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The Development of Tourism Areas in Abang Temple Yogyakarta, Using Engineering Geological Capability

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Abstract - Temples are interesting objects used for the exploration, exploitation, and development of tourist areas. However, these cultural sites and the surrounding environment need to be adequately preserved to prevent disasters. One of the interesting aspects of temples needed to be developed as tourist areas is its engineering geological capability. Therefore, this study aims to determine the engineering geological capability of Abang Temple located in the village of Jogotirto, Berbah, Sleman, Yogyakarta, Indonesia. This Buddhist heritage temple was built on an isolated hill with the constituent materials of red bricks, tuff, and andesite that have experienced weathering over the decades. The temple is geographically located in an interesting natural nuance, thereby making it a dilemma for developing tourist areas. This research was carried out by mapping and measuring field data on several influential aspects, including the carrying capacity of rocks and soil, slope, the potential for geological disasters, the depth of groundwater level, the ease of excavation, the land use, the rock weathering level, and the discontinuity field density. The results shows that there are three zones of engineering geological capability for developing temples into tourist areas, namely high, medium, and low capabilities.

Keywords: engineering geological capability, temple, tourism, geology

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INTRODUCTION

Background

Geotourism is a concept of tourism that combines the conservation of geological and the usefulness of local communities. Temple is one of tourist attraction places essential as a national cultural relic (Yan *et al.*, 2001). In addition, temple exploration and exploitation need to preserve the cultural site and the surrounding environment, so that it does not cause disaster. Abang Temple is located nearby the famous Prambanan Temple at Yogyakarta. The temple is not popular yet compared to other temples around Prambanan area. However, this temple has the potential to be developed as a tourist area.

The tourism industry plays a significant role in developing an area, enhancing its economy, creating jobs, and alleviating poverty (Pitana and Diarta, 2009). Furthermore, tourism is an activity dynamically involving various groups of society, and profitable for generating beneficial values (Ismayanti, 2010). According to a previous research, tourist objects need to be managed appropriately to attract numerous tourists, invariably increasing the local revenue and the surrounding community welfare (Ferdinan *et al.*, 2015). Therefore, to reap these positive results, an adequate attention needs to be paid to environmental threats to avoid unforeseen disasters (Hunger and Wheelen, 2001). A careful planning is needed to develop sustainable tourist area, to increase the economy around the temple, to utilize the cultural site value, and to conserve geological value (Purwanto *et al.*, 2020).

The engineering geological capability of a temple is an interesting aspect to consider while developing it into an environmentally friendly tourist area. This aspect is an engineering benchmark used to determine the structural ability of the land surrounding the temple to ensure that it carries out its functions by sustaining the environment without reducing the cultural-site value.

Geological and Stratigraphical Settings

Abang Temple is in Blambangan, Jogotirto Village, Berbah Subregency, Sleman Regency, Yogyakarta Special Region, Indonesia. The temple is a Buddhist heritage built on an isolated hill from various red bricks, tuff, and andesite materials that have highly weathered conditions (Degroot, 2009). A previous research stated that there was a determination of weathered red conditions from physical, petrographic, and X-Ray Diffraction (XRD) observations (Hidayat *et al.*, 2017). Meanwhile, other references reported that the bedrock where this temple was found was in the form of pyroclastic rocks with the Miocene age of approximately 20 million years (Rahardjo *et al.*, 1995; Smyth *et al.*, 2011).

Stratigraphically the researched area is in the Semilir Formation, which consists of a loop between breccia-tuff, pumice breccia, dacitic tuff, andesitic tuff, and clayey tuff. Physiographically, the area of Berbah is a small hill with the height of 100 m, around the area in the form of a cemetery. These small hills comprise Tertiary volcanic rocks that make up the southern mountains. The rice fields consist of alluvium deposits as a material of volcanic product. This area is controlled by the Opak Fault, which produces Kali Opak, the main river near the researched area. The main direction of the northeast-southwest opak fault resulted in many burly structures around the main northeast-southwest direction.

The temple is located on a hill with a fascinating natural nuance, thereby making it a potential tourist attraction of cultural sites and a dilemma for developing a tourist area. Geographically, the bedrock age where the temple was built is old, easily weathered, and tends to experience a lot of deformation. Therefore, it is essential to research the engineering geological capability of the Abang Temple area in the context of its development as an environmentally friendly tourist area.

METHODS AND MATERIALS

The research on the engineering geological capability for the development of Abang Temple into a tourist area was carried out by mapping and collecting data directly in the field. This method was performed to obtain information on its geological conditions, physical and mechanical properties of rocks and soil, as well as the presence of shallow groundwater. The information was then translated into several parameters capable of supporting tourism development based on engineering geological capability.

Based on a previous research, the parameters used to determine an area engineering geological capability include rock and soil bearing capacity, slope, ease of excavation, groundwater level depth, and vulnerability to geological disaster (Kristanto *et al.*, 2020). However, in this study, three parameters were added to complement the shortcomings of the method proposed including land use, rock weathering level, and discontinuity plane density. Furthermore, the above mentioned eight parameters were analyzed and weighed using the Analytic Hierarchy Process (AHP) proposed by Saaty (1977). Studies have shown that the more these parameters contribute to the problem, the greater the value.

