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THE USE OF GIS IN GEOTHERMAL RESOURCE MANAGEMENT: A CASE STUDY OF OLKARIA GEOTHERMAL PROJECT

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ABSTRACT

One of the major and greatest challenges facing geologists, earth scientists and engineers is the assimilation, dissemination, management and storage of the ever growing quantity of digital information. In order to solve these challenging problems we must change the way information, data, and knowledge are preserved, utilized, and disseminated. The earth science community is in need of systems that not only provide digital data, but as importantly, provide tools that allow users to manipulate, query, select, and cross-reference any part of data sets with efficiency and speed. It is therefore necessary to have in place an information system that ensures that decision maker has the knowledge/ and all information required to make the decision.

The work involved between identifying geothermal sites and drilling of wells can be simplified by means of a Geographical Information System (GIS), a decision-making tool used to determine the spatial association between exploration and the actual process involved in the drilling of the wells. Geographical Information Systems (GIS), have a role to play in all geographic and spatial aspects of the development and management of the industry. It aims at analysing and subsequent understanding of geographical phenomena involves searching for spatial patterns, followed by evaluating possible causes and effects of patterns, and predicting future patterns and has thus become a useful tool for analysing spatial impacts of various development scenarios.

This paper will investigate and discuss the importance and contribution of the Geographic Information System (GIS) in KenGen. Utilizing the role of GIS in handling complex spatial data encountered in this industry, and how it can help in better decision making processes.

1. INTRODUCTION

Geothermal energy has become a promising alternative energy resource that has shown continual growth throughout this century; regrettably, its fortunes have reflected the variable successes experienced when traditional exploration techniques are used. Because the areas with the world's highest temperatures and perhaps most abundant geothermal resources are associated with volcanic regions. A framework for exploration and development of geothermal resources in volcanic areas needs to be developed where several modern techniques and concepts need to be linked and integrated together.

1.1 Area of study

The Kenyan Rift Valley is part of the African Rift System that runs from Afar triple junction in the north to Beira, Mozambique in the south. It forms a classic graben 40-80 km wide on average. Geologically, the Rift is an intra-continental divergence zone where rift tectonism accompanied by intense volcanism, has taken place from late Tertiary to Recent. The cooling magma gives rise to hydrothermal activity and is envisaged to host extensive geothermal systems and which much of it remains untapped. The study area, Olkaria, Naivasha, falls within the central part of the Kenya's rift valley (Figure 1). It is one of the many geothermal potential areas in the rift.

