Jurnal Teknologi

Full paper

Spatial Multi Criteria Analysis For the Determination of Areas with High Potential Wave Energy

K. N. Abdul Maulud[a*], W. H. M. Wan Mohtar[a], O. A. Karim[a]

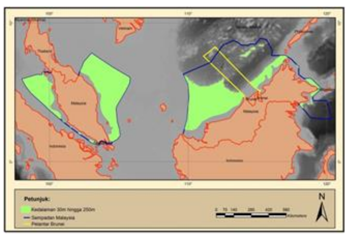
[a]*Department of Civil and Structural Engineering, Universiti Kebangsaan Malaysia, Bandar Baru Bangi, 43600, Selangor*

*Corresponding author: knam@eng.ukm.my

Article history

Received :20 August 2013
Received in revised form :
25 September 2013
Accepted :15 October 2013

Graphical abstract



Abstract

The strategic geographical location of Malaysia, with at least 60% of its shores are bordered with ocean, has high potential to sustain the country's energy supply by harnessing energy from wave. However, the oceans stretch of which is suitable for wave energy generation needs to be accurately determined, with the sensitive and protected areas are taken into account. This study describes the methodology and more developed approach to determine the area not only with high wave energy but also its legality. The area is restricted at a minimum of 12 nautical miles from the coastline and the water depth is between 30 - 250 meters. Factors of oil and gas cable routing, marine parks, petroleum mining area, submarine cables and ports are considered in the analysis. Several GIS models constructed to facilitate the analysis. The methods of overlay spatial multi criteria analysis and clipping, based on the Geographic Information System (GIS) were employed. The determination of area with high potential for wave energy is vastly improved, producing a more reliable map. The results are the location of the marine energy potential in Malaysia shelf.

Keywords: Spatial multi criteria analysis; GIS; wave energy

1.0 INTRODUCTION

The use of energy has been a key in the development of the human society by helping it to control and adapt to the environment. Primary energy is an energy form found in nature that has not been subjected to any conversion or transformation process (Han 2012). It can be non-renewable or renewable energy.

Malaysia recognises the importance of the reliability and security of energy since 1979 with the establishment of the National Energy Policy and the most recent five-Fuel Diversification Policy. The country has rapidly emerged as one of the developed country and have long depends on fossil fuels as the sole energy sources. With vast development and higher quality of life, the energy demand is foreseen to increase from 82,000 GWh in 2005 to 190,000 GWh in 2020 (9th MP, 2006), hence contributes to the emission of greenhouse gases from 43 million tons in 2005 to 110 million tons in 2010. Such increment in both energy demands and greenhouse gases emission has and will cause the country to suffer a number of adverse effects due to climate changes (Lim 2010). Although Malaysia has mixed up its energy resources with hydropower, natural gas and coal to support the utilisation of oil, these non-renewable energy resources are finitely depletable resources. Following this, Malaysia added the renewable energy as the fifth source in the diversification energy policy and mainly focused on biomass, solar, hydrogen fuel cells, landfill gas, incineration from municipal solid waste and nuclear (Oh 2010).

Despite the strategic geographical location of Malaysia in the South China Sea, alternative of utilising marine energy as one of the potential renewable energy resources is often overlooked. The ocean offers various methods of harnessing the energy through mechanical energy (i.e. tidal, current, wave) and thermal energy (i.e. temperature difference). Several studies have focused on the Malaysia's perspective, for example, an analytical assessment of harnessing energy from tidal current (Lim, 2010), energy policies and initiatives for sustainable energy use (Hashim, 2011) and future prediction of tidal current implementation (Hassan, 2012). A detailed study on the determination of high potential areas to harness marine energy is yet to be rigorously reviewed. This research not only proposes to develop enhanced methods to determine the area with high potential to generate energy, but also attempts to produce a more robust technique by including the sensitive and protected areas in the assessment. This study only focuses on the waves as marine energy resources and aim to present a final map with potential areas within the Malaysian waters to harness wave energy. The incorporation of themap of study area with the sensitive and protected regions was done using the GIS-based geo-spatial multi criteria analysis.

