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RESEARCH ARTICLES

IDENTIFICATION OF FLOOD VULNERABILITY PARAMETERS USING SCORING AND OVERLAY METHODS TO DETERMINE FLOOD ZONING IN NORTH SEMPAJA VILLAGE

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Abstract
Flood disasters are one of the natural disasters that often occur in Indonesia, flood disasters are spread almost throughout Indonesian cities. The city of Samarinda is one of the big cities in Kalimantan with the frequency of floods almost every year, this is seen from the varied climate and the role of humans. The purpose of this research is to create a flood vulnerability zoning in the Samarinda city area, namely North Sempaja village, the research method used is through GIS (Geographic Information System) in the form of *overlays* and *scoring* based on flood vulnerability parameters such as river buffer, soil type, slope slope, altitude/topography, rainfall, land cover. To support the data in the research area, this study also analyzed the subsurface using *the Active Digital Magnetotelluric* (*ADMT) method*. Based on the results of the overlay and scorring analysis that has been carried out, it is divided into 3 classes of flood vulnerability, namely safe, vulnerable, and very vulnerable. Each class has different characteristics, the class is very prone to have characteristics, namely being at an altitude of 0 to 25 m, slope of flat slopes to sloping, the dominance of land cover in the form of settlements, rice fields, water bodies and zoning is very prone to being close to the river side, the vulnerable class is dominant at an altitude of 25 – 50 m, the slope of the slope varies flat to slightly steep, The dominance of land cover is in the form of bushes, rice fields and a few settlements, quite close to the river side, the last safe class is at an altitude of 50 to more than 100 m, the slope is slightly steep to very steep, the dominance of forests, bushes, and far from the river side. In addition to GIS analysis, the analysis of *the ADMT* method obtained a water-saturated layer in the form of clay and silt, groundwater, this analysis was then linked to the potential for flooding to subsurface geological factors in North Sempaja Village.

Keywords: Flood, Vulnerable, *Scoring* and *overlay*, Below Surface, Samarinda

INTRODUCTION

Indonesia is geographically a country with an extreme level of vulnerability to various natural disaster threats. This condition is related to Indonesia's strategic location on the equator, the meeting of two continental plates, and flanked by two large oceans that form a complex maritime-continental climate system (Hermon, 2012). Flooding is a waterlogging occurs when the volume of water exceeds the capacity of the soil to absorb it, this can occur due to high rainfall or overflow from rivers (De Jesus, 2024).

Recent research shows that climate change and human activities, such as urbanization, deforestation, and riverbank utilization, are exacerbating flood events. This condition causes reduced connectivity between the river and the floodplain. As a result, the frequency and duration of inundation have increased and have a significant impact on the agricultural sector and natural ecosystems (Malik, 2021).

Hydrometeorology and geomorphology are things that need to be considered because this is an aspect of flooding (Rifandi & Putra, 2024). The causes of flooding can vary from location to location, the selection of parameters for flood zoning maps should be adjusted to local environmental conditions (Das, 2020). Here are some factors that can be parameters for flood vulnerability in summary, namely rainfall, soil type, slope slope, topography, land cover, river buffer. (Pourghasemi, 2020)

GIS is a computer-based tool used to manipulate maps, digital Figures, and data tables, often using a diverse array of digital data structures, and representing spatially varied phenomena in the form of data layers (Bonham-Carter, 1994). GIS is capable of analysis and visualization to support GIS prediction and planning based on geographic reality, including flood vulnerability mapping (Utomo Adymas, 2022)

Some of the factors that cause flooding in Samarinda include increased land use, siltation of the river due to sediment, accumulation of garbage in the water drainage system, decrease in river width, high rainfall, and the effect of tides at the mouth of the Karang Mumus river (Mislan et al., 2024). According to data from the Central Statistics Agency of Samarinda City, the total number of flood disasters is 129 from 2019.

North Samarinda District is one of the areas that often face flood events such as North Sempaja Village, therefore, this study aims to identify the distribution of potential flood vulnerability based on GIS in the research area so that it can increase the readiness of the government and the community in the research area to flood disaster risk.

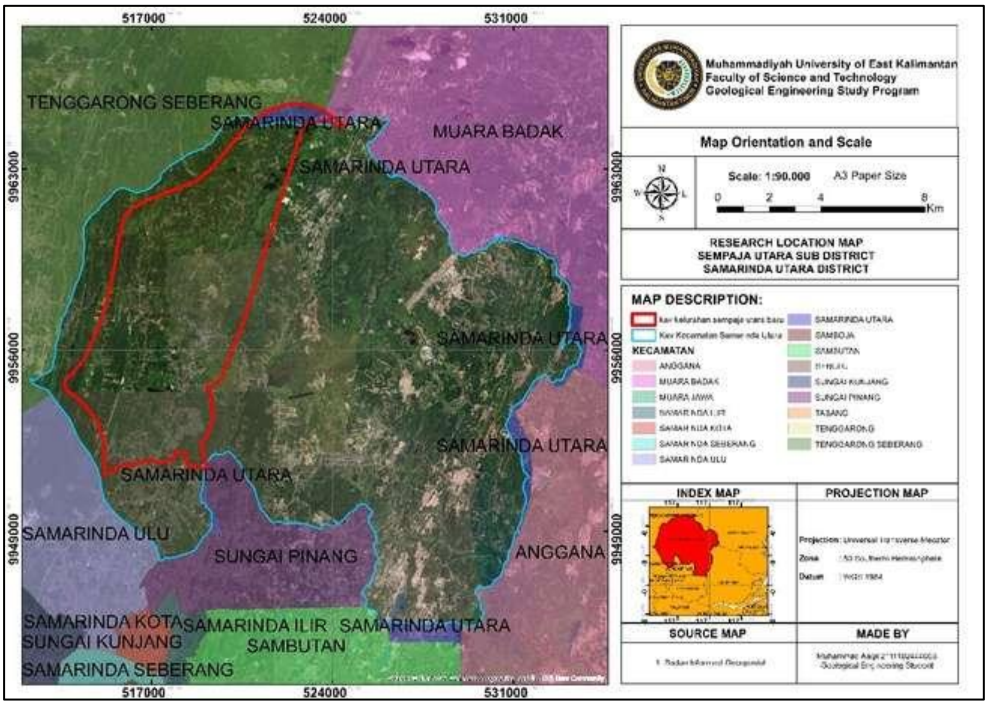

Figure 1. Administrative Research Location

RESEARCH METHODOLOGY

Research Methods:

This study uses a combination of survey methods, *Overlay* and *Scoring*. The survey method used in this study involves mapping surface geology through direct observation in the field, then the *Overlay* and *Scoring* was used to identify the zones of flood vulnerability levels in the study area by matching the relevant parameters. This parameter acts as an indicator that reflects the characteristics of the research area. All of these parameters are analyzed based on their similarity in characteristics to determine areas that have the potential to be affected by flooding.

Research Location:

Based on Figure 1, the research location is administratively located in North Sempaja Village, North Samarinda District, Samarinda City, East Kalimantan Province.

Research Procedure:

The research procedure includes aspects of several stages, namely:

1. Introductory Stages

This stage contains problem identification, problem formulation, research objectives and research methodology. In addition, a literature study was conducted based on literature references such as journals, books, and scientific articles with the aim of finding out the conditions in the research environment.

2. Stages of Data Collection

The field data collection stage consists of geological mapping, this data will be carried out geological analysis in the form of going directly to the field. In addition to field data, research data for flood vulnerability parameters. Then, data collection was carried out in the form of sedimentary rock samples to be tested for porosity and permeability, and finally subsurface resistivity data was collected through *ADMT* to model a solid model.