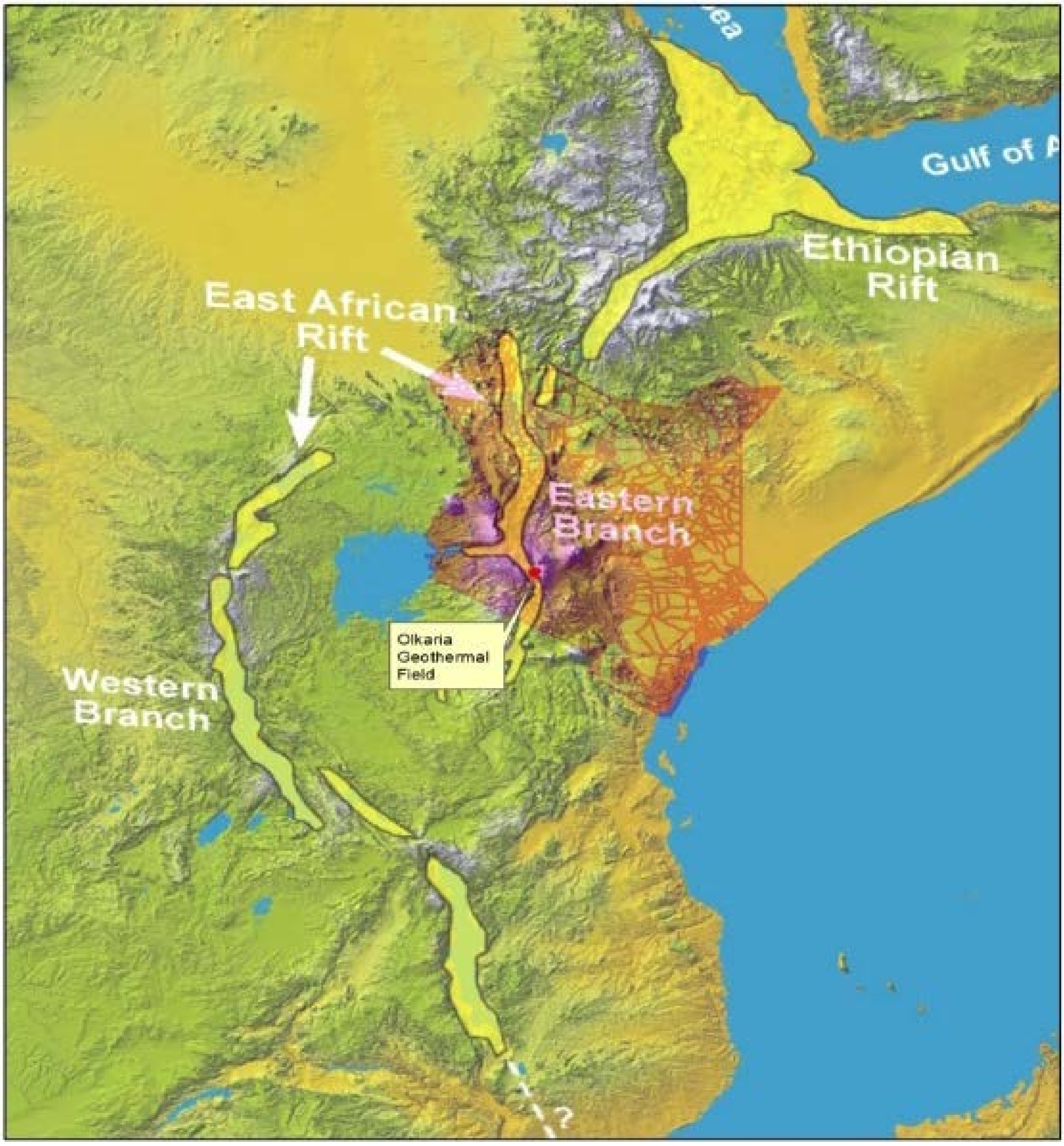

FIGURE 1: The location of Olkaria Geothermal project in relation to the EARS

1.2 Objectives

The main objective of this paper is to show the various uses that GIS have been put into applications within the industry. Here are some examples:

- To improve organizational integration: GIS integrates hardware, software, and data for capturing, managing, analysing, and displaying all forms of geographically referenced information.
- It allows us to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts.
- It allows cataloguing and storage of the vast amount of data/information that require generated in the exploration work.
- GIS helps you answer questions and solve problems by looking at your data in a way that is quickly understood and easily shared.

1.3 Problem statement

While it's easy to see that geothermal is a viable, growing and environmentally "friendly" energy source, many of its challenges are not easily met. They include:

- Extreme high temperatures;
- Hard and corrosive rock;
- Lost circulation;
- CO_2 intrusion/attack;
- Cement and casing integrity;
- Minerals and toxic gasses;
- Well site environmental concerns; and
- Well expansion/contraction from water injection and/or steam production.

All of these challenges, including the critical task of pinpointing geothermal reservoirs and then drilling into the subsurface to optimally intersect production thermal fluid channels and reservoir rock, have triggered the eagerness to develop more advanced capabilities which would rather reduce the much encountered challenges. This therefore calls for the use of GIS in modelling and visualizations of the subsurface systems.

1.4 Justification

Traditionally, potential areas and routes were sketched on paper and a set of criteria were developed for the evaluation of those areas. Criteria generally included geological and environmental hazards, infrastructure, a count of affected properties, and the size of the project area. The GIS is adaptable to a wide variety of projects. It has proven to be effective in improving efficiency in geothermal development and is well suited to large, complex projects. The model is also useful for rural environments that are harsh and difficult to evaluate visually, Naivasha being a good example.

2. METHODOLOGY

The datasets used in the analysis consist of geological, geochemical and geophysical information. GIS uses the commonality between these layers to search for their relationships. This is done through its ability to combine different map layers and observe them simultaneously to discover their relationship. This work leads to the hallmark of GIS functionality: spatial analysis. Spatial analysis in GIS is mainly used to uncover associations between data sets that are otherwise unknown. Exploring spatial association between data layers is ultimately used for prediction of suitable areas for a specific target. The prediction is based on mathematical and statistical models of many types.

