Identification of groundwater potential zones using AHP in district Kuala Krai, Kelantan, Malaysia

R M Jamil*, S S Hisham, M C Leong, S A Nawawi, A N M Nor, and N Ibrahim

1Faculty of Earth Science, Universiti Malaysia Kelantan Jeli Campus, 17600 Jeli, Malaysia
2Faculty of Bioengineering and Technology, Universiti Malaysia Kelantan Jeli Campus, 17600 Jeli, Kelantan, Malaysia
*Corresponding author: rohazaini@umk.edu.my

Abstract. Groundwater is one of the main sources of water in Kelantan which consumes 70% of the water supply. The rapid development in population, urbanization, agriculture, and industry has led to an increased water supply and demand. Hence, it is necessary to identify new groundwater potential sources to enhance groundwater supply in the study area. This study was carried out at Kuala Krai, Kelantan within latitude 5°36'30" to 5°33'50" N and longitude 102°8'25" to 102°11'10" E. The Analytical Hierarchy Process (AHP) method were used in this study and this method eventually came out with groundwater potential zones. The parameters such as lithology, geomorphology, land use, slope, drainage density, rainfall density, and soil type were chosen and spatially generated using GIS platform. Those parameters were subjected to weighted overlay analysis to obtain the potential zones of groundwater. The weights for the various layers were generated and assigned using the AHP technique which allows the comparison of criteria influencing the potential zone. The results of the study revealed that the good potential zone comprises 36.1%, moderate 32.4%, and poor 31.5% areas respectively.

In conclusion, factors such as low elevation, gentle slope, alluvial plains, and vegetation area have given a high potential of groundwater in this study area.

1. Introduction
Groundwater is an important resource for people all over the world since it can be found practically anywhere under the Earth's surface. It is not only a source of drinking water for us, but it is also necessary for the long-term viability of agriculture and industry. In Malaysia, groundwater resources account for less than 10% of total water consumption. Groundwater is only essential for home needs in rural and distant places where piped water is inaccessible. [1]. Meanwhile, over 70% of the people in Kelantan use groundwater as the main water supply for daily routine activities [2]. Groundwater usage in Kelantan has been used since year 1935. This suggests that water supply demand is exceptionally high, particularly in rural areas. In Kelantan, over 94 production wells have been developed to abstract for water supply [3].

Identification of groundwater resources plays a vital role to fulfil the demand of groundwater needs. Searching for groundwater is usually conducted with geophysical surveys and borehole data. These methods are costly and require great amount of time and work. As an alternative, the integration of geographical information systems (GIS) and remote sensing (RS) technologies have become a popular approach to determine the groundwater potential zones as this approach is less pricey and more environmentally efficient [4].
The use of GIS tools in conjunction with field observations is a particularly effective method for groundwater mapping and investigation. Over the previous decade, the scientific world has been quite concerned about this issue, and many researchers have adopted this technique in their research [5, 6]. GIS is the most efficient approach for organising vast amounts of geographical data, which is widely used in decision-making in a variety of disciplines, including geology and environmental management. The data generated in the GIS can be used to create a groundwater potential map [4].

The study area of this research is located at the northern part of Kuala Krai bounded near to the Machang and Tanah Merah district, Kelantan. The research region is 25 km² in size and is located between latitudes 5°36'30 to 5°33'50 N and longitudes 102°8'25 to 102°11'10 E. It is surrounded by numerous hills and rivers, along with the Kelantan River and the Nal River. The Nal River is a tributary of the main river, the Kelantan River. The research area's highest point is 120 metres above sea level (Figure 1).

![Figure 1. Location of the study area.](image)

This study aims to generate groundwater potential map using the GIS approach based on Analytical Hierarchy Process (AHP) technique. The groundwater potential map was created in this study utilising GIS software and the AHP technique to support the relative value of various thematic layers impacting groundwater. All thematic maps, comprising lithology, geomorphology, land use, slope, drainage density, rainfall density, and soil type, were classed and overlaid in the spatial analyst tool using the weighted overlay approach. The groundwater potential zones have been classified as poor, moderate, or good based on the results of the analysis.
2. Methodology

AHP is a social-economic decision-making technique that can be used to handle a variety of situations. AHP was employed when components were autonomous and was capable of solving problems involving dependent parameters, which had formerly been used in environmental management. Researchers can analyse groundwater potential by focusing on the ranking of each of the thematic layers by utilising the AHP approach [7, 8].

