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

Fred Wekesa and Beatrice Gichini

Olkaria Geothermal Project
Kenya Electricity Generating Company Ltd
fwekesa@kengen.co.ke
bgichini@kengen.co.ke

ABSTRACT

One of the major and greatest challenges facing geologists and earth scientists is the assimilation, dissemination, and management 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 in identifying geothermal sites 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 analyzing 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 analyzing spatial impacts of various development scenarios. This paper will investigate and discuss the importance and contribution of the Geographic Information System (GIS) to KenGen in its Geothermal development. It describes the role of GIS in handling the complex spatial data mix encountered in this industry, how it can help in better decision making processes and the way forward.

Key words: GIS, Geothermal, Geochemical Survey, Geophysical Survey

1.0 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. (K. Wohletz & G. Heiken; (1992) . Because 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 need 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 averaging 40-80km wide. 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 give rise to hydrothermal activity and are envisaged to host extensive geothermal systems and which much of it remains untapped. (Simiyu S, 2010), world geothermal Congress 2010, Bali, Indonesia)The study area, Olkaria - Naivasha, falls within the central part of the Kenya's rift valley. It is one of the many geothermal potential areas in the rift.

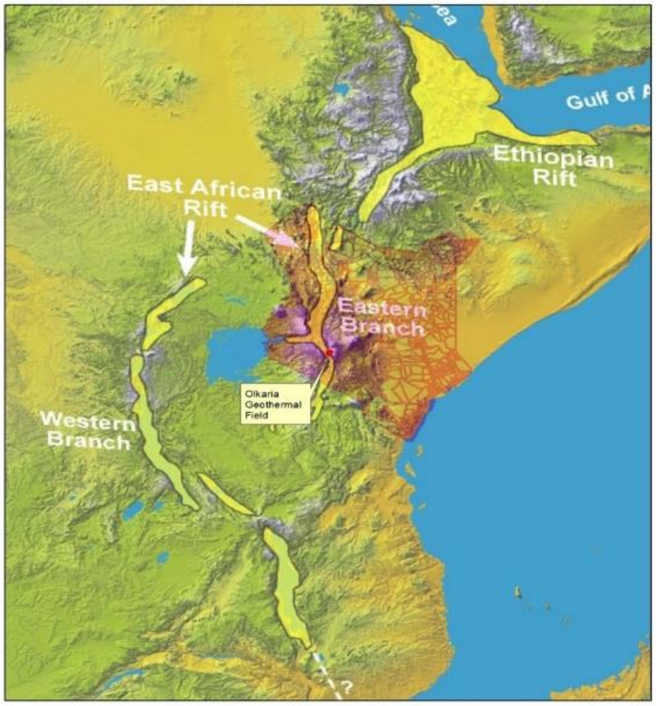


Figure 1: The location of Olkaria Geothermal Project in relation to the East Africa Rift System (source: modified from Wikipedia)

1.2 OBJECTIVE

The main objective of this paper is to showcase the various uses that GIS have been put into applications within the industry. Some of the uses are:-

- ✓ To Improve Organizational Integration- GIS integrates hardware, software, and data for capturing, managing, analyzing, 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
- 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 eager to develop more advanced capabilities which would rather reduce the much encountered challenges. This therefore calls for the use of GIS in modellings 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 & 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.