This method is a combination of skilled personnel, space data, analytical methods and computer software and hardware which were all organized to automate, manage and deliver information by geographic presentation. GIS is a set of tools for collecting, storing, retrieving, transforming, and displaying spatial data from the real world for a set of specific purposes (Burrough, 1987). As such, GIS is a reliable instrument for the determination of high potential of wave energy and able to produce a visual technique to support planning in the development of renewable energy (Miller *et al*., 2008). Recent studiesbyNobre *et al*. (2009) and Iglesias *et al*. (2009)shows that the decision was easily presented by producing a 3D visual display, with close similarity to the real situation.

■2.0 DETERMINATION OF FACTOR ANALYSIS OF PROTECTED AND SENSITIVEAREAS

The focus area in this study combines both peninsular and east Malaysia (i.e. Sabah and Sarawak). As Malaysia hosts several tourist spots with fragile coral reefs, for example, and these areas are essential to be correctly identified in the map. Mask analysis of the study area where the protected and sensitive areas are included, which is an important parameter needs to be filtered when determining the most ideal area to generate (maximum) energy waves on site. A set of 8 independent variables was chosen, including water depth, coastline borders, areas with oil cable routing, cable routing gas, marine parks, the location of the oil fields, the location of the gas, submarine cables and ports need to be identified. These criteria were specified based from previous studies and according to the guideline set by the government of Malaysia. Marine Park is zoned marine waters, a distance of two nautical miles from the lowest low tide, except PulauKapas in Terengganu, PulauKuraman, Rusukan Island Large and Small Island Labuan Rusukan a zoned single nautical miles from the lowest low tide. Marine Park was established to protect and preserve the aquatic flora and fauna (Malaysia 1985). Note that this study only determines for Malaysia's waters and took into account the international maritime borders of Indonesia and Brunei. Table 1 shows the details of the type of variables and the proposed buffering for each variable is also described.

Table 1 Independent variables and its proposed buffer zones

No.	Protected and sensitive areas	Buffering	Source	Proposed buffering
1.	Depths of sea	More than 50 meter 30m to 200m	Prest *et al*. (2007 *Nobreetal. (2009)*	30 m to 250m
2.	Coastline borders	12 Nautical mile	*Nobreetal. (2009)*	12 Nautical mile
3.	Submarine cable routes	500m	*Nobreetal.(2009)*, Prestetal. (2007)	500m (left and right)
4.	Port	-	*Nobreetal. (2009)*	1km
5.	International borders	-	Prestetal. (2007)	1km
6.	Marine park	-	*Nobre et al.(2009)*, Prestetal. (2007)	2 Nautical mile (Malaysia government gazette)
7.	Area of oil and gas	-	Prestetal. (2007)	3km
8.	Oil and gas routes cables	-	Prestetal. (2007)	500m (left and right)

To give a better illustration on the focus region, Figures 1 to 7 show the map of Malaysia with each figure highlights the variable chosen (as in Table 1). Figures 1 to 7 display the map with restricted water depth, submarine cable routes, ports, oil & gas structures, oil & gas transmission cable, buffer distance of 12 nautical miles from the coastline and the protected marine parks, respectively.

