

This research uses the APLIS Method for potential groundwater vulnerability. The APLIS method uses five variables based on the hydrological and geomorphological characteristics of an area. The five variables used in the APLIS Method are: *altitud*/altitude,*pediente*/slope, l*ithologie*/lithology, *modele d'infiltration et type de sol*/infiltration landform (infiltration zone), and *seule*/soil type (soil type). Each variable is scored according to its level of influence on groundwater recharge which will then reflect the level of groundwater vulnerability [5]. The variables that make up the APLIS
Method can be seen in the following tables:

Table 1. Scoring in the APLIS method

Variables	Classification	Score
Altitude	≤300 mdpal	1
	>300-600 mdpal	2
	>600-900 mdpal	3
	>900-1200 mdpal	4
	>1200-1500 mdpal	5
	>1500-1800 mdpal	6
	>1800-2100 mdpal	7
	>2100-2400 mdpal	8
	>2400-2700 mdpal	9
	>2700 mdpal	10
Slope	≤3%	10
	>3-8%	9
	>8-16%	8
	>16-21%	7
	>21-31%	5
	>31-46%	4
	>46-76%	3
	>76-100%	2

	>100%	1
Lithology	Limestones and dolostones karstified	9-10
	Limestones and dolostones fracturated, slighted karstified	7-8
	Limestones and dolostones fissured	5-6
	Sand and gravel colluvial	4
	Napal, breccia and conglomcrat	3
	Plutonic rocks and mctamorphic	2
	Shales, silts, clays	1
Infiltration landforms	Many infiltration landforms	10
	Scarce infiltration landforms	1
Soil	Leptosols	10
	Albic, Arenosols dan Calcic Xerosols	9
	Rendzina, Calcareous, Regosols dan Fluvisols	8
	Eutric dan Distric Regosc serta Solonchaks	7
	Calcic Cambisols	6
	Eutric Cambisols	5
	Eutric Histososla, Orthic dan Calcic Lucisols	4
	Chromic Luvisols	3
	Planosols	2
	Cromic Vertisols	1

Source : Andreo et al. (2008).

Table 2. Recharge rates by the APLIS method

Intervals of recharge values (%) APLIS method	Recharge class
≤20%	Very low
>20-40%	Low
>40-60%	Moderate
>60-80%	High
>80%	Very high

Source : Andreo et al. (2008).

The scoring results were then overlaid using a Geographic Information System (GIS). Overlapping was done using the following formula:

$$R=(A+P+3L+2I+S)/0.9 \quad (1)$$

R = Groundwater recharge in percent
A = Altitude
P = Slope
L = Lithology
I = Infiltration zone
S = Soil

3. Results and Discussion

3.1 Groundwater Vulnerability Level Zoning

The elevation map of the study area obtained from the extraction of DEMNAS data (Geospatial Information Agency), the elevation of the study area ranges from -3.42 - 13.8 meters above sea level, which means it has a score of 1 because the study area is at an altitude of ≤300 meters above sea level (Figure 2).

The slope of the study area has seven levels of slope, namely ≤ 3% there are swamps, rivers, fish ponds and settlements, at a slope of 3%-21% are residential areas, gardens and rice fields, and at a slope of 21%-76% is the slope of the landfill in Terjun landfill. Areas with flat slopes have greater infiltration power because water moves slowly so that infiltration power is greater because water moves slowly so that more water can seep into the groundwater [13].