2.0 METHODOLOGY

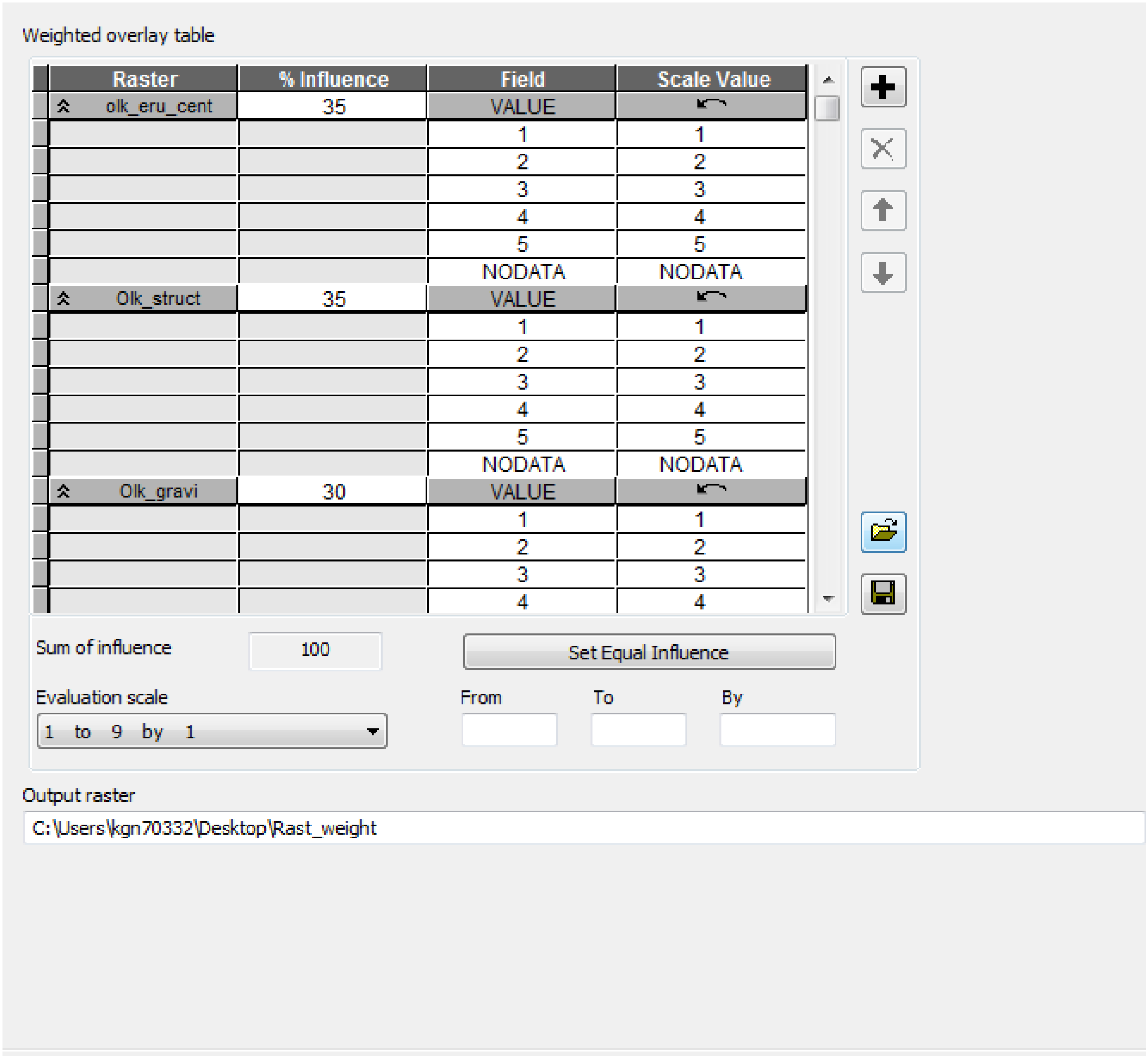
The datasets used in the analysis consist of geological, geochemical and geophysical information. GIS uses the commonality between these layers to search for their relationships. This is done through its ability to combine different map layers and observe them simultaneously to discover their relationship. 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. (Lucas D. Setijadji, 2003) The prediction is based on mathematical and statistical models of many types.
These contributions of GIS in the industry can broadly be categorized into three phases :

i) <u>The Exploration phase</u>: <u>Well Siting</u>

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.

All the data required from a variety of sources such as geology, geophysics and geochemistry, Environment and so on are gathered and overlaid. A weighted overlay analysis is then conducted where a raster dataset is created showing the most suitable areas with the highest rankings.

Table 1 showing a Model builder diagram used in a weighted overlay analysis to determine areas of suitable Geothermal wells.