Engineering Geological Capability Parameters

Bearing Capacity of Rock and Soil

According to Kristanto *et al.* (2020), the rock and soil bearing capacity parameters are dependent on the load bearing in square meters. The total number of living and dead loads are calculated using the Load Planning Guidelines for Homes and Buildings (Ministry of Public Works, 1987). The bearing capacity in this study was obtained from three classes, namely Qall ≥ 3230 kg/m² (good), Qall 540 - 230 kg/m² (sufficient), and Qall <540 kg/m² (poor). The class of bearing capacity was based on the regulation from the Ministry of Public Works. This parameter estimates the whole rock and soil bearing capacity. However, this parameter can not determine the small parts of the rock and the soil related to bearing capacity. Thus, to support this parameter, rock weathering and discontinuity plane density were added in this research.

Slope

The slope class proposed by Novianto *et al.* (1997) was based on the workability angle supporting the ease of engineering work, and divided the slope into three categories, namely those below 8°, 8 - 30°, and above 30°. However, adding classes with a narrower range is necessary, because the long ones already have different properties. Therefore, the slope class was changed into five categories consisting of 0 - 3° (Flat), 3 - 8° (Slightly flat), 8 - 16° (Inclined), 16 - 30° (Slightly Steep), and above 30° (Steep). This classification is based on the slope effect to the land damage.

Ease of Excavation

The parameter of ease of excavation is used as the basis for the effective and efficient determination of engineering work on the land developed. Pettifer *et al.* (1994) and Kristanto *et al.* (2020) stated that the level of ease excavation was obtained from the rock mass character as seen from the response to the compressive strength and discontinuity plane density. Further dividing the ease of excavation class into three, *i.e.* Easy to Dig, Hard to Dig-Extra Difficult to Plow, and Need Blasting.

Groundwater Depth

The groundwater level depth is an important parameter needed to support the resistance of the building foundation and the construction below the surface. Conversely, water-saturated areas tend to be more unstable and are more likely to cause problems with groundwater depth ideally measured at the peak of the rainy season to determine the shallowest depth. According to Kristanto *et al.* (2020), the minimum requirement for supporting shallow foundations is divided into three classes, namely those above three (Deep), 1−3 (Fairly Shallow), and below 1 (Shallow) (Kristanto *et al.*, 2020).

Potential Threat of Geological Disaster

The potential geological disaster parameter is obtained from the studied area, which has the most significant weight, because humans can not fully control it. Mitigation efforts are the wisest steps in addressing the threat of geological disasters.

Kristanto *et al.* (2020) also stated that the parameters for the potential threat of geological disasters were divided into three classes, namely high, medium, and low. The areas with high potential have a greater threat to the geological disaster that is evident. An example is an area with a slope of more than 30° or an active volcanic crater within a 1 km radius zone. The areas with medium potential show support for disasters, and are not within the radius of the centre. In contrast, those with low potential have the least probability of being affected by disasters, even in an extraordinary event.

Land Use

Land-use parameters are related to the ease of construction work in developed areas. This parameter is divided into seven categories, namely settlements, moor-bushes, rice fields, gardens, forests, swamps, and lakes. The land-use classification and scoring are based on the ease of land to be developed into tourist attractions.

Rock Weathering Level

This parameter is used to determine the level of rock weathering related to the strength as a support for the construction. Rock weathering level can support the rock bearing capacity parameter. Rocks with a low weathering rate tend to have greater strength. According to Kristanto *et al.* (2020), the rock weathering level parameters are divided into four criteria, namely fresh-colour change on the surface, colour and physical change below 25 %, physical change 25–50 %, and physical change above 50 %.

Discontinuity Plane Density

This parameter is obtained based on the presence of an average number of discontinuity planes in 1 m of observation. It indicates the rock mass strength with many discontinuity planes comprising low strength and bearing capacity compared to intact rock. Furthermore, this parameter can not be measured by rock bearing capacity and important to determine the land with massive discontinuity plane density. Kristanto *et al.* (2020) stated that the discontinuity plane density was divided into four categories: no discontinuity plane, 1 - 3 m, 3 - 10 m, and above 10 m.

Hierarchy Process Analysis

The analysis was carried out to determine the eight parameters using the weighting and scoring analytic hierarchy process with the results shown in Table 1. The classification and score is based on the building that tourism is based on the construction of tourism supporting buildings in the Indonesian Public Works Ministry Regulation (Badan Standarisasi Nasional, 1981). This basis is adjusted to tourist sites based on dead and live loads.

Table 1 shows the scoring results on the eight parameters of the engineering geological capability to develop a tourist area. They are further added and divided into four classes based on the total score range according to the engineering geological capability level as shown in Table 2.

The area recommended as the centre of tourist activities needs to possess a high capability level with an adequate load. Furthermore, the security and land stability level need to be classified as very good for heavy construction areas such as multistorey buildings and tourist sites. The intermediate level is a recommended tourism support area with a load below 3,230 kg/m². The security and land stability level in this area is classified as good, and can be developed into heavy construction sites.

