

# SELECTION OF POSSIBLE CANDIDATE AREA FOR NUCLEAR ENERGY FACILITY IN JOHOR, MALAYSIA

Nor Afifah Basri, Ahmad Termizi Ramli

*Department of Physics, Faculty of Science, Universiti Teknologi Malaysia, 81310 UTM Skudai Johor, Malaysia*

## ABSTRACT

*Nuclear power is considered as one of the best option for future energy development in Malaysia. Since Malaysia has no experience in nuclear energy generation, commissioning the first nuclear power plant needs tremendous effort in various aspects. Site selection is one of important step in nuclear power plant commissioning process. This paper proposes candidate sites for nuclear power plant in Mersing, Kota Tinggi, Muar and Batu Pahat district in Johor, Malaysia. The candidate selection process uses the IAEA document and AELB guideline as main reference, supported by site selection procedure by various countries. MapInfo Professional software was used to simulate the selection process for candidate areas for the nuclear power plant. This paper concluded that Tenggaraoh and Jemaluang area are the most suitable area for nuclear power plant facilities in Johor, Malaysia.*

## ABSTRAK

*Di Malaysia, tenaga nuklear dikenalpasti sebagai salah satu pilihan terbaik dalam pembangunan sumber tenaga masa hadapan. Pemilihan lokasi loji tenaga nuklear merupakan salah satu langkah penting dalam proses permohonan pembinaan loji nuclear. Kertas kerja ini mencadangkan pemilihan calon kawasan di daerah Muar, Batu Pahat, Mersing dan Kota Tinggi di Johor, Malaysia. Pemilihan calon lokasi dilakukan dengan merujuk kepada dokumen IAEA dan AELB sebagai sumber utama dan disokong oleh dokumen lain dari pelbagai negara. Perisian MapInfo Professional telah digunakan bagi memaparkan proses pemilihan calon kawasan untuk loji tenaga nuklear. Kertas kerja ini mencadangkan kawasan Tenggaraoh dan Jemaluang sebagai kawasan yang paling sesuai untuk pembinaan loji tenaga nuklear di negeri Johor.*

**Keywords:** nuclear facility, MapInfo

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## INTRODUCTION

Due to the need for secured future energy supply, Malaysia has decided to build a nuclear power plant in 2015. Commissioning procedures has started in 2008 and the requirement steps had been undertaken slowly and carefully (TNB, 2010). One of basic consideration in commissioning nuclear power plant is the proposal of candidate site. Selecting a site for nuclear power plant requires consideration in various aspects such as engineering features for the plant, transportation, safety management and emergency measurement (STUK, 2010). Apart from the requirement for the power plant itself, other crucial consideration is the impact to the environment, economy and social at the surrounding area.

A feasible site characteristic was not specifically regulated by IAEA. IAEA provides the basic requirement for commissioning nuclear facilities with general objective to ensure safety for the facilities itself, workers, population on surrounding area and the environment (IAEA, 2003). Selection and evaluation procedures for a suitable site depend on the regulator of the particular country. The procedures may differ with other country, since it is done depending to the purpose of building, environment and surrounding characteristic, as well as the management system in the particular country (Bishnoi and Prabir, 2005).

Since Malaysia has no experience nuclear energy generation, the commissioning process is done slowly and carefully too meet the international standard. AELB, as a regulatory body for nuclear and radiation facility and activity has been revising and upgrading related act to assist the commissioning process. In March 2011, AELB has published the nuclear power plant site selection guideline to determine a suitable site for nuclear power plant (AELB, 2011). The guideline gives the important characteristic that must be considered in site selection procedure.

Malaysia Peninsula has a total area of 131,598 km<sup>2</sup>. It is divided to 11 states and two federal cities. Currently, the population reaches 23,529,800 citizens with annual population growth rate 1.3% in 2010 (Department of Statistics, 2010). The population density is 84 people per square kilometre, mostly concentrated in the city centre, capital states and developed area.

Johor is the second biggest state in Peninsular Malaysia. The total area of Johor is 19,210 km<sup>2</sup> and divided into 8 districts. Population in Johor is 3,305,900 in 2010, with annual growth rate of 1.1% and population density of 170 people per square kilometre (Department of Statistics, 2010). Most of areas in Johor were covered with plantations and rain forests. The population was mainly concentrated at Johor Bahru, the state's capital city, as well as other city centres in every district.