Weighted overlay table

Raster	% Influence	Field	Scale Value
olk_eru_cent	35	VALUE	
		1	1
		2	2
		3	3
		4	4
		5	5
		NODATA	NODATA
Olk_struct	35	VALUE	
		1	1
		2	2
		3	3
		4	4
		5	5
		NODATA	NODATA
Olk_gravi	30	VALUE	
		1	1
		2	2
		3	3
		4	4

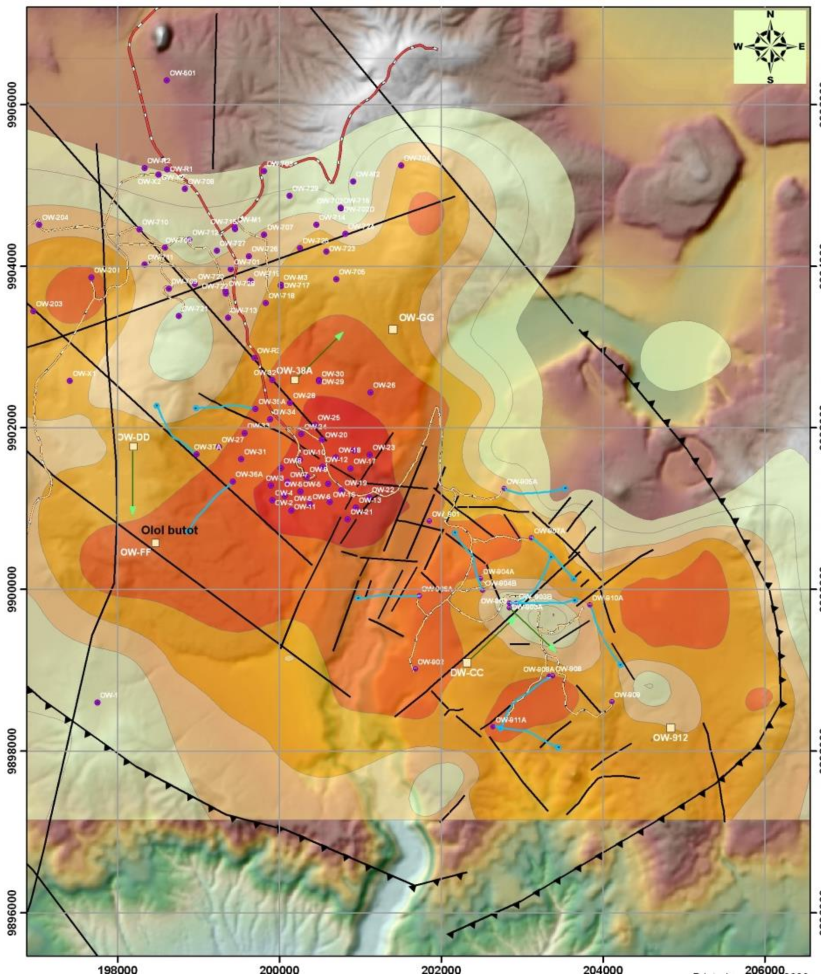


Figure 2: A map showing the possible well sites areas (final output grid). The most suitable areas are shown in red, brown areas are next followed by orange areas.

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.