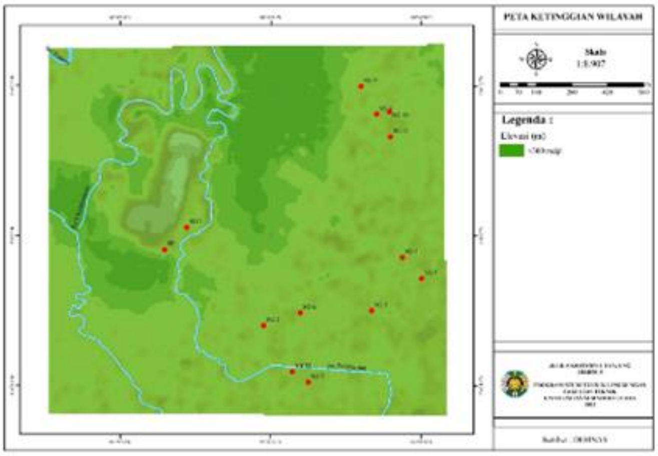

Fig. 2. The altitude map

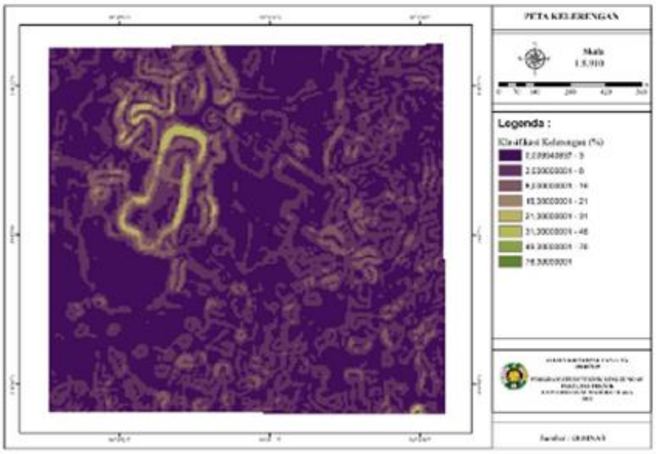

Fig. 3. Slope map

Rock type plays a major role in reduce groundwater pollution, the ability to reduce it includes permeability, infiltration power, rock absorption ability and others. Material Fine-grained rocks such as clay, marl compared to rocks with large-grained or crystalline materials. Rocks that have been compacted or solid are better than rocks that are still loose [14]. The lithology or rock composition in the study area has a score of 4 because the lithology of the study area is composed of chunks of gravel and fine sand.

The infiltration zone is determined by several factors, namely the level of rock graduation, rainfall, type of soil cover, slope, and depth of the water table [15, 16]. In the APLIS method, the main infiltration zone classification has a score of 10 and other infiltration zones have a score of 1.

Based on the Geological Agency (2007) infiltration zones that have a score of 30-33 are categorized into other infiltration zones, in this study the value of the infiltration zone is 33. Based on the APLIS Method classification of infiltration zone vulnerability has a score of 1.

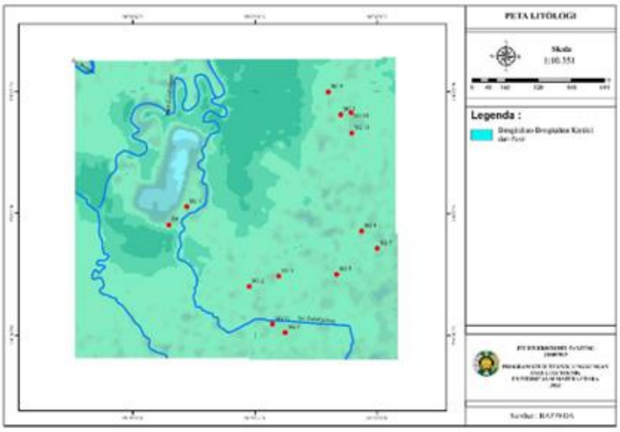

Fig. 4. Lithology map

Table 3. Calculation of Infiltration Zone Value

Parameters	Data	Category	Score	Quality	Value
Lithology	Chunks of gravel and sand	Tertiary sediments	5	2	10
Rainfall	1500 mm/year	1000-2000 mm/year	4	2	8
Slope	3-8%	5-10%	2	4	8
Depth of ground water table	0,51 – 3,3 m	<5 m	1	1	1
	Total				33

