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POTENTIAL SITE SELECTION FOR RADIOACTIVE WASTE REPOSITORY USING GIS (STUDY AREA: NEGERI SEMBILAN) – PHASE 1

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Abstract

The main purpose in this paper is to create the Geographic Information System (GIS) based analysis on the potential site area for near-surface radioactive waste repository in the state of Negeri Sembilan. There are several parameters should be considered related to the safety assessment in selecting the potential site. These parameters such as land-use, urban area, soil, rainfall, lithology, lineament, geomorphology, landslide potential, slope, elevation, hydrogeology and protected land need to be considered before choosing the site. In this phase, we only consider ten parameters for determining the potential suitable site.

Abstrak

Tujuan utama kertas kerja ini ditulis adalah untuk menghasilkan analisa Sistem Informasi Geografi (GIS) bagi kawasan yang berpotensi dijadikan repositori sisa radioaktif dekat permukaan yang merangkumi kawasan Negeri Sembilan. Terdapat beberapa parameter yang harus dipertimbangkan dalam penilaian keselamatan bagi memilih tapak yang berpotensi. Parameter tersebut adalah seperti tebus-guna tanah, kawasan urbanisasi, tanah, hujan, litologi, sesar, geomorfologi, potensi tanah runtuh, kecerunan, ketinggian, hidrogeologi dan kawasan tanah yang dilindungi yang mana perlu dipertimbangkan sebelum memilih kawasan tersebut. Melalui fasa ini, kita hanya mempertimbangkan sepuluh parameter bagi mengenalpasti kawasan yang sesuai dan berpotensi.

Keywords/ Kata kunci: near-surface radioactive waste repository, geographic Information System (GIS) based analysis

INTRODUCTION

This paper is prepared to analyze the potential sites for national radioactive waste repository in the state of Negeri Sembilan by using Arc GIS software version 9.3.
Arc GIS software is one of Geographical Information System (GIS) application or technique which is important in determining the potential site for radioactive waste repository. Remote sensing methods in GIS for are useful in site characterization by producing models related to the safety of the potential site.

Different sources of data from multiple maps have to be considered in the GIS modelling which can be used to carry out safety assessment. The variability of models which are produced depends on parameters such as topography, climate, hydrogeology, geology and so on. In the first phase, we need to consider the inclusionary and exclusionary criteria which will be discussed further in this report to screen the potential or the best site area for the repository.

Establishment of criteria for this study was driven from many references including Chuang, et al., (2006), Huang et al., (2006), and Risoluti, et al., (1999), as well as understanding environmental setting of the study area based on researcher's judgment.

OBJECTIVE

The main purpose of this paper is to create the potential area map for radioactive waste repository in the state of Negeri Sembilan. There are several parameters that are considered related to the safety assessment in selecting the potential site. These parameters are land-use, urban area, soil, rainfall, lithology, lineament, geomorphology, landslide potential, slope, elevation, hydrogeology and protected land. In this phase, we only consider ten parameters for determining the potential suitable site.

Data Requirements

There are several parameters which had been involved and need to be considered for site selection in this phase. The ten parameters involved are landuse, soil properties, rainfall, lithology, lineament, geomorphology, landslide potential, slope, hydrogeology and elevation.

METHODOLOGY

The method for selection of the site based on three aspects such as weighting system analysis, mapping analysis, and by GIS modelling. Weight analysis for potential repository site in Negeri Sembilan based on several input layers including lithology, geomorphology, lineament distance, soil, rainfall, and slope that need to be reclassified based on weight values, which have been considered through knowledge experience and expert opinion. The final repository site map can be prepared by following steps below:

Weighting system analysis

All the input data layers need to be analysed and reclassified before we put the appropriate weight value. Each class in every layer have to be assigned the weightage between 1 (lowest) to 10 (highest) according to the "Binary Evidence Analysis" based on their suitability for disposal site and criteria fixed.

Landuse

Landuse is a socio-economic parameter which has to be taken into account for screening the potential sites. The repository should be built on area with less vegetation but not on water body. Cleared land and grassland should have the highest weightage value and the lowest weightage value goes for urban, forest, and water bodies.