3. Stages of Data Processing

Analysis of geomorphological data, flow patterns, geology is carried out through direct observation in the field and projected through arqgis software, then structural analysis is carried out through software *DIPS* to determine the direction of stress. In addition, the data analysis of six parameters was carried out through the *Scoring* and *Overlay* di *arqgis software* with the aim of obtaining flood vulnerability zoning. To test the properties of rocks, porosity and permeability tests were carried out on each type of rock in the research area. Underwater analysis is modeled through software *Rockworks 2015* based on the resistivity value of the rock from the tool *ADMT*.

4. Stages of Completion and Presentation

This study produced maps (geomorphology, flow patterns, geology and maps of six flood vulnerability parameters, then flood vulnerability zoning maps. The result of the processing of the six-parameter map. Overlay and scoring methods are used to classify flood-prone areas. Also, the results of other geological supporting data support or add to this study.

RESULTS AND DISCUSSION

Geomorphology of Research Areas

The division of geomorphology in the study area is carried out by combining topographic map analysis and direct field surveys. Map analysis focuses on contour line density, while field observation includes the measurement of slope, vegetation conditions, and landscape interpretation from the perspective of bird's eye and frog's eye. As a result, the study area was divided into two main geomorphological units: structural, fluvial, and danudational, the results of the map and geomorphological aspects can be seen in Figure

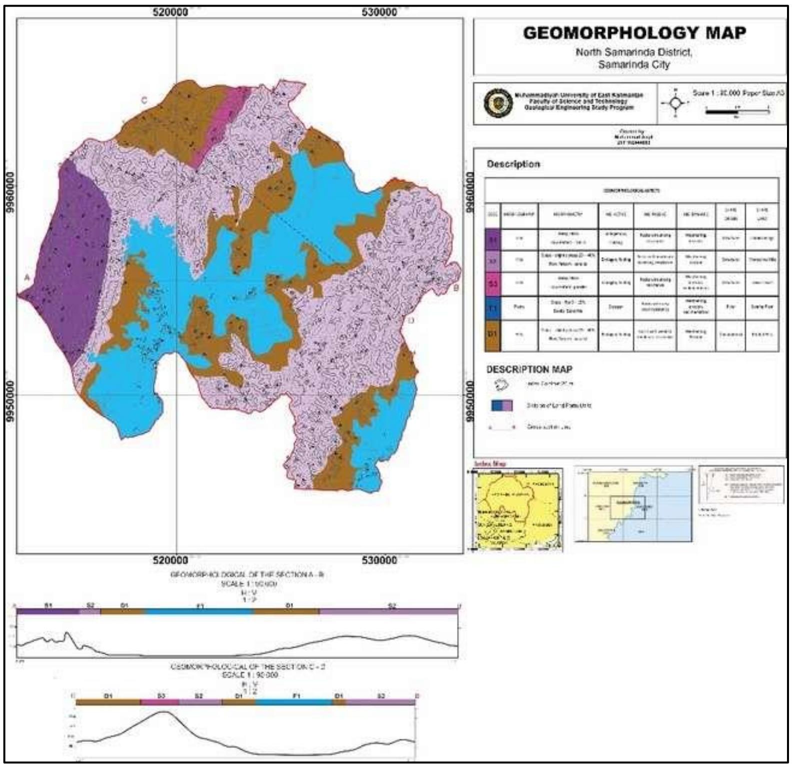

Figure 2. Geomorphological Map of the Research Area

1. Folded Land Form Unit (S1)

The Folding Unit, which occupies about 15% of the area on the southwest side, has a tectonic structural morphology in the form of hills, anticlines, and straight valleys. This unit is characterized by steep to very steep slopes and develops a trellis flow pattern. This condition is caused by structural control and moderate to very strong rock resistance, resulting in low erosion rates. The dominant lithology in this unit is crystalline limestone.

2. Monocline Hills Land Form Unit (S2)

The Monocline Hills unit is spread from the southwest to the northeast, covering about 45% of the research area. This unit displays the structural morphology of tectonic results in the form of hills, anticlines, and straight valleys. Its characteristics include varied slopes (flat to very steep) and parallel flow patterns formed due to structural control and rock resistance. Consistent exogenous processes (water and wind) then form a diverse topography with the dominant lithology in the form of sandstone.

3. Gawir Fault Land Form Unit (S3)

The fault is located in the northeast of the study, with an area of about 5%, the study area has a tectonic structure morphology consisting of hills and indications of rising faults, as well as straight slopes. This landscape represents the original structural form with the morphography of the hills. The slopes are steep to very steep, and the flow pattern that develops this land form is parallel, due to the influence of structural control with moderate to strong rock resistance, resulting in a moderate erosion rate. There is also an exogenous influence in the form of water and wind that is quite consistent, resulting in a diverse topography, ranging from low to high. The dominant lithology found in this fault slope unit is sandstone.

4. Swamp Plain Fluvial Land Form Unit (F1)

The Swamp Plains Fluvial Landscape is a geomorphological unit formed from the accumulation of eroded material transported and precipitated by water flows, with a highly variable granular composition, ranging from clay to sand. The characteristics of the landscape of this area are branching (dendritic) river flow patterns and valleys with V-U profiles. This dynamic occurs because the rocks in this area have weak durability. On the other hand, this fertile plain is the center of community activities, functioning as a residential area, rice farming, and plantations. However, its strategic location on the plains adjacent to the hills and the existence of the Karang Mumus river make it vulnerable to the threat of flooding, where rainwater from the highlands flows directly into the plains.

5. Eroded Hills Landform Unit (D1)

The eroded hilly unit is located on the edge of the alluvial plain, covering about 10% of the study area. It is a unit of hills resulting from the danudational process, it has a sloping to slightly steep slope with a parallel flow pattern. The fairly high level of erosion is due to the structural control and resistance of medium to strong rocks, while consistent exogenous influences (water and wind) form a diverse topography with the dominant lithology in the form of sandstone.

Geology Research Area

The geology of the research area aims to explain the rock units in the research area, this is done from the results of geological mapping. The geology of this study area produced several rock units, including brownish-gray crystalline limestone units, medium-grained sandstone units brown and greenish ash, fine-grained sandstone units brownish-yellow and dark ash alluvial plains and loose materials, geological maps can be observed in Figure 3 below.

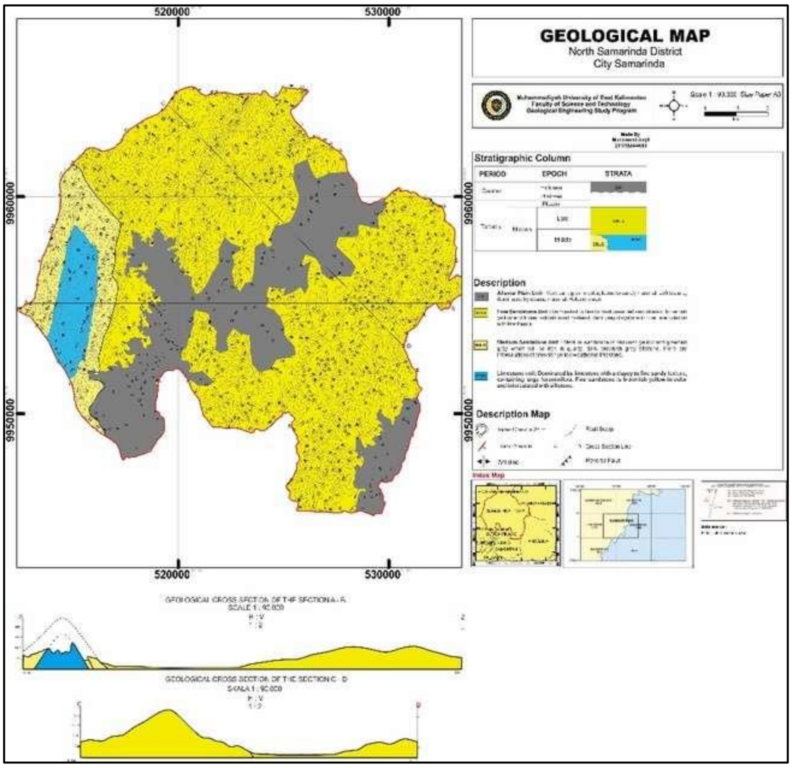

Figure 3. Geological Map of Research Areas

1. Stone Block Unit (BGPL)

These rock units account for about 15% of the total research area. This limestone unit dominates the cliffs on the roadside, especially in the Batubesaung area and Batuputih. This limestone is part of the Balang Island Formation in the research area and is of the same age as the medium sandstone, the documentation can be observed in Figure 4.