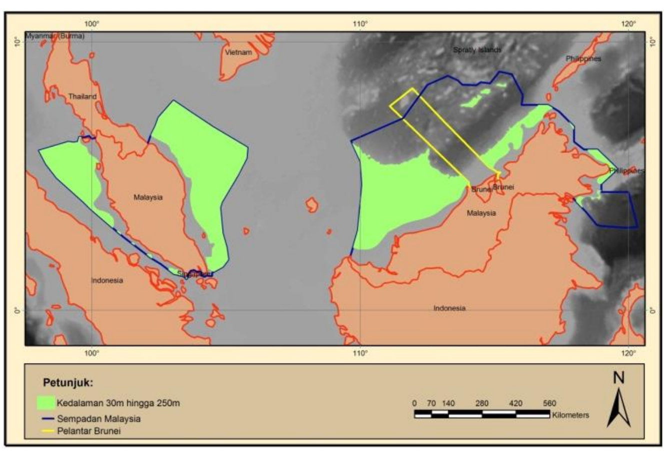


Figure 1 Depth 30 meters to 250 meter in Malaysian waters

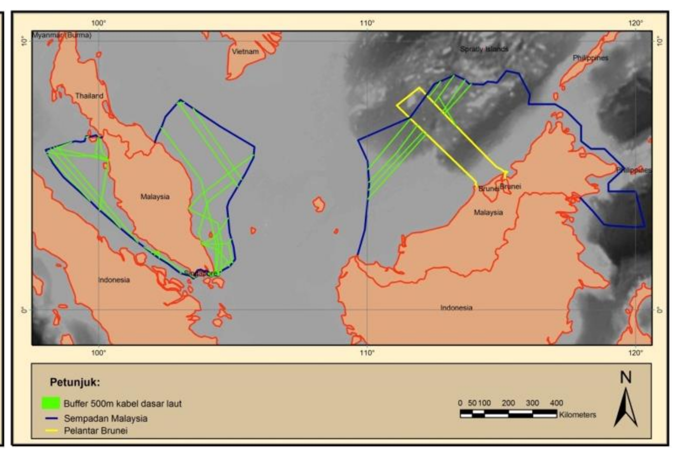


Figure 2 Buffer 500 meters left and right of the submarine cable route

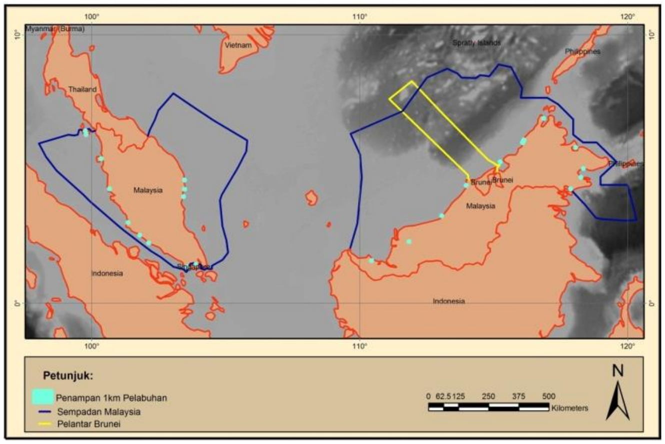


Figure 3 1 km Buffer ports

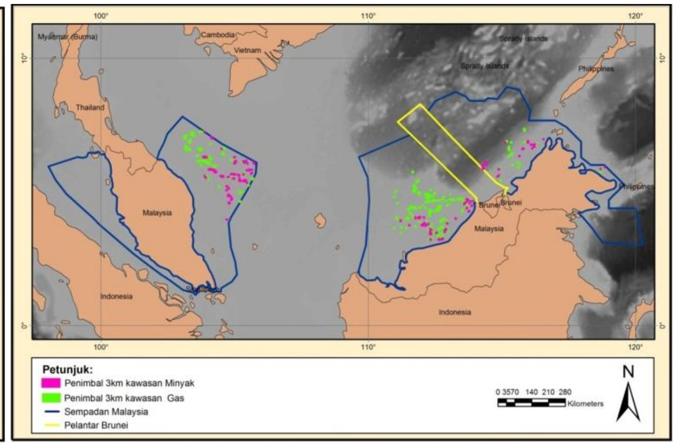


Figure 4 Buffer distance of 3km oil and gas areas

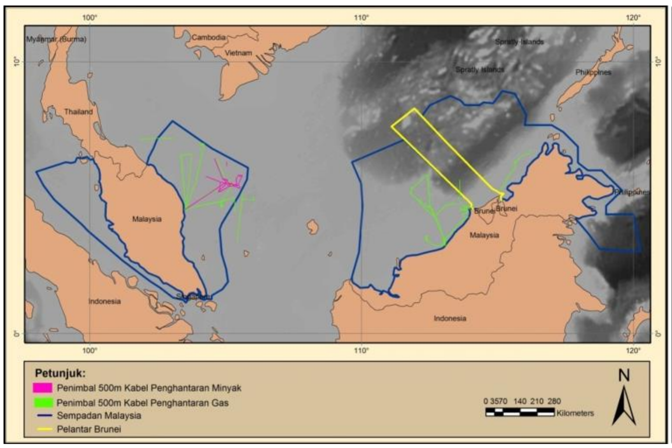


Figure 5 Buffer distance of 500m oil and gas transmission cable