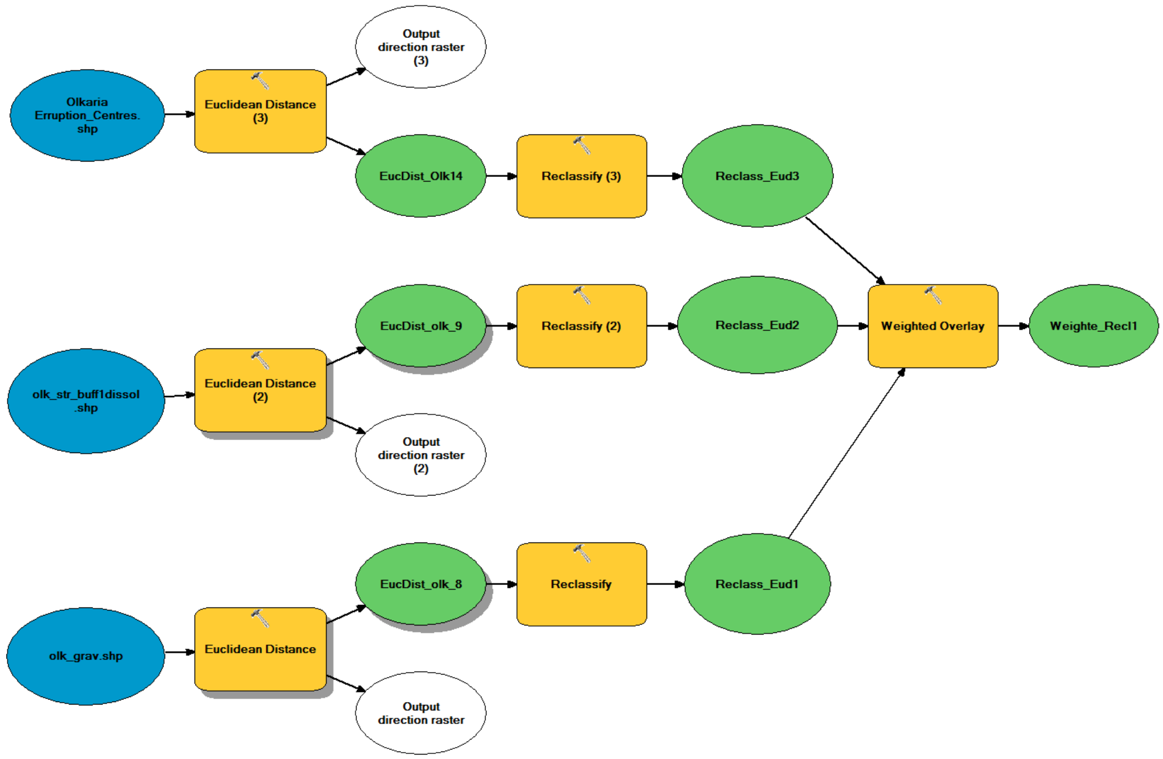


Figure 3: A model builder where all the necessary datasets are analyzed.

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

ii) <u>The Action phase: Drilling Phase</u>

- **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. These maps can also show distances between two directional wells on a flat surface, track inspections – helps check for collision of two wells.