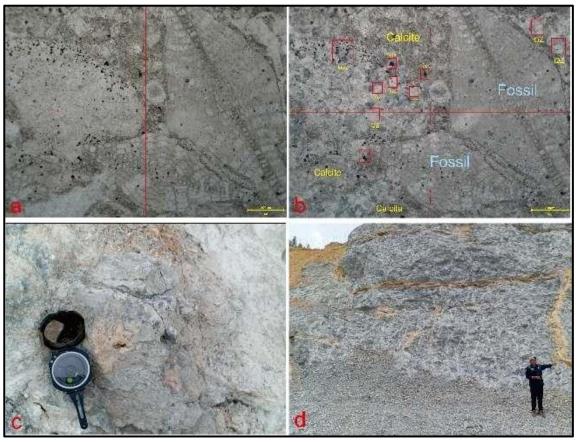

Figure 4. Explain the Appearance a. PPL Thin Incision, b. XPL Thin Incision, c. Megascopic Appearance, d. Limestone Outcrop Appearance.

The limestone in the study area has a bright brownish gray color, non-clastic texture and there are reef fossils in several places. Limestone has an even calcite content. Based on Figure 4 above, microscopic observations are carried out by 4x ocular magnification. Limestone incisions whitish gray color, non-clastic texture, clay grain size – fine sand (<0.001 - 0.02 mm). The main composition of calcite minerals (90%) is whitish ash, quartz (5%) is clear bright ash in the incision, and opak minerals are dark black (5%), there are also fossil indications *Lepidocylina* with a fossil size of 0.5 to 1 mm predominantly around', limestone type (Packstone, 1962).

2. Medium Sandstone Unit (BSLG)

Medium sandstone **(BSLG)** spread around 15%, especially in the Batubesaung area and in the middle of the limestone cliffs. The sandstone is included in the jar island formation in the research area, this sandstone unit is slightly the same age as the limestone unit. The sandstone unit contains sandstone lithology, limestone as an insert, and limestone as an insert, which can be observed in Figure 5.

Figure 5. Explain the Appearance a. PPL Thin Incision, b. XPL Thin Incision, c. Megascopic Appearance, d. Medium Sandstone Outcrop Appearance.

The sandstone in the study area is greenish-gray. Medium grain size – coarse, rounded clastic texture, tight arrangement, and massive. This sandstone contains predominantly quartz and feldspar minerals. Based on Figure 5 above, microscopic observations are carried out by 10x ocular magnification. Medium sandstone incisions whitish ash color, clastic texture, medium – coarse grain size (<0.005- 0.5 mm). The main composition of quartz minerals (30%) is clear whitish ash, feldspar (55%) is light gray gray, and oxidized clay minerals are dark brownish-black (15%), sandstone type (Arkose, R. Selley, 2000).

3. Fine Sandstone Unit (BHLB)

The fine sandstone unit is spread about 50%. Presence in the Bayur area and the Muara Badak Axis. The sandstone is included in the balikpapan formation in the research area, this sandstone unit is slightly younger than the Limestone Unit unit and the medium sandstone unit. The sandstone unit contains fine sandstone lithology, coalstone as an insert, clay as an interchange, and coal as an insert, which can be observed in Figure 6 below.

Figure 6. Explain the Appearance a. PPL Thin Incision, b. XPL Thin Incision, c. Megascopic Appearance, d. Fine Sandstone Outcrop Appearance.

Outcrops Fine sandstone is brownish-yellow in color. The grain size is very fine to smooth. There are coal fragments, clastic texture, compact, good sorting, and have a laminated structure as well as cross-stitching in several places. Sandstone contains quartz and feldspar. Then, the clay is dark gray with coal and coal inserts. The thickness of coal varies, ranging from 30 cm to 50 cm. Based on Figure 6 above, microscopic observations are carried out by 10x ocular magnification. Medium sandstone incisions of dark ash color, clastic texture, very fine grain size (<0.001- 0.05 mm). The main composition of quartz minerals (30%) is clear whitish ash, feldspar (40%) is light gray gray, and oxidized clay minerals are dark brownish ash (30%), sandstone type (Quartz Wacke, R. Selley, 2000).

4. Description of Batulempung

Clay is scattered in all rock units, present as layers or interlocks. Clay is dark gray in color, the size of a clay grain.

Figure 7. Explain the Appearance a. PPL Thin Incision, b. XPL Thin Incision, c. Megascopic Appearance, d. Clay Outcrop Appearance.

The outcrop of Batulempung is dark gray. The grain size is clay. Based on Figure 7 above, microscopic observations are carried out by 10x ocular magnification. The clay incision is dark blackish ash, clastic texture, grain size is very fine (<0.001- 0.05 mm). The main composition, clay minerals are dark brownish ash (85%), feldspar (10%) light gray gray color, and quartz minerals (5%) are clear whitish ash sandstone type (Claystone, R. Selley, 2000).

Flood Vulnerability Parameters

Contains an explanation of each parameter. The results of this parameter are score values and weights which then become the material for calculation data for scoring and overlapping methods.

1. Slope of the Research Area

The slope parameter is the dominant factor in the potential for flooding. Areas with sloping topography actually show a more significant level of vulnerability than steep areas because of their ability to accommodate a larger volume of surface water, the map results as shown in Figure 8 below.

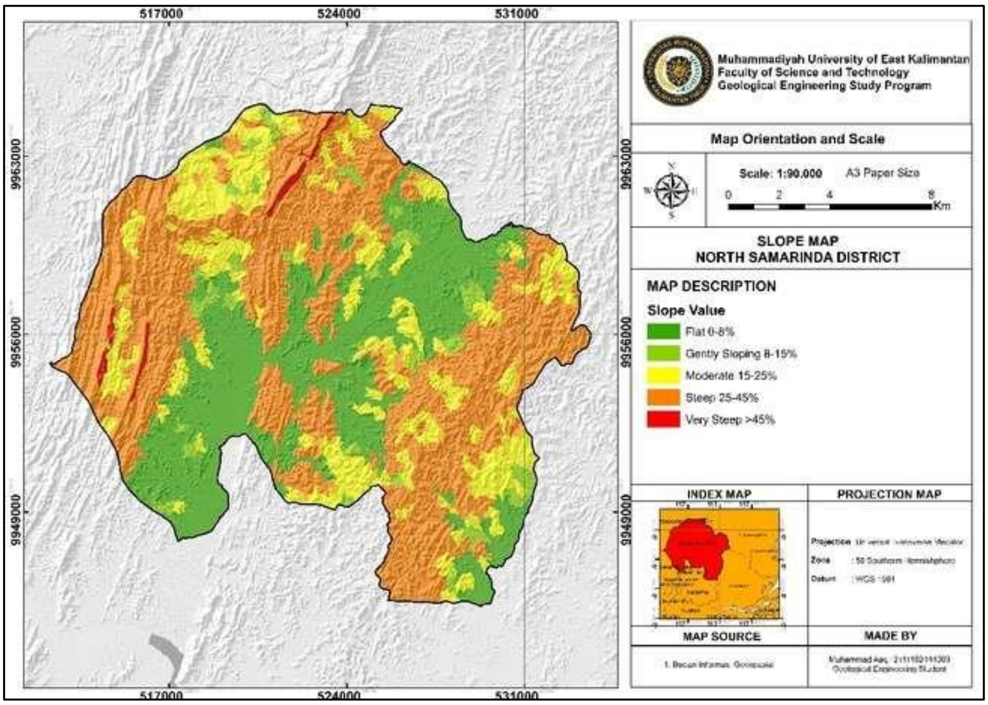

Figure 8. Slope Map of the Research Area

Based on Figure 8, the classification of slope slopes in the study area divides slopes into five main classes. In general, the study area showed significant topographic variation. On the resulting thematic map, each class is represented by a specific color gradient: flat classes (slope range 0-8%) are marked with dark green, sloping classes (8-15%) with light green, slightly steep classes (15-25%) with yellow, steep classes (25-40%) with orange, and very steep classes (>40%) with red.