The three following chapters describe how and what GIS can offer in the industry.

2.1 The exploration phase: **well siting**

Suitability Analysis and Weighted Overlay are used to identify suitable areas for a particular issue, such as locations suitable for a well. These are used in GIS analysis, when solving a multi criteria optimal site selection. For this type of analysis, the Spatial Analysis tool set is used for performing a Suitability Analysis and Weighted Overlay using the Model Builder (Figures 2-4).

All the data required from a variety of sources such as geology, geophysics and geochemistry, environmental science and so on are gathered and overlaid. A Weighted Overlay Analysis is then conducted where a raster dataset is created showing the possible area.

The exploration phase involves analysis and management of a bundle and varies kind of data like seismic survey maps, DEM, surface geology maps, satellite imagery, well locations, and so much more.

GIS is able to integrate these sets of data and tie them to the desired location. In addition, GIS offer the flexibility to overlay, view and also manipulate the data.

Weighted overlay table

Raster	% Influence	Field	Scale Value
Rcl_TEM700	10	Value	
		1	1
		5	5
		7	7
		9	8
		10	9
		126	NODATA
		NODATA	NODATA
Recl_faults	25	Value	
		1	1
		4	4
		7	5
		9	8
		10	9
		NODATA	NODATA
Rcl_CO2	5	Value	
		1	1
		4	2
		8	4
		10	9
		NODATA	NODATA
rcl_r220	5	Value	
		1	1
		2	2
		7	3
		9	6
		10	9
		NODATA	NODATA
rcl_gravity	2	Value	
		1	1
		5	3

FIGURE 2: Model builder diagram for transforming and reclassifying layers to perform a weighted overlay to determine areas of suitable Geothermal wells

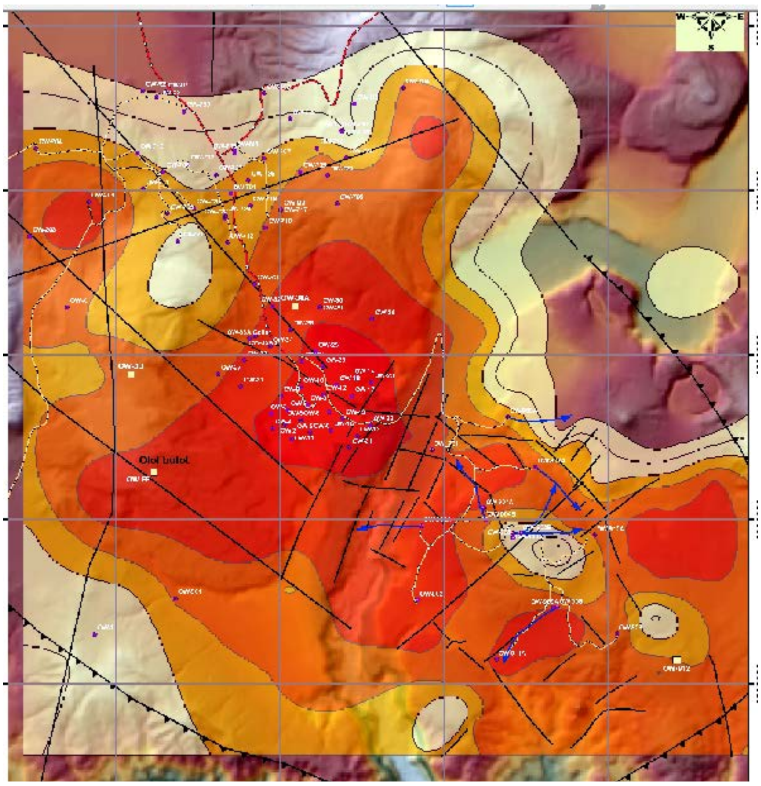

FIGURE 3: Map showing the possible wellsite areas (final output grid).
The most suitable areas are shown in red, brown areas are next, followed by orange.