A new model builder has to be developed and input data Landuse must be added into the model. By using Conversion Tools, the datasets will convert polygon datasets to the raster datasets. The value field also, must be identified as ALU_CODE to convert Polygon Feature to Land use data raster.

Twenty-nine classes need to be identified throughout the study area as shown in Table 1. Table 1 shows the weight values as recommended for land use. Each classes must have the weightage base on expertise judgement and each value need to be reclassified in the landuse raster datasets.

Table 1: Recommended weight value for land use

No.	Alu_Code	Description	Weight
1.	11	Estate Building and Associated Areas	1
2.	12	Tin Mines Area	1
3.	13	Other Tin Mines	1
4.	40	Cocoa	5
5.	41	Banana	3
6.	49	Orchards	8
7.	51	Diversified Crops	8
8.	52	Paddy	4
9.	53	Shifting cultivation	7
1.0	59	Improved Permanent Pasture	5
11.	60	Grassland	10
12.	61	Scrub	9
13.	71	Natural forest	1
14.	72	Bush (Shrubs)	7
15.	98	Ponds and lakes	1
16.	100	Urban and associated area	1
17.	101	Graveyard Area	4
18.	102	Recreational area	1
19.	200	Agriculture Station	2
20.	210	Mixed horticulture	5
21.	220	Market Gardening	6
22.	301	Rubber	8
23.	311	Oil palm	7
24.	322	Coconut	4
25.	800	Wetland forest	2
26.	7200	Plantation forest	3
27.	7330	Cleared land	10
28.	8100	Mangrove	1
29.	9810	Aquaculture	1

Soil Properties

The clay-rich soil are preferred because impermeable properties of the soil type can stand water from infiltrate into the repository. The soil must be very high impermeability and very high in water holding capacity. So, the highest weight value must be type of soil which contain clay and also depends on the porosity because the lowest value must be in the porous media such as sand and sandy loam as mention in Table 2.

A new model builder has to be developed and input data Soil Properties must be added into the model. By using Conversion Tools, the datasets will convert polygon datasets to the raster datasets. The value field also, must be identified as AST_CODE1 to convert Polygon Feature to soil data raster.

Ten classes need to be identified throughout the study area as shown in Table 2. Table 2 shows the weight values as recommended for soil properties. Each classes must have the weightage and each value need to be reclassified in the landuse raster datasets.

Table 2: Recommended weight value for soil properties

No.	Code	Description	Weight
1	W	Water	1
2	C	Clay	10
3	CL	Clay Loam	8
4	L	Loam	7
5	O	Organic Matter	6
6	Sa	Sand	2
7	SaC	Sandy Clay	5
8	SaCL	Sandy Clay Loam	4
9	SaL	Sandy Loam	3
10	SiC	Silty Clay	9

Rainfall

It is recommended that the repository site also must have lowest rainfall and highest evaporation for the highest weight value to be recommended in the particular area than others.

A new model builder has to be developed and input data Rainfall must be add into the model. By using Conversion Tools, the datasets will convert polygon datasets to the raster datasets. The value field also, must be identified as ARF_CODE to convert Polygon Feature to rainfall data raster.

Ten classes need to be identified throughout the study area as mention in Table 3. Table 3 shows the weight values as recommended for rainfall parameter. Each class then must have the weightage and each value need to be reclassified in the rainfall raster datasets.

Table 3: Recommended weight value for rainfall

No	Class (mm)	Weight
1	1 – 1000	10
2	1000 – 1250	9
3	1250 – 1500	8
4	1500 – 1750	7
5	1750 – 2000	6
6	2000 – 2250	5
7	2250 – 2500	4
8	2500 – 3000	3
9	3000 – 3500	2
10	> 3500	1

Lithology

In term of lithological study, the expertise prefer the repository to be built on hard rock such as granite and schist to ensure the stability from seismic effect and tectonic plate movement. So we need to study on the rock properties before assigning weight value as recommended. Lowest rank would be limestone and recent sediments aud the highest rank is the granitic rock such as basic or intermediate intrusive rock class.

A new model builder has to be developed and input data lithology must be add into the model. By using Conversion Tools, the datasets will convert polygon datasets to the raster datasets. The value field also, must be identified as LITH_CODE to convert Polygon Feature to lithology data raster.