A low capability level is recommended for green areas despite having the capacity for light construction. It has an inadequate level of security and land stability. Therefore, it requires large and complicated engineering costs and further research. Extremely low capability levels are areas that do not need tourism development due to their poor safety and stability.

RESULT AND DISCUSSION

The area surrounding the Abang Temple is mapped with field observations carried out in three main parts to determine its engineering geological capability. The first part is mapping, with the geological elements observed. Similarly, the second part is mapping and observed to determine the physical and mechanical properties of rock and soil. Meanwhile, the third part was mapped and observed to determine the dug wells. All points in the mapping and observation locations are shown in Figure 1.

Carrying Capacity of Rock and Soil

The test points and sampling location were used to determine the physical and mechanical properties of the rock and soil based on its distribution units. The value testing of the carrying capacity of rocks and soils, adjusted to the needs of tourism development based on in-situ tests and laboratory tests are shown in Figure 2.

Approximately 60 % of the area covering the western, northern, and southern parts of the study has rock and soil carrying capacity values in the range of 540 - 3,230 kg/m^2. This area is dominated by unconsolidated rock units from clay to gravel, which forms the plain to sloping morphology. Furthermore, 40 % of the area covering the study central and eastern parts is in the form of hills,

Table 1. Results of the Weighting and Scoring on the Engineering Geological Capability Parameters for the Development of a Tourist Area

Criteria	Subcriteria	Class	Class Value	Wight	Score
Bearing capacity of rock and soil	Qall ≥ 3230 kg/m^2	Good	3	0.161	0.484
	Qall 540-3230 kg/m^2	Sufficient	2		0.323
	Qall < 540 kg/m^2	Bad	1		0.161
Slope (Degree)	0-3 (Flat)	Very Good	5	0.109	0.545
	3-8 (Slightly Flat)	Good	4		0.436
	8-16 (Inclined)	Sufficient	3		0.327
	16-30 (Slightly Steep)	Bad	2		0.218
	>30 (Steep)	Very Bad	1		0.109
Potential threat of geological disaster	Low	Good	3	0.212	0.637
	Moderate	Bad	2		0.425
	High	Very Bad	1		0.212
Ease of excavation	Easy to Dig	Good	3	0.070	0.211
	Difficult to Dig – Extra Difficult to Plow	Sufficient	2		0.140
	Need Blasting	Bad	1		0.070
Groundwater depth to support foundation (meter)	>3 (Deep)	Good	3	0.103	0.308
	1-3 (Fairly Shallow)	Less Good	2		0.206
	<1 (Shallow)	Bad	1		0.103
Land use (Ease of Construction Work)	Settlement as temple	Very Easy	6	0.078	0.468
	Moor - Bushes	Easy	5		0.390
	Rice fields	Quite easy	4		0.312
	Garden	Quite Difficult	3		0.234
	Forest	Difficult	2		0.156
	Swamps and Lakes	Very Difficult	1		0.078
Rock Weathering level (Land Strength)	Fresh - Change Colour On Surface	Very Good	4	0.149	0.596
	Color And PhysicalChange <25%	Good	3		0.447
	Physical Change 25-50%	Moderate	2		0.298
	Physical Change > 50%	Bad	1		0.149
Discontinuity Plane Density (average in 1 m)	No discontinuity plane	Very Good	4	0.117	0.469
	1-3 m	Good	3		0.352
	3-10 m	Sufficient	2		0.234
	>10 m	Bad	1		0.117

Table 2. Level of Engineering Geological Capability for the Development of Tourist Areas

Capability Level	Total Score Range
High	>3.039
Moderate	2.359 – 3.039
Low	1.680 – 2.359
Very Low	<1.680

ridges, slopes, and valleys. This area has a rock and soil carrying capacity value greater than 3,230 kg/m^2 with dominant tuff and lapilli rock units.

Slope

The slopes were classified into five classes, namely 0 - 3^0, 3 - 8^0, 8 - 16^0, 16 - 30^0, and above 30^0. The slope of 0 - 3^o covers the southwestern and southern parts by 21%, while 3–8^o covers the northern, northwestern, and southern parts by 37 %. Furthermore, the area with a slope of 8−16^o covers parts of the southeast, south, and north by 8 %, while 16 - 30^o covers the centre and eastern parts by 24 %. Lastly, slopes above 30^o covers parts of the middle and northeastern parts of the studied area by 10 % (Figures 3 and 4).