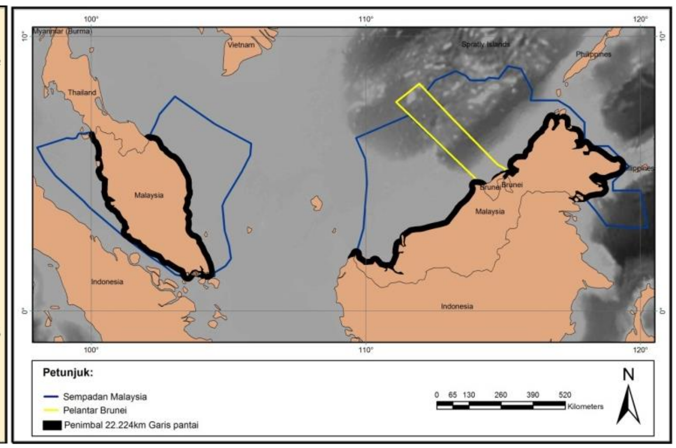


Figure 6 Buffer distance of 12 nautical miles from coastline

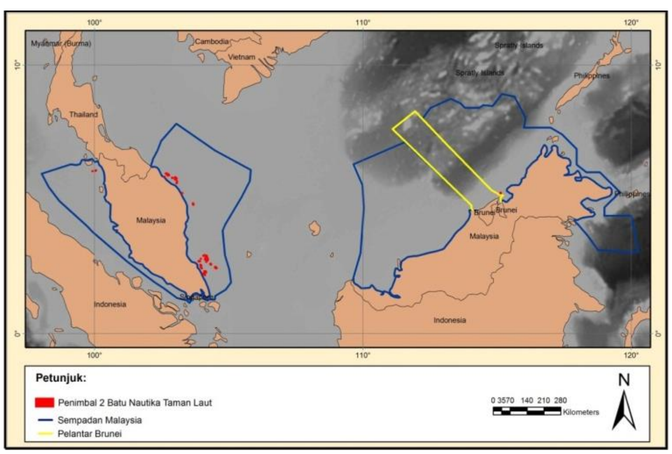


Figure 7 Buffer distance of 2 nautical miles marine park

A preliminary (mask) overlay analysis was performedon all the attributes, creating a new single suitability map, shown here in Figure 8. Figure 8 shows the details of spatial model for creating final study area based on the sensitive and protected factors.