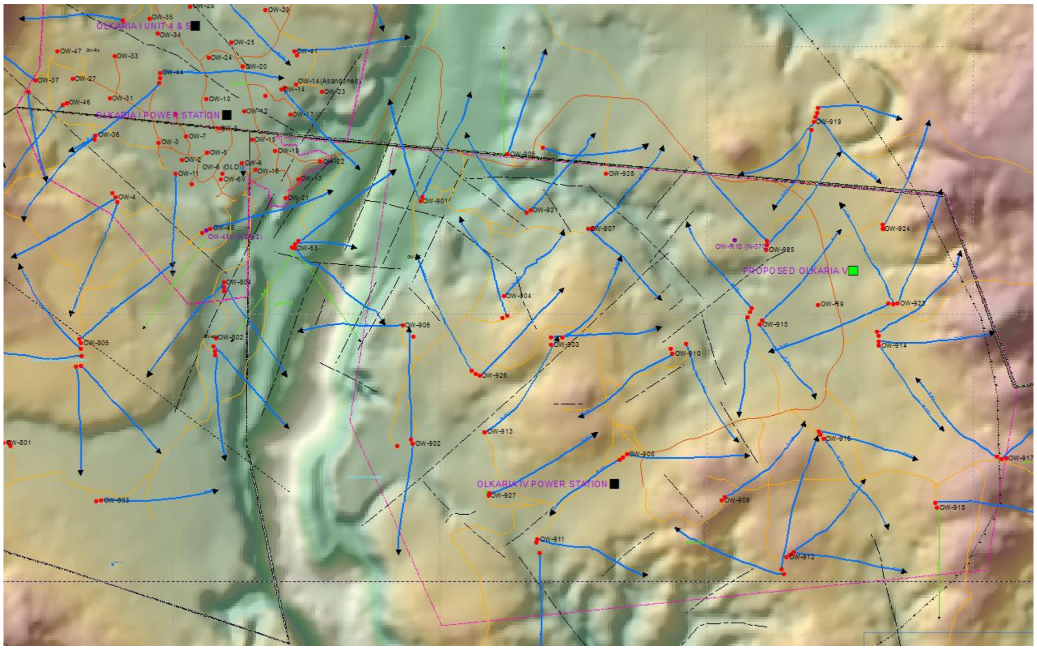


Figure 4: A section of Olkaria geothermal map on a 2D with drilling directions.(Source: Kengen records)

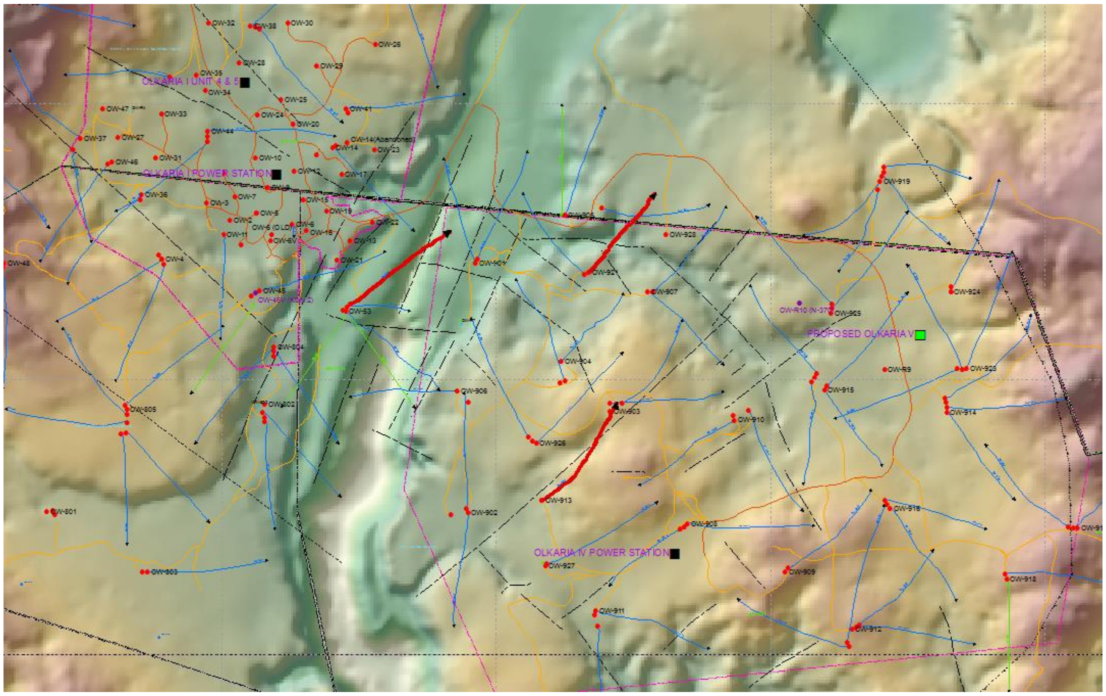


Figure 5: A section of Olkaria geothermal map on a 2D showing ongoing wells trajectories (Source: Kengen records)

iii) Water and Steam Pipeline Routing

Until recently, route determination was created on the topographical maps manually. But nowadays, GIS technologies are used effectively in route determination process. 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.