## HYPOTHESIS

AELB has suggested the important site characteristics to select a suitable site for nuclear power plant in the guideline. According to AELB (AELB, 2011), a site is considered acceptable in from the safety point of view if:

1. It cannot be affected by phenomena against which protection through the design is impracticable;
2. The probability of occurrence and the severity of destructive phenomena are not too high;
3. The site characteristics are such that the consequences of potential accident would be at acceptable limits.

The guideline proposes 11 characteristics as regulatory consideration for site selection process (AELB, 2011). Point 2.22 in the guideline stated that:

*2.22 The safety issues discussed in this section includes geologic/seismic, hydrologic, and meteorological characteristics of proposed sites; determination of exclusion area and low population zone; population considerations as they relate to protecting the general public from the potential hazards of serious accidents; potential effects on a plant from accidents associated with nearby industrial, transportation, and military facilities; emergency planning; and security plans. The environmental issues discussed concern potential impacts from the construction and operation of NPP on ecological systems, water and land use, the atmosphere, aesthetics, and socio-economics. (AELB, 2011)*

This paper takes 5 important characteristics into consideration to determine a suitable site for nuclear power plant. The chosen characteristic are: geological and seismological characteristics, meteorological characteristics, population distribution and safety measurement characteristic. The safety measurements characteristic consists of supporting characteristic for NPP and determination of safety zones from estimated radioactive dispersion from nuclear accidents.

## METHODOLOGY

### *M.1 – General steps and methodology*

General steps of selection were done according to the AELB guideline (AELB, 2011). However, the methodology of obtaining result was done as follows:

1. Determination of rejected area, area of interest and possible candidate area.
2. Determination of avoidance, important and supporting criteria.
3. Selection of candidate sites and data analysis.
4. Data plotting and mapping

### *M.2 Data Acquisition*

All information and data were provided by respective body according to the type of information;

1. Johor map were provided by Department of Agriculture Malaysia.
2. Seismological and meteorological data were provided by Malaysian Meteorological department.
3. General information of Johor was provided by website of Johor Government.

### *M.3 Data Analysis*

This study uses MapInfo Professional software to draw and plot all the acquired data. MapInfo Professional is software used for mapping applications. MapInfo Professional provides editing facilities to edit data in table, values, and the names according to users' needs.

This software provides built-in support for viewing various data formats at the same time. Using MapInfo, maps can be displayed in various file options, and users can draw maps, change the marking and the boundary line. Users can also use data from tables, statistics or any application of mathematics to see the distribution and pattern on the map. MapInfo Professional also has the ability to export data to any format and produce a large map complete with legend and charts, as well as an interactive map-sharing website.

## RESULTS

### *Avoidance, Important and Supporting criteria*

To determine a suitable site, one must determine the characteristics needed to prove the feasibility of the chosen site. A site is deemed suitable / feasible if the characteristic meet the requirements and purpose of building. This study uses Pressurised Water Reactor (PWR) as basic reference for requirement needed in suitability test.

An important need for a PWR is the water supply for cooling and generates steam to operate the turbine. Hence, a location near sufficient amount of water is considered important characteristic in this study (TNB, 2010). Other than sufficient water source, TNB stated that a location near coastal area must be selected to facilitate the safety and security issue of transporting nuclear fuel rods. TNB suggests the NPP to have its own jetty because existing roads and bridges in Malaysia are not designed to take the heavy load and large volume of the NPP modules.

Aside from fulfilling the most crucial needs, evading from disadvantages that may affect the NPP operation is almost as important. Characteristics that cannot be compromised by safety measurement or engineering solution must be avoided to ensure safety. This study enlists the avoidance criteria as follows:

1. Location is within 50 km from international boundary. Selecting a site near international border requires further consideration in safety, security and safeguard of NPP. Hence such location is preferably avoided.
2. Location is within 15 to 30 km from high density population. A location farther than any population is more favourable, as long as it fulfils the operation requirement of NPP.
3. Location with undulating or unstable geographical characteristics such as steep land, hills, and mine area.
4. Location is within 1.5 to 15 km from protected areas, industrial areas and military bases.

Other than important and avoidance criteria, supporting criteria helps to achieve the objective to ensure safety for people and environment. Any locations that have safety supporting characters are more at advantage than other location. Emergency supports such as fire station and hospital, adequate access for transportation and communication to the location are the examples of supporting criteria.