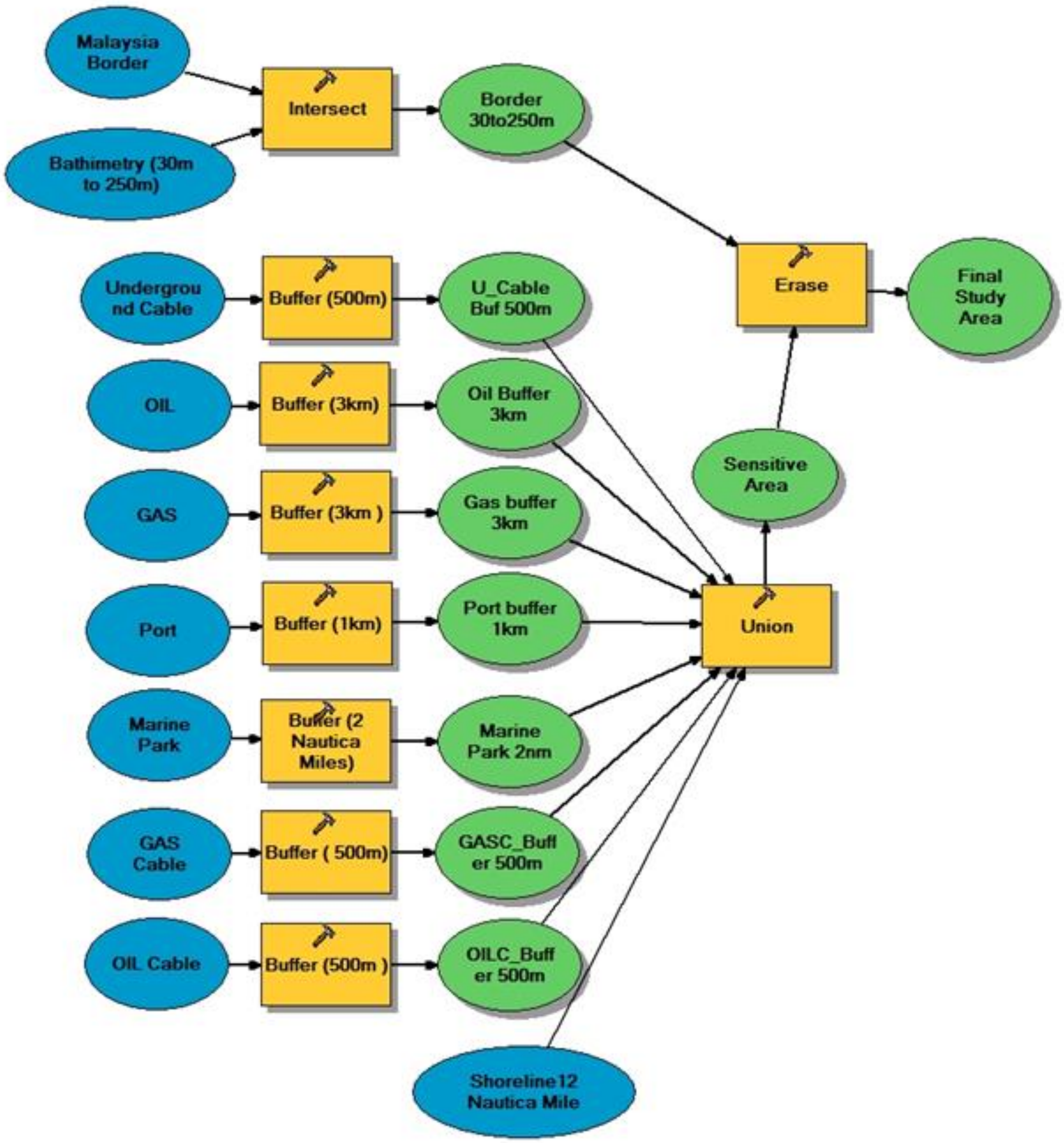


Figure 8 Model for identifying final study area

First analysis taken is to overlay the Malaysian border data with the map of sea depth of 30 meters to 250 meters. Protected areas and sensitive data in the buffer zones are also included based on a predetermined value. Results of the first boundary determination based on sensitive and protected areas, shown here in Figure 9, shows the area which are allowed to generate ocean waves.

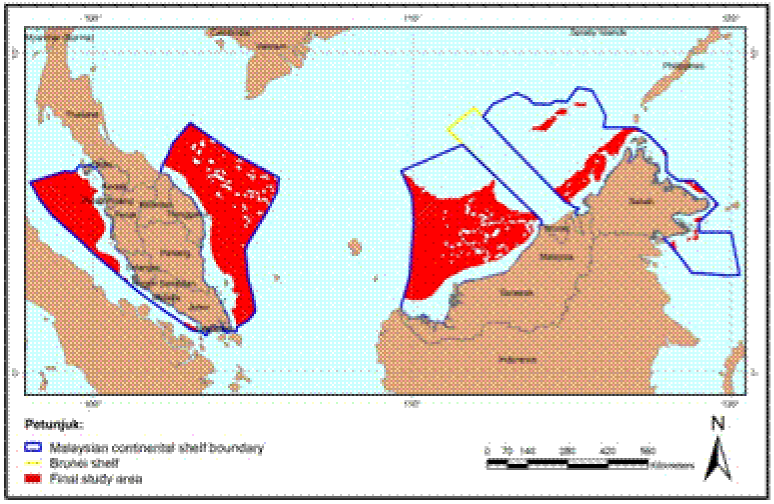


Figure 9 Final study area

■3.0 MULTI CRITERIA ANALYSIS FOR WAVE ENERGY

Multi-criteria analysis is an analysis involving various aspects of obtaining precise and accurate results and weighting factors is an important element in the multi-criteria analysis. Factors associated with the production of marine energy locations and weight-weight analyses were identified based on previous studies or additional studies that support the analysis (Nobre *et al*. 2009). Analysis combines the spatial marine data of wind, waves, bathymetry, topography and distribution of the power grid. The classification of data in wind, wave, grid, topography and bathymetryis introduced to simplify the process of spatial analysis. This method not only producing good quality results but also was able todecrease the time needed for processing analysis. Figure 10 shows the detailed model of the wave energy analysis employed in this study.