Geological Disaster Potential

The geological disasters in the researched area from the observation and mapping is divided into three classes, namely high, medium, and low as shown in Figure 5. Furthermore, the

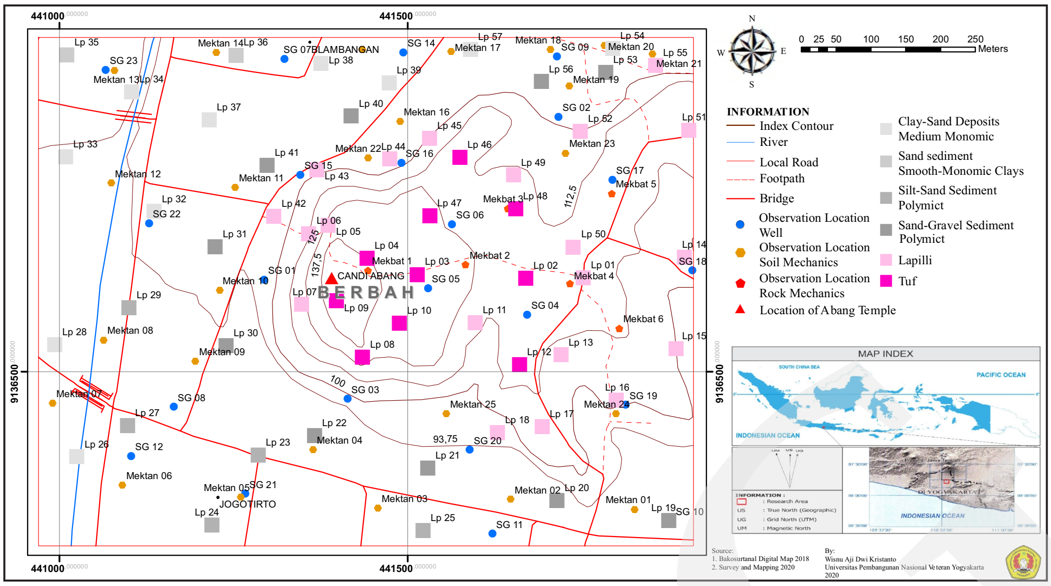

Figure 1. Observation location map of Abang Temple area, Sleman, Yogyakarta Special Region.

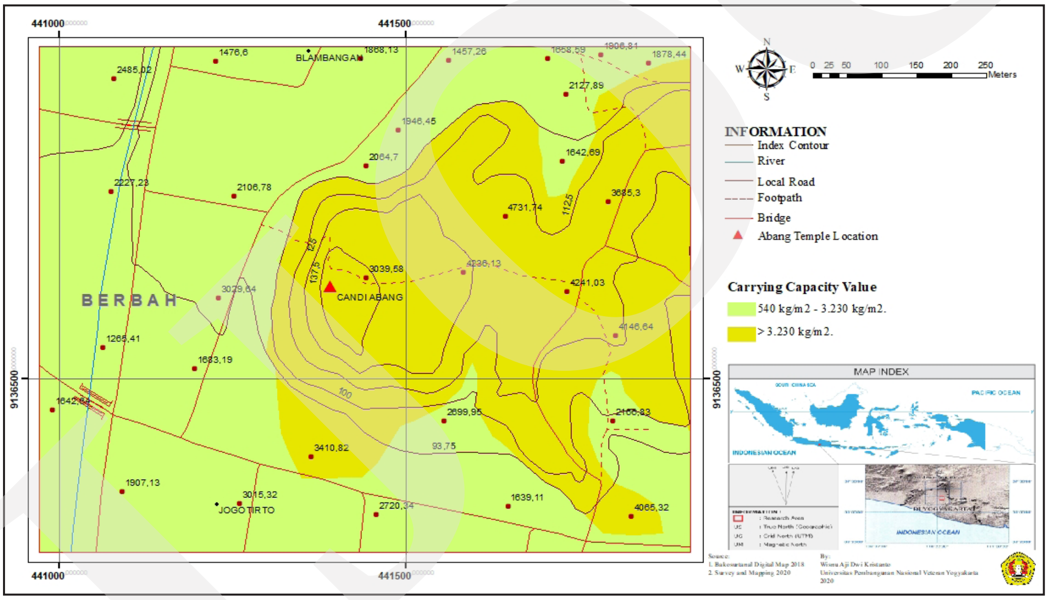

Figure 2. Map showing bearing capacity of rock and soil map of Abang Temple area, Sleman, Yogyakarta Special Region.

Figure 3. The appearance of hills and steep slopes on the southwest side of the Abang Temple area.

high geological disaster covers every steep slope and valley formation by 15 % of Abang Temple area, and close to the opaque fault line and the Merapi Volcano. Therefore, its biggest threat to a natural disaster such as earthquakes and volcanic eruptions is due to the landslides. Subsequently, the medium geological disasters include hills and ridges in the central and eastern parts, covering 25 % of the studied area, and similar to areas with high and low landslides. Low potential threat areas covers approximately 60 % of the western, northern, and southern regions.

Ease of Excavation

The results of mapping and field observations indicated that the level of ease of excavation in the studied area was divided into three groups, namely easy, difficult to extremely difficult, and needs to be blasted as shown in Figure 6. Approximately 60 % of the total area is easy to excavate and dominated by loose material from clay to gravel. While 22 % of the total area is in the difficult to extremely difficult excavation group, and located in the middle east dominated by rocks with moderate to extreme weathering. Areas with easy excavation requiring blasting, cover 18 % of the total studied area, dominated by rock with low weathering rates.