Twenty five classes need to be identified throughout the study area as mention in Table 4. Table 4 shows the weight values as recommended for lithology. Each classes must have the weightage and each value need to be reclassified in the lithology raster datasets.

Table 4: Recommended weight value for lithology

No.	Gln. Code	Description Class	Weight
1	1	Sand (mainly marine)	1
2	2	Clay and silt (marine)	1
3	3	Peat, humic clay and silt	2
4	4	Clay, silt, sand and gravel - undifferentiated (Continental)	4
5	10	Shale, mudstone, siltstone, phylite, slate and hornfels	6
6	11	Sandstone/meta sandstone	2
7	12	Conglomerate	2
8	13	Limestone / marble	2
9	14	Schist	9
10	20	Ignimbrite	7
11	21	Acid to Intermediate volcanics : mainly pyroclastics, rhyolitic to dacitic composition	7
12	22	Intermediate to basic volcanics : mainly pyroclastics	8
13	30	Acid Intrusive (undifferentiated)	10
14	31	Intermediate Intrusive (undifferentiated)	10
15	32	Basic intrusives, mainly gabro	9
16	33	Ultrabasic intrusives, commonly altered to serpentinite	8
17	34	Vein quartz	8
18	35	Clay, silt, sand, peat and minor gravel	1
19	36	Shale, sandstone, conglomerate and minor coal seams	3
20	37	Cross-bedded sandstone with subordinate conglomerate and shale/mudstone. Volcanics are locally present	5
21	38	Interbedded sandstone, siltstone and shale; widespread volcanics, mainly rhyolitic to dacitic tuffs. Conglomerate and chert local	5
22	39	Phylite, slate and shale with subordinate sandstone and schist. Prominent development of limestone throughout the succession	5
23	40	Phyllite, slate, shale and sandstone; argillaceous rocks are commonly carbonaceous. Limestone and acid to intermediate volcanics	6
24	41	Phyllite, schist and slate; limestone and sandstone locally prominent. Some interbeds of conglomerate and chert and rare volcanic	5
25	42	Schist, phyllite, slate and limestone. Minor intercalations of sandstone and volcanics	3

Lineament

Lineament parameter should consider the density for a number of faults in the kilometre square areas. Spatial Analyst Tools has been chosen to create the lineament density using the density calculation. To do this, Line Density tools enable us to calculate a magnitude per unit area from polyline features that fall within a radius around each cell. So, the Line Density will convert the Polygon Feature to lineament data raster.

The value in lineament data raster also need to be changed and reclassified as stated in Table 5. The lineament also need to be changed and reclassiffied.

Table 5: Recommended weight value for lineament density

No	Density (m/km^2)	Weight
1	0 – 1000	10
2	1000 – 2000	5
3	> 2000	1

Geomorphology

Geomorphological map represent different landform. Low weight value should be given for lowland area and the highest weight value to the isolated and hilly area. There are ten classes of landform which need to place the weight value.

A new model builder has to be developed and geomorphological input data must be add into the model. By using Conversion Tools, the datasets will convert polygon datasets to the raster datasets. The value field also, must be identified as GGM_CODE to convert Polygon Feature to geomorphology data raster.

The geomorphology output dataset also need to be reclassified base on the weight values recommended.

Table 6: Recommended weight for geomorphology

ID	GGM_Code	Description	Weight
1	31100	Active Floodplain	2
2	31200	Floodplain	2
3	31300	Infilled Valley	2
4	31400	Waterbody	1
5	31500	Peneplain	7
6	31600	Alluvial Plain	2
7	32100	Denudational Hill	7
8	32200	Residual Hill	8
9	32300	Piedmont	4
10	32400	Scarp	5
11	32600	Structure Hill	8
12	32700	Pediment	5
13	32800	Isolated Hill	10
14	33100	Delta	3
15	33200	Swamp	3
16	33800	Coastal Ridges And Swales	4
17	35500	Limestone Cuesta	5
18	35600	Isolated Limestone Hill	6
19	32900	Structure Denudational Hill	9
20	32910	Structure Denudational Hill (With Folding)	9