The thematic layers such as rainfall density, lithology, geomorphology, land use, slope, drainage density, and soil type were reclassified in the GIS environment. Each of the thematic layers were then assigned to the weightage factor. Weightage factor was used to indicate the influence on the availability of groundwater. Then all the thematic layers were combined for integration using Spatial Analyst tool in ArcGIS software to generate groundwater potential zones.

Preparation, data collecting, data analysis, and finalisation are the four (4) steps of the study flowchart (figure 2). Preliminary investigations, such as desktop studies and topography study, were carried out during the preparation phase. The next phase is data gathering, which consists primarily of secondary data acquired from numerous agencies between the years of 2018 and 2020. The GIS platform was used to process all of the obtained data, both thematically and spatially. Following that, a lot of geographic work was done during the third phase, which is data analysis. This involves GIS processing, the creation of a thematic map with seven (7) layers of parameters, weightage estimation using the AHP technique, integration and eventually the creation of a groundwater potential map. Finally, the outcome was interpreted, discussed, and finalised during the final phase (finalization).

![Figure 2. Research flowchart.](image-url)
3. Results

In this study, all the relevant thematic maps, including lithology, geomorphology, land use, slope, drainage density, rainfall density, and soil type, were classed (Figure 3) and overlaid in the spatial analyst tool by using weighted overlay method (ArcGIS software). Based on the findings of the analysis (Figure 4), the groundwater potential zones can be classified as poor, moderate, or good.

| Parameter       | Weight | Classes                        | Score |
|-----------------|--------|--------------------------------|-------|
| Lithology       | 8      | Schist, phyllite, slate        | 9     |
|                 |        | Limestone/marble               | 8     |
|                 |        | Acid to intermediate           | 7     |
|                 |        | Schist                         | 6     |
|                 |        | Phyllite, schist               | 6     |
|                 |        | Acid intrusive                 | 5     |
| Geomorphology   | 8      | Floodplain                     | 9     |
|                 |        | Water bodies                   | 8     |
|                 |        | Denudational hills slope       | 6     |
|                 |        | Denudational hills             | 5     |
| Land use        | 2      | Forest                         | 7     |
|                 |        | Rubber                         | 6     |
|                 |        | Crop                           | 6     |
|                 |        | Oil palm                       | 6     |
|                 |        | Clear land                     | 6     |
|                 |        | Urban area                     | 4     |
| Slope           | 4      | Floodplain                     | 9     |
|                 |        | Water bodies                   | 8     |
|                 |        | Hill slope                     | 5     |
| Drainage density| 3      | 0-2 (very low)                 | 9     |
| Density (km/km²)|        | 2-4 (low)                      | 8     |
|                 |        | 4-6 (moderate)                 | 5     |
|                 |        | 6-8 (high)                     | 3     |
|                 |        | >8 (very high)                 | 2     |
| Soil type       | 3      | Sand                           | 10    |
|                 |        | Coarse sandy clay              | 8     |
|                 |        | Sandy clay                     | 7     |
|                 |        | Coarse sandy clay–clay         | 7     |
|                 |        | Sandy loam–sandy clay          | 5     |
|                 |        | Fine sandy clay loam           | 4     |
|                 |        | Fine sandy clay                | 4     |
|                 |        | Clay                           | 2     |
| Rainfall density| 8      | < 2250                         | 4     |
|                 |        | 2250 - 2500                    | 6     |
|                 |        | 2500 - 2750                    | 8     |
The different thematic layers and their classes were assigned to various weightages based on the results of an expert opinion survey in order to identify groundwater potential zones. Land use variable obtained a low weightage score of 2 based on these criteria or factors, indicating its lower importance to favorability rating (Table 1). The next three variables to be identified as moderate weightage factors were drainage density, soil type, and slope. Lithology, rainfall, and geomorphology are the most important aspects impacting groundwater potential, as they help the groundwater system’s infiltration capacity.

