

# Application of Digital Elevation Models in Menengai Geothermal Field

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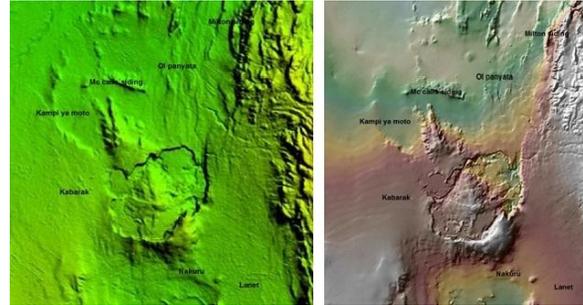
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## ABSTRACT

Digital Elevation Models (DEMs) are spatial data formats which depict the ground elevation of an area. DEMs have been used for the last two decades in various mapping and multi-disciplinary applications. In the Menengai Geothermal Field, DEMs have been used for visualization of topography and as basis of engineering works in road construction and waterline profiling. Also from already installed telecommunication equipment, view shed analysis resulting from terrain undulation is used to study the coverage of communication signals in different operation areas. Hydrological modeling has also been achieved through interpretation and analysis of DEM to generate flow directions of surface runoff. The DEMs used for this analysis are generated from contour interpolation from existing 1:50,000 topographic maps, small interval topographical surveys and Shuttle Radar Topography Mission (SRTM) 90 second DEM from USGS.

## 1.0 INTRODUCTION

DEMs depict the elevation of the earth's surface and it is therefore a continuous phenomenon. There are various sources of DEMs and the choice of what type of DEM to use depends on the particular application and the expected accuracy. For global and regional applications, SRTM data with grid cell size of 90m and accuracies of 10m-16m can be utilized effectively. Other sources of DEMs are from satellite imagery like SPOT and QUICKBIRD. On the other hand for applications requiring high ground accuracy, LiDAR and conventional surveying data can be used. LiDAR provide very accurate DEMs with grid cell sizes of less than 2m and accuracies of less than 10cm. Conventional surveying methods using levels, total stations and Differential GPS as a source of data can produce very highly accurate DEMs for engineering applications. The data is interpolated to generate elevation surfaces.

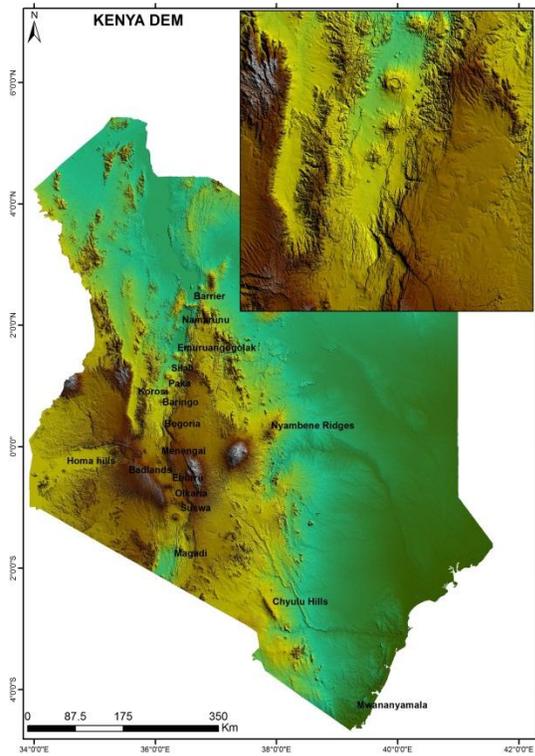


**Figure 53a & b: SRTM DEM and Contour DEM**

## 2.0 APPLICATIONS OF DIGITAL ELEVATION MODELS

### 2.1 Topography

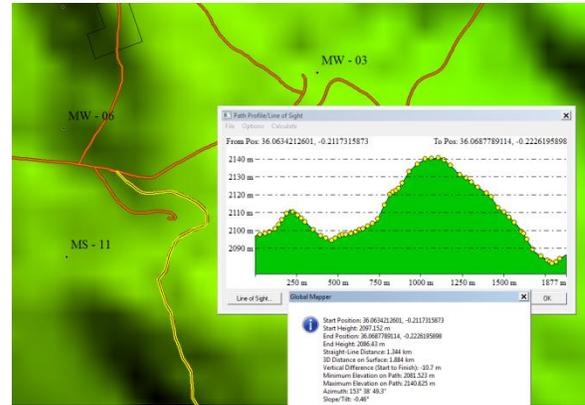
Topography refers to the relief features or surface configuration of an area. Topographical studies are important in earth sciences as they help in the depiction of land features and associated landforms. (Sulebak, 2000). Engineers and scientists have been contributing to the field of topography for centuries and the craft of mapping has become much more specific over the years. Elements of topographic maps that assist users include: relief shading, hypsometric tints and contour lines (Mitchell L., 2000). Topographic and thematic maps overlaid in DEM contributed in the selection of access routes and construction sites in Menengai. Apart from engineering applications, DEM complimented geological studies among other natural sciences in exploration and exploitation of geothermal resources in Menengai. The figure below shows a Kenya DEM and the various geological structures and landforms that can be derived from it.