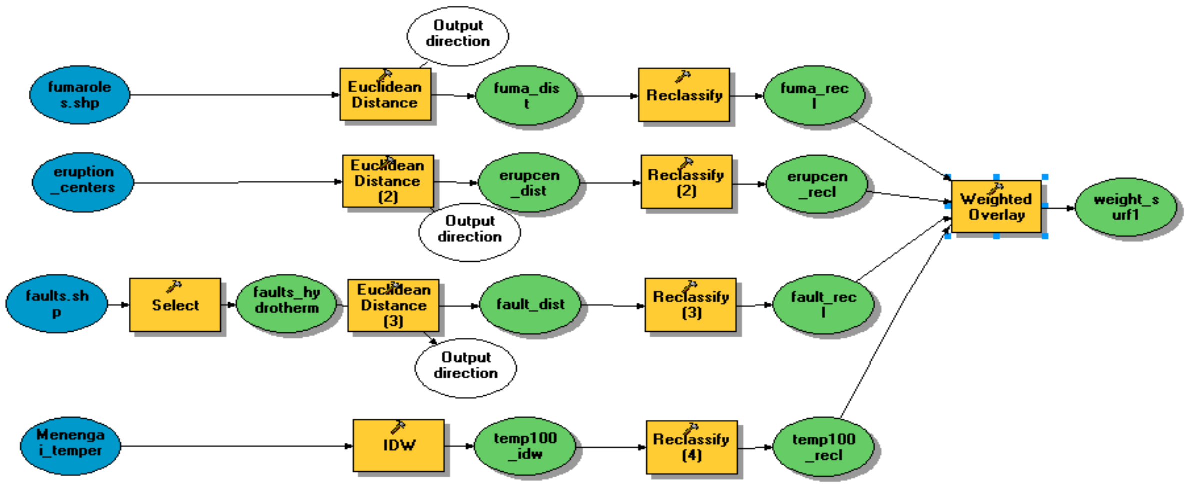

FIGURE 4: A model builder where all the necessary datasets are analysed

2.2 The action phase: Drilling phase

- *Well planning:* GIS is being used increasingly for well planning. Not only can GIS be used to plan well pad patterns around multiple surface drilling constraints, but its unique spatial analytics can be used to optimise drilling patterns to calculate the most efficient drilling configuration based on the distances and the angle deflections.
- *Drilling progress monitoring:* The data integration and visualization capabilities of GIS allow drilling engineers visualize maps containing production, type of well reinjection or production and helps in calculations of production efficiency. The production data can also be updated in a near real time on the map and this allows operators create production dashboard applications showing wells which are ongoing, proposed and production.

As drilling continues, there is always a need to check the direction the well is following on a 2D diagrams. GIS helps in production of such charts and maps which aids in decision making (Figures 5 and 6). These maps can also show distances between two directional wells on a flat surface, track inspections and helps check for collision of two wells.