### *Area of Interest*

This study investigates area to locate a NPP in Johor, Malaysia (see Figure 1). Mersing, Kota tinggi, Batu Pahat and Muar were chosen as these districts have the important criteria needed as were stated above. From those districts, areas within 10 km from coastal lines are marked as possible area of interest to conduct the study.

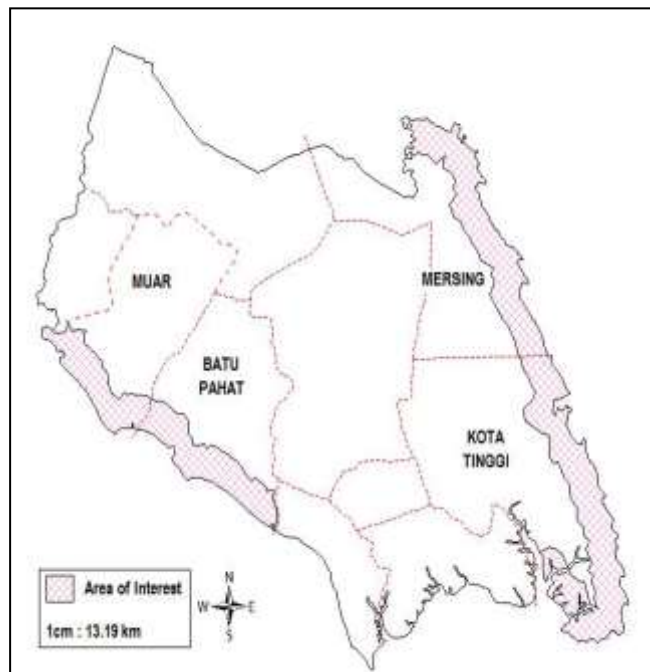


Figure 1 – Area of Interest

## DATA ANALYSIS

### *Geology and Seismology Analysis*

Ground movement and surface stability is important to evaluate external events and possible hazard related to seismological and geological condition (IAEA, 2003). Hence, geological and seismological condition in the area must be considered during selection.

IAEA stated two important events related to geological and seismological features – earthquakes and surface faulting (IAEA, 2003). Peninsular Malaysia has low possibility of earthquake event since it did not lie on the Pacific Ring of Fire. However, Malaysia did felt the effect of high magnitude earthquake occurred in the neighboring country like Indonesia. Malaysian Meteorological Department has recorded felt earthquake events and intensity in Johor. **Table 1** shows the intensity of felt earthquake in Johor recorded from 2007 until 2009.

**Table 1** – Felt Earthquake in Johor (2007 – 2009)

No	Date	Location	Magnitude (Richter Scale)	Intensity*
1	1 October 2009	Southern Sumatera	6.2	IV
2	16 August 2009	Southern Sumatera	6.5	IV
3	25 February 2008	Northern Sumatera	6.1	IV
4	4 January 2008	Southern Sumatera	6.5	II
5	13 September 2007	Southern Sumatera	6.1	IV
6	12 September 2007	Southern Sumatera	6.4	IV
7	6 March 2007	Southern Sumatera	5.8	IV

\* The intensity is based on modified Mercalli Scale

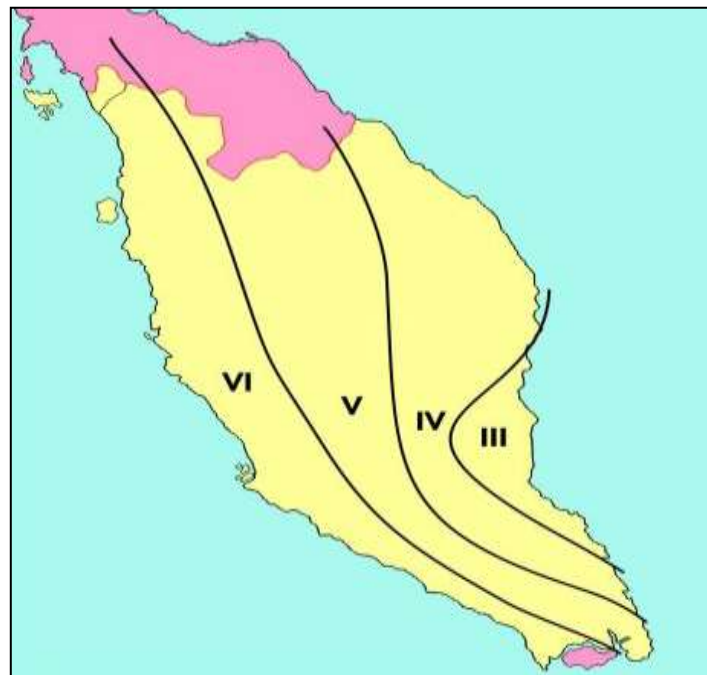


Figure 2 - Maximum Observed Earthquake Intensity for Peninsular Malaysia (1909 – 2011)