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

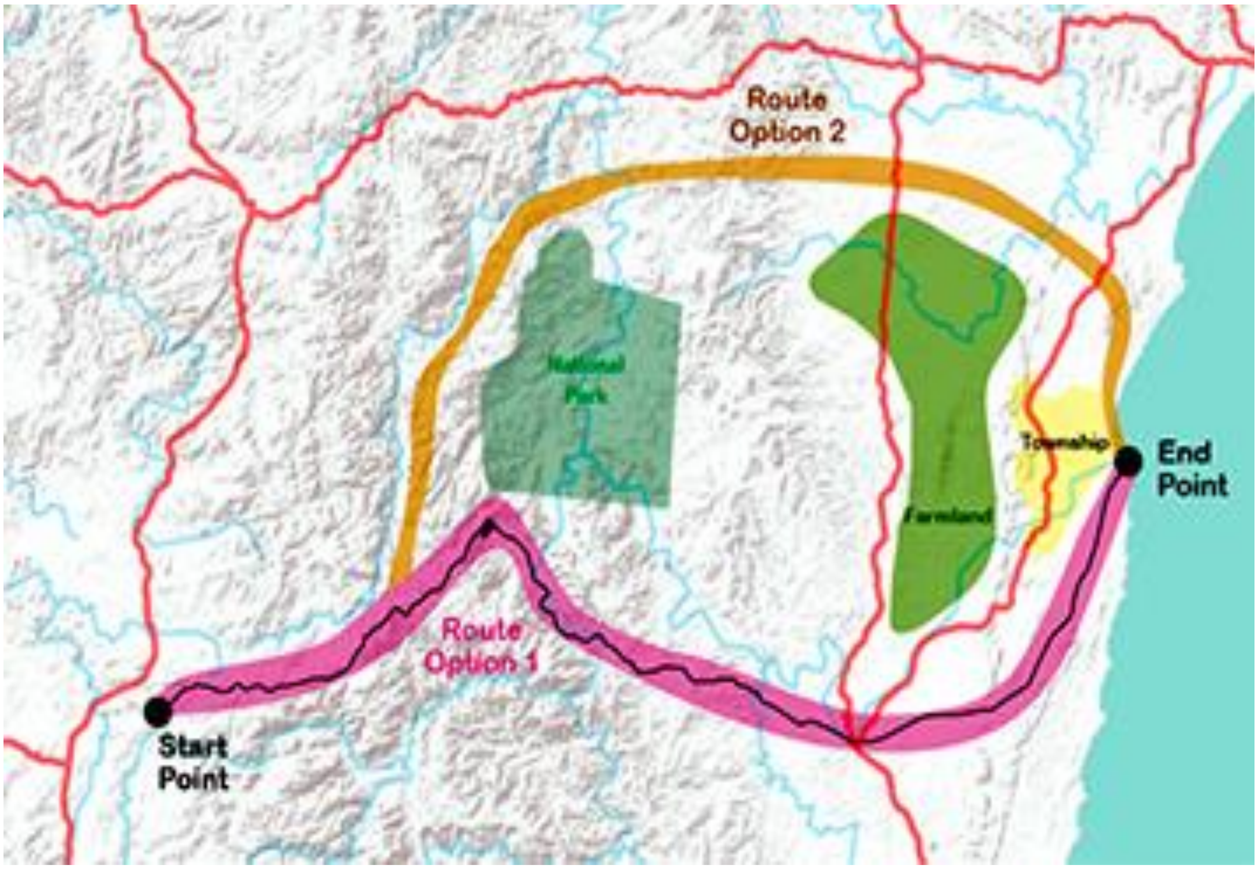


Figure 6: part of olkaria IV showing two set of options (source: KenGen records)