**Figure 2: Kenya SRTM DEM depicting the geothermal sites.**

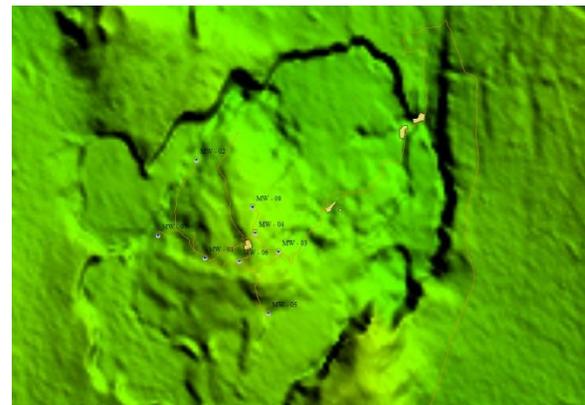
### 2.2 Civil Engineering works

Infrastructure forms key enablers towards geothermal exploitation. In the Menengai Geothermal Field, major infrastructural developments include access roads, drilling sites, water reservoirs and waterlines. DEMs have contributed enormously in profiling for roads and waterlines to ensure that these facilities are sited in regions with low gradients for efficiency and in the development of drilling sites. Developed DEMs show the topography and are used to generate profiles for waterlines, access roads to different drilling sites and for volumetric calculations to cut on cost of construction and water pumping. As an example, path profiling analysis was used to generate a vertical profile along the route below to evaluate the variation in gradient and associated cut and fill works at construction stage. Path profile for the access route to Menengai Well site 5 (highlighted in yellow) is shown in the figure below.

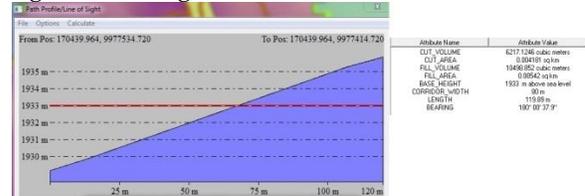


**Figure 3: Path profile from tank site junction to MW-05**

The profile shows the elevation changes in the y-axis, the distance from the start point in the x-axis and below the profile is a summary of the path details. This profile is important in the preliminary stages of road design as it gives a general overview of the topography within the study area. Drilling areas are sited using geoscientific data and the rugged terrain poses a challenge in opening up of the proposed sites. DEM is used to visualize the terrain of the area and to give preliminary guidelines of envisaged cut and fill operations in leveling of the site and eventual construction. Cut and Fill Analysis is done in Global Mapper and ArcGIS to generate the volumetric calculations for MW-07. The results are as indicated below:



**Figure 4: Menengai well 7 location**



**Figure 5: Cut and Fill results for MW-07**

The outcomes of this process are as outlined in the table below:

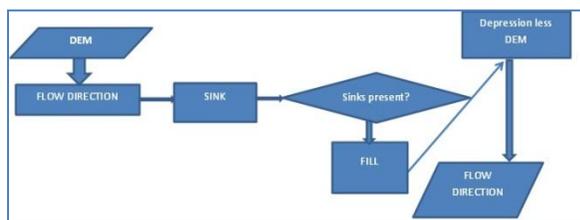
**Table 1: Outcome of Cut and Fill**

Cut Volume	6217.1246 cubic meters
Cut Area	0.004182 sq km
Fill Volume	10498.852 cubic meters
Fill Area	0.00542 sq km
Base height	1933m above sea level
Corridor width	80m
Length	119.89m

The results depict the general topography of the area and using a common base height of 1933m above sea level to level the drill site, the volume of materials to be cut and filled are as indicated on the attribute table above.

### 2.3 Hydrology

Hydrology is an important discipline in geothermal studies given that for any geothermal project to kick off, the recharge system of the area should be established and this involves the surface runoff studies and the ground water behavior studies. DEMs are crucial in hydrological modeling as topography controls the flow of water. Using DEM, the direction of flow within the study area was modeled to determine how water flows from one cell to the other. When modeling the flow of water, it is important to know where the water comes from and where it goes (Jenson, etal. 1988).The flow diagram below represents the model that was used to come up with the flow direction results.