Ground Water Level

The observation results of groundwater level area that acts as a support for shallow foundations

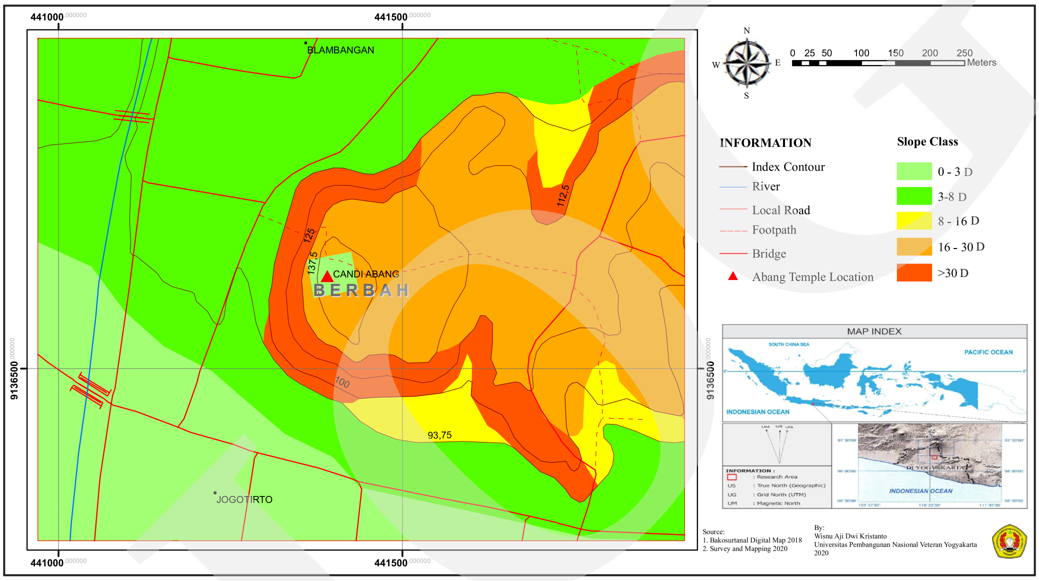

Figure 4. Locality map of slope in Abang Temple area, Sleman, Yogyakarta Special Region.

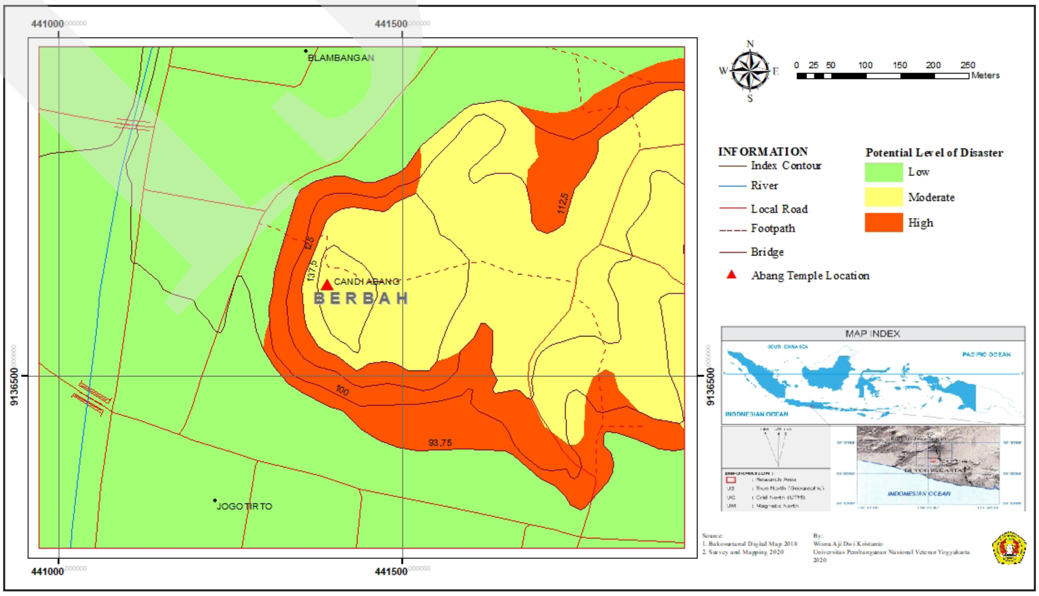

Figure 5. Map showing geological disaster potential of Abang Temple area, Sleman, Yogyakarta Special Region.