Most of the research area is in the form of hills with a relatively steep slope, which is about 48% of the area. Rainwater flows down a steep slope sliding down, eroding and washing away material along its path. This mixture of water and materials, when it reaches low-lying areas, can cause flooding with significant potential damage. Therefore, the rarer the contour, the higher the potential for flooding in the study area. The weight table can be observed in Table 1 below.

Table 1 Weighting Value of the Slope of the Research Area
Sources: (Syukri & Wilis, 2025)

Slopes	Score	Weightlifter	Value
Very steep (>40%)	1	0,20	0,20
Steep (25-40%)	2	0,20	0,40
Slightly steep (15-25%)	3	0,20	0,60
Sloping (8-15%)	4	0,20	0,8
Flat (0-8%)	5	0,20	1

Analysis of the correlation between geomorphological maps and slope maps reveals the relationship between geomorphological units and their slope characteristics. Geomorphological units Folds or anticlines are characterized by a very steep range of slopes, which reflects strong control of the structure. On the other hand, the Monocline Hills Geomorphology Unit shows a topography that varies from Very steep to somewhat steep, while the Gawir Fault Geomorphology Unit is dominated by a very steep to steep slope, which is the result of an endogenous process that is tectonic, then the Geomorphology of the Eroded Hills is dominated by slightly steep and sloping slopes, while the Geomorphology of the Alluvial Plains is dominated by a sloping to flat slope which is a catchment area.

2. Land Cover of the Research Area

Land cover is also one of the parameters that greatly affects the classification of potential flood vulnerability. Land cover can be tangible evidence of any human or community activity on the earth's surface. From the thematic map, namely the land cover map, this function is what functions with the purpose of knowing the characteristics of land use in the research area, the land cover map in Figure 9.

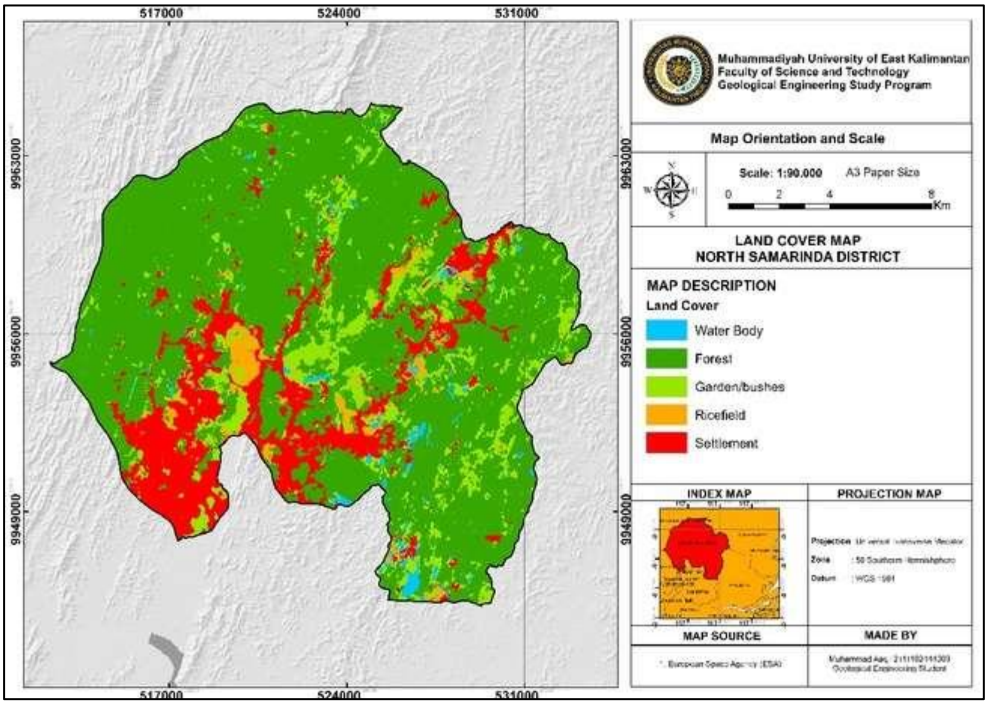

Figure 9. Land Cover Map

Based on the analysis of Figure 9 above, the land cover in the research area is divided into five main units. The first unit is orange cultivated land (rice fields) concentrated near settlements. Light green zones are classified as shrubs. The dark green color marks two units: the vegetation formation (succession stage) and the natural forest that dominates the plot. The last unit is a settlement (red color) that shows massive activity, located on a sloping plain with alluvial lithology.

The distribution of land cover shows forests as the most dominant, which directly influences the hydrological response to rainfall. Its vegetation structure (crown to root) serves as a flow trap, increasing the concentration time of surface runoff. Watertight land units such as settlements and open areas with minimal vegetation result in low infiltration and rapid surface runoff, which shortens concentration times and significantly increases susceptibility to flooding.

Table 2 Land Cover Weighting Values of Research Areas

Source: (Darmawan & Suprayogi, 2017) and Calculation Analysis

Land Cover	Score	Weightlifter	Value
Forest	1	0,20	0,20
Gardens/Shrubs	2	0,20	0,40
Rice Fields	3	0,20	0,60
Water bodies	4	0,20	0,8
Settlement	5	0,20	1

Based on Table 2 above, flat areas dominated by anthropogenic land cover (settlements, rice fields) have a higher potential for inundation. Instead, the steep slopes are covered with natural vegetation that serves as a stabilizer. There is a strong spatial correlation between lowland settlements and increased flood vulnerability due to significant accumulation of water runoff.

Areas with high annual rainfall show much greater vulnerability to this phenomenon, as the soil's capacity to absorb water (infiltration) is often exceeded by the rate and volume of falling water, resulting in extreme surface runoff. Although the dense vegetation cover in the highland areas supports the high infiltration and evapotranspiration processes. You can see Figure 10 below.