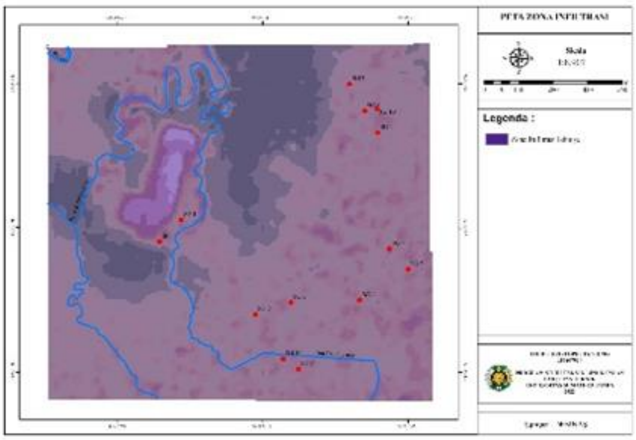

Fig. 5. Infiltration Zone

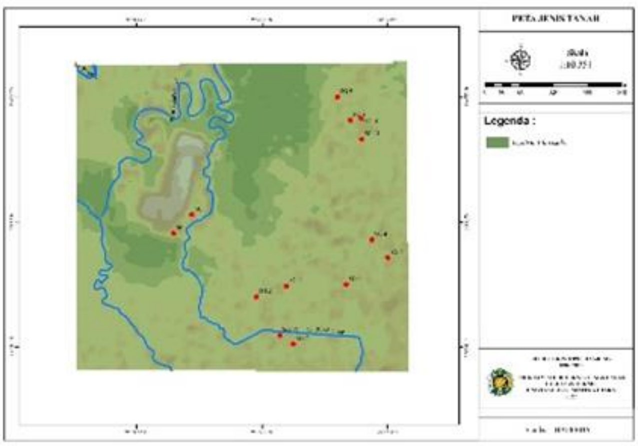

Fig. 6. Soil type map

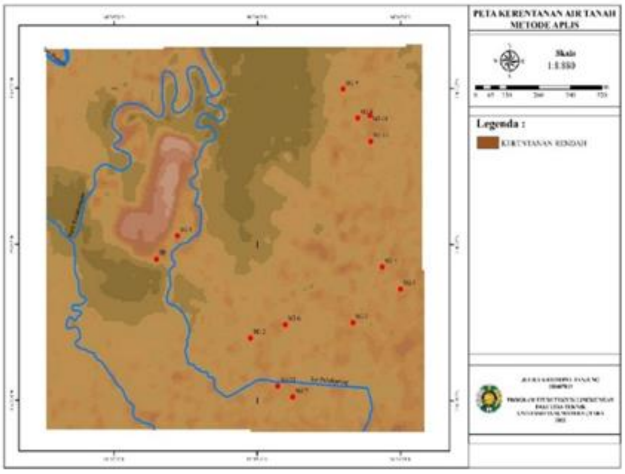

Fig. 7. Groundwater vulnerability map

The soil type in the study area is dystric fluvisols composed of tropopsamments and tropoquents which have a vulnerability score of 8. Tropopsamments are undeveloped soils, coarse/sand texture, fast drainage, coastal sand shoals suitable for coconut plantations while basins between shoals for rice fields with rice types that are more tolerant of salt water and Tropaquepts are generally medium to deep, generally fine texture and good drainage [17].
The results of the analysis based on the classification of groundwater vulnerability levels according to Andreo, et al. [5] show that the level of groundwater vulnerability in the study area is classified as low (Figure 7).

4. Conclusion

This study used the APLIS model to measure groundwater vulnerability around the Terjun landfill area, Medan Marelan sub-district. In addition, the effectiveness of the GIS environment was demonstrated in the calculation of groundwater recharge, which involves the integration of various factors such as elevation, slope, lithology, infiltration, and soil layers.. Based on the results of data overlay using the APLIS method, the research study area has low groundwater vulnerability (>20-40%).

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