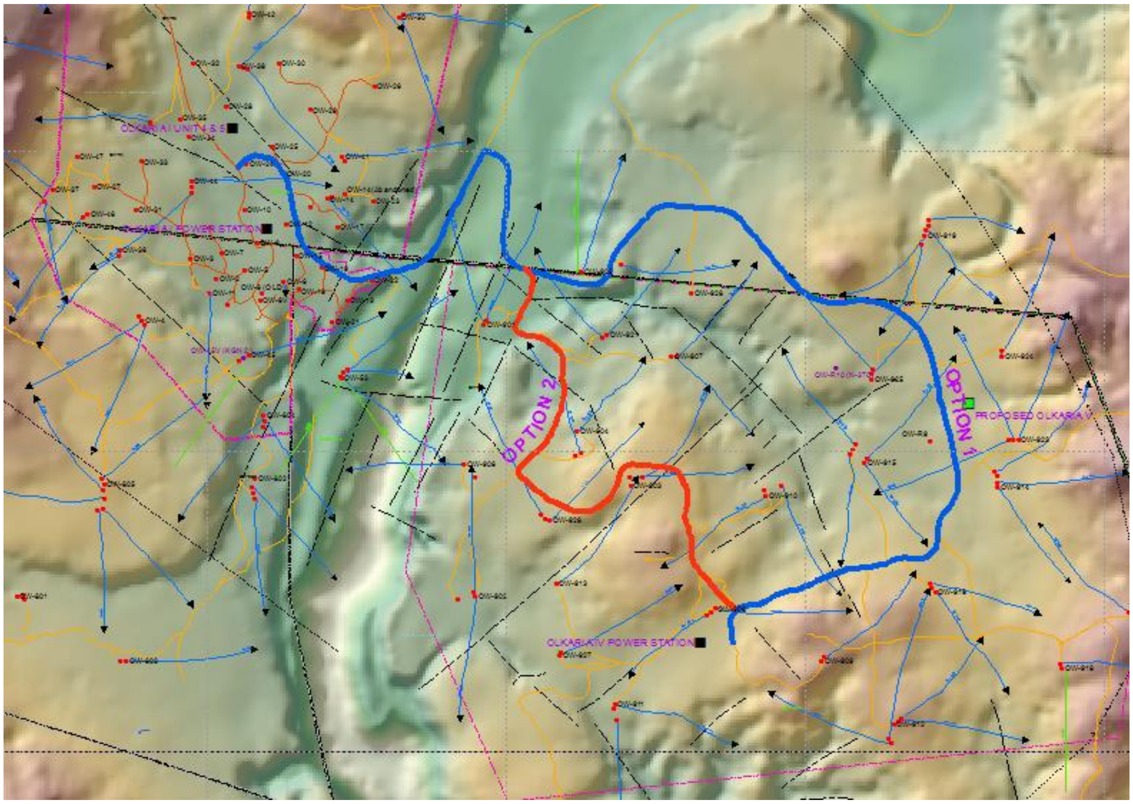


Figure 7: A section of olkaria IV showing a route selection planning (source: KenGen records)

3.0 THE FUTURE OF GIS IN GEOTHERMAL

3.1 3D – GIS AND FURTHER EXPLORATORY DATA ANALYSIS

GIS software has made great strides in being able to help geoscientists map sections of the Earth in 3-D. This discovery has been made significant by the ability to integrate other mapping software which interacts with GIS software.

3D data today can be created in several ways, LiDAR and photogrammetric modeling for example, it can even be transferred to a whole new vector style of cloud points, because of their accuracy, and not generalized lines and polygons. With the advent of more robust data like LiDAR data (.las), it is possible to show details with a sub meter accuracy. Rather than generalize it to a polygon with more than a meter inaccuracy. It’s a complete paradigm change.

Arcscene allows easy investigation of data quality, facilitates the understanding of complex structural geometry, and simultaneously visualizes multiple 3D model. It also allows overlaying of many components or layers for better interpretation. Its query environment combines patterns and spatial queries to support the analysis and interpretation of the complex relationships that characterize target environments.

The system supports real-time 3D-GIS properties, proximity, shell, meta-data, special feature, intersection and geological queries, providing geoscientists with a unique and powerful interpretive capability.