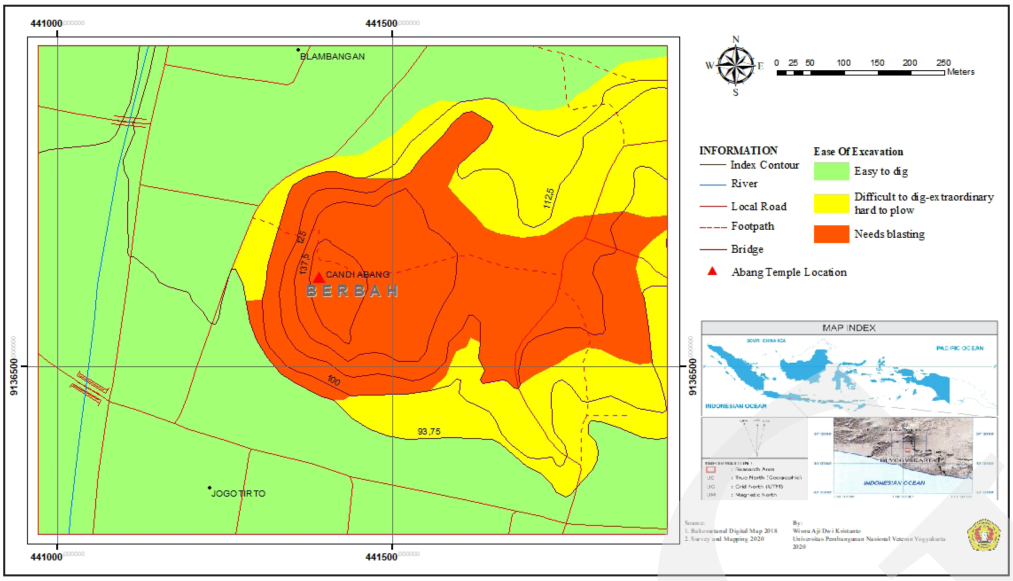

Figure 6. Locality map of ease of excavation in Abang Temple Area, Sleman, Yogyakarta Special Region.

are divided into two zones with depths of 1 - 3 m and above 3 m as shown in Figure 7. The areas with 1 - 3 m of groundwater level covers 50 % of the northern, western, and southeastern parts. Meanwhile, the remaining 50 % of the total areas are 3 m above the groundwater level, and these include the middle, eastern, and southern parts.

Land Use

The land is divided into five zones, namely temples, settlements, gardens, rice fields, and moor, in percentages of 2 %, 12 %, 14 %, 45 %, and 27 %, respectively. The temple has similar characteristics as settlement. Thus, for the scoring process with AHP, the temple was included in the settlement classification (Figures 8 and 9).

Discontinuity Plane Density

The mapping and field measurement results obtained four classes of discontinuity plane density in the studied area consisting of 1 - 3 m, 3 - 10 m, below 10 m, and above 10 m (soil) as shown in

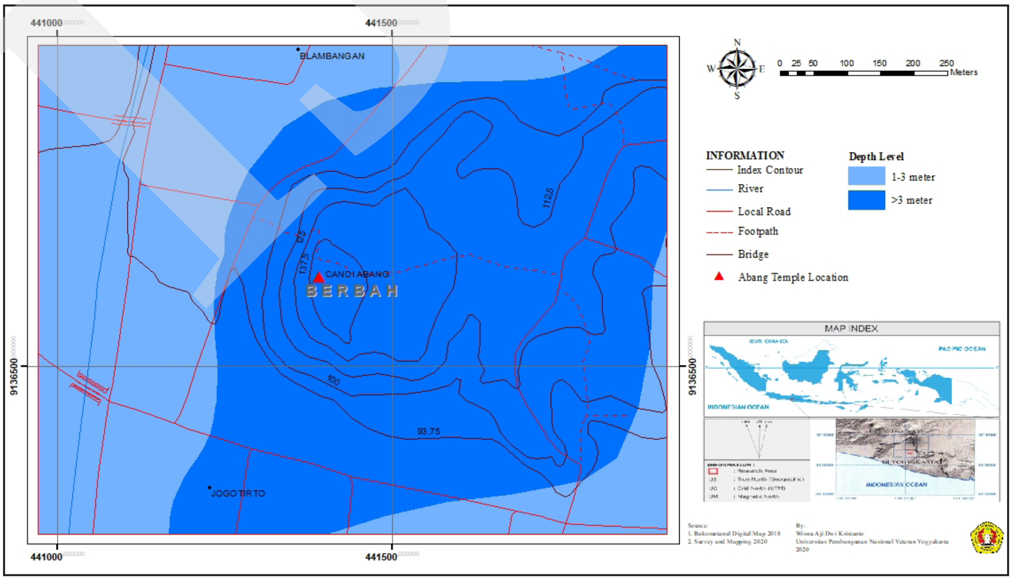

Figure 7. Map of groundwater-level of the Abang Temple Area, Sleman, Yogyakarta Special Region.