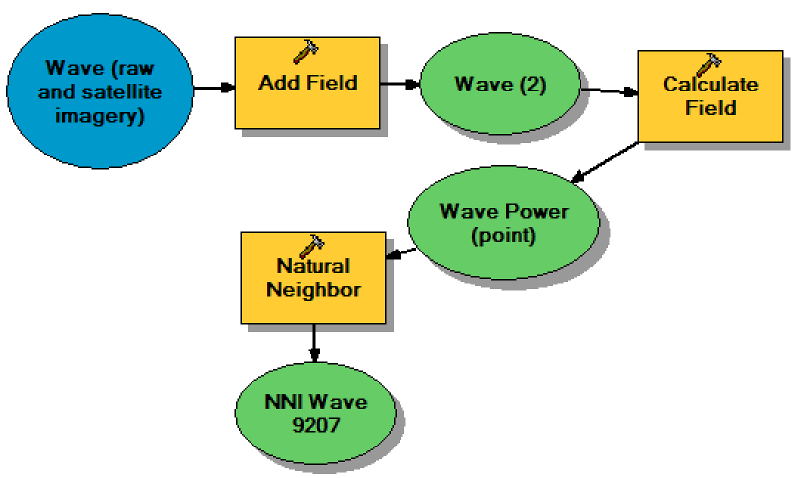


Figure 10 Spatial model for spatial wave energy analysis

The high quality wave data and the satellite imagery were acquired from the Malaysian Meteorological Department (JMM) and the Malaysian Remote Sensing Agency (ARSM), respectively. The data is processed and used as a form of checking before the data can be applied in the analysis. The major important parameter considered is the obtained coordinate data and the observed values of the characteristics of wave employed. Thus, the approximation of possible wave energy generation can be calculated using Equation (1), defined as;

$$P = \frac{\rho g^2 T H^2}{32\pi} \quad (1)$$

where,

P = wave energy (kilowatt/meter)
H = waveheight (meter)
T = wave period (second)
ρ = water density (kg/m^3)
g = gravity (9.8 m^2/s)

Analysis of the wave energy calculations was carried out in the spatial form, and the calculation units used was watt/meter. Wave energy generation formula included in the analysis code Structured Query Language (SQL). Performing the grid analysis on the data gives a specific form of spatial data, here named as *"NNI Wave 9207"* in Figure 10.

■4.0 DETERMINATION OF THE CLIPPING ANALYSIS

Clippinganalysis is the analysis involving the overlap between the analytical results. In this case, the final study area and wave energy (*NNI Wave 9207*) were layered and the detailed study of multi-criteria analysis of wave energy was performed. This resulted in the correct decision (i.e. the Final Output shown in Figure 11) to determine the best location to generate energy from wave. The analysis was done in raster format to simplify the process of superposition conducted. Figure 10 shows the flow of clipping analysis.

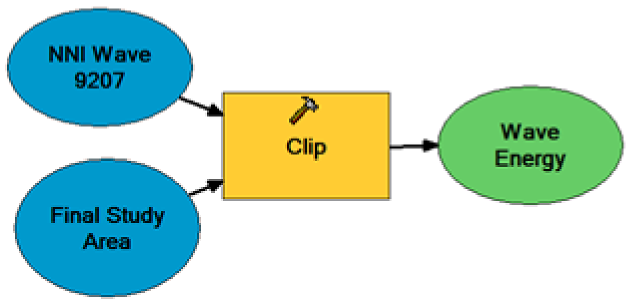


Figure 11 Overlaying analysisto produce the final output of the wave energy site

Clipping analysisas conducted in ArcGIS to obtain the final potential of wave energy.The process involves a clipping between the grid data of wave energy potential with the detailed map ofthe study area. Instructions process and the overview process diagram are referred to Figure 12.