Landslide Potential

Possibility for occurring landslide events also could be as parameters that have to be as consideration. There are also several factors that contribute in the GIS landslide potential map such as soil, geology, geomorphology and others, we can predict the areas in Negeri Sembilan which have risk for land failure. There are five severities to measure the capability of landslide events as shown in Table 7. The landslide potential datasets also need to reclassify in weight values. The recommended weight values for landslide potential are as follow:

Table 7: Recommended weight value for landslide potential

ID	GLP_Code	Description	Weight
1	6001	Very low	10
2	6002	Low	8
3	6003	Moderate	6
4	6004	High	4
5	6005	Very High	2

Slope

DEM (Digital Elevation Method) format data for slope could be converted into datasets using slope toolset in Arc GIS. The potential sites must not too steep or too flat and the best slope is between 15 to 26 degrees for construction of any facilities. These degree ranges comply with Public Work Department in building any facilities in Malaysia. The output datasets of the slope must be identified and reclassified.

Table 8: Recommended weight value for slope

ID	Slope Degree	Weight
1	0 – 15	6
2	15 – 26	10
3	26 – 35	4
4	>35	2

Hydrogeology

Department of Mineral and Geosciences Malaysia were given the authority to preserve digital maps which contain hydrogeology parameters in Malaysia. If the areas are low aquifer and low productivity the weight value must be 10 is considered suitable compared to area which is porous, extensive and highly productive. The area must be set for 1 which means the areas are unsuitable for locating the repository. Table 9 below shows the weight value in hydrogeological potential.

Table 9: Recommended weight value for hydrogeological potential

ID	Description	Weight
1	Low	10
2	Medium	6
3	High	4
4	Very high	2

Elevation

Elevation parameter study also had been carried out in this phase. The best recommended elevation range is between 50 to 300 meters above mean sea level (MSL). Elevation which is higher than 300 meter is not suitable and has been given with the less weight value because of easy access consideration aspect. The elevation which is less than 50 meter has been given with the lowest weight value because of flooding consideration. The suitable elevation would be 50m – 300m.

Table 10: Recommended weight value for slope

ID	Elevation (m)	Weight
1	0 – 50	2
2	50 – 300	10
3	> 300	5

RESULT AND DISCUSSION

From map analysis in selecting the suitable site, all the input layers need to be reclassified based on Weight System Analysis from the value in the table as shown above. Protected land or buffer zone must be 5 km radius from epicentre of the potential site nearby the urban area. To get the final repository site, we can calculate each cell from multiple raster using the Cell Statistic. This method will consider all the factors involved have the same weight values. The map will show different colour for each class base on low to potential value for sitting the final repository.

The input data raster from cell statistic and the input raster for 5 km from urban area will be combined as a layer using Times toolset. 5km from the urban area will assign as 1 and within the 5 km will assign as 0 using the binary analysis concept.

In GIS modelling, Input data layers assigned with different score in weight values. The highest score of value considered to the most suitable area for repository site need to be calculated. Any changes in values in a raster also need to be reclassified.

The raster outputs datasets then need to be converted into polygon to get the final result for the potential site. In this study, we also consider the areas of 100 hectares and above will be the best site in developing the facility.

Table 11: The ranking process for selecting the most recommended sites areas from physical observation

Location / Physical observation	Chennah, Jelebu	Petasih Hilir (Pertang)	Serting Hulu	Air Rengas, Johol	Gemencheh
Geology (preferred granite)	5	2	3	3	3
Less Population	4	4	1	4	3
Away from Orang Asli Settlement	3	5	5	1	5
Away from Felda Settlement	5	5	1	3	5
Forest Reserve	5	4	3	3	2
Access Road	5	5	3	5	5
Far from river	5	5	2	1	5
Total	32	30	23	21	28
Ranking	1	2	5	4	3

Note. Very strong recommended = 5; strongly recommended = 4, moderately recommended = 3; less recommended = 2; Not recommended = 1

CONCLUSION

According to the GIS based analysis in this first phase study, by using cell statistics and calculating the average for each parameter which have the same contribution in weightage, the potential areas for this purpose are assigned with the red colour. South-east of Jelebu, several area of west Tampin, and north-west of Port Dickson are the best option for selection purpose.

From physical observation study which covered 5 potential areas in different location and conducted in south-east of Jelebu, an area known as Chennah is suitable for this purpose and had been ranking for the best potential site as showed in the Table 11. The last ranking site area is in Serting Hulu which is located in North-west of Jempol.