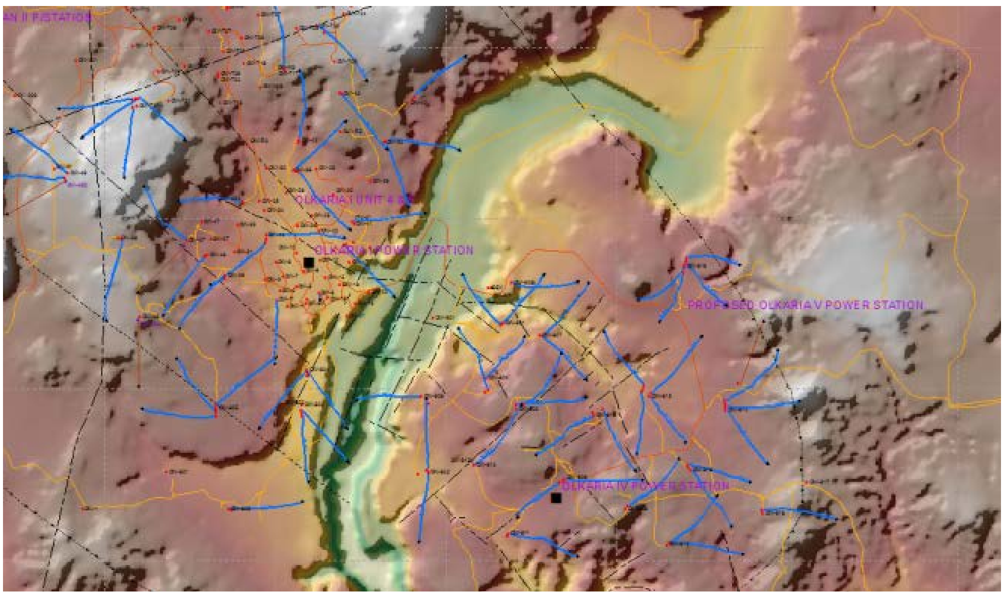

FIGURE 5: A section of Olkaria geothermal map with drilling directions

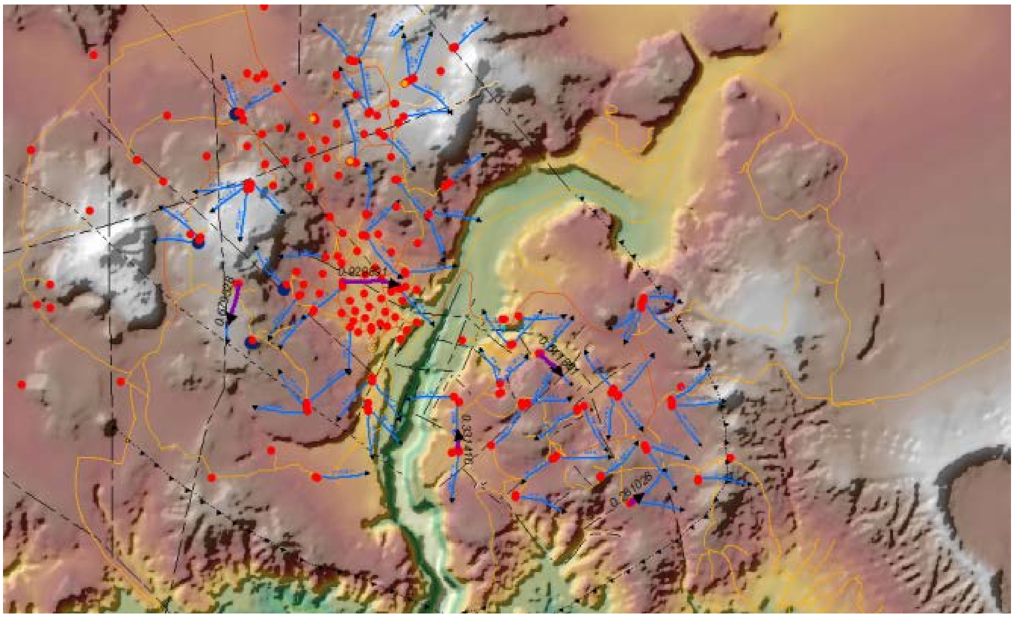

FIGURE 6: A section of Olkaria geothermal map showing ongoing wells and directions

2.3 The pipeline routing

Until recently, route determination was created on the topographical maps manually. But nowadays, GIS technologies are used effectively in route determination process (Figures 7 and 8). Route selection is a critical first step in the process of pipeline design and construction and has a potential significantly impacting the construction and operation of optimal path for the pipeline is determined by applying an optimal path algorithm. By applying the algorithm, the model takes a stepwise approach between a starting and ending point and it proceeds to calculate the most suitable route between the points by evaluating the criteria from the suitability surface.