**Figure 6: Flow diagram of modeling surface runoff**

#### 2.3.1 Flow Direction

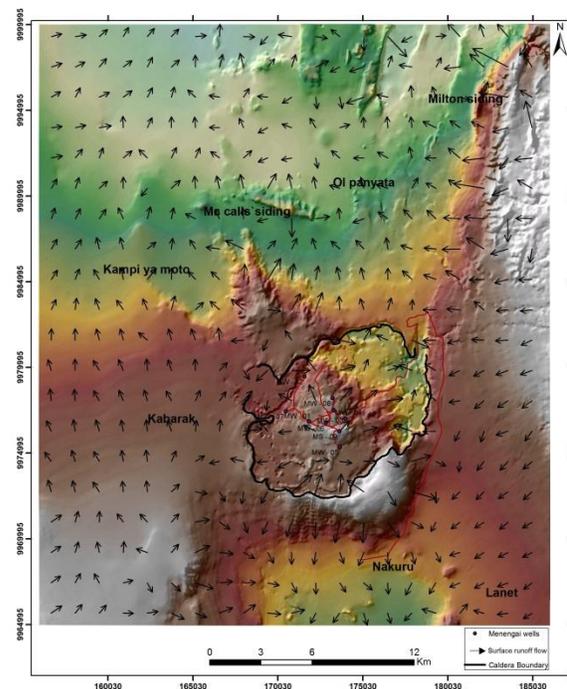
Flow direction determines the direction of water flow from every cell in the raster i.e. DEM. The direction of flow is determined by the direction of the steepest descent, or maximum drop, from each cell. This is calculated as follows:

$$\text{Maximum drop} = \text{change in z-value} / \text{distance} * 100$$

The distance is calculated between cell centers. Therefore, if the cell size is 1, the distance between two orthogonal cells is 1, and the distance between two diagonal cells is 1.414 (the square root of 2). If the maximum descent to several cells is the same, the neighborhood is enlarged until the steepest descent is found. The figure above represents the flow direction results of Menengai and the surrounding areas.

### 2.4 Telecommunications

Telecommunication towers or radio masts are necessary for any developed geothermal field to boost communication given that most of these fields are in remote areas or in rugged terrain regions. The placement of telecommunications towers is a critical component in the success of the system. If placed in the wrong location, coverage is not continuous. The building of an excess number of towers to assure continuous coverage is cost-prohibitive (Faintich, 1996).



**Figure 7: Surface runoff results**

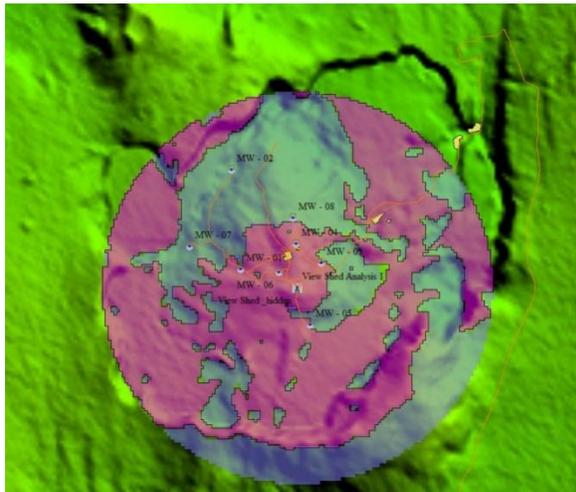
DEM obtained from the SRTM was used by telecommunication engineers to enable them plan where to place the towers for maximum coverage. With the analysis on the DEM, they determined not only where to place the towers or masts but also the appropriate height of masts for optimized coverage. View shed and line of sight analysis were used to determine the transmitter location, its height and the radius of coverage which shows how far in each

direction from the transmitter to check for connectivity. The parameters set are as indicated on the table below:

**Table 2: View shed parameters**

Transmitter Elevation	30metres above ground
Receiver elevation	2metres above ground
View radius	5.2kilometres

Areas with continuous internet coverage were depicted with the pink shed and areas with no coverage were shaded in purple. The DEM used for this analysis is SRTM and the transmitter location was at Mlima Punda in the Menengai Geothermal Field with coordinates 173342.33E, 9976356.312N, transmitter height used was 30m and the radius of coverage is 5.2km. The results of coverage are as depicted on the figure below:



**Figure 8: Menengai view shed analysis results**

### 3.0 CONCLUSIONS

DEMs form an integral part in geothermal studies and development of the geothermal fields as it assists in the determination of various parameters especially during the planning stages of geothermal projects. In the Menengai Field, DEMs have been used for infrastructural development planning, telecommunication network design, topographical mapping and basic hydrological modeling. The challenge has been to acquire the right type of DEMs for the different applications. Lidar DEMs are very accurate and appropriate for engineering planning works.

### 4.0 ACKNOWLEDGEMENTS

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## Correlating Resistivity with Temperature and Alteration Mineralogy in Menengai Geothermal Field: Case Study of Menengai Well MW-01

Yussuf Noor, Janet Suwai and Deflorah Kangogo