Recorded maximum earthquake intensity in Peninsular Malaysia was ranged from III to VI (JMM, 2012). In Johor, the intensity ranged from IV in the northeast area, V in central of Johor to southwest area and VI in the west area to the south [See figure 2].

Surface faulting can occur from natural geological and seismological features or human activity that may lead to surface change or movement. In site selection, area with minimum likelihood of surface faulting and earthquake are most preferred. Sites with competent bedrock generally have suitable foundation conditions. Otherwise, area with stable rocks and solid soils such as dense sands and glacial tills are considered suitable (AELB, 2011).

In this study, areas with the possibility of surface faulting and geological instability are rejected. The elimination was done using geological instability and surface faulting map published by the Minerals and Geoscience Department Malaysia. The rejected areas are shown as follows (Figure 3):

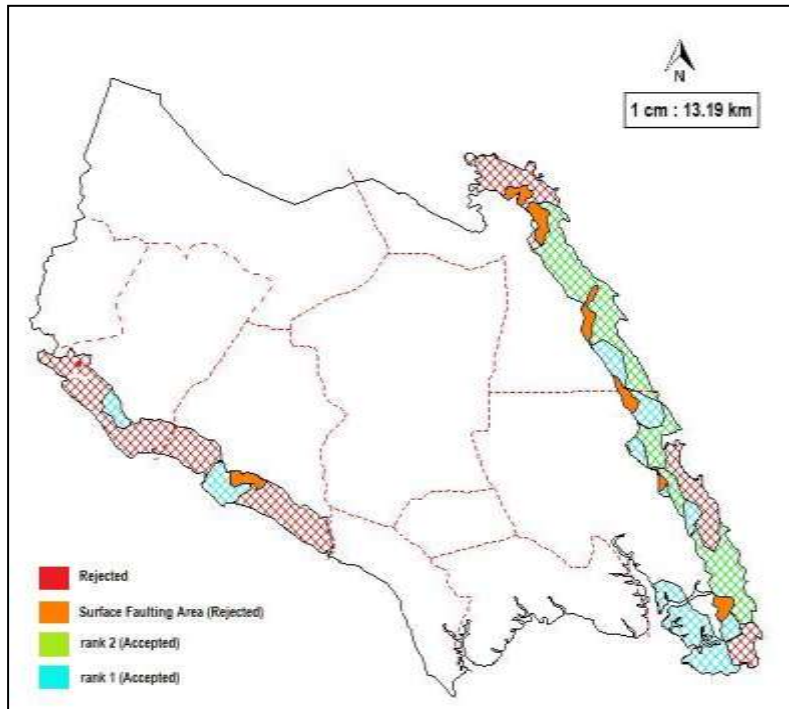


Figure 3 – Map of Geological Instability and Surface faulting in the Area of Interest

### Demographic Analysis

Consideration of population distribution and population density is important in NPP site selection. Population data is crucial to determine the safety issues regarding radioactive release to the environment. Safety measurement was planned to ensure safety and health impact from NPP is acceptable to the population on the surrounding area, see Figure 4.