3. Rainfall in the Research Area

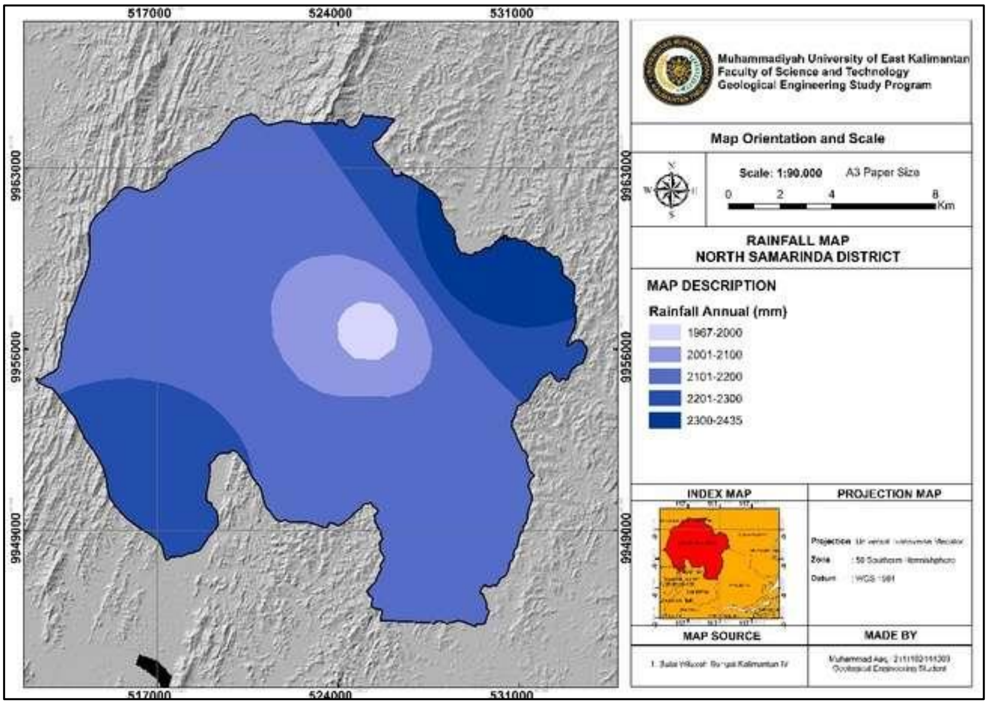

Figure 10. Rainfall Map of the Research Area

Based on Figure 10 above, it is divided into 5 different blue colors which indicate the difference in the average value of rainfall in an area. Friendly

Rainfall was taken from 2017 to 2024 and the highest was 3235 mm in 2023.

Table 3 Weighting Values of Rainfall Research Areas
Source: (Rifandi & Putra, 2024) and Calculation Analysis

Rainfall (mm3)	Score	Weightlifter	Value
1967-2000 (High)	3	0,10	0,3
2001-2500 (Very High	4	0,10	0,4

The weighting of rainfall based on Table 16 above only has values of 0.40 and 0.30. Geomorphologically, there are two main units, namely structural (hilly) and fluvial (sloping-flat). Rainfall with higher values and wider coverage is found in high areas, which are predominantly included in the category of structural units in the form of hills. Rain is the main trigger, but flooding will only occur if the characteristics of the area cause the soil absorption and drainage capacity to be exceeded by the volume of rainwater.

4. Soil Type of Research Area

Soil type shows the quality of infiltration in a research area, especially flood vulnerability research related to water and infiltration. Each type of soil, the infiltration value is also different, the difference in soil type can be due to external factors such as weathering and internal factors such as geological history at the research site.

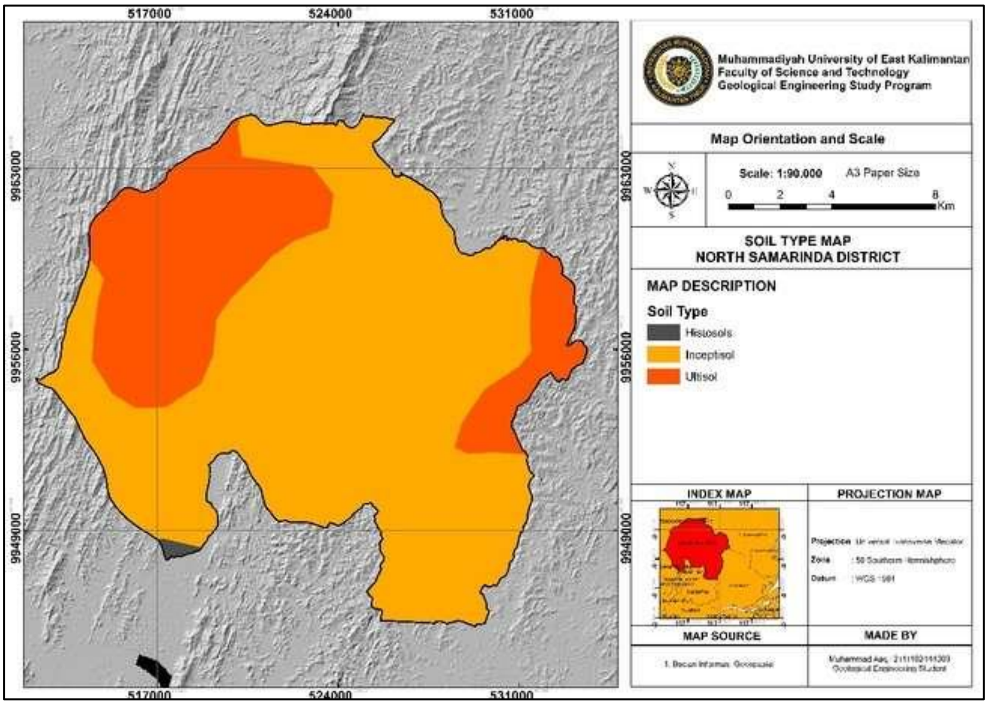

Figure 11. Map of Soil Type of Research Area

The ultisol soil type shows a lower flood potential because rainwater can seep deep into and replenish groundwater reserves. Inceptisol has a much higher surface flooding potential due to its layer-like texture Dense clay inhibits infiltration, making it highly susceptible to surface runoff. Finally, Histosol, an organic soil formed from prolonged water saturation conditions, is most susceptible to flooding, a map of soil types can be observed in Figure 11.

Table 4 Weighting Values of Soil Type in the research area
Source: (Probo Kusumo & Evi Nursari, 2016) and Author's Analysis

Soil Type	Score	Weightlifter	Value
Inceptisol	3	0,10	0,4
Vertisol, Oxysol, Histosol	4	0,10	0,4
Alfisol, Ultisol, Molisol	5	0,10	0,4

Based on Table 4 above, the distribution of soil types is dominated by the type of inceptisol soil by 84% of the research plot, then the distribution of the type of soil ultisol, and finally the smallest distribution, namely histosol, the distribution and naming are taken based on classification *FAO.* The relationship between soil type and flooding is related to the soil's ability to absorb, store, and drain rainwater. When it rains, some of the water will seep into the soil and some of it will flow on the surface of the ground. Each type of soil has a different ability to absorb water. Clay soil, for example, has very fine particles and small pores. Because the pores are small, water is difficult to penetrate the soil. As a result, when heavy rain falls, more water flows on the ground surface and easily causes inundation or flooding.

5. River Buffer Research Area

Buffer A river is a geomorphological unit that functions as a comparison (land) and aquatic system (river). The presence, thickness, and quality of vegetation within this zone directly control the hydrological and geomorphological dynamics of a watershed, map *Buffer* river can be observed in Figure 12. The existence of rivers in an area is a geomorphological feature, rivers provide natural channels to drain water, preventing permanent inundation of land. On the other hand, rivers are the main route, serving as the main route for flooding. Flood potential is not innate from the river itself, but the result of the interaction between the river and its watershed.