The final map of high potential wave energy generation in Malaysia is shown in Figure 12. The red colour indicates the highest potential and the green marked areas has the lowest potential.Analysis shows that the East Peninsular Malaysia (i.e. the state of Kelantan, Terengganu and part of Pahang) offers the most promising area to harness energy from wave. Several small areas in the West-North Sabah also possess quite high potential to exploit the marine energy. The Straits of Malacca however, offers minimal potential which is believed due to low wave height. Having said that, this study does not essentially rule out the potential of the states in the West Coast of Malaysia to harness the marine energy in the form of tidal.

■4.0 CONCLUSIONS

Climate change concerns, coupled with high oil prices, peak oil and increasing government supportare driving to increasethe renewable energy legislation, incentives and commercialisation. Malaysia in particular, has already taking initial steps to harness the energy from ocean such as wave. The process of selecting the best location to implement a wave energy farm is a complex procedure notably the identification of the sensitive and protected areas. A geo-spatial multi-criteria analysis, based on the GIS technology isused to assess a range of maps individually according to a set of eight independent variables. Analysis shows that by including these variables, GIS is an effective approach to determine the best location for wave energy farm in Malaysia. The results indicate several areas in Malaysiahave high potential to generate energy from waves, with the waters of Kelantan and Terengganu have theunlimited privilege to have their energy resources from the waves.