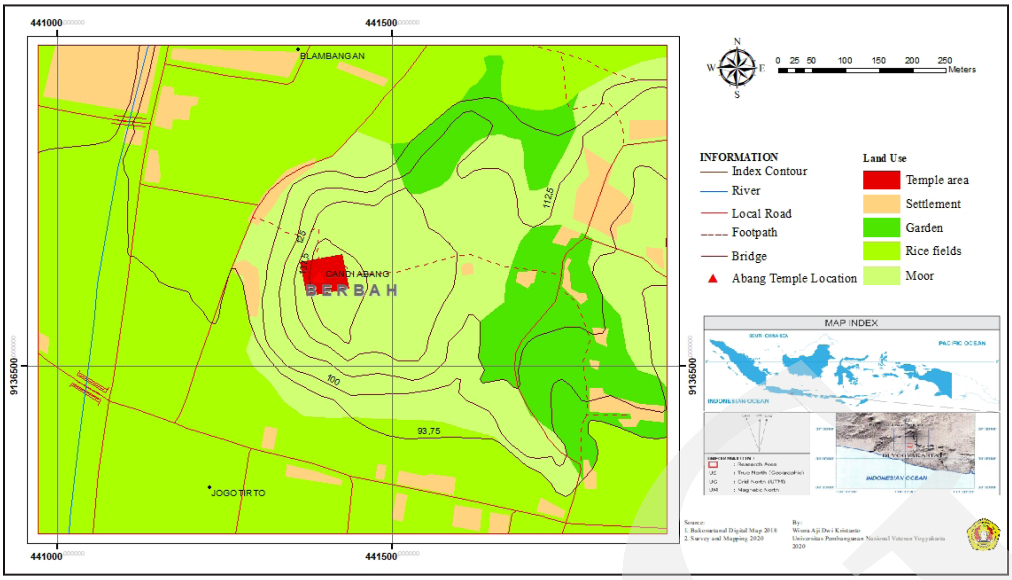

Figure 8. Land-use map of Abang Temple area, Sleman, Yogyakarta Special Region.

Figure 9. Discontinuity in the form of burly lapilli rock units with a density of 3 - 10 m.

Figure 10. The areas with a field of discontinuity density above 10 m (soil) is dominated by 60 %, and are composed of loose material units. While those below 10 m covers 13 %, and occupies part of the slope and valley. Furthermore, the area with 3 - 10 m density covers 25 %, and occupies the central and eastern parts. While those with a discontinuity area of 1 - 3 m density covers a small part of the southeast by 2 %. Soil is included into class of above 10 m.

Weathering Levels

The mapping and observation process shows that the level of rock weathering obtained four classes, namely soil, extreme, medium, and low as shown in Figure 11. Weathered soil includes areas with loose material that has not been consolidated comprising similar properties. This area covers the northern, western, and southern of the studied area by 60 %, while the extreme and moderate weathering cover a portion of the northern and southern slopes and the eastern ridge by 14 % and 22 %. Meanwhile, the area with a low weathering level covers occupies the hill and eastern ridge by 24 %.

Engineering Geological Capability for Tourism Development

Figure 12 shows the analysis results of engineering geological capability for developing tourist areas using the analytic hierarchy process. The eight parameters include rock and soil bearing capacity, slope, excavation ease, groundwater level depth, the potential threat of geological disasters, land use, discontinuity field density, and the level of rock weathering, which obtained three levels of engineering geological capability, namely high, medium, and low classes.

The areas with high level of engineering geological capability for the development of tourism include hill morphology with the closest location to Abang Temple, occupying 12 % of the total studied area. Furthermore, the engineering geological capability supporting the most capable tourism development has a score of eight parameters reach-

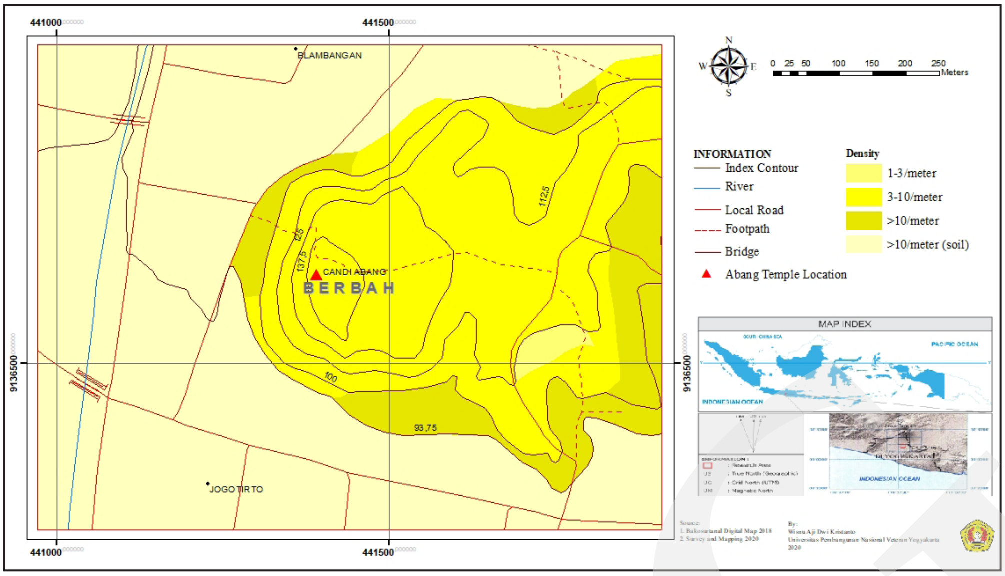

Figure 10. Locality map of discontinuity plane density map of Abang Temple area, Sleman, Yogyakarta Special Region.