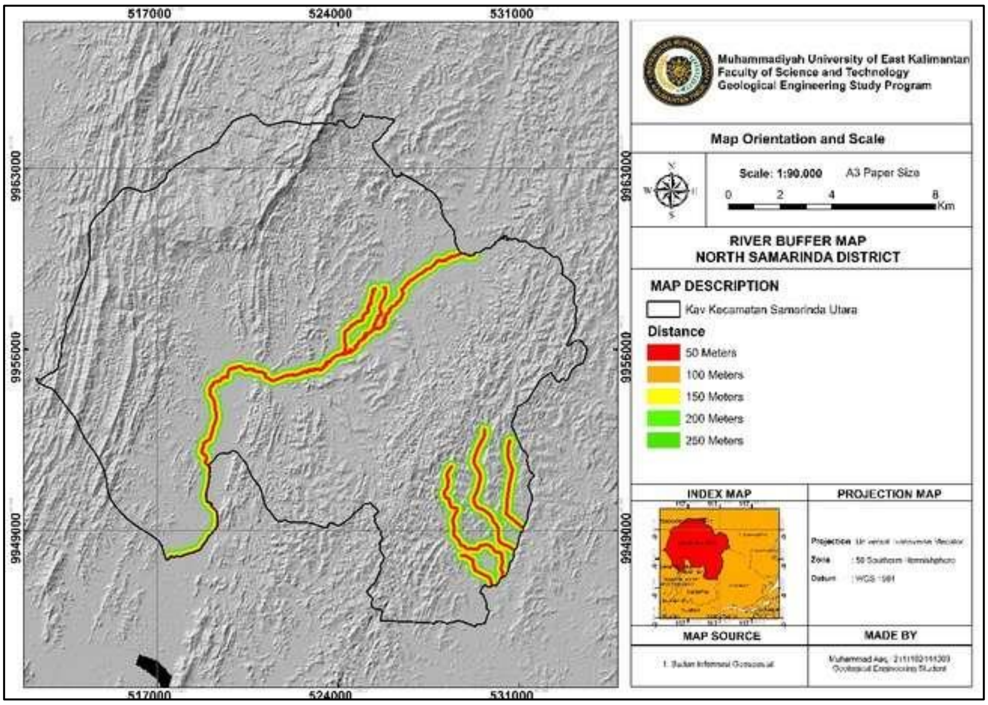

Figure 12. Map of the River Buffer Research Area

Based on Figure 12 above, the river buffer is divided into 5 classes, including the lowest distance, which is 50 meters, and the farthest, which is 250 meters. The existence of rivers in an area is one of the factors that will cause flooding and inundate the surrounding area, even more so when it rained. The presence of the main river in the research area is the Mahakam River branch, namely the Karang Mumus river which extends from south to north in the research area.

Table 5 Weighting Values of River Buffers in Research Areas
Source: (Sebayang & Rosanti, 2022) and Calculation Analysis

River Distance (m)	Score	Weightlifter	Value
0-50	5	0,20	1
50-100	4	0,20	0,80
100-150	3	0,20	0,60
150-200	2	0,20	0,40
200-250	1	0,20	0,20

Based on Table 5 above, there are 5 river buffer class divisions. The relationship between potential flood vulnerability and distance from the river is that the closer a location is to the river channel, the higher the potential for vulnerability, and the decrease in this potential is not constant but has a great effect on a certain distance. When it rains with high intensity, some of the water will flow from the mainland to the river. If there is a good river buffer around the river, the water flowing from the land does not directly enter the river. Areas close to rivers are often included in floodplains, which are areas that naturally become places where water spreads when rivers overflow. This plain actually serves as a natural space for rivers to accommodate excess water. However, if the area is used for settlements or human activities, then when there is an overflow of the river, the area will be more prone to flooding.

6. Land Elevation of the Research Area

Altitude is defined as the vertical distance of a point from the average sea level. This parameter determines the direction of the water flow, which always moves from regions with higher elevations to lower regions. Even areas with relatively safe topography can be flooded if they are in the form of valleys that drain water from upstream. Lowlands close to rivers or coasts have a greater risk of flooding. This is because water from overflowing rivers or high tide can easily enter the area. If the land level is very low, it will be more difficult for water to flow out so that flood inundation can last longer. In geomorphology, this explains why the lowlands, which serve as the receiving zone of the entire watershed, are very susceptible to waterlogging, the altitude/topography map can be observed in Figure 13 below.

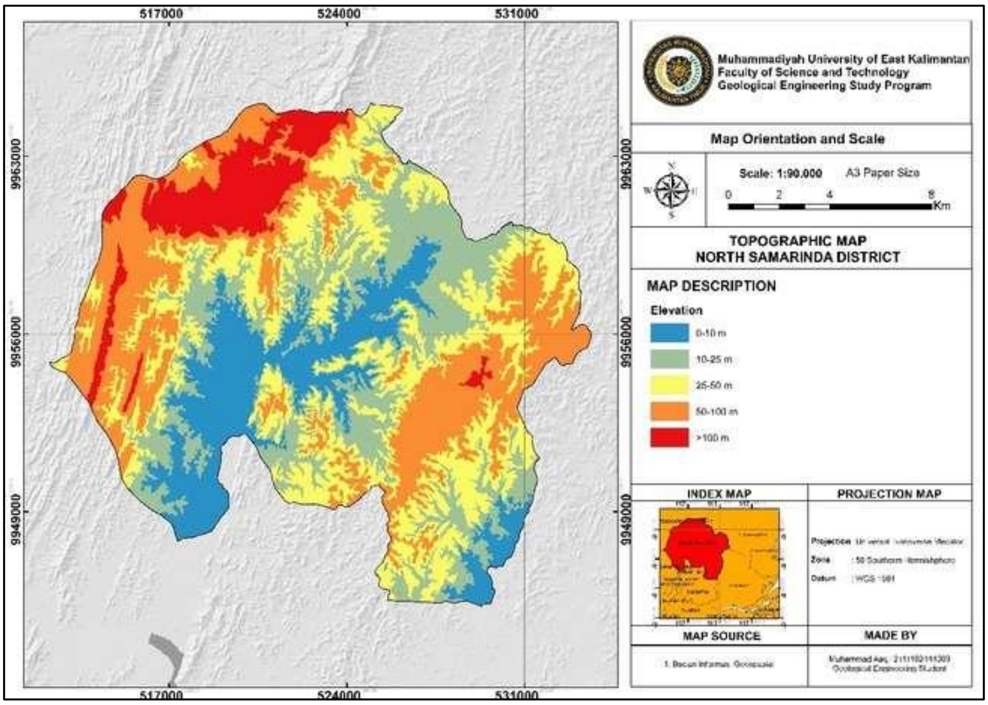

Figure 13. Land Elevation Map of the Research Area

Based on the altitude map or topography above, there are 5 altitude classes, ranging from 0-10 altitudes to more than 100 meters and the highest peak of a research area is in North Samarinda, which is more than 200 meters.

Table 6 Weighting Value of Land Height in the Research Area
Source: (Rifandi & Putra, 2024) and Calculation Analysis

Elevation (m)	Score	Weightlifter	Value
0-10	5	0,20	1
11-25	4	0,20	0,80
26-50	3	0,20	0,60
51-100	2	0,20	0,40
>100	1	0,20	0,20

Based on Table 6 and Figure 13 above, the height is divided into 5 elevation classes. The height of this land is one of the considerable influences on the potential for flooding, with that the weight value is 0.20 with different score values depending on the elevation value produced. The height of this land is also interrelated with the slope slope to determine the rate of water flow from upstream. The height distribution in the study area showed that elevations with an altitude of 26 to 100 m were the most dominant morphological units of plots. These land elevation conditions directly affect the region's hydrological response to rainfall. Areas with high altitudes, such as hills, have an orographic rain mechanism capacity value. The relationship between height and land cover and morphology can also be observed spatially, for example at an altitude of 0-10 m there are residential areas and alluvial plains, then at an altitude of >50 m there is land cover in the form of shrubs and forests or trees.

Porosity and Permeability Test of Sedimentary Rocks in the Research Area.

This sub-chapter explains the analysis of rocks from rock samples that have been taken in the field with testing properties, namely porosity and permeability.

1. Porosity Test of Sedimentary Rocks in the Research Area

Testing the porosity test based on sedimentary rock samples observed while in the field, there are 3 examples of sediment types taken, namely: sandstone, claystone, and limestone, you can see Table 7 below for the results and Figure 14 for the documentation.

Table 7 Table of Results of Porosity Test of Sedimentary Rocks in the Research Area

No	Rock Types	Porosity value %
1	Claystone	57,5
2	Sandstone	20
3	Limestone	8

Based on Table 22 above, the porosity value of clay is 57.5%, this is because the number of very dense grains in the same volume, the amount of space between the grains cumulatively becomes very large. Clay minerals are describes as the members of phyllosilicate minerals, have plasticity characteristics, and harden upon drying and firing. Clay minerals also can be formed naturally or synthetic. The examples of the clay minerals are kaolin, smectite, chlorite, and pyrophyllit.