However, after doing further GIS analysis by only choosing 100 ha areas from the selected site and by adding the elevation parameters as shown in Figure 1, the result had been changed and the selected area which not assigned with red colour such as, Chennah and Air Rengas areas were eliminated from the best ranking options.

So, the three best options from the site study area in the selected site are in Petasih Hilir, Gemencheh and Serting Hulu areas.

This study has been developed and used as open and objective approach to the site selection. The geographical system was used to integrate several information which was classified according to suitability criteria and processed to show how the most suitable areas for locating a National Waste Repository in Malaysia.

For further analysis, there are also other techniques such as weighted overlay analysis which means each parameter contributes different in weight and the selection process will base on the expertise judgement to select the best site for the repository. This technique needs a further study of sensitivity analysis and in order to calculate the suitability area for the repository. Therefore from this study it is concluded that the suitable candidate sites for radioactive waste repository in Negeri Sembilan are Petasih Hilir, Gemencheh and Serting Hulu areas.

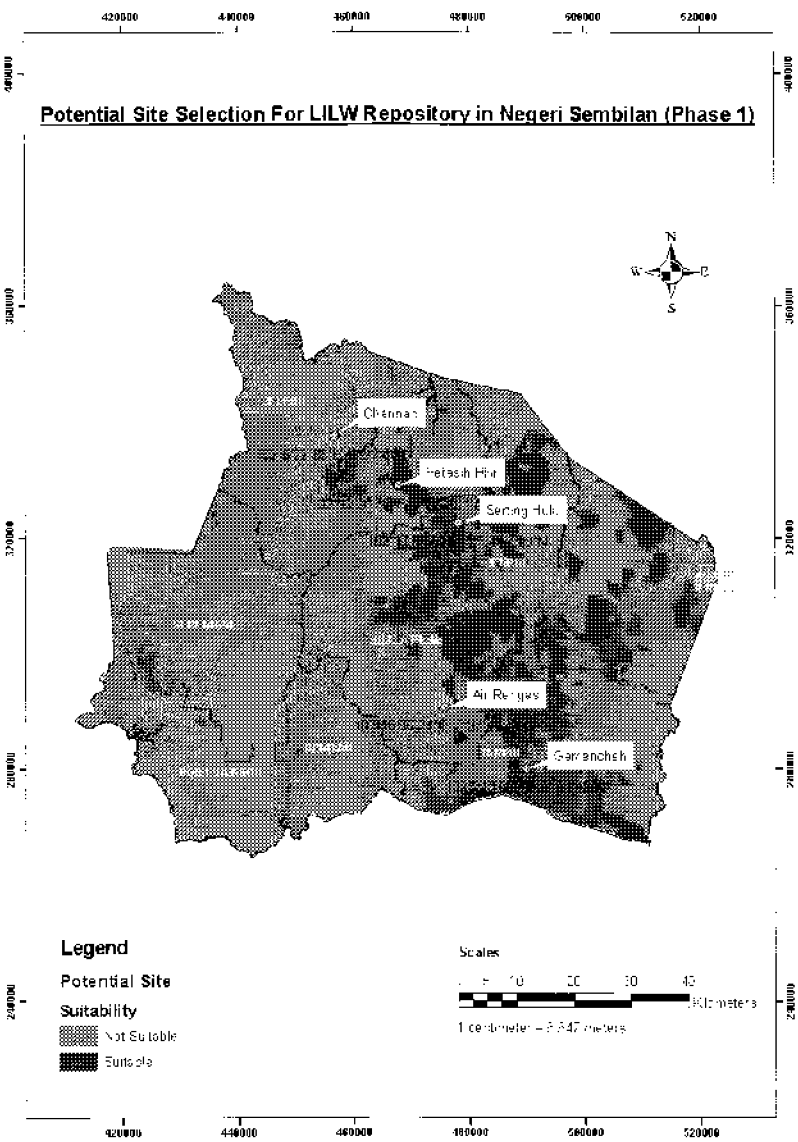

Fig. 1: Potential Site Selection for Low and Intermediate Level Waste (LILW) Repository in Negeri Sembilan – Phase 1

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