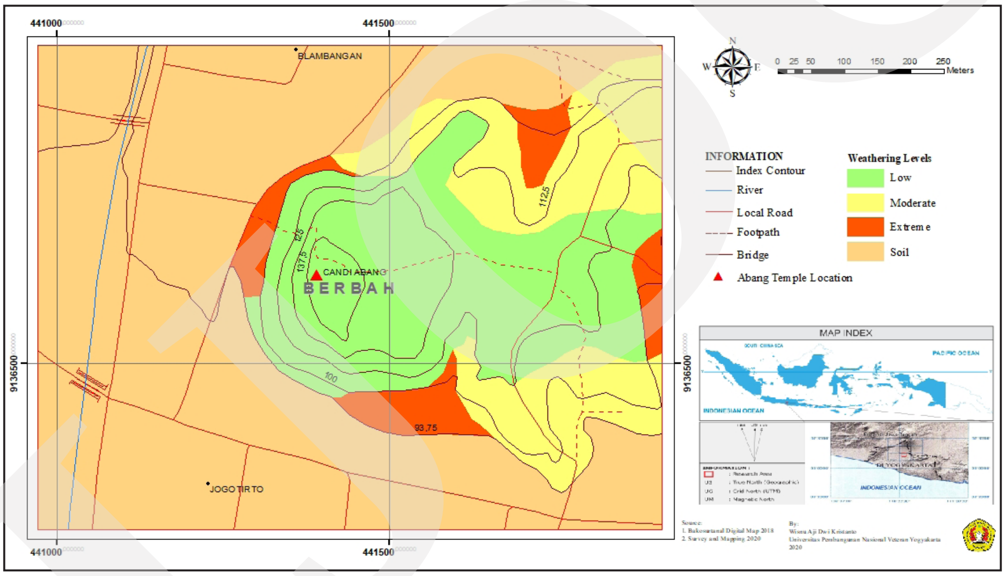

Figure 11. Map showing weathering levels of Abang Temple area, Sleman, Yogyakarta Special Region.

ing 3.07, which is included in the high category and used as a heavy construction site for tourist activities. Approximately 70 % of the areas cover the medium level of technical geology capability for tourism development. This area is dominated by the morphology of the plains, slopes, and ridges to the east of the hill, and supports tourism with a load of not more than 3,230 kg/m^2. The suitable developments for this area include parking for vehicles such as large buses with the capacity of 60, culinary areas, souvenir vendors, and other light supporting facilities. The areas with a low level of engineering geological capability for tourism development include steep slopes and valleys with percentages of 18 %. Furthermore, this covered an area with a total score of eight parameters in the range of 1.68 - 2.36, and included in the low capability category in engineering geology to develop tourist areas. The main factor that affects the low capacity of engineering geology is the high potential threat of geological disaster, one of which is landslides and steep slopes with a slope above

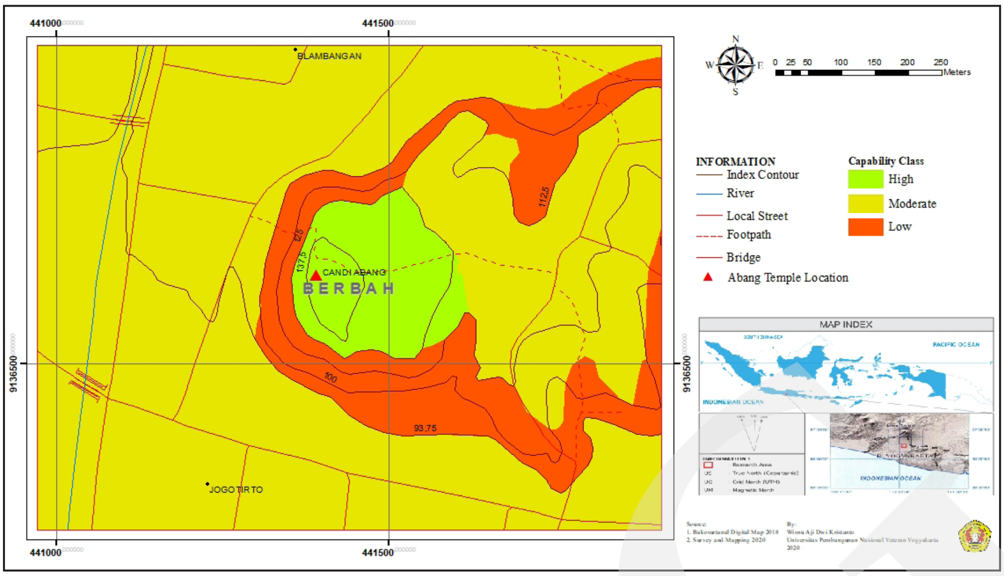

Figure 12. Map showing engineering geological capability for tourism development of Abang Temple area, Sleman, Yogyakarta Special Region.

30^0. This area is most suitable to be developed as a green and conservation region by planting trees controlling erosion.

CONCLUSIONS

In conclusion, the Abang Temple, Berbah, Sleman, Yogyakarta, in Indonesia has an engineering geological capability to be developed as a tourist area. This is because the three abilities, namely high, medium, and low. The high-capacity areas have an adequate carrying capacity and engineering geology factors to be developed. Furthermore, areas with low capability need to be avoided in tourism development, better designated as conservation areas. There is a significant delineation in determining the engineering geological capability for developing tourist areas with these eight parameters. Therefore, further research is needed.

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