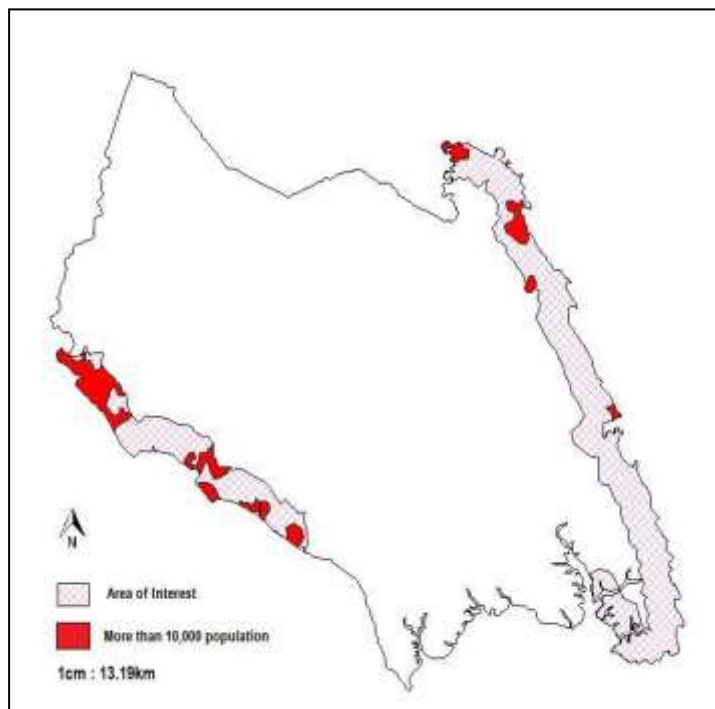


Figure 4 – Map of Population distribution with more than 10,000 people

From the area of interest, the following district and *mukim* were involved in this study:

Population data can be one of indicator in safety and emergency planning. The number of population and population density did not necessarily portray the population distribution in the area. Detailed map for population distribution was not yet published by Department of Statistics Malaysia. However, the distribution can be roughly predicted based on population trend in Malaysia. Most people concentrates in or surrounding area of main city, plantation area like Felda, and industrial area.

From the table above, west side of Johor are more populated than east of Johor. Populated area indicates both advantages and disadvantages in NPP safety measurement. Highly populated area provides better service and easier access to amenities / facilities such as hospital and fire department, transportation routes, communication and electricity grid, which were considered as supporting characteristics for NPP. However, a highly populated area will increase radiological risk, which will require more complicated safety measurement and emergency planning for NPP.

From the consideration above, this study decided to reject the most and the least populated area in the area of interest. According to Sourav, Shylamoni and Roshan (2005), areas with more than 25,000 people are considered highly populated, hence rejected as suitable candidate area. Safety facilities and supporting characteristics are most preferable within the safety zones (15 km square) from possible candidate sites. Areas with higher population density and sufficient supporting criteria are more favorable than areas with low population density without the supporting criteria, as long as the population did not exceed 25,000.

Table 2 – Population number in selected district

District	<i>Mukim</i>	Population
Muar	Sungai Balang	12,525
	Sri Menanti	11,630
	Parit Jawa	10,996
	Parit Bakar	11,200
	Bandar	94,929
Batu Pahat	Lubok	6,660
	Simpang Kiri	24,416
	Bagan	7,591
	Peserai	9,527
	Simpang Kanan	143,955
	Minyak Beku	17,324
	Kampung Bahru	11,997
	Sungai Punggor	10,417
Sungai Kluang	16,591	
Mersing	Triang	2,413
	Penyabong	1,318
	Tenglu	5,226
	Jemaluang	3,572
	Tenggaroh	3,290
Mersing (City)	39,312	
Kota Tinggi	Kambau	2,302
	Sedili Besar	10,403
	Sedili Kechil	14,288
	Pantai Timur	8,258

Based on the statement, the area of interest is reduced to areas with population less than 10,000. The areas are shown as follows:

### ***Meteorology Analysis***

In Malaysia, meteorological events such as change of monsoon seasons mostly inflict other natural events in the country. For example, in December 19th 2006, continuous heavy rain in Johor results the Malaysia floods of 2006-2007 (JMM, 2012). In Kuala Lumpur, continuous rain caused flash floods and landslide.

Meteorological data collected was wind speed and direction, as well rainfall amount in the respective districts. Those data was collected as it was the most important information to predict meteorological events in the area, as well as predicting radioactive dispersion through air in emergency planning and safety measurement. Wind and rain data was collected from 2 meteorology station in Johor. One was taken in the east side (Mersing Station) to represent data for Mersing and Kota Tinggi, and the other was taken in the west side (Batu Pahat Station) to represent data for Muar and Batu Pahat.