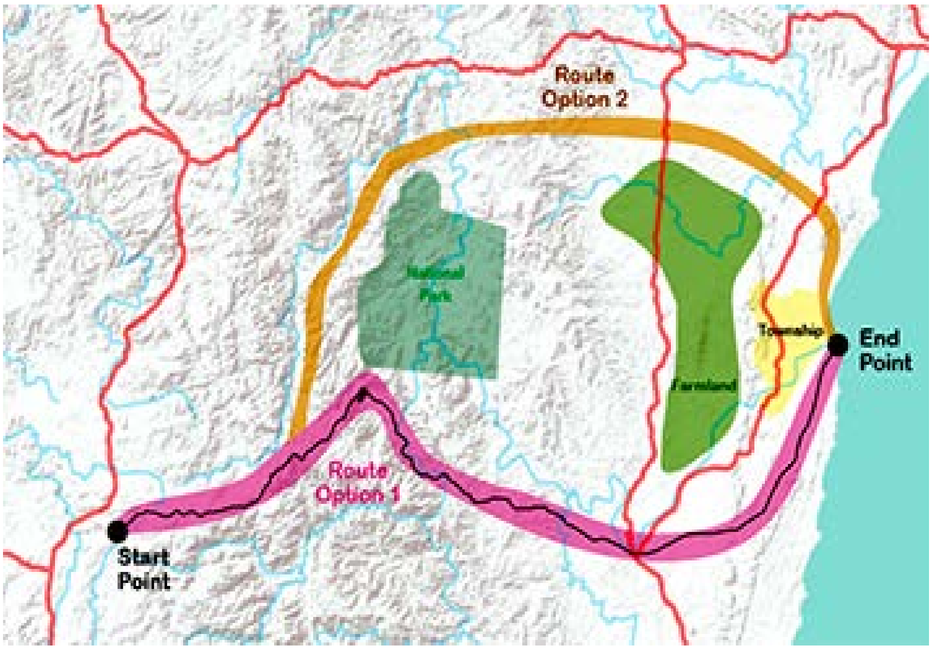

FIGURE 7: A section of Olkaria IV showing two sets of options

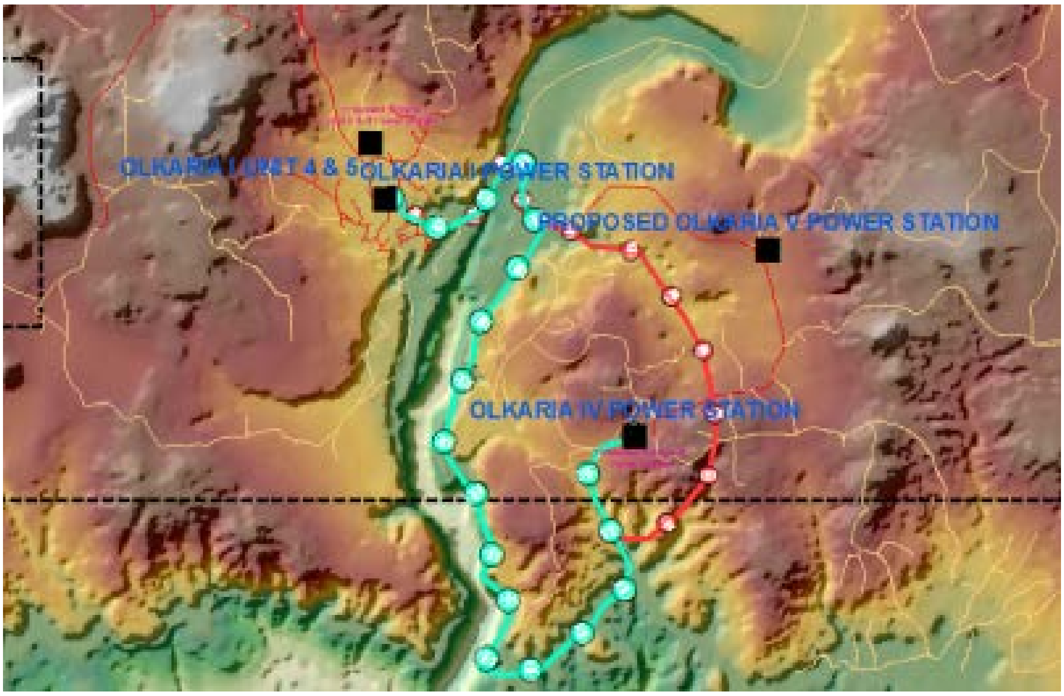

FIGURE 8: Olkaria IV route selection planning

GIS Technology has been an indispensable tool capable of helping the decision makers in order to select the best route for the new pipeline.

3. CONCLUSION AND RECOMMENDATIONS

Among the many functions of GIS, the main one is to integrate the possible geoscientific datasets into a single layer where influences are set based on each one of the layers. This enables creation of a suitability model for selecting best geothermal well sites. It has been clearly shown that on the suitability model, the highest priority areas correspond to areas of high priorities for the other geoscientific methods. These areas fall along zones of geological and tectonic significance.

Geothermal systems involve a lot of data and hence GIS should be the tool to go by, because it is a tool which has become universally vital, especially in data handling and integration with other disciplines. Generally, there are six core activities of GIS that can be applied in geothermal applications:

- Prediction, particularly to support decision making based on multiple factors of spatial information;
- Data organization (involving data modelling, data compilation, and database construction);
- Data visualization (producing data views and maps and graphically evaluating spatial patterns);
- Spatial data search (querying and feature extraction);
- Combining (integration) of diverse data types; and
- Data analysis and subsurface modelling.