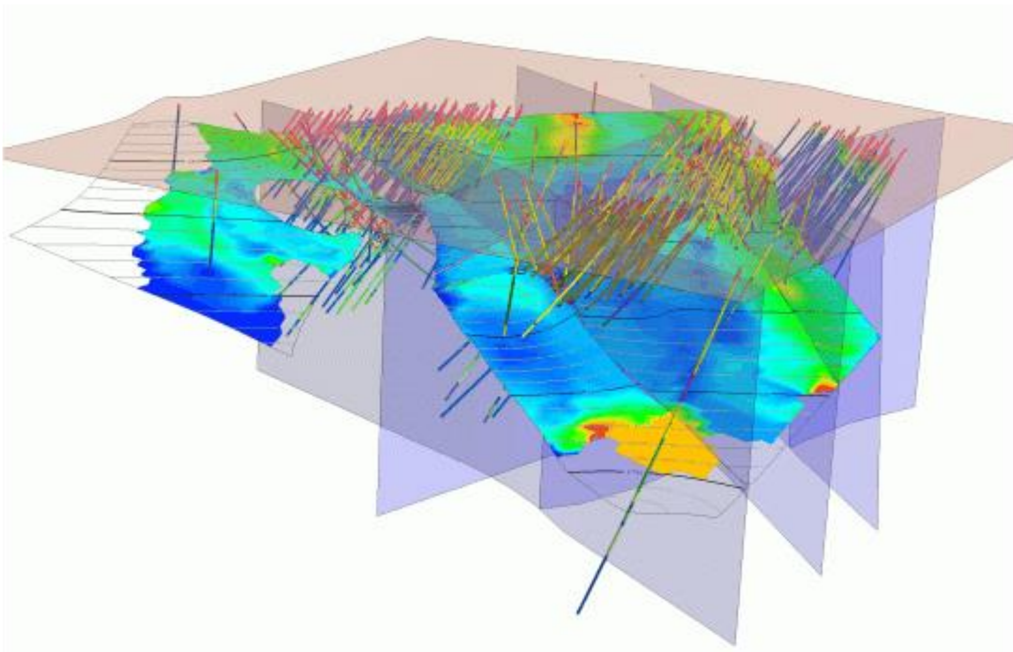


Figure 8: An interpretive environment, in which 3-D spatial data can be queried, manipulated and represented in a meaningful manner, so as to provide insight into recognizable patterns, anomalies and relationships.

4. CONCLUSION AND RECOMMENDATIONS

Among the many functions of GIS, the main one is to integrate the possible geo-scientific 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 geo-scientific methods. This areas falls along zones of geological and tectonic significance.

Geothermal systems involves 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:

- Data organization (involving data modeling, 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
- Data analysis and subsurface modelling
- Prediction, particularly to support decision making based on multiple factors of spatial information

REFERENCES

Bonham-Carter, G.F., (1994). "*Geographical Information Systems for Geoscientists: modeling with GIS*". Computer Methods in the Geosciences 13, Pergamon, New York, 398 pp.

Hossein Yousefi et al., (2007). Geothermal Potential Site Selection using GIS in Iran, *Proceedings*, 32nd Workshop on Geothermal Reservoir Engineering, , Stanford, California, USA (2007).

K. Wohletz & G. Heiken; (1992) Volcanology and Geothermal energy. Berkley, Los Angeles. Oxford, University of California press.

Lucas D. Setijadji, (2003). GIS for Subsurface Modelling. *Subsurface Modelling With GIS*, Draft may 4, 2003

Noorollahi, Y., R. Itoi, et al. (2007). "*GIS model for geothermal resource exploration in Akita and Iwate prefectures, northern Japan*." Journal of Computers & Geosciences 33(8): 1008-1021.

Rybach, L., Muffler, I.J.P., (1981). "*Geothermal Systems; Principles and Case Histories*". John Wiley & Sons Ltd, New York, 359 pp.

Sabalan geothermal field NW Iran", *United Nation University, Geothermal Training Program*, Iceland, paper No 19, 39pp.

Saffarzadeh, A. Noorollahi, Y. (2005) "*Geothermal Development in Iran", Proceedings, World Geothermal Congress*. Antalya, Turkey, 1-7 pp.

Simiyu S, (2010), Status of geothermal Exploration in Kenya and future plans for its Development. World Geothermal Congress 2010, Bali, Indonesia.

Yousefi. H, (2004)."Application of Geographic Information System in Environmental Impact Assessment of Geothermal Projects - case study