![Figure 3. Seven (7) thematic maps of parameters.](image)

The good groundwater potential in Figure 4 is primarily covered in the eastern part of the research region due to alluvial plains, low drainage density, low elevation, and slopes ranging from 0° to 8°. Meanwhile, due to high elevation, high drainage density, slopes ranging from 14° to 36°, and lithology with limited permeability, the western part of the study area seems to have poor groundwater potential. Alluvial plains have an immense potential for groundwater, but steeply hilly areas have a limited potential for groundwater [9,10].
Figure 4. Groundwater potential map.
4. Conclusions and recommendation

The study area’s potential groundwater zone map was created applying the weightage overlay method (AHP technique) in spatial analyst tools. As a result, the groundwater potential map was divided into three zones: poor, moderate, and good. Groundwater potential is high in areas with low elevation, gentle slopes, alluvial plains, and vegetation. The research area is dominated by groundwater potential that ranges from moderate to good.

Secondary data, which including digital elevation model, topographic maps, and existing data, were utilized to develop seven thematic layers: lithology, geomorphology, land use, slope, drainage density, rainfall, and soil type. These thematic layers were weighted using the AHP approach, enabling them easier to manage into the ArcGIS software.

As recommendation, since this study is based solely on secondary data, this study should conduct additional research. The research methods used in this study are generic in nature. As a result, it might be adequately changed or another technology, such as Electrical Resistivity Imaging (ERI), could be used for the next investigation.

Acknowledgement

The authors would like to express their gratitude to all groundwater experts from various departments and agency for cooperating and sharing their knowledge about groundwater studies in Malaysia.

References

[1] Nazaruddin D A, Amiruzan Z S, Hussin H and Jafar M T M 2017 Integrated geological and multi-electrode resistivity surveys for groundwater investigation in Kampung Rahmat village and its vicinity, Jeli district, Kelantan, Malaysia Journal of Applied Geophysics 138 23–32.
[2] Hussin N H, Yusoff I and Raksme M 2020 Comparison of applications to evaluate groundwater recharge at lower Kelantan river basin, Malaysia Geosciences (Switzerland) 10(8) 1–25.
[3] Tawnie I, Sefie A, and Suratman S 2011 National Geoscience Conference 2011 Groundwater Contamination in North Kelantan: How Serious? 24–25.
[4] Isnain Z, and Akhir J M 2017 Integrated GIS based approach in mapping groundwater potential zones in Kota Kinabalu, Sabah, Malaysia Indonesian Journal on Geoscience 4(2) 111–120.
[5] Prasad R K, Mondal N C, Banerjee P, Nandakumar M V and Singh V S 2008 Deciphering potential groundwater zone in hard rock through the application of GIS Environmental Geology 55(3) 467–475.
[6] Nagarajan Mand Singh S 2009 Assessment of groundwater potential zones using GIS technique Journal of the Indian Society of Remote Sensing 37(1) 69–77.
[7] Saaty T L and Vargas L G 2001 The Seven Pillars of the Analytic Hierarchy Process RWS Publications, 4922 Ellsworth Avenue, Pittsburgh PA 15213 27-46.
[8] Agarwal E, Agarwal R, Garg R D and Garg P K 2013 Delineation of groundwater potential zone: An AHP/ANP approach Journal of Earth System Science 122(3) 887–898.
[9] Nadun S N E M, Maarof I, Ghazali R, Samad A M and Adnan R 2010 Sustainable groundwater potential zone using remote sensing and GIS 6th International Colloquium on Signal Processing & its Applications pp. 1-6.
[10] Ghofur M N A, Udin W S, Mansor H E and Ali K M M 2020 Mapping of Groundwater Potential Zones in a Crystalline Terrain Using Remote Sensing, GIS Techniques and Field Observations: A Case Study in Parts of Tanah Merah, Kelantan. Malaysia IOP Conference Series: Earth and Environmental Science 549(1).