Then the porosity value of sandstone is 20%. Sandstone is formed from mineral grains (especially quartz) that have been transported and deposited. This deposition process naturally creates an arrangement that is not perfectly tight, leaving space in between. This is called primary porosity. If the grains of sand are uniform in size, they will be arranged in a way that leaves a lot of empty space between them and this results in high porosity.

Finally, the porosity value of limestone is 8%. This is because the empty space is filled by cement so that it becomes a layer that tends to be dense. This is what happens to reef limestone. The natural minerals that make up the skeleton of organisms, such as calcite, are chemically unstable over geological timeframes.

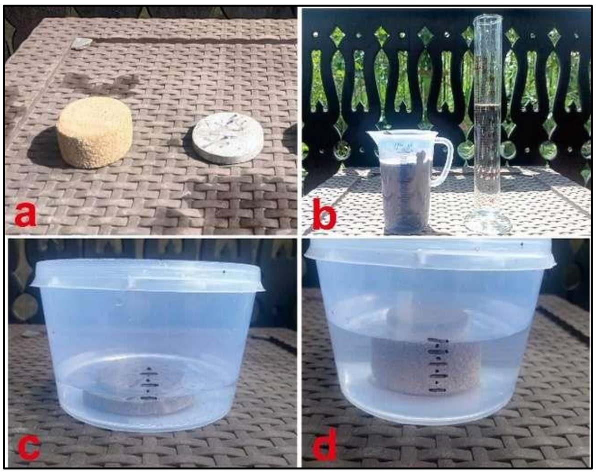

Figure 14. Explaining the Porosity Test Documentation, a. Sandstone and Limestone Samples, b. Clay Volume Test, c. Limestone Volume Test, d. Sandstone Volume Test.

2. Permeability Test of Sedimentary Rocks in the Research Area

The working principle of this test is carried out by allowing water to flow through the soil sample under constant (fixed) water pressure from the beginning to the end of the test. can be seen Table 8 for the results.

Table 8 Table of Permeability Test Results of Sedimentary Rocks in the Research Area

No	Rock Types	Permeability Value (cm/s)
1	Claystone	3.97 × 10-5
2	Sandstone	8.7 × 10-2
3	Limestone	9.8 × 10-8

Based on the results of the analysis of the permeability test of limestone samples, it was found that the value of the permeability coefficient was 9.8 × 10-8 which means that it is included in the Very low or impermeable type, with the type of crystalline limestone. The low permeability value is due to the influence of cement and calcite on limestone samples.

Based on the results of the analysis of the sandstone sample permeability test, it was found that the value of the permaability coefficient was 8.7 × 10-2 cm/s which means that it is included in the type or degree of permeability of Highly pervious, with the type of sandstone sample of medium sand size. Sandstone is made up of mineral particles, especially quartz, which are much larger in size than dust or clay. On the Wentworth scale, medium sandgrains have a diameter between 0.25 mm to 0.5 mm. Because the granules are large, the pore spaces formed between them are also wide and open, so water flows easily.

Based on the results of the analysis of the permeability test of clay stone samples, it was found that the value of the permaability coefficient was 3.97 × 10-5 cm/s which means that it is included in the low impermeable type, with the type of clay clay sample. This clay stone is formed from clay mineral particles that are very small in size, much smaller than sand or dust. Granules are microscopic in size (less than 1/256 millimeter). Since the grains are so small, the empty space between them is also very small.

Figure 15. Explaining the Permeability Test Documentation, a. Sandstone, Limestone, and Clay Samples, b. Permeability Test Based on the Amount of Water Coming Out of Sedimentary Rock Samples.

Magnetotelluric Audio Frequency Analysis Research Area

The location of ADMT (Audio Frequency Magnetotelluric) data collection is in Bengkuring, North Sempaja Village, North Samarinda District, Samarinda City. Data collection was carried out three different times at each location, each location consisted of 2 lines that had a length of up to 100 m and an interval of 2 m, as well as a depth of up to 100 m. The type of ADMT tool used is ADMT -300HT2 1 meter long, this tool is used through a bluetooth network, it can be observed at the research location as shown in Figure 16.

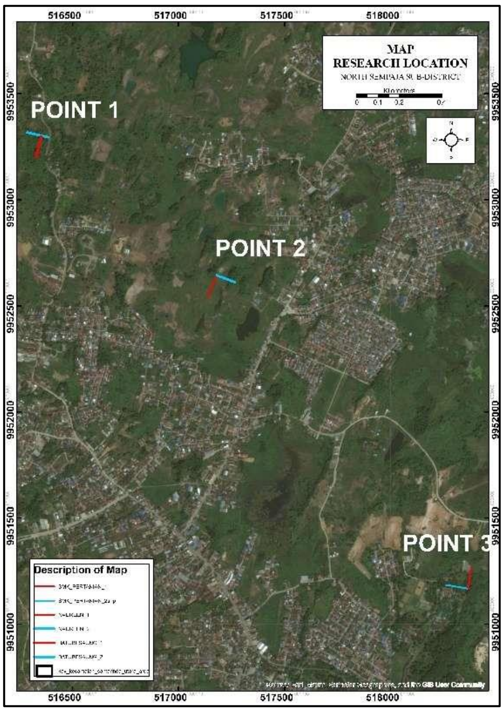

Figure 16. ADMT Location Point Map

Based on Figure 16 above, each point has 2 trajectories, namely trajectories that are in the direction of the rock layer (red) and perpendicular to the rock layer (blue). It aims to support subsurface data and find the resistivity value of each type of rock.

The working principle of ADMT is that the source of the electromagnetic field uses the natural fluctuations of the earth's magnetic and electric fields, the sensor measures the variation of the electric (E) and magnetic (H) fields on the earth's surface. Resistivity analysis By analyzing the response of these electromagnetic waves, the system calculates the resistivity map (ρ) below the surface. Then the interpretation of the data, namely a low resistivity value indicates a rock that contains water (aquifer), while a high value indicates dry rocks or different types.

1. Solid Model Modeling

This analysis is in the form of a model after measurements from the field, containing an explanation of subsurface results such as the indication of the layers of each lithology, the model results can be observed in Figure 17 below.

The results of this modeling are subsurface reconstruction to find out each layer, thereby becoming supporting data as a geological factor for potential flood vulnerability by looking at indications of water-saturated layers, groundwater, and layers with hard rocks.

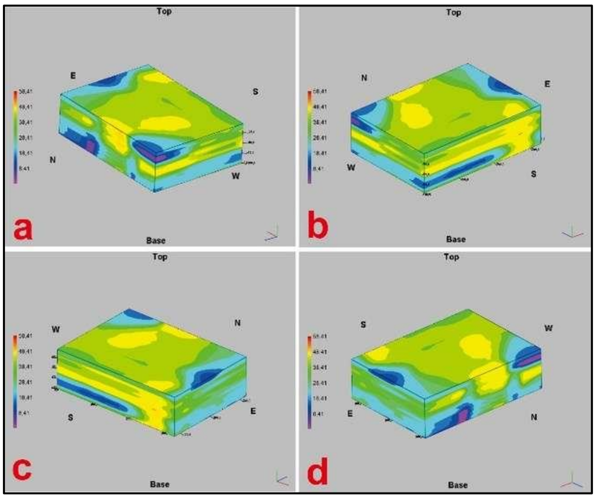

Figure 17. Explaining the Solid Model Results Through Rockwork Software from the ADMT Data Process, a. North and West Side Display, b. West and South Sides, c. South and East Sides, d. East and North Sides.