Rainfall and wind data varies according to the monsoon changing in a year. During monsoon season, wind speed and rainfall amount shows significant increase. Wind direction also changes with season. Climate in Johor were divided to two zones: Middle East Zone and West Coast Zone. The zones were divided according to dry and rain season for both areas. Middle East Zone covers Mersing, Kota Tinggi, Keluang and Segamat while West coast zones covers Johor Bahru, Kulaijaya, Pontian, Muar, Batu Pahat and Ledang.

Rainy season with heavy rain occurs in Middle East Zone in November, December and January while dry season occurs on July. In the West Coast Zone, heavy rains occur in October and November while dry season with least rain were recorded in February.

The east side of Johor receives higher maximum wind than the west side of Johor. The maximum wind occurred during northeast monsoon from November until March. On this season, maximum rainfall and wind speed occurs on the east coast of Johor.

Meteorological data is important to determine the dispersion of radioactive material in the air (AELB, 2011). Since the wind direction is rapidly changing throughout the year, careful consideration must be taken to ensure the surrounding population will not be affected from the radioactive dispersion analysis in any condition.

### ***Reduced area***

**Figure 5** shows the result after elimination process from geological and seismological analysis and demographic analysis.

### ***Supporting criteria***

In safety measurement, emergency support plays an important role to overcome or reduce risks from selected sites. For example, hospital and fire station are important during radiological emergency. Military support can hasten evacuation, hence reduce fatalities and exposure to the public (Sourav, Shylamoni and Roshan, 2005). **Figure 6** below shows the general hospital, fire station, and military base in the area of interest.

### ***Safety zones and proposed area***

There are 4 zones in site selection process (Sourav, Shylamoni and Roshan, 2005):

1. Exclusion zone (1.5 km) where the NPP facilities are located. Settlements are prohibited in this area
2. Sterilized zone (5 km from the exclusion zone). Settlements are controlled with population less than 10,000 people
3. Emergency planning zone (16 to 20 km from exclusion zone). Emergency supports are best located in this zone with population less than 25,000 people.
4. Outer zone (more than 20 km from exclusion zone).



From the zones stated above, the following figures show the proposed area as possible candidate site for NPP in Johor:

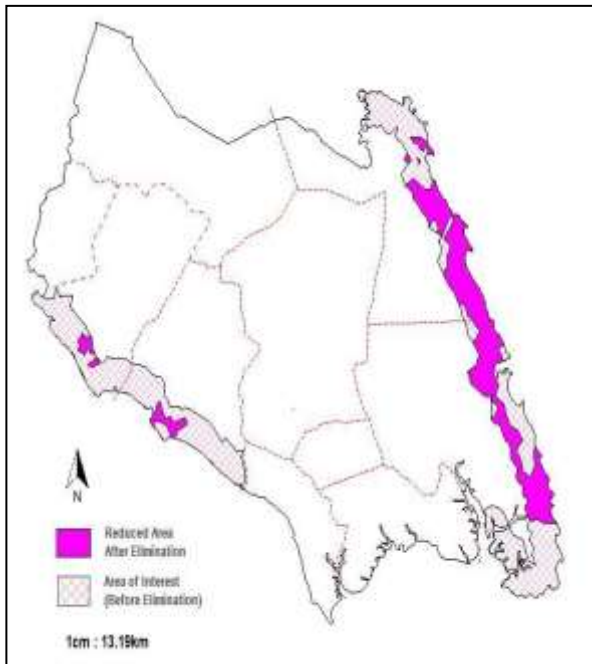


Figure 5 – Reduced area after before and after elimination

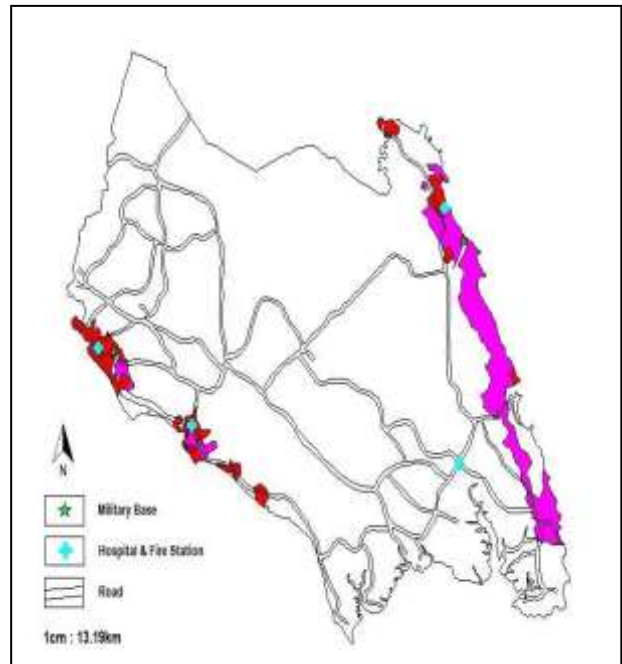


Figure 6 – Location of emergency support

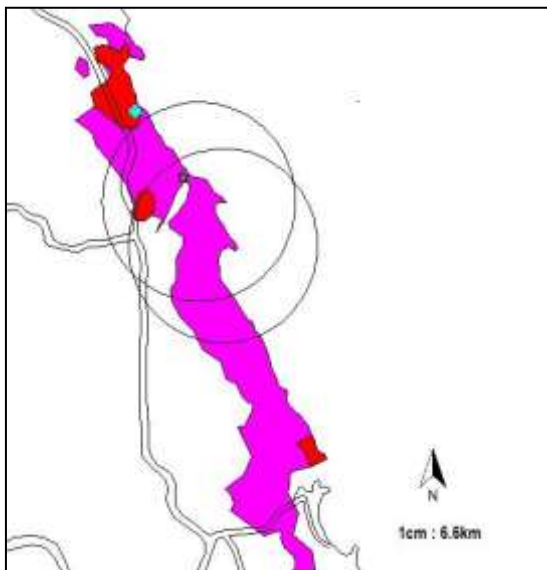


Figure 7 – Proposed Area (East of Johor)

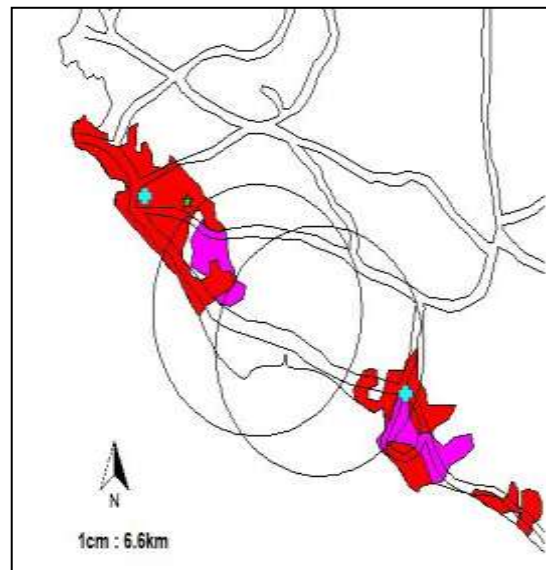


Figure 8 – Proposed Area (West of Johor)

## DISCUSSION

Proposed areas for possible candidate site of NPP are divided into 2 – in the east side and the west site of Johor. In the east side, the proposed area is in the *mukim* of Jemaluang and Tenggaroh in Mersing. Both Mukim have 3,000 to 5,000 people, giving huge advantage for safety measurement. Emergency supports such as hospital, fire station and military base are located in or near the emergency planning zone. The only disadvantage of the area is the poor access to the main road because the area is far from the main city and has low population density.

On the west side, the proposed area was located between Muar and Batu Pahat Districts. The area covers Seri Menanti and Sungai Balang in Muar, as well as Lubok, Bagan and Peserai in Batu Pahat. The proposed area is located in considerably high populated area and the rejected area from geological instability. High populated area was compensated by better emergency support from both Batu Pahat and Muar. If the geological instability problem can be compensated by any solution such engineering design or safety measurement, the area is deemed suitable as possible candidate for NPP in Johor.

## CONCLUSION

In this study, the proposed possible areas are not necessarily suitable for NPP site. However, the area has avoided all possible risks from the site that may affect the NPP and the environment. Rejected areas in this study are also not necessarily unsuitable for NPP if the deficiency can be compensated by engineering design, safety measurement and administrative procedures.

## ACKNOWLEDGEMENTS

This project used various facilities provided by Universiti Teknologi Malaysia. Helpful information and data provided by Malaysian Meteorological Department, Department of Agriculture Malaysia, and Johor Darul Ta'zim Government are highly appreciated and gratefully acknowledged. This work also supported by Universiti Teknologi Malaysia GUP grant [Q.J.130000.7126.00H70].

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