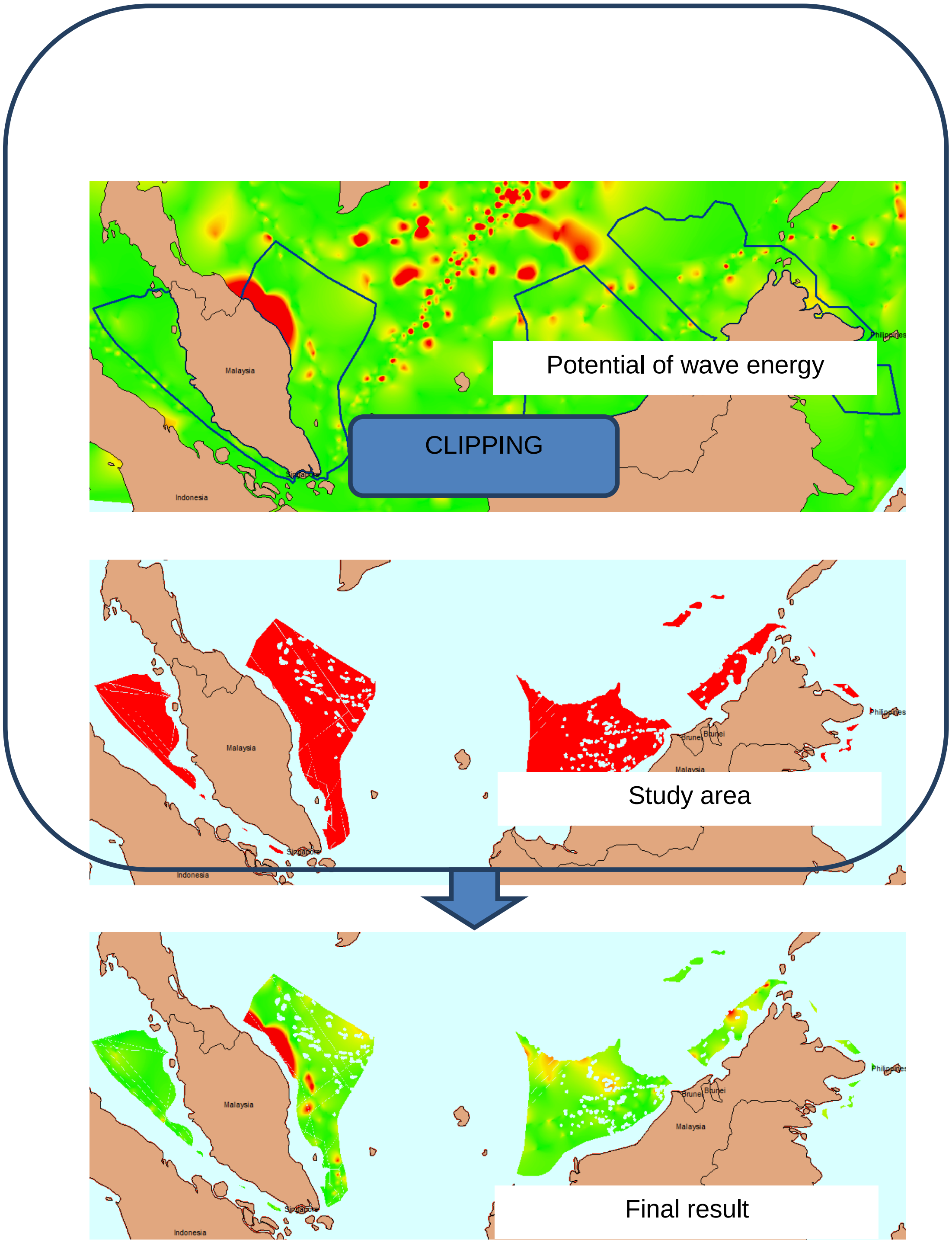


Figure 12 Clipping flow

Acknowledgments

The work reported here was partly financially supported by Research University Grant (UKM-GUP-2011-026)

References

[1] Burrough, P. A., & McDonnell, R. A. 1998. *Principles of Geographical Information Systems*. New York: Oxford University Press. 333.

[2] Department of Statistic Malaysia. 2010b. KompendiumPerangkaanAlamSekitar Malaysia 2010. http://www.statistics.gov.my/portal/download_Environment/files/Compendium_2010/04-BAB3.pdf [28 Mac 2012].

[3] Han, D. 2012. *Concise Environmental Engineering*. Ventus Publishing Aps.

[4] Hashim, H. and Ho, W. S. 2011. Renewable Energy Policies and Initiatives for a Sustainable Energy Future in Malaysia. *Renewable and Sustainable Energy Reviews*. 15: 4780–4787.

[5] Hassan, H. F., El-Shafie, A. and Karim, O. A. Tidal Current Turbine Glance at the Past and Look Into Future Prospects in Malaysia. *Renewable and Sustainable Energy Reviews*. 16: 5707–5717.

[6] Iglesias, G., López, M., Carballo, R., Castro, A., Fraguela, J., A. & Frigaard, P. 2009. Wave Energy Potential in Galicia (NW Spain). *International Journal of Renewable Energy*. 34: 2323–2333.
[7] Lim, Y. S. and Koh, S. L. 2010. Analytical Assessments on the Potential of Harnessing Tidal Currents for Electricity Generation in Malaysia. *Renewable Energy*. 35: 1024–1032.
[8] Malaysia. 1985. *Fisheries Act 1985.* (Act 317).
[9] Miller, D., Morrice, J., Coleby, A. &Messager, P. 2008. Visualization Techniques to Support Planning of Renewable Energy Developments. Dlm. Lovett, A. & Appleton, K. (pnyt.). *GIS for Environmental Decision-Making*. New York: CRC Press. 227–239.
[10] Ninth Malaysian Plan 2006-2010, Chapter 19: Sustainable Energy Development. Website :www.epu.jpm.my/rm9/html/english.htm.
[11] Nobre, A., Pacheco, M., Jorge, R., Lopes, M. F. P. &Gato, L. M. C. 2009. Geo-spatial multi-criteria Analysis for Wave Energy Conversion System Deployment. *International Journal of Renewable Energy*. 34: 97–111.
[12] Oh, T. H., Pang, S. Y. and Chua S. C. 2010. Energy Policy and Alternative in Malaysia: Issues and Challenges for Sustainable Growth. Renewable and Sustainable Energy Reviews. 14: 1241–1252.
[13] Prest, R., Daniell, T. &Ostendorf, B. 2007. Using GIS to Evaluate the Impact of Exclusion Zones on the Connection Cost of Wave Energy to the Electricity Grid. *Energy Policy*. 35(9): 4516–4528.
[14] WEC (World Energy Council). 2010. *2010 Survey of Energy Resources*. London, UK: World Energy Council.