Based on Figure 17 above, it is the result of subsurface analysis of the results of ADMT through rockworks software, the software used in the 2015 old version and the type of modeling in the form of a solid model based on x and y coordinate data for each location, the point of each trajectory datum, and the resistivity value of each depth. Based on the results of the model above, it was found that the highest resistivity value was 58.41 and the lowest was less than 8.41 and could be close to 0. Each resistivity depicts the subsurface with lithological differences, for the purple zone, the lowest resistivity is an indication of a water layer or a rock layer that is water-typed, then the turquoise zone with a resistivity value of about 20 to 25 is an indication of the clay layer, then the yellowish-green zone is an indication of the sand silt layer, and finally the red zone is an indication of the hard layer, It can be fine sandstone with strong compactness properties or medium coarse grain size.

This means that there is a geological role in the potential flood vulnerability factor in the study area, where the water-saturated layer is certainly a water-prone zone if it rains continuously so that it is no longer able to accommodate it, and so are indications of other layers.

Flood Vulnerability Zoning

This sub-chapter contains an explanation of the results of the calculation and the previous sub-chapter by dividing it into three classes of flood vulnerability and marked with colors. To get a flood vulnerability class, first determine the class interval based on the formula. See table 9.

Table 9 Results of Flood Vulnerability Class Interval
Source : Calculation Analysis

Flood Vulnerability Class	Class Intervals
Safe	0,20 – 1,76
Vurnerable	1,76 – 3,33
Very Vulnerable	3,33 – 4,9

Based on Table 9 above, the flood vulnerability classes that have been obtained are three classes, namely safe, vulnerable, and very vulnerable. The results of this distribution will be displayed in the form of zoning of potential flood vulnerability marked with colors in the research area.

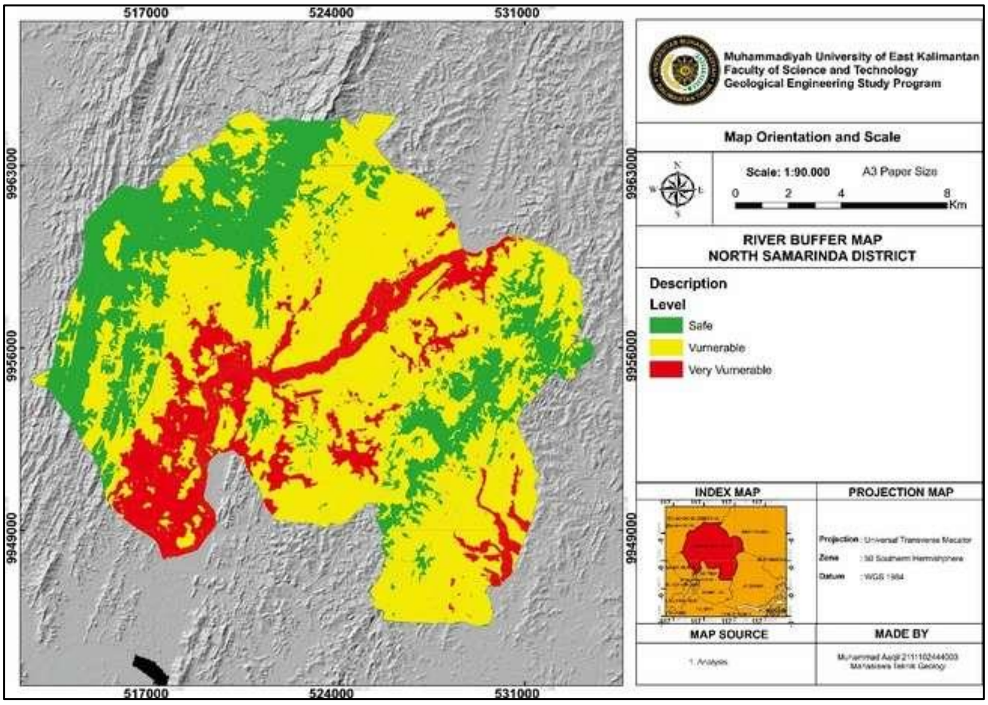

Figure 18. Flood Vulnerability Zoning Map of Research Locations

In Figure 18, the dark green area represents areas that are considered safe from potential flooding. Based on its parameters, this area has special characteristics. The slopes are relatively steep, some very steep (more than 40%), some steep (25-40%), and some somewhat steep (15-25%). In addition, the topography is steep, and the land is covered with bushes and forests. Looking at the shape of the land or geomorphology, in this safe zone, we can find formations such as folding wings, monocline hills, and fault cliffs. In terms of lithology, or rock type, this area has more resistant rocks or has higher durability compared to areas that are very prone to flooding. The types of rocks here are crystalline limestone and fine to coarse sandstone. Due to the steep slopes and high topography of this area, rainwater tends to flow directly into more sloping areas, i.e. residential areas.

Yellow areas indicate areas with a risk of prone flooding. In terms of land use, this area is dominated by residential and agricultural areas, such as rice fields. From a morphometric or landscape perspective, the area has slopes with varying gradients, ranging from sloping to steep. The most common landscapes or geomorphologies here are monocline hills and eroded hills. The types of rocks or lithology in this area are quite diverse, with varying levels of strength, ranging from strong to weak, such as fine sandstone and claystone. These low-strength rocks, because they are susceptible to chemical and physical weathering, tend to produce thick, loose, and unstable surface materials.

The red zone is categorized as a high-risk or "flood-prone" area. The area that has the potential to have a category of very vulnerable to flooding is the red part, which is clearly visible in the middle of the study area which has the lowest topography, the land cover in this area is dominated by settlements, rice fields, alluvial plains, and is on the river side, as well as the presence of water bodies, then this area has a sloping slope (8-15%) to flat (0-8%), the geomorphological unit present in this part of the area is a fluvial swamp plain with lithology that has The nature of rocks or soil that is easily saturated with water, alluvial deposits consisting of mud to clay, the texture of the soil type is very fine causing surface flow water from rain or river overflows to be difficult to absorb into the soil and inhibit the infiltration process so that it can make this area the most potentially flooded. This category of very vulnerable flood-prone areas is on the riverbank, when water overflows due to high rainfall intensity, water will stagnate on the river bank for a long time due to existing lithological factors such as clay and other watertight loose materials that are easily saturated with water.

CONCLUSION

Each parameter has a function and purpose in the research, such as soil type parameters show that soil also contributes to surface runoff, thereby increasing the potential for inundation, built-up land cover has a high vulnerability score value due to reduced water infiltration ability, slope slope and topography play a role in controlling the speed of surface flow, areas with sloping slopes and low elevation tend to have a level of flood vulnerability Higher than areas with steep slopes and higher elevations, the analysis of river buffers shows that areas near river banks have a higher level of flood vulnerability. Meanwhile, the rainfall parameter acts as the intensity of rainfall which increases the volume of surface runoff.

The results of all parameters through the overlay technique produced a flood vulnerability zoning map which is divided into three classes, namely safe, vulnerable, and very vulnerable vulnerabilities. Highly vulnerable zones are generally spread in lowland areas with the dominance of built-up land, soil types with low infiltration power, slope slopes < 8%, and are located in the nearest river buffer radius. Vulnerable vulnerability zones are in transitional areas with diverse physical characteristics, while safe vulnerability zones are generally in areas with higher topography, good vegetation cover, and greater distance from river channels.

Results Analysis of subsurface conditions aims to identify the structure of the rock layer, the presence of groundwater, and the saturated zone. The results of geoelectric modeling show a layer with a low resistivity value, interpreted as a layer that is easily saturated with water. This underground modeling explains that each rock has a different role, the more saturated the water in the layers means that the water is no longer able to hold water on the surface. In addition to geoelectricity, porosity and permeability tests also affect, the greater the porosity value, which means that it is a good container for storing water and the better the permeability, the better it is to pass water.

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